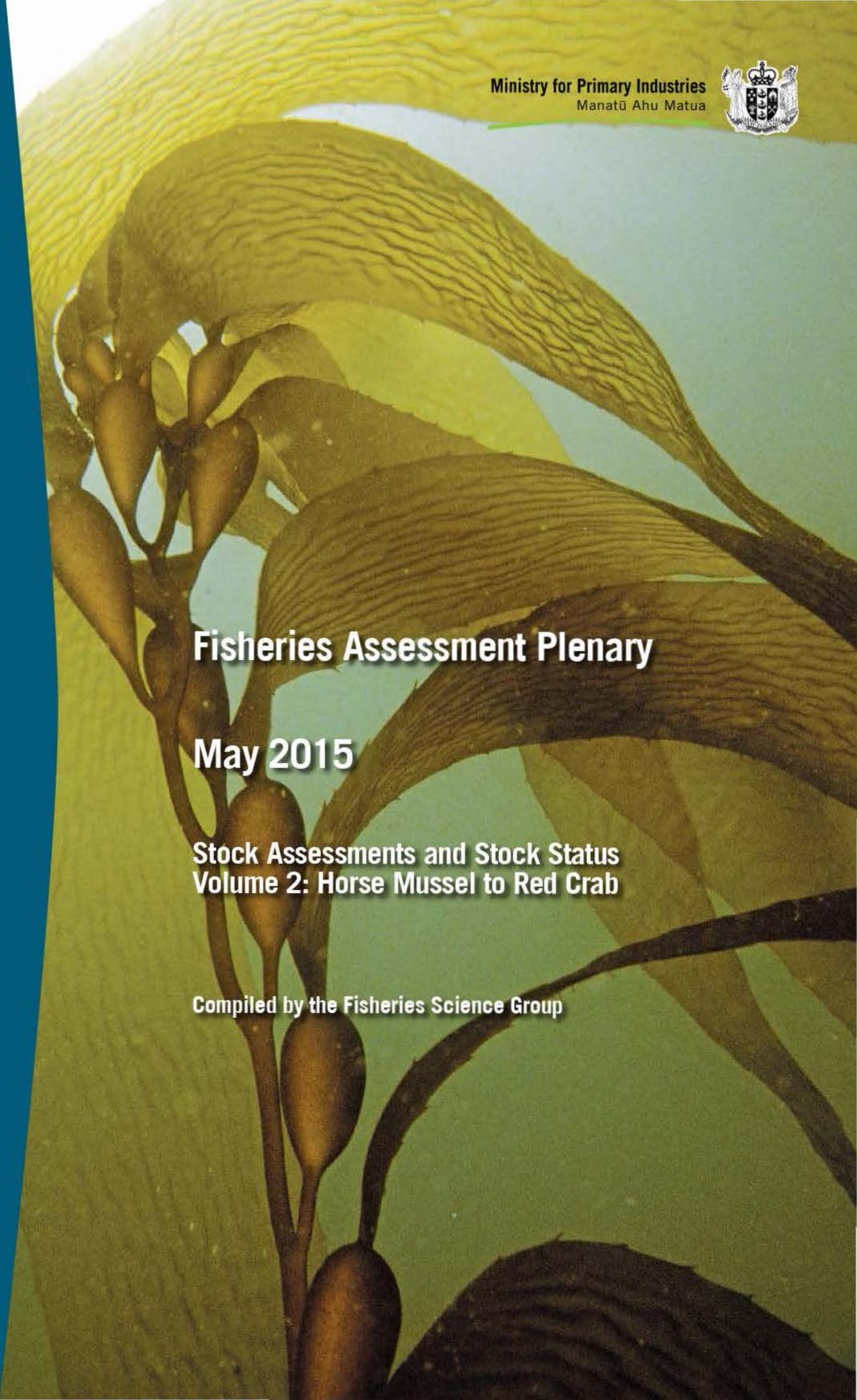


Ministry for Primary Industries
Manatū Ahu Matua

Fisheries Assessment Plenary

May 2015

Stock Assessments and Stock Status
Volume 2: Horse Mussel to Red Crab

Compiled by the Fisheries Science Group

Ministry for Primary Industries
Fisheries Science Group

Fisheries Assessment Plenary:
Stock Assessments and Stock Status

May 2015

Volume 2: Horse Mussel to Red Crab

ISBN 978-0-908334-66-7 (print)
ISBN 978-0-908334-65-0 (online)

Compiled and published by
Fisheries Science Group
Ministry for Primary Industries
Pastoral House, 25 The Terrace
PO Box 2526, Wellington 6140
New Zealand

Requests for further copies should be directed to:
Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140
Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
www.mpi.govt.nz/news-resources/publications.aspx

Or at:

fs.fish.govt.nz under document library and stock assessment plenary.

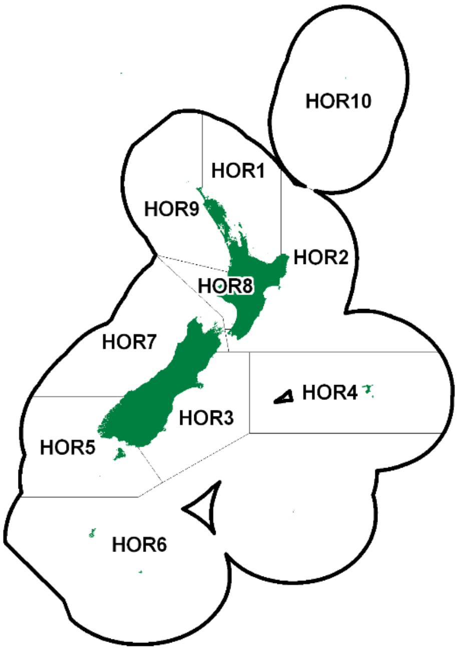
Cover photograph: Malcolm Francis
Images: Fishes – Neil Bagley, Nelson Boustead, Peter McMillan, Peter Marriott, NIWA
Invertebrates – Neil Bagley, Malcolm Clark, Martin Cryer, Reyn Naylor, NIWA, Darren Stevens, Ian Tuck, JJ Whalan, Chris Woods
Bladder kelp – Malcolm Francis
Printed by: Blue Star Group Limited, Printlink, Wellington.

Preferred citation

Ministry for Primary Industries (2015). Fisheries Assessment Plenary, May 2015: stock assessments and stock status. Compiled by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand. 1477p.

HORSE MUSSEL (HOR)

(*Atrina zelandica*)
Kukuroroa, Kupa, Hururoa



1. FISHERY SUMMARY

1.1 Commercial fisheries

Horse mussels (*Atrina zelandica*) were introduced into the Quota Management System on 1 April 2004, with a combined TAC of 103 t and TACC of 29 t. Customary non-commercial and recreational allowances are 9 t each, and 56 t was allowed for other sources of mortality. The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight. TACCs have been allocated in HOR 1–HOR 9. Most reported landings have been from HOR 1, and apart from 1994–95 and 2002–03, when catches of about 5 and 7 t respectively were reported, reported landings have all been small (Table 1). About 90% of the catch is taken as a bycatch during bottom trawling and the remainder is taken as a bycatch of dredge and Danish seine. It is likely that there is a reasonably high level of unreported discarded horse mussel catch.

1.2 Recreational fisheries

A. zelandica do not appear in records from recreational fishing surveys (Bradford 1998), but are nevertheless taken from time to time by recreational fishers. There are no estimates of recreational take for this species.

1.3 Customary non-commercial fisheries

A traditional food of Maori, although probably underrepresented in midden shell counts because of the fragile and short-lived nature of the shell. There are no estimates of current customary non-commercial use of this species.

1.4 Illegal catch

There is no known illegal catch of this mussel.

1.5 Other sources of mortality

There is no quantitative information on other sources of mortality, although widespread die-offs appear to be characteristic of this species. Storm scour, shell damage and subsequent predation, and exceeding carrying capacity have been suggested as possible reasons for this.

Table 1: TACCs and reported landings (t) of Horse mussel by Fishstock from 1990–91 to 2013–14 from CELR and CLR data. There have never been any reported landings in HOR 4, 5, 6 or 8. These fishstocks each have a TACC of 1 t and are not reported in Table 1 below.

	HOR 1		HOR 2		HOR 3		HOR 7		HOR 9		Total	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990–91	0.834	-	0	-	0	-	0	-	0	-	0.834	-
1991–92	0	-	0	-	0	-	0	-	0	-	0	-
1992–93	0	-	0	-	0	-	0	-	0	-	0	-
1993–94	0.003	-	0	-	0.016	-	0	-	0	-	0.019	-
1994–95	5.525	-	0	-	0	-	0	-	0	-	5.525	-
1995–96	0	-	0.019	-	0	-	0	-	0	-	0.019	-
1996–97	0.024	-	0	-	0	-	0	-	0	-	0.024	-
1997–98	0	-	0	-	0	-	0	-	0	-	0.128	-
1998–99	0	-	0	-	0	-	0	-	0	-	0	-
1999–00	0	-	0	-	0	-	0.81	-	0	-	0.1	-
2000–01	0	-	0	-	0	-	0.128	-	0	-	0.128	-
2001–02	0	-	0.002	-	0	-	0	-	0	-	0	-
2002–03	7.153	-	0	-	0	-	0	-	0	-	7.155	-
2003–04	0.026	4	0	2	0	2	0	16	0	1	0.026	29
2004–05	0.217	4	0	2	0	2	1.017	16	0.065	1	1.299	29
2005–06	0.026	4	0	2	0	2	0	16	0.942	1	0.968	29
2006–07	0	4	0	2	0	2	0.06	16	0.261	1	0.321	29
2007–08	0	4	0	2	0	2	0.451	16	0	1	0.451	29
2008–09	0.068	4	0	2	0	2	0	16	0	1	0.068	29
2009–10	0.289	4	0	2	0	2	0.112	16	0	1	0.401	29
2010–11	0	4	0	2	0	2	0.857	16	0	1	1	29
2011–12	0	4	0	2	0	2	0.605	16	0	1	0.605	29
2012–13	0	4	0	2	0	2	0	16	0	1	0	29
2013-14	0	4	0	2	0	2	0.214	16	0	1	0.214	29

2. BIOLOGY

The horse (or fan) mussel, *Atrina zelandica*, is a widespread endemic bivalve that lives mainly on muddy-sand substrates in the lowest inter-tidal and sub-tidal shallows of mainly sheltered waters. Horse mussels are also found in deeper waters (to 50 m) off open coasts. The horse mussel is a flattened, emergent, filter-feeding mollusc, particularly conspicuous because of its size and abundance. Although more usually 260–300 mm long (110–120 mm wide) it can reach 400 mm in length and is New Zealands largest bivalve. Horse mussels often live in groups, forming patches of up to 10 m^2 or more. The shell remains firmly embedded in the substrate by its pointed anterior end, the animal anchored to particles in the sediment by its byssus. The crenellated posterior edge projects a few centimetres above the substrate, keeping the water intake clear of surface deposits and providing attachment for an array of algae and invertebrates such as sponges and sea squirts.

Horse mussels are dioecious broadcast spawners. Although spawning may take place throughout much of the year it is probably mainly during summer. There is no information on the size or age at which breeding begins. A pelagic larva is free swimming for several days or weeks but nothing is known of its primary settlement locations, which may not necessarily be within the adult beds (some bivalves including soft sediment ones such as pipi settle in one area but later migrate to another where adult beds develop). Recruitment events can be sporadic and short-lived.

There is little published information on age, growth and mortality for horse mussels. It appears that *Atrina* grows rapidly for at least the first 2–4 years: shells about 120 mm long in a northern bed increased about 40 mm per year until 166 mm, after which growth slowed dramatically (Hay C. pers. comm. in Hayward et al 1999). Large shells are at least 5 y and possibly up to 15 y old. Widespread die-offs seem to be a feature of this species (Allan & Walshe 1984, Hayward et al 1999). For example, in the Rangitoto Channel, densities of 200–300 per m^2 reduced to 1–35 per m^2 over 2–3 y, with storm scour, shell damage and subsequent predation, and exceeding carrying capacity being possible reasons (Hayward et al 1999).

Horse mussels have widespread effects on ecosystem structure and function. They provide shelter and refuge for invertebrates and fish, and act as substrata for the settlement of epifauna such as sponges and soft corals. They also affect boundary layer dynamics, and facilitate productivity and biodiversity by depositing pseudofaeces. The horse mussel community in most northern harbours is almost entirely subtidal, in medium to fine muddy, but fairly stable, sand with moderate current velocities and no wave action. Similar communities have been observed in the Hauraki Gulf and Marlborough Sounds. Scallops, dredge oysters, and green lipped mussels are the main commercial shellfish species whose beds sometimes broadly overlap with the horse mussel.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, there is no biological information on stock structure, recruitment patterns, or other biological characteristics which might indicate stock boundaries.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any horse mussel fishstock.

4.2 Biomass estimates

There are no biomass estimates for any horse mussel fishstock.

4.3 Yield estimates and projections

There are no estimates of *MCY* for any horse mussel fishstock.

There are no estimates of *CAY* for any horse mussel fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any horse mussel fishstock. It is not known whether horse mussel stocks are at, above, or below a level that can produce *MSY*.

6. FOR FURTHER INFORMATION

Allan, L; Walshe, K (1984) Update on New Zealand horse mussel research. *Catch* ’84 11(8): 14.

Booth, J D (1983) Studies on twelve common bivalve larvae, with notes on bivalve spawning seasons in New Zealand. *New Zealand Journal of Marine and Freshwater Research* 17: 231–265.

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington.)

Cummings, V J; Thrush, S F; Hewitt, J E; Turner, S J (1998) The influence of the pinnid bivalve *Atrina zelandica* Gray on benthic macroinvertebrate communities in soft-sediment habitats. *Journal of Experimental Marine Biology and Ecology* 228: 227–240.

Estcourt, I N (1967) Distributions and associations of benthic invertebrates in a sheltered water soft-bottom environment (Marlborough Sounds, New Zealand). *New Zealand Journal of Marine and Freshwater Research* 1: 352–370.

Hayward, B W; Morley, M S; Hayward, J J; Stephenson, A B; Blom, W M; Hayward, K A; Grenfell, H R (1999) Monitoring studies of the benthic ecology of Waitemata Harbour, New Zealand. *Records of the Auckland Museum* 36: 95–117.

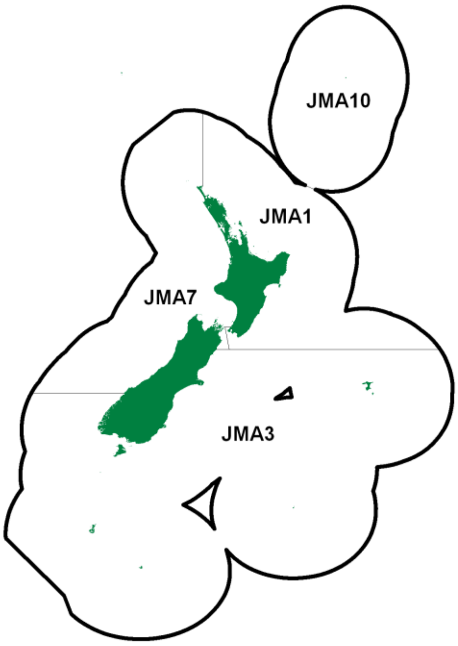
McKnight, D G (1969) An outline distribution of the New Zealand shelf fauna. Benthos survey, station list, and distribution of the Echinoidea. *New Zealand Oceanographic Institute Memoir* No. 47.

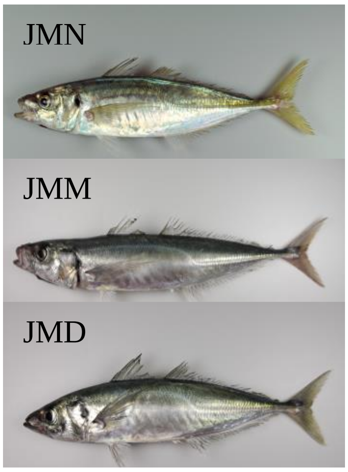
Paul, L J (1966) Observations on past and present distribution of mollusc beds in Ohiwa Harbour, Bay of Plenty. *New Zealand Journal of Science* 9: 30–40.

Warwick, R M; McEvoy, A J; Thrush, S F (1997) The influence of *Atrina zelandica* Gray on meiobenthic nematode diversity and community structure. *Journal of Experimental Marine Biology and Ecology* 214: 231–247.

JACK MACKERELS (JMA)

(*Trachurus declivis*, *Trachurus novaezelandiae*, *Trachurus murphyi*)
Hauture





1. FISHERY SUMMARY

The jack mackerel fisheries catch three species; two New Zealand species, *Trachurus declivis* and *T. novaezelandiae*, and *T. murphyi* which appeared in New Zealand in the 1980s.

Jack mackerels have been included in the QMS since 1 October 1996, with four QMAs. Previously jack mackerels were considered part of the QMS, although ITQs were issued only in JMA 7. In JMA 1 and JMA 3, quota for the fishery was fully allocated as IQs by regulation with the exception of the 20% allocated to customary non-commercial. Before the 1995 jack mackerel regulations were issued, catch in JMA 1 taken in the Muriwhenua area north of 36°S to the limit of the Territorial Sea was not covered by the JMA 1 regulations. Allowances for customary non-commercial fishers, recreational fishers and an allowance for other sources of mortality have not yet been set.

1.1 Commercial fisheries

In JMA 1, the jack mackerel catch is largely (about 96% of annual landings) taken by the purse seine fishery operating in the Bay of Plenty and on the east Northland coast, which was, prior to 1992, dominated by *T. novaezelandiae*, but included a small component of *T. declivis*. Between 1991–92 and 1995–96 the proportion of *T. murphyi* in the catch increased considerably, and markets were developed for large jack mackerels, but, by 1996–97, their low value resulted in less targeting of large fish. In recent years the proportion of *T. novaezelandiae* has been variable with an initial return to more than 95% in 1999–2000 and 2000–01, a decline to 46% in 2003–04, and an increase to 81% in 2004–05. Some trawl bycatch of jack mackerel has been recorded in JMA 1.

Since 1991–92, jack mackerel targeted landings in JMA 1 have represented more than 80% of total catch. The highest rates of bycatch are from kahawai and blue mackerel targeted operations which each account for about 7% of the total jack mackerel catch. The majority of JMA 1 catch over these years has been taken from statistical areas 008 and 009 (Bay of Plenty) between June and November; considerably less has been taken in statistical areas 002 and 003, although high catches were recorded from these areas in 1993–94 and 1994–95.

Jack mackerel catch in JMA 3 is almost exclusively *T. murphyi* and little targeting occurred before 1992–93. During the 1990s targeting increased and accounted for the majority of catch (about 50% between 1991–92 and 1996–97), but, after a peak of more than 80% in 1997–98 and 1998–99, has decreased again to about 50–60% in recent years. The balance of the catch in this area comes from trawl bycatch (squid 15–30%; barracouta 15–20%) on the Chatham Rise and in the Southland/Sub-Antarctic region. A purse seine fishery has operated between the Clarence River mouth and the Kaikoura Peninsula, which peaked at 4400 t in 1992–93 and averaged more than 3000 t between 1989–90 and 1993–94. Purse seine catches have shown a steady decline since, dropping from 1000 t in 1994–95, to 100 t in 2001–02 and 2002–03; no catch was recorded for 2003–04.

Increased availability of jack mackerels caused by the influx of *T. murphyi* resulted in increased quotas in JMA 1 and JMA 3, to 8000 t and 9000 t respectively for the 1993–94 fishing year, and a further increase to 10 000 t and 18 000 t respectively for the 1994–95 year. The latter increases were made under the proviso that they be accounted for by increased catches of *T. murphyi* only; combined landings of *T. declivis* and *T. novaezelandiae* in JMA 1 and JMA 3 must not exceed the original quotas of 5970 t and 2700 t respectively. Industry agreed to these limits and voluntarily introduced monitoring programmes to provide the information necessary for them to be met.

The three species occur in each of the Fishstocks, but have not been individually identified in catch records. Historical estimated and recent reported jack mackeral landings and TACCs are shown in Tables 1 and 2, while Figure 1 shows the historical landings and TACC values for the main JMA stocks.Total annual landings have ranged between 21 059 t and 47 855 t since 1986–87.

Table 1: Reported landings (t) for the main QMAs from 1931 to 1982

Year	JMA 1	JMA 3	JMA 7	Year	JMA 1	JMA 3	JMA 7
1931-32	0	0	0	1957	0	0	6
1932-33	0	0	0	1958	0	0	9
1933-34	0	0	0	1959	2	0	0
1934-35	0	0	0	1960	2	0	5
1935-36	0	0	0	1961	1	0	5
1936-37	0	0	0	1962	5	0	5
1937-38	0	0	0	1963	7	2	13
1938-39	0	0	0	1964	5	4	10
1939-40	1	0	0	1965	14	0	8
1940-41	1	1	2	1966	47	0	54
1941-42	0	0	2	1967	213	0	250
1942-43	3	0	2	1968	172	505	4558
1943-44	0	0	0	1969	128	388	7065
1944	9	0	0	1970	75	1029	7274
1945	7	0	0	1971	473	776	12684
1946	3	0	6	1972	350	5450	15581
1947	14	0	4	1973	395	1238	14648
1948	3	0	6	1974	1236	2016	16943
1949	5	0	22	1975	204	3615	10043
1950	7	6	3	1976	838	5690	14228
1951	4	4	1	1977	1317	5228	13729
1952	1	4	7	1978	1250	1547	4657
1953	0	3	9	1979	2158	516	4475
1954	3	0	1	1980	2504	104	3533
1955	3	0	12	1981	2815	110	8665
1956	1	0	2	1982	1607	119	8364

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 2: Reported landings (t) of jack mackerel by Fishstock from 1983–84 to 2012–13 and actual TACCs (t) for 1986–87 to 2012–13. QMS data from 1986–present. [Continued on next page]

	JMA 1		JMA 3		JMA 7		JMA 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings§	TACC
1983–84*	3 682	-	715	-	12 464	-	0	-	16 861	-
1984–85*	1 857	-	1 223	-	16 013	-	0	-	19 093	-
1985–86*	1 173	-	2 228	-	10 002	-	0	-	13 403	-
1986–87	4 056	5 970	1 638	2 700	19 815	20 000	0	10	25 509	28 680
1987–88	3 108	5 970	1 883	2 700	17 879	22 697	0	10	22 870	31 377
1988–89	2 986	5 970	1 919	2 700	17 403	26 008	0	10	22 308	34 688
1989–90	4 226	5 970	4 013	2 700	21 776	32 027	0	10	30 015	40 707
1990–91	6 472	5 970	6 403	2 700	17 786	32 069	0	10	30 661	40 749
1991–92	7 017	5 970	5 779	2 700	25 880	32 069	0	10	38 676	40 749
1992–93	7 529	5 970	15 399	2 700	24 659	32 537	0	10	47 587	41 216
1993–94‡	14 256	8 000	9 115	9 000	22 377	32 537	0	10	45 748	49 546
1994–95‡	7 832	10 000	11 519	18 000	18 912	32 537	0	10	38 263	60 547
1995–96	6 874	10 000	19 803	18 000	12 270	32 537	0	10	38 947	60 547
1996–97	6 912	10 000	15 687	18 000	12 056	32 537	0	10	34 655	60 547
1997–98	7 695	10 000	15 452	18 000	14 293	32 537	0	10	37 440	60 547
1998–99	5 641	10 000	15 111	18 000	13 629	32 537	0	10	34 381	60 547
1999–00	2 864	10 000	10 306	18 000	7 889	32 537	0	10	21 059	60 547
2000–01	8 360	10 000	2 744	18 000	15 703	32 537	0	10	26 807	60 547
2001–02	5 247	10 000	5 000	18 000	22 338	32 537	0	10	32 585	60 547
2002–03	6 172	10 000	2 225	18 000	26 084	32 537	0	10	34 481	60 547
2003–04	7 396	10 000	705	18 000	28 888	32 537	0	10	36 989	60 547
2004–05	9 418	10 000	716	18 000	36 507	32 537	0	10	46 641	60 547
2005–06	9 924	10 000	5 000	18 000	27 782	32 537	0	10	42 706	60 547
2006–07	5 293	10 000	1 857	18 000	32 039	32 537	0	10	39 189	60 547
2007–08	11 167	10 000	2 629	18 000	34 059	32 537	0	10	47 855	60 547
2008–09	9 791	10 000	1 964	18 000	28 828	32 537	0	10	40 583	60 547
2009–10	9 086	10 000	2 706	18 000	31 152	32 537	0	10	42 944	60 547
2010–11	8 262	10 000	3 592	18 000	28 177	32 537	0	10	40 031	60 547
2011–12	8 911	10 000	3 085	18 000	28 266	32 537	0	10	40 261	60 547
2012–13	8 054	10 000	3 830	18 000	31 776	32 537	0	10	43 659	60 547
2013-14	10 520	10 000	4 693	18 000	35 175	32 537	0	10	50 388	60 547

* FSU data.
§ Includes landings from unknown areas before 1986–87.
‡ JMA 1 & 3 landings are totals from CLR and CELR data.tab

Landings in JMA 1 before 1989–90 were generally well below the quota of 5970 t (Table 2), with the maximum in 1986–87 only slightly above 4000 t. Landings increased to 7529 t in 1992–93, followed by a substantial increase to the highest recorded value of 14 256 t in 1993–94, which was more than twice the original quota and exceeded the quota of 8000 t set for that year. In 1994–95 reported landings (7832 t) were half those of 1993–94. Landings from 1994–95 to 1997–98 were around 7000 t. Since 1997–98 landings have fluctuated with no real pattern between a low of 2864 t in 1999–00 and a high of 11 167 t in 2007–08. JMA 1 landings in 2011–12 were 8054 t.

Total landings in JMA 3 over the period 1984–85 to 1988–89 were relatively constant, at a level below the quota of 2700 t. Landings increased over subsequent years to peak in 1992–93 at almost three times that of the preceding year and more than five times the quota. Under the first of two consecutive annual increases to the JMA 3 TACC in 1993–94, landings were slightly above the limit set, but dropped almost to the higher TACC level in 1994–95. The lower 1994–95 catch relative to that in 1992–93 has been attributed to the delayed implementation of the quota, less targeting of jack mackerel, and low bycatch in the squid trawl fishery. The reduced effort is thought to be a result of marketing difficulties for the relatively lower valued *T. murphyi*. Landings in JMA 3 increased markedly in 1995–96 (19 803 t) to a value exceeding the quota, with catches remaining stable around 15 500 t over three subsequent years. More recently, landings have decreased to levels well below the TACC, fluctuating between 700 t and 5000 t since 2000–01. Declines in landings are attributed to declining abundance of *T. murphyi*, which historically comprised the bulk of JMA 3 landings. JMA 3 landings in 2011–12 were 3085 t.

Landings in JMA 7 represent the greatest proportion of total landings and are mainly taken by chartered trawlers. Landings fluctuated between 17 403 t and 25 880 t from the mid 1980s through the mid 1990s. The marked decrease to 12 270 t in 1995–96 is attributed to changes in fishing strategies (mid-water trawling between 2 a.m. and 4 a.m. is banned under a code of practice to eliminate dolphin bycatch in JMA 7 that has been operational since 1995–96), the withdrawal of a major company from the fishery for much of the season, and difficulty marketing the relatively low valued *T. murphyi*. From 1995–96 to 1998–99, landings were in the range 12 056–14 293 t. Subsequently, landings increased steadily from 15 703 t in 2000–01 to 28 888 t in 2003–04 and to 36 507 t in 2004–05. The 2004–05 landings were 3971 t in excess of the TACC. This increase in JMA 7 landings has been attributed to market demand and a lack of availability of preferred species quota as a result of cuts in quotas for other species and taking the lower-cost option of targeting jack mackerel instead of hoki. The 2007–08 landings were 34 059 t, about 1500 t larger than the TACC. In 2008–09 catches decreased below the TACC by nearly 4000 t but increased again in 2009–10 to 31 152 t, which is within 1500 t of the quota. JMA 7 landings in 2011–12 were 28 266 t.

A number of factors have been identified that can influence landing volumes in the jack mackerel fisheries. In the purse seine fishery, jack mackerel is often mixed with kahawai. Fishing companies will avoid these mixed schools to conserve kahawai quota, particularly at the beginning of the fishing year. When mixing of the two species is prevalent, low kahawai TACC can result in the targeting of jack mackerel being inhibited. Both skipjack tuna and blue mackerel have been fished in preference to jack mackerel in the purse seine fishery with the jack mackerel season being influenced by the availability of these species. However, global increases in the market price for jack mackerel have increased its importance in the purse seine fishery to a level similar to blue mackerel. This has provided fishers with a cost effective alternative to traditional purse seine targets, particularly skipjack tuna, which incurs higher costs related to on-board storage and handling.

A number of bycatch issues exist in the JMA 7 fishery. A large bycatch fishery for blue mackerel operates for many months of the year and other bycatch species taken in this fishery include barracouta, gurnard, John Dory, kingfish, and snapper. Although non-availability of ACE is unlikely to be constraining in the first three of these additional species, the same is not true of kingfish, blue mackerel, and snapper. Fishing company spokespersons have stated that known hotspots of snapper are avoided.

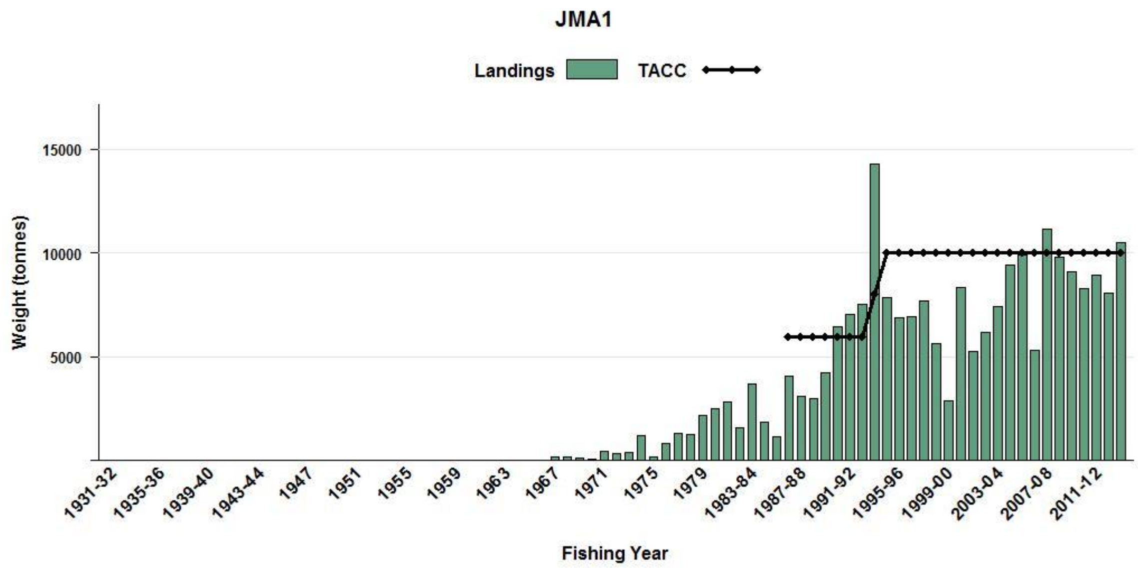
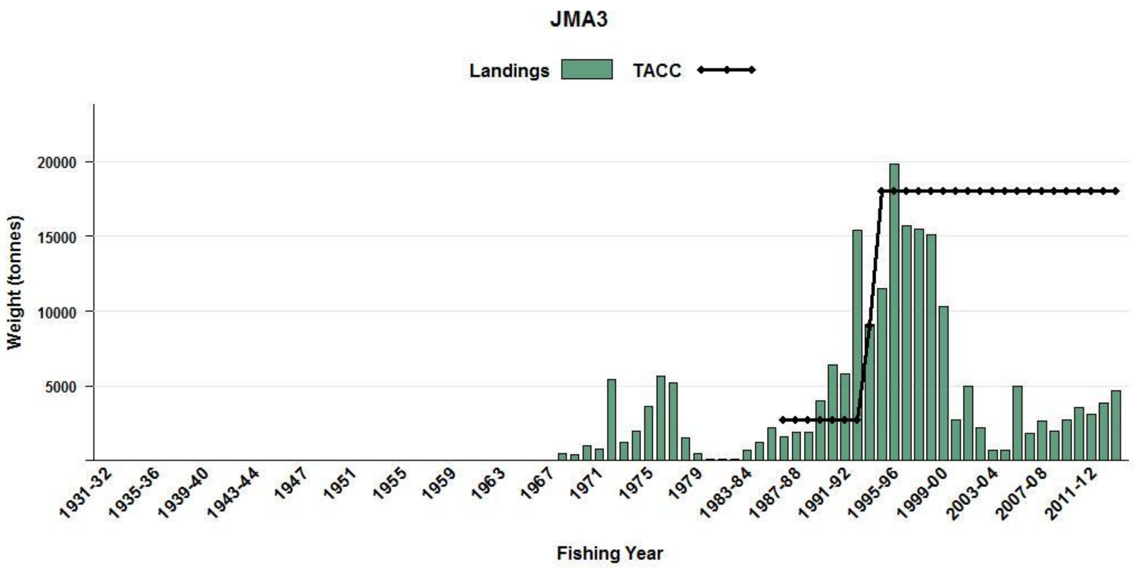


Figure 1: Reported commercial landings and TACC for the three main JMA stocks. From top left: JMA 1 (Auckland East, Central East). [Continued on next page].



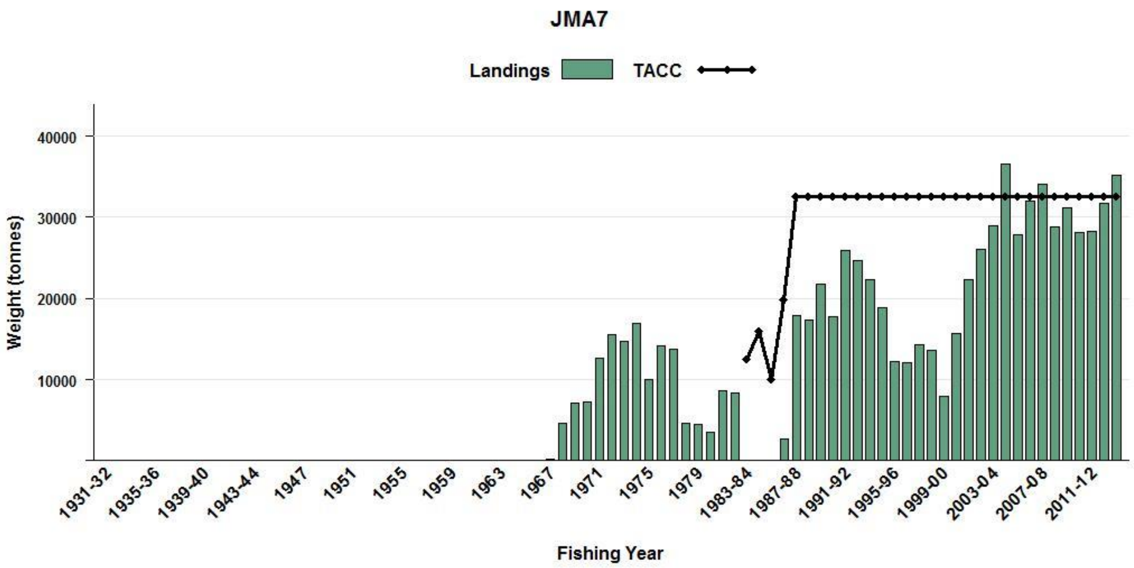


Figure 1: [Continued] Reported commercial landings and TACC for the three main JMA stocks. From top: JMA 3 (South East coast, South East Chatham Rise, Sub-Antarctic, Southland), and JMA 7 (Challenger, Central Egmont, Auckland West).

1.2 Recreational fisheries

Jack mackerels do not rate highly as a recreational target species although they are popular as bait.

There is some uncertainty with all recreational harvest estimates for jack mackerels and there is some confusion between blue and jack mackerels in the recreational data. The harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries.

Recreational catch in the northern region (JMA 1) was estimated at 333 000 fish (CV 0.13) by a diary survey in 1993–94 (Bradford 1996), 79 000 fish (CV 0.16) in a national recreational survey in 1996 (Bradford 1998), 349 000 fish (CV 39%) in the 2000 survey (Boyd & Reilly 2002) and 295 000 fish (CV 0.2%) in the 2001 survey (Boyd et al 2004). The surveys suggest a harvest of 80–110 t per year for JMA 1, insignificant in the context of the commercial catch. Estimates from other areas are very low (between 500 and 47 000 fish) and are likely to be insignificant in the context of the commercial catch.

1.3 Customary non-commercial fisheries

Quantitative information on the current level of Maori customary non-commercial catch is not available.

1.4 Illegal catch

There is no information on illegal activity or catch but it is considered to be insignificant.

1.5 Other sources of mortality

There is no information on other sources of mortality.

2. BIOLOGY

The three species of jack mackerel in New Zealand have different geographical distributions, but their ranges partially overlap. *T. novaezelandiae* predominates in waters shallower than 150 m and warmer than 13°C; it is uncommon south of latitude 42°S. *T. declivis* generally occurs in deeper (but less than 300 m) waters less than 16° C, north of latitude 45° S. *T. murphyi* occurs to depths of least 500 m and has a wide latitudinal range (0° S at the Galapagos Islands and coastal Ecuador, to south of 40° S off the Chilean coast).

T. murphyi was first described from New Zealand waters in 1987. Its presence was recorded off the south and east coasts of the South Island. It expanded onto the west coast of the South Island and the North and South Taranaki Bights by the late 1980s, reaching the Bay of Plenty in appreciable quantities by 1992 and becoming common on the east coast of Northland by June 1994. However, this extensive distribution has decreased in more recent years and, since the late 1990s, its presence north of Cook Strait has been sporadic with occasional landings in the JMA 1 purse seine fishery north of East Cape and from the JMA 1 inshore trawl fishery south of East Cape. The total range of *T. murphyi* extends along the west coast of South America, across the South Pacific, through to the New Zealand EEZ, and into waters off southeastern Australia.

All species can be caught by bottom trawl, mid-water trawl, or by purse seine targeting surface schools.

The vertical and horizontal movement patterns are poorly understood. Jack mackerels are presumed to be generally off the bottom at night, and surface schools can be quite common during the day.

Jack mackerels have a protracted spring-summer spawning season. *T. novaezelandiae* probably matures at about 26–30 cm fork length (FL) at an age of 3–4 years, and *T. declivis* matures when about 26–30 cm FL at an age of 2–4 years. Spawning occurs in the North and South Taranaki Bights, and probably in other areas as well.

The reproductive biology of *T. murphyi* in New Zealand waters is not well understood. Pre- and post-spawning fish have been recorded from the Chatham Rise, Stewart-Snares shelf, Northland east coast and off Kaikoura in summer, but it is unknown whether there has been any resulting recruitment in New Zealand waters. A recent study showed that older size/age groups become increasingly dominant in catches as one moves westward from the South American coast, suggesting that an eastward migration of oceanic spawned larvae and juveniles occurs in the South Pacific.

Initial ageing of *T. murphyi* taken in New Zealand waters has been completed, but the estimates are yet to be validated. Initial growth is rapid, slowing at 6–7 years, and *T. murphyi* is a moderately long-lived species with a maximum observed age of 32 years. *T. novaezelandiae* and *T. declivis* have moderate initial growth rates that slow after about 6 years. Both species reach a maximum age of 25+ years.

The best available estimate of M for *T. novaezelandiae* and *T. declivis* is 0.18 based on the age-frequency distributions of lightly exploited populations in the Bay of Plenty. Assuming $M = 0.18$, estimates of Z made in 1989 suggest that F is less than 0.05 for both endemic species off the central west coast (the main jack mackerel fishing ground). Biological parameters relevant to the stock assessment are shown in Table 3.

Table 3: Estimates of biological parameters.

Fishstock			Estimate	Source
1. Natural mortality (*M*)				
All			0.18	
	Considered best estimate for both endemic species from all areas.			Horn (1991a)
2. Weight = a(length)^b (Weight in g, length in cm fork length)				
			All	
		a	b	
T. declivis		0.023	2.84	Horn (1991a)
T. novaezelandiae		0.028	2.84	Horn (1991a)
3. von Bertalanffy growth parameters				
			All	
	L_∞	*k*	t_0	
T. declivis	46 cm	0.28	-0.40	Horn (1991a)
T. novaezelandiae	36 cm	0.30	-0.65	Horn (1991a)
T. s. murphyi	51.2 cm	0.155	-1.4	Taylor et al (2002b)

3. STOCKS AND AREAS

There is no new information that would alter the stock boundaries given in previous assessment documents. For assessment purposes the three jack mackerel species are treated separately where possible.

There are two possible hypotheses on the stock structure of *T. murphyi* in New Zealand waters: it is either a separate stock established by fish migrating from South America, or part of a single, extensive trans-Pacific stock. While successful recruitment in New Zealand waters would indicate the establishment of a separate stock, current evidence favours the latter hypothesis with an extensive stock between latitudes 35–50^o S, linking the coasts of Chile and New Zealand across what has been described as ‘the jack mackerel belt’. Few detailed data are available to document the process of range expansion by *T. murphyi* or indicate the relative abundance of the three species in particular areas. As a requirement of the increased TACCs introduced in 1994–95, improvements to jack mackerel catch monitoring were made to in order provide adequate data for quantifying species composition and the relative abundance in JMA 1 and JMA 3.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2013 Fishery Assessment Plenary based on reviews of similar chapters by the Aquatic Environment Working Group. This summary is for the jack mackerel fisheries, but a more detailed summary, issue-by-issue, is available in the 2012 Aquatic Environment and Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644).

4.1 Role in the ecosystem

A study of fish assemblages using research trawls suggested that *Trachurus novaezelandiae* is part of an inshore assemblage that prefers shallow northern waters (centred on about 60 m depth and latitude about 38.7° S). All three species overlap spatially, but *T. declivis* is part of a deeper assemblage around central New Zealand (centred on about 130 m and about 40.1° S), and *T. murphyi* occurs deeper still and further south (centred on about 220 m and about 44.7° S) (Francis et al 2002). *T. novaezelandiae* and *T. declivis* range through the water column from surface to the sea floor. The behaviour of *T. murphyi* in New Zealand is less well known but studies off Chile suggest that this species tends to aggregate at night and that this could reflect nocturnal foraging (Bertrand et al. 2004, 2006). The effect on the ecosystem of extracting, for example, about 30 000 t per year (2001–02 to 2010–11) of jack mackerels from the west coast of New Zealand is unknown.

4.1.1 Trophic interactions

Stevens et al (2011) reported the diet of *T. novaezelandiae* and *T. declivis* from the Bay of Plenty, Northland and the west coast South Island to be predominantly euphausiids with fewer amphipods and fish (see also Hurst 1980). Crustaceans (several groups) were the dominant prey of *T. novaezelandiae* in the Hauraki Gulf, with fewer fish and polychaetes (Godfriaux 1968 and 1970). The diet of *T. murphyi* from research trawls on shelf areas around New Zealand, mainly down to 500 m depth, included: crustaceans (55%, mainly euphausiids 38%, amphipods 12%, and *Munida* 6%); salps (36%); and teleosts (11% percentage frequency of occurrence in stomachs with food, Stevens et al 2011).

Predators of jack mackerels are likely to include many fishes, seabirds and marine mammals given the relative high abundance of jack mackerels. The diet of gemfish from research trawls in Southland included *Trachurus* spp. (6% of total, Stevens et al 2011). *T. declivis* and *T. murphyi* were identified from the stomachs of leafscale gulper shark and Plunket's shark and *T. declivis* from the stomachs of school shark (Dunn et al 2010). The diet of spiny dogfish included scavenged jack mackerel (Dunn et al 2013).

4.2 Incidental catch (fish and invertebrates)

Anderson (2007) used data from scientific observers and commercial catch-effort returns to estimate the rates and annual levels of fish bycatch and discards in the jack mackerel trawl fishery, from 2001–02 to 2004–05. Jack mackerel species accounted for 70% of the total estimated catch from trawls targeting jack mackerels between 1 October 2001 and 30 September 2005. The remaining 30% comprised mostly other commercial species, especially barracouta (Table 4). Although over 99% of the catch was of commercial species, altogether about 130 taxa were identified by observers. The main species discarded were spiny dogfish (only 8% of which was retained) and thresher shark (3% retained).

Table 4: Bycatch and discards from all observer records for the target trawl fishery for jack mackerel from 1 October 2001 to 30 September 2005 for species or species groups with a total catch of 100 t or more, ordered by decreasing percentage of catch.

Species code	Common name	Scientific name	Estimated catch (t)	% of catch	% retained
JMA	Jack mackerel	*Trachurus declivis, T.m., T.nz.*	15 978	69.53	100.0
BAR	Barracouta	*Thyrsites atun*	3 593	15.64	100.0
EMA	Blue mackerel	*Scomber australasicus*	1 093	4.76	100.0
FRO	Frostfish	*Lepidopus caudatus*	712	3.10	100.0
RBT	Redbait	*Emmelichthys nitidus*	627	2.73	95.0
SQU	Arrow squid	*Nototodarus sloanii* & *N. gouldi*	184	0.80	100.0
HOK	Hoki	*Macruronus novaezelandiae*	138	0.60	100.0
WAR	Blue warehou	*Seriolella brama*	128	0.56	100.0
SPD	Spiny dogfish	*Squalus acanthias*	101	0.44	8.0
-	Others	-	419	1.84	-

Between 2009 and 2011, *T. novaezelandiae* dominated 97% of purse seine landings in JMA 1 (Walsh et al 2012). The estimated proportions by year were 1–17% for *T. declivis*, 0–3% for *T. murphyi*, and 81–99% for *T. novaezelandiae*. There was spatial and temporal heterogeneity in size and abundance; *T. novaezelandiae* dominated landings from the Bay of Plenty throughout the year and large *T. declivis* and *T. murphyi* were common in east Northland during winter.

4.3 Incidental Catch (seabirds, mammals, and protected fish)

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality e.g., seabirds struck by a warp but not brought onboard the vessel (Middleton & Abraham, 2007).

4.3.1 Marine mammal interactions

Jack mackerel trawlers occasionally catch marine mammals, primarily common dolphin, long-finned pilot whale, and NZ fur seal (which were all classified as “Not Threatened” under the NZ Threat Classification System in 2010, Baker et al 2010).

Between 2002–03 and 2012–13, there were 148 observed captures of whales and dolphins in jack mackerel trawl fisheries. Observed captures were common dolphin (134), long-finned pilot whale (12), Risso’s dolphin (1), and dusky dolphin (1). In the 2012–13 fishing year there were 15 observed captures of common dolphins in jack mackerel trawl fisheries (Table 5). Estimated captures for 2002–03 to 2011–12 are shown in Table 5. Common dolphins were observed captured off the Taranaki coast or off the west coast of the North Island (Thompson et al 2013). The rate of capture of common dolphins varied in these years from 0.28 to 11.18 per 100 tows with a ten-year average of 1.30 and with lower rates of capture in recent years (Table 5).

Table 5: Number of tows by fishing year and observed and model-estimated total common dolphin captures in jack mackerel trawl fisheries, 2002–03 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and provisional data for 2012–13 are based on data version 20140131.

		Observed				Estimated		
	Tows	No.obs	%obs	Captures	Rate	Captures	95%c.i.	%inc.
2002–03	3 067	346	11.3	21	6.07	142	58–270	74.9
2003–04	2 383	152	6.4	17	11.18	99	46–180	94.6
2004–05	2 509	558	22.2	21	3.76	78	42–126	93.7
2005–06	2 808	709	25.2	2	0.28	10	2–27	74.1
2006–07	2 711	800	29.5	11	1.38	50	21–92	79.5
2007–08	2 649	816	30.8	20	2.45	41	23–69	82.9
2008–09	2 170	813	37.5	11	1.35	25	12–46	82.9
2009–10	2 406	786	32.7	4	0.51	25	6–57	91.8
2010–11	1 880	593	31.5	7	1.18	60	25–110	83.4
2011–12	2 032	1 550	76.3	5	0.32	7	5–14	80.9
2012–13†	2 208	1 935	87.6	15	0.78	15	15-19	76.9

† Provisional data, no model estimates available.

In the 2012–13 fishing year there were 3 observed captures of NZ fur seals in jack mackerel trawl fisheries (Table 6). Estimated total captures of NZ fur seals are shown in Table 6. Only a small fraction of the total captures of NZ fur seal in trawl fisheries have been taken when targeting jack mackerel. Fur seal captures in the jack mackerel trawl fishery have been off the Taranaki coast, off the west coast of the North Island, or off the east coast of the South Island. The ten year average of the rate of capture for NZ fur seals is 0.46 captures per 100 tows (range 0.00 to 1.32), with lower capture rates since 2008–09.

Table 6: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in jack mackerel trawl fisheries, 2002–03 to 2011–12. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and provisional data for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures		
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.	% included
2002–03	3 067	346	11.3	1	0.29	16	4–40	100.0
2003–04	2 383	152	6.4	2	1.32	14	4–34	100.0
2004–05	2 510	558	22.2	5	0.90	25	9–56	100.0
2005–06	2 808	709	25.2	6	0.85	26	10–61	100.0
2006–07	2 711	800	29.5	2	0.25	13	3–38	100.0
2007–08	2 650	818	30.9	7	0.86	32	11–102	100.0
2008–09	2 169	813	37.5	8	0.98	16	9–32	100.0
2009–10	2 406	786	32.7	2	0.25	5	2–13	100.0
2010–11	1 881	593	31.5	0	0.00	3	0–11	100.0
2011–12	2 031	1 548	76.2	5	0.32	8	5–20	100.0
2012–13†	2 210	1 937	87.6	3	0.15	-	-	-

† Provisional data, no model estimates available.

4.3.2 Seabird interactions

Annual observed seabird capture rates ranged from 0 to 2.56 per 100 tows in jack mackerel fisheries between 1998–99 and 2007–08 (Baird 2001, 2004a,b,c, 2005, Abraham & Thompson 2009, Abraham et al 2009, Abraham & Thompson 2011). Capture rates have fluctuated without obvious trend at this low level (Table 7). In the 2012–13 fishing year there were 33 observed captures of birds in the jack mackerel trawl fishery at a rate of 1.70 birds per 100 observed tows (Abraham et al 2013). Total estimated seabird captures in the jack mackerel trawl fishery varied from 7 to 28 between 2002–03 and 2011–12 (MPI 2013, Table 7). The average capture rate in jack mackerel trawl fisheries over the last ten years is 0.72 birds per 100 tows, a low rate relative to trawl fisheries for squid (13.79 birds per 100 tows), scampi (5.57 birds per 100 tows) and hoki (2.16 birds per 100 tows) over the same time period.

Table 7: Number of tows by fishing year and observed seabird captures in jack mackerel trawl fisheries, 2002–03 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Abraham et al (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and provisional data for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures		
	Tows	No. Obs	% obs	Captures	Rate	Mean	95% c.i.	% included
2002–03	3 067	346	11.3	4	1.16	26	12–49	100.0
2003–04	2 383	152	6.4	0	0.00	6	1–14	100.0
2004–05	2 509	558	22.2	7	1.25	16	10–26	100.0
2005–06	2 808	709	25.2	0	0.00	29	10–65	100.0
2006–07	2 711	800	29.5	1	0.12	8	2–18	100.0
2007–08	2 649	816	30.8	1	0.12	6	2–14	100.0
2008–09	2 170	813	37.5	6	0.74	13	7–24	100.0
2009–10	2 406	786	32.7	3	0.38	9	4–19	100.0
2010–11	1 880	593	31.5	7	1.18	20	10–40	100.0
2011–12	2 032	1 550	76.3	5	0.32	10	5–21	100.0
2012 -13†	2 208	1 935	87.6	34	1.76	34	33-36	100.0

† Provisional data, no model estimates available.

Table 8: Number of observed seabird captures in jack mackerel trawl fisheries, 2002–03 to 2012–13, by species and area. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard & Abraham 2013 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for jack mackerel. Other data, version 20140131.

Species	Risk Ratio	Taranaki	West Coast North Island	Stewart Snares Shelf	East Coast South Island	West Coast South Island	Total
Southern Buller's albatross	Very high	0	0	0	2	0	2
NZ white capped albatross	Very high	2	0	4	3	0	9
Total albatrosses	**N/A**	**2**	**0**	**4**	**5**	**0**	**11**
Westland petrel	Medium	0	0	0	0	1	1
White chinned petrel	Medium	0	0	20	5	0	25
Cape petrel	High	1	0	0	0	1	2
Common diving petrel	–	0	0	2	0	1	3
Fairy prion	–	5	0	0	0	0	5
Fulmar prion	–	3	0	0	0	0	3
Sooty shearwater	–	1	0	12	2	0	15
NZ white-faced storm petrel	–	0	1	0	0	0	1
Unknown seabird	**N/A**	1	0	0	0	0	1
Total other birds	**N/A**	**11**	**1**	**34**	**7**	**3**	**56**

Observed seabird captures since 2002–03 have been mostly prions, shearwaters, and petrels (56 of the 67 observed seabird captures), with 11 observed albatross captures (Table 8). Seabird captures in the jack mackerel fishery have been observed mostly off Taranaki and on the Stewart-Snares shelf. These numbers should be regarded as only a general guide on the distribution of captures because the

numbers are small, and the observer coverage is not uniform across areas and may not be representative.
Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the jack mackerel trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Department of Internal Affairs 2006). The 2006 Notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling ("paired streamer lines", "bird baffler" or "warp deflector" as defined in the Notice).

4.4 Benthic interactions

Jack mackerel are taken using trawls that are sometimes fished on or near the seabed. Black et al (2013) estimated that between 2006–07 and 2010–11, 78% of jack mackerel catch was reported on TCEPR forms. Target jack mackerel tows accounted for about 3.5% of all tows reported on TCEPR forms to have been fished on or close to the bottom between 1989–90 and 2004–05 (Baird et al 2011). These tows were located in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2009) classes C, E (shelf), H (upper slope), and J (mid-slope) (Baird & Wood 2012), and 91% were in water shallower than 200 m (Baird et al 2011).

Trawling for jack mackerel with some or all of the gear contacting the bottom, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review (MPI 2013).

4.5 Other considerations

4.5.1 Spawning disruption

Fishing may disrupt spawning activity or success. Canadian research carried out on Atlantic cod (*Gadus morhua*) concluded that "Cod exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae"(Morgan et al 1999). Morgan et al (1997) also reported disruption of a spawning shoal of Atlantic cod: "Following passage of the trawl, a 300-m-wide "hole" in the aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl." There have been no specific studies for jack mackerel in New Zealand waters, but information on the timing and location of spawning and fishing exists. *T. declivis* and *T. novaezelandiae* are serial spawners with a protracted spring-summer spawning season (Hurst et al 2000). *T. murphyi* appears to spawn from late winter through to summer (Horn 1990, Hurst et al 2000). The JMA 7 trawl fishery has peaks of catch and effort in spring–summer (Oct-ober–March) and in winter (April–September), (McKenzie, 2008), the former overlapping with spawning. Most of the purse-seine catch taken from the Bay of Plenty is in September–October, but an increasing proportion has been caught in November–December since 2005–06 (Walsh et al 2012), also overlapping the spring–summer spawning.

4.5.2 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management (HPSFM) does not have a policy definition (MPI, 2013) although work is underway to generate one. Studies of potential relevance have identified areas of importance for spawning and juveniles (Hurst et al 2000). *T. declivis* spawning was found to be common on the southwest and northwest outer shelf North Island, and moderate to high abundance of juveniles was recorded from northwest North Island, Hauraki Gulf, and Bay of Plenty outer shelf. *T. novaezelandiae* spawning was found to be common on the southwest and northwest inner and outer shelf North Island, and moderate to high abundance of juveniles was recorded from Hauraki Gulf and Bay of Plenty inner and outer shelf, East Cape inner shelf, and Tasman/Golden Bays. *T. murphyi* spawning was found to be common on the southwest outer shelf and only low abundance of juveniles was recorded from the outer Southland shelf and 300–600 m on the Chatham Rise.

4.5.3 Genetic effects
Fishing and environmental changes, including those caused by climate change or pollution, could alter the genetic composition or diversity of a species. There are no known studies of the genetic diversity of jack mackerels in New Zealand.

5. STOCK ASSESSMENT

Stock assessments for jack mackerel are complicated by the reporting and management of three species under a single code. Preliminary stock assessments for *T. declivis* and *T. novaezealandiae* in JMA 7 were undertaken in 2007 based on data from a new Bayesian analysis for splitting the recorded commercial catch into *T. declivis*, *T. novaezealandiae*, and *T. murphyi* components. This analysis was used to derive CPUE indices and a catch history for the *T. declivis* fishery in JMA 7, which were incorporated along with a proportions-at-age series into the assessments.

The assessment for *T. declivis* is described below, but the assessment for *T. novaezealandiae* is not included because of convergence problems with the assessment model which led to its rejection by the working group.

Otherwise, there are no new data that would alter the yield estimates given in the 1996 Plenary Report. Estimates of *MCY* for JMA 1 and JMA 3 have not changed since the 1993 Plenary Report. Other yield estimates have not changed since the 1991 Plenary Report. The yield estimates are based on biomass estimates from a stock reduction analysis and aerial sightings data.

5.1 *T. declivis* in Challenger, Central West and Auckland West (JMA 7)

Species Proportion Estimates

A Bayesian species proportions model was used to estimate the proportion of *T. declivis* in the reported (TCEPR) catch for the JMA 7 fishery from 1989–90 through to 2004–05. Six spatial-temporal strata were used in the model: three spatial strata in combination with two temporal strata. The three spatial strata consisted of three regions with differing patterns in the relative proportions of the three jack mackerel species. The two temporal strata are a summer fishery (October–March) and a winter fishery (April–September). In the model the species proportions are estimated for each year (1989–90 to 2004–05), and the six strata for that year.

CPUE

The Bayesian species proportions model was used to estimate the *T. declivis* catch for each TCEPR tow, and the derived catch-effort data used in a standardised CPUE analysis. Based on changes in jack mackerel fishery practice, and changes in vessel composition over time, the CPUE analysis was split into two time periods: an early period covering the years 1989–90 to 1995–96, and a late period covering 1996–97 to 2004–05 (Table 9).

Table 9: Standardised CPUE indices (relative year effects) with number of tows from 1989–90 to 2004–05.

	Year	CPUE index	CV	Number of tows
1989–90	1990	2.07	0.1	716
1990–91	1991	2.05	0.1	688
1991–92	1992	1.9	0.1	947
1992–93	1993	1.56	0.09	1 088
1993–94	1994	1.37	0.09	1 444
1994–95	1995	1.28	0.09	597
1995–96	1996	0.89	0.1	502
1996–97	1997	1.69	0.13	160
1997–98	1998	0.92	0.11	252
1998–99	1999	2.7	0.08	712
1999–00	2000	2.15	0.08	717
2000–01	2001	2.67	0.07	1 240

Table 9 [continued]:

	Year	CPUE index	CV	Number of tows
2001–02	2002	2.85	0.07	1 760
2002–03	2003	2.38	0.06	2 272
2003–04	2004	2.59	0.07	2 055
2004–05	2005	3.23	0.07	2 002

Catch History

Catch records for jack mackerel extend back to 1946, though landings are small until the mid 1960s. The Bayesian model annual species proportions were used to estimate the *T. declivis* landings from 1991–92 to 2004–05, while previous species proportions were used to estimate landings for the earlier years (Table 10).

Recreational catch, illegal catch, and customary non-commercial catch are not well known, though are thought to be small relative to the commercial catch, so no components are included for these in the catch history.

Catch at Age

Catch-at-age data were used from the commercial fishery in the years 1989–90, 1990–91, 1995–96, and 2004–05.

Table 10: Catch history (t) for *T. declivis* in the JMA 7 fishery. The year denotes the calendar year at the end of the fishing year.

Year	Estimated catch	Year	Estimated catch	Year	Estimated catch
1946	3	1967	3 326	1988	10 340
1947	1	1968	3 326	1989	10 963
1948	2	1969	3 326	1990	6 315
1949	8	1970	2 787	1991	6 759
1950	0	1971	4 634	1992	12 422
1951	0	1972	6 405	1993	7 925
1952	3	1973	5 284	1994	10 741
1953	4	1974	6 423	1995	6 809
1954	0	1975	4 591	1996	5 276
1955	5	1976	5 518	1997	4 702
1956	1	1977	6 151	1998	5 002
1957	3	1978	2 197	1999	10 045
1958	4	1979	2 524	2000	4 339
1959	0	1980	1 522	2001	6 595
1960	2	1981	3 547	2002	13 403
1961	2	1982	3 372	2003	12 781
1962	2	1983	5 540	2004	16 752
1963	5	1984	6 980	2005	17 154
1964	4	1985	8 967	2006	_
1965	3	1986	6 801	2007	_
1966	23	1987	11 493	2008	_

Model Structure

In 2007, the observational data were incorporated into an age-based Bayesian stock assessment to estimate stock size. The stock was considered to reside in a single area, with no partition by sex or maturity. In the model age groups were 1–25 years, with a plus group of 25+. The model covered the period 1965–2005 (estimated catch was insignificant before 1965).

There was a single time step in the model, in which the order of processes is ageing, recruitment, and mortality (natural and fishing). Recruitment numbers followed a Beverton-Holt relationship with steepness of 0.924 derived from a mean value over a number of species similar to jack mackerel. Maturation was not explicitly modeled; instead a maturity-at-age logistic ogive was used with an a_{50} of 3 and an a_{to95} of 9 years. Growth was assumed to follow a von Bertalanffy curve.

The model was fitted to: (a) an early CPUE series covering the years 1990 to 1996, (b) a late CPUE series covering the years 1997 through to 2005, (c) and a commercial proportions-at-age series for 1990, 1991, 1996, and 2005. A research trawl proportions-at-age for 1981 was not entered into the model, but the fit to it was evaluated outside the model assuming that the research trawl selectivity is the same as the commercial trawl selectivity. A double half normal curve was used to model the commercial trawl selectivity.

The relative influence of the different data series in the model was evaluated by dropping the early CPUE series, dropping the late CPUE series, and putting more weight on the proportions-at-age data by increasing their effective sample size.

Results

For the base model in this preliminary assessment it was estimated that current biomass is at 53% of virgin biomass (B_0). The biomass trajectory indicates a decline in biomass until the mid 1990s, followed by an increase in biomass until 2002, subsequently followed by a slight decline (Figure 2).

Dropping the early CPUE series put the estimate of current biomass at 76% B_0, in contrast dropping the late CPUE series put the current biomass at only 30% B_0. Doubling the effective sample sizes for all the proportions-at-age data put the estimate of current biomass at 66% B_0.

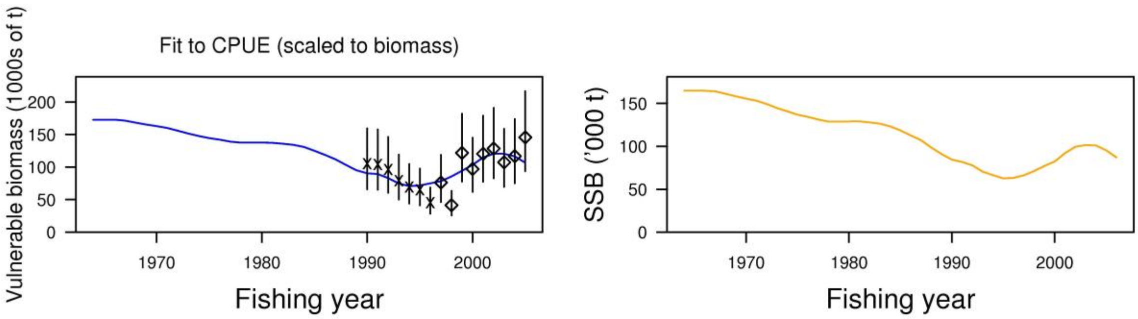


Figure 2: Biomass trajectories for the base case. The left-hand graph shows the fit of the CPUE indices to the vulnerable biomass; the right-hand graph shows the mature biomass trajectory. The year denotes the calendar year at the end of the fishing year.

5.2 Estimates of fishery parameters and abundance

Estimates of fishery parameters are given in Table 11.

Table 11: Estimates of fishery parameters.

Parameter	Fishstock	Estimate	Species	Source
$F_{0.1}$	JMA 7	0.23	*T. declivis*	Horn (1991a)
		0.33	*T. novaezelandiae*	Horn (1991a)

5.3 Biomass estimates

Biomass estimates are discussed in the section on estimation of *MCY*. Estimates of current biomass are not available.

5.4 Yield estimates and projections

The 2007 assessment for *T. declivis* did not include yield estimates so there is no information to update the historical estimates described below.

(i) Challenger, Central (West) and part of Auckland (West) (FMAs 7, 8, and part of 9)

MCY was estimated in the early 1990s for the two endemic jack mackerel species separately using the equation *MCY* = 2/3 *MSY* (Method 3). The deterministic *MSY* values (8.8% and 14.7% of B_0 for *T. declivis* and *T. novaezelandiae* respectively) were calculated using a yield per recruit analysis and a Beverton and Holt stock-recruitment relationship with an assumed steepness of 0.95. B_0 was estimated using a backward projection of a stock reduction analysis that produced biomass trajectories over the period 1970–90.

For *Trachurus declivis*, B_0 = 200 000 t,
MCY = 2/3 * (0.088 * 200 000 t) = 11 800 t
For *Trachurus novaezelandiae*, B_0 = 100 000 t,
MCY = 2/3 * (0.147 * 100 000 t) = 9800 t

Because these yield estimates are based on an assumed stock-recruitment relationship, they are highly uncertain.

(ii) Northland, Bay of Plenty, east coast North Island (FMAs 1 and 2)

Annual landings before 1990–91 ranged from 1173 t to less than 5000 t. Landings subsequently increased markedly as a result of the increased availability of *T. murphyi* to a maximum in excess of 14 000 t in 1993–94. Concerns about the assumptions used to produce the original yield estimate and the production of time series abundance indices from aerial sightings data resulted in a revised yield estimate in the mid 1990s. The aerial sightings indices showed little change in jack mackerel abundance estimates in JMA 1 between 1976 and 1990.

MCY was estimated in 1993 using the equation $MCY = cY_{AV}$ (method 4) incorporating the mean of removals from 1983–84 to 1989–90, before the *T. murphyi* invasion influenced total catches. It is assumed that this represents a period when fishing effort was relatively stable, thus satisfying the criterion for the use of method 4. The calculated *MCY* applies only to *T. declivis* and *T. novaezelandiae*.

Using M = 0.18 and therefore c = 0.8, *MCY* = 0.8 * 3013 = 2410 t (rounded to 2400 t).

(iii) Rest of the EEZ (QMAs 3–6)

Trawl surveys in QMAs 3–6 are not considered to be a suitable means to estimate biomass of jack mackerels, due primarily to the slow towing speed. Landings from JMA 3 have fluctuated widely since 1983–84, and were relatively high in the 1990s due probably to an increased abundance of *T. murphyi*.

For JMA 3 there are no available estimates of biomass and no series of catch data from a period of relatively constant fishing mortality. Therefore, it is not possible to estimate *MCY* for this Fishstock.

The level of risk to the stock by harvesting the population at the estimated *MCY* value cannot be determined.

Estimates of current biomass are not available for any jack mackerel stock, so *CAY* cannot be estimated.

Yield estimates for *T. declivis* and *T. novaezelandiae* are shown in Table 12.

Table 12: Yield estimates for *T. declivis* and *T. novaezelandiae* (t).

Parameter	Fishstock	Estimate
MCY	JMA 1	2 400
	JMA 3	Cannot be determined
	JMA 7	21 600
CAY	All	Cannot be determined

5.5 Other yield estimates and stock assessment results

For *T. declivis* and *T. novaezelandiae* catch-at-age proportions are available for the years 2006–07 through to 2008–09 in JMA 7. These were used to estimate instantaneous total mortality Z values by the Chapman-Robson maximum likelihood method (Chapman & Robson 1960). As a sensitivity analysis the assumed age of recruitment was varied between three and six years (Smith 2011).

For *T. declivis* estimates of *Z* varied between 0.17 y^{-1} and 0.23 y^{-1}. For *T. novaezelandiae*, *Z* varied between 0.23 $y^{-1}$and 0.43 y^{-1}. Estimates were lowest in the 2008–09 year for both species. The accepted value of natural mortality for both species is 0.18 y^{-1}, indicating that estimates of average instantaneous fishing mortality (*F*) were well below *M* for *T. declivis* and about equal to *M* for *T. novaezelandiae*.

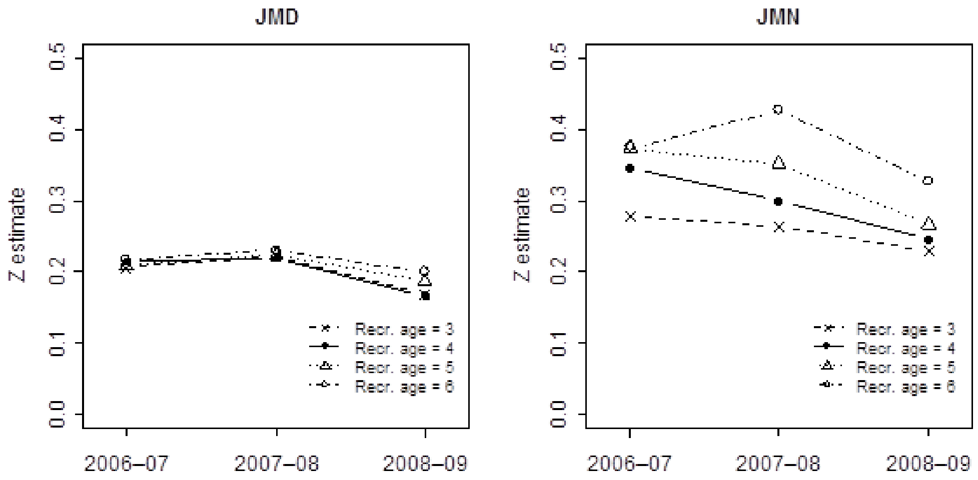


Figure 3: Estimates of instantaneous total mortality (Z) by year for T. declivus and T. novaezelandiae in JMA 7.

5.6 Other factors

The estimates of *MCY* given above are likely to be conservative as they do not take into account the presence of the third species, *T. murphyi*, which has been known at times to comprise a substantial proportion of the purse seine catches in the area between Cook Strait and Kaikoura, in the Bay of Plenty and on the east Northland coast, although the proportion of this component has declined considerably since the late 1990s. *T. murphyi* has also been an important component of the west coast North Island jack mackerel trawl fishery but has declined in recent years. Thus, there has been a contraction in the range of this species in New Zealand waters, although it is unknown yet whether this represents a decrease in its overall abundance here. The effect of *T. murphyi* on the range and abundance of the other two species is unknown.

Aerial sightings data were used to produce a time series of relative abundance indices for jack mackerel. The time series covered the period from the beginning of the purse seine fishery in 1976 to 1993. It indicated an increase in abundance in JMA 1 from the early 1990s, and, although the result is not as clear, a similar trend in JMA 3 and JMA 7. These increases were attributed to the invasion of *T. murphyi*.

The validity of this early aerial sightings abundance index is uncertain. Further analysis of these data have been the focus of considerable effort in recent years and the Northern Inshore Working Group had not yet accepted revised abundance indices due to data and model concerns.

The stipulation that catches in JMA 1 and JMA 3 above the original TACs (5970 t and 2700 t, respectively) be accounted for by increases in *T. murphyi* only, is a method of managing this species independently of the other two. This approach was introduced as a means of maintaining stocks of the endemic species while allowing exploitation of increased stocks of *T. murphyi* resulting from its invasion.

6. STATUS OF THE STOCKS

Assessment of the status of JMA is complicated by the reporting and management of three species under a single code. This is further complicated by the uncertain ‘status’ of *T. murphyi*. The effect of the *T. murphyi* invasion on stocks of the New Zealand jack mackerels is unknown.

Stock Structure Assumptions
The three species have different levels of mobility and different spatial distributions within New Zealand. *T. murphyi* has been extremely mobile, with a widespread distribution throughout New Zealand during the 1990s, but is now rarely seen in areas where once it was common. The degree to which its biomass has actually declined is difficult to determine and there are no recent reliable estimates of its current spatial distribution. There are reports from hoki surveys in Cook Strait of aggregations of *T. murphyi* lying in deeper water.

T. declivis is also believed to be highly mobile within New Zealand. Because of this, a single biological stock is assumed, but this has not yet been reliably determined The mobility of *T. novaezelandiae* is assumed to be lower, given that it is a smaller animal with a more northerly and inshore distribution than *T. declivis*. Consequently, there is a higher probability of multiple independent breeding populations for *T. novaezelandiae*.

JMA 1

Stock Status	
Year of Most Recent Assessment	1993: $MCY = cY_{AV}$
Reference Points	Target(s): Not established but B_{MSY} assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status	
-	
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	An index for JMA 1 is not available at this time. Recent work and discussions concerning the use of aerial sightings data for annual relative abundance indices concluded that the inter-annual variation was too great for these data to provide a reliable index.
Recent Trend in Fishing Mortality or Proxy	-
Trends in other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	It is not known whether catches at the level of the current TACCs or recent catch levels are sustainable in the long-term.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Assessment Methodology	
Assessment Type	Level 3 — Qualitative Evaluation: Fishery characterisation with evaluation of fishery trends (e.g., catch, effort and nominal CPUE, length-frequency information) - there is no agreed index of abundance

Assessment Method	-	
Main data inputs	Species proportions estimates	
Period of Assessment	Latest assessment: 1993	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-
Fishery Interactions
JMA 1 catches are primarily taken by targeted purse seine. Because jack mackerel often occur in mixed schools with kahawai, particularly towards the end of the fishing year, this can inhibit jack mackerel targeting in this fishery at this time.

JMA 3

Stock Status	
Year of Most Recent Assessment	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status	
-	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	-
Recent Trend in Fishing Mortality or Proxy	-

Projections and Prognosis		
Stock Projections or Prognosis	It is not known whether catches at the level of the current TACCs or recent catch levels are sustainable in the long-term.	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology		
Assessment Type	Level 4: Low information evaluation — there are only data on catch and TACC, with no other fishery indicators. Catch is qualified with species proportions estimates from MFish observer data. Some length-frequency information is available.	
Assessment Method	-	
Main data inputs	Species proportions estimates	
Period of Assessment	Latest assessment: -	Next assessment: -
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	
Qualifying Comments		
-		

Fishery Interactions
JMA 3 catches are primarily taken by midwater trawl and have comprised a high percentage of *T. murphyi* in some years.

JMA 7

Stock Status	
Year of Most Recent Assessment	2011
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status	
-	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	-
Recent Trend in Fishing Mortality or Proxy	Estimates of total mortality for *T. declivis* (JMD) and *T. novaezelandiae* (JMN) from catch curve analyses in 2011 suggest that fishing mortality was well below *M* for JMD and about equal to *M* for JMN; i.e. it is Unlikely (< 40%) that overfishing is occurring.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis		
Stock Projections or Prognosis	Unknown	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology		
Assessment Type	Level 2 - Partial quantitative stock assessment	
Assessment Method	Catch curve analysis	
Main data inputs	-	
Period of Assessment	Latest assessment: 2011	Next assessment: 2014
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	No abundance indices are available. The analyses (catch curves) may not provide accurate values of average fishing mortality.	

Qualifying Comments
-

Fishery Interactions
JMA 7 catches are primarily taken by targeted midwater trawl. A number of bycatch issues exist with blue mackerel, an important component of this fishery, and non-availability of ACE for kingfish, blue mackerel, and snapper potentially influences targeting in some sub-areas. Incidental interactions and associated mortality of common dolphins occurs in this fishery.

Yield estimates, TACCs and reported landings for the 2013–14 fishing year are summarised in Table 13.

Table 13: Summary of TACCs (t) and reported landings (t) for all three species in the most recent fishing year.

Fishstock		FMAs	2013–14 Actual TAC	2013–14 Reported landings
JMA 1	Auckland (East)/ Central (East)	1, 2	10 000	10 520
JMA 3	South-East/Southland/Sub-Antarctic	3, 4, 5, 6	18 000	4 693
JMA 7	Challenger/Central (West)/Auckland (West)	7, 8, 9	32 537	35 175
JMA 10	Kermadec	10	10	0
Total			60 547	50 388

7. FOR FURTHER INFORMATION

Abraham, E.R.; Thompson, F.N. (2009). Capture of protected species in New Zealand trawl and longline fisheries, 1998–99 to 2006–07 New Zealand Aquatic Environment and Biodiversity Report No. 32. 197 p.

Abraham, E R; Thompson, F N (2011) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 80*.

Abraham, E R; Thompson, F N; Berkenbusch, K (2013) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Ministry for Primary Industries, Wellington).

Abraham, E R; Thompson, F N; Oliver, M D (2010) Summary of the capture of seabirds, mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No.45*. 149 p.

Anderson, O F (2004) Fish discards and non-target fish catch in the trawl fisheries for arrow squid, jack mackerel, and scampi in New Zealand waters. *New Zealand Fisheries Assessment Report 2004/10*. 61 p.

Anderson, O F (2007) Fish discards and non-target fish catch in the New Zealand jack mackerel trawl fishery: 2001–02 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report 8*. 36 p.

Baird, S.J. (2001). Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1998-99. New Zealand Fisheries Assessment Report 2001/14.43 p.

Baird, S J (2004a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999–2000. *New Zealand Fisheries Assessment Report 2004/41*.56 p.

Baird, S J (2004b) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000–01. *New Zealand Fisheries Assessment Report 2004/58*. 63 p.

Baird, S J (2004c) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001–02. *New Zealand Fisheries Assessment Report 2004/60*. 51 p.

Baird, S J (2005) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/2*. 50 p.

Baird, S J; Smith, M H (2007) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 14*. 98 p.

Baird, S J; Wood, B A (2012) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. *New Zealand Aquatic Environment and Biodiversity Report 89*. 43 p.

Baird, S J; Wood, B A; Bagley, N W (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989–90 to 2004–05. *New Zealand Aquatic Environmental and Biodiversity Report No. 73*. 143 p.

Baker, C S; Chilvers, B L; Constantine, R; DuFresne, S; Mattlin, R H; van Helden, A; Hitchmough, R (2010) Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. *New Zealand Journal of Marine and Freshwater Research 44*: 101–115.

Ballara, S L; Anderson, O F (2009) Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 38*. 102 p.

Bertrand, A; Barbieri, M A; Córdova, J; Hernández, C; Gómez, F; Leiva, F (2004) Diel vertical behaviour, predator-prey relationships, and occupation of space by jack mackerel (*Trachurus murphyi*) off Chile. *ICES Journal of Marine Science 61*: 1105–1112.

Bertrand, A; Barbieri, M A; Gerlotto, F; Leiva, F; Córdova, J (2006) Determinism and plasticity of fish schooling behaviour as exemplified by the South Pacific jack mackerel *Trachurus murphyi*. *Marine Ecology Progress Series 311*: 145–156.

Black, J; Wood, R; Berthelsen, T; Tilney, R (2013) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2009–2010. *New Zealand Aquatic Environment and Biodiversity Report No. 110*. 57 p.

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 National marine recreational fishing survey: diary results and harvest estimates. Draft New Zealand Fisheries Assessment Report (Unpublished report held by Ministry for Primary Industries.)

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Draft New Zealand Fisheries Assessment Report. (Unpublished report held by Ministry for Primary Industries.)

Bradford, E (1996) A comparison of the 1993-94 diary and boat ramp surveys of recreational fishing in the Ministry of Fisheries North region New Zealand Fisheries Assessment Research Document 96/5. 21 p.

Bradford, E (1997) Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993–94. New Zealand Fisheries Assessment Research Document 1997/7. 16 p. (Unpublished document held by NIWA library, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document. 1998/16. 27 p.

Bradford, E; Taylor P R (1995) Trends in pelagic fish abundance from aerial sightings data. New Zealand Fisheries Assessment Research Document 1995/8. 60 p. (Unpublished document held by NIWA library, Wellington.)

Brothers, N; Duckworth, A R; Safina, C; Gilman, E L (2010) Seabird bycatch in pelagic longline fisheries is grossly underestimated when using only haul data. *PloS One 5*: e12491. doi: 10.1371/journal.pone.001249.

Chapman, D G; Robson, D S (1960) The analysis of a catch curve. *Biometrics 16*: 354–368.

Department of Internal Affairs. (2006). Seabird Scaring Devices – Circular Issued Under Authority of the Fisheries (Commercial Fishing) Amendment Regulations 2006 (No. F361). New Zealand Gazette 6 April 2006 : 842-846.

Dunn, M R; Stevens, D W; Forman, J S; Connell, A (2013) Trophic Interactions and Distribution of Some Squaliforme Sharks, Including New Diet Descriptions for *Deania calcea* and *Squalus acanthias*. PLoS ONE 8(3): e59938. doi:10.1371/journal.pone.0059938.

Dunn, M R; Szabo, A; McVeagh, M S; Smith, P J (2010) The diet of deepwater sharks and the benefits of using DNA identification of prey. *Deep-Sea Research I 57*: 923–930.

Elizarov, A A; Grechina, A S; Botenev, B N; Kuzetsov, A N (1993) Peruvian jack mackerel, *Trachurus symmetricus*, in the open waters of the South Pacific. *Journal of Ichthyology 33(3)*: 86–104.

Francis, M P; Hurst, R J; McArdle, B; Bagley, N W; Anderson, O F (2002) New Zealand demersal fish assemblages. *Environmental Biology of Fishes 65*: 215–234.

Godfriaux, B L (1968) The food and feeding relationships of snapper (*Chrysophrys auratus*) and some other fish-species trawled in Hauraki Gulf. Unpublished MSc (Hons) thesis, Victoria University of Wellington.

Godfriaux, B L (1970) Food of predatory demersal fish in Hauraki Gulf. II. Five fish species associated with snapper. *New Zealand Journal of Marine and Freshwater Research 4:* 248−266.

Hermsen, J M; Collie, J S; Valentine, P C (2003) Mobile fishing gear reduces benthic megafaunal production on Georges Bank. *Marine Ecology Progress Series 260*: 97–108.

Hiddink, J G; Jennings, S; Kaiser, M J; Queiros, A M; Duplisea, D E; Piet, G J (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Sciences 63*: 721–36.

Horn, P L (1990) Trawl survey of jack mackerels (*Trachurus* spp.) off the central west coast, New Zealand, February-March 1990. *New Zealand Fisheries Technical Report 28*. 39 p.

Horn, P L (1991a) Assessment of jack mackerel stocks off the central west coast, New Zealand, for the 1990–91 fishing year. New Zealand Fisheries Assessment Research Document 1991/6. 14 p. (Unpublished report held in NIWA library, Wellington.)

Horn, P L (1991b) Trawl survey of jack mackerels (*Trachurus* spp.) off the central west coast, New Zealand, February-March 1990. *New Zealand Fisheries Technical Report No. 28*: 39 p.

Horn, P L (1993) Growth, age structure, and productivity of jack mackerels (*Trachurus* spp.) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 27*: 145–155.

Hurst, R J (1980) Studies on the life cycle of some New Zealand Anisakidae (Nematoda). Unpublished PhD thesis, Victoria University of Wellington, New Zealand. 212 p.

Hurst, R J; Stevenson, M L; Bagley, N W; Griggs, L H; Morrison, M A; Francis, M P (2000) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand coastal fish. Final Research Report for Ministry of Fisheries Research Project ENV1999/03. (Unpublished report held by Ministry for Primary Industries, Wellington).

Jennings, S., Dinmore, T. A., Duplisea, D. E., Warr, K. J. and Lancaster, J. E. (2001), Trawling disturbance can modify benthic production processes. *Journal of Animal Ecology*, 70: 459–475.

Jones, J B (1988) Jack mackerels. New Zealand Fisheries Assessment Research Document 1988/19. 19 p. (Unpublished report held in NIWA library, Wellington.)

Jones, J B (1990) Jack mackerels (*Trachurus* spp.) in New Zealand waters. *New Zealand Fisheries Technical Report No. 23*: 28 p.

Kawahara, S; Uozumi, Y; Yamada, H (1988) First record of a carangid fish, *Trachurus murphyi* from New Zealand. *Japanese Journal of Ichthyology 35(2)*: 212–214.

Leathwick, J R; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J; Hadfield, M; Currie, K; Goh, A (2009) Benthic-optimised marine environment classification for New Zealand waters. Final Research Report project BEN2006/01. 52 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

McKenzie, A (2008) Standardised CPUE analyses for *Trachurus declivis* and *Trachurus novaezealandiae* in the JMA 7 jack mackerel fishery to 2004–05. *New Zealand Fisheries Assessment Report 2008/46*.

MacKenzie, D; Fletcher, D (2006) Characterisation of seabird captures in commercial trawl and longline fisheries in New Zealand 1997/98 to 2003/04. Final Research Report for ENV2004/04, held by Ministry of Fisheries, New Zealand. 102 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Middleton, D A J; Abraham, E R (2007) The efficacy of warp strike mitigation devices: Trials in the 2006 squid fishery. Final Research Report for research project IPA2006/02. (Unpublished report held by Ministry for Primary Industries, Wellington).

MPI (2013). Aquatic Environment and Biodiversity Annual Review 2013. Compiled by the Fisheries Management Science. Ministry for Primary Industries, Wellington, New Zealand. 538pp.

Morgan, M J; Deblois, E M; Rose, G A. (1997) An observation on the reaction of Atlantic cod (*Gadus morhua*) in a spawning shoal to bottom trawling. Conference - Symposium on the Biology and Ecology of Northwest Atlantic Cod, St. John's, NF (Canada), 24–28 Oct 1994.

Morgan, M J; Wilson, C E; Crim, L W (1999) The effect of stress on reproduction in Atlantic cod. *Journal of Fish Biology54(3)*: 477–488.

Reiss, H; Greenstreet, SPR; Seibe, K; Ehrich S; Piet GJ; Quirijns F; Robinson L; Wolff WK; Kronke I (2009) Effects of fishing disturbance on benthic communities and secondary production within an intensively fished area. *Marine Ecology Progress Series* 394:201–213.

Rice, J (2006) Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. Canadian Science Advisory Secretariat Research Document 2006/057. 35 p. (available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf).

Richard, Y; Abraham, E R (2013) Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report No. 109.* 58 p.

Robertson, D A (1978) The New Zealand jack mackerel fishery. *In* Habib, G. and Roberts, P.E. (Eds.). Proceedings of the pelagic fisheries conference, July 1977. *FRD Occasional Publication No. 15*. pp. 43–47.

Smith, M H (2011) Catch curves for JMA species in JMA 7. DWWG-2011/27. 6 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Stevens, D W; Hurst, R J; Bagley, N W (2011) Feeding habits of New Zealand fishes: a literature review and summary of research trawl database records 1960 to 2000. *New Zealand Aquatic Environment and Biodiversity Report No. 85*. 218 p.

Taylor, P R (2000) Species composition and seasonal variability in commercial catches and aerial sightings of jack mackerel, T*rachurus declivis, T. symmetricus murphy*i, and *T. novazelandiae*, in JMA 1, JMA 3, and JMA 7. *New Zealand Fisheries Assessment Report 2000/45*. 25 p

Taylor, P R (2002a) Stock structure and population biology of the Peruvian jack mackerel, *Trachurus symmetricus murphyi*. *New Zealand Fisheries Assessment Report 2002/21*. 78 p.

Taylor, P R (2002b) Species composition and seasonality of jack mackerel (*Trachurus declivis*, *T. symmetricus murphyi*, and *T. novaezelandiae*) in commercial catches from JMA 1, 3, and 7 during 1998–99 and 1999–2000, with a summary of biological information from 1990–91 to 1999–2000. *New Zealand Fisheries Assessment Report 2002/51*. 72 p.

Taylor, P R (2004) Species composition and seasonal variability in commercial catches of jack mackerel (*Trachurus declivis*, *T. symmetricus murphyi*, and *T. novaezelandiae*) in JMA 1, JMA 3, and JMA 7 during 2000–01. *New Zealand Fisheries Assessment Report 2004/28*. 22 p.

Taylor, P R (2008) Factors affecting fish size and landed volumes in the purse-seine and TCEPR charter-boat fisheries in 2004–05 and 2005–06. *New Zealand Fisheries Assessment Report 2008/32*. 17 p.

Taylor, P R; Horn, P L; O'Maolagain, C (2012 Commercial catch sampling for species proportion, sex, length, and age of jack mackerels in JMA 1 in the 2006–07, 2007–08 and 2008–09 fishing years. *New Zealand Fisheries Assessment Report 2012/48*. 36 p.

Taylor, P R; Julian, K A (2008) Species composition and seasonal variability in commercial catches of jack mackerel (*Trachurus declivis*, *T. murphyi* and *T. novaezelandiae*) in JMA 1, 3, and 7 during 2004–05. *New Zealand Fisheries Assessment Report 2008/25*. 24 p.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held by NIWA library, Wellington.)

Thompson, F N; Abraham, E R (2009) Dolphin bycatch in New Zealand trawl fisheries, 1995–96 to 2006–07. *New Zealand Aquatic Environment and Biodiversity Report No.36*. 24 p.

Thompson, F N; Abraham, E R; Oliver, M D (2010) Estimation of fur seal bycatch in New Zealand trawl fisheries, 2002–03 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 56*. 39 p.

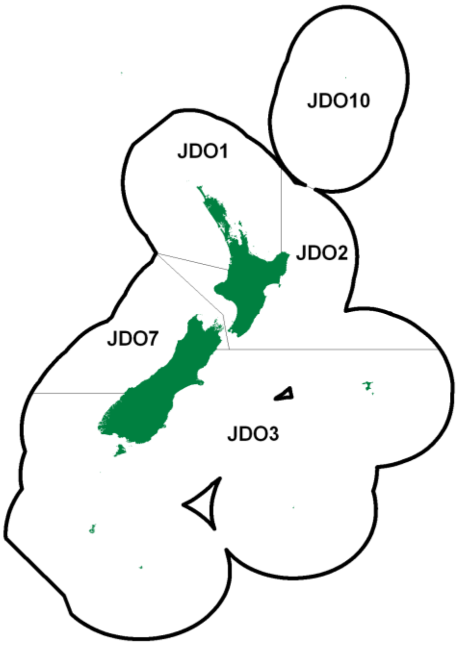
Thompson, F N; Berkenbusch, K; Abraham, E R (2013) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. *New Zealand Aquatic Environment and Biodiversity Report No. 105*. 73 p.

Tuck, I; Cole, R; Devine, J (2009) Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 42.* 188 p.

Walsh, C; Bian, R; McKenzie, J M; Miller, A; Spong, K; Armiger, H (2012) Species composition and seasonal variability in commercial purse-seine catches of jack mackerel (*Trachurus declivis, T. murphyi, and T. novaezelandiae*) in JMA 1 between January 2009 and September 2011. *New Zealand Fisheries Assessment Report 2012/46.* 41 p.

JOHN DORY (JDO)

(*Zeus faber*)
Kuparu



1. FISHERY SUMMARY

John Dory was introduced into the QMS on 1 October 1986 with allowances, TACCs, and TACs in Table 1, except that the TACC for JDO 7 was increased from 131 to 150 t in October 2012.

Fishstock	Recreational Allowance	Customary non-commercial allowance	Other mortality	TACC	TAC
JDO 1	-	-	-	-	704
JDO 2	-	-	-	-	269.5
JDO 3	-	-	-	-	31.9
JDO 7	2	1	8	161	150
JDO 10	-	-	-	-	10

Table 1: TAC's. TACC'S and allowances for John Dory

1.1 Commercial fisheries

John dory are taken mainly as a bycatch of the trawl and Danish seine fisheries. In recent years, around 50–65% of the total reported catch has been taken in JDO 1, and around 20% taken in JDO 2. Recent reported landings by Fishstock are shown in Table 3, while the historical landings and TACC values for the three main JDO stocks are depicted in Figure 1.

The increase in JDO 1 landings after 1986–87 is largely attributed to increased targeting of John dory by trawl and Danish seine. The TACC in JDO 1 was exceeded (slightly) in 1994–95, but in the following years landings steadily decreased, reaching a low of 440 t in 2002–03. Landings increased to 549t in 2005–06 but have since declined to 349 t. It is estimated that during the 1990s about 10–20% of the annual JDO 1 landings were taken in FMA 9, mainly as bycatch in fisheries targeting snapper and trevally. Landings from the eastern part of JDO 1 (FMA 1) are taken primarily in target fisheries for John dory and snapper.

Annual landings in JDO 2 have never exceeded the TACC and in the mid 90s, were around 50% of the TACC in each year (Figure 1). From 1999–00 to 2002–03 landings were above 200 t, but in recent years landings have decreased, being below 150t since 2005–06. Landings from JDO 2 are considered to be approximately equally split between FMAs 2 and 8. Substantial proportions of John dory landings are taken as bycatch in target trawl fisheries for jack mackerels in FMA 8, and as tarakihi and red gurnard bycatch in FMA 2. Landings from JDO 7 increased markedly after 1999–2000, as a result of increasing abundance. JDO 7 is taken largely as a bycatch by FMA 7 trawl fisheries. The JDO 7 TACC has been increased three times since 2003–04 and is currently 150 t (Table 3).

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982

Year	JDO 1	JDO 2	JDO 3	JDO 7	Year	JDO 1	JDO 2	JDO 3	JDO 7
1931–32	70	0	0	0	1957	110	37	0	20
1932–33	60	0	0	0	1958	132	54	0	40
1933–34	57	0	0	0	1959	157	64	0	50
1934–35	42	0	0	0	1960	158	81	0	53
1935–36	92	0	0	0	1961	156	76	0	52
1936–37	105	4	0	1	1962	150	87	0	38
1937–38	80	3	0	0	1963	114	96	0	44
1938–39	78	3	1	0	1964	112	85	1	30
1939–40	40	5	0	0	1965	111	101	0	32
1940–41	0	2	1	1	1966	148	110	0	37
1941–42	0	7	1	3	1967	162	102	0	41
1942–43	3	4	3	3	1968	203	83	0	36
1943–44	12	4	3	3	1969	189	96	0	19
1944	11	7	2	5	1970	259	137	0	24
1945	12	6	0	1	1971	234	141	1	38
1946	27	7	0	3	1972	213	122	0	34
1947	23	12	2	12	1973	259	99	0	30
1948	21	20	1	1	1974	340	101	0	28
1949	22	79	0	4	1975	261	92	0	22
1950	17	65	0	6	1976	362	135	0	55
1951	5	38	0	2	1977	315	141	0	73
1952	34	50	0	5	1978	392	119	0	24
1953	163	62	0	7	1979	503	121	0	29
1954	181	52	0	25	1980	563	173	0	26
1955	162	50	0	24	1981	646	186	0	38
1956	175	46	0	24	1982	577	162	0	28

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings (t) of John dory by Fishstock from 1983–84 to 2013–14 and actual TACCs (t) for 1986–87 to 2013–14. QMS data from 1986–present.

Fishstock		JDO 1		JDO 2		JDO 3		JDO 7
FMA (s)		1 & 9		2 & 8		3, 4, 5 & 6		7
	Landings	TACC	Landings	TAC	Landings	TACC	Landings	TACC
1983–84*	659	-	131	-	1	-	35	-
1984–85*	620	-	110	-	0	-	36	-
1985–86*	531	-	158	-	1	-	45	-
1986–87	409	510	168	240	3	30	57	70
1987–88	476	633	192	246	1	30	89	75
1988–89	480	662	151	253	6	30	47	82
1989–90	494	704	152	262	1	30	54	88
1990–91	505	704	171	269	1	31	53	88
1991–92	562	704	214	269	1	31	60	88
1992–93	578	704	217	269	8	31	50	91
1993–94	640	704	186	269	2	32	37	91
1994–95	721	704	140	270	3	32	30	91
1995–96	696	704	139	270	< 1	32	42	91
1996–97	689	704	140	270	< 1	32	35	91
1997–98	651	704	134	270	< 1	32	26	91
1998–99	672	704	182	270	< 1	32	34	91
1999–00	519	704	235	270	< 1	32	71	91
2000–01	497	704	217	270	1	32	104	91
2001–02	453	704	240	270	4	32	124	91
2002–03	440	704	239	270	2	32	114	91
2003–04	492	704	184	270	< 1	32	155	91
2004–05	561	704	182	270	1	32	133	114
2005–06	549	704	159	270	1	32	124	114
2006–07	544	704	143	270	1	32	127	114
2007–08	482	704	133	270	< 1	32	110	114

Table 3 [continued]

Fishstock	JDO 1		JDO 2		JDO 3		JDO 7	
FMA (s)	1 & 9		2 & 8		3, 4, 5 & 6		7	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2008–09	411	704	136	270	< 1	32	116	114
2009–10	359	704	152	270	< 1	32	109	125
2010–11	386	704	138	270	< 1	32	112	125
2011–12	351	704	131	270	< 1	32	126	125
2012–13	365	704	138	270	< 1	32	128	150
2013–14	349	704	142	270	<1	32	151	151

Fishstock	JDO 10			
FMA (s)	10		Total	
	Landings	TACC	Landings	TACC
1983–84*	0	-	826	-
1984–85*	0	-	766	-
1985–86*	0	-	735	-
1986–87	< 1	10	638	860
1987–88	0	10	758	994
1988–89	0	10	684	1 037
1989–90	0	10	701	1 094
1990–91	0	10	730	1 102
1991–92	0	10	837	1 102
1992–93	0	10	853	1 105
1993–94	0	10	865	1 106
1994–95	0	10	894	1 107
1995–96	0	10	877	1 107
1996–97	0	10	864	1 107
1997–98	0	10	811	1 107
1998–99	0	10	889	1 107
1999–00	0	10	826	1 107
2000–01	0	10	819	1 107
2001–02	0	10	819	1 107
2002–03	0	10	795	1 107
2003–04	0	10	832	1 107
2004–05	0	10	877	1 129
2005–06	0	10	833	1 129
2006–07	0	10	815	1 129
2007–08	0	10	725	1 129
2008–09	0	10	663	1 129
2009–10	0	10	620	1 140
2010–11	0	10	637	1 140
2011–12	0	10	609	1 140
2012–13	0	10	633	1 165
2013–14	0	10	642	1 165

* FSU data.

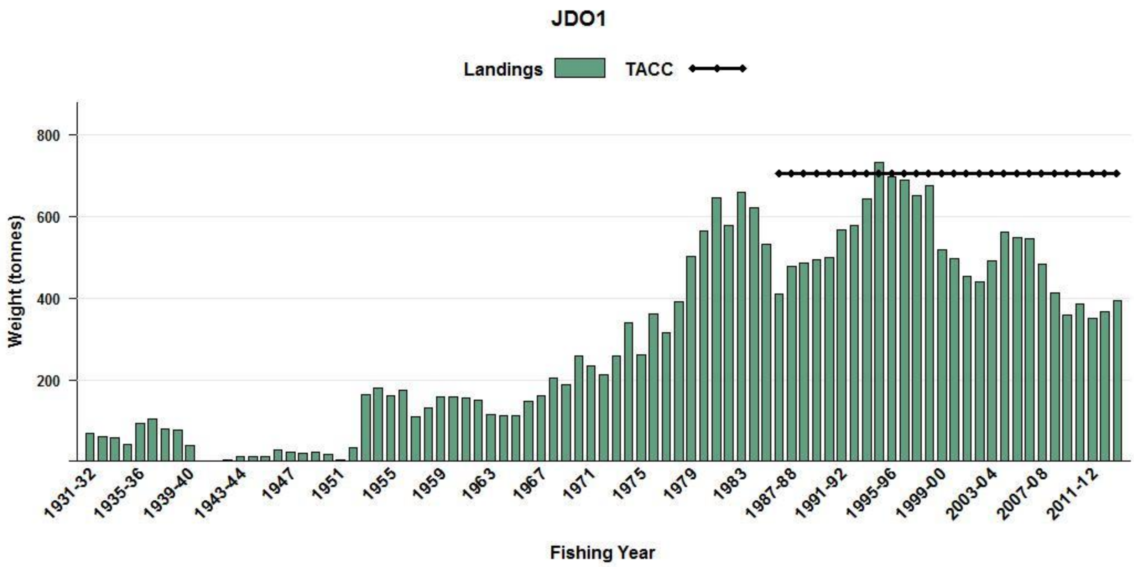
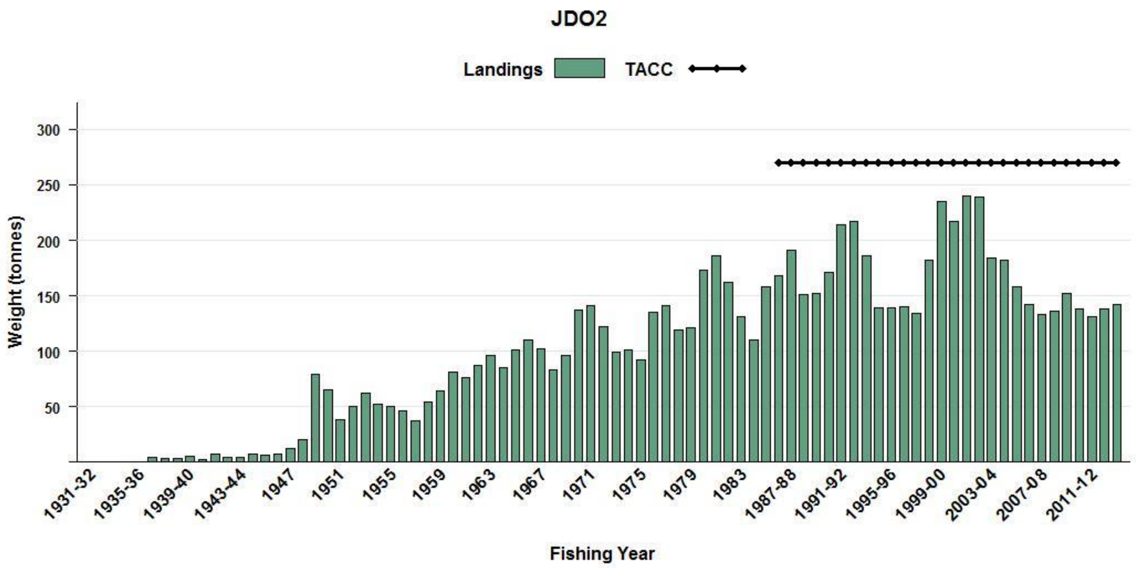


Figure 1: Reported commercial landings and TACC for the three main JDO stocks. JDO 1 (Auckland East). (Continued on next page).



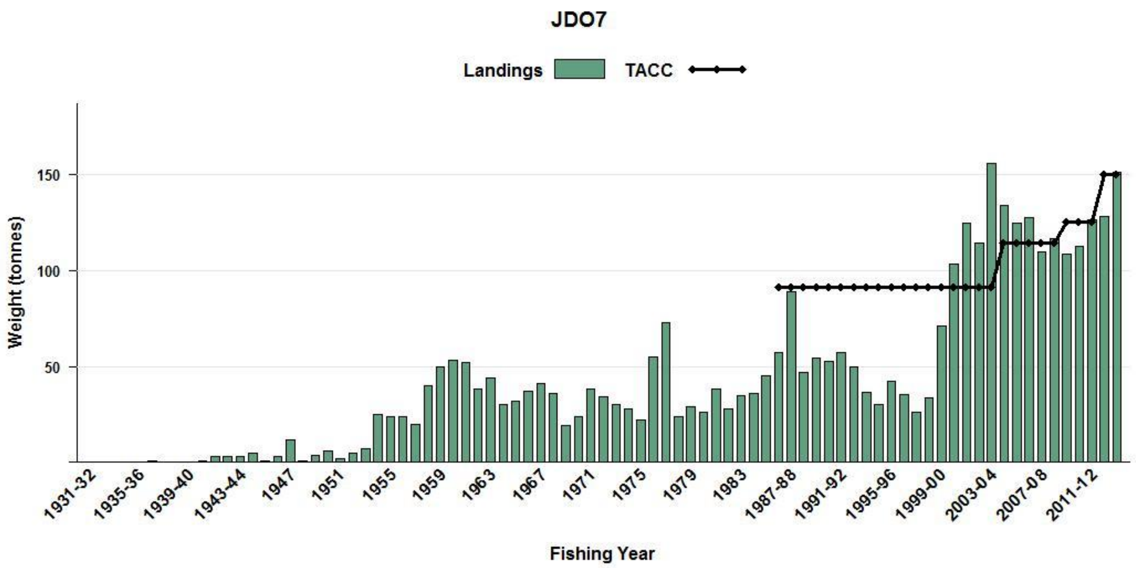


Figure 1: Reported commercial landings and TACC for the three main JDO stocks. From top: JDO 2 (Central East), and JDO 7 (Challenger).

Overall the majority of John dory catch is reported in the snapper bottom trawl fishery (16%), followed by the John dory bottom trawl (14%) and the tarakihi bottom trawl fisheries (14%). Danish seine accounts for the second largest John dory catch across fishing methods (Figure 2).

Catches of John dory in JDO 1 are predominantly taken through bottom trawl in the snapper (23%), John dory (19%) and trevally (10%) target fisheries. Danish seine, bottom pair trawl and bottom longline comprise the remaining John dory catch by fishing method (Figure 3). John dory catch in JDO 2 are taken predominantly by bottom trawl targeting tarakihi (30%) and gurnard (25%), with mid-water and setnet fishing methods comprising the remainder of catch (Figure 4). John dory in JDO 7 is predominantly caught by bottom trawl targeting flatfish (25%), barracouta (23%) and tarakihi (18%) (Figure 5). Throughout the North Island, the trawl and Danish seine fisheries targeting John dory take the majority of their catch targeting snapper (33%) followed by the John dory target fishery (23%) (Figure 6). No data were available for JDO setnet fisheries in the South Island.

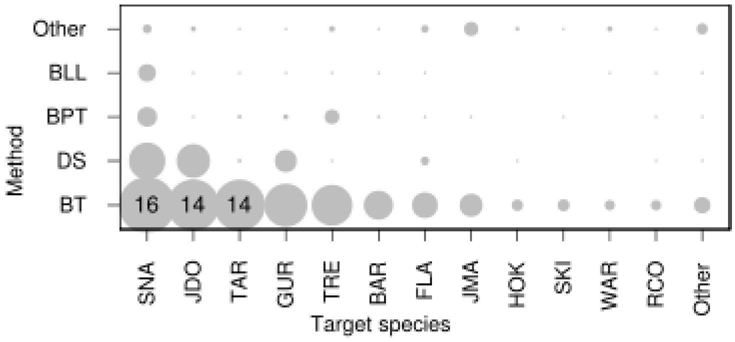


Figure 2: A summary of the proportion of landings of John dory (all QMAs) taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bubble is the percentage. BT = bottom trawl, DS = Danish seine, BPT = bottom pair trawl, BLL = bottom longline (Bentley et al 2012).

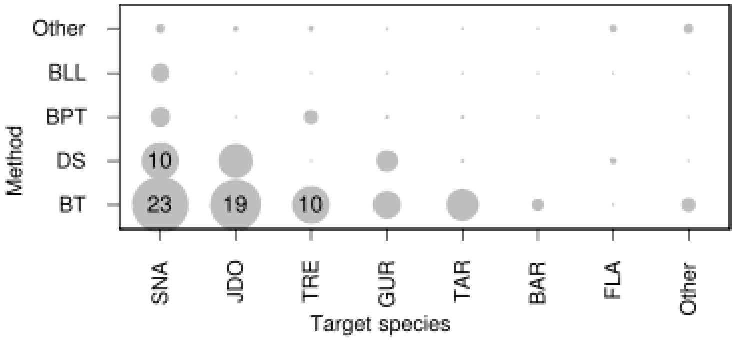


Figure 3: A summary of the proportion of landings of JDO 1 taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bubble is the percentage. BT = bottom trawl, DS = Danish seine, BPT = bottom pair trawl, BLL = bottom longline (Bentley et al 2012).

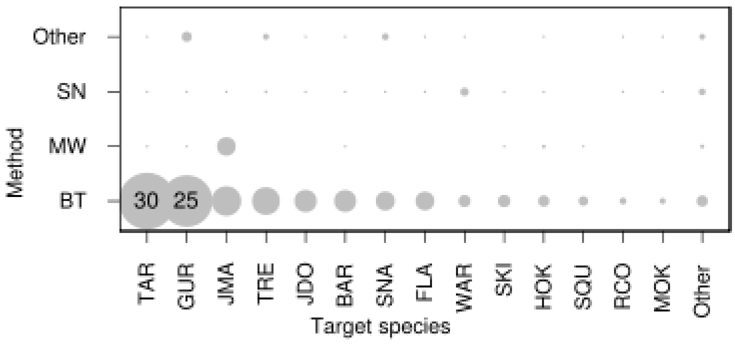


Figure 4: A summary of the proportion of landings of JDO 2 taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bubble is the percentage. BT = bottom trawl, MW = mid-water, SN = setnet (Bentley et al 2012).

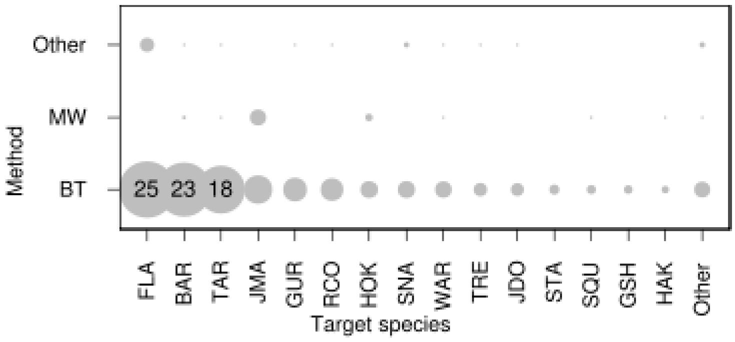


Figure 5: A summary of the proportion of landings of JDO 7 taken by each target fishery and fishing method. The area of each circle is proportional to the percentage of landings taken using each combination of fishing method and target species. The number in the bubble is the percentage. BT = bottom trawl, MW = mid-water (Bentley et al 2012).

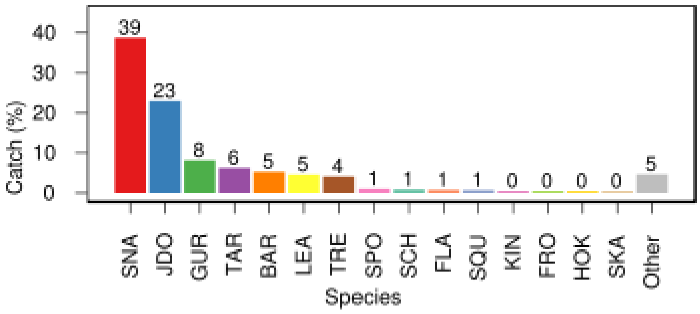


Figure 6: A summary of species composition of the reported trawl and Danish seine catch in trips targeting John dory off the North Island. Catch is expressed as the percentage by weight of each species calculated for all trawl and Danish seine trips (Bentley et al 2012).

1.2 Recreational fisheries

John dory is an important recreational species in the north of New Zealand. They are caught using line fishing methods, predominantly on rod and reel with some longline catch.

1.2.1 Management controls

The main method used to manage recreational harvests of John dory is daily bag limits. Fishers can take up to 20 John dory as part of their combined daily bag limit in the Auckland and Kermadec, Central, and Challenger Fishery Management Areas.

1.2.2 Estimates of recreational harvest

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for John dory were calculated using an offsite approach, the offsite regional telephone and diary survey approach. Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2005. The harvest estimates provided by these telephone diary surveys (Table 4) are no longer considered reliable.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. Note that the national panel survey estimate does not include harvest taken on recreational charter vessels, or recreational harvest taken under s111 general approvals. Recreational catch estimates from the national panel survey are given in Table 4 (Wynn-Jones et al 2014).

Table 4: Recreational harvest estimates for John dory stocks. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. The national panel survey ran through the October to September fishing year but is denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey harvest estimates).

Stock	Year	Method	Number of fish	Total weight (t)	CV
JDO 1	1996	Telephone/diary	49 000	87	0.09
	2000	Telephone/diary	129 000	227	0.23
	2012	Panel survey	28 863	36	0.13
JDO 2	2000	Telephone/diary	9 000	16	0.43
	2012	Panel survey	2 000	3	0.33

1.3 Customary non-commercial fisheries
No quantitative information is available on the current level of Maori customary non-commercial catch.

1.4 Illegal catch
No quantitative information is available.

1.5 Other sources of mortality
No quantitative information is available.

2. BIOLOGY

John dory are widespread, being found in the eastern Atlantic Ocean, the Mediterranean Sea and around New Zealand, Australia and Japan. They are common in the inshore coastal waters of northern New Zealand, and to a lesser extent in Tasman Bay, to depths of 50 m. In the Hauraki Gulf, adults move to deeper waters during summer, and occasional feeding aggregations occur during winter.

John dory are serial spawners (spawning more than once in a season). There appears to be substantial variation in the time of spawning in New Zealand, with spawning occurring between December and April on the northeast coast. The eggs are large and pelagic, taking 12–14 days to hatch. Initially John dory grow rapidly with both males and females reaching 12 to 18 cm standard length (SL) after the first year. From the second year onwards females grow faster than males and reach a greater maximum length. Females mature at a size of 29 to 35 cm SL and in general, larger females mature earlier in the season and are more fecund. Males mature at 23 to 29 cm SL.

M was estimated using the equation $M = \log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using a maximum observed age of 12 years, M was estimated to equal 0.38. Biological parameters relevant to the stock assessment are shown

Table 5: Estimates of biological parameters of John dory.

Fishstock							Estimate	Source
1.Weight = a (length)^b (Weight in g, length in cm total length)								
Combined sexes						a	b	
JDO 1						0.048	2.7	from *Ikatere* 2003
2. von Bertalanffy growth parameters								
			Females				Males	
	K	t_0	$L\infty$		*K*	t_0	$L\infty$	
JDO 1	0.425	-0.223	41.13		0.48	-0.251	36.4	Hore (1982)

3. STOCKS AND AREAS

In 2012 the stock structure of John dory was reviewed (Dunn & Jones 2013). The approach evaluated patterns in the distribution of catch and CPUE, research survey biomass trends, location of spawning and nursery grounds, size and age compositions, and anecdotal information from the fishery.

John dory have been caught around most of the North Island and the northern South Island, indicating that the QMA boundaries are not biologically appropriate. The analysis suggested five stocks around New Zealand: (1) Hauraki Gulf and east Northland; (2) Bay of Plenty; (3) west coast North Island; (4) southeast North Island; and (5) northern South Island.

Spawning fish and nursery grounds are found in all five stocks. In addition, on the east coast North Island, CPUE analyses support the separation of the Hauraki Gulf, Bay of Plenty, and Hawkes Bay fisheries, and research trawl survey biomass estimates had different trends in Hauraki Gulf and the Bay of Plenty. Very few John dory are found south of Hawkes Bay on the southeast North Island, providing a gap between the east and west coast components of JDO 2. There is relatively strong evidence to separate the northeast and northwest coasts of JDO 1, including fishery CPUE analyses, length and age compositions, and research trawl survey biomass trends. The distribution of John dory on the west coast North Island is continuous between JDO 1 and the northern part of the west coast JDO 2, and the combination of these areas is also supported by CPUE analyses. There is evidence to separate the northern South Island from stocks to the north including the occurrence of unusually large fish on the northern South Island, and CPUE analyses. John dory appear to reach the southern limit of their range off the north and northwest coasts of the South Island.

4. STOCK ASSESSMENT

The yield estimates are based on commercial landings data only and have not changed since the 1992 Plenary Report.

4.1 Estimates of fishery parameters and abundance

An investigation into the stock structure of New Zealand John dory (Dunn and Jones 2013) supported five biological stocks: (1) Hauraki Gulf and east Northland, (2) Bay of Plenty, (3) West coast North Island, (4) Southeast North Island, and (5) Northern South Island. The first three stocks are found within JDO 1, the fourth consists of the east coast portion of JDO 2 and the fifth of JDO 7 and the portion of JDO 2 located on the south and east coast of the North Island.

JDO 1

Relative abundance indices have been obtained from trawl surveys of the Bay of Plenty, west coast North Island, and Hauraki Gulf within the JDO 1 Fishstock (Table 5). However, there was a change in the configuration of the trawl gear following the 1988 trawl survey. Modifications to the trawl gear may have resulted in a change in the catchability of John dory part way through the time series.

Therefore, surveys conducted between 1982 and 1988 and from 1989 onwards should be considered separately for comparisons of biomass indices to be valid.

In 2015, the CPUE indices for the three sub-areas within JDO 1 (Hauraki Gulf and east Northland, Bay of Plenty, and west coast North Island) were updated and refined. The catch and effort data set included individual bottom trawl records from trawl targeting a range of inshore finfish species (BAR, TAR, TRE, GUR, SNA and JDO). The landed catch of John dory from a trip was allocated to the individual trawl records in proportion to the estimated catch. The analyses used a delta-lognormal CPUE model incorporating positive catch (lognormal) and presence/absence (binomial) components. For a number of analyses, different trends were apparent between the lognormal and binomial CPUE models. Further investigation indicated that the differences may have been attributable to changes in the recording of smaller John dory catches over the time period. Potential biases introduced by changes in catch reporting are likely to be adequately accounted for by applying the delta-lognormal approach.

Hauraki Gulf and east Northland (part of JDO 1)
In Hauraki Gulf and east Northland, the standardised CPUE indices fluctuated during the 1990s and 2000s and then steadily declined from 2004–05 to 2012–13 (Figure 7).

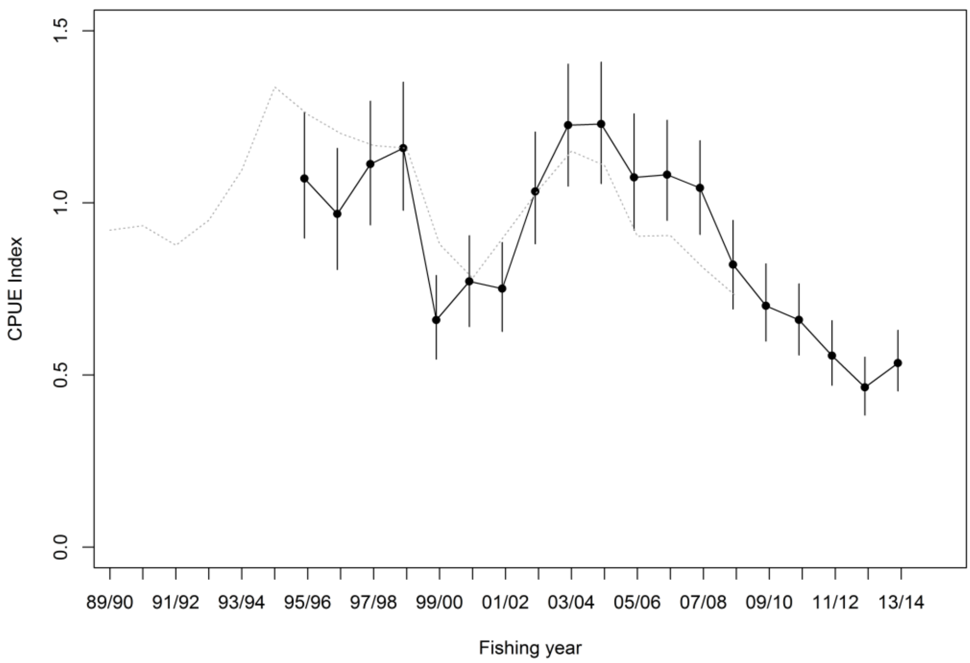


Figure 7: CPUE indices of abundance for Hauraki Gulf and east Northland (part of JDO 1): solid points and line, combined model of catch rates in mixed species bottom trawl tows; dotted line, a lognormal model of positive catches in mixed species bottom trawl tows (Kendrick & Bentley 2011). Indices are scaled to have the same geometric mean over the overlapping years. Vertical lines show the 95% confidence intervals.

Bay of Plenty (part of JDO 1)
The standardised CPUE series declined during the late 1990s, remained relatively stable during the 2000s and then declined from 2010–11 to 2013–14 (Figure 8).

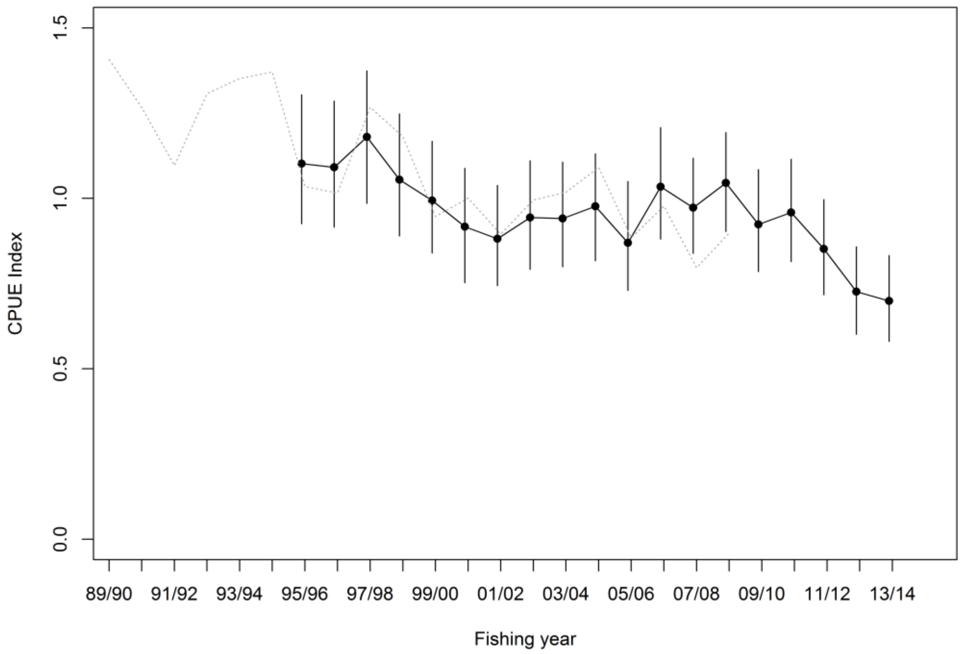


Figure 8: CPUE indices of abundance for the Bay of Plenty (part of JDO 1): solid points and line, combined model of catch rates in mixed species bottom trawl tows (Langley in prep)); dotted line, a lognormal model of positive catches in mixed species bottom trawl tows (Kendrick & Bentley 2011). Indices are scaled to have the same geometric mean over the overlapping years. Vertical lines show the 95% confidence intervals.

West Coast North Island (parts of JDO 1 and JDO 2)

The standardised CPUE series suggests that biomass has fluctuated about the average level since the late 1990s (Figure 9).

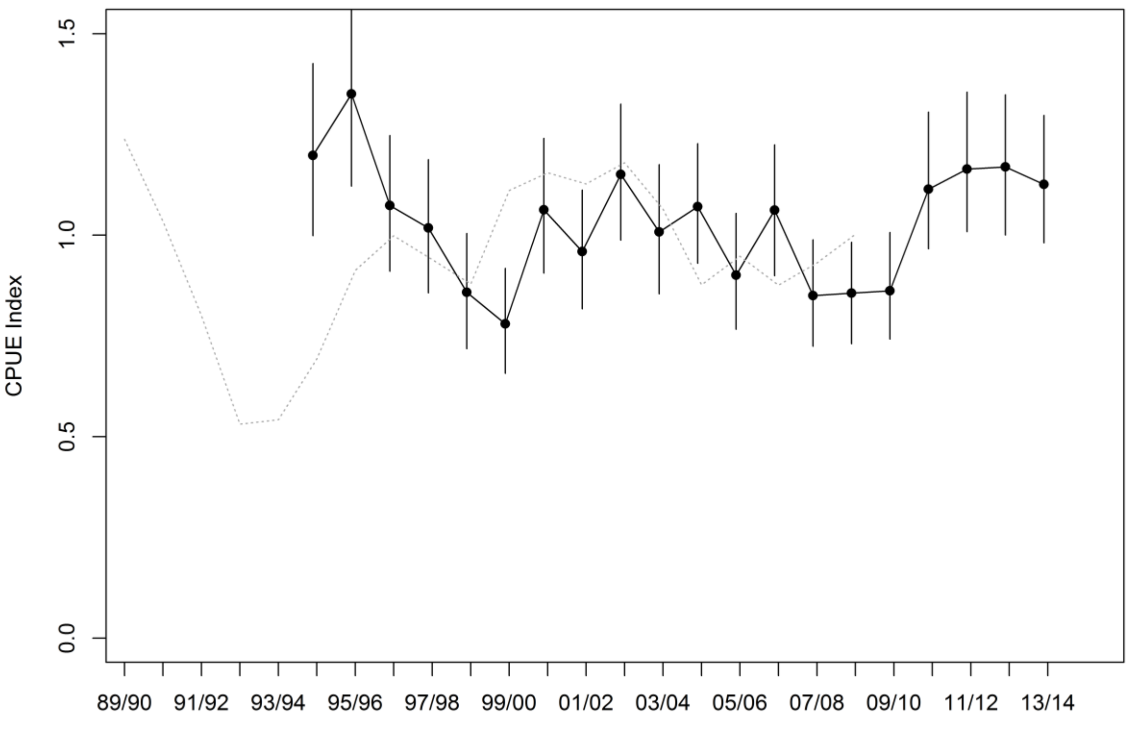


Figure 9: CPUE indices of abundance for the West Coast North Island (part of JDO 1 and part of JDO 2): solid points and line, combined model of catch rates in mixed species bottom trawl tows; dotted line, a lognormal model of positive catches in mixed species bottom trawl tows for the west coast North Island (JDO 1 only) (Kendrick & Bentley 2011). Indices are scaled to have the same geometric mean over the overlapping years. Vertical lines show 95% credible intervals.

Southeast North Island (part of JDO 2)

The standardised CPUE series suggests an increase in abundance from a low in the mid-1990s to a peak in 2000–01, followed by a steady decline to a series low in 2010–11 (Figure 10).

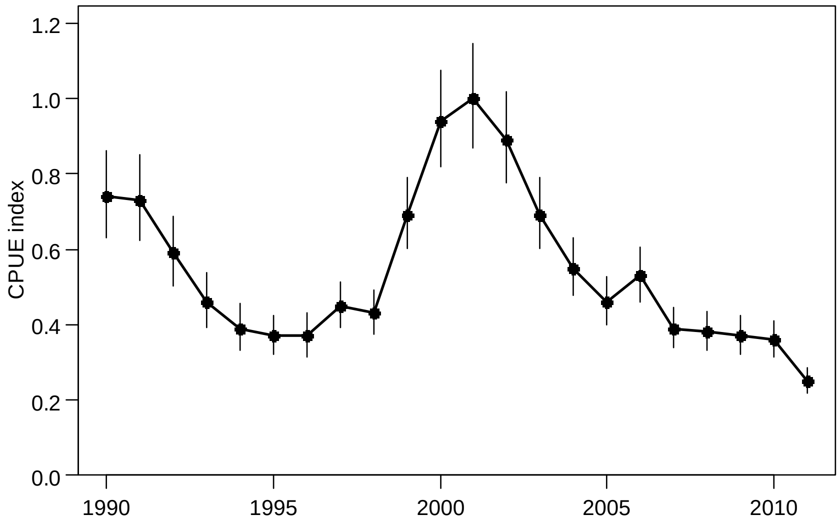


Figure 10: CPUE indices of abundance for the Southeast North Island (part of JDO 2), combined model of catch rates in mixed species bottom trawl tows (Dunn & Jones 2013). Vertical lines show the 95% credible intervals. Years labeled as year-ending (i.e., 1990 is 1989–90).

Northern South Island (JDO 7, and part of JDO 2)

In 2014, the CPUE indices for the Northern South Island zone (JDO 7, and part of JDO 2) were revised and updated to include data to 2012–13 (Langley 2014). The CPUE index was based on JDO bycatch from the following bottom trawl targets: BAR, FLA, GUR, JDO, JMA, RCO & TAR, in statistical areas: 33–39.

The Southern Inshore Working Group noted that the West Coast South Island trawl survey series appears to be monitoring trends in abundance of the John dory, particularly recruited biomass (defined as fish of at least 25 cm TL) (Figure 11). Length frequency trends for the John dory survey catch from the West Coast South Island and Tasman Bay/Golden Bay are presented in Figure 12. Smaller (20–35cm) fish tend to be caught in the latter survey region. Biomass levels were low before 2003, with recruited biomass increasing two to three fold since then. Pre-recruits first appeared in 2007, and persisted to 2013.

The last three trawl surveys (2009, 2011 and 2013) have estimated the recruited biomass of John Dory in the WCSI area to be at the highest level of the entire time series (Figure 11).

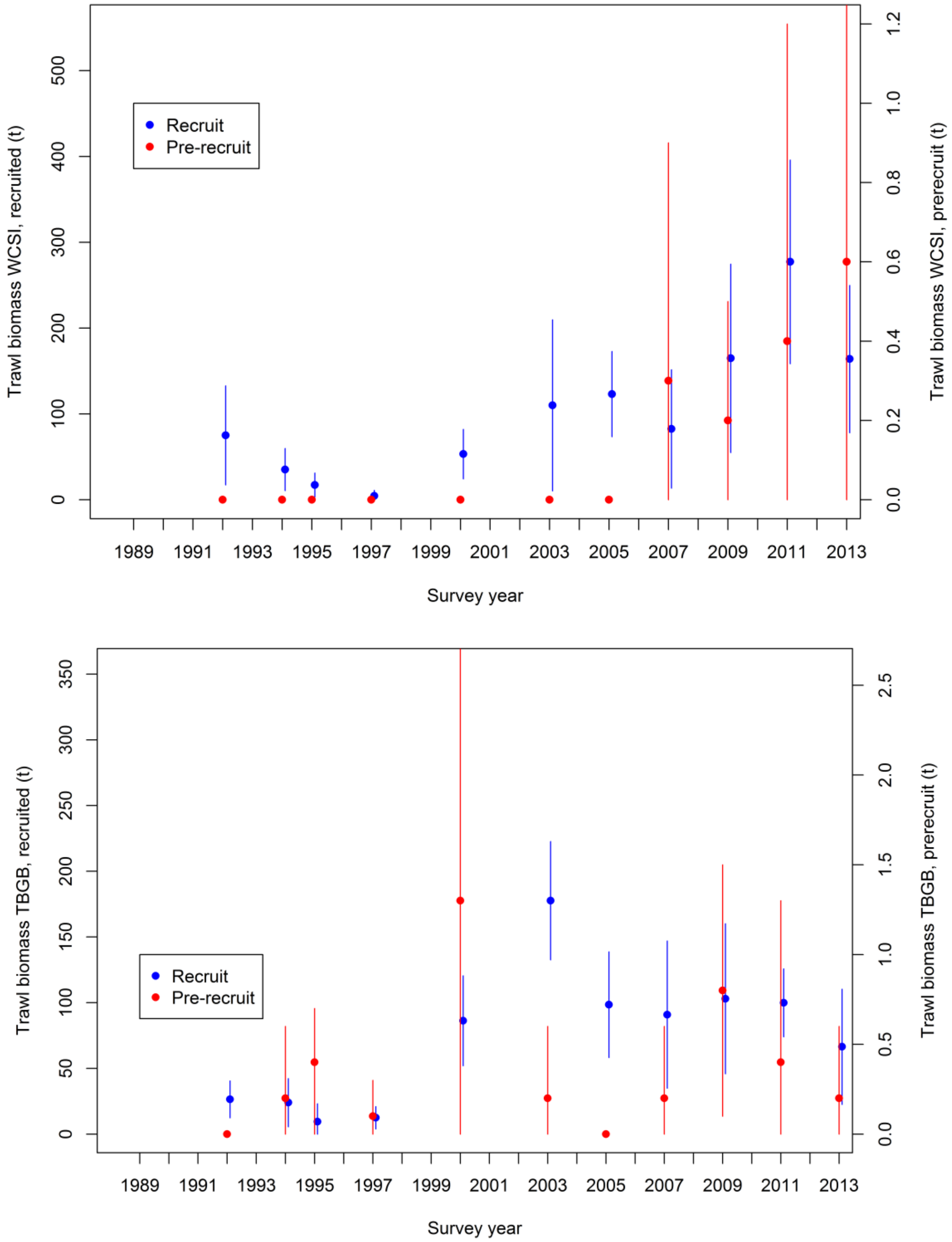


Figure 11: WCSI trawl survey Biomass estimates of recruited and pre-recruit John dory ±95% CI (estimated from survey CVs assuming a lognormal distribution) from the West Coast (top panel) and Tasman Bay/Golden Bays (Bottom Panel). John dory are assumed to recruit to the commercial fishery at 25 cm TL.

The standardised CPUE series shows a similar trend to the trawl survey biomass index, with a large increase in biomass between the late 1990s and early 2000s, which has persisted to the present (2013) (Figure 13).

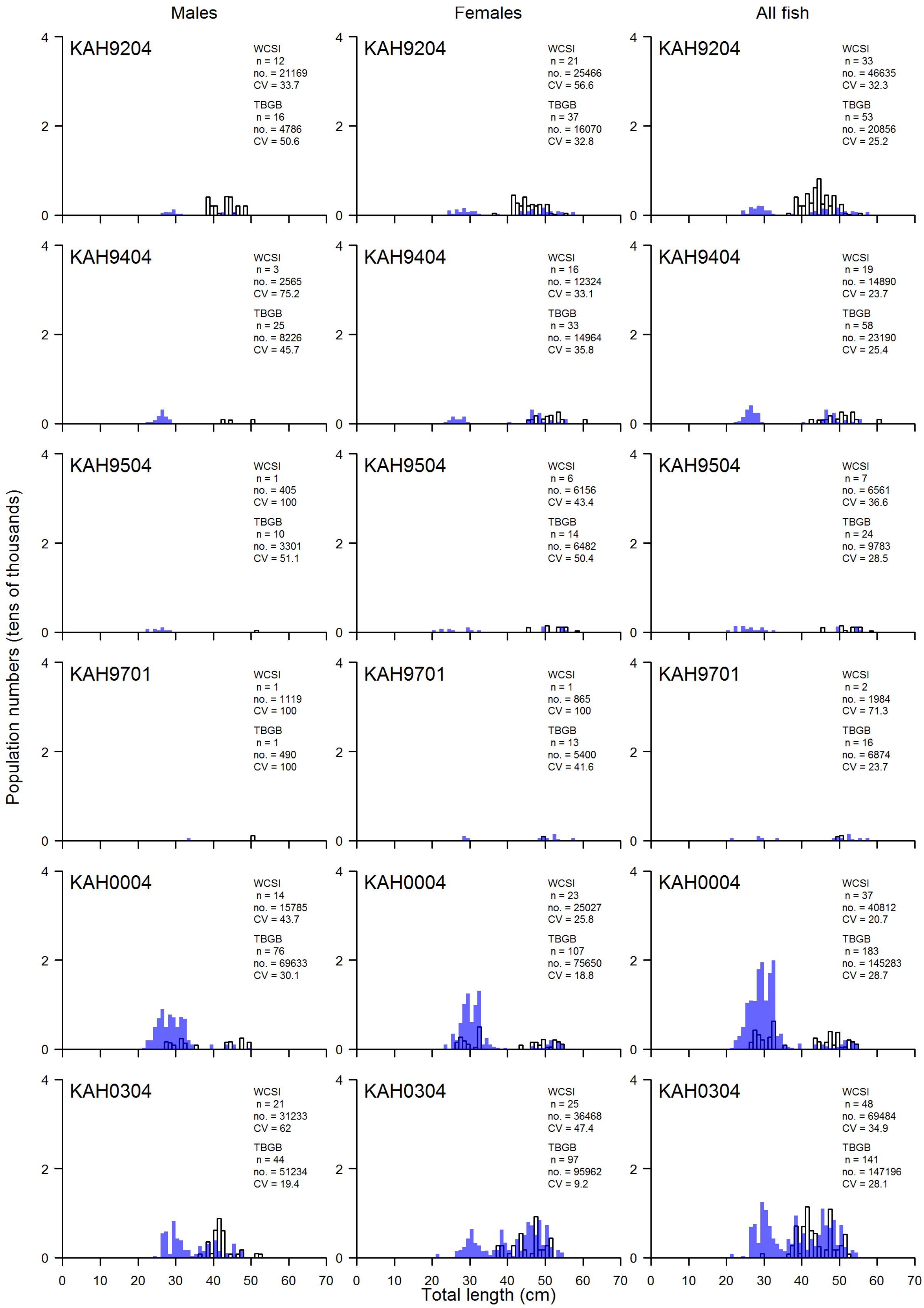


Figure 12: Scaled length frequency distributions for John dory in 30–400 m for West Coast (white) and Tasman Bay/Golden Bay (blue), from WCSI surveys. M, males; F, females; (CV%).**[Continued on next page].**

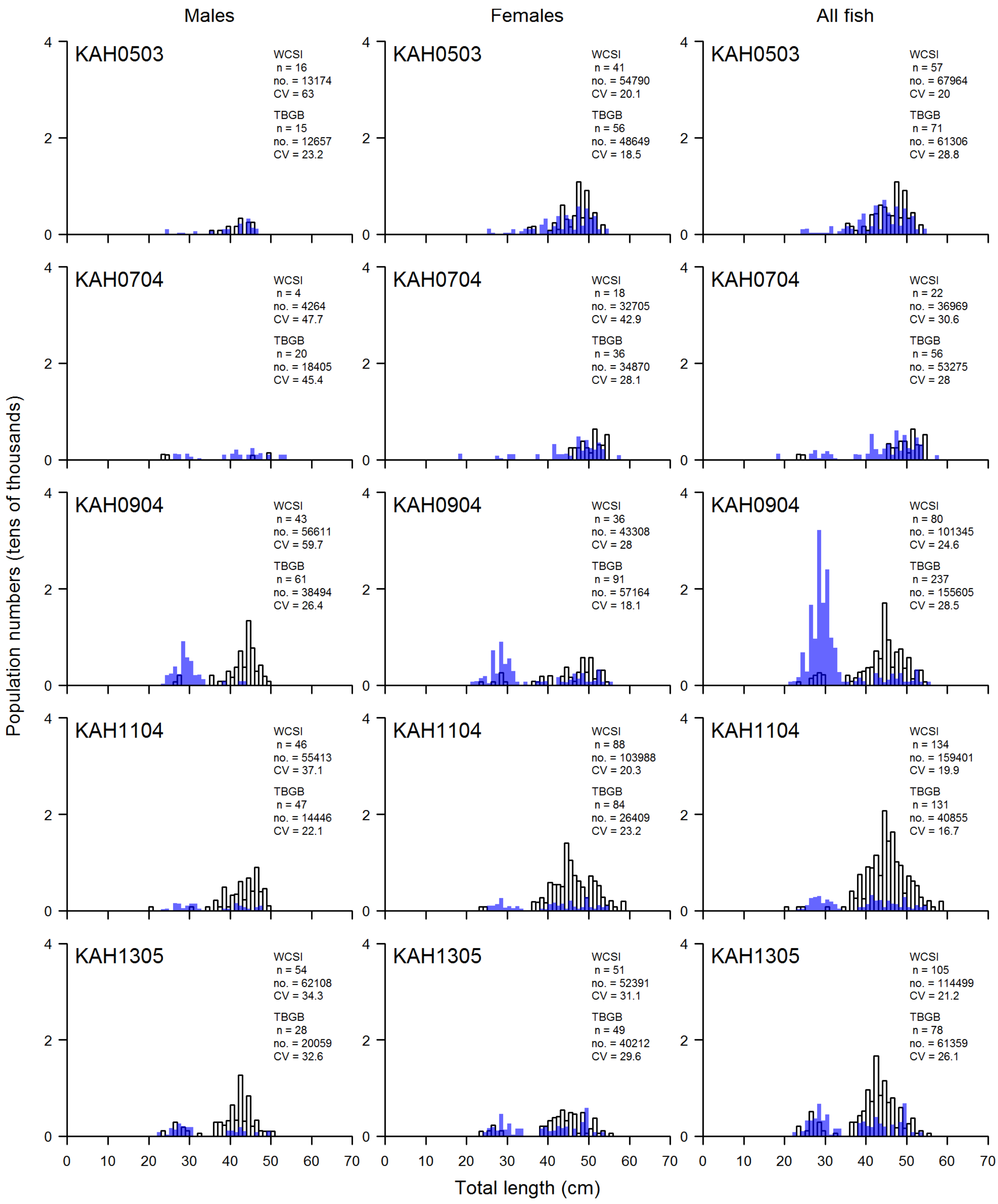


Figure 12 [Continued].

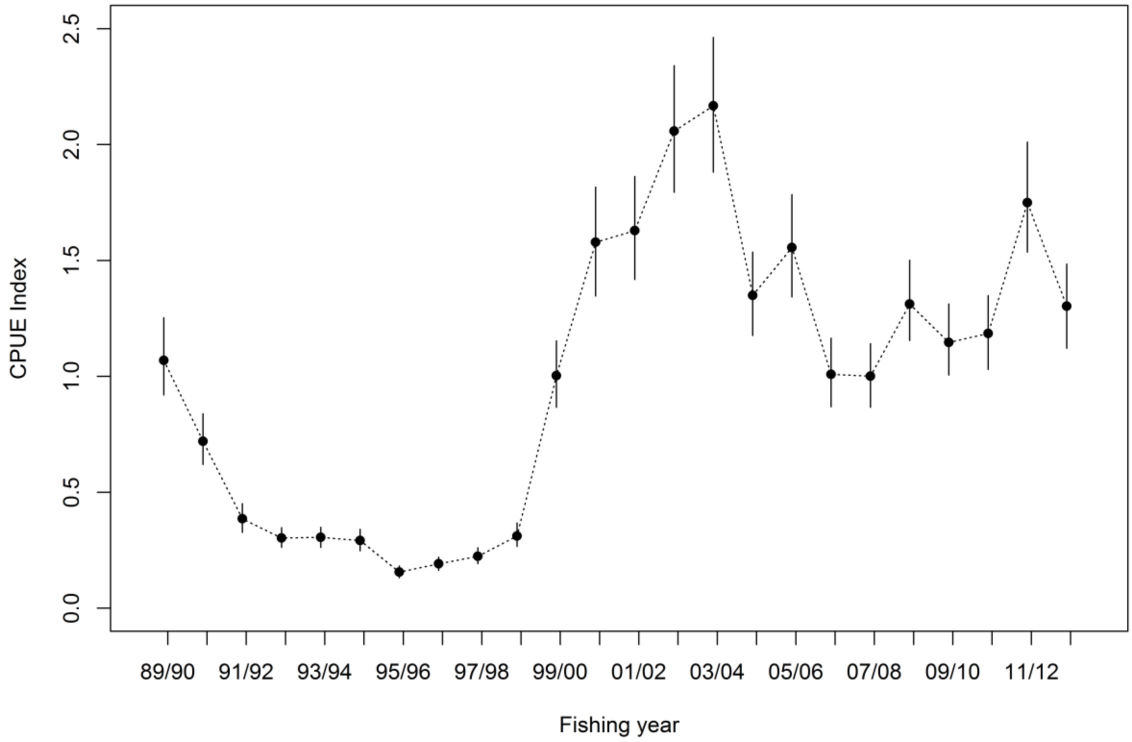


Figure 13: CPUE indices of abundance for the northern South Island (JDO 7 and part of JDO 2), combined model of catch rates in mixed species bottom trawl tows (Langley 2014). Vertical lines show the 95% credible intervals.

4.2 Biomass estimates

Estimates of absolute reference and current biomass are not available.

Table 6: Estimates of John dory biomass (t) from *Kaharoa* trawl surveys. [Continued on next page].

Year	Trip Code	Biomass	CV (%)
Bay of Plenty			
1983	KAH8303	113	24
1985	KAH8506	128	12
1987	KAH8711	155	38
1990	KAH9004	157	16
1992	KAH9202	236	12
1996	KAH9601	193	44
1999	KAH9902	176	14
North Island west coast (FMA 8)			
1989	KAH8918	68	25
1991	KAH9111	142	62
1994	KAH9410	33	47
1996	KAH9615	19	38
North Island west coast (FMA 9)			
1986	KAH8612	155	35
1987	KAH8715	160	16
1989	KAH8918	148	16
1991	KAH9111	216	37
1994	KAH9410	102	47
1996	KAH9615	147	15
1999	KAH9915 (FMAs 8 & 9 combined)	374	9

Table 6 [Continued].

Year	Trip Code	Biomass	CV (%)
Hauraki Gulf			
1984	KAH8421	292	22
1985	KAH8517	245	20
1986	KAH8613	211	25
1987	KAH8716	181	12
1988	KAH8810	477	32
1989	KAH8917	250	22
1990	KAH9016	322	13
1992	KAH9212	227	35
1993	KAH9311	374	24
1994	KAH9411	288	17
1997	KAH9720	387	18
2000	KAH0012	260	26
North Island east coast			
1993	KAH9304	265	17
1994	KAH9402	268	31
1995	KAH9502	170	18
1996	KAH9605	172	48
West Coast South Island			
1992	KAH9204	102	29
1994	KAH9404	59	26
1995	KAH9504	27	36
1997	KAH9701	17	31
2000	KAH0004	141	16
2003	KAH0304	288	19
2005	KAH0503	222	14
2007	KAH0704	174	26
2009	KAH0904	269	23
2011	KAH1104	378	18
2013	KAH1305	231	21

4.3 Yield estimates and projections

The level of risk to the stock by harvesting the population at the estimated MCY value cannot be determined.

No estimates of current biomass are available which would permit the estimation of *CAY*

4.4 Other yield estimates and stock assessment results

Current estimates of yield are based upon commercial landings only and are assumed to be independent of the non-commercial catch. There was no indication that John dory were overfished at the time of the introduction of the QMS.

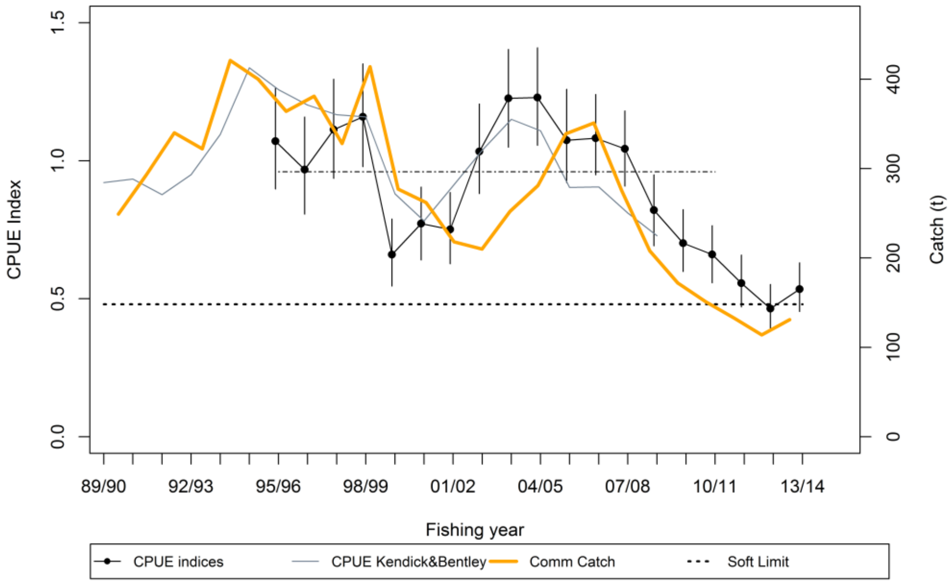
5. STATUS OF THE STOCKS

- **JDO 1 (Hauraki Gulf and east Northland)**

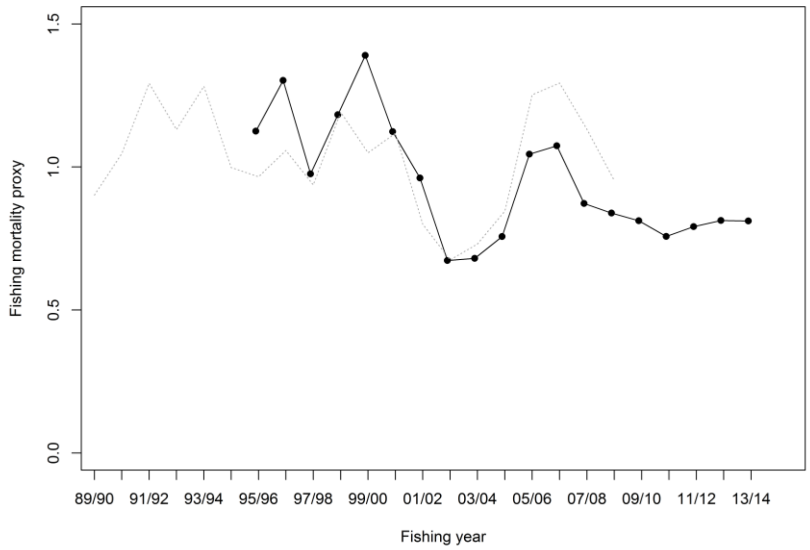
Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Standardised CPUE
Reference Points	Interim Target: Mean of the CPUE indices for John dory in Hauraki Gulf and east Northland from combined binomial and lognormal models from 1995–96 to 2010–11 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY}
Status in relation to Target	Very Unlikely (< 10%) to be at or above the target

Status in relation to Limits	Soft Limit: About as Likely as Not (40-60%) to be below Hard Limit: Unlikely (< 40%) to be below
Status in relation to Overfishing	Unlikely (< 40%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status



Standardised CPUE indices for John dory in Hauraki Gulf and east Northland from combined binomial and lognormal models of catch rate in bottom trawl tows in a mixed target fishery (Langley in prep). Broken horizontal lines indicate the target and soft limit. The grey line represents a lognormal model of positive catches in mixed species bottom trawl tows, including data recorded on earlier (i.e., CELR) form types (Kendrick & Bentley 2011). Indices are scaled to have the same geometric mean over the overlapping years. The commercial catch from the area is also presented. Vertical lines show the 95% confidence intervals.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE series has steadily declined from the mid-2000s. The 2013–14 index is 56% of the target CPUE.
Recent Trend in Fishing Mortality or Proxy	 **Relative fishing mortality proxy derived from total area catch divided by CPUE indices from the recent CPUE analysis (Black points) and the CPUE analysis of Kendrick & Bentley 2011 (grey line).** The fishing mortality proxy indicates fishing mortality has been lower in the recent period as total catch from the fishery has declined more

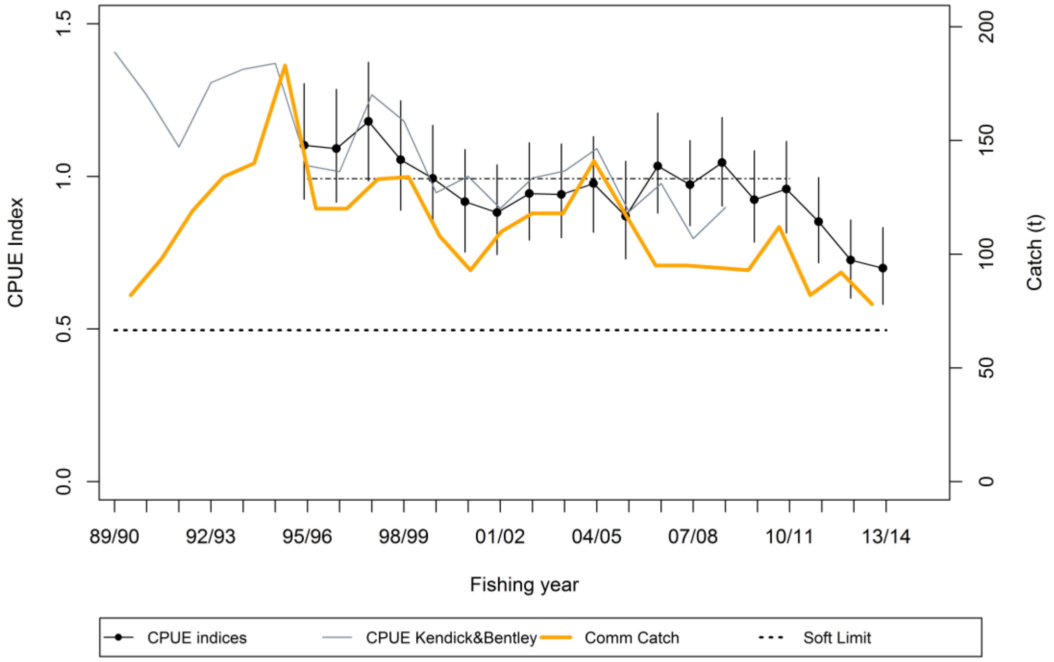
	than the decline in CPUE. The level of fishing mortality that corresponds to the target biomass level is unknown.
Other Abundance Indices	The trend in Danish seine CPUE indices from the Hauraki Gulf fishery is comparable to the BT CPUE index.
Trends in Other Relevant Indicators or Variables	-

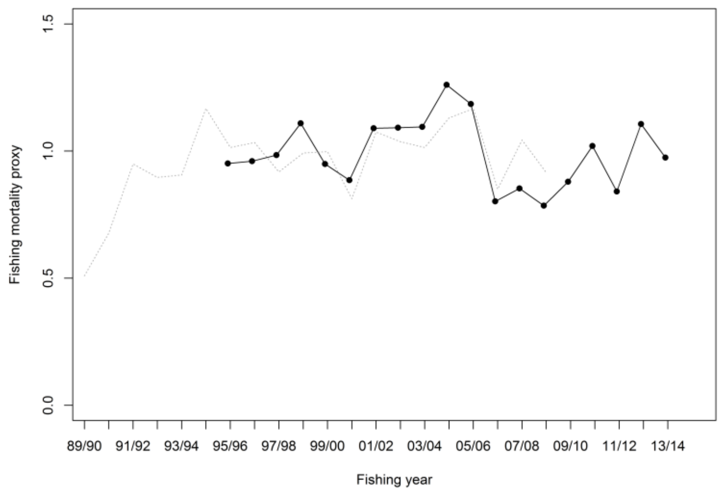
Projections and Prognosis	
Stock Projections or Prognosis	Annual catches and fishing mortality has been relatively low over the last five years, although there is no indication that the stock is recovering. It is likely that recruitment has been low over the recent period (5–10 years). The rebuilding of the stock to the target biomass level will depend on an increase in the level of recruitment (from recent levels).
Probability of Current Catch or TAC causing decline below Limits	Soft Limit: About as Likely as Not (40–60%) at current catch Hard Limit: Unknown
Probability of Current Catch or TAC causing Overfishing to continue or to commence	Current catch is Unlikely (< 40%) to cause overfishing

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2015	Next assessment: 2017
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Lack of information on incoming recruitment	
Qualifying Comments		
As both catch and CPUE are declining there is some concern over the status of this stock and the analysis should be updated in 2017.		
Fishery Interactions		
John dory is taken on the east coast by bottom trawl and Danish seine targeted at John dory and snapper. Incidental captures of seabirds and dolphins occur; there is a risk of incidental capture of New Zealand fur seal.		

- **JDO 1 (Bay of Plenty)**

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Standardised CPUE
Reference Points	Interim Target: Mean of the CPUE indices for John dory in Bay of Plenty from combined binomial and lognormal models from 1994–95 to 2010–11 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold F_{MSY}
Status in relation to Target	Very Unlikely (<10%) to be at or above the target
Status in relation to Limits	Soft Limit: Unlikely (< 40%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	About as Likely as Not (40–60%) that overfishing is occurring

Historical Stock Status Trajectory and Current Status

Standardised CPUE indices for John dory in Bay of Plenty from combined binomial and lognormal models of catch rate in bottom trawl tows in a mixed target fishery (Langley in prep). Broken horizontal lines indicate the target and soft limit. The grey line represents a lognormal model of positive catches in mixed species bottom trawl tows, including data recorded on earlier (i.e., CELR) form types (Kendrick & Bentley 2011). Indices are scaled to have the same geometric mean over the overlapping years. The total catch from the area is also presented. Vertical lines show the 95% confidence intervals.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE series declined from 2010–11 and the 2013–14 index is at 70% of the target biomass level.
Recent Trend in Fishing Mortality or Proxy	 **Relative fishing mortality proxy derived from total area catch divided by CPUE indices from the recent CPUE analysis (Black points) and the CPUE analysis of Kendrick & Bentley 2011 (grey line).** The fishing mortality proxy has increased since 2008–09 and in 2013–14 was close to the average for the series.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

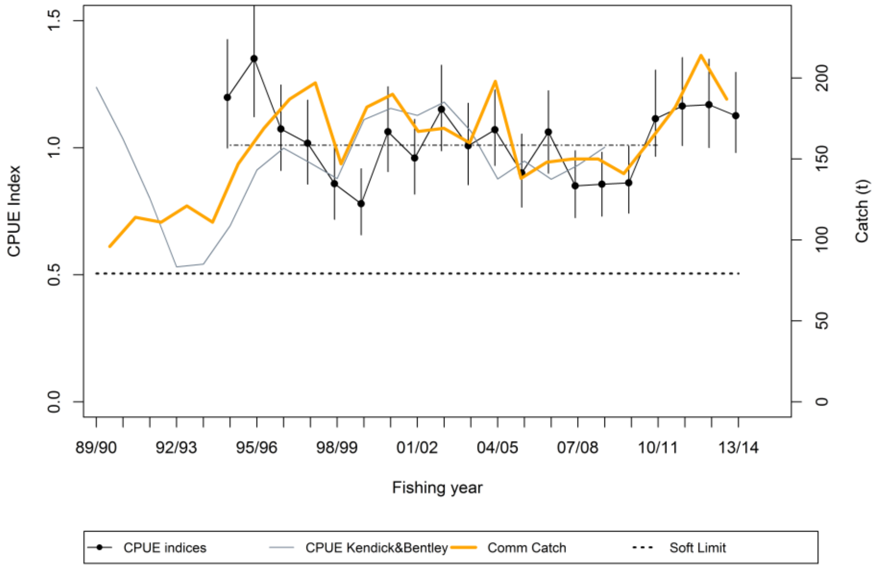
Projections and Prognosis	
Stock Projections or Prognosis	Annual catches and fishing mortality were relatively low during the last 5–7 years. The recent decline in stock biomass may be attributable to low recruitment over the recent period (5 years). The rebuilding of the stock to the target biomass level will be dependent on an increase in the level of recruitment (from recent levels).
Probability of Current Catch or TAC causing decline below Limits	Soft Limit: About as Likely as Not (40–60%) at current catch levels Hard Limit: Unlikely (< 40%) at current catch levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60 %)

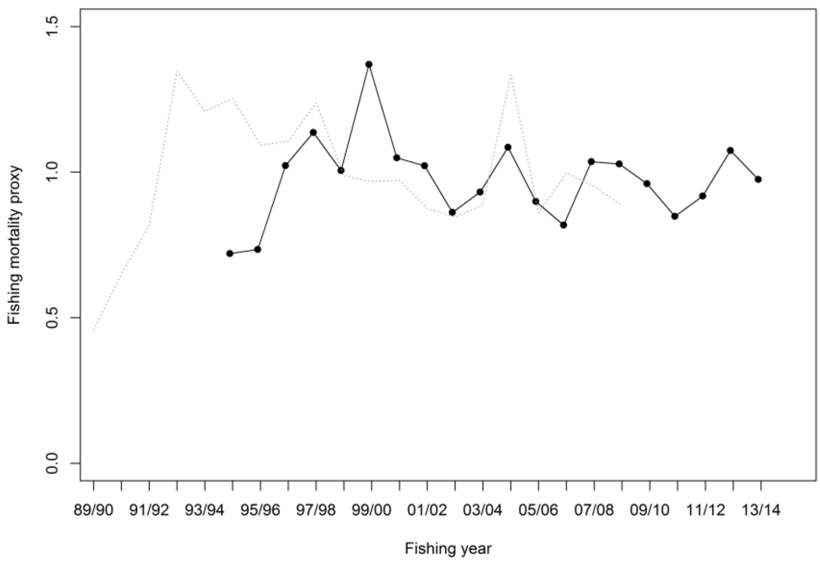
Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and standardised CPUE	
Assessment Dates	Latest assessment: 2015	Next assessment: 2017
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- 2015 CPUE analysis - 2010 CPUE analysis	1 – High Quality 1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	
Qualifying Comments		
Stock biomass is variable, probably in response to recruitment variation, and the current trend is downward. This makes it difficult to predict future trends without recruitment information.		

Fishery Interactions
John dory is taken in the Bay of Plenty by bottom trawl targeted at John dory, snapper, trevally, tarakihi and gurnard; and by Danish seine targeted at snapper and gurnard. Incidental captures of seabirds and dolphins occur; there is a risk of incidental capture of New Zealand fur seal.

- **JDO 1 (West Coast North Island)**

Stock Status	
Year of Most Recent Assessment	2015
Assessment Runs Presented	Standardised CPUE
Reference Points	Interim Target: Mean of the CPUE indices for John dory in West Coast North Island from combined binomial and lognormal models from 1994–95 to 2010–11 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold: F_{MSY}
Status in relation to Target	Likely (> 60%) to be above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status

Standardised CPUE indices for John dory in West Coast North Island from combined binomial and lognormal models of catch rate in bottom trawl tows in a mixed target fishery (Langley In prep). Broken horizontal lines indicate the target and soft limit. The grey line represents a lognormal model of positive catches in mixed species bottom trawl tows, including data recorded on earlier (i.e., CELR) form types (Kendrick & Bentley 2011). Indices are scaled to have the same geometric mean over the overlapping years. Vertical lines show the 95% credible intervals. Commercial catch represents the catch from this area.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Both CPUE series have fluctuated without trend.
Recent Trend in Fishing Mortality or Proxy	 **Relative fishing mortality proxy derived from total area catch divided by CPUE indices from the recent CPUE analysis (Black points) and the CPUE analysis of Kendrick & Bentley 2011 (grey line).** Fishing mortality has fluctuated without trend over the time-series corresponding to the CPUE indices.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock biomass is expected to continue to fluctuate about the target biomass level.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) at current catch levels Hard Limit: Very Unlikely (< 10%) at current catch levels
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%) at current catch levels

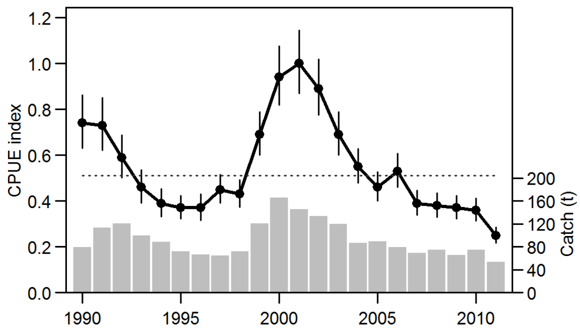
Assessment Methodology		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and standardised CPUE	
Assessment Dates	Latest assessment: 2015	Next assessment: 2017
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	2015 CPUE analysis 2010 CPUE analysis	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- The stock relationship between JDO 1 and JDO 2	
Qualifying Comments		
-		

Fishery Interactions
John dory is taken on the west coast by bottom trawl targeted at snapper trevally, gurnard and tarakihi. Incidental captures of seabirds and dolphins occur; there is a risk of incidental capture of New Zealand fur seal and Maui's dolphins.

- **JDO 2 (Southeast North Island)**

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Standardised CPUE
Reference Points	Interim Target: Mean of the CPUE indices for John dory in South East coast of the North Island from combined binomial and lognormal models from 1989–90 to 2010–11 Soft Limit: 50% of target Hard Limit: 25%of target Overfishing threshold F_{MSY}
Status in relation to Target	Unlikely (< 40%) to be at or above the target
Status in relation to Limits	Soft Limit: About as Likely as Not (40–60%) to be below Hard Limit: Unlikely (< 10%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE indices for John dory in Southeast North Island from combined binomial and lognormal models of catch rate in bottom trawl trips in a mixed target fishery (Dunn & Jones In press). Broken horizontal line indicates the mean from 1989–90 to 2010–11; Bars represent catch from this area.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The CPUE series has fluctuated with a cyclical trend. The data points since 2006–07 have been below the long-term mean. 2010–11 is the lowest in the series.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

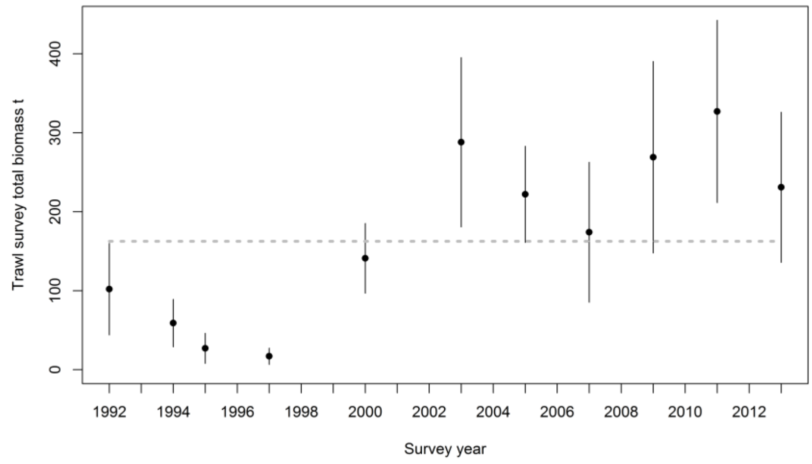
Projections and Prognosis	
Stock Projections or Prognosis	Without information on recruitment, it is not possible to predict how the stock will respond in the next few years.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Likely (> 60%) Hard Limit: About as Likely as Not (40–60%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and standardised CPUE	
Assessment Dates	Latest assessment: 2013	Next assessment: 2016
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch and effort data	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- The stock relationship between JDO 1 and JDO 2 - Lack of information on incoming recruitment	
Qualifying Comments		
As the John dory fishery in FMAs 1 and 9 has a long history, it is not possible to infer stock status from abundance trends from only the last 22 years. This sub-stock appears to be cyclical, probably in response to recruitment variation. This makes it difficult to predict future trends without recruitment information.		
Fishery Interactions		
John dory is taken on the east coast by bottom trawl targeted primarily at tarakihi and red gurnard.		

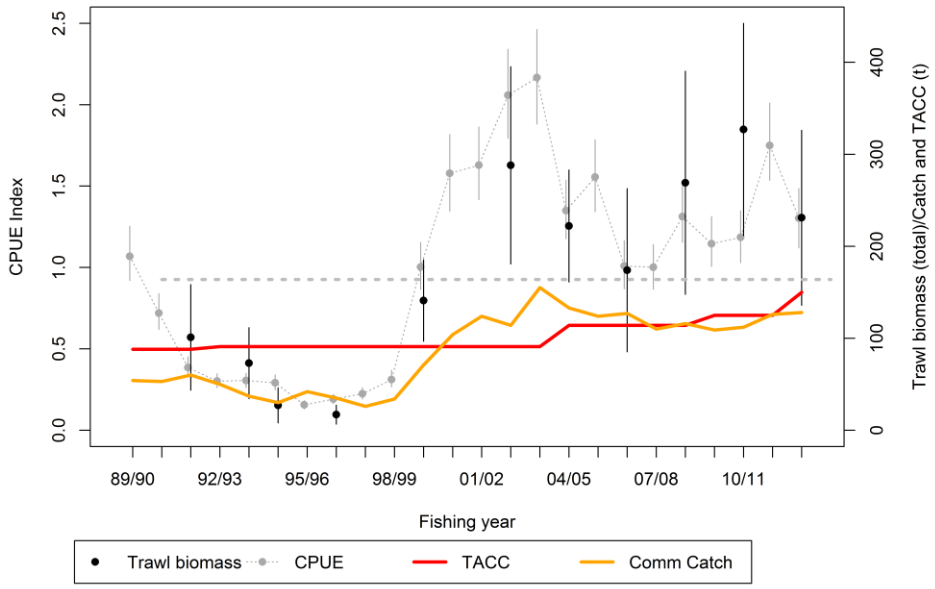
- **JDO 7 (Northern South island)**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Trawl survey biomass index and standardised CPUE
Reference Points	Interim Target: Mean total biomass from the West Coast South Island trawl survey (WCSI and TBGB) from 1992 to 2011 Soft Limit: 50% of target Hard Limit: 25% of target Overfishing threshold F_{MSY}
Status in relation to Target	Likely (> 60%) to be above the target
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Very Unlikely (< 10%) to be below
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) and the time series mean (dotted line) from the Challenger trawl surveys.



A comparison of trends in trawl survey biomass estimates (total biomass, WCSI), CPUE indices and the commercial catch relative to the TACC. The dashed line represents the interim target biomass level relative to the trawl survey biomass indices.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The trawl survey series declined through the 1990s then increased between 1997–98 and 2003–04. The series has been above the long term mean since 2000–01. Trends in CPUE are comparable to trawl survey biomass trends.
Recent Trend in Fishing Mortality or Proxy	The commercial catch trends generally followed those of the trawl survey biomass estimates up to 2006–07. Since then, the annual catch has been maintained at about the annual TACC level, while trawl survey biomass has increased.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Length frequency analysis from the West Coast South Island trawl survey showed very good recruitment in 2000, 2003 and 2009 and these are probably supporting the high biomass at this time. Recruitment from the 2011 and 2013 surveys is more modest.

Projections and Prognosis	
Stock Projections or Prognosis	The stock is currently at a relatively high level, above the interim target biomass level, and previous high catches appear to have been sustained by intermittent high recruitment. Biomass levels may decline below the target biomass level if strong recruitment does not occur in the next few years.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%). Non target species so that even if abundance declines considerably the exploitation rates are unlikely to substantially increase.

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of survey biomass and length frequencies. Standardised CPUE	
Assessment Dates	Latest assessment: 2013 (Survey) 2014 (CPUE)	Next assessment: 2015 (survey) 2016 (CPUE)
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- West Coast South Island trawl survey - Survey length frequency - CPUE	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- More complete data set obtained for CPUE analysis	
Major Sources of Uncertainty	- The stock relationship between JDO 7 and JDO 2	

Qualifying Comments
-
Fishery Interactions
John dory are primarily taken in conjunction with the following QMS species: barracouta, red cod, stargazer, red gurnard and tarakihi in the Northern South Island bottom trawl fishery.

6. FOR FURTHER INFORMATION

Bentley, N; Langley, A D; Lallemand, P (2012) Commercial fisheries of New Zealand, 1989/90–2010/11. Trophia Ltd. http://finz.trophia.com. [Accessed 15 March 2013].

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries Research Project REC9803. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished document held in NIWA library, Wellington.)

Dunn, M R; Jones, E (2013). Stock structure and fishery characterisation for New Zealand John dory. *New Zealand Fisheries Assessment Report 2013/40*. 99 p.

Fu, D; Gilbert, D J; Baird, S J; Manning, M J (2008) CPUE analysis of John dory (*Zeus faber*) in New Zealand's main fishery (JDO1). *New Zealand Fisheries Assessment Report 2008/14*. 42 p.

Hanchet, S M; Francis, M P; Horn, P L (2001) Age and growth of John dory (*Zeus faber*). *New Zealand Fisheries Assessment Report 2001/10*. 26 p.

Hore, A J (1982) The age growth and reproduction of the John dory, *Zeus faber*. (Unpublished MSc thesis, University of Auckland.)

Hore, A J (1985) John dory *In*: Colman, J.A.; McKoy, J.L.; Baird, G.G. (1985). Background papers for the 1985 Total Allowable Catch recommendations, pp. 117–122. (Unpublished report, held in NIWA library, Wellington.)

Hore, A J (1988) John dory. New Zealand Fisheries Assessment Research Document 1988/39. 8 p. (Unpublished document held in NIWA library, Wellington.)

Horn, P L; Hanchet, S M; Stevenson, M J; Kendrick, T H; Paul, L J (1999) Catch history, CPUE analysis, and stock assessment of John dory (*Zeus faber*) around the North Island (Fishstocks JDO1 and JDO2). New Zealand Fisheries Assessment Research Document 99/33. 58 p. (Unpublished document held in NIWA library, Wellington.)

Kendrick, T H; Bentley, N (2011) Fishery characterisation and catch-per-unit-effort indices for three sub-stocks of John dory in JDO1, 1989–90 to 2008–09. *New Zealand Fisheries Assessment Report 2011/38*.

Langley. A.D. (2014). Updated CPUE analyses for selected South Island inshore finfish stocks. *New Zealand Fisheries Assessment Report 2014/40*.

MacGibbon, D.J.; Stevenson, M.L. (2013). Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2013 (KAH1305). *New Zealand Fisheries Assessment Report 2013/66.* 115 p.

Morrison, M A; Francis, M P; Parkinson, D M (2002) Trawl survey of the Hauraki Gulf, 2000 (KAH0012). *New Zealand Fisheries Assessment Report 2002/46*. 49 p.

Stevenson, M L (2007) Inshore trawl surveys of the west coast of the South Island and Tasman and Golden Bays, March-April 2007 (KAH0704). *New Zealand Fisheries Assessment Report 2007/41*. 64 p.

Stevenson, M L (2010) Inshore trawl surveys of the west coast of the South Island and Tasman and Golden Bays, March-April 2009 (KAH0704). *New Zealand Fisheries Assessment Report 2010/11*.

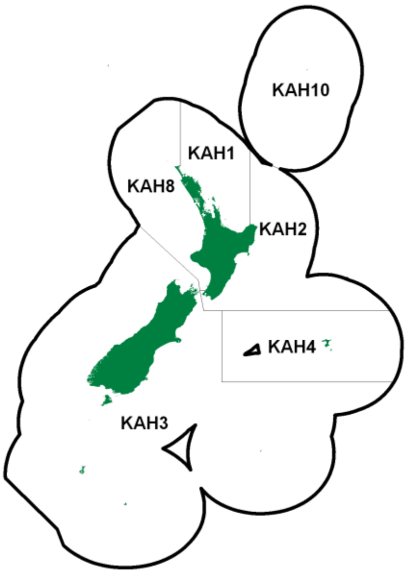
Stevenson, M L (2012) Inshore trawl survey of the west coast of the South Island and Tasman and Golden Bays, March-April 2011. *New Zealand Fisheries Assessment Report* 2012/50.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94 New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished document held in NIWA library, Wellington.)

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

KAHAWAI (KAH)

(Arripis trutta and Arripis xylabion)
Kahawai



1. FISHERY SUMMARY

Kahawai (*Arripis trutta*) and Kermadec kahawai (*Arripis xylabion*) were introduced into the QMS on 1 October 2004 under a single species code, KAH. Within the QMS, kahawai management is based on six QMAs (KAH 1, KAH 2, KAH 3, KAH 4, KAH 8 and KAH 10).

These QMAs differ from the Management Areas used before kahawai were introduced into the QMS. The definitions of KAH 1, KAH 2 and KAH 10 remain unchanged, but KAH 4 was formerly part of KAH 3, as was that part of KAH 8 which is south of Tirua Point. The area of KAH 8 which is north of Tirua point was formerly called KAH 9.

TACs totalling 7612 t were set on introduction into the QMS. These TACs were based on a 15% reduction from both the level of commercial catch and assumed recreational use prior to introducing kahawai into the QMS. The Minister reviewed the TACs for kahawai for the 2005–06 fishing year. Subsequently, he decided to reduce TACs, TACCs and allowances by a further 10% as shown in Table 1.

Table 1: KAH allowances, TACCs, and TACs, 1 October 2010.

Fishstock	Recreational Allowance	Customary Non-Commercial Allowance	Other mortality	TACC	TAC
KAH 1	900	200	45	1 075	2 200
KAH 2	610	185	30	705	1 530
KAH 3	390	115	20	410	935
KAH 4	4	1	0	9	14
KAH 8	385	115	20	520	1 040
KAH 10	4	1	0	9	14

1.1 Commercial fisheries

Commercial fishers take kahawai by a variety of methods. Purse seine vessels take most of the catch; however, substantial quantities are also taken seasonally in set net fisheries and as a bycatch in longline and trawl fisheries.

The kahawai purse seine fishery cannot be understood without taking into account the other species that the vessels target. The fleet, which is based in Tauranga, preferentially targets skipjack tuna (*Katsuwonus pelamis*) between December and May, with very little bycatch. When skipjack are not available, usually from June through to November, the fleet fishes for a mix of species including kahawai, jack mackerels (*Trachurus* spp.), trevally (*Pseudocaranx dentex*) and blue mackerel (*Scomber australasicus*). These are caught 'on demand' as export orders are received (to reduce product storage costs). However, since the mackerels and kahawai school together there is often a bycatch of kahawai resulting from targeting of mackerels. Historical estimated kahawai landings are shown in Table 1 from 1931 1982. Reported landings, predominantly of *A. trutta*, are shown for 1962 up to and including 1982 in Table 3 by calendar year for all areas combined, and from 1983–84 onwards by fishing year and by historic management areas in Table 4 and by QMAs in Table 5. The historical landings and TACC for the main KAH stocks are depicted in Figure 1.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	KAH 1	KAH 2	KAH 3	KAH 4	Year	KAH 1	KAH 2	KAH 3	KAH 4
1931-32	1	0	0	0	1957	25	6	0	0
1932-33	1	0	0	0	1958	33	13	0	0
1933-34	0	0	1	0	1959	31	2	0	0
1934-35	0	0	0	0	1960	40	1	0	0
1935-36	0	0	0	0	1961	40	0	0	0
1936-37	0	0	0	0	1962	54	7	0	0
1937-38	2	1	1	0	1963	60	11	0	0
1938-39	2	2	1	0	1964	75	4	1	0
1939-40	1	1	1	0	1965	85	13	0	0
1940-41	1	4	2	0	1966	143	106	0	0
1941-42	2	1	1	0	1967	147	303	0	0
1942-43	21	1	2	0	1968	107	159	29	0
1943-44	58	3	4	0	1969	163	29	12	0
1944	90	7	4	0	1970	141	59	22	0
1945	102	2	3	0	1971	185	258	10	0
1946	94	0	4	0	1972	168	151	22	0
1947	54	0	4	0	1973	295	132	13	0
1948	58	2	1	0	1974	357	206	17	0
1949	23	3	0	0	1975	140	28	18	0
1950	34	2	1	0	1976	401	108	30	0
1951	22	1	0	0	1977	631	385	218	0
1952	27	2	0	0	1978	1237	487	279	0
1953	14	1	0	0	1979	1642	552	608	0
1954	18	2	0	0	1980	1213	885	810	0
1955	19	6	0	0	1981	659	625	1301	0
1956	16	3	0	0	1982	1133	639	980	0

Year	KAH 8	Year	KAH 8
1931-32	0	1957	13
1932-33	0	1958	12
1933-34	0	1959	14
1934-35	3	1960	10
1935-36	0	1961	12
1936-37	0	1962	16
1937-38	0	1963	11
1938-39	0	1964	7
1939-40	0	1965	4
1940-41	1	1966	5
1941-42	0	1967	5
1942-43	0	1968	7
1943-44	3	1969	33
1944	6	1970	74
1945	1	1971	119
1946	9	1972	53
1947	1	1973	147
1948	1	1974	226
1949	1	1975	154
1950	1	1976	186
1951	2	1977	224
1952	3	1978	217
1953	4	1979	267
1954	2	1980	350
1955	7	1981	498
1956	7	1982	484

Notes:
The 1931–1943 years are April–March but from 1944 onwards are calendar years.
Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting.

Table 3: Reported total landings (t) of kahawai from 1970 to 1982. Note that these data include estimates of kahawai from data where kahawai were reported within a general category of 'mixed fish' rather than separately as kahawai.

Year	Landings	Year	Landings	Year	Landings
1962	76	1969	234	1976	729
1963	81	1970	294	1977	1 461
1964	86	1971	572	1978	2 228
1965	102	1972	394	1979	3 782
1966	254	1973	586	1980	5 101
1967	457	1974	812	1981	3 794
1968	305	1975	345	1982	5 398

Source: 1962 to 1969 - Watkinson & Smith (1972); 1970 to 1982 - Sylvester (1989).

Before 1988 there were no restrictions in place for the purse seine fishery.

Table 4: Reported landings (t) of kahawai by management areas as defined prior to 2004 from 1983–84 to 2003–04. Estimates of fish landed as bait or as 'mixed fish' are not included. Data for the distribution of catches among management areas and total catch are from the FSU database through to 1987–88 and from the CELR database after that date. Total LFRR or MHR values are the landings reported by Licensed Fish Receivers (to 2000–01) or on Monthly Harvest returns (to 2003–04).

Fishstock	KAH 1	KAH 2	KAH 3	KAH 9	KAH 10	Unknown Area	Total Catch	Total LFRR/MHR
FMA(s)	1	2	3–8	9	10			
1983–84	1 941	919	813	547	0	46	4 266	-
1984–85	1 517	697	1 669	299	0	441	4 623	-
1985–86	1 597	280	1 589	329	0	621	4 416	-
1986–87	1 890	212	3 969	253	0	1 301	7 525	6 481
1987–88	4 292	1 655	2 947	135	0	581	9 610	9 218
1988–89	2 170	779	4 301	179	0	-	7431	7 377
1989–90	2 049	534	5 711	156	0	16	8 466	8 696
1990–91	1 617	872	2 950	242	0	4	5 687	5 780
1991–92	2 190	807	1 900	199	< 1	7	5 104	5 071
1992–93	2 738	1 132	1 930	832	2	0	6 639	6 966
1993–94	2 054	1 136	1 861	98	15	0	5 164	4 964
1994–95	1 918	1 079	1 290	168	0	24	4479	4 532
1995–96	1 904	760	1 548	237	7	46	4 502	4 648
1996–97	2 214	808	938	194	1	3	4 158	3 763
1997–98	1 601	291	525	264	0	19	2 700	2 823
1998–99	1 833	922	1 209	468	0	3	4 435	4 298
1999–00	1 616	1 138	718	440	0	< 1	3 912	3 941
2000–01	1 746	886	925	272	0	1	3 829	3 668
2001–02	1 354	816	377	271	0	< 1	2 819	2 796
2002–03	933	915	933	221	0	< 1	3 001	2 964
2003–04	1 624	807	109	205	0	0	2 745	2 754

A total commercial catch limit for kahawai was set at 6500 t for the 1990–91 fishing year, with 4856 t set aside for those harvesting kahawai by purse seine (Table 6 Before the 2002–03 fishing year a high proportion of the purse seine catch was targeted, but in recent years approximately half of the landed catch has been reported as a bycatch while targeting other species with purse seine gear

Table 5: Prorated landings (t) of kahawai by the Fishstocks defined in 2004 for the fishing years between 1998–99 and 2013–14. Distribution of data were derived by linking through the trip code, catch landing data (CLD), statistical areas and landing points and prorating to CLD totals. Landings since 2004–05 are from QMS MHR data. The TACC is provided for those years since the introduction to the QMS.

	KAH 1		KAH 2		KAH 3		KAH 4		KAH8&9		KAH 10			
	1		2		3, 5, 7		4		8, 9		10		Total	
	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC
1998–99	1 652	-	975	-	697	-	0	-	1 120	-	0	-	4 444	-
1999–00	1 677	-	973	-	499	-	0	-	768	-	0	-	3 917	-
2000–01	1 678	-	922	-	425	-	0	-	581	-	0	-	3 606	-
2001–02	1 326	-	857	-	156	-	0	-	489	-	0	-	2 831	-
2002–03	869	-	855	-	650	-	0	-	542	-	0	-	2 916	-
2003–04	1 641	-	806	-	33	-	0	-	342	-	0	-	2 822	-
2004–05	1 147	1 195	708	785	129	455	< 1	10	544	580	0	10	2 529	3 025
2005–06	903	1 075	530	705	233	410	0	9	346	520	0	9	2 013	2 728
2006–07	1 046	1 075	672	705	382	410	< 1	9	407	520	0	9	2 507	2 728
2007–08	1 002	1 075	564	705	152	410	0	9	570	520	0	9	2 288	2 728
2008–09	945	1 075	823	705	157	410	0	9	381	520	0	9	2 306	2 728
2009–10	988	1 075	518	705	38	410	< 1	9	451	520	0	9	1 995	2 728
2010–11	1 002	1 075	719	705	46	410	0	9	454	520	0	9	2 221	2 728
2011–12	1 004	1 075	498	705	310	410	0	9	514	520	0	9	2 326	2 728
2012–13	1 095	1 075	502	705	195	410	0	9	468	520	0	9	2 260	2 728
2013-14	1 062	1 075	196	705	372	410	<1	9	472	520	0	9	2 102	2 728

In KAH 1, a voluntary moratorium was placed on targeting kahawai by purse seine in the Bay of Plenty from 1 December 1990 to 31 March 1991, which was extended from 1 December to the Tuesday after Easter in subsequent years. While total landings decreased in 1991–92, landings in KAH 1 increased, and in 1993–94 the competitive catch limit for purse seining in KAH 1 was reduced from 1666 t to 1200 t. Purse seine catches reported for KAH 9 were also included in this reduced catch limit, although seining for kahawai on the west coast of the North Island ceased after the reduction in the KAH 1 purse seine limit. Purse seine catch limits were reached in KAH 1 between 1998–99 and 2000–01 and in 2003–04.

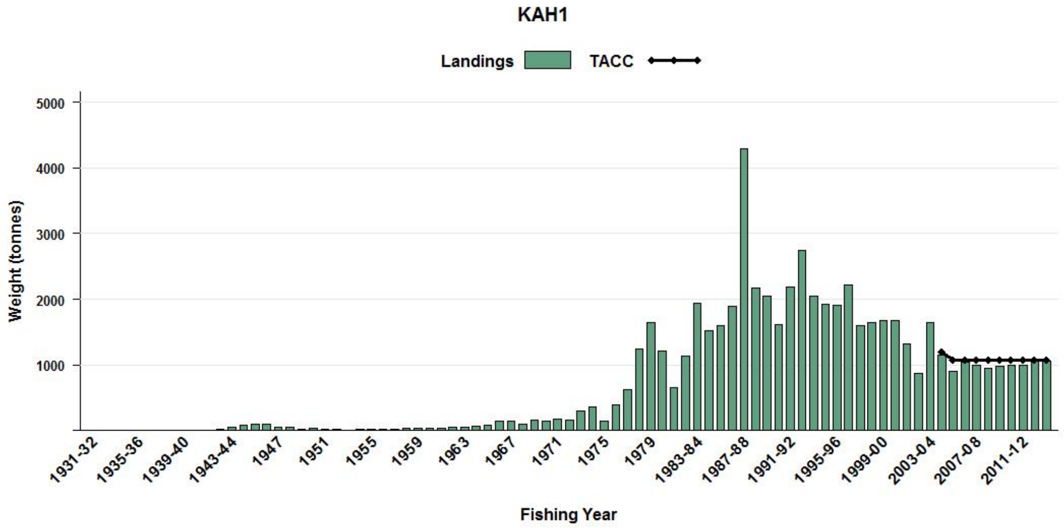
Prior to the introduction to the QMS, no change was made to the purse seine limit of 851 t for KAH 2. The KAH 2 purse seine fishery was closed early due to the catch limit being reached before the end of the season in each year between 1991–92 and 1995–96 and between 2000–01 and 2001–02.

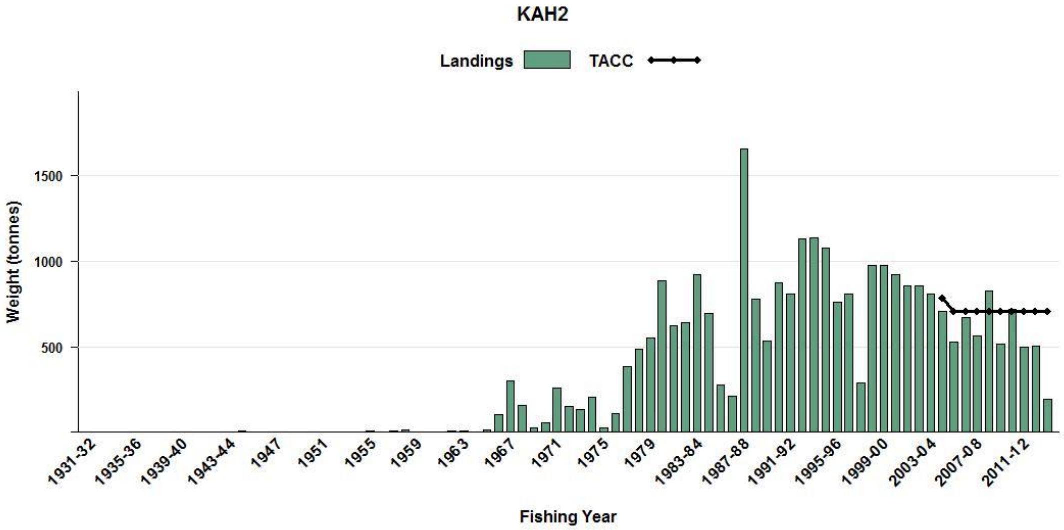
Within KAH 3, the kahawai purse seine fleet has voluntarily agreed since 1991–92 not to fish in a number of near-shore areas around Tasman and Golden Bays, the Marlborough Sounds, Cloudy Bay, and Kaikoura. The main purpose of this agreement is to minimise local depletion of schools of kahawai found in areas where recreational fisheries occur, and to minimise catches of juveniles. The purse seine catch limit for KAH 3 was reduced from 2339 to 1500 tonnes from 1995–96. Purse seine catch limits have never been reached in KAH 3.

Table 6: Reported catches (t) by purse seine method and competitive purse seine catch limit (t) from 1990–91 to 2003–04. All data are from weekly reports furnished by permit holders to the Ministry of Fisheries except those for 1993–94 which are from the CELR database. Fishstocks are as defined prior to 2004.

	KAH 1		KAH 2		KAH 3		KAH 9		KAH 10		Total	
Year	catch	catch limit	catch	catch limit	catch	Catch limit	catch	catch limit	catch	catch limit	catch	catch limit
1990–91	1 422	1 666	493	851	n/a#	2 839*	0	none	0	none	n/a	5 356
1991–92	1 613	1 666	735*	851	1 714	2 339	0	none	0	none	4 080	4 856
1992–93	1 547	1 666	795*	851	1 808	2 339	140	none	0	none	4 290	4 856
1993–94	1 262	1 200	1 101*	851	1 714	2 339	15	§	0	none	4 092	4 390
1994–95	1 225	1 200	821*	851	1 644	2 339	0	§	0	none	3 690	4 390
1995–96	1 077	1 200	805*	851	1 146	1 500	0	§	0	none	3 028	3 551
1996–97	1 017	1 200	620	851	578	1 500	0	§	0	none	2 784	3 551
1997–98	969	1 200	175	851	153	1 500	0	§	0	none	1 297	3 551
1998–99	1 416*	1 200	134	851	463	1 500	2	§	0	none	2 015	3 551
1999–00	1 371*	1 200	553	851	520	1 500	0	§	0	none	2 444	3 551
2000–01	1 322*	1 200	954*	851	430	1 500	0	§	0	none	2 706	3 551
2002–02	838	1 200	747*	851	221	1 500	0	§	0	none	1 806	3 551
2002–03	514	1 200	819	851	816	1 500	0	§	0	none	2 149	3 551
2003–04	1 203*	1 200	714	851	1	1 500	0	§	0	none	1 918	3 551

By March 1991 when the catch limit was imposed, the purse seine catch had already exceeded 2339 t and the fishery was immediately closed. As the catch already exceeded 2339 t before the Minister's decision was announced, an extra 500 t was allocated to cover kahawai bycatch only.
§ Combined landings from KAH 9 and KAH 1 were limited to 1200 t., * Purse seine fishery for kahawai closed.





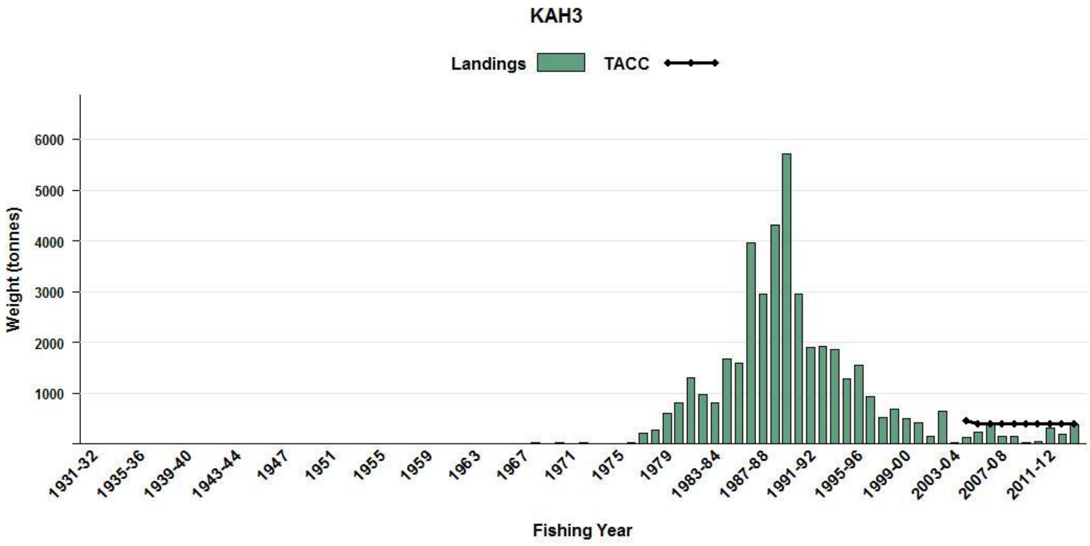


Figure 1: Total commercial landings and TACC for the four main KAH stocks. From top left to bottom right: KAH 1 (Auckland East), KAH 2 (Central East), KAH 3 (South East Coast, South East Chatham Rise, Sub-Antarctic, Southland, Challenger). [Continued on next page].

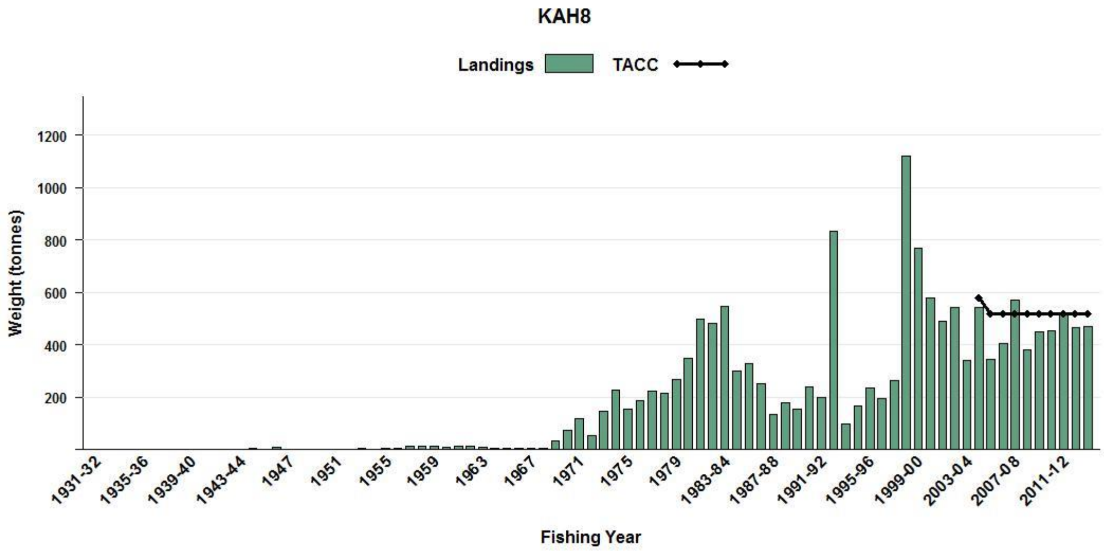


Figure 1: [Continued] Total commercial landings and TACC for the four main KAH stocks: KAH 8 (Central Egmont, Auckland West).

Since kahawai entered the Quota Management System on 1 October 2004, the purse seine catch limits no longer apply and landings, regardless of fishing method, are now restricted by quota availability and fishing company policies.

1.2 Recreational fisheries

Kahawai is the second most important recreational species in FMA 1 (after snapper). Kahawai are highly prized by many recreational fishers, who employ a range of shore and boat based fishing methods to target and/or catch the species. Kahawai is one of the fish species more frequently caught by recreational fishers, and recreational groups continue to express concern about the state of kahawai stocks in some areas. Historical kahawai recreational catches are poorly known. The current allowances within the TAC for each fishstock are shown in Table 1.

Information from the 2011–12 national panel survey (Wynne-Jones et al 2014) show kahawai were mainly caught by rod or line (93.7%), with just over half of the landed catch taken from trailer boats (54.4%), and a third were taken off land.

1.2.1 Management controls

The main method used to manage recreational harvests of kahawai is the daily bag limit. The current limits for kahawai are: up to 20 kahawai within a multi-species bag limit of 20 fish in the Auckland, Kermadec, Central and Challenger management areas; up to 15 kahawai within a multi-species bag limit of 30 fish in the South-East, Southland and Fiordland management areas; and up to 10 kahawai within a multi-species bag limit of 30 fish in the Kaikoura management area. A minimum net mesh size applies in all areas (the mesh sizes do vary by management area and net type).

.2.1 Harvest estimates

There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods, where fishers are surveyed or counted at their fishing location, or at an access point when they return to land after their fishing trip; and offsite methods, where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for kahawai were generated using an offsite regional telephone and diary survey approach in: MAF Fisheries South (1991–92), Central (1992–93) and North (1993–94) regions (Teirney et al 1997). Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2005) and a rolling replacement of diarists in 2001 (Boyd & Reilly 2004) provided estimates for a further year (mean weights were not re-estimated in 2001). Other than for the 1991–92

MAF Fisheries South survey, the diary method used mean weights of kahawai obtained from fish measured at boat ramps.

The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. Surveys up until 1996 relied on a telephone survey to estimate the proportion of the fishing population who fished, and to recruit fisher diarists. Telephone surveys are prone to several sources of bias, however, including soft refusal bias, where interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population (and, hence, the harvest) is thereby under-estimated. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the outset. Another equally serious cause of bias in telephone/diary surveys was that diarists who did not immediately record their day's catch after a trip sometimes overstated their catch or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright et al 2004).

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys are thought to be implausibly high for many species including kahawai, which led to the development of an alternative maximum count aerial-access onsite method, that provides a more direct means of estimating recreational harvests for boat based fisheries. The maximum count aerial-access approach combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an aerial survey count of vessels observed to be fishing at the approximate time of peak fishing effort on the same day. The ratio of the aerial count in a particular area relative to the number of interviewed parties who claimed to have fished in that area at the time of the overflight was used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. The methodology is further described by Hartill et al (2007).

This aerial-access method was first use to estimate the recreational snapper harvest in the Hauraki Gulf in 2003–04 (Hartill et al 2007a), which was subsequently extended to survey the wider SNA 1 fishery in 2004–05 (Hartill et al 2007b). One benefit of this method is that it also provides harvest estimates for other key species, in particular kahawai. The Recreational Working Group has concluded that this approach generally provides broadly reliable estimates of recreational harvest for KAH 1. It is not, however, possible to reliably quantify shore based fishing from the air, and for this reason it is necessary to derive scalars from offsite surveys to account for the shore-based kahawai catch. Aerial-access surveys, focusing on snapper, have provided kahawai harvest estimates for the Hauraki Gulf in 2003–04 and for all of FMA 1 in 2004–05 and 2011–12. The most recent aerial-access survey was conducted in QMA 1 in 2011–12 (Hartill et al 2013), to independently provide harvest estimates for comparison with those generated from a concurrent national panel survey.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of 30, 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch to avoid recall bias, and all information was collected by standardised phone interviews.

The two 2011-12 surveys appear to provide plausible results that corroborate each other for KAH 1, and are therefore considered to be broadly reliable (Hartill et al 2013). Note that neither of these estimates includes catch taken under s111 general approvals.

Recreational harvest estimates up to and including 2011-12 are given in Table 7. The KAH QMAs do not all match up with the strata used for the historical harvest estimates (in particular for KAH 3 and 8).

1.2.1 Monitoring harvest

In addition to estimating absolute harvests, a system to provide relative estimates of harvest over time for key fishstocks has been designed and implemented for some key recreational fisheries. The system uses web cameras to continuously monitor trends in trailer boat traffic at key boat ramps. This monitoring is complemented by creel surveys that provide estimates of the proportion of observed boats that were used for fishing, and of the average harvest of snapper and kahawai per boat trip. These data are combined to provide relative harvest estimates for KAH 1. Differences between aerial-access harvest estimates in the Hauraki Gulf in 2004-05 and in 2011–12 are of a similar magnitude to those inferred from the web cameras index, which suggests that web camera based relative harvest indices are reasonably robust. The web camera/creel index suggests that the recreational kahawai in the Hauraki Gulf decreased by over a half -71%) between 2011–12 and 2012-13, followed by a further slight decline in 2013-14. In East Northland, the catch in 2012-13 was similar to that in 2011-12, but declined to almost half that level in 2013-14 (-49%). In the Bay of Plenty the trend is generally flat. These data reflect the variability of recreational harvests, in particular that it is not just abundance which drives harvest levels, but also changes in localised availability.

Table 7: Recreational catch estimates for kahawai stocks. Totals for a stock are given in bold. The surveys ran from October or December through to September or November but are denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey catch estimates).

Stock	Year	Method	Number of fish (thousands)	Mean weight (g) (summer/winter)	Total weight (t)	CV
KAH 1	1994	Telephone/diary	727	[1]	978	-
	1996	Telephone/diary	666		960	0.06
	2000	Telephone/diary	1 860		2 195	0.13
	2001	Telephone/diary	1 905	[2]	2 248	0.13
Hauraki Gulf only	2004	Aerial-access			56	0.15
East Northland	2005	Aerial-access			129	0.14
Hauraki Gulf	2005	Aerial-access			98	0.18
Bay of Plenty	2005	Aerial-access			303	0.14
Total	2005	Aerial-access			530	0.09
East Northland	2012	Aerial-access		1 473/1 220[3]	191	0.16
Hauraki Gulf	2012	Aerial-access		1 565/1 475[3]	483	0.13
Bay of Plenty	2012	Aerial-access		1 477/1 628[3,4]	268	0.12
Total	2012	Aerial-access		[3,4,5]	942	0.08
East Northland	2012	Panel survey	139	1 473/1 220[3]	198	0.14
Hauraki Gulf	2012	Panel survey	245	1 565/1 475[3]	377	0.09
Bay of Plenty	2012	Panel survey	238	1 477/1 628[3,4]	238	0.11
Total	2012	Panel survey	638	[3,4,5]	958	0.07
KAH 2	1993	Telephone/diary	195		298	-
	1996	Telephone/diary	142		217	0.09
	2000	Telephone/diary	1 808		2 937	0.74
	2001	Telephone/diary	492	[2]	799	0.20
	2012	Panel survey	146	1 583/1 449[3]	228	0.12
KAH 3	1992	Telephone/diary	231		210	-
	1994	Telephone/diary	6	[6]	8.4	-
	1996	Telephone/diary	226		137	0.07
	2000	Telephone/diary	413		667	0.16
	2001	Telephone/diary	353	[2]	570	0.18
	2012	Panel survey	105	1 279/2 340[3]	147	0.18
KAH 8	1994	Telephone/diary	254	[1]	340	-
	1996	Telephone/diary	199		204	0.09
	2000	Telephone/diary	337		441	0.20
	2001	Telephone/diary	466	[2]	609	0.24
	2012	Panel survey	282	1 664/1 318[3]	452	0.11

[1] Mean weight obtained from 1992–93 boat ramp sampling.
[2] The 2000 mean weights were used in the 2001 estimates.
[3] Separate mean weight estimates were used for summer (1 October 2011 to 30 April 2012) and for winter (1 May to 30 September 2012).
[4] Separate mean weight estimates were used for the eastern and western Bay of Plenty.
[5] Temporally and spatially separate mean weight estimates used as per notes 3 and 4.
[6] No harvest estimate available in the survey report, estimate presented is calculated as average fish weight for all years and areas by the number of fish

Table 8: Estimated kahawai harvest by recreational fishers (in numbers and weight) by Fishstock as defined prior to 2004. (Source: Tierney et al 1997, Bradford 1997, Bradford 1998, Boyd & Reilly 2002, Boyd et al 2004).

	KAH 1				KAH 2			
Year	Number	CV (%)	Range (t)	Estimate (t)	Number	CV (%)	Range (t)	Estimate (t)
1992–93	-	-	-	-	195 000	-	245–350	298
1993–94	727 000	-	920–1 035	978	-	-	-	-
1996	666 000	6	900–1 020	960	142 000	9	190–240	217
2000	1 860 000	13	916–2 475	2 195	1 808 000	74	769–5 105	2 937
2001	1 905 000	13	-	2 248	492 000	20	-	799

	KAH 3				KAH 9			
Year	Number	CV (%)	Range (t)	Estimate (t)	Number	CV (%)	Range (t)	Estimate (t)
1991–92	231 000	-	160–260	210				
1993–94	6000	-	-	8.4#	254 000	-	285–395	340
1996	226 000	7	125–145	137	199 000	9	195–225	204
2000	413 000	16	564–771	667	337 000	20	354–527	441
2001	353 000	18	-	570	466 000	24	-	609

#No harvest estimate available in the survey report, estimate presented is calculated as average fish weight for all years and areas by the number of fish estimated caught.

Table 9: Summary of kahawai harvest estimates (t) derived from an aerial overflight survey of the Hauraki Gulf in 2003–04 (1 December 2003 to 30 November 2004; Hartill et al 2007b) and a similar KAH 1 wide surveys conducted in 2004–05 (1 December 2004 to 30 November 2005; Hartill et al 2007c) and in 2011–12 (1 October 2011 to 30 November 2012; Hartill et al. 2013). Values in brackets denote CVs associated with each estimate.

Year	East Northland	Hauraki Gulf	Bay of Plenty	KAH 1
2003–04	-	56 (0.15)	-	-
2004–05	129 (0.14)	98 (0.18)	303 (0.14)	530 (0.09)
2011–12	191 (0.16)	483 (0.13)	268 (0.12)	942 (0.08)

The Recreational Technical Working Group (RTWG) concluded that the framework used for the telephone interviews for the 1996 and previous surveys contained a methodological error, resulting in biased eligibility figures. Consequently the harvest estimates derived from these surveys are unreliable.

This group also indicated concerns with some of the harvest estimates from the 2000–01 survey. The following summarises that group's views on the telephone /diary estimates:

"*The RTWG recommends that the harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and, c) the 2000 and 2001 harvest estimates are implausibly high for many important fisheries*."

In 2007, the Pelagic Working Group made the following conclusions in relation to the recreational harvest estimates for KAH 1 based on their current understanding:

- recreational catches are likely to be variable between years;
- the 2000 and 2001 harvest estimates (2195 and 2248 t) are:
    - possibly overestimated for those years and some PELWG members felt that the estimates were implausibly high;
    - are implausibly high if considered as a long term (back to the early 1990s) average; and
    - are likely to represent the upper limit of the harvest that may have occurred in any year since the 1990s (after the period of increased commercial landings);
- the aerial overflight estimate for kahawai harvest in 2004–05 of 530 t is:
    - possibly underestimated for that year, and
    - some PELWG members felt that it was implausibly low if considered as a long term average back to the early 1990s;
- the earlier diary survey estimates, although biased, are likely to be at plausible levels for those years, but are still uncertain; and

- the aerial overflight estimates for kahawai should be treated with caution due to the limited overlap between the method’s sampling technique and the fisheries for kahawai, e.g., the significant proportion of harvest taken by shore-based methods that requires auxiliary data to allow estimation of total harvest.

In 2008, the Northern Inshore Finfish Working Group (NINSWG) made the following conclusions in relation to the recreational harvest estimates for other KAH QMAs based on their conclusions for KAH 1:

- the current KAH QMAs do not match up with the strata used for the historical harvest estimates (KAH 3 and 8);
- recreational catches are likely to be variable between years;
- the 2000 harvest estimate for KAH 2 is implausibly high;
- the 2000 and 2001 harvest estimates for the remaining KAH areas are possibly overestimated.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year (Wynne-Jones et al. 1014). The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. Note that the national panel survey estimate does not include harvest taken on recreational charter vessels, or recreational harvest taken under s111 general approvals. Recreational harvest estimates from this survey for kahawai were: 933 t (cv 0.07) in KAH 1); 227 t (cv 0.12) in KAH 2; 146 t (cv 0.18) in KAH 3; and 415 t (cv 0.12) in KAH 8.

The most recent aerial-access survey was conducted in QMA 1 in 2011–12 (Hartill et al 2013), to independently provide harvest estimates for comparison with those generated from the concurrent national panel survey. The KAH 1 recreational harvest estimate from this survey was 942 t (cv 0.08).

Both surveys appear to provide plausible results that corroborate each other for KAH 1, and are therefore considered to be broadly reliable (Hartill et al 2013). Note that neither of these estimates includes catch taken on recreational charter vessels, or recreational catch taken under s111 general approvals.

1.3 Customary non-commercial fisheries

Kahawai is an important traditional and customary food fish for Maori. The level of customary catch has not been quantified and an estimate of the current customary non-commercial catch is not available. Some Maori have expressed concern over the state of their traditional fisheries for kahawai, especially around the river mouths in the eastern Bay of Plenty.

1.4 Illegal catch

Estimates of illegal catch are not available, but are probably insignificant.

1.5 Other sources of mortality

There is no information on other sources of mortality. Juvenile kahawai may suffer from habitat degradation due to run-off, situation and loss of shelter in estuarine areas.

2. BIOLOGY

Kahawai (*Arripis trutta*) are a schooling pelagic species belonging to the family Arripididae. Kahawai are found around the North Island, the South Island, the Kermadec and Chatham Islands. They occur mainly in coastal seas, harbours and estuaries and will enter the brackish water sections of rivers. A second species, *A. xylabion*, has been described (Paulin 1993). It is known to occur in the northern EEZ, at the Kermadec Islands and seasonally around Northland.

Kahawai feed mainly on fishes but also on pelagic crustaceans, especially krill (*Nyctiphanes australis*). Kahawai smaller than 100 mm mainly eat copepods. Although kahawai are principally pelagic feeders, they will take food from the seabed.

The spawning habitat of kahawai is unknown but is thought to be associated with the seabed offshore. Schools of females with running ripe ovaries have been caught by bottom trawl in 60–100 m in Hawke Bay (Jones et al 1992). Other females with running ripe ovaries have been observed in east coast purse seine landings sampled in March and April 1992, and between January and April in 1993 (McKenzie NIWA, unpublished data). Length-maturation data collected from thousands of samples in the early 1990s suggest that the onset of sexual maturity in males occurs at around 39 cm (fork length) and in females at 40 cm (McKenzie NIWA, unpublished data). This closely matches an estimate of 39 cm used for Australian *A. trutta* (Morton et al 2005). This length roughly corresponds to fish of four years of age in both countries. Eggs have been found in February in the outer Hauraki Gulf. Juvenile fish (0+ year class) can be found in shallow water over eelgrass meadows (*Zostera* spp.) and in estuaries.

Kahawai are usually aged using otoliths, following an ageing technique that has been validated (Stevens & Kalish 1998). Kahawai grow rapidly, attaining a length of around 15 cm at the end of their first year, and maturing after 3–5 years at about 35–40 cm, after which their growth rate slows. The longest recorded *A. trutta* had a fork length of 79 cm and was caught by a recreational fisher in the Waitangi Estuary, in Hawke Bay in August 1997 (Duffy & Petherick 1999). Northern kahawai, *Arripis xylabion*, grow considerably bigger than kahawai and attain a maximum length of at least 94 cm, but beyond this, little is known about the biology of *A. xylabion*. Male and female von Bertalanffy growth curves appear to be broadly similar, with females attaining a slightly higher value for L_{∞}, although statistical comparison of sex specific curves using a likelihood ratio test (Kimura 1980) suggests that they are statistically different (Hartill & Walsh 2005). Combined-sex growth curves are probably adequate for modelling purposes and are provided for some areas in Table 10. Sex specific growth parameters given for KAH 1 in previous plenary documents have higher estimates for L_{∞} (56.93 for males and 55.61 for females).

The maximum recorded age of kahawai is 26 years and this age has been previously used to estimate the instantaneous rate of natural mortality (*M*) using the equation $M = \log_e 100/\text{maximum age}$ (Jones et al. 1992). The resulting estimate of *M* of 0.18 assumes that this maximum observed age equates to that at which 1% of the population would survive in an unexploited stock, but a higher value for M is now considered more likely. This is because a reanalysis of purse seine catch-at-age data collected by Eggleston from KAH 2 & 3 between 1973 and 1975 suggests that 1% of the unexploited population would have lived for 20 years, which equates to an *M* of 0.23. A Chapman-Robson estimate of *M* of 0.22 was also derived from these catch-at-age data. Estimates of M ranging from 0.18 to 0.23 were therefore considered in the 2015 stock assessment and the assumed value used in the base case model was 0.20

Table 10: Estimates of biological parameters.

Fishstock			Estimate	Source
1. Natural mortality (*M*)				
All			0.20	Hartill & Bian (in prep)
2. Weight = a(length)^b (weight in g, length in cm fork length)				
		a	b	
KAH 1 (resting)		0.0306	2.82	Hartill & Walsh (2005)
KAH 1 (mature)		0.0103	3.14	Hartill & Walsh (2005)
KAH 1 & 3 (all)		0.0236	2.89	Hartill & Walsh (2005)
3. von Bertalanffy growth parameters				
	K	t_0	$L\infty$	
KAH 1	0.35	0.13	54.6	Hartill & Bian (in prep)
KAH 2	0.34	0.60	53.5	Drummond (1995)
KAH 3	0.30	0.25	54.2	Drummond & Wilson (1993)
KAH 9	0.23	-0.26	55.9	McKenzie, NIWA, unpubl. data

3. STOCKS AND AREAS

Kahawai are presently defined as separate units for the purpose of fisheries management: KAH 1 (FMA 1); KAH 2 (FMA 2); KAH 3 (FMAs 3, 5, 6 & 7); KAH 4 (QMA 4); KAH 8 (FMAs 8 & 9) and KAH 10 (FMA 10).

Returns from tagging programmes do not provide definitive information on the level of potential mixing between KAH QMAs, but tagging returns suggest that most kahawai (*A. trutta*) remain in the same area for several years, but some move throughout the kahawai habitat. The pattern of kahawai movement around New Zealand is poorly understood and there are regional differences in age structure and abundance that are consistent with limited mixing between regions.

Smith et al (2008) compared otolith micro-chemistry (multi-element chemistry and stable isotopes) and meristics (e.g., fin counts) from 0-group kahawai from two regions (Okahu Bay, Waitemata Harbour and Hakahaka Bay, Port Underwood). Two distant sites were chosen in order to provide the best chance of successful discrimination. Neither meristics nor stable isotopes provided any discrimination and magnesium and barium concentrations provided only weak discriminatory power.

On balance it seems possible that there are least two stocks of kahawai (*A. trutta*) within New Zealand waters with centres of concentration around the Bay of Plenty and the northern tip of the South Island. These two areas could be assumed to be separate for management purposes. Tagging data show that there is some limited mixing between these areas. Due to the shared QMA boundaries in the lower North Island and South Island, there is likely to be more mixing between the southern KAH QMAs than with the northern QMA (KAH 1).

There is no information about stock structure of *A. xylabion.*

4. STOCK ASSESSMENT

An age-structured assessment of the KAH 1 stock was first undertaken in 2007 (Hartill 2009), and was updated and revised in 2015 (Hartill & Bian in prep). Both assessments were undertaken using CASAL (Bull et al 2004). This assessment is reported below.

There are no accepted assessments for kahawai stocks outside of KAH 1, although there are some catch curve estimates of Z from these areas from the early 1990s, which are reported here.

4.1 KAH 1

4.1.1 Estimates of catch, selectivity and abundance indices

(i) Commercial catch

The commercial catch history used in the assessment is provided in Table 11. Annual catch by method landings statistics up until 1981–82 were provided by Francis & Paul (2013), and Fisheries Statistics Unit data were used to generate landings statistics for the period 1982–83 to 1988–89. It is noted that catches during these early years are less certain due to reporting issues (e.g. see Table 4 legend).

Table 11: Commercial catch time series used in the 2015 stock assessment of KAH 1.

Fishing year	trawl	Bottom Set net	Purse Seine	Other	KAH 1
1930–31	0.1	0.3	–	0.1	1
1931–32	0.3	0.8	–	0.3	1
1932–33	–	–	–	–	–
1933–34	–	–	–	–	–
1934–35	–	–	–	–	–
1935–36	–	–	–	–	–
1936–37	0.4	1.3	–	0.4	2
1937–38	0.3	0.9	–	0.3	2
1938–39	0.3	0.9	–	0.3	1
1939–40	0.3	0.8	–	0.3	1
1940–41	0.4	1.1	–	0.4	2
1941–42	4.2	12.6	–	4.2	21
1942–43	11.6	34.9	–	11.6	58
1943–44	18.0	53.9	–	18.0	90
1944–45	20.4	61.3	–	20.4	102
1945–46	18.7	56.2	–	18.7	94
1946–47	10.7	32.2	–	10.7	54
1947–48	11.6	34.7	–	11.6	58
1948–49	4.6	13.8	–	4.6	23
1949–50	6.7	20.1	–	6.7	34
1950–51	4.4	13.2	–	4.4	22
1951–52	5.4	16.2	–	5.4	27
1952–53	2.7	8.2	–	2.7	14
1953–54	3.6	10.9	–	3.6	18
1954–55	3.9	11.6	–	3.9	19
1955–56	3.3	9.8	–	3.3	16
1956–57	5.0	15.0	–	5.0	25
1957–58	6.5	19.6	–	6.5	33
1958–59	6.2	18.6	–	6.2	31
1959–60	8.1	24.2	–	8.1	40
1960–61	7.9	23.7	–	7.9	40
1961–62	10.9	32.6	–	10.9	54
1962–63	12.0	35.9	–	12.0	60
1963–64	15.0	45.1	–	15.0	75
1964–65	17.0	50.9	–	17.0	85
1965–66	28.5	85.5	–	28.5	143
1966–67	29.4	88.2	–	29.4	147
1967–68	21.4	64.2	–	21.4	107
1968–69	32.5	97.6	–	32.5	163
1969–70	28.1	84.4	–	28.1	141
1970–71	36.9	110.8	–	36.9	185
1971–72	33.6	100.9	–	33.6	168
1972–73	58.9	176.7	–	58.9	295
1973–74	71.4	214.3	–	71.4	357

Fishing year	trawl	Bottom Set net	Purse seine	Other	KAH 1
1974–75	19.0	63.8	37.7	19.8	140
1975–76	65.0	148.4	139.5	47.7	401
1976–77	122.7	163.0	270.6	74.5	631
1977–78	200.4	460.6	431.8	144.2	1 237
1978–79	379.5	228.2	875.4	159.4	1 642
1979–80	249.6	270.4	561.3	132.1	1 213
1980–81	131.7	158.6	292.3	76.7	659
1981–82	201.9	357.0	439.5	134.9	1 133
1982–83	105.6	526.4	169.1	180.9	982
1983–84	64.4	320.9	1 445.4	110.3	1 941
1984–85	82.5	410.9	882.4	141.2	1 517
1985–86	52.8	263.1	1 190.8	90.4	1 597
1986–87	44.9	223.8	1 544.4	76.9	1 890
1987–88	42.6	212.4	3 964.0	73.0	4 292
1988–89	68.2	339.8	1 644.0	116.8	2 169
1989–90	42.0	293.6	1 699.4	58.6	2 094
1990–91	66.6	321.2	1 562.9	62.1	2 013
1991–92	38.8	319.8	1 725.4	68.8	2 153
1992–93	70.5	532.5	3 066.3	111.5	3 781
1993–94	31.2	538.2	1 322.8	105.8	1 998
1994–95	35.0	389.0	1 290.8	135.9	1 851
1995–96	74.8	294.6	1 270.0	131.9	1 771
1996–97	69.6	253.8	1 291.4	100.3	1 715
1997–98	42.0	318.3	1 056.4	62.9	1 480
1998–99	94.3	167.9	1 573.8	75.3	1 911
1999–00	105.8	196.7	1 352.7	36.8	1 692
2000–01	74.6	199.5	1 393.3	52.7	1 720
2001–02	58.8	244.8	938.9	61.4	1 304
2002–03	44.1	199.0	765.6	33.2	1 042
2003–04	45.8	178.0	1 263.0	21.4	1 508
2004–05	48.5	161.5	833.5	35.6	1 079
2005–06	68.1	199.6	570.8	51.7	890
2006–07	39.2	255.3	686.8	52.9	1 034
2007–08	57.6	253.1	767.9	32.7	1 111
2008–09	30.2	266.2	658.7	33.3	988
2009–10	61.9	307.0	554.9	40.7	964
2010–11	61.5	292.0	700.1	56.3	1 110
2011–12	67.5	178.9	862.9	80.1	1 189
2012–13	114.7	211.1	706.4	50.8	1 083

(ii) Recreational catch

The recreational catch history in KAH 1 is poorly known. Aerial overflight estimates are available for the Hauraki Gulf in 2003–04 (Hartill et al 2007b) and for all three regions of KAH 1 in 2004–05 (Hartill et al 2007c) and in 2011–12 (Hartill et al. 2013). Recreational harvest estimates for all three regions of KAH 1 are also available from a National Panel Survey undertaken in 2011–12 (Wynne-Jones et al. 2014), which were of a similar magnitude to those provided by the aerial-access survey.

Levels of recreational harvesting vary from year to year, however, and the aerial-overflight estimates were therefore used to scale up regional catch per trip (landed catch weight per hour fished) indices derived from creel surveys conducted since 1990, to gauge likely levels of harvesting taking place across a wider range of years (Figure 2). The coefficient used to scale up the catch rate index in each region was the geometric mean of the aerial overflight estimates divided by the geometric mean of catch index during the aerial overflight survey years. The 2011–12 aerial overflight estimate was not used to inform the Bay of Plenty recreational catch history because the closure of waters of around Motiti Island following the grounding of the M.V. Rena in early October 2011, would have reduced levels of recreational catch and effort in an atypical fashion. The constant catch history estimates given in Figure 2 were used to inform regional constant catch histories for the period 1974–75 to 2012–13.

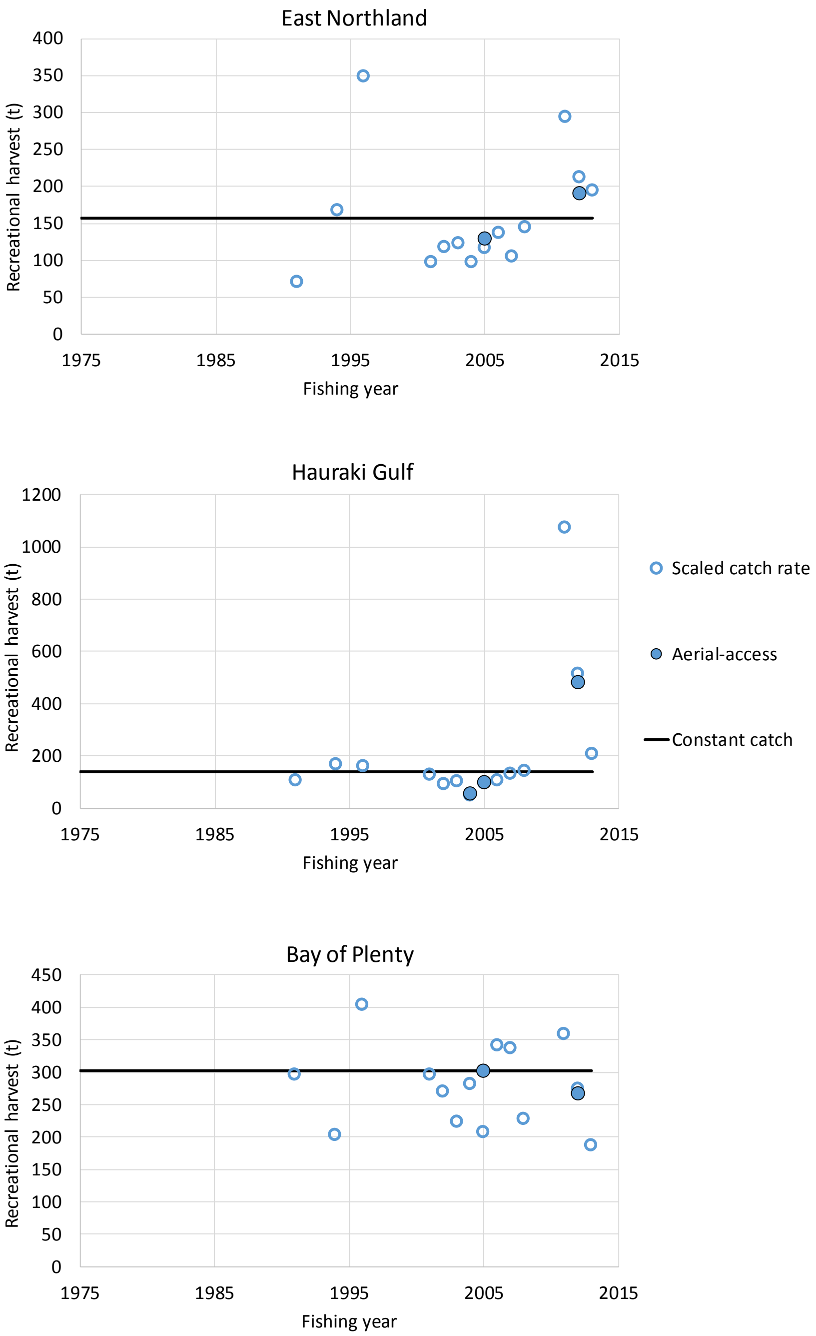


Figure 2: Regional recreational catch histories based on estimates provided by recent aerial-access surveys in 2004–05 and 2011–12. The 2011–12 estimate for the Bay of Plenty was not used as harvests in this year may have been adversely affected by the grounding of the M.V. Rena.

Constant harvest tonnages were used as there was concern that if a catch history with an assumed trend was used, this trend could influence the model results, despite being essentially unknown. Estimates of recreational harvest were required back to 1930–31, however, and the harvest at that time was assumed to be 10% of that in 1974–75, which was then ramped up to that value over the intervening years. These regional catch histories were then combined into a single catch history for KAH 1, which is assumed to include harvests taken by customary fishers (Figure 3).

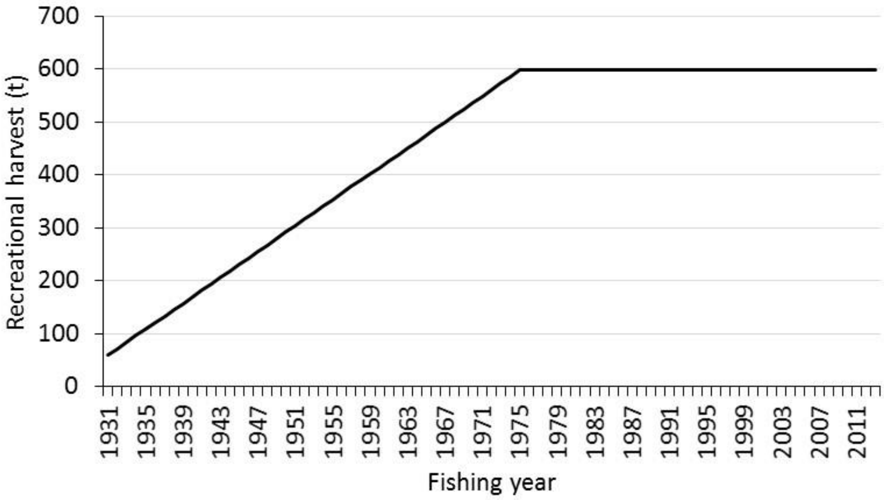


Figure 3: Recreational catch history for KAH 1 from 1931 to current that was assumed in the 2015 assessment.

(iii) Catch composition data and selectivity estimates

The earliest catch-at-age data that are available were collected from single trawl and purse seine landings sampled in 1991, 1992 and 1993. Purse seine landings were also sampled in 2005, 2011 and 2012. Catch-at-age data were available from set net landings from the Hauraki Gulf in 2011 and 2012, which were sampled so that the selectivity for this method could be estimated.

Recreational landings sampled during 10 years between 2001 and 2012 provided the most consistently sampled source of catch-at-age data used in the assessment (Hartill et al 2007a, 2007d, 2008, Armiger et al 2006, 2009, 2014). Boat ramp surveys were conducted in East Northland, the Hauraki Gulf, and the Bay of Plenty between January and April in each year. Annual catch-at-age distributions for each of the three regions were weighted together given the assumed catch history for each region, to provide a single time series for KAH 1 for this fishery.

All composition data were iteratively reweighted following the Francis method, which resulted in effective sample sizes being down weighted by about 98% for the recreational and purse seine catch-at-age data and by 85% of the single trawl data. This process maintained CVs for the abundance indices at the level originally estimated outside of the model.

Logistic selectivity ogives were estimated for the purse seine, single trawl and recreational fisheries, and the single trawl ogive was also used when accounting for the relatively small tonnage landed by other methods such as Danish seine and beach seine. A double normal selectivity was estimated from the set net catch-at-age data and subsequently fixed at MPD parameter values.

(iv) Indices of abundance

Three indices of abundance were available for the assessment, but only two of these were ultimately offered to the model. Both a recreational CPUE and an aerial Sightings per Unit Effort (SPUE) were considered informative, but the set net CPUE index used in the 2007 assessment was no longer considered reliable because ring net fishing is often reported as set net fishing.

Recreational CPUE index

The recreational CPUE index used in the model was based on creel survey data collected at boat ramps during surveys conducted intermittently since 1991. Creel survey data were only used from

East Northland and the Bay of Plenty, as catch rates in the Hauraki Gulf in about 2008 increased as a result of an influx of large kahawai, reflecting localised availability rather than abundance.

Separate CPUE (kg/hr) indices were initially calculated for East Northland and the Bay of Plenty, which were then weighted together based on the relative harvest taken from these regions, to provide a single abundance index for the KAH 1 stock. These indices were calculated from data collected between January and April only, as few surveys were conducted at other times of the year. Rod and line catch rate data were used from a core set of ramps only, which were surveyed in all past surveys.

Attempts were made to generate a standardised index but very few variables were available to inform any standardisation, especially as neither fisher nor vessel identifiers are recorded during creel surveys. The first term selected by any of the standardisations attempted was always fishing year, and remaining terms such as fishing location and month were often not selected or had little effect on the indices produced. The recreational CPUE index used in this assessment was therefore unstandardized (Figure 4).

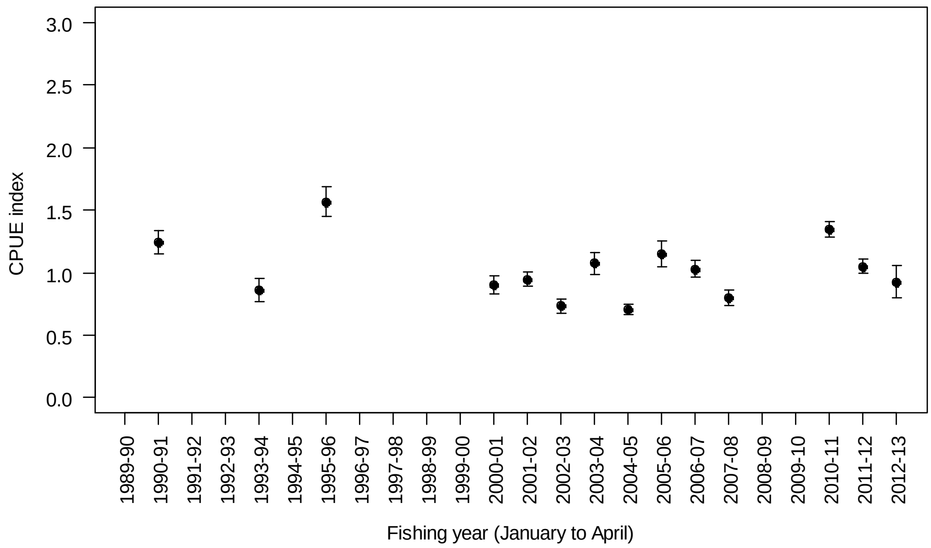


Figure 4: Unstandardised recreational CPUE (kg/hr). Vertical lines are bootstrap 95% confidence intervals.

Aerial Sightings Index

In 2012, an index of abundance [sightings per unit effort (SPUE)] based on commercial aerial sightings data was accepted by the Northern Inshore Working Group. This index was calculated using data from the Ministry for Primary Industries database *aer_sight* and applying a generalised additive model (GAM) to produce standardised annual relative abundance indices (Taylor Draft).

Flights were restricted to those that were exclusive to the Bay of Plenty (BoP) (i.e., those having flight paths that remained within an area defined as the BoP), only flown by pilot #2 and were the first flight of the day (apart from some defined exceptions, e.g., short refuelling flights at the start of the day).

Estimates of relative year effects were obtained using a forward stepwise GAM, where the data were fitted using two models: 1) the probability of a flight having a positive sighting modelled using a binomial regression; and 2) the tonnage sighted on positive flights modelled using a lognormal regression. These two models were combined into a single index. The data used for the SPUE analyses consisted of aerial sightings of kahawai, trevally, jack mackerel, blue mackerel, and skipjack tuna collected over the period 1986–87 to 2010–11, with missing years in 1988–89, from 1994–95 to 1996–97 and in 2006–07. Most of these missing years were the result of there being no available data. By contrast, 2006–07 was dropped because the working group identified a bias in the annual index for that year because of the low number of available flights. The first year of the original series (1985–86) was dropped by the working group for the same reason.

The species with the maximum daily purse-seine catch from the vessels that the pilot was working in the BoP was used as a proxy for target species. Catch data before 1989 were from the *fsu-new* database and data from 1989 to 2013 were from the *warehou* database.

Table 12: Standardised sightings per unit effort (SPUE) indices for the Bay of Plenty KAH 1 stock, derived as a combination of year effect estimates from a lognormal and a binomial regression for the period 1986–87 to 2012–13.

Fishing year	Combined	cv
1986–87	1.14	0.31
1987–88	0.86	0.27
1988–89	No data	No data
1989–90	0.58	0.27
1990–91	0.78	0.27
1991–92	0.66	0.28
1992–93	1.19	0.27
1993–94	1.17	0.30
1994–95	No data	No data
1995–96	No data	No data
1996–97	No data	No data
1997–98	0.81	0.28
1998–99	0.45	0.28
1999–00	0.47	0.54
2000–01	0.70	0.29
2001–02	0.66	0.29
2002–03	0.36	0.29
2003–04	1.30	0.35
2004–05	1.67	0.30
2005–06	1.93	0.29
2006–07	Insufficient data	Insufficient data
2007–08	2.45	0.27
2008–09	1.25	0.28
2009–10	1.49	0.28
2010–11	1.72	0.27
2011–12	1.78	0.32
2012–13	1.43	0.28

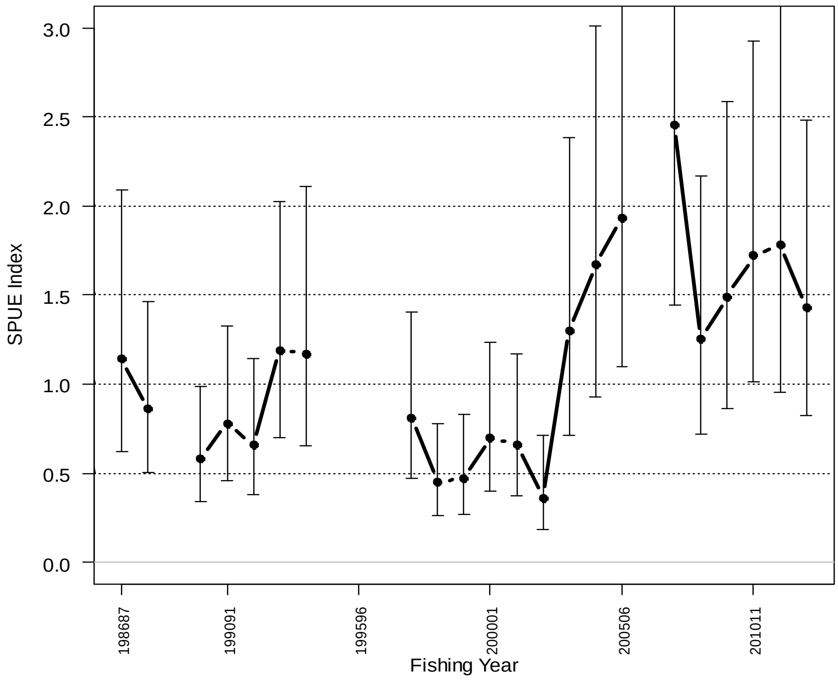


Figure 5: Standardised sightings per unit effort (SPUE) indices for the Bay of Plenty KAH 1 stock, derived as a combination of year effect estimates from a lognormal and a binomial regression. Vertical lines are 95% confidence intervals.

The Working Group accepted the combined model of SPUE for kahawai as an index of abundance in the BoP. The BoP combined SPUE index for kahawai shows substantial inter-annual variation with an overall gradual declining trend from 1986–87 to 2002–03; thereafter increasing sharply to a peak in 2007–08, and then declining to points above the long-term mean (Table 12, Figure 5).

4.1.2 Model structure

The stock assessment was restricted to KAH 1, because this is the QMA where most of the observational data have been collected. Future assessments may consider a broader stock definition, but improved understanding of the movement dynamics of this species and further development of this model are required before this can be attempted. Even within KAH 1 there is little information on connectivity between the three main areas of the fishery: East Northland, Hauraki Gulf and the Bay of Plenty. There are few tag data available that can be used to estimate these migration processes, because almost all of the kahawai that have been tagged have been released in the Bay of Plenty. This provides little information about emigration from the Hauraki Gulf and from East Northland. Recreational catch-at-age data collected since the 2007 assessment now suggest that size based migration between areas may vary more considerably and unpredictably than previously thought. For these reasons, the data used in the assessment were no longer regionally partitioned, but were combined into a single stock model which includes most of the currently available data.

In the stock assessment model it is assumed that KAH 1 is a single biological stock, exploited by several fisheries. Deviations from the spawner recruitment curve were estimated for those years when there were three or more years of observational catch-at-age data, and were constrained to a mean of 1.0 across all fishing years from 1974–75 to 2012–13.

A single annual time step was used, in which ageing was followed by recruitment, maturation, growth, and then mortality (natural and fishing). The relationships between length and age, and length and weight, were both assumed to be constant through time and were based on updated parameter values given in Table 10. Annual abundances of the age classes 1 to 20 were estimated in the model, with 20 year olds representing all fish older than 19 years. The model was not sex specific. Maturation was knife edged at four years of age. There is no information on the relationship between stock size and recruitment, and the rate of natural mortality is uncertain. Sensitivity to these parameters is discussed in the next section.

It was assumed that the population was at an unfished equilibrium state (B_0) in 1930, as reported commercial landings between 1930 and 1940 were only in the order of 1 to 2 tonnes per year. Key model outputs are probably robust to this assumption as commercial landings were only of the order of a few hundred tonnes and recreational landings were assumed to be low relative to stock size prior to this time. Total fishing mortality was apportioned between fisheries according to observed catches and estimated selectivities. Method specific annual landings from five fishing methods were considered: recreational, purse seine, single trawl, set net, and other minor commercial fisheries.

4.1.3 Evaluation of uncertainty

Evaluations of preliminary models identified three sources of uncertainty which were subsequently investigated in more detail: the assumed value for natural mortality (M); choice of abundance index; and the assumed steepness (h) of the Beverton-Holt stock recruitment relationship.

Alternative values of steepness of 0.75 and 0.90 appeared to have little influence on either current biomass or stock status, as sensitivity model runs suggested the spawning stock biomass has never fallen to low enough levels for this to have an effect. A base case value of 0.75 was assumed for all subsequent model runs.

An M of 0.20 was assumed for the base case model, in which both the SPUE and Recreational CPUE were considered. Three sensitivity models were also considered: two with alternative M estimates (0.18 and 0.23), and another where M was assumed to be 0.20, but only the recreational CPUE index was offered to the model (i.e. the SPUE index was omitted).

MCMCs were run for all four of these models. However, the M = 0.23 sensitivity model performed poorly despite an extended burn in period of 2 million iterations. MCMC traces for some parameters fluctuated markedly and the run terminated as it approached its 4 millionth iteration. This model was rejected due to the lack of convergence and results are not reported here.

The three remaining models were projected for a five year period (2014 to 2019), with future catches for each fishing year being set to those in 2012–13. Year class strengths were drawn from the 10-year period, 2000-2009.

4.1.4 Results

All of the models suggested that the stock was gradually fished down until the late 1970s, followed by a steeper decline that coincided with the development of the purse seine fishery during the 1980s. There have since been marked fluctuations in stock size but there is general evidence of a rebuild since the early 2000s.

The assumed value for *M* had the greatest influence on the model results, with the base case of *M* = 0.2 producing higher stock biomass and stock status (Figure 6). The lower value of 0.18 resulted in lower biomass estimates and lower current stock status when both abundance indices were offered to the model. Dropping the SPUE index suggested there had been less of a rebuild since the early 1990s, but there was still evidence of an increase in spawning stock biomass in recent years.

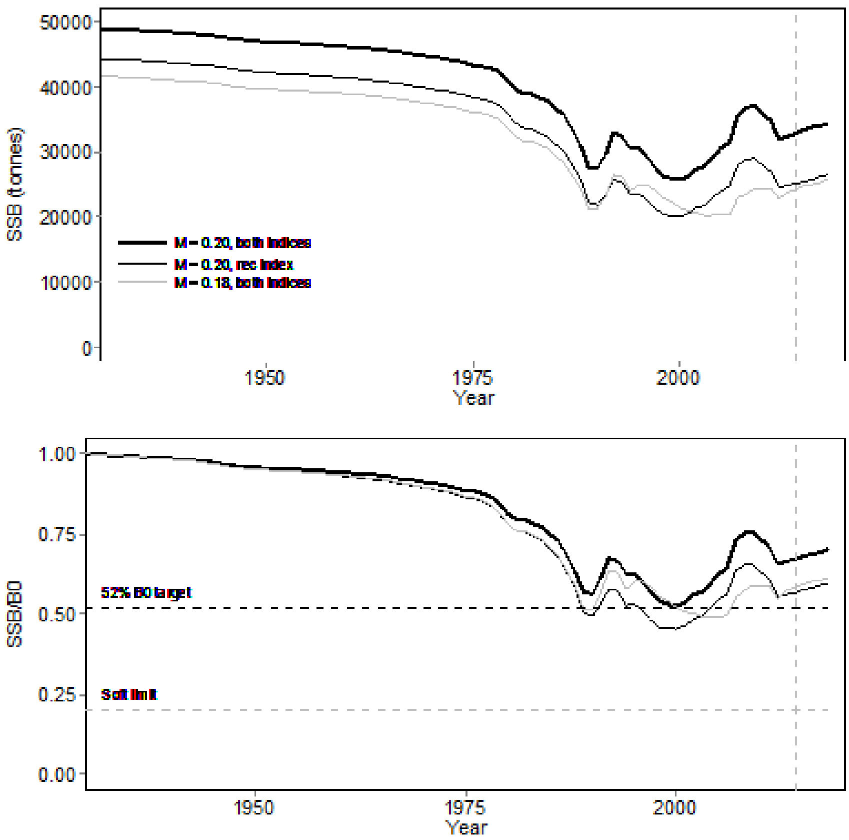


Figure 6: Comparison of spawning stock biomass (upper panel) and stock status trajectories (lower panel) for the base case (where M was assumed to be 0.20 and both the recreational CPUE and SPUE indices were offered to the model) and for two other sensitivities. The vertical dashed line denotes first year of the projection period (2014).

All three model runs suggest that the KAH 1 stock has never fallen below about 40% B_0 (Figure 6). Median %B_0 in 2013 was estimated to be 66% for the base case, 56% for the case with lower *M* and 58% when the SPUE was excluded (Table 13). In 2010 the Minister of Fisheries set a target reference point of 52% B_0 for this shared fishery, and although two of the sensitivity runs suggest that the KAH 1 stock biomass has fallen below this level at times, there is a high probability that the current biomass predicted by each model is well above this level (Table 13).

Table 13: Biomass and stock status estimates derived from MCMC runs for the base model (M_20_both; three chains combined) and two sensitivity models (medians with 95% credible intervals in parentheses).

Model	SSB_0	SSB_{2013}	$SSB_{52\%}$	SSB_{2013}/SSB_0	$SSB_{2013}/SSB_{52\%}$
M20_both	48 888	31 889	25 225	0.663	1.275
(Base case)	(38 973–92 822)	(20 334–79 232)	(20 266–48 267)	(0.521–0.854)	(1.000–1.641)
M18_both	44 340	24 952	17 736	0.563	1.407
	(38 536–56 991)	(17 250–39 700)	(15414–22 796)	(0.448–0.697)	(1.119–1.7415)
M20_rec	41 569	23 933	16 628	0.576	1.439
	(38 305–46 362)	(20 054–29 511)	(15 322–18 545)	(0.524–0.637)	(1.309–1.591)

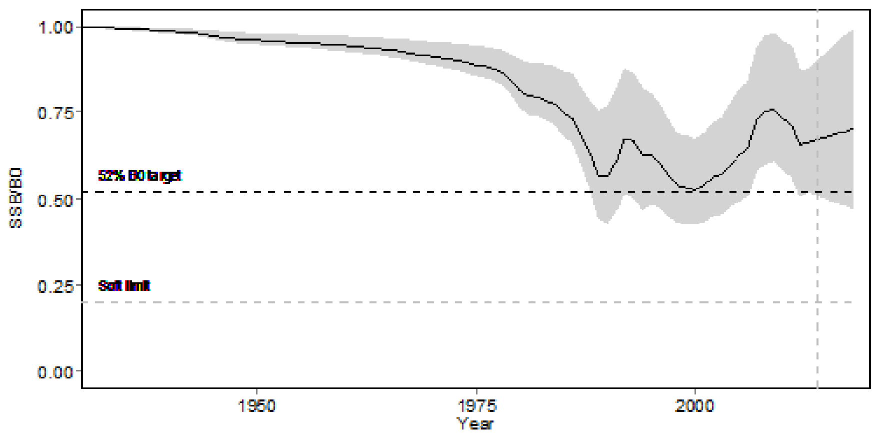


Figure 7: Spawning stock biomass relative to B_0 for the base model (M = 0.20, both abundance indices used; three chains combined). The 52% B_0 target set by the Minister of Fisheries in 2010 is denoted by a black dashed line and the 20% B_0 soft limit is denoted by the grey dashed line. The grey shaded area denotes 95% credible intervals derived from the MCMC model run and the black line denotes the median estimate for each year. The vertical dashed line denotes first year of the projection period (2014).

Table 14: Probability of the KAH 1 stock in 2013 falling below soft and hard limits and being at or above the target reference point. The target reference point of 52% B_0 was set by the Minister of Fisheries for this stock in 2010. Probabilities are calculated from the distribution of MCMC estimates calculated from each model.

Model	Pr(SSB_{2013} < 10% SSB_0)	Pr(SSB_{2013} < 20% SSB_0)	Pr(SSB_{2013} > 52% SSB_0)
M20_both	0.000	0.000	0.975
M18_both	0.000	0.000	0.738
M20_rec	0.000	0.000	0.755

4.1.5 Projections and yield estimates

The base and sensitivity models were projected forward five years, with empirical resampling from the 10-year period, 2000-2009, using the reported 2013 catch. These projections suggest that current stock status is likely to improve further under all three scenarios, with a faster level of increase seen in the less optimistic lower M scenario. The probability of the stock being at or above 52% B_0 in 2018 is 0.945 for the base case.

Table 15: Probability of the KAH 1 stock in 2018 falling below soft and hard limits and being at or above the target reference point. The target reference point of 52% B_0 was set by the Minister of Fisheries for this stock in 2010. Probabilities are calculated from the distribution of MCMC estimates calculated from each model (three chains combined for the base model).

Model	SSB_{2018}/SSB_0	Pr(SSB_{2018} < 10% SSB_0)	Pr(SSB_{2018} < 20% SSB_0)	Pr(SSB_{2018} > 52% SSB_0)
M20_both	0.693 (0.629–0.742)	0.000	0.000	0.940
M18_both	0.596 (0.563–0.648)	0.000	0.000	0.756
M20_rec	0.620 (0.557–0.673)	0.000	0.000	0.755

The deterministic yield corresponding to 52% B_0 from the base case model is 2414 t.

4.1.6 Catch-curve analysis

Annual estimates of total mortality (Z) have also been derived from recreational catch data sampled in East Northland and the Bay of Plenty. They were calculated using a Chapman Robson estimator independently from the stock assessment model (Table 12). These estimates were calculated using a range of assumed ages for full recruitment to demonstrate the sensitivity of the results to this assumption.

Table 16: Estimates of Z derived from recreational catch sampling in KAH 1, by survey year by assumed age at recruitment (from Armiger et al 2014).

Age at												East Northland
recruitment	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
3	0.33	0.33	0.32	0.28	0.24	0.23	0.28	0.24	–	–	0.20	0.21
4	0.34	0.38	0.35	0.31	0.28	0.26	0.32	0.28	–	–	0.23	0.22
5	0.30	0.37	0.39	0.33	0.33	0.32	0.35	0.33	–	–	0.27	0.25
6	0.30	0.40	0.41	0.38	0.36	0.36	0.41	0.34	–	–	0.32	0.28

Age at												Bay of Plenty
recruitment	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
3	0.23	0.25	0.28	0.20	0.27	0.25	0.24	0.24	–	–	0.20	0.23
4	0.26	0.30	0.32	0.23	0.29	0.30	0.27	0.27	–	–	0.23	0.26
5	0.28	0.33	0.34	0.26	0.30	0.30	0.24	0.29	–	–	0.26	0.29
6	0.30	0.36	0.38	0.32	0.30	0.32	0.26	0.29	–	–	0.31	0.31

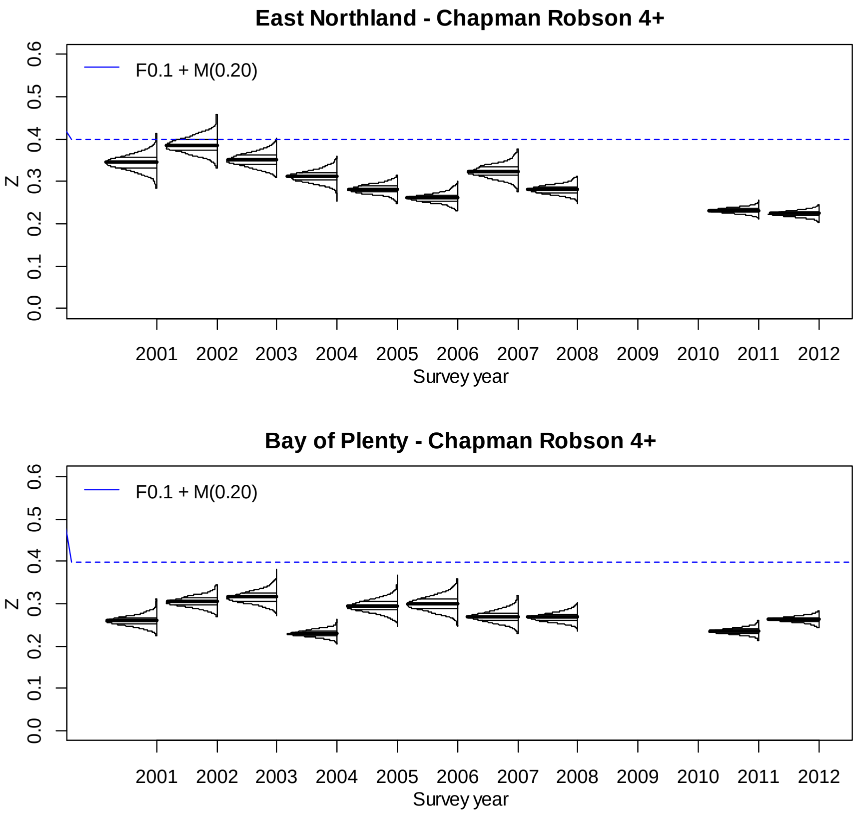


Figure 8: The distribution of bootstrap Chapman Robson estimates of total mortality (*Z*) by survey year for East Northland (top panel) and the Bay of Plenty (lower panel). A theoretical optimal level of *Z* derived from a YPR curved generated from the 2015 assessment is denoted as a horizontal line for reference purposes (adapted from Armiger et al 2014).

4.1.7 Future research needs

- Otoliths from the Hauraki Gulf should be collected in future recreational catch-at-age creel surveys so that they are available for reading if required, as this was not done in 2011 and 2012.
- A spatial model should be considered for the next assessment if there are data to inform it on movements of different age/size classes between sub-areas. This may reduce the patterns in residuals for model fits to recreational catch at age.

5. STATUS OF THE STOCKS

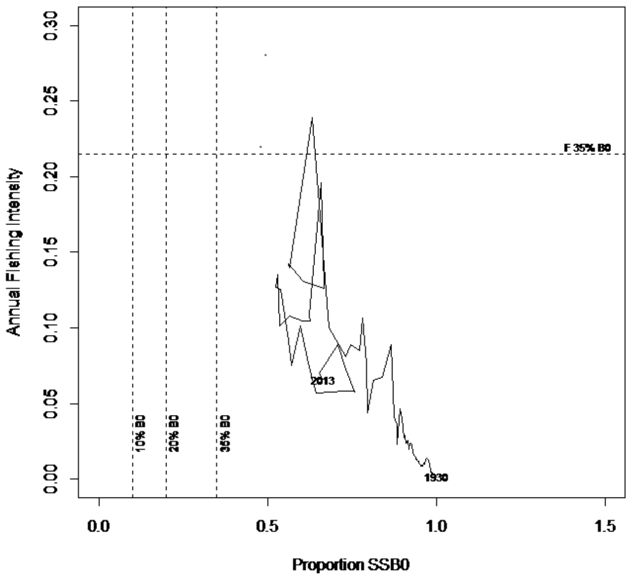
KAH 1

Stock Structure Assumptions
Two stocks of kahawai (*A. trutta*) are assumed to exist within New Zealand waters with centres of concentration around the Bay of Plenty and the northern tip of the South Island. Tagging data show that there is limited mixing between these areas.

Stock Status	
Year of Most Recent Assessment	2015: Age based stock assessment
Assessment Runs Presented	Base case model with M=0.2 and two abundance indices (recreational CPUE and aerial sightings)
Reference Points	Target: 52% B_0 (set by Minister of Fisheries in 2010) Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{35\%B0}$

Status in relation to Target	Very Likely (> 90%) to be at or above
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below. Hard Limit: Exceptionally Unlikely (< 1%) to be below
Status in relation to Overfishing	Overfishing is Very Unlikely (<10%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory of spawning stock biomass relative to B_0 for the base model (M = 0.20, both abundance indices used) and annual fishing intensity. The 52% B_0 target set by the Minister of Fisheries in 2010 is denoted by a black dashed line and the 20% B_0 soft limit and 10% B_0 hard limit are denoted by the grey dashed lines.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Stock biomass has increased in recent years.
Recent Trend in Fishing Mortality or Proxy	Fishing mortality has declined since the early 1990s and is now well below the overfishing threshold.
Other Abundance Indices	None available other than regional set net CPUE indices which are not considered to be reliable because of confusion between set net and ring net effort reporting.
Trends in Other Relevant Indicators or Variables	- A time series of total mortality estimates for East Northland and the Bay of Plenty from 2001 to 2012, based on recreational catch-at-age data, suggests that there has been little change in fishing mortality over this period. Estimates of total mortality were at or below that associated with $F_{0.1}$ suggesting that fishing mortality was at or below F_{MSY}.

Projections and Prognosis	
Stock Projections or Prognosis	The KAH 1 stock is likely to increase over the next five years at 2013 catch levels.
Probability of Current Catch or TAC causing biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of current catch or TAC causing overfishing to continue or to commence	Exceptionally Unlikely (< 1%)

Assessment Methodology		
Assessment Type	Level 1 – Full Quantitative Stock Assessment	
Assessment Method	Statistical catch at age model implemented under CASAL	
Period of Assessment	Latest assessment: 2015	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs	- Proportions-at-age from purse seine, single trawl, set net and recreational fisheries - Unstandardised recreational CPUE index - Estimates of biological parameters (e.g. growth, age-at-maturity, length/weight) - Estimates of recreational harvest - Commercial catch statistics - Aerial SPUE index	1 – High Quality: but set net data were only used to estimate MPD selectivity 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality 2 – Medium or Mixed Quality: only covers western Bay of Plenty
Data not used	- Set net CPUE indices	3 – Low Quality: confusion between set net and ring net fishing reporting
Changes to Model Structure and Assumptions	-Change from grid to age structured base case with MCMC -Change from quasi regional to single stock structure -Dropped set net CPUE -Included age composition for set net catch -Included SPUE -Started model in 1930 at equilibrium instead of 1975 -Changed default M from 0.18 to 0.20	
Major Sources of Uncertainty	- Under-reported commercial catch prior to 1980 - Recreational catch history, especially prior to 1990 - Assumption of constant selectivity and catchability in the abundance indices may compromise their ability to index biomass - Spatial complexity in the movement of different sizes/ages of kahawai - Age composition and selectivity of purse seine unlikely to be consistent from year to year due to kahawai schooling by age/size	

Qualifying Comments
-

Fishery Interactions
Commercial catches of KAH 1 are primarily taken by purse-seine in association with jack mackerel, blue mackerel and trevally.

All other KAH regions

No accepted assessment is available that covers these regions. It is not known if the current catches, allowances or TACCs are sustainable. The status of KAH 2, 3 and 8 relative to B_{MSY} is unknown.

6. FOR FURTHER INFORMATION

Armiger, H; Hartill, B; Tasker, R; Smith, M (2006) Length and age compositions of recreational landings of kahawai in KAH 1 in January to April 2003–04 and 2004–05. Final Research Report for Ministry of Fisheries Research Project KAH2003/01 Objectives 1 & 2. 33 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Armiger, H; Hartill, B; Rush, N; Vaughan, M; Smith, M; Buckthought, D (2009) Length and age compositions of recreational landings of kahawai in KAH 1 in January to April 2008 and KAH 8 in January to April 2007. *New Zealand Fisheries Assessment Report 2009/36*. 40 p.

Armiger, H; Hartill, B; Rush, N; Buckthought, D; Smith, M (2014) Length and age compositions of recreational landings of kahawai in KAH 1 in January to April in 2011 and 2012. *New Zealand Fisheries Assessment Report 2014/60*. 39 p.

Bradford, E (1997) Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993–94. New Zealand Fisheries Assessment Research Document 1997/7. 16 p. (Unpublished report held by NIWA library, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document. 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington.)

Bradford, E; Fisher, D; Bell, J (1998) National recreational fishing survey 1996: overview of catch and effort results. *NIWA Technical Report* 18. 55 p.

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. New Zealand Fisheries Research Report. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 National marine recreational fishing survey: diary results and harvest estimates. New Zealand Fisheries Research Report. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Bull, B; Francis, R I C C; Dunn, A; McKenzie, A; Gilbert, D J; Smith, M H (2004) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manualv2.01.2003/08/01. *NIWA Technical Report* 124. 223 p.

Drummond, K L (1995) Report on investigations into the Central New Zealand kahawai purse seine fishery over the 1992/93 summer. Central Fisheries Region Internal Report 25. 33 p.

Drummond, K L; Wilson, A L (1993) The biology and purse-seine fishery of kahawai (*Arripis trutta* Bloch and Schneider) from central New Zealand, during 1990/91–1991/92. Central Fisheries Region Internal Report 22. 42 p.

Duffy, C A J; Petherick, C (1999) A new size record for kahawai (*Arripis trutta*) from New Zealand. *New Zealand Journal of Marine and Freshwater Research* 33: 565–569.

Francis, R.I.C.C (2011) Data weighting in statistical fisheries stock assessment models. Canadian Journal of fisheries and Aquatic Sciences. 68. 1124–1138.

Francis, M.P.; Paul, L.J. (2013) New Zealand inshore finfish and shellfish commercial landings, 1931-82. *New Zealand Fisheries Assessment Report 2013/55*. 136 p.

Hartill, B (2009). Assessment of the KAH 1 fishery for 2006. *New Zealand Fisheries Assessment Report 2009/24*. 43 p

Hartill, B; Bian, R (In prep) Stock assessment for KAH 1 for 2015. Draft FAR based on unpublished Research Progress Report held by MPI.

Hartill, B; Armiger, H; Tasker, R; Middleton, C; Fisher, D (2007a) Monitoring the length and age composition of recreational landings of kahawai in KAH 1 in 2000–01, 2001–02 and 2002–03. *New Zealand Fisheries Assessment Report 2007/6*. 38 p.

Hartill, B.; Watson, T.; Cryer, M.; Armiger, H. (2007b). Recreational marine harvest estimates of snapper and kahawai in the Hauraki Gulf in 2003-04. *New Zealand Fisheries Assessment Report 2007125.55* p.

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007c) Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004–05. *New Zealand Fisheries Assessment Report 2007/26*. 44 p.

Hartill, B; Smith, M; Rush, N; Vaughan, M; Armiger, H (2007d) Length and age composition of recreational landings of kahawai in KAH 1 from January to April 2005–06. *New Zealand Fisheries Assessment Report 2007/28*. 30 p.

Hartill, B; Walsh, C (2005) Characterisation of kahawai fisheries of New Zealand and a review of biological knowledge. Final Research Report for Ministry of Fisheries Research Project KAH200401. 160 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Hartill, B.; Armiger, H.; Vaughan, M.; Rush, N.; Smith, M. (2008). Length and age compositions of recreational landings of kahawai in KAH 1 from January to April 2007. New Zealand Fisheries Assessment Report 2008/63. 40 p.

Hartill, B.; Bian, R.; Rush, N.; Armiger, H. (2013). Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. *New Zealand Fisheries Assessment Report 2013/70*. 44 p.

Jones, J B; Cresswell, P; Drummond, K; McKenzie, J (1992) Kahawai. New Zealand Fisheries Assessment Research Document 1992/2. 27 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Kimura, D K (1980) Likelihood methods for the von Bertalanffy growth curve. *Fishery Bulletin* 77: 765–776.

Morton, A; Lyle, J; Welsford, D (2005) Biology and status of key recreational finfish species in Tasmania. *Tasmanian Aquaculture and Fisheries Institute Technical Report Series* 25. 52 p.

Paulin, C (1993) Review of Australasian fish family Arripididae (Percomorpha), with the description of a new species. *Australian journal of marine and freshwater research* 44: 459–471.

Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: weighting methodology for harvest estimates. Draft report by Statistical Insights Ltd. 25 p.

Smith, P J; Hartill, B; Hamer, P; McKenzie, A (2008) Stock structure of kahawai, *Arripis trutta*. *New Zealand Fisheries Assessment Report 2008/20*. 42 p.

Stevens, D W; Kalish, J (1998) Validated age and growth of kahawai (*Arripis trutta*) in the Bay of Plenty and Tasman Bay. *NIWA Technical Report* 11. 33 p.

Sylvester, C T A (1989) Kahawai fishery assessment 1989. New Zealand Fisheries Assessment Research Document 1989/10. 17 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Taylor, P R (Draft) Developing indices of relative abundance from observational aerial sightings of inshore pelagic finfish; step 1, exploring the data. Draft New Zealand Fisheries Assessment Report. 66 p.

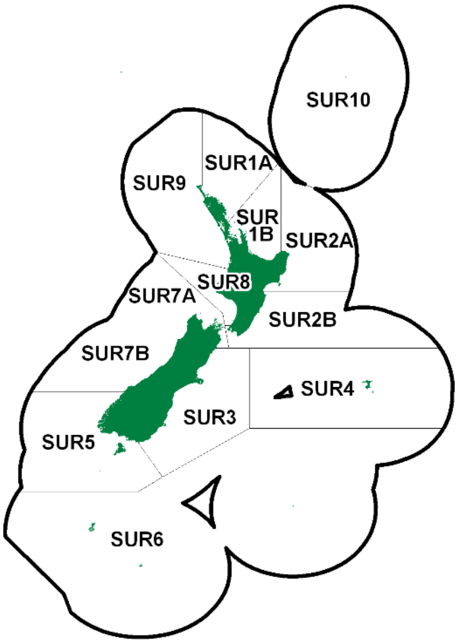
Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Watkinson, J G; Smith, R (1972) *New Zealand Fisheries*. New Zealand Government Print. 91 p.

Wynne-Jones, J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011–12: Harvest estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

KINA (SUR)

(*Evechinus chloroticus*)
Kina



1. FISHERY SUMMARY

South Island kina was introduced into the Quota Management System in October 2002. North Island kina was introduced into the Quota Management System from October 2003. Five Quota Management Areas based on the FMAs 3, 4, 5, 7A (Marlborough Sounds) and 7B (west coast) were created in the South Island, and current allowances, TACCs, and TACs are summarised in Table 1. Seven Quota Management Areas based on the FMAs 1A (Auckland-North), 1B (Auckland-South), 2A (Central (East-North)), 2B (Central (East-South)), 8, 9 and 10 were created in the North Island, and the current allowances, TACCs and TACs are summarised in Table 2. The historical landings and TACC values for the main SUR stocks are depicted in Figure 1.

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs (t) for kina Fishstocks 3, 4, 5, and 7 for the latest fishing year.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other Mortality Allowance	TACC	TAC
SUR 3	10	10	1	21	42
SUR 4	7	20	3	225	255
SUR 5	10	10	5	455	480
SUR 7A	20	80	3	135	238
SUR 7B	5	10	1	10	26

Table 2: Recreational and customary non-commercial allowances, TACCs and TACs (t) for kina Fishstocks 1,2,8,9 and 10 for the latest fishing year.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other Mortality Allowance	TACC	TAC
SUR 1A	65	65	2	40	172
SUR 1B	90	90	4	140	324
SUR 2A	60	60	4	80	204
SUR 2B	35	35	2	30	102
SUR 8	12	12	1	1	26
SUR 9	11	11	1	10	33
SUR 10	0	0	0	0	0

1.1 Commercial fisheries

Most kina are found in waters less than 10 m deep and are harvested by breath-hold diving, although about 10% of the total catch in 1998–99 was by taken by dredge in SUR 7. Some target dredging also occurs in SUR 7. There is no minimum legal size for kina. Almost all of the roe harvested in this fishery is consumed on the domestic market. In 1988–89, competitive TACCs were established in the more important FMAs but not in east Northland (SUR 1) or at the Chatham Islands (SUR 4), both of which developed into productive fisheries in the 1990s (Table 3). On 1 October 1992 the Ministry of Fisheries placed a moratorium on the issue of permits to commercially harvest kina. The kina fishery has evolved considerably since the imposition of the moratorium. Where present, the competitive TACCs were either not caught or were exceeded, both by wide margins. Much of the increase in catch observed in SUR 5 in the early 1990s can be attributed to an experimental fishery developed in SUR 5, between Puysegur Point and Breaksea Island. The short-lived Kina Development Programme harvested kina from Dusky Sound in 1993 under special permit.

Table 3: Total reported catch (t greenweight) of kina (SUR) by FMA and fishing year by all methods and target species.

Year	SUR 1	SUR 1A	SUR 1B	SUR 2	SUR 2A	SUR 2B	SUR 3	SUR 4	SUR 5	SUR 6, 8, & 9	SUR 7	SUR 7A	SUR 7B	Total
1983	66.2	-	-	33.0	-	-	4.8	11.3	0.5	3.6	26.3	-	-	157
1984	81.4	-	-	180.3	-	-	14.4	4.0	0.9	0.3	55.1	-	-	342
1985	64.5	-	-	83.8	-	-	4.0	7.4	4.6	0.9	99.6	-	-	275
1986	72.0	-	-	139.1	-	-	6.2	52.7	0.2	2	86.6	-	-	360
1987	52.1	-	-	142.6	-	-	2.4	28.4	4.3	0.1	52.6	-	-	283
1988	22.1	-	-	154.1	-	-	1.7	76.5	2.3	-	175.6	-	-	432
1989	35.5	-	-	92.8	-	-	0.8	216.6	19	1.5	6.2	-	-	372
1990	10.0	-	-	282.4	-	-	4.1	190.0	13.4	6.5	41.5	-	-	548
1991	71.5	-	-	87.2	-	-	21.3	35.3	166.9	4.4	56.3	-	-	443
1992	78.7	-	-	37.3	-	-	15.8	192.9	272.2	5	114.4	-	-	717
1993	89.7	-	-	170.4	-	-	9.9	21.8	*530.3	-	210.2	-	-	1 032
1994	150.7	-	-	176.7	-	-	8.8	55.3	327.2	2.3	98.2	-	-	820
1995	155.9	-	-	129.7	-	-	7.1	100.7	342.9	89.5	149	-	-	975
1996	174.5	-	-	41.2	-	-	6.0	99.5	446.4	0.1	142.2	-	-	910
1997	161.6	-	-	49.9	-	-	5.4	225.7	171.6	0.2	121.7	-	-	736
1998	134.8	-	-	36.5	-	-	3.8	303.1	91.2	1.4	144.7	-	-	716
1999	201.4	-	-	20.2	-	-	38.4	168.2	120.6	0.5	113.9	-	-	663
2000	297.4	-	-	14.5	-	-	50.4	396.5	106.3	0.1	87.9	-	-	956
2001	184.5	-	-	11.4	-	-	11.2	472.6	69.8	3.1	80.1	-	-	832
2001–02	237.0	-	-	3.0	-	-	5.2	368.0	184.9	-	31.7	-	-	829.7
2002–03	211.2	-	-	30.4	-	-	0.3	167.3	132.5	0.9	1.3	63.2	0	607.4
2003–04	1.7	26.9	111.0	0	14.5	4.6	0.3	114.8	199.1	3.8	0	85.4	0	562.3
2004–05	-	20.9	131.1	-	6.5	1.4	0.5	91.7	350.4	0.9	-	101.3	-	704.7
2005–06	-	41.0	138.6	-	22.1	0.2	< 0.1	70.2	473	4.0	-	72.1	5.3	826.5
2006–07	-	37.1	147.3	-	13.8	< 0.1	3.2	108.3	423	8.6	-	117.3	9.2	868
2007–08	-	31.7	140.4	-	18.0	0.2	2.1	147.4	276.2	5.8	-	134.6	6.5	762.9
2008–09	-	30.5	130.6	-	19.8	< 0.1	4.2	135.6	294.9	3.4	-	128.7	6.1	753.8
2009–10	-	40.8	129.9	-	0.1	0.3	5.1	89.7	320.4	2.3	-	119.7	3.5	711.9
2010–11	-	31.7	122.1	-	4.1	< 0.1	5.2	134.9	339.2	0	-	97.4	7.2	741.9
2011–12	-	37.9	134.2	-	5.9	1.1	4.3	137.7	402	0	-	131.6	6	862.1
2012–13	-	38.7	145.4	-	10.6	0	4.8	76.2	474.8	4	-	115.5	5	875
2013-14	-	43.4	139.3	-	10.1	3.8	0.4	101.2	462.8	9.1	-	126.3	0	896

Data from 1989 and 1990 are combined from the FSU and CELR databases. – indicates no recorded catch. Data for the period 1983 to 1999 are from Andrew (2001), and have been groomed. Catch estimates for 2000 and 2001 are taken directly from MFish. * includes 133 t caught in Dusky Sound experimental fishery. Catches from SUR 6, 8, and 9 have been pooled because too few permit holders recorded catches in these FMAs to report them singly.

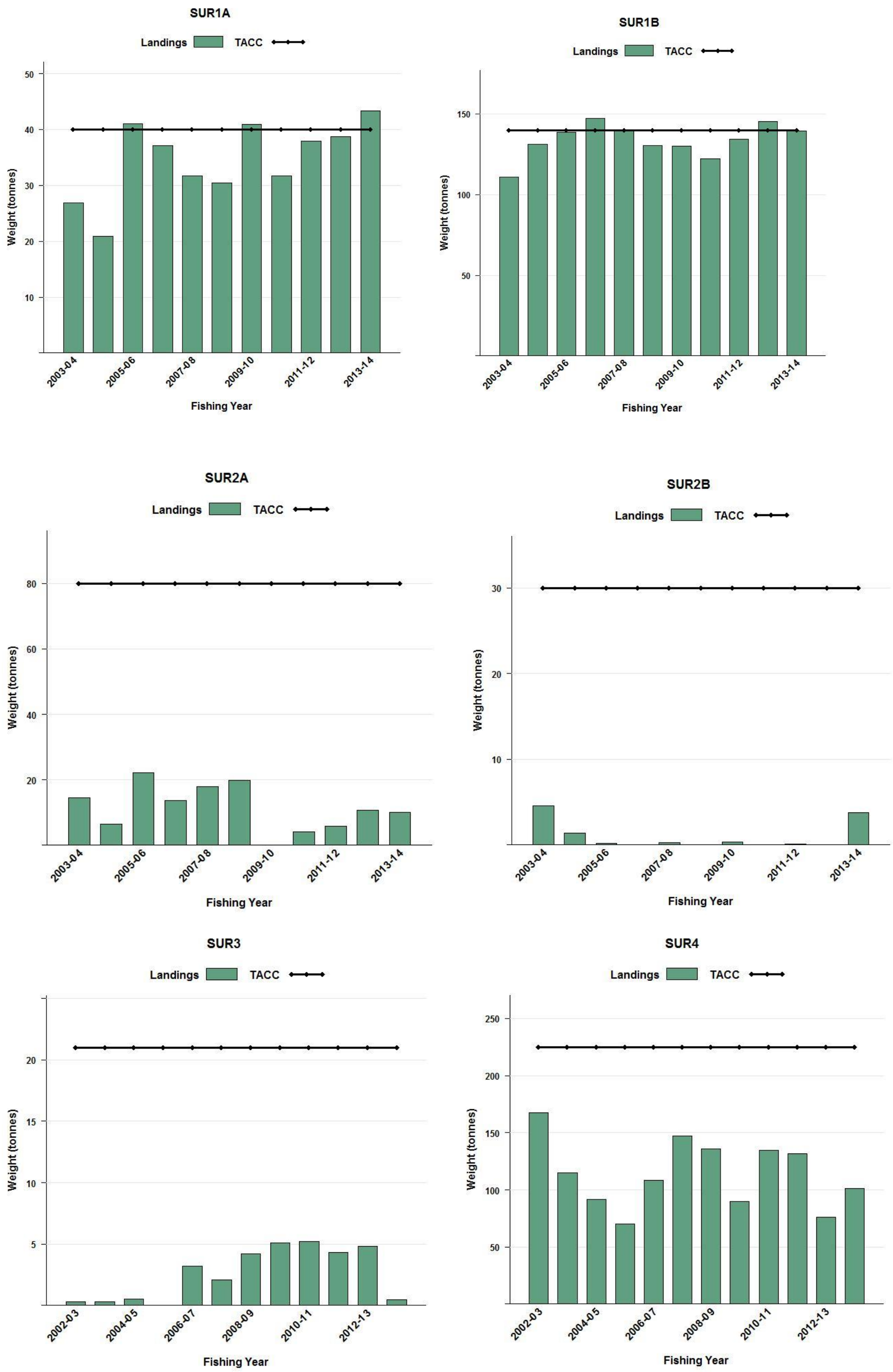


Figure 1: Reported commercial landings and TACC for the nine main SUR stocks. From top left to bottom right: SUR 1A (Northland) and SUR 1B (Hauraki Gulf, Bay of Plenty). 2A (East Coast), SUR 2B (Wairarapa, Wellington), SUR 3 (South East Coast), SUR 4 (South East Chatham Rise). [Continued on next page]. Note that these figures do not show data prior to entry into the QMS.

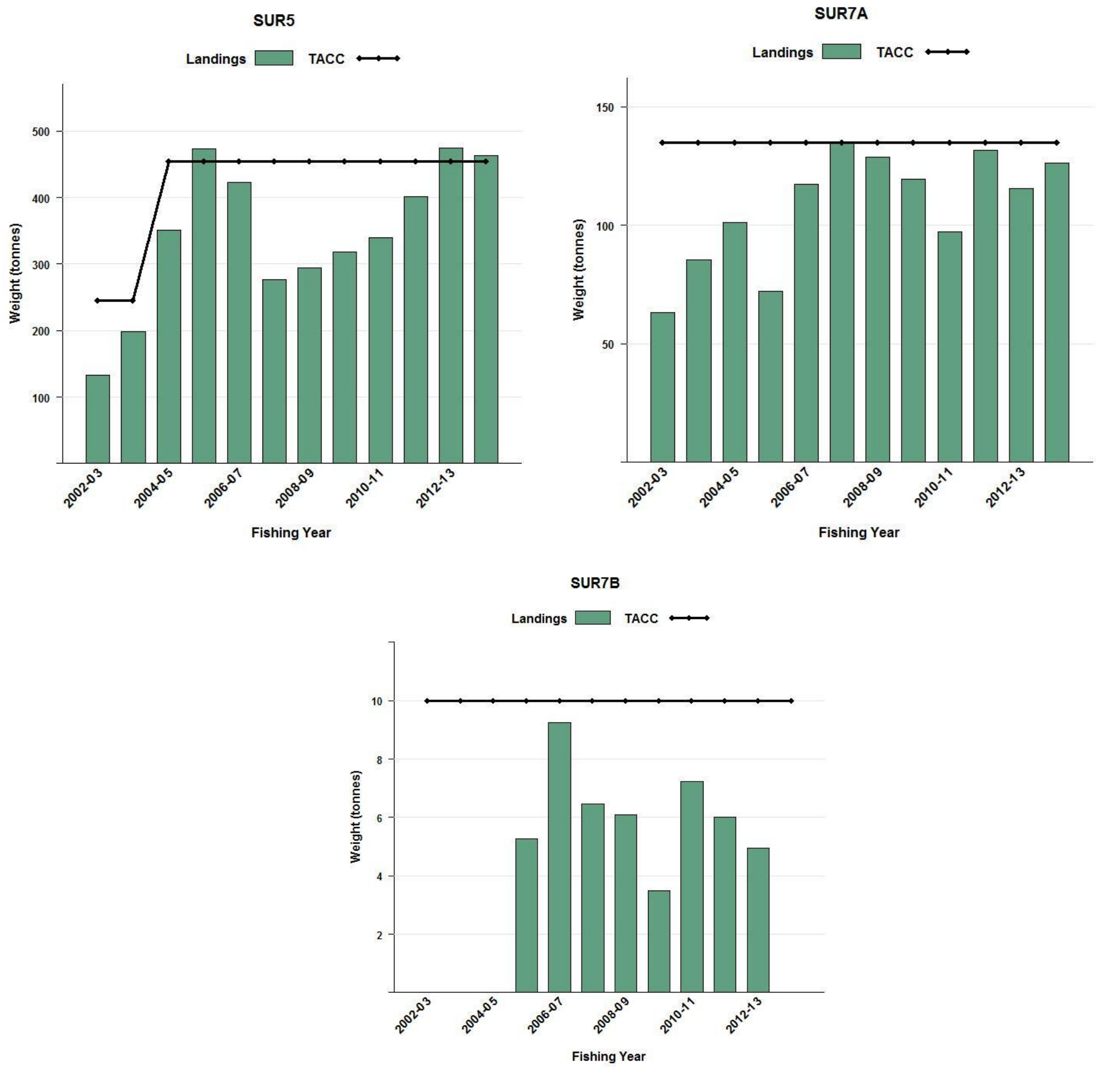


Figure 1 [Continued]: Reported commercial landings and TACC for the nine main SUR stocks. From top left: SUR 5 (Southland), and SUR 7A (Challenger Nelson Marlborough) and SUR 7B (Challenger Westland). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

Recreational catch was estimated in a national survey in 1996 (Fisher & Bradford 1998, Bradford 1998) and 2000 (Boyd & Reilly 2002, Boyd et al 2004) (Table 4). There are no estimates of recreational catch from the Chatham Islands. In many instances, insufficient kina were caught to provide reliable estimates of the error associated with the estimates of total harvest. The recreational harvest estimates for 1996 are not considered reliable as estimates of total harvest but provide relative estimates between areas. The harvest estimates for 2000 are considered to be more reliable as absolute estimates with the exception of SUR 2.

1.3 Customary non-commercial fisheries

There is an important customary non-commercial harvest of kina by Maori for food. Where data are available, only small catches of kina have been reported under the customary non-commercial harvest provisions of the Fisheries Act 1996. In SUR 3, 5, and 7, all catches were less than 1 t per year (Table 5). These catch estimates are probably under-estimates as an unknown proportion of the kina harvested by Maori is caught outside of Taiapure or Mataitai and not recorded as customary non-commercial harvest (P. Grimshaw, Ngai Tahu Development Corporation, pers. comm.). No data are available for other regions of New Zealand (S. Kerins, Te Ohu Kai Moana, pers. comm.).

Table 4: Recreational harvest of kina for 1993–94 and 1996.

Area	Number of kina (× 1 000)	CV (%)	Catch (t)*
1993–94			
East Northland	109	60	27.1
Hauraki Gulf	14	-	3.5
Bay of Plenty	648	49	160.9
SUR 1	801	41	198.9
SUR 9	30	72	7.4
1996			
SUR 1	316	24	78.5
SUR 2	61	-	15.1
SUR 3	12	-	3.0
SUR 5	20	-	5.0
SUR 7	2	-	0.5
SUR 8	43	-	10.7
SUR 9	30	-	7.4
2000			
SUR 1	1 793	35	445.2
SUR 2	1 026	57	254.7
SUR 3	8	58	2.0
SUR 5	70	101	17.4
SUR 7	2	101	0.5
SUR 8	85	85	21.1
SUR 9	82	67	20.4

CVs are indicated only for those samples with adequate sample sizes. Data compiled from Bradford (1998) and Fisher & Bradford (1998).

Catches in numbers have been converted to catch in tonnes by assuming an average whole weight of 248.3 g per kina. In the absence of size-specific catch statistics, a parsimonious conversion assumes that kina are caught in equal proportion across a size range of 60 to 110 mm TD. The lower size in this range is approximately the size-at-maturity (see Barker 2001) and the upper size is close to maximum harvested size. Weight-at-size was calculated using a test diameter-weight relationship ($W = (6.27\times10^{-4})TD^{2.88}$) derived for kina of 60–110 mm TD from Dusky Sound (*n* = 1063, unpublished data). The estimates of total catch in tonnes should be considered as indicative only.

Table 5: Reported customary catch by FMA for SUR 3, 5, and 7.

Year	SUR	Count	Weight (kg)
1998–99	3	100	25
	5	1 522	433
	7	0	0
1999–2000	3	0	0
	5	1 631	405
	7	0	0

Data as numbers caught supplied by Ngai Tahu Development Corporation. Catch in kilograms was estimated using the conversion rules described in the paragraph above.

1.4 Illegal catch
Current levels of illegal harvest are not known.

1.5 Other sources of mortality
Although there is no minimum legal size for kina, some incidental mortality is likely because roe quality (recovery rate and colour) is commonly assessed by opening 'test' kina underwater. These animals are not subsequently landed. There are no estimates of the magnitude to this incidental mortality.

2. BIOLOGY

The biology and ecology of kina has been extensively studied; this literature has most recently been reviewed by Barker (2001). *Evechinus chloroticus* is found throughout New Zealand and the sub-Antarctic Islands. Kina has an annual reproductive cycle which culminates in spawning between November and March (Dix 1970, Walker 1984, McShane et al 1994 & 1996, Lamare & Stewart 1998, Lamare 1998). Size at maturity appears to vary considerably and may be as small as 30 mm and as large as 75 mm TD (Dix 1970, Barker et al 1998). In Dusky Sound, kina are reproductively mature at 50–60 mm T.D. (McShane et al 1996). Within these seemingly consistent patterns in the seasonality of the reproductive cycle there are many differences in the gonad size at small spatial scales.

Settlement is likely to be vary between years and appears to differ among locations and habitats (Dix 1972, Walker 1984). Laboratory work has shown that kina larval mortality increased with increasing concentrations of suspended sediment at realistic concentrations (Phillips & Shima 2006). In the field, but not in the laboratory, development abnormalities were found associated with suspended sediment concentrations, this suggests the importance of other environmental factors associated with terrestrial runoff (Schwarz et al 2006). Juvenile settlement and mortality has also been observed to increase with sediment at realistic concentrations in a size-specific manner in the laboratory; this agrees with juvenile patterns of distribution observed in the field (Walker 2007). Few small kina were observed in any of the surveys in Dusky Sound (McShane et al 1993). These results suggest that the productivity of stocks in Fiordland may be low and that recruitment over-fishing is a real possibility.

There is relatively little information available on the interactions between kina and its predators and competitors. Although a wide range of fish and invertebrates eat kina, there is limited evidence that these species control or limit populations of kina in Fiordland. Work in a marine reserve, where large predators such as reef fishes and crayfish are abundant, indicates that predators can control numbers of kina surviving the transition from crevice-bound to open substratum grazing (Cole & Keuskamp 1998, Babcock et al 1999). Babcock et al (1999) have drawn a direct link between the increases in snapper and crayfish populations and the long-term decline in kina populations in the Leigh Marine Reserve. There is however, no evidence that high kina densities limit rock lobster populations (Andrew & MacDiarmid 1991). It is likely, however, that changes in the abundance of kina, and the consequent changes in habitat representation, are part of a complex set of interacting processes, including but not exclusively, increased predation.

Kina compete with a range of invertebrate herbivores, including paua. There is no published evidence that high densities of kina limit paua populations in Fiordland. McShane (1997) reported that paua are abundant in Dusky Sound, and in Chalky and Preservation Inlets, but are rare in the fjords.

Lamare & Mladenov (2000) estimate that kina grow 8–10 mm in their first year of life. Growth rates will vary considerably depending on local conditions but kina may take 8–9 years to reach 100 mm TD, and very large individuals may reach ages of more than 20 years (Lamare & Mladenov 2000).

3. STOCKS AND AREAS

There appear to be few genetic differences in kina populations from Leigh (North Auckland) and Stewart Island (Mladenov et al 1997) which suggests that there is at least some mixing among populations. There is no direct evidence that populations of kina at the Chatham Islands differ genetically from those on the mainland, nor is there evidence that “populations” of kina at the Chatham Islands are dependent on the dispersal of larvae from the mainland.

4. STOCK ASSESSMENT

Although there is a wealth of information on the biology and ecology of this species (see Barker 2001 for reviews), there is relatively little that can be used to assess the status of exploited stocks. There have been no assessments of sustainable yield nor are there estimates of biomass or trends in relative abundance for any Fishstock (Annala 1995).

4.1 Estimates of fishery parameters and abundance

Andrew (2001) reported catch rates from both dive and dredge fisheries but advised caution in the interpretation of catch rate information of sedentary invertebrates, like kina, gathered at broad spatial scales.

Indices of relative abundance using timed swims have been reported for Ariel Reef in SUR 2 (Anderson & Stewart 1993), Chatham Islands (Schiel et al 1995, Naylor & Andrew 2002), and D’Urville Island and Arapawa Island in SUR 7 (McShane et al 1994a). Numerous surveys of kina have been done over the last 30 years in fished areas, mostly by university-based researchers (e.g. Dix 1970, Choat & Schiel 1982, Schiel et al 1995, Cole & Keuskamp 1998, Babcock et al 1999, Wing et al 2001). Naylor & Andrew (2002) reported a range of densities for kina around Chatham Island from 0.17/m^2 (northwest Chatham Island) to 1.6/m^2 (south east Chatham Island). These were generally lower than estimates made in the mid 1990s by Schiel et al (1995) (0.2/m^2 to 6/m^2). By contrast, even lower kina densities of around 0.1/m^2 were reported by McShane et al (1994a) for both Arapawa and D'Urville Island. Dix (1970) reported much higher mean relatively high densities of kina ranging from 2.2/m^2 in Queen Charlotte Sound to 6/m^2 at Kaikoura.

4.2 Biomass estimates

McShane & Naylor (1993) reported biomass estimates of 2500 and 500 t respectively for D'Urville and Arapawa Islands (SUR 7), presumably based on an expansion of density estimates reported in McShane et al (1994) by an area estimate, however, the methods are not detailed.

Biomass was estimated for Dusky Sound and Chalky Inlet (SUR 5) prior to Dusky Sound being opened as an experimental fishery in May 1993 (McShane & Naylor 1991, 1993). Productivity and biomass was to be estimated by depletion methods but this was unsuccessful because only 133 t of the projected 1000 t was caught (McShane et al 1994b) and this catch was insufficient to cause a measurable change in the estimated biomass of kina.

4.3 Yield estimates and projections

MCY has not been estimated for any SUR fishstock. Within SUR 5, an *MCY* estimate of sustainable yield within Dusky Sound and Chalky Inlet was reported in Annala (1995). This estimate used Method 1 of Annala (1995) for new fisheries based on surveys done by McShane & Naylor (1991, 1993) and an estimate of a reference fishing mortality derived from McShane et al (1994a). The estimated annual sustainable yield of 275 t for these two areas has never been harvested because they are closed to commercial fishing except under special permit.

CAY has not been estimated for any SUR fishstock.

5. STATUS OF THE STOCKS

For all Fishstocks it is not known if current catch levels or TACCs are sustainable, or if they are at levels which will allow the stocks to move towards a size that will support sustainable yields.

6. FOR FURTHER INFORMATION

Anderson, O; Stewart, R (1993) Gisborne kina survey. (Unpublished report held in the NIWA library, Wellington.) 2 p.

Andrew, N L (1986) The interaction between diet and density in influencing reproductive output in the echinoid *Evechinus chloroticus* (Val.). *Journal of Experimental Marine Biology and Ecology* 97: 63–79.

Andrew, N L (2001) Sea urchin fisheries: their status and management with special reference to the New Zealand kina fishery. (Unpublished report to the Ministry of Fisheries and Te Ohu Kai Moana , held by Ministry for Primary Industries, Wellington) 124 p.

Andrew, N L; Choat, J H (1985) Habitat related differences in the survivorship and growth of juvenile sea urchins. *Marine Ecology Progress Series* 27: 155–161.

Andrew, N L; MacDiarmid, A B (1991) Interrelations among sea urchins (*Evechinus chloroticus*) and spiny lobsters (*Jasus edwardsii*) in northern New Zealand. *Marine Ecology Progress Series* 70: 211–222.

Annala, J H (1995) Report from the Fishery Assessment Plenary, May 1995. Stock assessments and yield estimates. 277 p.

Babcock, R C; Kelly, S; Shears, N T; Walker, J W; Willis, T J (1999) Changes in community structure in temperate marine reserves. *Marine Ecology Progress Series* 189: 125–134.

Barker, M F (2001) The ecology of Evechinus chloroticus. In: Lawrence, J. (ed.). Edible Sea Urchins: Biology and Ecology. Elsevier Science, Amsterdam. 245–260 p.

Barker, M F; Keogh, J A; Lawrence, J M; Lawrence, A L (1998) Feeding rate, absorption efficiencies, growth, and enhancement of gonad production in the New Zealand sea urchin *Evechinus chloroticus* Valenciennes (Echinoidea: Echinometridae) fed prepared and natural diets. *Journal of Shellfish Research* 17: 1583-1590.

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 national marine recreational fishing survey: diary results and harvest estimates. Final Research Report for Ministry of Fisheries Project REC2000/03 (Unpublished report held by Ministry for Primary Industries, Wellington.)

Boyd, R O; Reilly, J L (2002) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries project REC98/03. 28 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bradford, E (1998) Harvest estimated from the 1996 national marine recreational surveys. New Zealand Fisheries Assessment Research Document 1998/16: 27p. (Unpublished report held by NIWA library, Wellington.)

Brewin, P E; Lamare, M D; Keogh, J A; Mladenov, P V (2000) Reproductive variability over a four-year period in the sea urchin *Evechinus chloroticus* (Echinoidea: Echinodermata) from differing habitats in New Zealand. *Marine Biology* 137: 543–557.

Choat, J H; Schiel, D R (1982) Patterns of distribution and abundance of large brown algae and invertebrate herbivores in subtidal regions of northern New Zealand. *Journal of Experimental Marine Biology and Ecology* 60: 129–162.

Cole, R G; Keuskamp, D (1998) Indirect effects of protection from exploitation: patterns from populations of *Evechinus chloroticus* (Echinoidea) in northeastern New Zealand. *Marine Ecology Progress Series* 173: 215–226.

Dix, T G (1970) Biology of *Evechinus chloroticus* (Echinodermata: Echinometridae) from different localities. 3. Reproduction. *New Zealand Journal of Marine and Freshwater Research* 4: 385–405.

Dix, T (1972). Biology of Evechinus chloroticus (Echinoidea: Echinometridae) from different localities.4. Age, growth, and size. *New Zealand Journal of Marine and Freshwater Research* 6: 48–68.

Fisher, D; Bradford, E (1998) National marine recreational fishing survey 1996: catch and effort results by fishing zone. Final Research Report for Ministry of Fisheries Research Project REC9701. 38 p. (Unpublished report held by Ministry for Primary Industries, Wellington).

Lamare, M (1998). Origin and transport of larvae of the sea urchin *Evechinus chloroticus* (Echinodermata: Echinoidea) in a New Zealand fiord. *Marine Ecology Progress Series* 174: 107–121.

Lamare, M; Stewart, B (1998) Mass spawning by the sea urchin *Evechinus chloroticus* (Echinodermata: Echinoidea) in a New Zealand fiord. *Marine Biology 132*(1): 135–140.

Lamare, M D; Mladenov, P V (2000) Modelling somatic growth in the sea urchin *Evechinus chloroticus* (Echinoidea: Echinometridae). *Journal of Experimental Marine Biology and Ecology* 243: 17-43.

MacDiarmid, A B; Breen, P A (1993) Spiny lobster population changes in a marine reserve. *In:* Battershill, C N; Schiel, D R; Jones, G P; Creese, R G; MacDiarmid, A B (eds.). Proceedings of the Second International Temperate Reef Symposium. 47–56. NIWA Marine, Wellington.

McShane, P E (1992) Sea urchins in Dusky Sound-Prospects for a major kina industry in New Zealand. *New Zealand Professional Fisherman* December 92: 34–40.

McShane, P E (1997) A summary of commercial catch data and biological information for kina (Evechinus chloroticus). New Zealand Fisheries Assessment Research Document. 1997/16: 7 p. (Unpublished report held by Ministry for Primary Industries, Wellington).

McShane, P E; Anderson, O F; Gerring, P K; Stewart, R A; Naylor, J R (1994a) Fisheries biology of kina (*Evechinus chloroticus*). New Zealand Fisheries Assessment Research Document. 1994/17: 34 p. (Unpublished report held by Ministry for Primary Industries, Wellington).

McShane, P E; Naylor, J R (1991) A survey of kina populations (*Evechinus chloroticus*) in Dusky Sound and Chalky Inlet, southwest New Zealand. (Unpublished report held in the NIWA library, Wellington.) 34 p.

McShane, P E; Naylor, J R (1993) SUR 7 - Prospects for development of a kina fishery. *Seafood New Zealand* 1: 33–34.

McShane, P; Naylor, J; Anderson, O; Gerring, P; Stewart, R (1993). Pre-fishing surveys of kina (*Evechinus chloroticus*) in Dusky Sound, Southwest New Zealand. *New Zealand Fisheries Assessment Research Document 93/11*. 27 p. (Unpublished report held in NIWA library, Wellington.)

McShane, P; Gerring, P; Anderson, O; Stewart, R (1996). Population differences in the reproductive biology of Evechinus chloroticus (Echinoidea: Echinometridae). *New Zealand Journal of Marine and Freshwater Research 30*: 333–339.McShane, P E; Stewart, R; Anderson, O; Gerring, P K (1994b) Failure of kina fishery leaves bitter taste. *Seafood New Zealand* 2: 35–36.

Mead, S (1996) Fertilization success, sustainable management and commercial development of the New Zealand sea urchin, *Evechinus chloroticus*. Unpublished M.Sc. Thesis, University of Auckland.

Mladenov, P V; Allibone, R M; Wallis, G P (1997) Genetic differentiation in the New Zealand sea urchin *Evechinus chloroticus* (Echinodermata: Echinoidea). *New Zealand Journal of Marine and Freshwater Research* 31: 261–269.

Naylor, R.; Andrew, N. (2002). Relative abundance and size frequency of kina (*Evechinus chloroticus*) in the Chatham Islands in the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2002/35*. 8 p.

Phillips, N E; Shima, J (2006) Differential effects of suspended sediments on larval survival and settlement of New Zealand urchins *Evechinus chloroticus* and abalone *Haliotis iris*. *Marine Ecology Progress Series* 314: 149–158.

Schiel, D R (1990) Macroalgal assemblages in New Zealand: structure, interactions and demography. *Hydrobiologia* 192: 59-76.

Schiel, D R; Andrew, N L; Foster, M S (1995) The structure of subtidal algal and invertebrate assemblages at the Chatham Islands, New Zealand. *Marine Biology* 123: 355–367.

Schwarz, A; Cole, R; Budd, R; Taylor, R; Hewitt, J; Hunt, L; Shima, J; Phillips, N (2006) Impacts of terrestrial runoff on the biodiversity of rocky reefs. *New Zealand Aquatic Environment Biodiversity Report* 7 109 p.

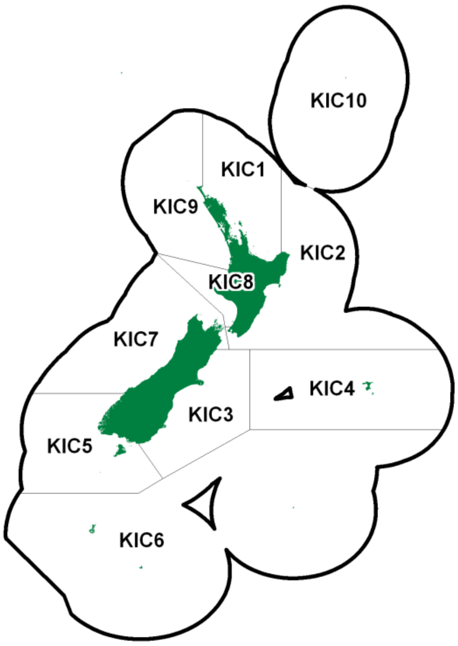
Walker, M (1984) Larval life span, larval settlement, and early growth of *Evechinus chloroticus*(Valenciennes). *New Zealand Journal of Marine and Freshwater Research* 18: 393–397.

Walker, J (2007) Effects of fine sediments on settlement and survival of the sea urchin *Evechinus chloroticus* in northeastern New Zealand. *Marine Ecology Progress Series* 331: 109–118.

Wing, S R; Lamare, M D; Vasques, J (2001) Population structure of sea urchins (*Evechinus chloroticus*) along gradients in benthic productivity in the New Zealand fjords. In: Barker, M F (ed.). Proceedings of the 10th International Echinoderm Conference. University of Otago, Dunedin. A.A. Balkema, Rotterdam. Pp 569–576.

KING CRAB (KIC)

(*Lithodes aotearoa, Neolithodes brodiei*)



Lithodes aotearoa

Neolithodes brodiei

1. FISHERY SUMMARY

1.1 Commercial fisheries

King crabs (*Lithodes aoteroa* and *Neolithodes brodiei*) were introduced into the Quota Management System on 1 April 2004 with a combined TAC of 9 t and TACC 9 t (Table 1). There are no allowances for customary, recreational or other sources of mortality. The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight. The two crabs are relatively distinct, and are found at different depths, but may be confused with other species of *Lithodes*.

Landings have been reported from all QMAs except KIC 7 and KIC 9, however these landings are small and are unlikely to reflect the real catch as these crabs are generally discarded at sea and remain unreported. Most of the landed catch has been reported under the aggregated code KIC, although there are a few records by species (i.e., *L. aotearoa* [LMU] and *N. brodiei* [NEB]).

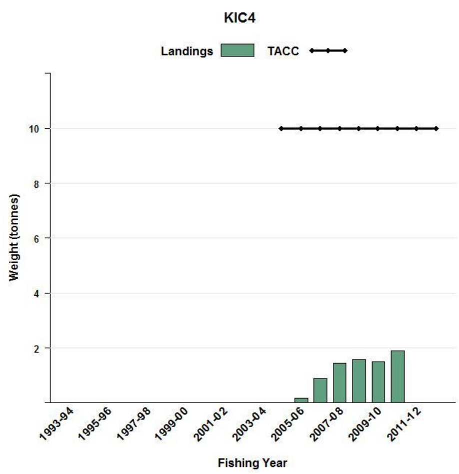


Figure 1: Reported commercial landings and TACC for KIC 4 (South East Chatham Rise). Note that this figure does not show data prior to entry into the QMS.

Most of the reported landings since 1992–93 are from KIC 6, and most of this was landed in the 1996–97 fishing year under a special permit. Between 2000 and 2002 landings were also made under a special permit (Table 1). Target fishing is by potting, although the crabs are taken as bycatch in the orange roughy fishery off the Wairarapa coast and in Queen Scallop dredging off the Otago coast. Figure 1 shows the historical landings and TACC for KIC 4.

1.2 Recreational fisheries
There are no records of recreational use of these crabs, and because of their depth range recreational catch is unlikely.

1.3 Customary non-commercial fisheries
There are no known records of customary use of these crabs, and because of their depth range customary take is unlikely.

1.4 Illegal catch
There is no known illegal catch of these crabs.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although the crabs are sometimes taken as a bycatch in orange roughy fishing and queen scallop fishing.

Table 1: TACCs and reported landings (t) of king crab by Fishstock from 1992–93 to 2013–14 from CELR and CLR data. [Continued on next page].

	KIC 1		KIC 2		KIC 3		KIC 4		KIC 5	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1993–94	0	-	0.119	-	0.064	-	0	-	0	-
1994–95	0	-	0	-	0	-	0	-	0	-
1995–96	0	-	0	-	0.055	-	0	-	0	-
1996–97	0	-	0.08	-	0	-	0	-	0	-
1997–98	0	-	0	-	0	-	0	-	0	-
1998–99	0	-	0	-	0	-	0	-	0	-
1999–00	0	-	0	-	0.021	-	0	-	0	-
2000–01	0	-	0	-	0	-	0	-	0	-
2001–02	0.135	-	0.26	-	0	-	0	-	0	-
2002–03	0.01	-	0.005	-	0	-	0	-	0.032	-
2003–04	0	10	0	10	0.009	10	0.012	10	0	10
2004–05	0	10	0.073	10	0.133	10	0.025	10	0.013	10
2005–06	0	10	0.211	10	0.118	10	0.181	10	0.028	10
2006–07	0	10	0.041	10	0.24	10	0.896	10	0.126	10
2007–08	0.078	10	0.408	10	0.206	10	1.455	10	0.068	10
2008–09	0.010	10	0.185	10	0.244	10	1.566	10	0.073	10
2009–10	0	10	.197	10	0.352	10	1.493	10	0.030	10
2010–11	0.018	10	0.183	10	0.253	10	1.898	10	0.143	10
2011–12	0	10	2.476	10	0.066	10	0.016	10	0.037	10
2012-13	0	10	3.758	10	0.125	10	0.018	10	.107	10
2013-14	0.001	10	10.31	10	0.105	10	0.119	10	0.331	10

	KIC 6		KIC 7		KIC 8		KIC 9		KIC ET	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1993–94	0	-	0	-	0	-	0	-	0	-
1994–95	0	-	0	-	0	-	0	-	0	-
1995–96	0	-	0	-	0	-	0	-	0	-
1996–97	4	-	0	-	0	-	0	-	0	-
1997–98	0	-	0	-	0	-	0	-	0	-
1998–99	0.026	-	0	-	0	-	0	-	0	-
1999–00	0.035	-	0	-	0.072	-	0	-	0	-
2000–01	0.055	-	0	-	0	-	0	-	0	-
2001–02	0.029	-	0	-	0	-	0	-	0	-
2002–03	0.045	-	0	-	0	-	0	-	0	-
2003–04	0.456	10	0	10	0	10	0	10	0	-
2004–05	0.698	10	0	10	0	10	0	10	0	-
2005–06	0.505	10	0	10	0	10	0	10	0.02	-
2006–07	0.308	10	0	10	0	10	0	10	0.004	-
2007–08	0.492	10	0.080	10	0	10	0.019	10	0	-

Table 1 [Continued]

	KIC 6		KIC 7		KIC 8		KIC 9		KIC ET	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2008–09	0.424	10	0.063	10	0	10	0	10	0	-
2010–11	1.037	10	0	10	0.204	10	0	10	0	-
2011–12	0.343	10	0	10	0	10	0.026	10	0	-
2012-13	0.141	10	0	10	0	10	0.004	10	0	-
2013-14	0.703	10	0.004	10	0	10	0.0390	10	0	-

	TOTAL*	
Fishstock	Landings	TACC
1993–94	0.119	-
1994–95	0	-
1995–96	0.102	-
1996–97	4.104	-
1997–98	0	-
1998–99	0.011	-
1999–00	0.119	-
2000–01	0.035	-
2001–02	0.45	-
2002–03	0.063	-
2003–04	0.482	90
2004–05	0.942	90
2005–06	1.063	90
2006–07	1.615	90
2007–08	2.806	90
2008–09	0.487	90
2009–10	2.466	90
2010–11	3.736	90
2011–12	2.964	90
2012-13	4.153	90
2013-14	11.57	90

*In 1995–96 and 1998–99, 47 kg and 1 kg of LMU were landed respectively, but no FMA was assigned to the landings. In 1996–97 24 kg of NEB was landed but no FMA was assigned to this landing. These reported landings by species are included in the total landings for KIC in those years.

2. BIOLOGY

King crabs belong to the infra order *Anomura*, and differ from true crabs (*Brachyura*) in that the last pair of walking legs is reduced and folded inside the carapace.

L. aotearoa is a large, pear-shaped, dark purplish-red or brick red crab that has been found at depths between 120 m and 700 m. from the east coast of Northland to southern parts of the Campbell Plateau. It is a circumpolar, Southern Ocean species growing so large that the distance between the tips of the second legs can reach 1.25 m. The carapace width in males of this species may exceed 200 mm. Females are smaller.

N. brodiei is also pear-shaped, and typically a uniform brick to bright red colour. It is widely distributed from the Three Kings Islands to the Campbell Plateau, where it occurs on soft and rocky bottom between about 800 and 1100 m. Carapace width in this species is up to about 180 mm.

King crabs are thought to aggregate for protection during breeding and moulting. Migrations between shallow and deep waters also probably occur in response to moulting and mating, at least in near-shore populations. They occur mainly on soft substrates but have also been found on rocky bottoms. They are probably omnivorous, although animal food (sessile, sedentary, and mobile invertebrates, and small fish), including dead material, is their predominant food. Their principal predators are fish and seals.

Sexes are separate in all species of king crabs and they appear to be seasonal spawners, probably spawning in summer or autumn.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs, however, there is currently no biological or fishery information which could be used to identify stock boundaries.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any king crab fishstock.

4.2 Biomass estimates

There are no biomass estimates for any king crab fishstock.

4.3 Yield estimates and projections

There are no estimates of *MCY* and *CAY* for any king crab fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any king crab fishstock.

6. FOR FURTHER INFORMATION

Arnaud, P M; Do-Chi, T (1977) Donnees biologiques et biometriques sur les lithodes *Lithodes aotearoa* (Crustacea: Decapoda: Anomura) des Iles Crozet (SW Ocean Indien). *Marine Biology* 39: 147–159.

Clark, M R; King, K J (1989) Deepwater fish resources off the North Island, New Zealand: results of a trawl survey, May 1985 to June 1986. *New Zealand Fisheries Technical Report* No. 11.

Dawson, E W (1989) King crabs of the world (Crustacea: Lithodidae) and their fisheries. A comprehensive bibliography. *New Zealand Oceanographic Institute Miscellaneous Publication* 101.

Food and Agriculture Organisation (1985) Southern Ocean CCAMLR Convention area, fishing areas 48, 58 and 88. pp. 89–92. FAO species identification sheets for fishery purposes. Vol. 1.

McClay, C L (1988) Brachyura and crab-like Anomura of New Zealand. *Leigh Laboratory Bulletin* No. 22.

Macpherson, E (2001) New species and new records of lithodid crabs (Crustacea, Decapoda) from the southwestern and central Pacific Ocean. *Zoosystema. Paris* 23: 797–805.

Melville-Smith, R (1982) A brief exploitation of the stone crab *Lithodes aotearoa* (Henderson) off South West Africa, 1979/80. *Fisheries Bulletin of South Africa* 16: 45–55.

Naylor, J R; Webber, W R; Booth, J D (2005) A guide to common offshore crabs in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report* No. 2. 47 p.

Miquel, J C; Arnaud, P M (1987) Aspects de la biologie de *Lithodes aotearoa* (Crustacea : Decapoda) aux Iles Crozet, Ocean Indien Subantarctique. CNFRA 57: 81–89.

Miquel, J C; Arnaud, P M; Do-Chi, T (1985) Population structure and migration of the stone crab *Lithodes aotearoa* in the Crozet Islands, Subantarctic Indian Ocean. *Marine Biology* 89: 263–269.

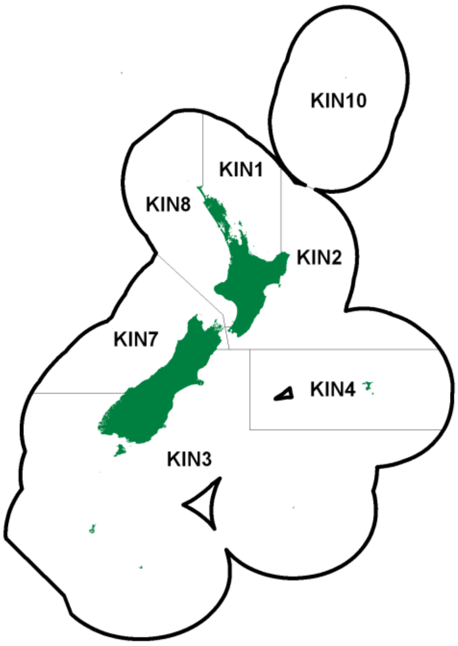
O'Driscoll, R L; Booth, J D; Bagley, N W; Anderson, O F; Griggs, L H; Stevenson, M L; Francis, M P (2001) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. Final Research Report for Ministry of Fisheries Research Project ENV2000/04. Objectives 1, 2, & 3. (Unpublished report held by Ministry for Primary Industries.)

Webb, B F (1972) Report on the investigations of the 'Lloret Lopez II' - 8 January to 2 April 1970. Section 3 Crab survey - 18 February to 27 February 1970. *Fisheries Technical Report* No. 97.

Webber, R (1997) The royal family: king crabs at home and abroad. *Seafood New Zealand* May 1997: 81–84.

KINGFISH (KIN)

(*Seriola lalandi*)
Haku



1. FISHERY SUMMARY

Kingfish were introduced into the QMS on 1 October 2003, with allowances, TACCs and TACs in Table 1 except that the TACC for KIN 8 was increased from 36 to 45 t in October 2012.

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs by Fishstock.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of fishing related mortality	TACC	TAC
KIN 1	459	76	47	91	673
KIN 2	65	18	24	63	170
KIN 3	1	1	0	1	3
KIN 4	1	1	0	1	3
KIN 7	10	2	2	15	21
KIN 8	31	9	7	45	92
KIN 10	1	0	0	1	2

An increased minimum legal size (MLS) to 75 cm (from 65 cm) for recreationally caught kingfish was introduced on 15 January 2004. Kingfish were added to the 6th Schedule of the Fisheries Act (1996) in October 2005 for all fishing methods except setnet and in all areas. A special reporting code for 6th Schedule releases was introduced on 1 October 2006 to allow monitoring of releases. Kingfish released in accordance with 6th Schedule conditions and reported against this code are not counted against ACE.

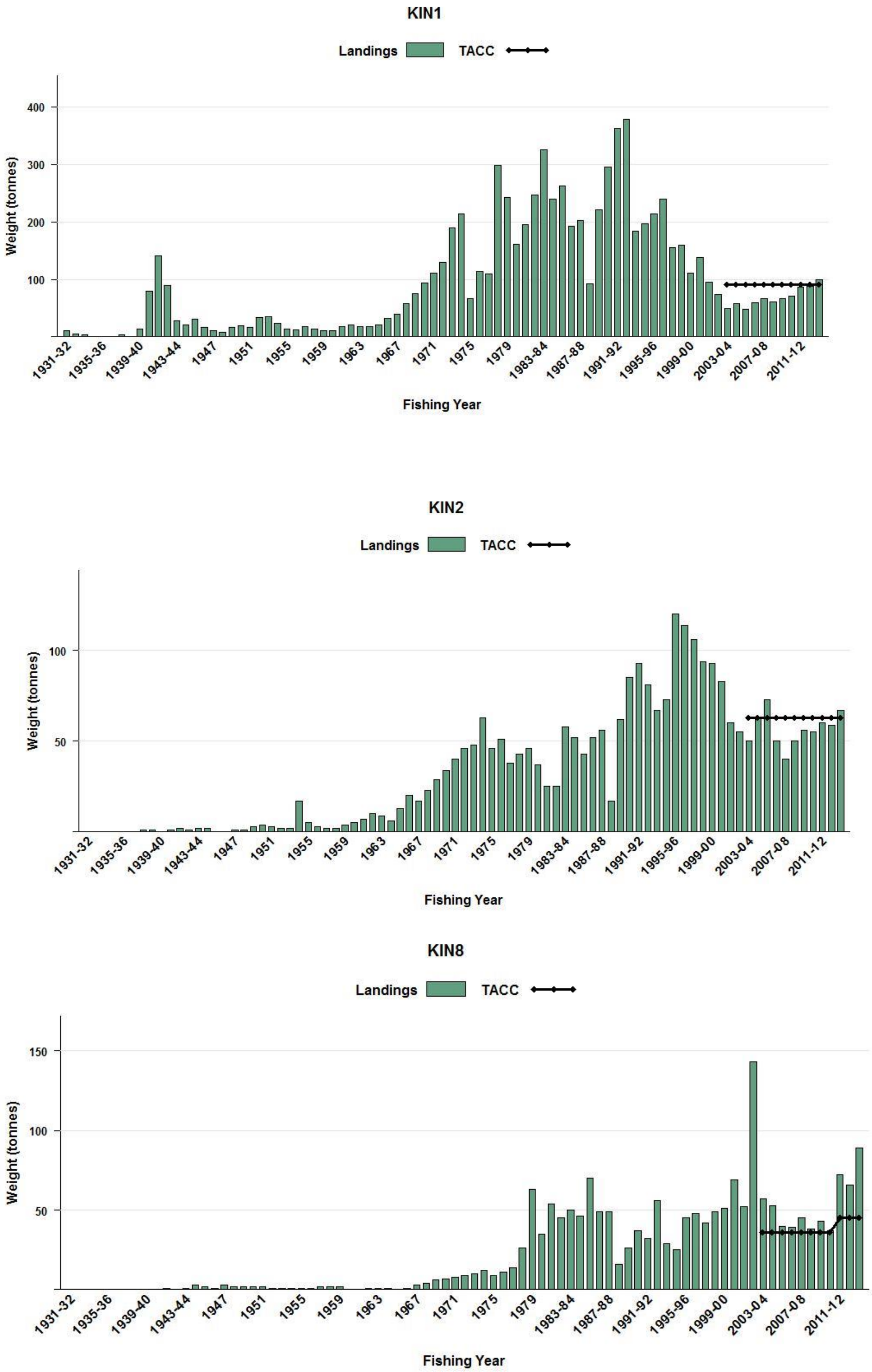


Figure 1: Reported commercial landings and TACC for the three largest KIN stocks. From top to bottom: KIN 1 (Auckland East), KIN 2 (Central East) and KIN 8 (Central Egmont).

1.1 Commercial fisheries

Kingfish commercial landings are reported largely as bycatch of inshore setnet, trawl and longline fisheries. From 1991 to late 2003, targeting of kingfish (as a non-QMS species) was prohibited unless the species was identified on a fisher's permit. A few permit holders were authorized to target kingfish and most of their catch was taken using setnets.

Commercially, kingfish is a moderately high value species and is usually sold as fillets or whole chilled.
The main fishing areas for kingfish are the east (KIN 1 and KIN 2) and west coast (KIN 8) of the North Island of New Zealand (Table 2). The largest commercial catches generally come from KIN 1. Landings were relatively large in 1983–84, especially in KIN 1, and were probably due to the greater number of vessels in the fishery prior to the introduction of the QMS in 1986. In addition, there was increased effort and better reporting as fishers sought to establish a catch history for the main species in anticipation of the introduction of the QMS. By 1988–89, reported catches of kingfish had reduced to their lowest levels across most areas. This was most likely due to the under-reporting of less common species in the catch (which includes kingfish) and the introduction of non-QMS restrictions. An increase in kingfish landings in FMA 1 between 1988–89 and 1992–93 and in FMA 2 between 1988–89 and 1991–92 may be due to a number of factors. These include: better reporting of catches; changes in fishing patterns with increased catch by setnet; increased numbers of vessels reporting kingfish catch; and increased targeting of kingfish.

Historical estimated and recent reported kingfish landings and TACCs are shown in Tables 2 and 3, while Figure 1 shows the historical and recent landings and TACC values for the main kingfish stocks.

The total reported catch across all FMAs peaked in 1992–93 at 532 t, with 73% of the catch from KIN 1. By 1993–94, the reported catch of kingfish over all QMAs decreased considerably, mainly because of the reduced catch from KIN 1. Possible reasons for this decrease include: the effect of the October 1993 introduction of a MLS of 65 cm on all methods other than trawl; changes in fishing patterns in the snapper and trevally target setnet, trawl, and bottom longline fisheries (that were responsible for most of the non-target catch of kingfish); decreased target fishing for kingfish; and setnet area closures in FMA 1 from October 1993. The trawl exemption with respect to MLS was removed in December 2000.

The annual catch of kingfish from KIN 1 fluctuated between 100 and 250 t from 1993–94 through to 2000–01 and has remained below 100 t since 2001–02. The kingfish annual catch from KIN 2 declined from the high of 120 t in 1995–96 to 50 t in 2003–04, and has mostly been below 60 t since then. Landings from KIN 8 have averaged approximately 35 t for the last 19 years, with catches ranging from 19–70 t. In 2002–03 landings nearly triple the 2001–02 level were reported in KIN 8, the highest ever landing in this area. Landings returned to near average in 2003–04 and 2004–05, but were still above the TACC. Annual catches in KIN 8 have remained below 50 t since 2005–06, but were often above the 36 t TACC Although the TACC was increased to 45 t in October 2011 to accommodate previous levels of by-catch, the 2011–12 commercial catch increased substantially to 92 t. In addition to annual catches reported for kingfish QMAs, about 5 t of kingfish has been taken by New Zealand flagged vessels fishing outside NZ fishing waters.

Assuming that kingfish targeting effectively ceased during the mid 1990s, catches since the early 2000s possibly reflect 'true' bycatch levels.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	KIN 1	KIN 2	KIN 8	Year	KIN 1	KIN 2	KIN 8
1931-32	10	0	0	1957	18	2	2
1932-33	5	0	0	1958	13	2	2
1933-34	3	0	0	1959	10	4	2
1934-35	1	0	0	1960	11	5	0
1935-36	0	0	0	1961	18	7	0
1936-37	0	0	0	1962	20	10	1
1937-38	3	1	0	1963	18	9	1
1938-39	1	1	0	1964	18	6	1
1939-40	13	0	0	1965	21	13	0
1940-41	80	1	0	1966	32	20	1
1941-42	141	2	1	1967	40	17	3
1942-43	90	1	0	1968	58	23	4
1943-44	28	2	1	1969	75	29	6
1944	20	2	3	1970	93	34	7
1945	31	0	2	1971	111	40	8
1946	16	0	1	1972	129	46	9
1947	11	1	3	1973	189	48	10
1948	8	1	2	1974	214	63	12
1949	16	3	2	1975	66	46	9
1950	19	4	2	1976	114	51	11
1951	17	3	2	1977	109	38	14
1952	33	2	1	1978	299	43	26
1953	35	2	1	1979	242	46	63
1954	23	17	1	1980	161	37	35
1955	14	5	1	1981	195	25	54
1956	12	3	1	1982	247	25	45

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 3: Reported landings (t) of kingfish by area (QMA) from 1983–84 to 2013–14. From 1986–87 to 2000–01, total landings are from LFRRs and landings by QMA are from CLRs prorated to the LFRR total. Totals include landings not attributed to the listed QMAs. MHR data from 2001–present. [Continued on next page].

Year	KIN 1		KIN 2		KIN 3		KIN 4	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	326	-	58	-	11	-	0	-
1984–85*	239	-	52	-	8	-	0	-
1985–86*	262	-	43	-	4	-	0	-
1986–87	192	-	52	-	9	-	0	-
1987–88	202	-	56	-	9	-	0	-
1988–89	92	-	17	-	4	-	0	-
1989–90	221	-	62	-	2	-	0	-
1990–91	295	-	85	-	6	-	< 1	-
1991–92	362	-	93	-	4	-	< 1	-
1992–93	378	-	81	-	4	-	0	-
1993–94	184	-	67	-	2	-	< 1	-
1994–95	196	-	73	-	2	-	0	-
1995–96	214	-	120	-	2	-	< 1	-
1996–97	240	-	114	-	7	-	< 1	-
1997–98	155	-	106	-	2	-	< 1	-
1998–99	159	-	94	-	3	-	< 1	-
1999–00	111	-	93	-	4	-	< 1	-
2000–01	138	-	83	-	4	-	< 1	-
2001–02	95	-	60	-	2	-	< 1	-
2002–03	73	-	55	-	1	-	0	-
2003–04	49	91	50	63	1	1	< 1	1
2004–05	58	91	63	63	1	1	0	1
2005–06	48	91	73	63	< 1	1	0	1
2006–07	60	91	50	63	1	1	0	1
2007–08	66	91	40	63	< 1	1	< 1	1
2008–09	61	91	50	63	< 1	1	< 1	1
2009–10	66	91	56	63	< 1	1	< 1	1
2010–11	71	91	55	63	< 1	1	< 1	1
2011–12	87	91	60	63	< 1	1	< 1	1
2012-13	88	91	59	63	2	1	<1	1
2013-14	100	91	67	63	1	1	<1	1

Table 3 [Continued]

Year	KIN 7		KIN 8		KIN 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	3	-	50	-	0	-	448	-
1984–85*	< 1	-	46	-	0	-	345	-
1985–86*	1	-	70	-	0	-	380	-
1986–87	1	-	49	-	0	-	356	-
1987–88	1	-	49	-	0	-	373	-
1988–89	< 1	-	16	-	0	-	460	-
1989–90	3	-	§26	-	< 1	-	428	-
1990–91	2	-	§37	-	< 1	-	448	-
1991–92	2	-	§32	-	9	-	512	-
1992–93	1	-	§56	-	< 1	-	532	-
1993–94	4	-	29	-	< 1	-	288	-
1994–95	6	-	25	-	< 1	-	302	-
1995–96	7	-	45	-	< 1	-	380	-
1996–97	11	-	48	-	6	-	427	-
1997–98	7	-	42	-	1	-	326	-
1998–99	16	-	49	-	< 1	-	323	-
1999–00	10	-	51	-	0	-	270	-
2000–01	11	-	69	-	< 1	-	304	-
2001–02	22	-	52	-	0	-	231	-
2002–03	20	-	143	-	0	-	292	-
2003–04	3	7	57	36	0	1	160	200
2004–05	19	7	53	36	0	1	195	200
2005–06	7	7	40	36	< 1	1	169	200
2006–07	13	7	39	36	0	1	161	200
2007–08	5	7	45	36	0	1	157	200
2008–09	5	7	38	36	0	1	154	200
2009–10	7	7	43	36	0	1	172	200
2010–11	6	7	37	36	0	1	171	200
2011–12	15	7	72	45	0	1	235	209
2012-13	12	7	66	45	0	1	226	209
2013-14	26	15	89	45	0	1	283	217

* FSU data (Area unknown data prorated in proportion to recorded catch).
§ Some data included in FMA 1.

1.2 Recreational fisheries

Kingfish is highly regarded by recreational fishers in New Zealand for its sporting attributes and large size. Kingfish are most often caught by recreational fishers from private boats and from charter boats, but are also a prized catch for spearfishers and shore based game fishers. Kingfish are recognized internationally as a sport fish, and kingfish caught in New Zealand waters hold 20 of the 22 International Gamefish Association World Records.

1.2.1 Management controls

The main methods used to manage recreational harvests of kingfish are minimum legal size limits (MLS), method restrictions and daily bag limits. Fishers can take up to three kingfish as part their daily bag limit and the MLS is 75 cm.

Recreational fishers have voiced concerns over a perceived marked decline in the size of kingfish available to them in recent years. Many clubs, competitions and charter boats have implemented a voluntary one kingfish per person per day limit in response. A number of gamefish clubs have also adopted a minimum size limit of 100 cm for kingfish.

1.2.2 Estimates of recreational harvest

Recreational catch estimates are given in Table 4. There are two broad approaches to estimating recreational fisheries harvest: the use of onsite or access point methods where fishers are surveyed or counted at the point of fishing or access to their fishing activity; and, offsite methods where some form of post-event interview and/or diary are used to collect data from fishers.

The first estimates of recreational harvest for kingfish were calculated using an offsite approach, the offsite regional telephone and diary survey approach. Estimates for 1996 came from a national telephone and diary survey (Bradford 1998). Another national telephone and diary survey was carried out in 2000 (Boyd & Reilly 2005) and a rolling replacement of diarists in 2001 (Boyd & Reilly 2004 allowed estimates for a further year (population scaling ratios and mean weights were not re-estimated in 2001).

The harvest estimates provided by these telephone diary surveys are no longer considered reliable for various reasons. With the early telephone/diary method, fishers were recruited to fill in diaries by way of a telephone survey that also estimates the proportion of the population that is eligible (likely to fish). A "soft refusal" bias in the eligibility proportion arises if interviewees who do not wish to co-operate falsely state that they never fish. The proportion of eligible fishers in the population (and, hence, the harvest) is thereby under-estimated. Pilot studies for the 2000 telephone/diary survey suggested that this effect could occur when recreational fishing was established as the subject of the interview at the outset. Another equally serious cause of bias in telephone/diary surveys was that diarists who did not immediately record their day's catch after a trip sometimes overstated their catch or the number of trips made. There is some indirect evidence that this may have occurred in all the telephone/diary surveys (Wright et al 2004).

The recreational harvest estimates provided by the 2000 and 2001 telephone diary surveys are thought to be implausibly high for many species, which led to the development of an alternative maximum count aerial-access onsite method that provides a more direct means of estimating recreational harvests for suitable fisheries. The maximum count aerial-access approach combines data collected concurrently from two sources: a creel survey of recreational fishers returning to a subsample of ramps throughout the day; and an aerial survey count of vessels observed to be fishing at the approximate time of peak fishing effort on the same day. The ratio of the aerial count in a particular area to the number of interviewed parties who claimed to have fished in that area at the time of the overflight was used to scale up harvests observed at surveyed ramps, to estimate harvest taken by all fishers returning to all ramps. The methodology is further described by Hartill et al (2007).

This aerial-access method was first employed and optimised to estimate snapper harvests in the Hauraki Gulf in 2003–04. It was then extended to survey the wider SNA 1 fishery in 2004–05 and to provide estimates for other species, including kingfish. The PELWG indicated that the kingfish estimate should be considered with considerable caution due to the limited overlap between this methods sampling technique and the fisheries for kingfish, e.g., the target fisheries for kingfish are usually in offshore areas from launches which were not sampled by the boat ramp survey. For this reason the results from this survey have not been accepted or included in the working group report at this time.

In response to the cost and scale challenges associated with onsite methods, in particular the difficulties in sampling other than trailer boat fisheries, offsite approaches to estimating recreational fisheries harvest have been revisited. This led to the development and implementation of a national panel survey for the 2011–12 fishing year. The panel survey used face-to-face interviews of a random sample of New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and catch information collected in standardised phone interviews. Note that the national panel survey estimate does not include harvest taken on recreational charter vessels, or recreational harvest taken under s111 general approvals.

Table 4: Recreational harvest estimates for kingfish stocks. The telephone/diary surveys ran from December to November but are denoted by the January calendar year. The national panel survey ran through the October to September fishing year but is denoted by the January calendar year. Mean fish weights were obtained from boat ramp surveys (for the telephone/diary and panel survey harvest estimates). (Source: Tierney et al 1997, Bradford 1997, Bradford 1998, Boyd & Reilly 2002, MPI unpublished data).

Stock	Year	Method	Number of fish	Total weight (t)	CV
KIN 1	1992	Telephone/diary	186 000	260	-
	1994	Telephone/diary	180 000	228#	0.09
	1996	Telephone/diary	194 000	234	0.07
	2000	Telephone/diary	127 000	800	0.18
	2001	Telephone/diary	449 000	434	0.19
	2012	Panel survey	47 463	488	0.14

Table 4 [Continued]

Stock	Year	Method	Number of fish	Total weight (t)	CV
KIN 2	1992	Telephone/diary	68 000	92	-
	1994	Telephone/diary	62 000	78	0.18
	1996	Telephone/diary	67 000	70	0.11
	2000	Telephone/diary	25 000	138	0.38
	2001	Telephone/diary	107 000	124	0.21
	2012	Panel survey	3 681	37	0.25
KIN 7	1992	Telephone/diary	10 000	20	-
	1994	Telephone/diary	-	-	-
	1996	Telephone/diary	9 000	13	0.19
	2000	Telephone/diary	2 000	11	0.55
	2001	Telephone/diary	32 000	33.9	0.23
	2012	Panel survey	2 081	21	0.38
KIN 8	1992	Telephone/diary	6 000	7.6#	-
	1994	Telephone/diary	-	-	-
	1996	Telephone/diary	2 000	2.5#	-
	2000	Telephone/diary	1 000	7	0.63
	2001	Telephone/diary	2 000	1.7	0.46
	2012	Panel survey	5 257	53	0.26

#No harvest estimate available in the survey report, estimate presented is calculated as average fish weight for all years and areas by the number of fish estimated caught.

All indications are that the recreational catch is in the range of 500–700 t in KIN 1. The earlier telephone/diary surveys and the recent national panel survey also indicate that over 85% of the recreational kingfish catch is taken in the northern QMAs (1 & 8).

It was assumed that the introduction of the higher MLS of 75 cm on 15 January 2004 for kingfish would reduce recreational catches.

1.3 Customary non-commercial fisheries

Kingfish is an important traditional food fish for Maori, but no quantitative information on the level of Maori customary non-commercial catch is available. The extent of the traditional fisheries for kingfish in the past is described by the Muriwhenua Fishing Report (Waitangi Tribunal 1988). Because of the coastal distribution of the species and its inclination to strike lures, it is likely that historically Maori caught considerable numbers of kingfish.

1.4 Illegal catch

There is no known illegal catch of kingfish.

1.5 Other sources of mortality

The extent of any other sources of mortality is unknown, however, handling mortality for sub-MLS size fish is likely to occur in both the recreational (sub 75 cm) and commercial (sub 65 cm) fisheries.

2. BIOLOGY

In New Zealand, kingfish are predominantly found in the northern half of the North Island but also occur from 29° to 46° S, Kermadec Islands to Foveaux Strait (Francis 1988) and to depths of 200 m. Kingfish are large predatory fish with adults exceeding one and a half metres in length. They usually occur in schools ranging from a few fish to well over a hundred fish. Kingfish tend to occupy a semi-pelagic existence and occur mainly in open coastal waters, preferring areas of high current and or tidal flow adjacent to rocky outcrops, reefs and pinnacles. However, kingfish are not restricted to these habitats and are sometimes caught or observed in open sandy bottom areas and within shallow enclosed bays.

Estimates of age have been derived from opaque-zone counts in sagittal otolith thin sections. Estimates of kingfish von Bertalanffy growth parameters were also derived from recreational tagging data and otoliths collected from the eastern Bay of Plenty. Estimates of K and L_∞ were similar being 0.128 and

130 cm from the otolith age data and 0.130 and 142 cm from the tagging increment data respectively (Table 5). The hard-structure ageing techniques have yet to be validated for New Zealand kingfish, although the position of the first annulus has been validated using regular samples of 0+ year old fish from a fish aggregating device (Holdsworth et al 2013; Francis et al 2005).

A Bayesian analysis of length and maturity data suggests that the length of 50% maturity is 97 cm in females and 83 cm in males.

The recent research has provided estimates of *M* ranging from 0.20–0.25, however, these estimates are thought to represent an upper bound as the samples were taken from an exploited population.

Available biological parameters relevant to stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters.

Fishstock		**Estimate**	**Source**
2. Weight = a(length)^b (Weight in g, length in cm fork length).			
	Both Sexes		
	a	b	
KIN 1	0.03651	2.762	Walsh et al (2003)

3. von Bertalanffy growth parameters

	Females			Males			Combined		
	L_∞	k	t_0	L_∞	k	t_0	L_∞	k	t_0	
Bay of Plenty (2002?)										
	135.79	0.119	-0.976	123.81	0.137	-0.911	130.14	0.128	-0.919	McKenzie et al (in press)
East Northland (2010)										
	124.48	0.232	-0.890	113.69	0.279	-0.790				Holdsworth et al (2013)
Bay of Plenty (2010)										
	125.63	0.211	-0.987	119.32	0.226	-0.976				Holdsworth et al (2013)

3. STOCKS AND AREAS

A study based on meristic characters and parasite loads suggests two stocks of kingfish off the west and east coasts. These stocks are contained within the Tasman current on the west coast and the east Auckland current and east Cape current on the east coast, with little mixing between them. The east coast stock may be further subdivided into northeast and Hawkes Bay stocks based on limited exchange from tagging studies and parasite marker prevalence.

Tagging results suggest that most adult kingfish do not move outside local areas, with many tag returns close to the release site. However, some tagged kingfish have been found to move very long distances; there are validated reports of New Zealand tagged kingfish being caught in Australian waters and Australian tagged kingfish being recaptured in New Zealand waters.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

Total mortality (*Z*) was estimated for kingfish stocks in East Northland and in the Bay of Plenty based on the age structure of the recreational catches in 2010 (Holdsworth and Saul 2010). In the Bay of Plenty estimates of *Z* for offshore (i.e., White Island) and inshore samples were 0.3 and 0.38, respectively; assuming an age of full recruitment of 5 yrs. Assuming an instantaneous rate of natural mortality (*M*) of 0.2, the target reference point of $F_{40\%}$ for kingfish in KIN 1 was calculated to be 0.1. This suggests that overfishing of kingfish in the Bay of Plenty is not occurring.

Total mortality for East Northland was estimated to be 0.77. However, fishing pressure is expected to be lower in East Northland than in the Bay of Plenty and since no samples were obtained from offshore areas known to be inhabited by large kingfish – i.e. Three Kings Islands and Ranfurly Bank – the Northern Inshore Working Group concluded that the recreational catch sampled in 2010 was unlikely to reflect the age structure of the entire East Northland population. As the 2010 estimate of *Z* for East Northland may well have been biased (high) by emigration to offshore areas, this estimate is considered to be unreliable.

4.2 Biomass estimates

Few kingfish are encountered in trawl surveys, suggesting that trawling is not a suitable method for monitoring changes in kingfish abundance. Kingfish are amenable to mark-recapture studies. However, up to now, tagging studies have been conducted solely to describe kingfish movement patterns and to estimate growth. Data from these programmes is inadequate to estimate stock biomass.

4.5 Yield estimates and projections

No information is available.

4.6 Other factors

Kingfish in New Zealand can be regarded as a high value species from customary, commercial and recreational perspectives. Although fluctuating, catches of kingfish have shown very little trend over the last 20 years and there is no direct evidence to suggest that the current catch levels are not sustainable. However, recreational fishers are concerned about a perceived decline in the quality of the fishery.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

The movement of New Zealand kingfish has been extensively studied through mark-recapture programmes. Although some kingfish moved considerable distances (e.g., from New Zealand to Australia) most kingfish were recaptured close to the site of release, regardless of time at liberty. It is therefore assumed that New Zealand kingfish are comprised of several biological stocks. In addition to the results from tagging studies, the age structure of recreational catches suggests that kingfish off East Northland and in the Bay of Plenty in KIN 1 comprise separate stocks.

- **KIN 1 – Bay of Plenty**

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Base case model only
Reference Points	Target: $F_{40\%}$ Soft Limit: $20\%B_0$ Hard Limit: $10\%B_0$ Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	*F* is About as Likely as Not (40–60%) to be at or below the target
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unknown Overfishing is Unlikely (< 40%) to be occurring
Historical Stock Status Trajectory and Current Status	
-	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	-
Recent Trend in Fishing Mortality or Proxy	Low estimates of fishing mortality for 2010 and low and stable catches over the previous 10 years, suggest that fishing mortality has been low for a decade.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-
Projections and Prognosis	
Stock Projections or Prognosis	Catch curve analysis from recent catch sampling (2010) indicates that total mortality is low, with fishing mortality below natural mortality and close to the target. Given the low TACC for KIN 1, inclusion on Schedule 6, increased MLS, and practice of catch and release by recreational anglers, stock size is unlikely to decline in the medium-term.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown Overfishing: Unlikely (< 40%)

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative stock assessment	
Assessment Method	Estimates of total mortality using Chapman-Robson estimator	
Assessment dates	Latest assessment: 2013	Next assessment: 2017
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	-Age structure of recreational catch in 2010 -Instantaneous rate of natural mortality (*M*) of 0.20 based on a maximum age of 23 years. - Age at 50% maturity (6 yrs) -Age at MLS (4 yrs) -Growth rate	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	-	-
Assessment dates	Latest assessment: 2013	Next assessment: 2017
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Uncertainty in the estimate of *M*	

Qualifying Comments
-
Fishery Interactions
Commercial kingfish catch is almost all bycatch in fisheries for other species.

Research Needs
Future kingfish catch at age sampling in KIN 1 needs to include samples from offshore fishing grounds. CPUE based on charterboat catch and effort forms should be investigated once there are sufficient data.

- **KIN 1 – East Northland**

- **KIN 1 – East Northland**

A status of the stock summary table is not included for the East Northland substock as the 2010 estimates of mortality (*Z*) for this area are not reliable.

Yields, TACCs and reported landings for the 2013–14 fishing year are summarised in Table 6.

Table 6: Summary of yields (t) from the commercial fishery, and reported commercial landings (t) for the most recent fishing year.

Fishstock		FMAs	*MCY*	2013–14 Actual TACC	2013–14 Reported landings
KIN 1	Auckland (East)	1	195	91	100
KIN 2	Central	2	40	63	67
KIN 3	South-east (Coast), Southland, Sub-Antarctic	3, 5 & 6	-	1	2
KIN 4	South-east (Chatham)	4	-	1	< 1
KIN 7	Challenger	7	-	15	26
KIN 8	Central (West) and Auckland (West)	8 & 9	20	45	45
KIN 10	Kermadec	10	-	1	0
Total			260*	217	284

*5 ton *MCY* estimate for FMAs 3,4,5,6 & 7 combined included in total.

6. FOR FURTHER INFORMATION

Bradford, E (1997) Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993–94. New Zealand Fisheries Assessment Research Document 1997/7. 16 p. (Unpublished report held by NIWA library, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document. 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington.)

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000/2001 National marine recreational fishing survey: diary results and harvest estimates. Draft New Zealand Fisheries Research Report. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Boyd, R. O.; Reilly, J. L. (2002). 1999/2000 National Marine Recreational Fishing Survey: recreational harvest estimates. Draft New Zealand Fisheries Assessment Report 2002/XX

Hartill, B; Bian, R; Armiger, H; Vaughan, M; Rush, N (2007) Recreational marine harvest estimates of snapper, kahawai, and kingfish in QMA 1 in 2004–05. *New Zealand Fisheries Assessment Report. 2007/26*. 44p

Hartill, B; Davies, N M (1999) New Zealand billfish and gamefish tagging, 1997–98. *NIWA Technical Report No. 57*. 39 p.

Francis, M; McKenzie, J; Ó Maolagáin, C (2005) Attempted validation of the first annual growth zone in kingfish (*Seriola lalandi*) otoliths. Final Research Report for Ministry of Fisheries research project SAP2004-04, Objective 1. 22 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Francis, R I C C (1988) Maximum likelihood estimation of growth and growth variability from tagging data. *New Zealand Journal of Marine and Freshwater Research* 22: 42–51.

Holdsworth, J C; McKenzie, J R; Walsh, C; van der Straten, K M; Ó Maolagáin, C (2013) Catch-at-age of yellowtail kingfish (*Seriola lalandi*) caught by recreational fishers in KIN 1, New Zealand. *New Zealand Fisheries Assessment Report 2013/3*. 31 p.

Holdsworth, J; Saul, P (2003) New Zealand: billfish and game tagging 2001–02. *New Zealand Fisheries Assessment Report 2003/15*. 39 p.

Holdsworth, J; Saul, P (2004) New Zealand billfish and gamefish tagging, 2002–2003. *New Zealand Fisheries Assessment Report 2004/50*. 27 p.

Holdsworth, J; Saul, P (2005) New Zealand billfish and gamefish tagging, 2003–2004. *New Zealand Fisheries Assessment Report 2005/36*. 30 p.

Holdsworth, J; Saul, P (2006) New Zealand billfish and gamefish tagging, 2004–05. *New Zealand Fisheries Assessment Report 2006/18*. 28 p.

Holdsworth, J; Saul, P (2007) New Zealand billfish and gamefish tagging, 2005–06. *New Zealand Fisheries Assessment Report 2007/02*. 29 p.

Holdsworth, J. C., & Saul, P. J. (2010). New Zealand billfish and gamefish tagging, 2008–09. *New Zealand Fisheries Assessment Report*, *12*, 34

Holdsworth, J.C.; McKenzie, J.R.; Walsh, C.; van der Straten, K.M.; Ó Maolagáin, C. (2013). Catch-at-age of yellowtail kingfish (*Seriol lalandi*) caught by recreational fishers in KIN 1, New Zealand. *New Zealand Fisheries Assessment Report 2013/3*. 31 p.

McKenzie, J. R. (2014). Review of productivity parameters and stock assessment options for kingfish (Seriola lalandi lalandi). *New Zealand Fisheries Assessment Report*, 04.

McKenzie, J.; Smith, M.; Watson, T.; Francis, M.; Ó Maolagáin, C.; Poortenaar, C.; Holdsworth, J. (2014). Age, growth, maturity and natural mortality of New Zealand kingfish (Seriola lalandi lalandi). New Zealand Fisheries Assessment Report 2014/03. 36 p.

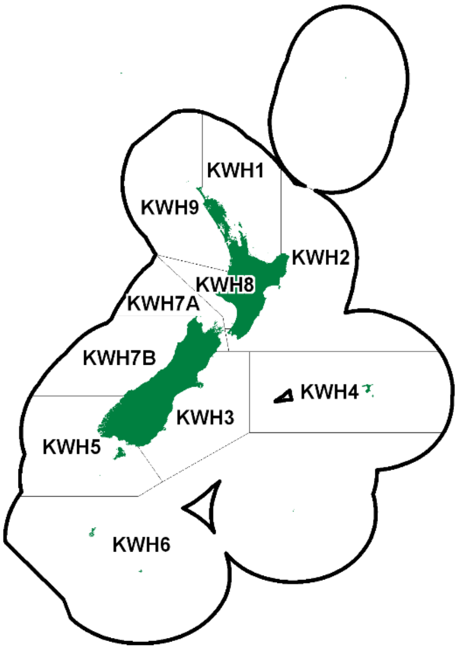
Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Waitangi Tribunal. (1988). Muriwhenua fishing report. Department of Justice, Wellington.

Walsh, C; McKenzie, J; McGregor, G; Poortenaar, C; Hartill, B; Smith, M (2003) Information available for the management of New Zealand kingfish (*Seriola lalandi lalandi*) stocks. *New Zealand Fisheries Assessment Report 2003/25*. 57 p.

KNOBBED WHELK (KWH)

(*Austrofusus glans*)



1. FISHERY SUMMARY

Knobbed whelks (*Austrofusus glans*) were introduced into the Quota Management System on 1 October 2006. The fishing year is from 1 October to 30 September and commercial catches are measured in greenweight. TACs have been allocated in 10 QMAs (Table 1). This species is managed under Schedule 6 of the Fisheries Act for all stocks, which allows for them to be returned to where they were taken (as soon as practicable after being taken) providing they are likely to survive.

Table 1: Current TAC, TACC and allowances for customary fishing, recreational fishing and other sources of mortality for *Austrofusus glans*.

QMA	TAC (t)	TACC (t)	Customary fishing	Recreational fishing	Other sources of mortality
KWH1	3	1	1	1	0
KWH 2	3	1	1	1	0
KWH 3	5	3	1	1	0
KWH 4	8	6	1	1	0
KWH 5	3	1	1	1	0
KWH 6	4	2	1	1	0
KWH 7A	53	50	1	1	1
KWH 7B	3	1	1	1	0
KWH 8	3	1	1	1	0
KWH 9	3	1	1	1	0
Total	**88**	**67**	**10**	**10**	**1**

1.1 Commercial fisheries

Target fishing for knobbed whelks is by baited pots. Because economic returns for whelk fishing are poor, most of the historical catch is bycatch from oyster and scallop dredging and from bottom trawling. Due to the low value of this species it is likely that there is a high level of unreported discarded catch.

Landings shown in Table 2 for the period 1990–91 to 2005–06 were recorded under the generic code for whelks (WHE), however the Ministry considers that in FMA 1, 2, 7, and 8, most reported landings were of the knobbed whelk *Austrofusus glans*. In FMA 3, 4, 5, and 6, the Ministry considers that about a third of reported landings were of the knobbed whelk, while the remainder were the large ostrich foot shell *Struthiolaria papulosa*.

Reported landings of knobbed whelk in FMA 1, FMA 2, and FMA 8 have been relatively low and variable since the 1990s and have been (largely or all) accounted for as bycatch. In FMA 7 in the early 1990s higher catches were reported as part of experimental fisheries in Golden and Tasman Bay to provide stock assessment information in these areas (Tables 2 and 3). Landings are split into two tables (before and after the 2006 fishing year) as reporting requirements changed when knobbed whelks entered the QMS.

Table 2: Reported landings (t) of whelks (WHE) by FMA from 1990–91 to 2005–06 from landing returns. See section 1.1 for an explanation of the proportion of WHE that are considered to be knobbed whelks.

FMA	FMA 1	FMA 2	FMA 3	FMA 4	FMA 5	FMA 6	FMA 7	FMA 8	FMA 9	Total
1990–91	0	0	0	0	0	0	44.976	0	0	44.976
1991–92	0	0	0	0	0	0	26.935	0	0	26.935
1992–93	0.021	0	0.018	0	0	0	1.762	0	0	1.801
1993–94	0	0.135	0	0	0	0	49.278	0	0	49.413
1994–95	0	0.707	0.545	0	0	0	21.458	0.593	0	23.303
1995–96	0	0.089	0.178	0	0	0	27.596	0	0	27.863
1996–97	0.002	0.174	0.144	0	0.003	0	8.959	0	0	9.282
1997–98	0	0	0.102	0.150	0	0	0.884	0	0	1.136
1998–99	0	0	0.223	2.205	2.470	0.150	0.570	0	0	5.618
1999–00	0	0	2.286	7.953	3.250	0.790	0.080	0	0	14.359
2000–01	0	0	10.467	17.497	3.538	4.765	0.141	0	0	36.408
2001–02	0	0	1.474	3.995	0.515	1.755	0.002	0	0	7.741
2002–03	0	0	0.212	0.020	0.004	0.780	0.077	0	0	1.093
2003–04	0.035	0	0.491	0	0	0.335	4.217	0	0	5.078
2004–05	0.008	0	0.021	0	0	0.335	0.234	0	0.047	0.639
2005–06	0	0	0.163	0	0	0	0.032	0	0	0.195

Table 3: Landings of Knobbed whelk (KWH) by QMA from 2006–07 to present from monthly harvest returns (MHR).

QMA	1	2	3	4	5	6	7A	7B	8	9	Total
2006–07	0.080	0	0.010	0	0	0	0.046	0	0	0	0.136
2007–08	0.077	0	0.006	0	0	0	9.174	0.104	0	0	9.361
2008–09	0.103	0	0.121	0	0	0.001	0.226	0.008	0	0	0.459
2009–10	0.088	0	0.053	0	0	0	18.50	0	0	0	18.614
2010–11	0.473	0.036	0	0	0	0	16.033	0	0	0	16.542
2011–12	0.721	0.07	0.088	0	0	0	0	0.008	0	0	0.887
2012–13	0.551	0	0.003	0	0.001	0	0	0.014	0	0	0.569
2013-14	0.116	0	0.159	0	0.002	0	0	0	0	0	0.277

1.2 Recreational fisheries
There are no estimates of recreational catch.

1.3 Customary non-commercial fisheries
There are no estimates of current customary catch.

1.4 Illegal catch
There is no known illegal catch of this whelk.

1.5 Other sources of mortality
There is no information on other sources of mortality for this whelk.

2. BIOLOGY

The knobbed whelk *A. glans*, is a widely distributed gastropod found from low tide to about 600 m (Powell 1979). This carnivorous whelk grows up to 5 cm long, and occurs throughout New Zealand where it is found on sandy/silt/mud substrate. There is very little published about the biology of this species; most references are identification notes or records of occurrence. It is a scavenger that buries in the substrate when not feeding. A wide variety of invertebrates including polychaetes, gastropods, and bivalves occur within the wide depth range of the knobbed whelk, but no interdependent relationships are documented with *A. glans*.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on FMAs. There is no biological information on stock structure, recruitment patterns, or other biological characteristics which might indicate alternative stock boundaries.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section has yet to be drafted and approved by the Aquatic Environment Working Group.

5. STOCK ASSESSMENT

5.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any knobbed whelk fishstock.

5.2 Biomass estimates

There are no biomass estimates for any knobbed whelk fishstock.

5.3 Yield estimates and projections

There are no estimates of *MCY* for any knobbed whelk fishstock.

There are no estimates of *CAY* for any knobbed whelk fishstock.

6. STATUS OF THE STOCKS

- **KWH 7A -** *Austrofusus glans*

Stock Status	
Year of Most Recent Assessment	No formal assessment done of any of the stocks
Assessment Runs Presented	-
Reference Points	Target: None Soft Limit: None Hard Limit: None
Status in relation to Target	-
Status in relation to Limits	-
Historical Stock Status Trajectory and Current Status Unknown	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	In 1990–96 the landings for KWH 7 averaged 28.7 t. However since that time landings have declined in this area to less than 10 t per year. Landings in all other Fishstocks have been variable but total catch across all Fishstocks has been less than 10 t per year since 2001–02.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown It is unknown what effect fishing to date has had on *Austrofusus glans* stocks

Assessment Methodology		
Assessment Type	-	
Assessment Method	-	
Main data inputs	-	
	Latest assessment: -	Next assessment: -
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-

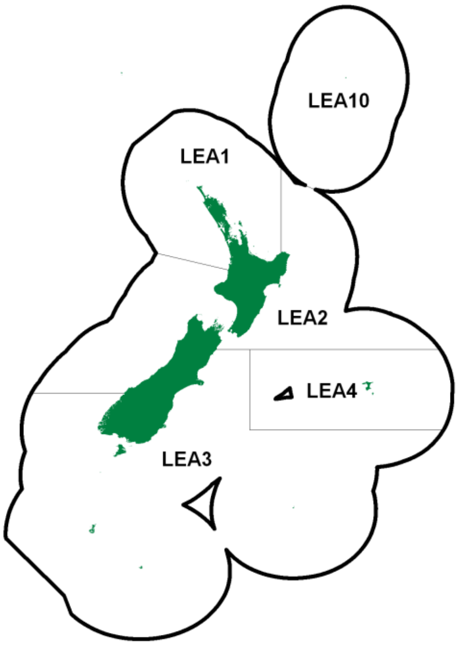
Fishery Interactions
-

7. FOR FURTHER INFORMATION

Morton, J; Miller, M (1968) *The New Zealand sea shore*. Collins, Auckland. 638 p.
Powell, A W B (1979) *New Zealand Mollusca*. Marine, land and freshwater shells. Collins, Auckland. 500 p.

LEATHERJACKET (LEA)

(*Meuschenia scaber*)
Kokiri, Hiriri



1. FISHERY SUMMARY

Leatherjacket was introduced into the QMS on 1 October 2003, with allowances, TACCs and TACs shown in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs for leatherjacket by Fishstock.

Fishstock	Recreational Allowance	Customary Non-Commercial Allowance	Other sources of mortality	TACC	TAC
LEA 1	5	1	9	188	203
LEA 2	2	1	57	1 136	1 196
LEA 3	2	1	5	100	108
LEA 4	1	1	1	7	10
LEA 10	0	0	0	0	0
Total	10	4	72	1 431	1 517

1.1 Commercial fisheries

Nationally, very small landings were first reported in 1948. Most of the current leatherjacket catch is taken as a bycatch, and it is very likely that leatherjacket has always been primarily a bycatch species. From only a few tonnes in the early 1960s, reported landings increased to 200–400 tonnes in the 1970s, 1980s and early 1990s (Table 3). Figure 1 shows the historical landings and TACC values for the main leatherjacket stocks. Landings increased further in the late 1990s to around 1000 to 1300 tonnes, but have decreased to less than 600 t since 2010–11. It is possible that actual catches were higher than reported prior to the 1970s, but that some catches were discarded without being reported due to low market demand in this period. On average over the last four years total landings have only been 41% of the TACC.

1.2 Recreational fisheries

The National Marine Recreational Fishing surveys in 1994, 1996 and 2000 do not provide an estimate of the non-commercial catches of leatherjacket because very few were caught. It is likely that recreational fishers, especially in the northern region, will have caught some leatherjacket by spear fishing, in rock lobster pots and setnets. Leatherjackets are seldom caught by hook and line.

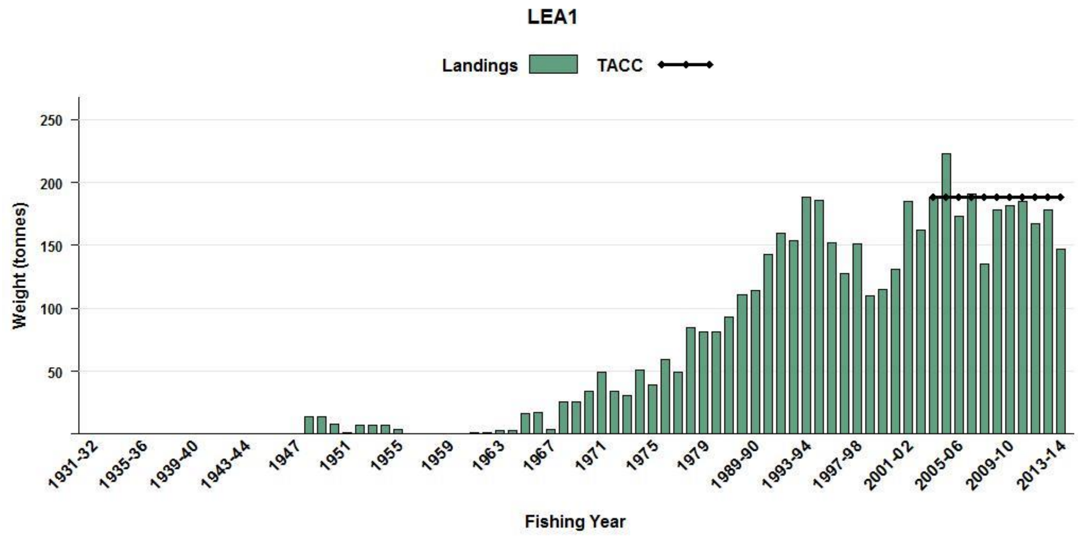
Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

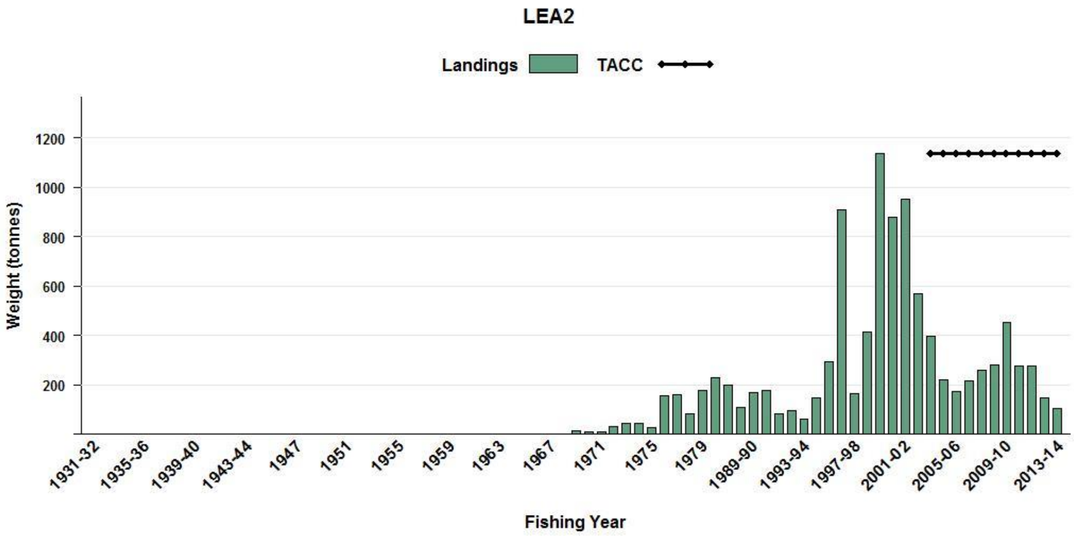
Year	LEA 1	LEA 2	LEA 3	LEA 4	Year	LEA 1	LEA 2	LEA 3	LEA 4
1931-32	0	0	0	0	1957	0	0	0	0
1932-33	0	0	0	0	1958	0	0	0	0
1933-34	0	0	0	0	1959	0	0	0	0
1934-35	0	0	0	0	1960	0	0	0	0
1935-36	0	0	0	0	1961	1	0	0	0
1936-37	0	0	0	0	1962	1	0	0	0
1937-38	0	0	0	0	1963	3	0	0	0
1938-39	0	0	0	0	1964	3	0	0	0
1939-40	0	0	0	0	1965	16	0	0	0
1940-41	0	0	0	0	1966	17	0	0	0
1941-42	0	0	0	0	1967	4	0	0	0
1942-43	0	0	0	0	1968	26	4	0	0
1943-44	0	0	0	0	1969	26	13	0	0
1944	0	0	0	0	1970	34	11	0	0
1945	0	0	0	0	1971	49	11	0	0
1946	0	0	0	0	1972	34	32	0	0
1947	0	0	0	0	1973	31	46	0	0
1948	14	0	0	0	1974	51	46	0	0
1949	14	0	0	0	1975	39	29	0	0
1950	8	0	0	0	1976	59	155	0	0
1951	1	0	0	0	1977	49	163	0	0
1952	7	0	0	0	1978	85	85	0	0
1953	7	0	0	0	1979	81	179	0	0
1954	7	0	0	0	1980	81	232	173	0
1955	4	0	0	0	1981	93	199	68	0
1956	0	0	0	0	1982	111	111	5	0

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported commercial landings (tonnes) of leatherjacket by fishstock for the fishing years from 1989–90 to 2013–14. Landings for LEA 10 have not been shown as these were negligible and were rounded to zero.

Fishstock	LEA 1		LEA 2		LEA 3		LEA 4			
FMA (s)	1&9		2&8		3, 5 & 6		4		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1989–90	114	-	169	-	42	-	-	-	325	-
1990–91	143	-	178	-	61	-	-	-	382	-
1991–92	160	-	85	-	100	-	-	-	345	-
1992–93	154	-	98	-	41	-	-	-	293	-
1993–94	188	-	62	-	37	-	-	-	287	-
1994–95	186	-	148	-	50	-	-	-	384	-
1995–96	152	-	296	-	38	-	-	-	486	-
1996–97	128	-	908	-	70	-	-	-	1 106	-
1997–98	151	-	165	-	66	-	-	-	382	-
1998–99	110	-	413	-	30	-	-	-	553	-
1999–00	115	-	1 136	-	35	-	-	-	1 286	-
2000–01	131	-	880	-	41	-	-	-	1 052	-
2001–02	185	-	953	-	43	-	-	-	1 181	-
2002–03	162	-	568	-	67	-	0	-	797	-
2003–04	189	188	396	1 136	28	100	0	7	613	1 431
2004–05	223	188	221	1 136	56	100	< 1	7	500	1 431
2005–06	173	188	172	1 136	60	100	0	7	405	1 431
2006–07	191	188	215	1 136	49	100	0	7	454	1 431
2007–08	135	188	258	1 136	73	100	0	7	466	1 431
2008–09	178	188	282	1 136	122	100	0	7	582	1 431
2009–10	181	188	455	1 136	117	100	0	7	754	1 431
2010–11	185	188	276	1 136	112	100	< 1	7	573	1 431
2011–12	167	188	277	1 136	127	100	< 1	7	571	1 431
2012-13	178	188	150	1136	114	100	0	7	442	1 431
2013-14	147	188	105	1136	132	130	0	7	384	1 461





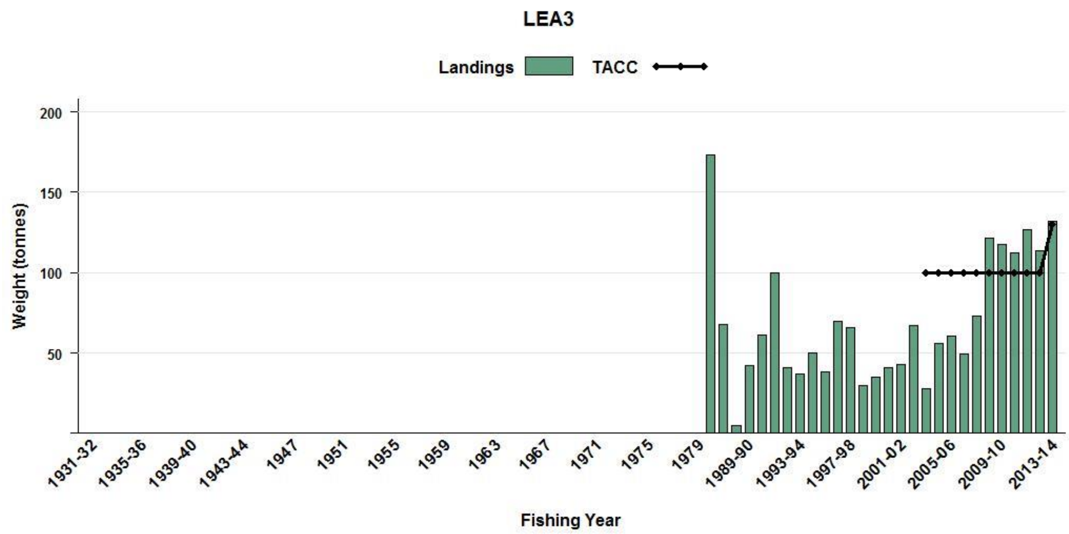


Figure 1: Reported commercial landings and TACCs for the main LEA stocks. From top to bottom: LEA 1 (Auckland), LEA 2 (Central), and LEA 3 (South East).

1.3 Customary non-commercial fisheries

There is no quantitative information available to allow the estimation of the amount of leatherjacket taken by customary non-commercial fishers.

2. BIOLOGY

The New Zealand leatherjacket (*Meuschenia scaber*) is present around much of New Zealand, but is most common in the north. Trawl survey records show it to be widespread over the inner shelf north of East Cape and Cape Egmont, in the South Taranaki Bight, in Tasman and Golden Bays, Pegasus Bay and the South Canterbury Bight, extending to depths below 100 m, but with greatest abundance at 40–60 m (Anderson et al 1998). It was less commonly caught along the east coast of the North Island south of East Cape, off the northeast South Island (Cook Strait to Pegasus Bay), northwest South Island (Cape Farewell to Cape Foulwind), and around the South Otago and Southland coast. It has not been taken by trawl on the west coast south of Cape Foulwind.

The New Zealand leatherjacket also occurs in Australia, from New South Wales to the southern coast of West Australia. In the Australian southeast trawl fishery, *Meuschenia scaber* is the main leatherjacket species caught (Yearsley et al 1999). It was once believed that two similar species of leatherjacket occurred in New Zealand – ‘rough’ and ‘smooth’ – but these are now considered to be a single species with variable colouring. Kokiri is the Maori name, but is not in common usage. ‘Creamfish’ is a New Zealand trade name for the processed (headed/gutted/skinned) product, rather than a name for the fish itself.

Leatherjacket usually occur near reefs and over rough seafloor, but may be found over sand or some distance above the bottom. Although not a schooling species, it does occur in small groups.

There are no published studies on the age and growth *M. scaber*. According to Francis (1996, 2012) they live to at least seven years, maturing at two years and 19–22 cm. The males defend territories and eggs are laid within nests on the seafloor in spring and summer (Ayling & Cox 1982, Milicich 1986).

3. STOCKS AND AREAS

3.1 Biomass estimates

There have been no biological studies directly relevant to the recognition of separate stocks.

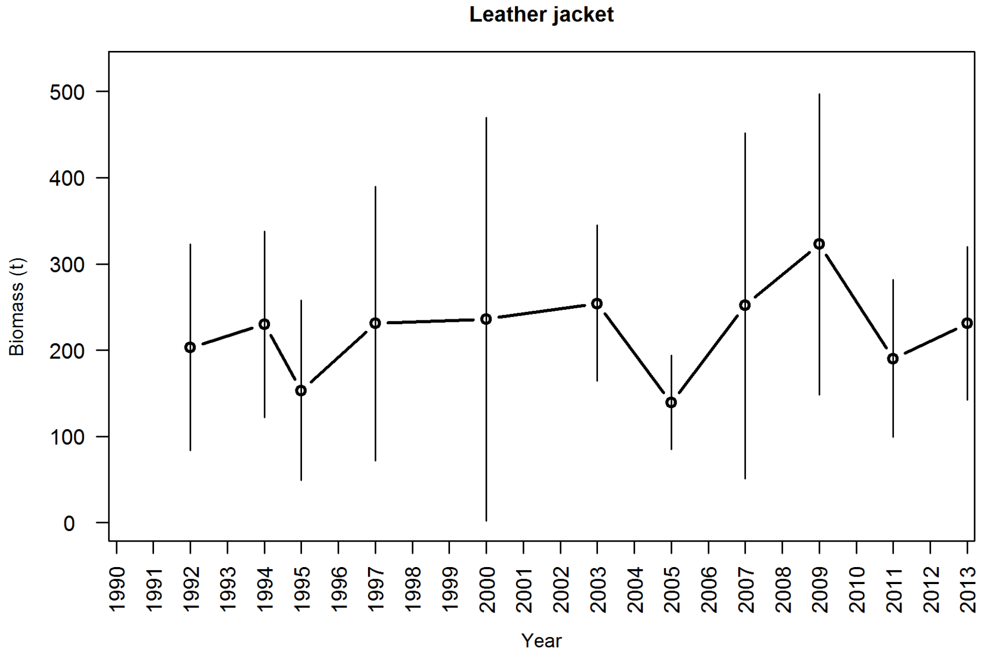


Figure 2: Leatherjacket biomass ±95% CI (estimated from survey CV's) and the time series mean (dotted line) estimated from the West Coast South Island trawl survey series.

The West Coast South Island (WCSI) trawl survey probably monitors pre-recruit biomass of leatherjacket. The total biomass trends are shown in Figure 2. Biomass estimates have fluctuated around the series mean since the survey began in 1993.

East coast South island winter trawl survey biomass estimates in the core strata (30–400 m) are not valid given that so few fish were caught, and coefficients of variations are generally high ranging from 36 to 66% (mean = 55%) and no biomass estimates are provided. Most of the biomass is captured in the 10–30 m depth indicating that the core plus shallow strata (10–400 m) is the only valid depth range within which to monitor leatherjacket biomass although it is doubtful that these surveys index leatherjacket abundance given that are found more commonly over foul ground and hence not fully available to trawl gear (Beentjes and MacGibbon 2013).

3.2 Length distributions

LEA were not caught in significant numbers on the ECSI winter surveys until 2007 when the shallow strata were included in the surveys. The length distributions in the core plus shallow strata (10–400 m) show at least three clear modes at about 10 cm, 16 cm, and 23 cm (combined males, females, and unsexed) (Beentjes and MacGibbon 2013). The core plus shallow strata survey is monitoring both pre-recruited cohorts, and fish in the recruited size range.

4. STOCK ASSESSMENT

There has been no scientific assessment of the maximum sustainable yield, reference or current biomass of any of the leatherjacket stocks.

A characterisation and CPUE analysis for the LEA 3 fishery was undertaken by Langley (2013). Leatherjacket in LEA 3 are landed throughout the year, taken almost exclusively by bottom trawl gear in Statistical Areas 021–025 and 030 (Figure 3). Almost all of the LEA catch is taken in the 10–50 m depth range. The characterisation revealed that most of the increase in LEA 3 catch since 2005–06 is attributable to increased landings of leatherjacket catch from bottom trawls targeting spiny dogfish in Foveaux Strait (025).

A CPUE standardisation was undertaken using catch and effort data that included all trips that landed or targeted LEA 3, but did not include trips that did not catch LEA 3. Landed catch was assigned to effort records proportional to estimated catch, following the Starr (2007) methodology, with some refinements where the data were aggregated to CELR equivalent format (vessel/day/method/statistical area/target species) and then the records were defined as CELR equivalent. This method was somewhat problematic due to difference in the reliability of reporting of fishing location and target species between the CELR and TCER form types. The Foveaux Strait and Canterbury Bight fisheries were analysed separately. The Foveaux Strait analysis was rejected by the Working Group and is therefore not reported further.

The Canterbury Bight analysis was limited to the bottom trawl (BT) fishery in Statistical Areas 020 and 022, targeting a range of target species (RCO, BAR, FLA, ELE, TAR, WAR and GUR). The dataset included trips where 1 kg or more of LEA 3 were landed. The analysis had large numbers of very small catches. Eight vessels accounted for 80% of the catch. The working group requested that the Canterbury Bight delta lognormal model targeting FLA, ELE, GUR from 2002 (Target FLA, GUR, ELE post QMS) be used as these are the years when the reporting is likely to be more reliable. There was an indication that CPUE from the Canterbury Bight fishery has increased since the early 2000s, and these indices were robust to some key assumptions. The index (Figure 4) showed that the CPUE remained low at the start of the series and then began to increase from 2007–08 to 2011–12. However, some concerns were raised about the low number of vessels in the analysis and the development of new markets for this species that may have increased targeting or retention of this species in recent years, suggesting that the index may not be reliable as an index of abundance.

The Working Group concluded that this analysis only pertains to the stock unit for the East Coast of the South Island; is the best available information on the stock abundance at this stage but trawl survey data may provide better information in the medium and long-term; and that this is a Level 2 assessment and should be given a medium or mixed (2) overall assessment quality rank.

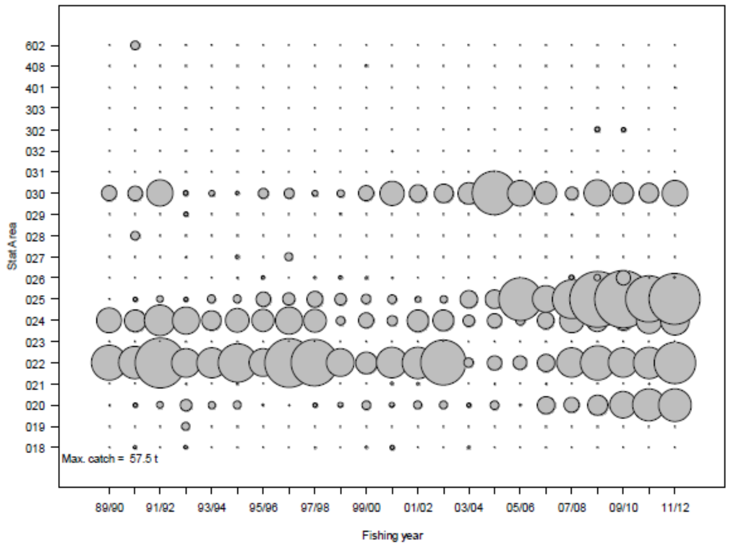


Figure 3: Distribution of reported catch for bottom trawl by Statistical Area in LEA 3 and fishing year from trips which landed leatherjacket in LEA 3 (Langley 2013).

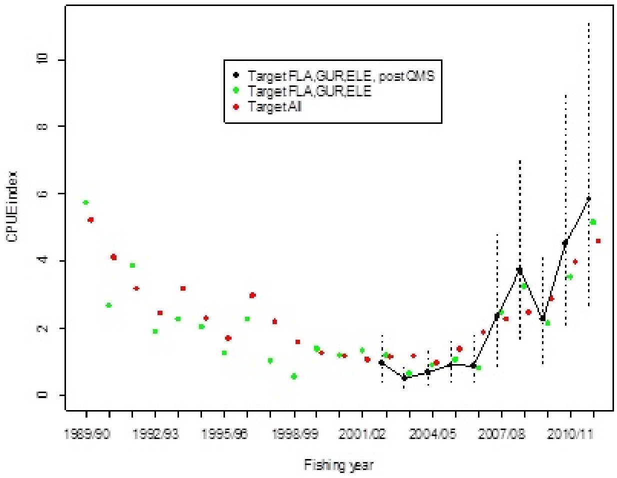


Figure 4: A comparison of three standardised CPUE indices for leatherjacket on the East Coast South Island Langley (2013).

5. STATUS OF THE STOCK

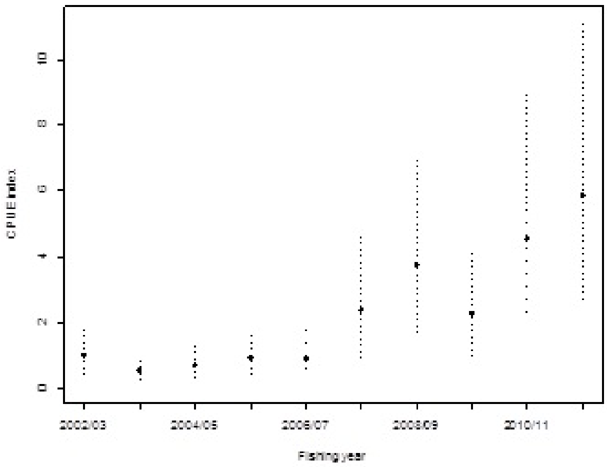
Stock Structure Assumptions

Stock structure is unknown but for management purposes the QMA boundaries are assumed to represent the stock boundaries for this species. There are two distinct areas of catch distribution within LEA 3 (Foveaux Strait and East Coast South Island) and these may represent distinct biological stocks.

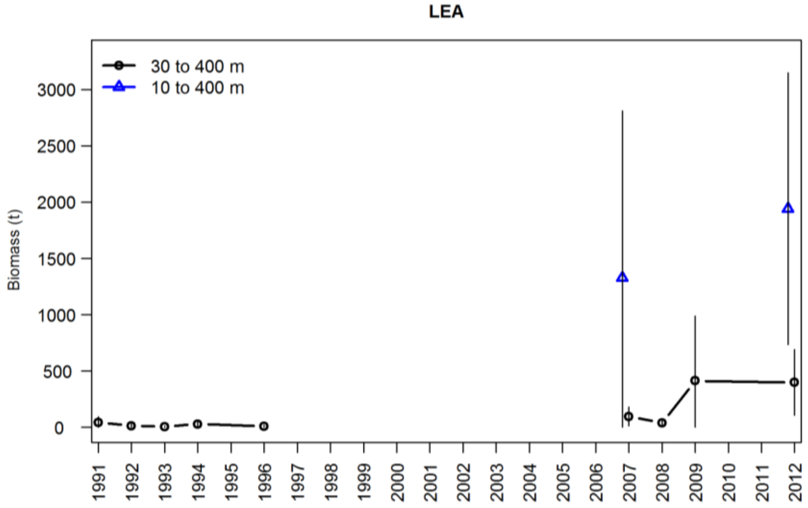
LEA 3 (East Coast South Island only**)**

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	CPUE: Target FLA, GUR, ELE post QMS
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%)
Status in relation to Overfishing	It is unknown whether overfishing is occurring

Historical Stock Status Trajectory and Current Status



The 2013 standardised CPUE index for leatherjacket on the East Coast South Island.



Biomass and 95% confidence intervals (total biomass only) for leatherjacket caught by the ECSI trawl survey core strata (30–400), and core plus shallow strata (10–400 m).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE remained low at the start of the series (2002) and then began to increase from 2007–08 to 2011–12. The biomass index from the East Coast South Island trawl survey 30–400m strata has increased since 2008.
Recent Trend in Fishing Intensity or Proxy	Unknown because new markets for this species may have increased targeting or retention in recent years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE	
Assessment Dates	Latest assessment: 2013	Next assessment: 2015
Overall assessment quality rank	2 - Medium or Mixed Quality: CPUE may be compromised by the low number of vessels in the analysis and trends in targeting or retention of leatherjacket; the trawl survey has only covered the entire habitat since 2007.	
Main data inputs (rank)	- catch and effort data from bottom trawl sets targeting FLA, GUR and ELE trawl survey biomass index	2 - Medium or mixed quality 2 - Medium or mixed quality
Data not used (rank)	Foveaux Strait CPUE index The trawl survey biomass estimates from the 10–400m strata.	3 – Low Quality: based on only a single vessel that has recently started targeting LEA. 3 – Low Quality: confidence intervals large and only two data points
Changes to Model Structure and Assumptions	New model	
Major sources of Uncertainty	The low number of vessels in the analysis and new markets for this species may have increased targeting or retention in recent years. Trends in CPUE may therefore be a result of changes in reporting and retention rather than abundance. Total trawl survey biomass estimates for the entire survey area (10–400m) have large confidence intervals.	

Qualifying Comments
-

Fishery Interactions
Leatherjacket are landed in fisheries targeting RCO, BAR, FLA, ELE, TAR, WAR and GUR, but are most commonly caught in FLA, GUR and ELE target bottom trawl sets. Some concerns have been raised about catch being taken in “hay paddocks”; these are polychaete worm beds that are biologically sensitive, habitat forming areas, which appear to be diminishing in areal extent as a consequence of disturbance from bottom trawling

Research Needs
Fishery characterisations that include interviews with fishers and processors are required to assess the degree to which changes in fishing practices and economic drivers may have influenced CPUE trends. Trawl surveys need to continue to include the shallow strata in order to monitor the abundance of leatherjacket on the east coast of the South Island.

Reported landings and TACCs by Fishstock for the 2013–14 fishing year are summarised in Table 4.

Table 4: Summary of TACCs (t) and reported landings (t) of leatherjacket for the most recent fishing year.

Fishstock		FMA	2013–14 Actual TACC	2013–14 Reported landings
LEA 1	Auckland (East) (West)	1, &9	188	178
LEA 2	Central (East) (West), Challenger	2,7&8	1 136	150
LEA 3	South east (coast), Southland, Sub-Antarctic	3, 4, 5 & 6	100	114
LEA 4	South east (Chatham)		7	0
Total			1 431	442

6. FURTHER INFORMATION

Anderson, O F; Bagley, N W; Hurst, R J; Francis, M P; Clark, M R; McMillan, P J (1998) Atlas of New Zealand fish and squid distributions from research bottom trawls. *NIWA Technical Report* 24. 303 p.

Ayling, A M; Cox, G J (1982) *Collins guide to the sea fishes of New Zealand.* Collins, Auckland. 343 p.

Beentjes, M P; MacGibbon, D; Lyon, W S (2015) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2014 (KAH1402). *New Zealand Fisheries Assessment Report 2015/14*. 136 p.

Beentjes, M P; MacGibbon, D J (2013) Review of QMS species for inclusion in the east coast South Island winter trawl survey reports. *New Zealand Fisheries Assessment Report 2013/35*. 102 p.

Beentjes, M P; MacGibbon, D (2013) Review of QMS species for inclusion in the east coast South Island winter trawl survey reports. *New Zealand Fisheries Assessment Report* 2013/35, 109 p.

Francis, M P (1996) *Coastal fishes of New Zealand. An identification guide*. Revised edition. Reed books, Auckland.

Francis, M (2012) *Coastal Fishes of New Zealand.* Fourth edition. Craig Potton Publishing, Nelson. 268 p.

Langley, A (2013) Characterisation and CPUE analysis for the LEA 3 fishery. SINS-WG-2013-27. 37 p. (Unpublished Working Group document held by Ministry for Primary Industries.).

MacGibbon, D J; Stevenson, M L (2013) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2013 (KAH1305) *New Zealand Fisheries Assessment Report 2013/66.* 115 p.

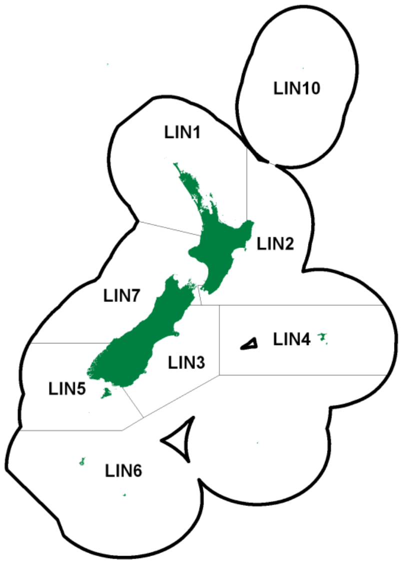
Milicich, M J (1986) Aspects of the early life history of *Paricka scabe*r (Pisces: Monacanthidae). M.Sc. thesis, University of Auckland.

Starr, P J (2007) Procedure for merging MFish Landing and Effort data. V2.0. Adaptive Management Programme Working Group paper 07/04. 17 p. (Unpublished document held by Ministry for Primary Industries, Wellington.)

Yearsley, G K; Last, P R; Ward, R D (Eds) (1999) Australian seafood handbook. An identification guide to domestic species. CSIRO Marine Research, Australia. 461 p.

LING

(*Genypterus blacodes*)
Hoka



1. FISHERY SUMMARY

Ling was introduced into the Quota Management System on 1 October 1986 with the following TACs, TACCs and allowances (Table 1).

Table 1: TACs (t), TACCs (t) and allowances (t) for ling.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
LIN 1	40	20	3	400	463
LIN 2	-	-	-	982	-
LIN 3	0	0	0	2060	2060
LIN 4	0	0	0	4200	4200
LIN 5	1	1	79	3955	4036
LIN 6	0	0	85	8505	8590
LIN 7	1	1	62	3080	3144
Total	42	22		23 182	22 493

1.1 Commercial fisheries

Ling was introduced into the Quota Management System (QMS) on 1 October 1986. Ling are widely distributed through the middle depths (200–800 m) of the New Zealand EEZ, particularly south of latitude 40° S. From 1975 to 1980 there was a substantial longline fishery on the Chatham Rise (and to a lesser extent in other areas) carried out by Japanese and Korean longliners. Since 1980 ling have been caught by large trawlers, both domestic and foreign owned, and by small domestic longliners and trawlers. In the early 1990s the domestic fleet was increased by the addition of several larger longliners with autoline equipment, resulting in a large increase in the catches of ling off the east and south of South Island (LIN 3, 4, 5 and 6). However, since about 2000 there has been a declining trend in catches taken by line vessels in most areas, offset, to some extent, by increased trawl landings.

The principal grounds for smaller domestic vessels are the west coast of South Island (WCSI) and the east coast of both main islands south of East Cape. For the large trawlers the main sources of ling are Puysegur Bank and the slope of the Stewart-Snares shelf and waters in the Auckland Islands area, and the Chatham Rise, primarily as bycatch of target fisheries for hoki. Longliners fish mainly in LIN 3, 4, 5 and 6. In 2013–14, landings from Fishstocks LIN 2, LIN 3, LIN 4 and LIN 6 were significantly under-caught relative to their TACCs, and the LIN 7 TACCs was slightly over-caught. Reported landings by nation from 1975 to 1987–88 are shown in Table 1, and reported landings by Fishstock from 1983–84 to 2013–14 are shown in Table 2. Figure 1 shows the historical landings and TACC values for the main LIN stocks.

Under the Adaptive Management Programme (AMP), the TACC for LIN 1 was increased to 400 t from 1 October 2002, and it remained at this level when LIN 1 was removed from the AMP on 30 September 2009. In a proposal for the 1994–95 fishing year, TACCs for LIN 3 and 4 were increased to 2810 and 5720 t, respectively. These stocks were removed from the AMP from 1 October 1998, with TACCs maintained at the increased level. However, from 1 October 2000, the TACCs for LIN 3 and 4 were reduced to 2060 and 4200 t, respectively. From 1 October 2004, the TACCs for LIN 5 and LIN 6 were increased by about 20% to 3595 t and 8505 t, respectively, and the LIN 5 was increased by a further 10% (to 3955 t) from 1 October 2013. From 1 October 2009, the TACC for LIN 7 was increased from 2225 t to 2474 t, and further increased to 3080 t from 1 October 2013. All other TACC increases since 1986–87 in all stocks are the result of quota appeals.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

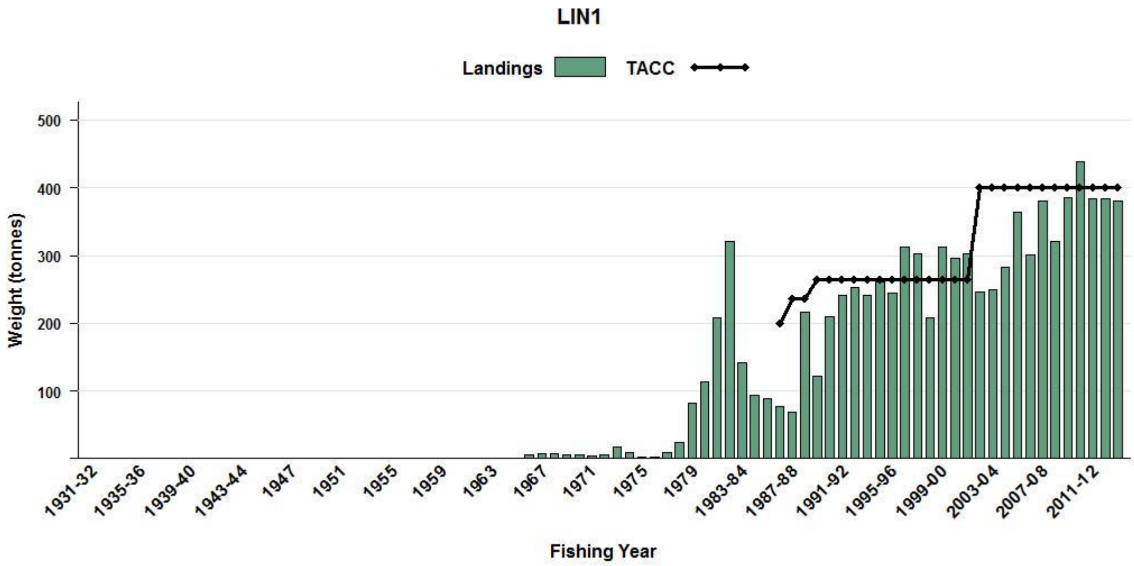
Year	LIN 1	LIN 2	LIN 3	LIN 4	Year	LIN 1	LIN 2	LIN 3	LIN 4
1931-32	0	0	11	0	1957	0	34	175	0
1932-33	0	63	14	0	1958	0	43	178	0
1933-34	0	146	59	0	1959	0	39	157	0
1934-35	0	217	70	0	1960	0	26	196	0
1935-36	0	146	124	0	1961	0	25	230	0
1936-37	0	133	103	0	1962	1	27	211	0
1937-38	0	91	320	0	1963	1	17	213	0
1938-39	0	66	280	0	1964	1	20	223	0
1939-40	0	40	320	0	1965	1	21	195	0
1940-41	1	85	286	0	1966	5	52	141	0
1941-42	0	64	308	0	1967	7	40	106	0
1942-43	0	54	254	0	1968	7	55	88	0
1943-44	0	83	264	0	1969	5	52	154	0
1944	0	103	224	0	1970	6	67	167	0
1945	1	122	199	0	1971	4	49	203	0
1946	0	153	348	0	1972	6	37	522	6
1947	0	203	474	0	1973	18	73	1425	0
1948	0	120	403	0	1974	9	102	575	42
1949	0	108	402	0	1975	3	70	1770	15
1950	0	84	352	0	1976	2	60	1567	14
1951	0	60	230	0	1977	9	100	1149	466
1952	0	69	235	0	1978	24	144	487	0
1953	0	62	212	0	1979	82	228	799	246
1954	0	75	208	0	1980	114	205	265	182
1955	0	48	160	0	1981	208	429	427	444
1956	0	27	155	0	1982	320	625	924	435

Year	LIN 5	LIN 6	LIN 7	Year	LIN 5	LIN 6	LIN 7
1931-32	1	0	0	1957	8	0	19
1932-33	2	0	35	1958	15	0	28
1933-34	1	0	67	1959	13	0	27
1934-35	1	0	94	1960	21	0	19
1935-36	1	0	66	1961	20	0	19
1936-37	1	0	61	1962	13	0	16
1937-38	1	0	57	1963	14	0	11
1938-39	24	0	37	1964	16	0	13
1939-40	16	0	26	1965	24	0	13
1940-41	21	0	46	1966	16	0	17
1941-42	22	0	40	1967	14	0	36
1942-43	24	0	29	1968	11	0	42
1943-44	19	0	40	1969	10	0	23
1944	13	0	46	1970	14	0	51
1945	13	0	80	1971	20	1	37
1946	9	0	78	1972	22	0	33
1947	24	0	96	1973	23	0	41
1948	24	0	66	1974	335	44	82
1949	20	0	67	1975	1513	344	224
1950	29	0	61	1976	2630	0	1739
1951	16	0	34	1977	1683	0	2810
1952	16	0	36	1978	2515	391	240
1953	19	0	34	1979	4400	1431	454
1954	7	0	44	1980	4064	933	928
1955	6	0	27	1981	3576	636	1020
1956	4	0	15	1982	2109	317	1208

Table 3: Reported landings (t) from 1975 to 1987–88. Data from 1975 to 1983 from MAF; data from 1983–84 to 1985–86 from FSU; data from 1986–87 to 1987–88 from QMS. –, no data available.

Fishing year	New Zealand			Foreign Licensed					Grand total
				Longline	Trawl			Total	
	Domestic	Chartered	Total	(Japan + Korea)	Japan	Korea	USSR	Total	
1975*	486	0	486	9 269	2 180	0	0	11 499	11 935
1976*	447	0	447	19 381	5 108	0	1 300	25 789	26 236
1977*	549	0	549	28 633	5 014	200	700	34 547	35 096
1978–79#	657	24	681	8 904	3 151	133	452	12 640	13 321
1979–80#	915	2 598	3 513	3 501	3 856	226	245	7 828	11 341
1980–81#	1 028	–	–	–	–	–	–	–	–
1981–82#	1 581	2 423	4 004	0	2 087	56	247	2 391	6 395
1982–83#	2 135	2 501	4 636	0	1 256	27	40	1 322	5 958
1983†	2 695	1 523	4 218	0	982	33	48	1 063	5 281
1983–84§	2 705	2 500	5 205	0	2 145	173	174	2 491	7 696
1984–85§	2 646	2 166	4 812	0	1 934	77	130	2 141	6 953
1985–86§	2 126	2 948	5 074	0	2 050	48	33	2 131	7 205
1986–87§	2 469	3 177	5 646	0	1 261	13	21	1 294	6 940
1987–88§	2 212	5 030	7 242	0	624	27	8	659	7 901

* Reported by calendar year
\# Reported April 1 to March 31(except domestic vessels, which reported by calendar year).
† Reported April 1 to Sept 30 (except domestic vessels, which reported by calendar year).
§ Reported Oct 1 to Sept 30.



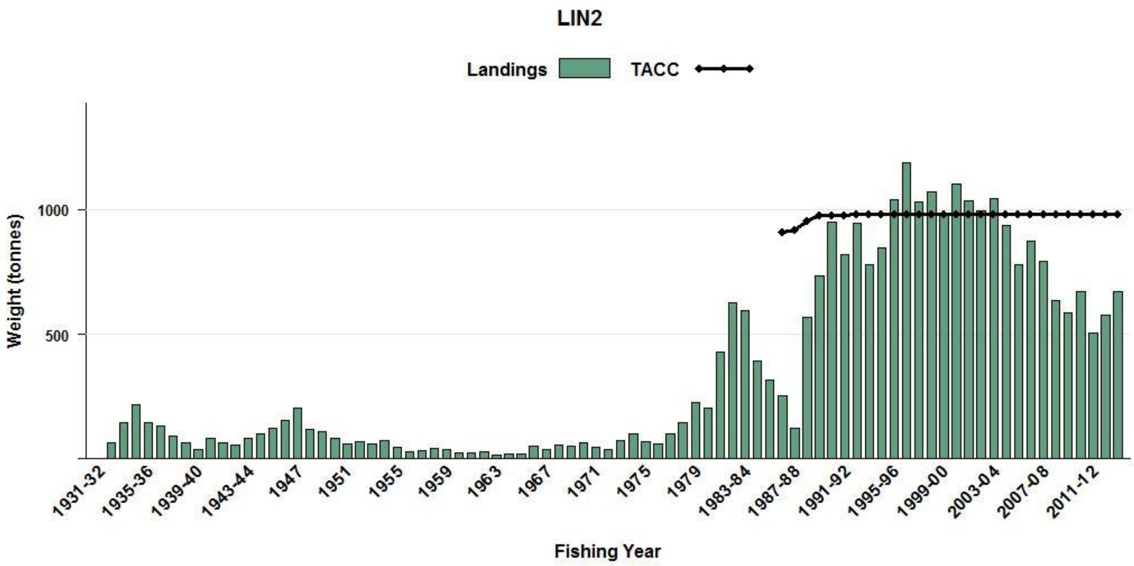
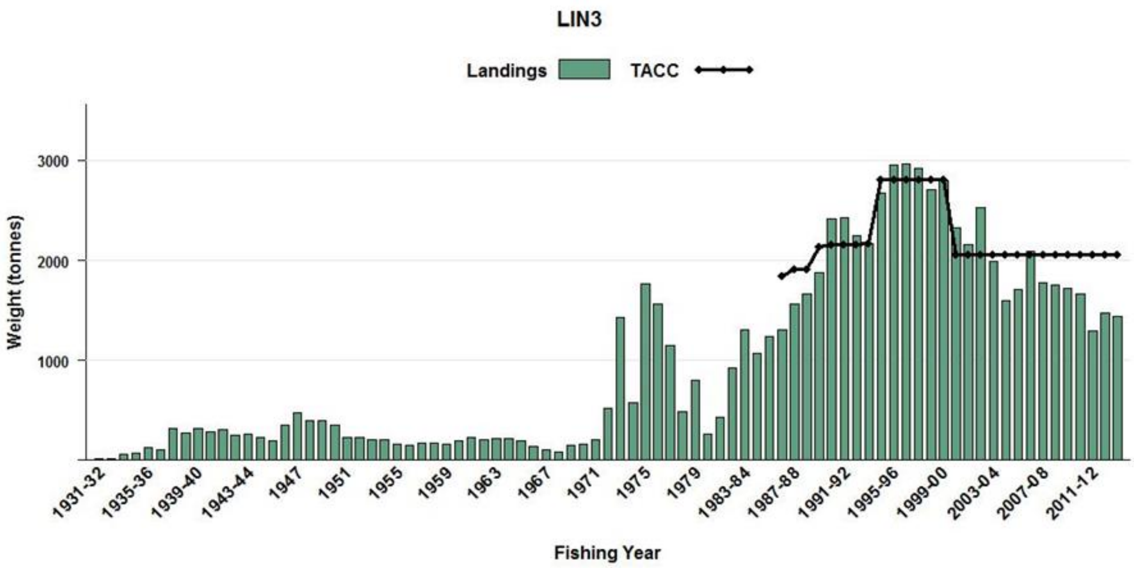
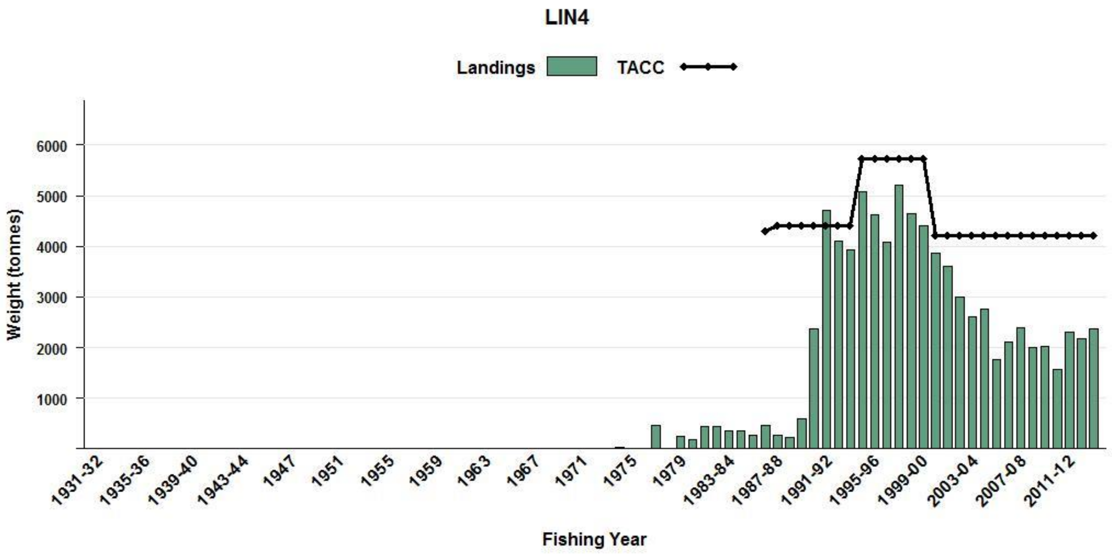


Figure 1: Reported commercial landings and TACC for the seven main LIN stocks. From top to bottom: LIN 1 (Auckland East) and LIN 2 (Central East) {Continued on next page].





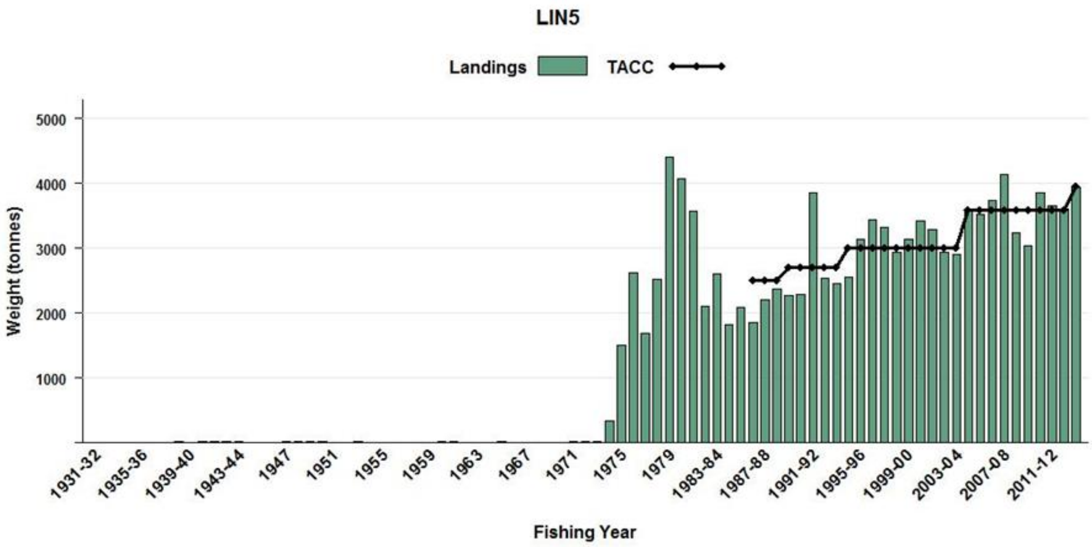
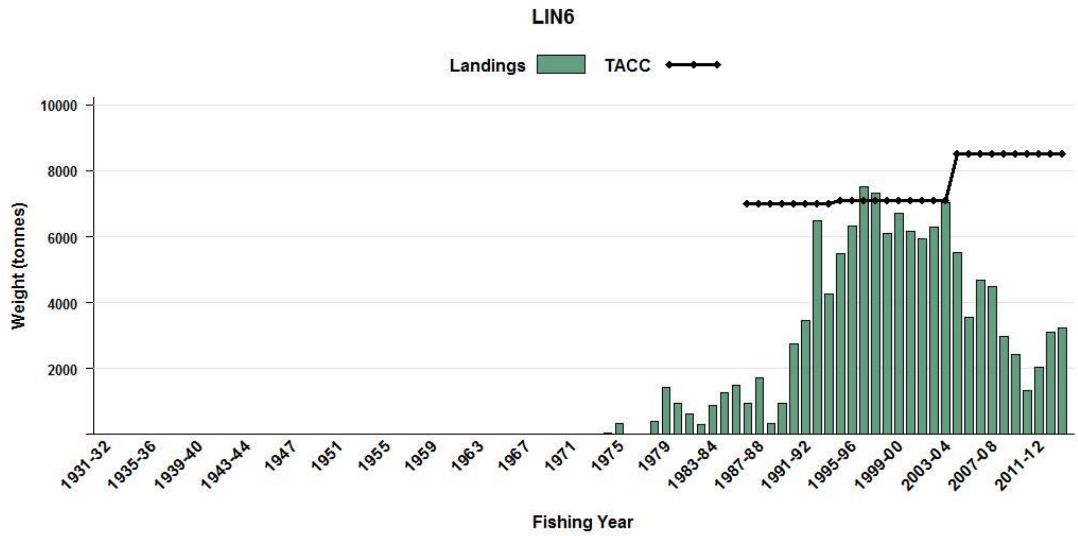


Figure 1 (continued): Reported commercial landings and TACC for the seven main LIN stocks. From top to bottom: LIN 3 (South East Coast), LIN 4 (South East Chatham Rise) and LIN 5 (Southland). [Continued on next page].



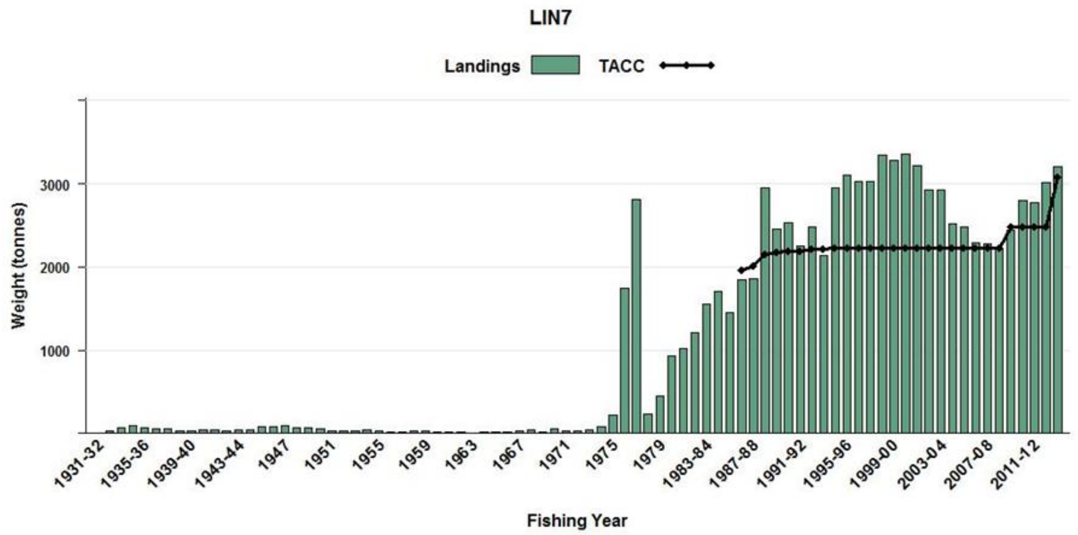


Figure 1 (continued): Reported commercial landings and TACC for the seven main LIN stocks. From top to bottom: LIN 6 (Sub-Antarctic), and LIN 7 (Challenger)

1.2 Recreational fisheries

The 1993–94 North region recreational fishing survey (Bradford 1996) estimated the annual recreational catch from LIN 1 as 10 000 fish (CV 0.23). With a mean weight likely to be in the range of 1.5 to 4 kg, this equates to a harvest of 15–40 t.

Recreational catch was recorded from LIN 1, 5, and 7 in the 1996 national diary survey. The estimated harvests (LIN 1, 3000 fish; LIN 5, less than 500; LIN 7, less than 500) were too low to provide reliable estimates.

1.3 Customary non-commercial fisheries

Quantitative information on the level of Maori customary non-commercial take is not available. Ling bones have been recovered from archaic middens throughout the South Island and southern North Island, and on Chatham Island (Leach & Boocock 1993). In South and Chatham Islands, ling comprised about 4% (by number) of recovered fish remains.

1.4 Illegal catch

It is believed that up to the mid-1990s some ling bycatch from the west coast hoki fishery was not reported. Estimates of total catch including non-reported catch are given in Table 4 for LIN 7. It is believed that in recent years, some catch from LIN 7 has been reported against other ling stocks (probably LIN 3, 5, and 6). The likely levels of misreporting are moderate, being about 250–400 t in each year from 1989–90 to 1991–92 (Dunn 2003).

1.5 Other sources of mortality

The extent of any other sources of mortality is unknown.

Table 4: Reported landings (t) of ling by Fishstock from 1983–84 to 2013–14 and actual TACCs (t) from 1986–87 to 2013–14. Estimated landings for LIN 7 from 1987–88 to 1992–93 include an adjustment for ling bycatch of hoki trawlers, based on records from vessels carrying observers. QMS data from 1986-present.

Fishstock	LIN 1		LIN 2		LIN 3		LIN 4		LIN 5	
FMA (s)	1 & 9		2		3		4		5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	141	–	594	–	1 306	–	352	–	2 605	–
1984–85*	94	–	391	–	1 067	–	356	–	1 824	–
1985–86*	88	–	316	–	1 243	–	280	–	2 089	–
1986–87	77	200	254	910	1 311	1 850	465	4 300	1 859	2 500
1987–88	68	237	124	918	1 562	1 909	280	4 400	2 213	2 506
1988–89	216	237	570	955	1 665	1 917	232	4 400	2 375	2 506
1989–90	121	265	736	977	1 876	2 137	587	4 401	2 277	2 706
1990–91	210	265	951	977	2 419	2 160	2 372	4 401	2 285	2 706
1991–92	241	265	818	977	2 430	2 160	4 716	4 401	3 863	2 706
1992–93	253	265	944	980	2 246	2 162	4 100	4 401	2 546	2 706
1993–94	241	265	779	980	2 171	2 167	3 920	4 401	2 460	2 706
1994–95	261	265	848	980	2 679	2 810	5 072	5 720	2 557	3 001
1995–96	245	265	1 042	980	2 956	2 810	4 632	5 720	3 137	3 001
1996–97	313	265	1 187	982	2 963	2 810	4 087	5 720	3 438	3 001
1997–98	303	265	1 032	982	2 916	2 810	5 215	5 720	3 321	3 001
1998–99	208	265	1 070	982	2 706	2 810	4 642	5 720	2 937	3 001
1999–00	313	265	983	982	2 799	2 810	4 402	5 720	3 136	3 001
2000–01	296	265	1 105	982	2 330	2 060	3 861	4 200	3 430	3 001
2001–02	303	265	1 034	982	2 164	2 060	3 602	4 200	3 295	3 001
2002–03	246	400	996	982	2 529	2 060	2 997	4 200	2 939	3 001
2003–04	249	400	1 044	982	1 990	2 060	2 618	4 200	2 899	3 001
2004–05	283	400	936	982	1 597	2 060	2 758	4 200	3 584	3 595
2005–06	364	400	780	982	1 711	2 060	1 769	4 200	3 522	3 595
2006–07	301	400	874	982	2 089	2 060	2 113	4 200	3 731	3 595
2007–08	381	400	792	982	1 778	2 060	2 383	4 200	4 145	3 595
2008–09	320	400	634	982	1 751	2 060	2 000	4 200	3 232	3 595
2009–10	386	400	584	982	1 718	2 060	2 026	4 200	3 034	3 595
2010–11	438	400	670	982	1 665	2 060	1 572	4 200	3 856	3 595
2011–12	384	400	504	982	1 292	2 060	2 305	4 200	3 649	3 595
2012–13	383	400	579	982	1 475	2 060	2 181	4 200	3 610	3 595
2013–14	380	400	673	982	1 442	2 060	2 373	4 200	3 935	3 955

Fishstock	LIN 6		LIN 7			LIN 10		Total	
FMA (s)	6		7 & 8			10			
	Landings	TACC	Reported Landings	Estimated Landings	TACC	Landings	TACC	Landings§	TACC
1983–84*	869	–	1 552	–	–	0	–	7 696	–
1984–85*	1 283	–	1 705	–	–	0	–	6 953	–
1985–86*	1 489	–	1 458	–	–	0	–	7 205	–
1986–87	956	7 000	1 851	–	1 960	0	10	6 940	18 730
1987–88	1 710	7 000	1 853	1 777	2 008	0	10	7 901	18 988
1988–89	340	7 000	2 956	2 844	2 150	0	10	8 404	19 175
1989–90	935	7 000	2 452	3 171	2 176	0	10	9 028	19 672
1990–91	2 738	7 000	2 531	3 149	2 192	< 1	10	13 506	19 711
1991–92	3 459	7 000	2 251	2 728	2 192	0	10	17 778	19 711
1992–93	6 501	7 000	2 475	2 817	2 212	< 1	10	19 065	19 737
1993–94	4 249	7 000	2 142	–	2 213	0	10	15 961	19 741
1994–95	5 477	7 100	2 946	–	2 225	0	10	19 841	22 111
1995–96	6 314	7 100	3 102	–	2 225	0	10	21 428	22 111
1996–97	7 510	7 100	3 024	–	2 225	0	10	22 522	22 113
1997–98	7 331	7 100	3 027	–	2 225	0	10	23 145	22 113
1998–99	6 112	7 100	3 345	–	2 225	0	10	21 034	22 113
1999–00	6 707	7 100	3 274	–	2 225	0	10	21 615	22 113
2000–01	6 177	7 100	3 352	–	2 225	0	10	20 552	19 843
2001–02	5 945	7 100	3 219	–	2 225	0	10	19 561	19 843
2002–03	6 283	7 100	2 918	–	2 225	0	10	18 903	19 978
2003–04	7 032	7 100	2 926	–	2 225	0	10	18 760	19 978
2004–05	5 506	8 505	2 522	–	2 225	0	10	17 189	21 977
2005–06	3 553	8 505	2 479	–	2 225	0	10	14 184	21 977
2006–07	4 696	8 505	2 295	–	2 225	0	10	16 102	21 977
2007–08	4 502	8 505	2 282	–	2 225	0	10	16 264	21 977
2008–09	2 977	8 505	2 223	–	2 225	0	10	13 137	21 977
2009–10	2 414	8 505	2 446	–	2 474	0	10	12 609	22 226
2010–11	1 335	8 505	2 800	–	2 474	0	10	12 337	22 226
2011–12	2 047	8 505	2 771	–	2 474	0	10	12 953	22 226
2012–13	3 102	8 505	3 010	–	2 474	0	10	14 339	22 226
2013–14	3 221	8 505	3 200	–	3 080	0	10	15 224	23 192

* FSU data.

§ Includes landings from unknown areas before 1986–87, and areas outside the EEZ since 1995–96.

2. BIOLOGY

The maximum age recorded for New Zealand ling is 46 years, although only 0.5% of successfully aged ling have been older than 30 years. A growth study of ling from five areas (west coast South Island, Chatham Rise, Bounty Plateau, Campbell Plateau, Cook Strait) showed that females grew significantly faster and reached a greater size than males in all areas, and that growth rates were significantly different between areas. Ling grow fastest in Cook Strait and slowest on the Campbell Plateau (Horn 2005).

M was initially estimated from the equation $M = \log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. The mean M calculated from five samples of age data was 0.18 (range = 0.17–0.20). However, a recent review of M, and results of modelling conducted in 2007, suggests that this parameter may vary between stocks (Horn 2008b). The M for Chatham Rise ling appears to be lower than 0.18, while for Cook Strait and west coast South Island the value is probably higher than 0.18. M has been estimated in assessment model runs for some stocks (see section 4).

Ling in spawning condition have been reported in a number of localities throughout the EEZ (Horn 2005, 2015). Time of spawning appears to vary between areas: August to October on the Chatham Rise; September to December on Campbell Plateau and Puysegur Bank; September to February on the Bounty Plateau; July to September off west coast South Island and in Cook Strait. Little is known about the distribution of juveniles until they are about 40 cm total length, when they begin to appear in trawl samples over most of the adult range.

Ling appear to be mainly bottom dwellers, feeding on crustaceans such as *Munida* and scampi and also on fish, with commercial fishing discards being a significant dietary component (Dunn et al. 2010). However, they may at times be caught well above the bottom, for example when feeding on hoki during the hoki spawning season.

Biological parameters relevant to the stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters. See Section 3 for definitions of Fishstocks.

Fishstock	Estimate
1. Natural mortality (M)	
All stocks average (both sexes)	$M = 0.18$

2. Weight = a (length)^b (Weight in g, length in cm total length)

	Female		Male		Combined		Area
	a	b	a	b	a	b	
LIN 3&4	0.00114	3.318	0.00100	3.354	–	–	Chatham Rise
LIN 5&6	0.00128	3.303	0.00208	3.190	–	–	Southern Plateau
LIN 6B	0.00114	3.318	0.00100	3.354	–	–	Bounty Plateau
LIN 7WC	0.000934	3.368	0.001146	3.318	0.001040	3.318	West Coast S.I.
LIN 7CK	0.000934	3.368	0.001146	3.318	–	–	Cook Strait

3. von Bertalanffy growth parameters

	Female			Male			Combined			Area
	K	t_0	L_∞	K	t_0	L_∞	K	t_0	L_∞	
LIN 3&4	0.083	–0.74	156.4	0.127	–0.70	113.9	–	–	–	Chatham Rise
LIN 5&6	0.124	–1.26	115.1	0.188	–0.67	93.2	–	–	–	Southern Plateau
LIN 6B	0.101	–0.53	146.2	0.141	0.02	120.5	–	–	–	Bounty Plateau
LIN 7WC	0.078	–0.87	169.3	0.067	–2.37	159.9	0.077	-1.37	150.8	West Coast S.I.
LIN 7CK	0.097	–0.54	163.6	0.080	–1.94	158.9	–	–	–	Cook Strait

3. STOCKS AND AREAS

A review of ling stock structure (Horn 2005) examined diverse information from studies of morphometrics, genetics, growth, population age structures, and reproductive biology and behaviour, and indicated that there are at least five ling stocks, i.e., west coast South Island, Chatham Rise, Cook Strait, Bounty Plateau, and the Southern Plateau (including the Stewart-Snares shelf and Puysegur Bank). Stock affinities of ling north of Cook Strait are unknown, but spawning is known to occur off Northland, Cape Kidnappers, and in the Bay of Plenty.

4. STOCK ASSESSMENT

LIN 1 was previously managed and assessed under the Adaptive Management Program (see section 5). An updated CPUE analysis for the ling target bottom longline fishery in LIN 2 was conducted in 2014. The stock assessments for two ling stocks (LIN 3&4, Chatham Rise; LIN 5&6, Sub-Antarctic) were updated in 2015. Assessments for other stocks were updated in 2007 (LIN 6B, Bounty Plateau, with a CPUE update in 2014), or 2013 (LIN 7WC, west coast South Island; LIN 7CK, Cook Strait). All assessments (excluding LIN 1 and LIN 2) were updated using a Bayesian stock model implemented using the general-purpose stock assessment program CASAL (Bull et al. 2012).

4.1 Estimates of fishery parameters and abundance

Catch histories by stock and fishery are presented in Table 6, and other model input parameters are shown in Table 7. Estimates of relative abundance from standardised CPUE analyses (Table 8) and trawl surveys (Table 9) are also presented below.

Table 6: Estimated catch histories (t) for LIN 2 (ECNI), LIN 3&4 (Chatham Rise), LIN 5&6 (Campbell Plateau), LIN 6B (Bounty Platform), LIN 7WC (WCSI section of LIN 7), and LIN 7CK (Cook Strait). Landings have been separated by fishing method (trawl or line), and, for the LIN 5&6 line fishery, by pre-spawning (Pre) and spawning (Spn) season.

Year	LIN 2		LIN 3&4		LIN 5&6			LIN 6B	LIN 7WC		LIN 7CK	
	trawl	line	trawl	line	trawl	line	line	line	trawl	line	trawl	line
	–	–				Pre	Spn					
1972	–	–	0	0	0	0	0	0	0	0	0	0
1973	–	–	250	0	500	0	0	0	85	20	45	45
1974	–	–	382	0	1 120	0	0	0	144	40	45	45
1975	–	–	953	8 439	900	118	192	0	401	800	48	48
1976	–	–	2 100	17 436	3 402	190	309	0	565	2 100	58	58
1977	–	–	2 055	23 994	3 100	301	490	0	715	4 300	68	68
1978	–	–	1 400	7 577	1 945	494	806	10	300	323	78	78
1979	–	–	2 380	821	3 707	1 022	1 668	0	539	360	83	83
1980	–	–	1 340	360	5 200	0	0	0	540	305	88	88
1981	–	–	673	160	4 427	0	0	10	492	300	98	98
1982	–	–	1 183	339	2 402	0	0	0	675	400	103	103
1983	–	–	1 210	326	2 778	5	1	10	1 040	710	97	97
1984	–	–	1 366	406	3 203	2	0	6	924	595	119	119
1985	–	–	1 351	401	4 480	25	3	2	1 156	302	116	116
1986	–	–	1 494	375	3 182	2	0	0	1 082	362	126	126
1987	–	–	1 313	306	3 962	0	0	0	1 105	370	97	97
1988	–	–	1 636	290	2 065	6	0	0	1 428	291	107	107
1989	–	–	1 397	488	2 923	10	2	9	1 959	370	255	85
1990	134	85	1 934	529	3 199	9	4	12	2 205	399	362	121
1991	185	162	2 563	2 228	4 534	392	97	33	2 163	364	488	163
1992	299	110	3 451	3 695	6 237	566	518	908	1 631	661	498	85
1993	381	97	2 375	3 971	7 335	1 238	474	969	1 609	716	307	114
1994	397	96	1 933	4 159	5 456	770	486	1 149	1 136	860	269	84
1995	398	97	2 222	5 530	5 348	2 355	338	396	1 750	1 032	344	70
1996	350	149	2 725	4 863	6 769	2 153	531	381	1 838	1 121	392	35
1997	269	168	3 003	4 047	6 923	3 412	614	340	1 749	1 077	417	89
1998	387	148	4 707	3 227	6 032	4 032	581	395	1 887	1 021	366	88
1999	257	169	3 282	3 818	5 593	2 721	489	563	2 146	1 069	316	216
2000	286	166	3 739	2 779	7 089	1 421	1 161	991	2 247	923	317	131
2001	344	216	3 467	2 724	6 629	818	1 007	1 064	2 304	977	258	80
2002	366	212	2 979	2 787	6 970	426	1 220	629	2 250	810	230	171
2003	344	124	3 375	2 150	7 205	183	892	922	1 980	807	280	180
2004	420	82	2 525	2 082	7 826	774	471	853	2 013	814	241	227
2005	333	54	1 913	2 440	7 870	276	894	49	1 558	871	200	282
2006	365	45	1 639	1 840	6 161	178	692	43	1 753	666	129	220
2007	425	87	2 322	1 880	7 504	34	651	236	1 306	933	107	189
2008	457	37	2 350	1 810	6 990	329	821	503	1 067	1 170	115	110
2009	394	49	1 534	2 217	5 225	276	432	232	1 089	1 009	108	39
2010	409	37	1 484	2 257	4 270	864	313	1	1 346	1 063	74	14
2011	426	51	1 191	2 046	4 404	567	169	51	1 733	1 011	115	67
2012	288	57	1 407	2 190	4 384	934	376	2	1 744	976	96	47
2013	317	44	1 113	2 543	6 234	135	340	3	1 915	1 045	104	106
2014	–	–	1 340	2 250	4 900	550	330	–	–	–	–	–

Table 7: Input parameters for the assessed stocks.

Parameter	LIN 3&4	LIN 5&6	LIN 6B	LIN 7WC	LIN 7CK
Stock-recruitment steepness	0.84	0.84	0.9	0.84	0.9
Recruitment variability CV	0.6	0.6	1.0	0.6	0.7
Ageing error CV	0.05	0.06	0.05	0.05	0.07
Proportion male at birth	0.5	0.5	0.5	0.5	0.5
Proportion of mature that spawn	1.0	1.0	1.0	1.0	1.0
Maximum exploitation rate (U_{max})	0.6	0.6	0.6	0.6	0.6

Maturity ogives*

Age	3	4	5	6	7	8	9	10	11	12	13	14	15
LIN 3&4 (and assumed for LIN 6B)													
Male	0.0	0.027	0.063	0.14	0.28	0.48	0.69	0.85	0.93	0.97	0.99	1.00	1.0
Female	0.0	0.001	0.003	0.006	0.014	0.033	0.08	0.16	0.31	0.54	0.76	0.93	1.0
LIN 5&6													
Male	0.0	0.00	0.10	0.30	0.50	0.80	1.00	1.00	1.00	1.0			
Female	0.0	0.00	0.05	0.10	0.30	0.50	0.80	1.00	1.00	1.0			
LIN 7WC (and assumed for LIN7CK)													
Male	0.0	0.015	0.095	0.39	0.77	0.94	1.00	1.00	1.00	1.0			
Female	0.0	0.004	0.017	0.06	0.18	0.39	0.65	0.85	0.94	1.0			
Combined	0.0	0.010	0.056	0.23	0.48	0.67	0.83	0.93	0.97	1.0			

*Proportion mature at age

Table 8: Standardised CPUE indices (with CVs) for the ling line and trawl fisheries. Year refers to calendar year; sp=spawning fishery; nsp=non-spawning fishery.

	LIN 2 line		LIN 3&4 line		LIN 5&6 line (sp)		LIN 5&6 line (nsp)		LIN 6B line	
Year	CPUE	CV	CPUE	CV	CPUE	CV	CPUE	CV	CPUE	CV
1991	–	–	1.67	0.06	1.39	0.17	0.67	0.12	–	–
1992	1.64	0.09	2.43	0.06	1.81	0.14	1.07	0.09	1.74	0.15
1993	1.40	0.08	1.73	0.05	1.78	0.11	1	0.10	1.41	0.13
1994	1.55	0.09	1.65	0.05	1.48	0.11	0.76	0.09	0.95	0.16
1995	1.54	0.07	1.68	0.05	1.48	0.17	1.10	0.08	1.24	0.13
1996	1.34	0.07	1.31	0.05	1.40	0.11	0.85	0.09	1.15	0.12
1997	1.29	0.07	0.88	0.04	1.22	0.11	0.96	0.06	0.92	0.14
1998	1.27	0.07	0.90	0.05	1.10	0.11	0.90	0.07	1.06	0.12
1999	1.13	0.07	0.80	0.04	1.25	0.10	0.64	0.05	1.07	0.11
2000	0.80	0.07	0.93	0.05	1.32	0.10	0.74	0.07	0.95	0.10
2001	0.60	0.08	0.93	0.04	1.27	0.09	0.90	0.08	0.76	0.11
2002	0.97	0.08	0.77	0.04	1.58	0.10	0.77	0.10	0.69	0.11
2003	0.88	0.07	0.85	0.05	1.14	0.12	0.60	0.12	0.78	0.10
2004	1.07	0.07	0.81	0.04	1.04	0.09	0.57	0.09	0.74	0.16
2005	1.00	0.08	0.85	0.04	1.47	0.12	0.52	0.13	–	–
2006	0.88	0.07	0.74	0.05	1.30	0.12	0.60	0.14	–	–
2007	0.95	0.07	0.81	0.04	1.39	0.11	0.74	0.26	–	–
2008	0.85	0.07	1.04	0.04	1.05	0.14	0.87	0.13	–	–
2009	0.89	0.08	0.73	0.04	2.09	0.19	0.76	0.13	–	–
2010	0.90	0.07	0.84	0.04	0.69	0.19	0.91	0.09	–	–
2011	0.82	0.06	0.65	0.04	1.04	0.15	0.58	0.09	–	–
2012	0.56	0.07	0.79	0.05	1.13	0.15	0.73	0.08	–	–
2013	0.65	0.08	0.80	0.07	–	–	–	–	–	–

	LIN 7WC line		LIN 7CK line		LIN 7CK trawl		LIN 7WC trawl	
Year	CPUE	CV	–	–	CPUE	CV	CPUE	CV
1987	–	–	–	–	–	–	0.49	0.07
1988	–	–	–	–	–	–	0.92	0.06
1989	–	–			–	–	1.33	0.06
1990	0.90	0.07	1.29	0.15	–	–	1.27	0.06
1991	1.07	0.06	1.44	0.13	–	–	0.81	0.06
1992	1.25	0.05	1.43	0.11	–	–	0.76	0.07
1993	0.90	0.05	1.11	0.11	–	–	1.04	0.06
1994	0.88	0.05	0.90	0.11	1.25	0.05	0.91	0.05
1995	0.90	0.04	0.83	0.12	1.16	0.04	1.31	0.06
1996	0.68	0.04	0.97	0.13	1.12	0.04	1.73	0.05
1997	0.80	0.05	1.32	0.18	1.00	0.04	1.40	0.06
1998	0.92	0.05	0.83	0.15	1.01	0.04	1.36	0.05
1999	0.95	0.05	1.54	0.18	1.02	0.03	1.59	0.05
2000	0.96	0.04	1.45	0.19	1.27	0.04	1.23	0.04
2001	1.12	0.05	1.27	0.18	1.46	0.04	0.94	0.04
2002	1.06	0.05	2.04	0.11	1.27	0.05	1.27	0.04
2003	1.10	0.04	1.66	0.10	1.27	0.04	0.71	0.05
2004	1.10	0.05	1.45	0.09	1.13	0.04	1.12	0.04
2005	0.84	0.04	1.16	0.10	1.18	0.04	0.79	0.04
2006	0.84	0.05	0.97	0.15	1.10	0.05	0.73	0.04
2007	1.11	0.04	0.70	0.12	0.73	0.06	0.55	0.06
2008	1.13	0.05	0.82	0.22	0.90	0.06	0.54	0.06
2009	1.14	0.05	0.60	0.28	0.44	0.07	0.48	0.06
2010	1.39	0.05	0.35	0.30	0.44	0.07	0.63	0.06
2011	1.28	0.07	0.22	0.30	0.23	0.09	1.06	0.06

Table 9: Biomass indices (t) and estimated coefficients of variation (CV).

Fishstock	Area	Vessel	Trip code	Date	Biomass	CV (%)
LIN 3	ECSI (winter)	*Kaharoa*	KAH9105*	May–Jun 1991	1 009	35
			KAH9205*	May–Jun 1992	525	17
			KAH9306*	May–Jun 1993	651	27
			KAH9406*	May–Jun 1994	488	19
			KAH9606*	May–Jun 1996	488	21
			KAH0705*	May–Jun 2007	283	17
			KAH0806*	May–Jun 2008	351	22
			KAH0905*	May–Jun 2009	262	19
			KAH1207*	May–Jun 2012	265	21
LIN 3 & 4	Chatham Rise	*Tangaroa*	TAN9106	Jan–Feb 1992	8 930	5.8
			TAN9212	Jan–Feb 1993	9 360	7.9
			TAN9401	Jan 1994	10 130	6.5
			TAN9501	Jan 1995	7 360	7.9
			TAN9601	Jan 1996	8 420	8.2
			TAN9701	Jan 1997	8 540	9.8
			TAN9801	Jan 1998	7 310	8.0
			TAN9901	Jan 1999	10 310	16.1
			TAN0001	Jan 2000	8 350	7.8
			TAN0101	Jan 2001	9 350	7.5
			TAN0201	Jan 2002	9 440	7.8
			TAN0301	Jan 2003	7 260	9.9
			TAN0401	Jan 2004	8 250	6.0
			TAN0501	Jan 2005	8 930	9.4
			TAN0601	Jan 2006	9 300	7.4
			TAN0701	Jan 2007	7 800	7.2
			TAN0801	Jan 2008	7 500	6.8
			TAN0901	Jan 2009	10 620	11.5
			TAN1001	Jan 2010	8 850	10.0
			TAN1101	Jan 2011	7 030	13.8
			TAN1201	Jan 2012	8 098	7.4
			TAN1301	Jan 2013	8 714	10.1
			TAN1401	Jan 2014	7 489	7.2
LIN 5 & 6	Southern Plateau	*Amaltal Explorer*	AEX8902*	Oct–Nov 1989	17 490	14.2
			AEX9002*	Nov–Dec 1990	15 850	7.5
LIN 5 & 6	Southern Plateau (summer)	*Tangaroa*	TAN9105	Nov–Dec 1991	24 090	6.8
			TAN9211	Nov–Dec 1992	21 370	6.2
			TAN9310	Nov–Dec 1993	29 750	11.5
			TAN0012	Dec 2000	33 020	6.9
			TAN0118	Dec 2001	25 060	6.5
			TAN0219	Dec 2002	25 630	10.0
			TAN0317	Nov–Dec 2003	22 170	9.7
			TAN0414	Nov–Dec 2004	23 770	12.2
			TAN0515	Nov–Dec 2005	19 700	9.0
			TAN0617	Nov–Dec 2006	19 640	12.0
			TAN0714	Nov–Dec 2007	26 492	8.0
			TAN0813	Nov–Dec 2008	22 840	9.5
			TAN0911	Nov–Dec 2009	22 710	9.6
			TAN1117	Nov–Dec 2011	23 178	11.8
			TAN1215	Nov–Dec 2012	27 010	11.3
			TAN1412*	Nov–Dec 2014	30 010	7.7
LIN 5 & 6	Southern Plateau (autumn)	*Tangaroa*	TAN9204	Mar–Apr 1992	42 330	5.8
			TAN9304	Apr–May 1993	37 550	5.4
			TAN9605	Mar–Apr 1996	32 130	7.8
			TAN9805	Apr–May 1998	30 780	8.8
LIN 7WC	WCSI	*Tangaroa*	TAN0007	Aug 2000	1 861	17
			TAN1210	Aug 2012	2 169	18
			TAN1308*	Aug 2013	2 000	15
LIN 7WC	WCSI	*Kaharoa*	KAH9204*	Mar–Apr 1992	286	19
			KAH9404*	Mar–Apr 1994	261	20
			KAH9504*	Mar–Apr 1995	367	16
			KAH9701*	Mar–Apr 1997	151	30
			KAH0004*	Mar–Apr 2000	95	46
			KAH0304*	Mar–Apr 2003	150	33
			KAH0503*	Mar–Apr 2005	274	37
			KAH0704*	Mar–Apr 2007	180	27
			KAH0904*	Mar–Apr 2009	291	37
			KAH1104*	Mar–Apr 2011	235	43
			KAH1305*	Mar–Apr 2013	405	44

* Not used in the reported assessment.

4.2 East Coast North Island, (LIN 2, statistical areas 11–15)

In 2014 a catch-per-unit-effort (CPUE) analysis was conducted on data from the LIN 2 fishery (Roux 2015). Estimated catch data and effort data from bottom longliners that fished in FMA 2 statistical areas 11–15 (ECNI) targeting ling where there was a positive catch were used. The estimated catch and effort data were rolled up by vessel/day/statistical area after a filter was applied to individual fishing events to retain estimated catch from the top five species together with all effort.

A GLM model (model 1) was fitted using a core vessel fleet where individual vessels had to have fished for four or more years in the fishery, and fished a minimum of 10 days per year. One auto-longlining vessel was excluded because it was an outlier in terms of numbers of hooks set, and created patterns in the residuals.

The sensitivity of the CPUE time series was tested for a range of alternative sets of input data: vessels using very large numbers of hooks per day (>10 000) were either included or excluded; changes in fishing power and fleet were minimised by fitting only the most recent time series (2000–2013); data from statistical area 16 (Cook Strait) were either included or excluded; and fitting was carried out with/without the use of interaction terms. An all-target model using bottom longline data that targeted or caught ling was also developed with 'target species' included as an explanatory variable. The GLM trend was robust to all sensitivities investigated.

The standardized CPUE index for ling from the ECNI demonstrates an initial decline consistent with the previous assessment (Horn 2004), followed by a period of stability (2002–2010) with lower CPUE in 2011–12 and 2012–13 (Figure 2). This pattern was consistent across all GLM scenarios examined.

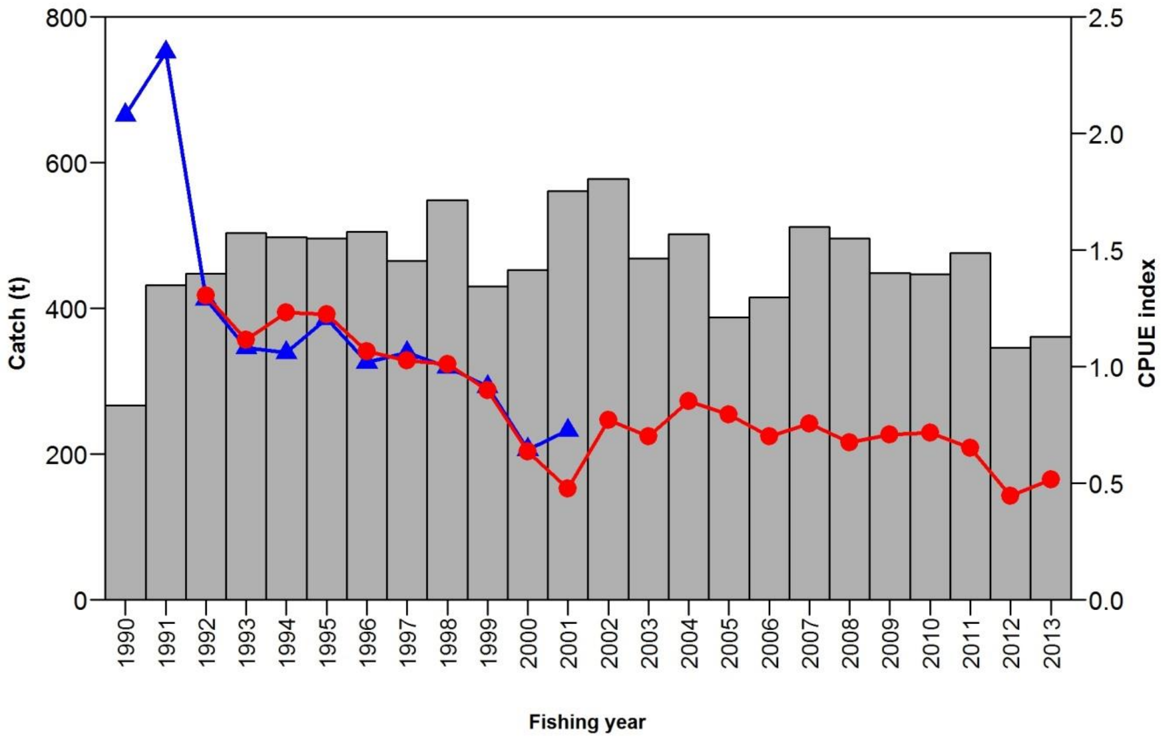


Figure 2. Estimated ling catch (bars) and standardized CPUE indices. Blue line and triangles from Horn (2004). Red line and circles for ECNI statistical areas 11–15 for core bottom longline vessels targeting ling, from Roux (2015). The two CPUE series were normalised to the overlapping fishing years (1992–2001).

4.3 Chatham Rise, LIN 3 & LIN 4

4.3.1 Model structure and inputs

The stock assessment for LIN 3&4 (Chatham Rise) was updated in 2015 (McGregor 2015). For final model runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2014}) biomass were obtained. Year class strengths and fishing selectivity ogives were estimated in the model. Trawl fishery and research survey selectivity ogives were fitted as double normal curves; line fishery ogives were fitted as logistic curves. Selectivities were assumed constant over all years in each fishery/survey. Instantaneous natural mortality (*M*) was estimated as a constant in the model. MCMCs were estimated using a burn-in length of $2\text{x}10^5$ iterations, with every 1000^{th} sample kept from the next $6\text{x}10^6$ iterations (i.e., a final sample of length 6000 was taken from the Bayesian posterior).

For LIN 3&4, model input data included catch histories, biomass and sexed catch-at-age data from a summer trawl survey series, sexed catch-at-age from the trawl fishery, line fishery CPUE, unsexed catch-at-age and catch-at-length from the line fishery, and estimates of biological parameters (Table 10). The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 5-9. The stock assessment model partitioned the population into two sexes, and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 9.

Table 10: LIN 3&4 — Summary of the relative abundance series applied in the models, including source years (Years).

Data series	Years
Trawl survey proportion at age (*Amaltal Explorer*, Dec)	1990
Trawl survey biomass (*Tangaroa*, Jan)	1992–2014
Trawl survey proportion at age (*Tangaroa*, Jan)	1992–2014
CPUE (longline, all year)	1991–2013
Commercial longline proportion-at-age (Jun–Oct)	2002–09, 2013
Commercial longline length-frequency (Jun–Oct)	1995–2002
Commercial trawl proportion-at-age (Oct–May)	1992, 1994–2013

Table 11: LIN 3&4 — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	*M*¹	Age²	Description	%*Z*³
1	Dec–Aug	Recruitment fisheries (line & trawl)	0.9	0.5	Trawl survey (summer) Line CPUE Line catch-at-age/length Trawl catch-at-age	0.2 0.5
2	Sep–Nov	Spawning and increment ages	0.1	0	–	

1. *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur by the start of that time step.
3. %*Z* is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

The error distributions assumed were multinomial for the at-age and at-length data, and lognormal for all other data. The weight assigned to each data set was controlled by the error coefficient of variation (CV). The observation-error CVs were calculated using standard formulae. An additional process error CV of 0.15 was added to the trawl survey biomass index following Francis et al. (2001), and a process error CV for the line fishery CPUE was estimated at 0.15 following Francis (2011). The multinomial observation error CVs for the at-age and at-length data were adjusted using the reweighting procedure of Francis (2011).

Most priors were intended to be uninformed, and were specified with wide bounds. One exception was an informative prior for the trawl survey *q*. The prior on *q* for all the *Tangaroa* trawl surveys was estimated assuming that the catchability constant was a product of areal availability (0.5–1.0), vertical availability (0.5–1.0), and vulnerability between the trawl doors (0.03–0.40). The resulting (approximately lognormal) distribution had mean 0.13 and CV 0.70, with bounds assumed to be 0.02 to 0.30. The other exception was the normal prior on p_male with μ=0.5, CV=0.15. Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

In all model runs, the catchability coefficients (q's) were free, unless there were difficulties in convergence, in which case they were set as nuisance variables (they were integrated out). The runs that included the longline CPUE had difficulty converging.

There is a conflict between the line fishery CPUE and the trawl survey biomass index, where the line fishery biomass index declined between 1991 and 1997, but the trawl survey index remained relatively flat throughout. To remove this conflict, a base case model run (Base) used all the observational data except the line fishery CPUE. The trawl survey biomass index was preferred in the base case because these data were fishery independent, and there was evidence that the longline fishery q had changed over time as very large fish were removed from the population (Horn 2015). A sensitivity run (Longline) then included the line fishery CPUE, and excluded the trawl survey biomass series; this model is considered a likely 'worst case' scenario. Additional models included both biomass indices (All), tested logistic, rather than double normal, selectivity ogives for trawl survey and fishery (Selectivity), and estimated a separate natural mortality for each sex (M), but these models are not reported in detail here.

4.3.2 Model estimates

The fits to the biomass indices, catch-at-age and catch-at-length data, were all fairly good, and almost indistinguishable between model runs. Year class strength estimates (Figure 3) were generally average or below average since 1980, except for 1994 and 1995. Estimated year class strengths were not widely variable, with all medians being between 0.5 and 2. Ling were first caught by the trawl survey (age at full selectivity 6 years), then the trawl fishery (age 8 years), and then the line fishery (age 16 years). Selectivities for the trawl fishery and survey tended towards a logistic distribution, although a double normal distribution was offered. Males were estimated to be less vulnerable than females to the trawl fishery. The estimated median M (for sexes combined) was 0.15.

The assessment is driven by the catch history, and by catch-at-age data, which contain information indicative of a stock decline during the 1990s.

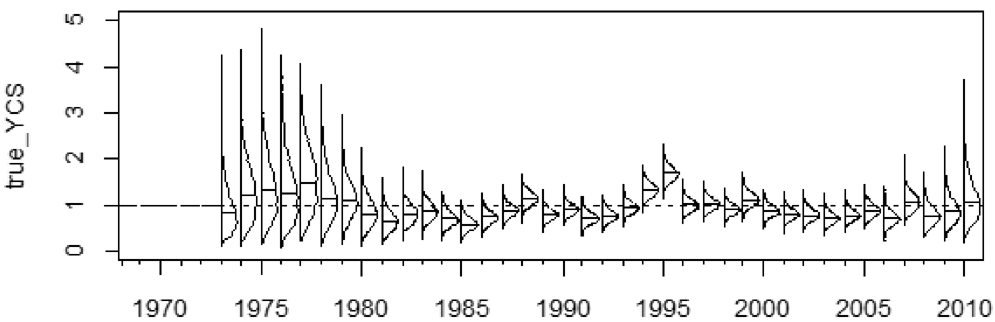


Figure 3: LIN 3&4 — Estimated posterior distributions of year class strength for the base model. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

Although estimates of current and virgin stock size were imprecise, it was unlikely that B_0 was lower than 110 000 t for this stock, or that biomass in 2014 was less than 44% of B_0 (Table 12, Figure 4). Annual exploitation rates (catch over vulnerable biomass) were estimated to be lower than 0.15 (often much lower) since 1979 (Figure 5).

Table 12: LIN 3&4 — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2014} (in tonnes, and as a percentage of B_0) for the Base and Longline model runs, and the probability that B_{2014} is above 40% of B_0 from the Base model run.

Model run	B_0		B_{2014}		B_{2014} (%B_0)		P(40% B_0)
Base	126 600	(110 700–165 100)	71 800	(50 500–115 200)	57	(45–71)	0.003
Longline	107 400	(98 700–122 700)	60 900	(42 000–85 600)	40	(30–51)	–

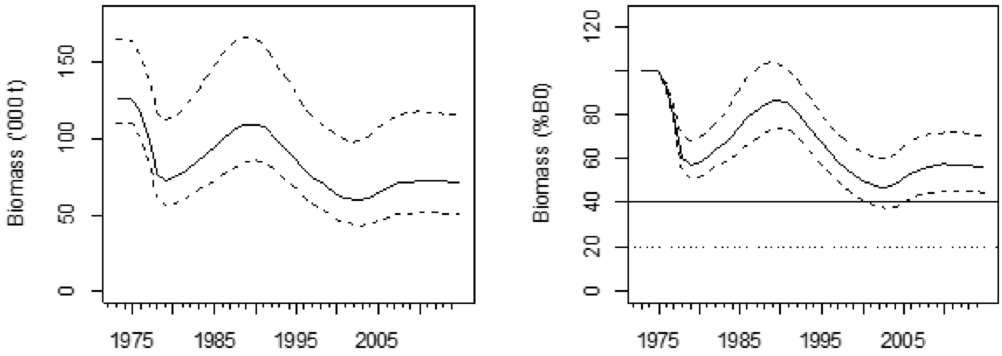


Figure 4: LIN 3&4 base model — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0.

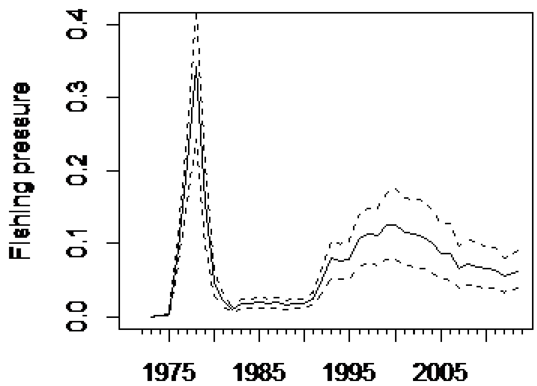


Figure 5: LIN 3&4 base model — Exploitation rates (catch over vulnerable biomass) with 95% credible intervals shown as dashed lines.

The model indicated a relatively flat biomass trajectory since about 2006 (Figure 4). Annual landings from the LIN 3&4 stock have been less than 4600 t since 2004, markedly lower than the 6000–8000 t taken annually between 1992 and 2003. Biomass projections derived from this assessment are shown below (Section 4.9).

4.4 Sub-Antarctic, LIN 5 & LIN 6 (excluding Bounty Plateau)

4.4.1 Model structure and inputs

The stock assessment for LIN 5&6 (Sub-Antarctic) was updated in 2015 (Roberts in prep.). For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2014}) biomass were obtained. Year class strengths and fishing selectivity ogives were also estimated in the model. Trawl fishery selectivity ogives were fitted as double normal curves; line fishery and research survey ogives were fitted as logistic curves. Selectivities were assumed constant over all years in each fishery/survey.

MCMC chains with a total length of $1x10^7$ iterations were constructed. A burn-in length of $2.5x10^6$ iterations was used, with every 2500th sample taken from the final $7.5x10^6$ iterations (i.e., a final sample of length 3,000 was taken from the Bayesian posterior).

For LIN 5&6, model input data include catch histories, biomass and catch-at-age data from summer and autumn trawl survey series, two line fishery CPUE series (from the spawning and home ground fisheries), catch-at-age from the spawning ground and home ground line fisheries, catch-at-age data from the trawl fishery, and estimates of biological parameters. A reference model run that incorporated all the data except the CPUE series and used nuisance-*q*'s for the trawl survey biomass series is presented, along with the base case run, which used free-*q*'s. The stock assessment model partitions the population into two sexes, and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 13.

Table 13: LIN 5&6 — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	**Period**	**Processes**	**M^1**	**Age[2]**	**Description**	**$\%Z^3$**
1	Dec–Aug	Recruitment Non-spawning fisheries (trawl & line)	0.75	0.4	Trawl survey (summer) Trawl survey (autumn) Line CPUE (non-spawn) Line (non-spawn) catch-at-age Trawl catch-at-age	0.1 0.5 0.7
2	Sep–Nov	Increment ages Spawning fishery (line)	0.25	0.0	Line CPUE (spawning) Line (spawning) catch-at-age	0.5

1. *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. %*Z* is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

A summary of all observations used in this assessment and the associated time series is given in Table 14. Lognormal errors, with known CVs, were assumed for all relative biomass observations. The CVs available for those observations of relative abundance allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error was fixed to 0.15 in all model runs, following the recommendations of Francis (2011). Multinomial errors were assumed for all age composition observations. The effective sample sizes for the composition samples were estimated following method TA1.8 as described in Appendix A of Francis (2011) and values used in this assessment are given in Table 15.

Table 14: LIN 5&6 — Summary of the relative abundance series applied in the models, including source years (Years).

Data series	Years
Trawl survey proportion at age (*Amaltal Explorer,* Nov)	1990
Trawl survey biomass (*Tangaroa*, Nov–Dec)	1992–94, 2001–10, 2012–13
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–10, 2012–13
Trawl survey biomass (*Tangaroa*, Mar–May)	1992–93, 1996, 1998
Trawl survey proportion at age (*Tangaroa*, Mar–May)	1992–93, 1996, 1998
CPUE (longline, spawning fishery)	1991–2012
CPUE (longline, non-spawning fishery)	1991–2012
Commercial longline proportion-at-age (spawning, Oct–Dec)	2000–08, 2010
Commercial longline proportion-at-age (non-spawn, Feb–Jul)	1999, 2001, 2003, 2005, 2009–12
Commercial trawl proportion-at-age (Sep–Apr)	1992–94, 1996, 1998, 2001–13

Table 15: LIN 5&6, multinomial effective sample sizes (EFS) assumed for the age composition data sets. The initial EFS are estimated from the sample data, and the reweighted EFS have been scaled following the technique of Francis (2011).

Summer trawl survey proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
1990	277	50
1992	499	90
1993	450	82
1994	451	82
2001	510	92
2002	491	89
2003	469	85
2004	427	77
2005	398	72
2006	419	76
2007	386	70
2008	401	73
2009	352	64
2010	374	68
2012	415	75
2013	396	72

Fishery trawl proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
1992	442	39
1993	310	27
1994	221	20
1996	337	30
1998	254	23
2001	450	40
2002	320	28
2003	500	44
2004	334	30
2005	381	34
2006	428	38
2007	322	29
2008	335	30
2009	440	39
2010	424	38
2011	411	36
2012	368	33
2013	427	38

Autumn trawl survey proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
1992	436	70
1993	473	76
1996	414	66
1998	403	65

Fishery longline spawn proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
2000	471	72
2001	230	35
2002	357	54
2003	419	64
2004	439	67
2005	170	26
2006	315	48
2007	271	41
2008	85	13
2010	165	25

Fishery longline non-spawn proportion-at-age

Fishing Year	Initial EFS	Reweighted EFS
1999	789	95
2001	302	36
2003	218	26
2005	272	33
2009	207	25
2010	179	22
2011	251	30
2012	321	39

The assumed prior distributions used in the assessment are given in Table 16. Most priors were intended to be relatively uninformed, and were specified with wide bounds. The exceptions were the choice of informative priors for the trawl survey *q*. The priors on *q* for all the Tangaroa trawl surveys were estimated assuming that the catchability constant was a product of areal availability (0.5–1.0), vertical availability (0.5–1.0), and vulnerability between the trawl doors (0.03–0.40). The resulting (approximately lognormal) distribution had mean 0.13 and CV 0.70, with bounds assumed to be 0.02 to 0.30.

Table 16: LIN 5&6 — Assumed prior distributions and bounds for estimated parameters in the assessments. The parameters for lognormal priors are mean (in log space) and CV

Parameter description	Distribution	Parameters		Bounds	
B_0	Uniform-log	–	–	50 000	800 000
Year class strengths	Lognormal	1.0	0.70	0.01	100
Trawl survey *q*	Lognormal	0.13	0.70	0.02	0.3
CPUE *q*	Uniform-log	–	–	1e-8	1e-3
Selectivities	Uniform	–	–	0	20–200*
M (x_0, y_0, y_1, y_2)	Uniform	–	–	3, 0.01, 0.01, 0.01	15, 0.6, 1.0, 1.0

* A range of maximum values were used for the upper bound

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1. The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 5-9.

4.4.2 Model estimates

Descriptions of two model runs reported are as follows:

- Reference model — catch history, all relative abundance series listed in Tables 8 and 9, double-exponential *M* estimated as an ogive independent of sex, double-normal selectivity ogives for the trawl fishery, logistic ogives for the line fisheries and the resource survey series, multinomial error associated with age composition estimates, nuisance *q*'s for the resource survey series.
- Base case — as the reference model, but using free *q*'s for the resource survey series.

Four other sensitivities were investigated: (1) estimating constant *M* with respect to age, (2) logistic selectivity ogive for longline spawn, (3) halved multinomial weightings associated with age composition estimates, and (4) fitted to spawning and non-spawning longline fishery CPUE. These models all produced estimates of stock status that were little different to those from the reported models.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 6; the distribution from the base case model (using free trawl survey *q*'s) differed little from the reference model (using nuisance trawl survey *q*'s). Year classes were generally weak from 1982 to 1992, strong from 1993 to 1996, and average since then (although 2005 may be strong). Overall, estimated year class strengths were not widely variable, with all medians being between 0.5 and 1.5. Consequently, biomass estimates for the stock declined through the 1990s, but have exhibited an upturn during the last 15 years (Figure 7). The biomass trajectory from the base case model was little different to that derived from the reference model.

Biomass estimates for the stock appear very healthy, with estimated current biomass from the two reported models at 85–90% of B_0 (Figure 7, Table 17). Annual exploitation rates (catch over vulnerable biomass) were low (less than 0.06) in all years as a consequence of the high estimated stock size in relationship to the level of relative catches (Figure 8).

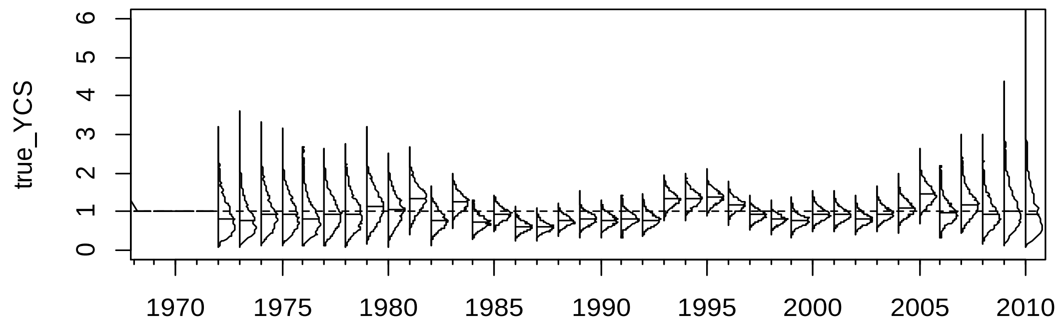
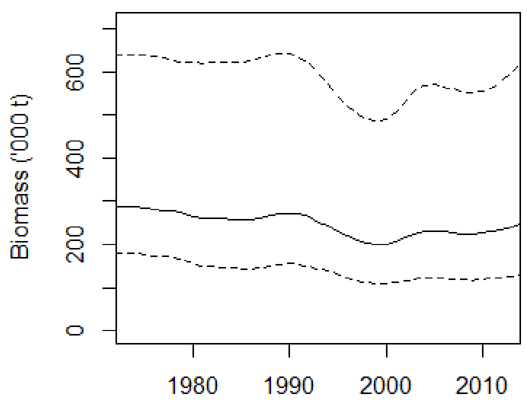


Figure 6: LIN 5&6 — Estimated posterior distributions of year class strength from the base case run. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.



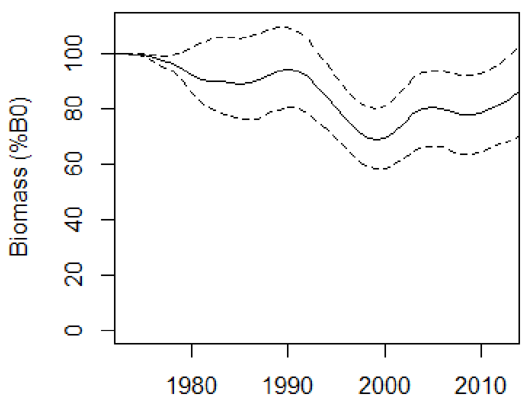


Figure 7: LIN 5&6 base model — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0.

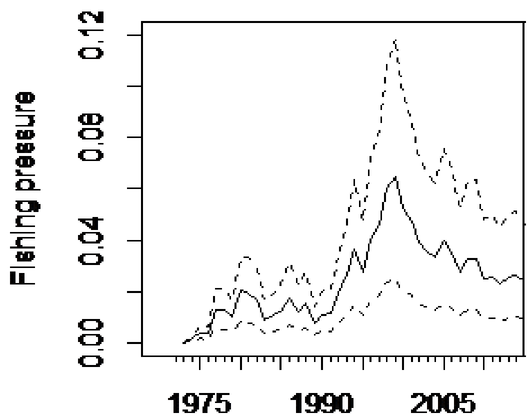


Figure 8: LIN 5&6 base model — Exploitation rates (catch over vulnerable biomass) with 95% credible intervals shown as dashed lines.

Table 17: LIN 5&6 — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2014} (in tonnes), and B_{2014} as a percentage of B_0 for both model runs, and the probability that B_{2014} is above 40% of B_0 from the Base model.

Model run	B_0		B_{2014}		B_{2014} (% B_0)		P(40% B_0)
Reference model	354 000	(204 000–673 000)	317 000	(155 000–655 000)	89	(72–104)	–
Base case model	289 000	(179 000–665 000)	251 000	(127 000–651 000)	86	(69–103)	0.000

Resource survey and fishery selectivity ogives were relatively tightly defined. The survey ogive suggested that ling were fully selected by the research gear at about age 7–9. Estimated fishing selectivities indicated that ling were fully selected by the trawl fishery at about age 9 years, and by the line fisheries at about age 12–16.

The assessments indicated a biomass trough about 1999, and some recovery since then. Although estimates of current and virgin stock size are very imprecise, it is most unlikely that B_0 was lower than 200 000 t for this stock, and it is very likely that current biomass is greater than 70% of B_0. Biomass projections derived from this assessment are shown below (Section 4.9).

4.5 Bounty Plateau, LIN 6B (Bounty Plateau only)

4.5.1 Model structure and inputs

The stock assessment for the Bounty Plateau stock (part of LIN 6) was updated in 2007 (Horn 2007b). For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2006}) biomass were obtained. Year class strengths and fishing selectivity ogives were also estimated in the model. Line fishery ogives were fitted as logistic curves.

MCMC chains were constructed using a burn-in length of 5×10^5 iterations, with every 1000th sample taken from the next 10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

For LIN 6B, model input data include catch histories, line fishery CPUE, catch-at-age and catch-at-length from the line fishery, and estimates of biological parameters. In the absence of sufficient stock-specific data, maturity ogives were assumed to be the same as for LIN 3&4, a stock with comparable growth parameters to LIN 6B. Only a base case model run is presented. The stock assessment model partitions the population into two sexes, and age groups 3 to 35 with a plus group. There is one fishery (longline) in the stock. The model's annual cycle is described in Table 18

Lognormal errors, with observation-error CVs, were assumed for all relative biomass, proportions-at-age, and proportions-at-length observations. Additional process error was estimated in MPD runs of the model (Table 19) and fixed in all subsequent runs.

Table 18: LIN 6B — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	M^1	Age[2]	Description	$\%Z^3$
1	Dec–Sep	Recruitment	0.9	0.5	Line CPUE	0.5
		fisher y (line)			Line catch-at-age/length	0.5
2	Oct–Nov	increment ages	0.1	0	–	

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. $\%Z$ is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Table 19: LIN 6B — Summary of the relative abundance series applied in the models, including source years (Years), and the estimated process error (CV) added to the observation error.

Data series	Years	Process error CV
CPUE (longline, all year)	1992–2004	0.15
Commercial longline length-frequency (Nov–Feb)	1996, 2000–04	0.50
Commercial longline proportion-at-age (Dec–Feb)	2000–01, 2004	0.40

The assumed prior distributions used in the assessment are given in Table 20. All priors were intended to be relatively uninformed, and were estimated with wide bounds.

Table 20: LIN 6B — Assumed prior distributions and bounds for estimated parameters for the assessments. The parameters are mean (in log space) and CV for lognormal.

Parameter description	**Distribution**	**Parameters**		**Bounds**	
B_0	uniform-log	–	–	5000	100 000
Year class strengths	lognormal	1.0	0.7	0.01	100
CPUE q	uniform-log	–	–	1e-8	1e-3
Selectivities	uniform	–	–	0	20–200
Process error CV	uniform-log	–	–	0.001	2

* A range of maximum values were used for the upper bound

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 5-9.

4.5.2 Model estimates

Only a base case model run was completed.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 9.

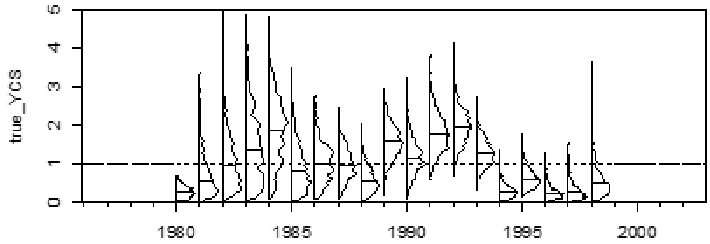


Figure 9: LIN 6B — Estimated posterior distributions of year class strength from the base case run. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The assessment was driven largely by the catch-at-age and catch-at-length series from the line fishery; the first two years of CPUE data were not well fitted. Biomass estimates are listed in Table 21 and the biomass trajectory is shown in Figure 10. The assessment indicates a declining biomass throughout the history of the fishery. Estimates of current and virgin stock size are not well known, but current biomass is very likely to be above 50% of B_0.

Table 21: LIN 6B — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2006} (in t), and B_{2006} as a percentage of B_0 for the base case model run.

Model run	B_0		B_{2006}		B_{2006} (% B_0)	
Base case	13 570	(10 850–19 030)	8 330	(4 860–14 730)	61	(45–79)

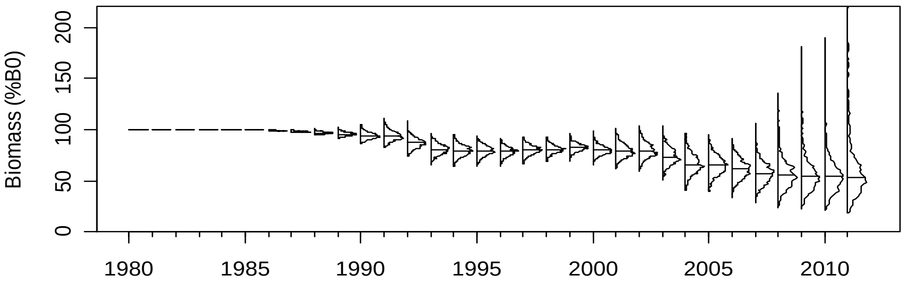


Figure 10: LIN 6B — Estimated posterior distributions of biomass trajectories as a percentage of B_0, from the base case model run (including 5-year projections through to 2011 with assumed constant annual catch of 400 t). Distributions are the marginal posterior distribution, with horizontal lines indicating the median.

Biomass projections derived from this assessment are shown below (Section 4.9).

4.6 West Coast South Island, LIN 7WC

4.6.1 Model structure and inputs

The stock assessment for LIN 7WC (west coast South Island) was updated in 2013 (Dunn et al. 2013). The assessment model partitions the population into age groups 3 to 28 with a plus group, with no sex in the partition. The model's annual cycle is described in Table 22.

Table 22: LIN 7WC — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	M^1	Age[2]	Description	$\%Z^3$
1	Oct–May	Recruitment	0.75	0.5		0.5
		fishery (line)			Line catch-at-age	
2	Jul–Sep	increment ages	0.25	0	Trawl survey biomass and catch at age	0.5
		fishery (trawl)			Trawl catch-at-age	
					Trawl CPUE	

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. $\%Z$ is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

The chosen base case was developed following the investigation of numerous previous models. It was found that the model could not reconcile some differences in sex ratios of the age-frequency data, so sex was removed from the partition.

Year class strengths and fishing selectivity ogives were also estimated in the model. Commercial trawl and research survey selectivities were fitted as double normal curves; the line fishery ogive was fitted as a logistic curve.

For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2012}) biomass were obtained. MCMC chains were constructed using a burn-in length of 2×10^6 iterations, with every 4000^{th} sample taken from the next 4×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). Single chain convergence tests were applied to resulting chains to determine evidence of non-convergence. No evidence of lack of convergence was found in the estimates of B_0 or $B_{current}/B_0$ from the base case model run.

For LIN 7WC, model input data include catch histories, trawl fishery CPUE, extensive catch-at-age data from the trawl fishery, sparse catch-at-age data from the line fishery, biomass estimates and proportion-at-age from comparable *Tangaroa* surveys in 2000 and 2012, and estimates of biological parameters (Table 23). A line fishery CPUE series was available, but was rejected as unlikely to be indexing stock abundance. The base case estimated instantaneous natural mortality, M, as a constant.

The error distributions assumed were multinomial for the proportions-at-age and lognormal for all other data. Biomass indices had assumed CVs set equal to the sampling CV, with additional process error of 0.2. The multinomial observation error effective sample sizes for the trawl fishery at-age data were adjusted using the reweighting procedure of Francis (2011). An *ad hoc* procedure was used for the at-age data from the line fishery and *Tangaroa* survey at-age data, giving the survey a relatively high weighting.

Table 23: LIN 7WC — Summary of the relative abundance series applied in the models, including source years (Years).

Data series	Years
CPUE (hoki trawl, Jun–Sep)	1987–2011
Commercial trawl proportion-at-age (Jun–Sep)	1991, 1994–2008
Commercial longline proportion-at-age	2003, 2012
Trawl survey biomass (*Tangaroa*, July)	2000, 2012
Trawl survey age data	2000, 2012

The assumed prior distributions used in the assessment are given in Table 24. Most priors were intended to be relatively uninformed, and were specified with wide bounds. The prior for the survey q was informative and was estimated using the Sub-Antarctic ling survey priors as a starting point (see Section 4.4.1) because the survey series in both areas used the same vessel and fishing gear. However, the WCSI survey area in the 200–650 m depth range in strata 0004 A–C and 0012 A–C comprised 6619 km^2; seabed area in that depth range in the entire LIN 7 WC biological stock area (excluding the Challenger Plateau) is estimated to be about 20 100 km^2. So, because biomass from only 33% of the WCSI ling habitat was included in the indices, the Sub-Antarctic prior on μ was modified accordingly (i.e., $0.13 \times 0.33 = 0.043$), and the bounds were also reduced from [0.02, 0.30] to [0.01, 0.20]. The prior for M was informed and based on expert opinion. Priors for all selectivity parameters were assumed to be uniform.

Table 24: LIN 7WC — Assumed prior distributions and bounds for parameters estimated in the models. For lognormal distributions the figures are the logspace mean and the CV, and for normal distributions the figures are the mean and standard deviation .

Parameter description	Distribution	Parameters		Bounds	
B_0	uniform-log	–	–	10 000	500 000
Year class strengths	lognormal	1.0	0.7	0.01	100
Tangaroa survey q	lognormal	0.043	0.70	0.01	0.2
CPUE q	uniform-log	–	–	1e-8	1e-3
Selectivities	uniform	–	–	0	20–200*
M	normal	0.20	0.025	0.1	0.3

* A range of maximum values was used for the upper bound.

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 5-9.

4.6.2 Model estimates

MCMC runs of the base case and one sensitivity (where *M* was fixed at 0.18) were conducted.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 11. The YCS distribution from the sensitivity run was not visually different and is not shown.

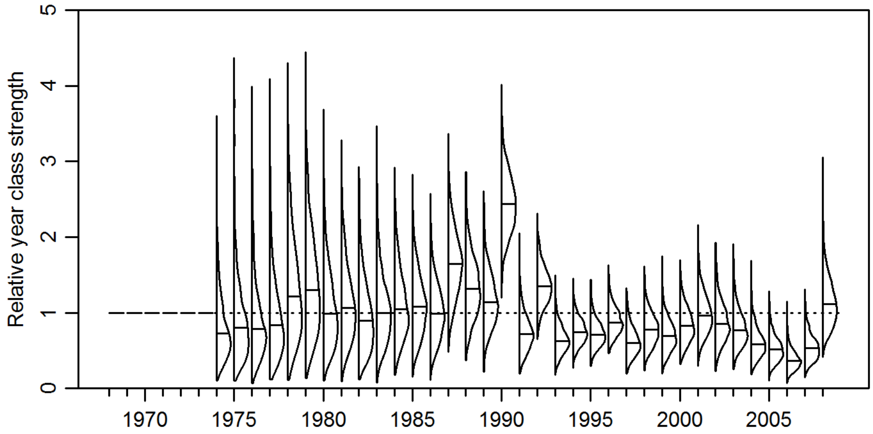


Figure 11: LIN 7WC — Estimated posterior distributions of year class strength. The horizontal dashed line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

Both model runs were indicative of a B_0 greater than about 50 000 t (Table 25). The upper bound on B_0 is highly uncertain and dependent on the priors on the survey *q* and *M*. Both model runs also indicated a biomass decline from 2000–2012 (Figure 12). The model fit to the CPUE series was poor (Figure 13). Model estimates suggest a period of higher recruitment from 1978 to 1990 followed by lower recruitment since 1992. There was also some evidence for stronger recruitment in the most recent year for which an estimate can be made but this is highly uncertain (Figure 11).

Table 25: LIN 7WC — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2012} (in tonnes), and B_{2012} as a percentage of B_0 for all model runs. The base case estimates *M*.

Model run	B_0		B_{2012}		B_{2012} (% B_0)	
Base case	99 200	(58 400–304 600)	70 350	(33 000–248 400)	71	(56–85)
M = 0.18	66 100	(50 300–142 900)	39 580	(23 600–109 200)	59	(46–79)

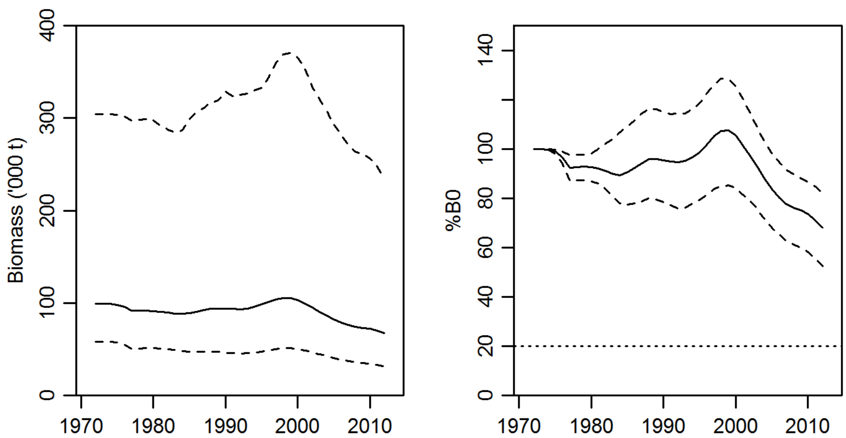


Figure 12: LIN 7WC — Estimated posterior distributions of the biomass (t) trajectory and % B_0 for the base case. The solid lines are the median values and the dashed lines are the 95% CIs.

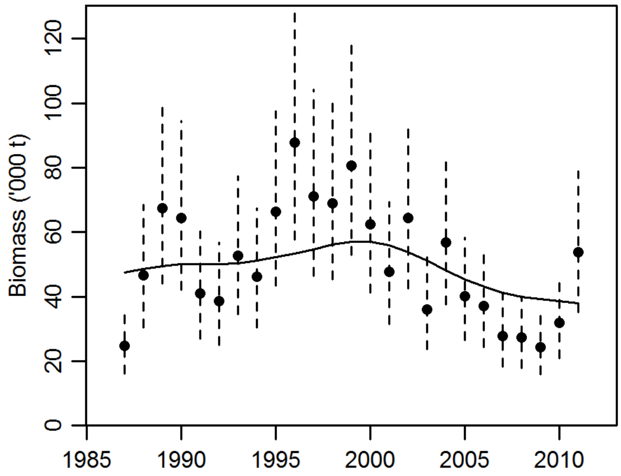


Figure 13: LIN 7WC —The fit of the base case model (MPD) to the commercial trawl CPUE index. The CPUE index has been scaled to the biomass using the estimated *q*.

4.7 Cook Strait, LIN 7CK

4.7.1 Model structure and inputs

A stock assessment of ling in Cook Strait (LIN 7CK) was completed in 2013 (Dunn et al. 2013). Because it is believed that the true *M* for the Cook Strait stock is higher than the 'default' value of 0.18, it was considered desirable to estimate *M* in the model, and so incorporate the effect of this uncertainty in *M* in the assessment. However, the simultaneous estimation of B_0 and *M* was not successful owing to the adoption of a multinomial likelihood (rather than lognormal) for proportions-at-age. Consequently, models with fixed *M* values were run, and although the age data were reasonably well fitted, the model failed to accurately represent declines in resource abundance that appear evident from CPUE values, which have been declining since 2001. As a consequence the model was considered unsuitable for the provision of management advice.

The last stock assessment for LIN 7CK (Cook Strait) accepted by the Working Group was completed in 2010 (Horn & Francis 2013), and it is reported here. The stock assessment model partitions the population into two sexes, and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 26. Year class strengths and fishing selectivity ogives were also estimated in the model. Commercial trawl selectivity was fitted as double normal curves; line fishery ogives were fitted as logistic curves.

For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2008}) biomass were obtained. MCMC chains were constructed using a burn-in length of 4×10^6 iterations, with every 2000th sample taken from the next 20×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

For LIN 7CK, model input data include catch histories, trawl and line fishery CPUE, extensive catch-at-age data from the trawl fishery, sparse catch-at-age data from the line fishery, and estimates of biological parameters. Initial modelling investigations found that the line CPUE produced implausible results; this series was rejected as a useful index. The base case used all catch-at-age data from the fisheries, and the trawl CPUE series. Instantaneous natural mortality was estimated in the model

Lognormal errors, with observation-error CVs, were assumed for all CPUE and proportions-at-age observations. Additional process error, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance (Table 26).

Table 26: LIN 7CK — Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	M^1	Age[2]	Description	$\%Z^3$
1	Oct–May	Recruitment fishery (line)	0.67	0.5	Line CPUE Line catch-at-age	0.5
2	Jun–Sep	increment ages fishery (trawl)	0.33	0	Trawl CPUE Trawl catch-at-age	0.5

1. *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. %*Z* is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Table 27: LIN 7CK — Summary of the available data including source years (Years), and the estimated process error (CV) added to the observation error.

Data series	Years	Process error CV
CPUE (hoki trawl, Jun–Sep)	1994–2009	0.2
Commercial trawl proportion-at-age (Jun–Sep)	1999–2009	1.1
Commercial longline proportion-at-age	2006–07	1.1

The assumed prior distributions used in the assessment are given in Table 26. Most priors were intended to be relatively uninformed, and were specified with wide bounds.

Table 28: LIN 7CK — Assumed prior distributions and bounds for estimated parameters in the assessments. The parameters are mean (in log space) and CV for lognormal, and mean and standard deviation for normal.

Parameter description	Distribution	Parameters		Bounds	
B_0	uniform-log	–	–	2 000	60 000
Year class strengths	lognormal	1.0	0.9	0.01	100
CPUE q	uniform-log	–	–	1e-8	1e-2
Selectivities	uniform	–	–	0	20–200*
M	lognormal	0.18	0.16	0.1	0.3

* A range of maximum values was used for the upper bound

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 5-9.

4.7.2 Model estimates

A single model was presented incorporating a catch history, trawl and line fishery catch-at-age, trawl CPUE series, with double-normal ogives for the trawl fishery and logistic ogives for the line fishery, and *M* estimated in the model.

Posterior distributions of LIN 7CK year class strength estimates from the base case model run are shown in Figure 14.

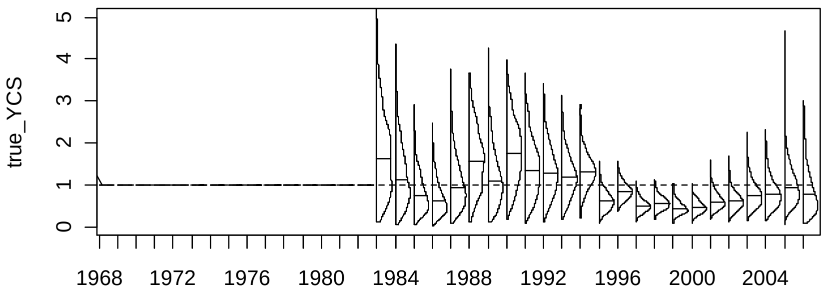


Figure 14: LIN 7CK — Estimated posterior distributions of year class strength. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The assessment is driven by the trawl fishery catch-at-age data and tuned by the trawl CPUE. Both input series contain information indicative of an overall stock decline in the last two decades. The confidence bounds around biomass estimates are wide (Table 29, Figure 15). Probabilities that current and projected biomass will drop below selected management reference points are shown in Table 28. Median *M* was estimated to be 0.24 (95% confidence interval 0.16–0.30). Estimates of biomass are very sensitive to small changes in *M*, but clearly there is information in the model encouraging an *M* higher than the 'default' value of 0.18. The model indicated a slight overall biomass decline to about 2000, followed by a much steeper decline from 2000 to 2010. Exploitation rates (catch over vulnerable biomass) were very low up to the late 1980s, and have been low to moderate (up to about 0.12 yr^{-1}) since then. Since the early 1990s, trawl fishing pressure has generally declined, while line pressure has generally increased.

Table 29: LIN 7CK — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2010} (in tonnes), and B_{2010} as a percentage of B_0 for all model runs.

Model run	B_0		B_{2010}		B_{2010} (% B_0)	
Base case	8 070	(5 290–53 080)	4 370	(1 250–40 490)	54	(23–80)

Table 30: LIN 7CK — Probabilities that current (B_{2010}) and projected (B_{2015}) biomass will be less than 40%, 20% or 10% of B_0. Projected biomass probabilities are presented for two scenarios of future annual catch (i.e., 220 t, and 420 t).

Biomass	Management reference points		
	40% B_0	20% B_0	10% B_0
B_{2010}	0.248	0.006	0.000
B_{2015}, 220 t catch	0.179	0.010	0.000
B_{2015}, 420 t catch	0.328	0.094	0.019

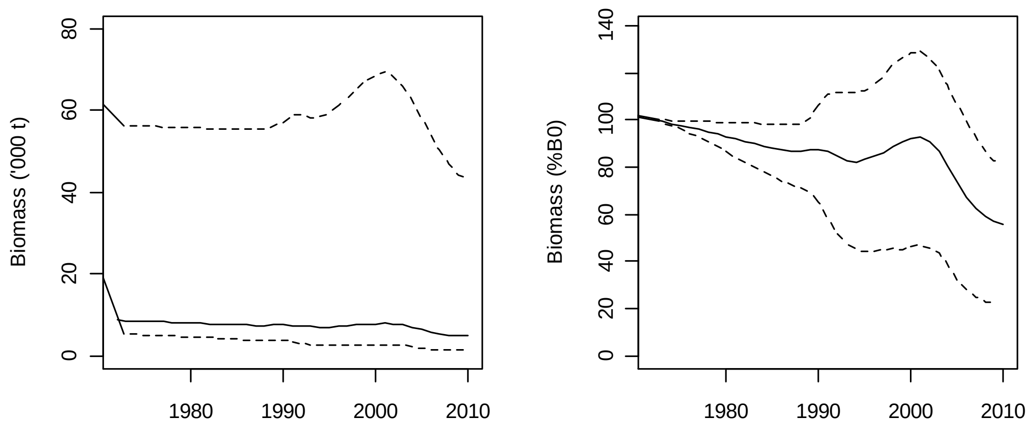


Figure 15: LIN 7CK — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0.

Estimates of biomass projections derived from this assessment are shown below (Section 4.9).

4.8 LIN 1

In October 2002, the TACC for LIN 1 was increased from 265 t to 400 t within an Adaptive Management Plan (AMP). Reviews of the LIN 1 AMP were carried out in 2007 and 2009. The AMP programme was discontinued by the Minister of Fisheries in 2009–10. An update of the LIN 1 CPUE analyses was commissioned by MPI in 2013, which is reported here.

4.8.1 Fishery Characterization

- 53% of LIN 1 landings come from the bottom trawl fishery and a further 46% by bottom longline since 1989–90. The remaining methods account for < 2% of the total landings.
- Most BT and BLL landings come from the Bay of Plenty. The majority of bottom trawl catches are taken in Statistical Areas 008 to 010, although there have been significant bottom trawl catches of ling on the west coast of the North Island in some years in Areas 046 to 048. There were substantial ling by-catches made by trawl on the North Island west coast from 1996–97 to 2000–01 in the

gemfish fishery (which has since ceased), and longline catches have increased from the East Northland area.

- Ling are caught in small quantities across many fisheries. The distribution of BT effort is broader than the distribution of catch, with effort taking some LIN 1 in East Northland and the west coast in most years. Bottom longline landings of LIN 1 have a wider distribution and are more sporadic, with the Bay of Plenty landings coming primarily from Areas 009 and 010. Bottom longline landings increased after about 2000 in East Northland Area 002, but have fallen off considerably in 2007–08.
- There is a small targeted ling trawl fishery, while trawl catches of LIN1 are mainly made in the scampi and gemfish targeted fisheries. The gemfish fishery mainly contributed catches from 1996–97 to 2000–01 and has since considerably diminished with the reduction of the SKI 1 TACC. The Bay of Plenty scampi fishery has also changed considerably during this period, particularly after SCI entered the QMS, moving from a competitive fishery requiring multiple vessels to a more rationalised fishery requiring only a single vessel. In contrast, ~75% of the ling longline catch is taken in a targeted ling fishery, with only minor by-catches coming from bluenose, ribaldo and hapuku targeted longline fisheries.
- The bottom longline landings of LIN 1 are taken mainly in the final two months of the fishing year, probably due to the economics of the vessels switching from tuna longlining to cleaning up available quota at the end of the fishing year. Bottom trawl catches of ling tend to be more evenly distributed across the year and reflect the fishing patterns of the diverse trawl targets, such as scampi which is also a consistent fishery over the entire year. Both of the major fishing methods which take ling have sporadic seasonal patterns, reflecting the small landings in most years and the by-catch nature of many of the fisheries.
- The depth distribution of ling catches in the trawl fisheries shows two main depths associated with the target species. Most ling are caught in the scampi / hoki / ling fishery at ~400 m depth, but some are taken in the tarakihi / snapper / barracouta / trevally fisheries around 100 m depth. Bottom longline depth records indicate that target ling fishing (as well as target bluenose fishing) takes place at even deeper depths, with most of the records lying between 500 and 600 m.

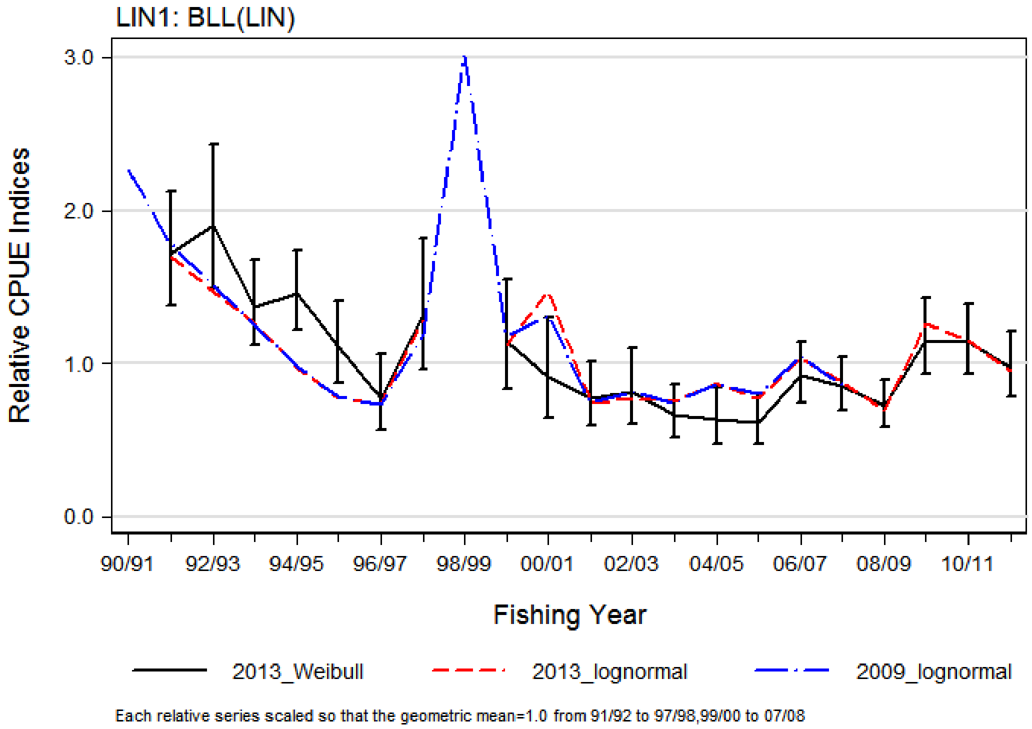


Figure 16: LIN 1 CPUE analyses based on target ling bottom longline data stratified by trip, target species and statistical area for Statistical Areas 002, 003, 004, 008, 009 and 010 standardised with respect to fishing year, number of hooks, vessel, month and number of lines set. Three sets of standardised indices are presented: a) 2013 Weibull index using the distributional assumption with the best fit to the data; b) 2013 lognormal index provided for comparison to the 2009 index; c) 2009 lognormal index, including the anomalous 1998–99 index value omitted from the 2013 series.

4.8.2 Abundance Indices

In 2009, the WG concluded that the BT(SCI) index was not an appropriate index for LIN 1, and had numerous shortcomings related to limited number of vessels, particularly in the most recent 4 years and poor linkage across years. In 2013, the NINSWG agreed with these conclusions, which also applied to the alternative BT(LINHOK, TAR) series developed in response to a 2009 WG recommendation. Consequently the NINSWG agreed that neither BT series was adequate for monitoring LIN 1 CPUE and should be discarded. The WG requirement that CPUE index values should be determined by at least 3 vessels furthermore resulted the discarding of a large number of index values from both BT series.

In 2009, the WG concluded that the BLL(LIN) target index appeared to have more potential as an index for LIN 1, but thought that the anomalous peak in 1998–99 was troubling and was also concerned about the relatively small amount of data in this analysis. Closer examination of the data in 2013 has shown that the anomalous 1998–99 peak was caused by a small amount of very localised fishing by two experienced vessels. The NINSWG concluded that this pattern was extremely non-representative of the fishery and the standardisation model was unable to use these data to estimate a credible year index. While this solved the mystery of the "anomalous 1998–99 index", the problem of very small amount of data in this analysis remains. The NINSWG tentatively accepted the BLL(LIN) index with the 1998–99 index value removed (Fig. 16) as an index of LIN 1 abundance with a research credibility rating of "2".

4.9 Projections

Projections for LIN 6B from the 2006 assessment are shown in Table 31. The LIN 6B stock (Bounty Plateau) was projected to decline out to 2011, but probably still be higher than 50% of B_0. Projections out to 2015 for LIN 7CK indicated that biomass was likely to increase with future catches equal to recent previous catch levels, or decline slightly if catches were equal to the mean since 1990 (Table 32). New projections made in 2014 out to 2019 for LIN 3&4 and 5&6 are shown in Table 32. For LIN 3&4, stock size is likely to remain about the same assuming future catches equal to recent catch levels, or decrease to around 90% of the 2014 biomass by 2019 if catches reach the TACC. For LIN 5&6, the probability of B_{2019} being below 40% of B_0 is very small when assuming either one of two future annual catch scenarios (the recent catch level of 5700 t or the TACC of 12 100 t). For LIN 7 WC the Working Group did not consider that projections using either run were reliable and so no projections are shown.

Table 31: LIN 6B Bayesian median and 95% credible intervals (in parentheses) of projected B_{2011}, B_{2011} as a percentage of B_0, and B_{2011}/B_{2006} (%) for the 2006 base case.

Stock and model run		Future catch (t)	B_{2011}		B_{2011} (% B_0)		B_{2011}/B_{2006} (%)	
LIN 6B	Base	600	7 460	(2 950–18 520)	53	(26–116)	86	(51–168)

Table 32: LIN 7CK Bayesian median and 95% credible intervals (in parentheses) of projected B_{2015}, B_{2015} as a percentage of B_0, and B_{2015}/B_{2010} (%) for the base case.

Stock and model run		Future catch (t)	B_{2015}		B_{2015} (% B_0)		B_{2015}/B_{2010} (%)	
LIN 7CK	Base	220	5 030	(1 310–43 340)	59	(24–97)	110	(82–158)
		420	4 320	(590–42 910)	52	(11–92)	95	(45–136)

Table 33: LIN 3&4 and LIN 5&6 Bayesian median and 95% credible intervals (in parentheses) of projected B_{2019}, B_{2019} as a percentage of B_0, and B_{2019}/B_{2014} (%) for the base case runs.

Stock and model run		Future catch (t)	B_{2019}		B_{2019} (% B_0)		B_{2019}/B_{2014} (%)	
LIN 3&4	Base	6 260	64 000	(38 900–112 100)	51	(35–69)	89	(73–106)
		3 564	75 200	(50 400–122 700)	59	(45–75)	104	(91–120)
LIN 5&6	Base	5 700	265 500	(129 100–714 800)	91	(69–118)	104	(86–136)
		12 100	240 300	(104 000–697 300)	82	(56–113)	94	(73–127)

5. STATUS OF THE STOCKS

Stock Structure Assumptions

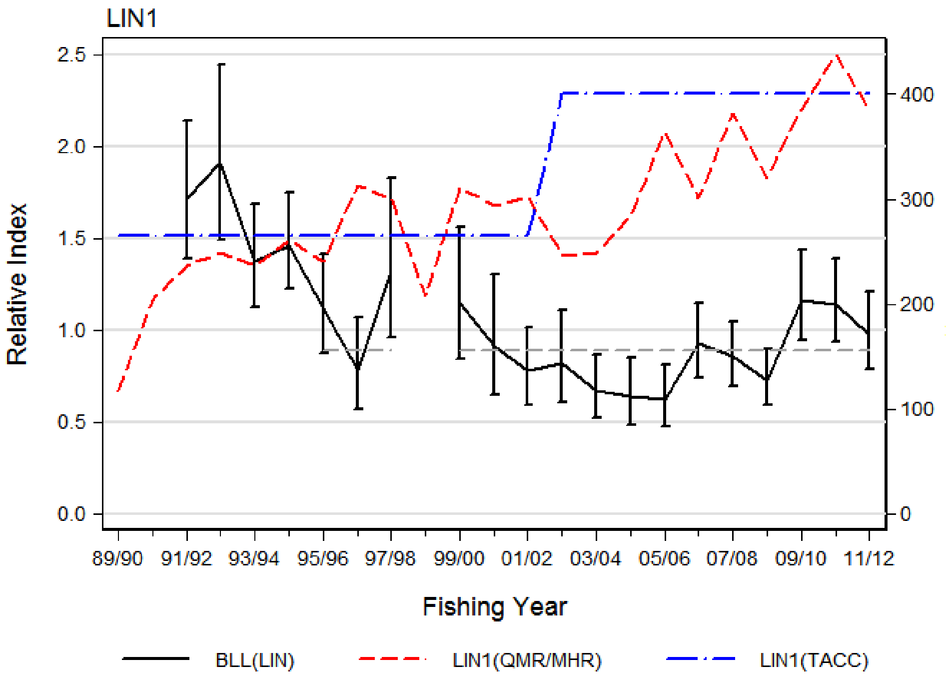
Ling are assessed as six independent biological stocks, based on the presence of spawning areas and some differences in biological parameters between areas (Horn 2005).

The Chatham Rise biological stock comprises all of Fishstock LIN 4, and LIN 3 north of the Otago Peninsula. The Sub-Antarctic biological stock comprises all of Fishstock LIN 5, all of LIN 6 excluding the Bounty Plateau, and LIN 3 south of the Otago Peninsula. The Bounty Plateau (part of Fishstock LIN 6) holds another distinct biological stock. The WCSI biological stock occurs in Fishstock LIN 7 west of Cape Farewell. The Cook Strait biological stock includes those parts of Fishstocks LIN 7 and LIN 2 between the northern Marlborough Sounds and Cape Palliser. Ling around the northern North Island (Fishstock LIN 1) are assumed to comprise another biological stock, but there is no information to support this assumption. The stock affinity of ling in LIN 2 between Cape Palliser and East Cape is unknown.

LIN 1 Stock

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Standardised Longline CPUE (BLL LIN)
Reference Points	Interim Target: Not determined but 40% B_0 assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Comparison of the BLL(LIN) CPUE series with the LIN 1 QMR/MHR landings and the LIN 1 TACC. The dashed horizontal grey line shows the mean CPUE index from 1995–96 to 2011–12.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The BLL(LIN) CPUE series declined from 1991-92 to 2005-06 and then increased to 2011-12.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Not evaluated
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Not evaluated

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative stock assessment	
Assessment Method	Evaluation of fishery trends.	
Assessment Dates	Latest assessment: 2013	Next assessment: unlmown
Overall assessment quality rank	2 – Medium or Mixed Quality	
Main data inputs (rank)	One bottom longline CPUE series, target LIN only, all LIN 1 statistical areas	2 – Medium or Mixed Quality
Data not used (rank)	Two bottom trawl CPUE series: - SCI target - combined LIN, HOK, TAR target	3 – Low Quality: do not track stock biomass and lack data
Changes to Model Structure and Assumptions		
Major Sources of Uncertainty	The biological stock affinities of ling in LIN 1 are unknown.	

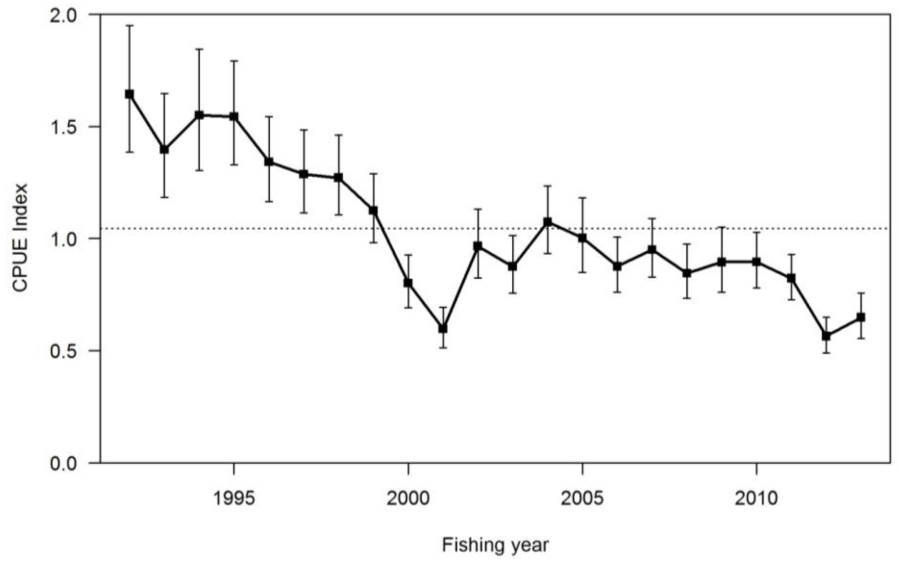
Qualifying Comments
Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries, and scampi target trawl fisheries off northern New Zealand. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

East coast North Island (part of LIN 2, statistical areas 11–15)

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	A CPUE time series based on bottom longline ling target fishing.
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F corresponding to 40% B_0
Status in relation to Target	Unknown. The CPUE has declined by between about 50–60% since the start of the time series in 1992.

Status in relation to Limits	B_{2014} is Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit.
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardized CPUE index (± 95% CI) for bottom longline vessels targeting ling from the ECNI statistical areas 11–15 (1992–2013). The dashed horizontal line is the time series mean.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have declined from 1992 by 50–60%.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2014)	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	CPUE has declined while catches have been below the TACC. There is some probability that fishing at the TACC or current catch may lead to overfishing.

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial quantitative stock assessment	
Assessment Method	Evaluation of a CPUE time series from 1992–2013 for bottom longliners targeting ling in statistical areas 11–15.	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Bottom longline effort and estimated catch	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	

Major Sources of Uncertainty	It is assumed that the longline CPUE time series tracks the entire biomass of ling in this stock. The boundaries of this biological stock, particularly towards the Cook Strait, are uncertain.

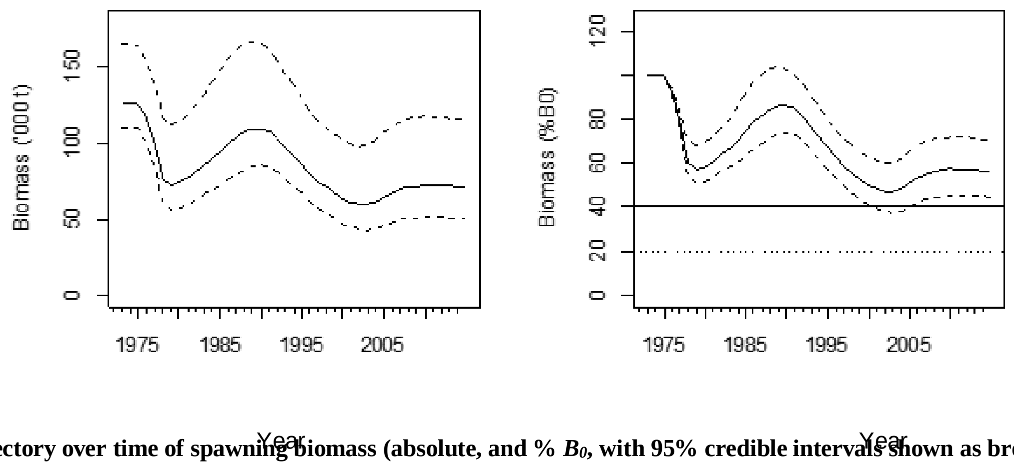
Qualifying Comments
-

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates, and ribaldo. Low productivity species taken as incidental bycatch include sharks and skates. Incidental captures of protected species are reported for seabirds.

Chatham Rise (LIN 3 & 4)

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	One base case
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%}$
Status in relation to Target	B_{2014} was estimated to be about 57% B_0; Very Likely (> 90%) to be above the target
Status in relation to Limits	B_{2014} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.
Status in relation to Overfishing	Overfishing is Very Unlikely (<10%) to be occurring.

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and % B_0, with 95% credible intervals shown as broken lines) for the Chatham Rise ling stock from the start of the assessment period in 1972 to the most recent assessment in 2014, for the base case model run. Years on the x-axis are fishing year with "1990" representing the 1989–90 fishing year. Years on the x-axis are fishing year with "2010" representing the 2009–10 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is very unlikely to have been below 40% B_0. Biomass is estimated to have been increasing or stable since 2003.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been generally declining since 1999.
Other Abundance Indices	–

Trends in Other Relevant Indicators or Variables	Recruitment since 1996 is estimated to have been fluctuating around or slightly below the long-term average for this stock.

Projections and Prognosis (2014)	
Stock Projections or Prognosis	Biomass is uncertain but current catch is unlikely to cause decline. Catches at level of the TACC are likely to cause the stock to decline by about 10% in 5 years.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) at current catch Hard Limit: Exceptionally Unlikely (< 1%) at current catch Soft Limit: Exceptionally Unlikely (< 1%) at TACC Hard Limit: Exceptionally Unlikely (< 1%) at TACC
Probability of Current Catch or TACC causing Overfishing to continue or commence	Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Assessment Dates	Latest assessment: 2014	Next assessment: 2017
Main data inputs	- Summer research trawl survey series, annually since 1992. - Proportions-at-age data from the commercial fisheries and trawl survey. - Line fishery CPUE series (annual indices since 1991): series not used in the base assessment model. - Estimates of biological parameters (but note that *M* was estimated in the models)	1 – High Quality 1 – High Quality 2 – Medium Quality: likely change in *q* over time 1 – High Quality
Data not used (rank)	*Kaharoa* ECSI trawl survey abundance index	3– Low Quality: inadequate spatial coverage of the stock distribution
Changes to Model Structure and Assumptions	No significant changes since the previous assessment.	
Major Sources of Uncertainty	Lack of contrast in survey indices; uncertain catchability of trawl survey	

Qualifying Comments
-

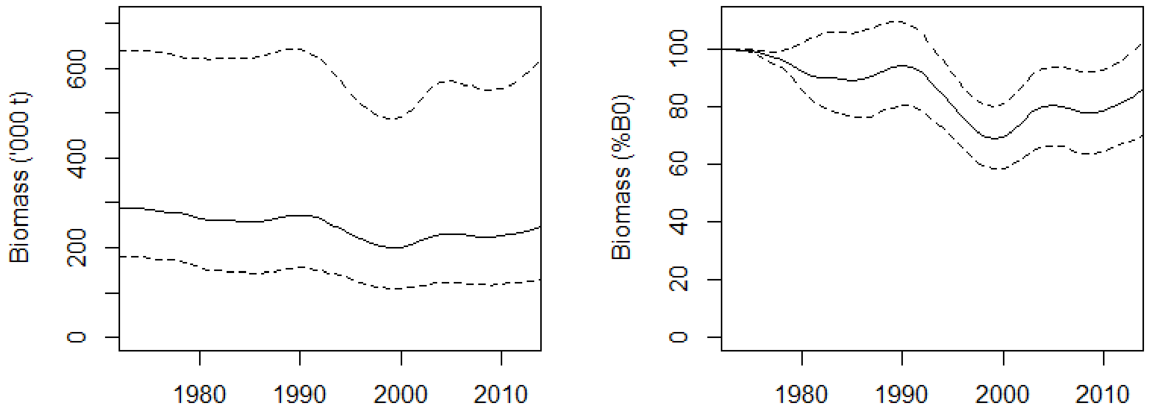
Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates, and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

- **Sub-Antarctic (LIN 5 & 6, excluding the Bounty Plateau)**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	One base case
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0

	Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2014} was estimated to be between 70% and 101% B_0; Virtually Certain (> 99%) to be above the target
Status in relation to Limits	B_{2014} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and % B_0, with 95% credible intervals shown as broken lines) for the Sub-Antarctic ling stock from the start of the assessment period in 1972 to the most recent assessment in 2014, for the base case model run. Years on the x-axis are fishing year with "1990" representing the 1989–90 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass appears to have been increasing since about 1999.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have always been low, and declining since 1998.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2014)	
Stock Projections or Prognosis	Stock status is unlikely to change over the next 5 yearsat recent catch levels or the level of the TACC (i.e., 12 100 t).
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) at current catch or TACC Hard Limit: Exceptionally Unlikely (< 1%) at current catch or TACC
Probability of Current Catch or TACC causing Overfishing to continue or commence	Exceptionally Unlikely (< 1%)

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Assessment Dates	Latest assessment: 2014	Next assessment: 2017
Main data inputs	- Summer and autumn *Tangaroa* trawl survey series. - Proportions-at-age data from the commercial fisheries and trawl surveys. - Line fishery CPUE series (annual indices since 1991).	1 – High Quality 1 – High Quality

	- Estimates of biological parameters (but note that M was estimated in the models)	2 – Medium Quality: possible changes in q over time 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	No significant changes since the previous assessment, except that M was estimated (age specific) rather than being fixed at 0.18.	
Major Sources of Uncertainty	The summer trawl survey biomass estimates are variable and catchability appears to vary between surveys. The lack of contrast in this series (the main relative abundance series) makes it difficult to accurately estimate past and current biomass.	

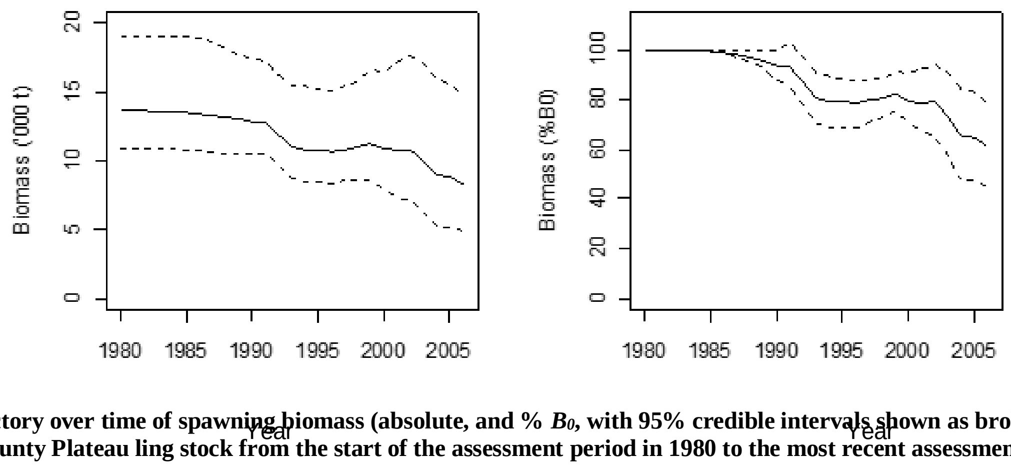
Qualifying Comments
The current assessment assumes that LIN 5 and LIN 6 (except Bounty Islands LIN 6B) are a single stock.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates, and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

Bounty Plateau (part of LIN 6)

Stock Status	
Year of Most Recent Assessment	2006
Assessment Runs Presented	A single model run
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2006} was estimated to be 61% B_0; Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2006} is Very Unlikely (< 10%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and % B_0, with 95% credible intervals shown as broken lines) for the Bounty Plateau ling stock from the start of the assessment period in 1980 to the most recent assessment in 2006. Years on the x-axis are fishing year with "1995" representing the 1994–95 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Median estimates of biomass are unlikely to have been below 61% B_0. Biomass is estimated to have been declining since 1999.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been low, but erratic, since 1980.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment was above average in the early 1990s, but below average in the late 1990s. No estimates of recruitment since 1999 are available.
Projections and Prognosis (2006)	
Stock Projections or Prognosis	Stock status is predicted to continue declining slightly over the next 5 years at a catch level equivalent to the average since 1991 (i.e., 600 t per year).
Probability of Current Catch or TACC causing decline below Limits	Note that there is no specific TACC for the Bounty Plateau stock. Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Proportions-at-age data from the commercial line fishery. - Line fishery CPUE series (annual indices since 1992). - Estimates of biological parameters.	1 – High quality 3 – Low quality: fishery-dependent with possible changes in q over time 1 – High quality
Data not used (rank)	-	
Period of Assessment	Latest assessment: 2006	Next assessment: Unknown
Changes to Model Structure and Assumptions	No significant changes since the previous assessment.	
Major Sources of Uncertainty	There are no fishery-independent indices of relative abundance, so the assessment is driven largely by the line fishery CPUE series. Stock projections are based on a constant future catch of 600 t per year. However, historic catches from this fishery have fluctuated widely, so future catches could be markedly different from 600 t per year.	

Qualifying Comments
There is no separate TACC for this stock; it is part of the LIN 6 Fishstock that has a TACC of 8505 t.

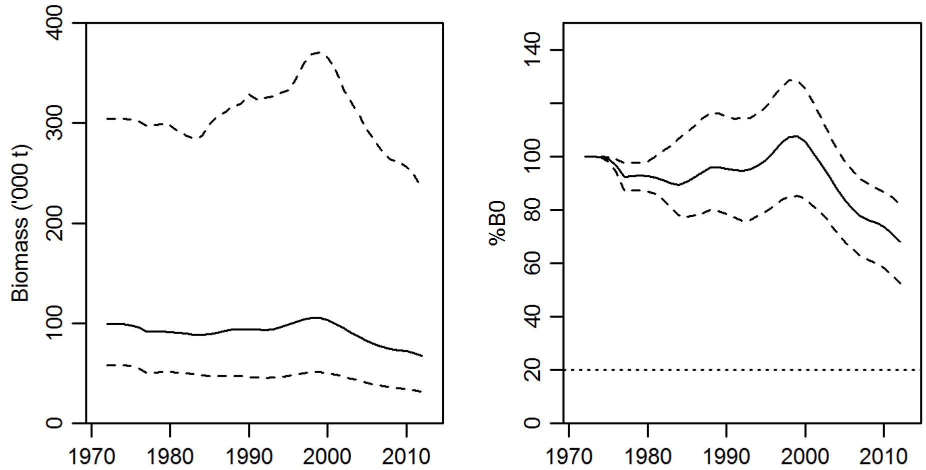
Fishery Interactions
Target line fisheries for ling have the main bycatch species of spiny dogfish, sharks and skates, and ribaldo. Bycatch species of concern include sharks, skates and seabirds.

West coast South Island (LIN 7)

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	A base case and one sensitivity model run.
Reference Points	Target: 40% B_0. Soft Limit: 20% B_0. Hard Limit: 10% B_0. Overfishing threshold: $F_{40\%B0}$

Status in relation to Target	B_{2012} was estimated to be about 71% B_0; Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2012} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and % B_0, with 95% credible intervals shown as broken lines) for the WCSI ling stock from the start of the assessment period in 1972 to the most recent assessment in 2013. Years on the x-axis are fishing year with "1990" representing the 1989–90 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been declining
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	A CPUE index was available from the line (target) fishery but was not considered reliable. The time series of the inshore *Kaharoa* survey does not adequately cover the distribution of ling on the west coast.
Trends in Other Relevant Indicators or Variables	The age structures of both the commercial catch and trawl survey catch are broad, indicating a low exploitation rate.

Projections and Prognosis	
Stock Projections or Prognosis	No projections were reported
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2013	Next assessment: 2016
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch history	1 – High Quality

	- Abundance index from two WCSI trawl surveys (2000, 2012) - Abundance index from the commercial trawl hoki-hake-ling target fishery CPUE - Proportions at age data from the commercial fisheries and trawl surveys - Estimates of fixed biological parameters	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- Commercial line fishery CPUE - *Kaharoa* trawl survey abundance index	3 – Low Quality: does not track stock biomass 3– Low Quality: inadequate spatial coverage of the stock distribution
Changes to Model Structure and Assumptions	Single sex model. *M* estimated in the base case with an informed prior. Reweighted sample sizes for age frequency data. Inclusion of a relative trawl survey index with an informed prior on *q*.	
Major Sources of Uncertainty	There is inadequate contrast in the biomass indices to inform on the magnitude of the biomass. Although the catch history used in the assessment has been corrected for some misreported catch (see Section 1.4), it is possible that additional misreporting exists. It is assumed in the assessment models that natural mortality is constant over all ages. Trawl survey selectivity. YCS estimation for recent year classes is highly uncertain because it is based on only one survey.	

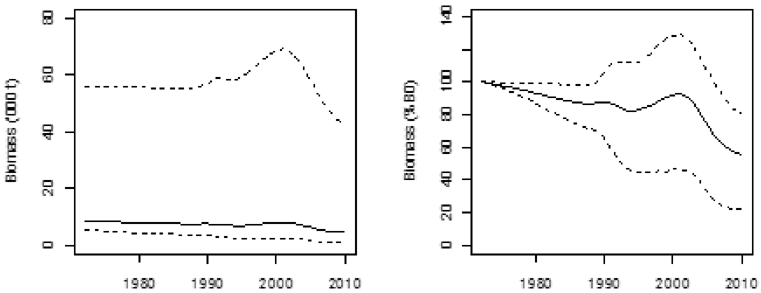
Qualifying Comments
This assessment is very uncertain but it is highly probable that B_{2012} is greater than 40% B_0 and it could be much higher.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates, and ribaldo. Low productivity species taken as incidental bycatch include sharks and skates. Protected species interactions are reported for seabirds and fur seals.

Cook Strait (LIN 2 [statistical area 16] & part of LIN 7)

Stock Status	
Year of Most Recent Assessment	2010 (an assessment in 2013 was rejected)
Assessment Runs Presented	A base case.
Reference Points	Target: 40% B_0. Soft Limit: 20% B_0. Hard Limit: 10% B_0. Overfishing threshold: F corresponding to 40% B_0
Status in relation to Target	B_{2010} was estimated to be 54% B_0; Likely (> 60%) to be at or above the target.
Status in relation to Limits	B_{2010} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring.

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and % B_0, with 95% credible intervals shown as broken lines) for the Cook Strait stock from the start of the assessment period in 1972 to the most recent assessment in 2010. Years on the x-axis are fishing year with "1990" representing the 1989–90 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been declining since 1999, but is unlikely to have dropped below 30% B_0.
Recent Trend in Fishing Intensity or Proxy	Overall fishing pressure is estimated to have been relatively constant since the mid-1990s, but has trended down for trawl and up for line.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment from 1995 to 2006 was low relative to the long-term average for this stock. There are no estimates for the more recent year classes.

Projections and Prognosis	
Stock Projections or Prognosis	Stock status is predicted to improve slightly over the next 5 years at a catch level equivalent to that since 2006 (i.e., 220 t per year), or remain relatively constant at a catch equivalent to the mean since 1990 (i.e., 420 t per year).
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Note that there is no specific TACC for the Cook Strait stock. Soft Limit: Catch 220 t, Very Unlikely (< 10%); Catch 420 t, Very Unlikely (< 10%). Hard Limit: Catch 220 t, Exceptionally Unlikely (< 1%); Catch 420 t, Very Unlikely (< 10%).
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%).

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full quantitative stock assessment.	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Assessment Dates	Latest assessment: 2010	Next assessment: 2016
Overall assessment quality rank	3 – Low Quality: The only accepted relative abundance series (trawl fishery CPUE) was not well fitted. A subsequent assessment in 2013 was rejected by the Working Group.	
Main data inputs (rank)	- Proportions-at-age data from the commercial trawl fishery.	1 – High Quality
	- Proportions-at-age data from the commercial line fishery.	3 – Low Quality
	- Trawl fishery CPUE series (annual indices since 1994).	2 – Medium Quality
	- Estimates of biological parameters.	1 – High Quality

Data not used (rank)	Line fishery CPUE	3 – Low quality: does not track stock biomass
Changes to Model Structure and Assumptions	No significant changes since the previous assessment.	
Major Sources of Uncertainty	There are no fishery-independent indices of relative abundance. It is not known if the trawl CPUE series is a reliable abundance index. The stock structure of Cook Strait ling is uncertain. While ling in this area are almost certainly biologically distinct from the WCSI and Chatham Rise stocks, their association with ling off the lower east coast of the North Island is unknown. It is possible that trawl selectivity has varied over time, resulting in poor fits to some age classes in some years. Line fishery selectivity is based on only two years of catch-at-age data from the autoline fishery. No information is available from the 'hand-baiting' line fishery. The model is moderately sensitive to small changes in *M*, and *M* is poorly estimated.	

Qualifying Comments
There is no separate TACC for this stock; it comprises parts of Fishstocks LIN 7 and LIN 2.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates. Low productivity species taken as incidental bycatch include sharks and skates. Protected species interactions are reported for seabirds and fur seals.

7. FUTURE RESEARCH

A review of the ling stock structure for LIN 2 should be completed before further assessments are conducted for this QMA.

8. FOR FURTHER INFORMATION

Ballara, S L; Horn, P L (2015) A descriptive analysis of all ling (*Genypterus blacodes*) fisheries, and CPUE for ling longline fisheries for LIN 3&4 and LIN 5&6, from 1990 to 2013. *New Zealand Fisheries Assessment Report 2015/11*. 55 p.

Bull, B; Francis, R I C C; Dunn, A; McKenzie, A; Gilbert, D J; Smith, M H; Bian, R (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL user manual v2.30-2012/03/21. *NIWA Technical Report 135*. 280 p.

Bradford, E (1996) Marine recreational fishery survey in the Ministry of Fisheries North region, 1993–94. *NZ Fisheries Data Report No. 80*. 83 p.

Dunn, A (2003) Investigation of evidence of area misreporting of landings of ling in LIN 3, 4, 5, 6, and 7 from TCEPR records in the fishing years 1989–90 to 2000–01. Final Research Report. (Unpublished document held by Ministry for Primary Industries, Wellington.)

Dunn, M R; Connell, A; Forman, J; Stevens, D W; Horn, P L (2010) Diet of two large sympatric teleosts, the ling (*Genypterus blacodes*) and hake (*Merluccius australis*). *PLoS ONE 5(10)*: e13647. doi:10.1371/journal.pone.0013647

Dunn, M R; Edwards, C T T; Ballara, S L; Horn, P L (2013) Stock assessment of ling (*Genypterus blacodes*) in Cook Strait and off the West Coast South Island (LIN 7), and a descriptive analysis of all ling fisheries, for the 2012–13 fishing year. *New Zealand Fisheries Assessment Report 2013/63*. 102 p.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences 68*: 1124–1138.

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1*. 37 p.

Horn, P L (1993) Growth, age structure, and productivity of ling, *Genypterus blacodes* (Ophidiidae), in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 27*: 385–397.

Horn, P L (2003) CPUE from commercial fisheries for ling (*Genypterus blacodes*) around the North Island, New Zealand: an evaluation of series for LIN 1, LIN2, and Cook Strait. *New Zealand Fisheries Assessment Report 2003/13*. 49 p.

Horn, P L (2004) CPUE from commercial fisheries for ling (*Genypterus blacodes*) in Fishstocks LIN 3,4,5,6, and 7 from 1990 to 2003. *New Zealand Fisheries Assessment Report 2004/62*. 40 p.

Horn, P L (2004) A review of the auto-longline fishery for ling (*Genypterus blacodes*) based on data collected by observers from 1993 to 2003. *New Zealand Fisheries Assessment Report 2004/47*. 28 p.

Horn, P L (2005) A review of the stock structure of ling (*Genypterus blacodes*) in New Zealand waters. *New Zealand Fisheries Assessment Report 2005/59*. 41 p.

Horn, P L (2007a) A descriptive analysis of commercial catch and effort data for ling from New Zealand waters in Fishstocks LIN 2, 3, 4, 5, 6, and 7. *New Zealand Fisheries Assessment Report 2007/22*. 71 p.

Horn, P L (2007b) Stock assessment of ling (*Genypterus blacodes*) on the Bounty Plateau and in Cook Strait for the 2006–07 fishing year. Final Research Report for Ministry of Fisheries Research Project LIN2005-01, Objective 3. 51 p. (Unpublished document held by Ministry for Primary Industries, Wellington.)

Horn, P L (2008) Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise, Campbell Plateau, and in Cook Strait for the 2007–08 fishing year. *New Zealand Fisheries Assessment Report 2008/24*. 76 p.

Horn, P L (2009) Stock assessment of ling (*Genypterus blacodes*) off the west coast of South Island for the 2008–09 fishing year. *New Zealand Fisheries Assessment Report 2009/16*. 42 p.

Horn, P L (2010) CPUE from commercial fisheries for ling (*Genypterus blacodes*) in Fishstocks LIN 3, 4, 5, 6, and 7 from 1990 to 2008, and a descriptive analysis update. *New Zealand Fisheries Assessment Report 2010/25*. 54 p.

Horn, P L (2015) Spatial and temporal changes in ling (*Genypterus blacodes*) population structure on the Chatham Rise and off West Coast South Island. *New Zealand Fisheries Assessment Report 2015/3*. 23 p.

Horn, P L; Dunn, M R; Ballara, S L (2013) Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise (LIN 3&4) and in the Sub-Antarctic (LIN 5&6) for the 2011–12 fishing year. *New Zealand Fisheries Assessment Report 2013/6*. 87 p.

Horn, P L; Francis, R I C C (2013) Stock assessment of ling (*Genypterus blacodes*) in Cook Strait for the 2010–11 fishing year. *New Zealand Fisheries Assessment Report 2013/7*. 35 p.

Leach, B F; Boocock, A S (1993) Prehistoric fish catches in New Zealand. *British Archaeological Reports International Series* 584. 38 p.

McGregor, V (in prep.) Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise (LIN 3&4) for the 2014–15 fishing year. Draft New Zealand Fisheries Assessment Report.

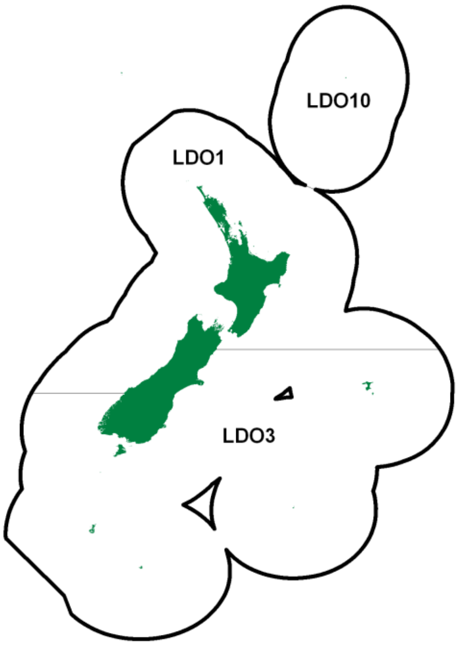
Roberts, J (in prep.) Stock assessment of ling (*Genypterus blacodes*) in the Sub-Antarctic (LIN 5&6) for the 2014–15 fishing year. Draft New Zealand Fisheries Assessment Report.

Roux, M-J (2015) Review of the longline fishery for ling (*Genypterus blacodes*) in LIN 2, and an update of the CPUE index. *New Zealand Fisheries Assessment Report 2015/6*. 26 p.

Starr, P J; Kendrick, T H; Lydon, G J; Bentley, N (2007). Full term review of the LIN 1 adaptive management programme. Report to the Adaptive Management Fishery Assessment Working Group. (Unpublished document held by Ministry for Primary Industries, Wellington.)

LOOKDOWN DORY (LDO)

(Cyttus traversi)



1. FISHERY SUMMARY

Lookdown dory was introduced into the Quota Management System (QMS) on 1 October 2004 with the allowances, TACs and TACCs in Table 1. It is currently managed as three stocks: LDO 1 which comprises FMAs 1-2 and 7-9; LDO 3 which comprises FMAs 3-6; and LDO 10 (Kermadec region).

Table 1: Recreational and customary non-commercial allowances, TACCs and TACs, by Fishstock, for lookdown dory.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	TACC	TAC
LDO 1	0	0	168	168
LDO 3	0	0	614	614
LDO 10	0	0	1	1
Total	0	0	783	783

1.1 Commercial fisheries

Reliable landings data are available from 1989-90 onwards, after the introduction of Catch Landing Returns (CLRs) in the previous year (Table 2). Annual landings are also available from Licensed Fish Receiver Returns (LFRRs), and these agree well with CLR figures in most years (within 10%), but differ by 20-27% in 4 of the 12 years with comparable data (Table 3). Total landings (CLR) have increased steadily from 127 t in 1989-90 to 760 t in 2001-02. Estimated catch as a percentage of recorded landings were moderate in the early 1990s at 60-70%, but subsequently declined to around 30%. Lookdown dory will often not be included within the top five species in a trawl haul, but the reason for the declining percentage of landings recorded as catch is unknown.

Since entering the QMS, catches in LDO 1 have exceeded the TACC slightly in the 2005-06 and 2007-08 fishing years (Table 2). The TACC in LDO 3 has never been caught. This probably reflects the reduction in the size of the trawl fishery on the Chatham Rise where the greatest proportion of lookdown dory has been taken as bycatch. No catch has been reported from LDO 10. Figure 1 shows the historical landings and TACC values for LDO 1 and LDO 3.

There is a seasonal pattern of catch of lookdown dory on the west coast South Island in relation to target fishing for spawning hoki and hake in winter. Catches elsewhere are also dependent on fishing activity in target fisheries but, other than a slight decline in winter months in relation to the shift in area of operation of the hoki fleet, they tend to be less seasonal.

Table 2: Reported domestic landings (t) of lookdown dory by Fishstock and TACC from 2004-05 to 2013-14.

Fishstock	LDO1		LDO3		LDO10			
FMA	1,2,7,8&9		3,4,5&6		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004-05	110	168	272	614	0	1	382	783
2005-06	180	168	290	614	0	1	470	783
2006-07	147	168	284	614	0	1	431	783
2007-08	174	168	256	614	0	1	430	783
2008-09	144	168	315	614	0	1	459	783
2009-10	161	168	274	614	0	1	435	783
2010-11	165	168	216	614	0	1	380	783
2011-12	153	168	229	614	0	1	382	783
2012-13	185	168	309	614	0	1	494	783
2013-14	204	168	256	614	0	1	460	783

Table 3: Reported landings and estimated catch (t) of lookdown dory by fishing year. Also, percentage of landings recorded as catch in the catch effort databases.

Year	Landings (CLR)	Landings (LFRR)	Estimated catch (t)	% of CLR landings recorded as estimated catch
1989-90	127	161	80	63
1990-91	164	182	105	64
1991-92	249	216	177	71
1992-93	275	264	159	58
1993-94	188	226	117	62
1994-95	283	277	125	44
1995-96	260	276	107	41
1996-97	354	426	173	49
1997-98	564	557	265	47
1998-99	625	640	228	36
1999-00	637	605	215	34
2000-01	694	504	157	23
2001-02	760	-	254	33

-, data not available

Lookdown dory is generally caught by bottom trawling in depths of 200 to 800 m mainly as bycatch in the hoki fishery, but also in a variety of other target fisheries such as barracouta, hake, ling, scampi, squid and jack mackerel. A small amount of target fishing is reported from FMA 7. Most of the catch has come from FMA 3 (east coast South Island), FMA 4 (Chatham Rise), and FMA 7 (west coast South Island) (Table 4). Landings from around the North Island have been restricted mostly to a few tonnes each year from FMAs 1, 2, 8 and 9. In FMA 5 (Southland) and FMA 6 (Sub-Antarctic) landings have been in the order of 10-30 t over the past six years. 123 kg of lookdown dory were reported to have been caught from outside the New Zealand EEZ in the 2012–13 fishing year.

Table 4: Reported historic landings (rounded to nearest tonne) of lookdown dory by FMA and fishing year 1989-90 to 2003-04.

Year	FMA 1	FMA 2	FMA 3	FMA 4	FMA 5	FMA 6	FMA 7	FMA 8	FMA 9	FMA 10
1989-90	2	1	40	20	12	2	51	-	-	-
1990-91	3	4	46	59	10	11	33	< 1	-	-
1991-92	1	2	96	75	17	3	55	-	-	-
1992-93	1	4	63	112	10	2	83	-	-	-
1993-94	< 1	2	62	50	4	3	67	-	< 1	-
1994-95	1	6	73	108	7	3	85	-	< 1	-
1995-96	2	4	99	78	11	3	62	-	< 1	-
1996-97	7	10	108	110	11	7	100	< 1	< 1	-
1997-98	5	8	159	272	11	25	82	-	< 1	-
1998-99	3	3	161	295	21	17	124	< 1	10	-
1999-00	3	5	161	295	21	17	124	< 1	10	-
2000-01	2	6	203	318	24	25	111	< 1	4	-
2001-02	10	10	181	331	26	28	170	3	2	-
2002-03	8	8	261	365	48	32	167	1	2	-
2003-04	13	8	135	210	22	24	113	3	1	-

1.2 Recreational fisheries

There is no quantitative information on recreational harvest levels of lookdown dory. Due to the offshore location and depth distribution of lookdown dory recreational catch is thought to be negligible.

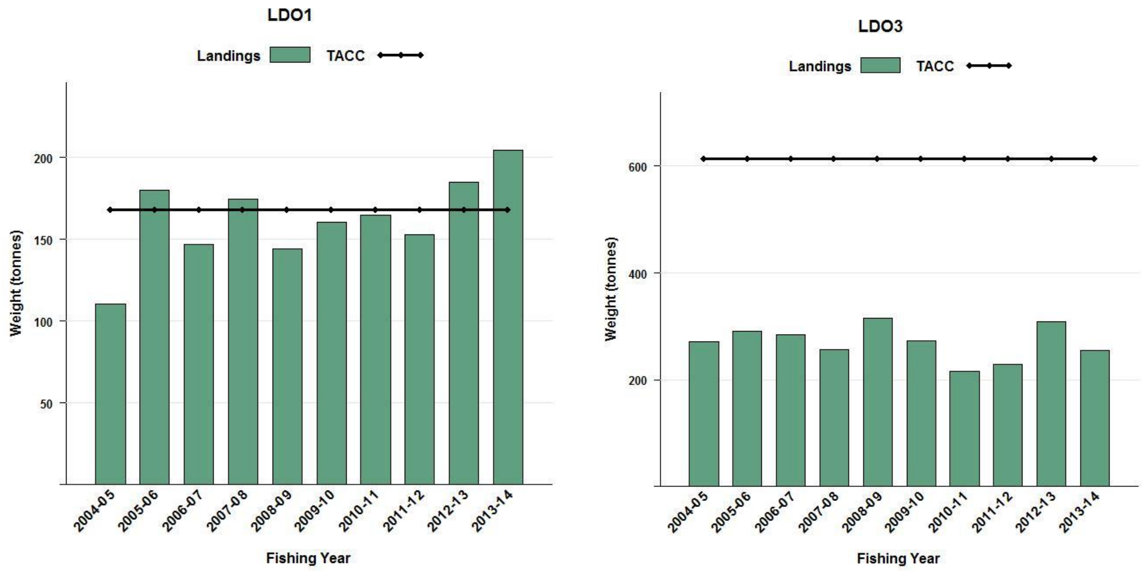


Figure 1: Reported commercial landings and TACC for the two main LDO stocks. Left to right: LDO1 (Challenger, Central, Auckland), and LDO3 (South East Chatham Rise, South East Coast, Sub Antarctic, Southland). Note that this figure does not show data prior to entry into the QMS.

1.3 Customary non-commercial fisheries

An estimate of current catch is not available but given the offshore location and depth distribution of lookdown dory customary non-commercial catch is thought to be negligible.

1.4 Illegal catch

Estimates of illegal catch are not available.

1.5 Other sources of mortality

There is no quantitative information on the level of other sources of mortality.

2. BIOLOGY

Lookdown dory (*Cyttus traversi*) belongs to the family Zeidae. This family includes 13 species in seven genera distributed among the Atlantic and Pacific Oceans and the Mediterranean Sea. Lookdown dory also occurs in Australian waters, mostly east and south of Tasmania (where it is known as king dory), and also in South Africa. It is widely distributed throughout New Zealand waters with most records from the Chatham Rise. The geographical and depth distribution of immature (< 33 cm) fish is similar to that of adults (Hurst et al, 2000).

It is one of the less abundant members of a loosely associated group of about 23 common species, which together form the upper slope assemblage of New Zealand's continental shelf (Francis et al, 2002). The main species in this group are hoki, javelin fish, ling, pale ghostshark, sea perch, hake, and longnose spookfish (chimaerid). It was identified as a key species characterising the demersal fish community 350-550 m on the Chatham Rise (Bull et al, 2001).

Juveniles are found in surface waters up to a length of approximately 12 cm (May & Maxwell 1986), at which stage a metamorphosis occurs associated with the transition from a pelagic to a demersal habitat (James 1976). Adults are most common between 400 to 600 m, but have a wide depth range, from 50 to 1200 m (Anderson et al, 1998). Immature fish less than 33 cm have a similar geographical and depth distribution to adults (Hurst et al, 2000, O'Driscoll et al, 2003). The main prey of lookdown dory are natant decapod crustaceans, followed by euphausid, mysid, galatheid, and nephropsid crustaceans, and fish (Clark & King 1989, Forman & Dunn, 2010). Lookdown dory is likely to be prey of larger fish and have occasionally been recorded in the stomachs of large ling.

Trawl survey catch distribution across the Chatham Rise is fairly even, with females ranging from 10 to 55 cm total length, and males ranging from 10 to 45 cm. Lookdown dory show early signs of ripening to spawn in the January surveys (Livingston et al, 2002). Catch distribution across the Sub-Antarctic is patchier than across the Chatham Rise, particularly during autumn surveys (O'Driscoll & Bagley 2001). Lookdown dory appear to grow larger in the SubAntarctic than on the Chatham Rise with females ranging from 12 to 60 cm total length, and males ranging from 12 to 45 cm.

There are no known aggregations or migrations associated with spawning lookdown dory. Around the North Island, female lookdown dory were reported to mature at about 35 cm (May & Maxwell 1986). Ripe specimens are usually seen in autumn and winter but have also been observed in summer (Clark & King 1989). Livingston et al, (2002) reported early signs of ripening in January Chatham Rise trawl surveys. Observer records from the east coast South Island and Chatham Rise show that ripe females are more common in summer months and spent females are more common in winter (MacGibbon et al, 2012). Females on the west coast South Island are mostly resting, immature or spent in winter. Although most spawning takes place in autumn and winter it is likely that it is not a discrete event but occurs over much of the year. Research data from other areas are sparse, but show the presence of fish in spawning condition in most months of the year.

Although there are no published studies of validated age and growth of lookdown dory, preliminary work in Australia suggests this species may live to over 30 years (Stewart & Smith 1992). Tracey et al (2007) attempted to use lead-radium techniques to validate ageing by zone counts of otoliths but were unsuccessful. Based on unvalidated zone counts, they observed maximum ages of 38 and 25 years for males and females respectively for New Zealand lookdown dory from the Chatham Rise. Von Bertalanffy growth parameters are given in Table 5 and length-weight parameters are given in Table 6.

Table 5: Summary of von Bertalanffy growth parameters for Chatham Rise lookdown dory. Source : Tracey et al, 2007. NB : Ageing in this study used unvalidated methods.

Sex	*N*	L_∞	SE	95% CI	*K*	SE	95% CI	t_0	SE	95% CI
All	382	50.72	2.53	(45.75, 55.68)	0.058	0.007	(0.044, 0.073)	-3.53	0.67	(-4.84, -2.21)
Males	191	38.78	1.68	(35.49, 42.06)	0.074	0.011	(0.053, 0.095)	-4.28	0.87	(-5.97, -2.57)
Females	191	69.94	5.71	(58.75, 81.13)	0.039	0.006	(0.027, 0.051)	-3.90	0.72	(-5.31, -2.49)

Table 6: Length-weight parameters for Chatham Rise and SubAntarctic lookdown dory.

Fishstock				**Estimate**	**Source**
1.Weight = a(length)b (Weight in g, length in cm total length)					
FMA 3 & 4	Females		Males		Tracey et al (2007)
	a	b	a	b	
	0.022	2.98	0.025	2.96	
FMA 5 & 6			Sexes combined		Bagley et al, (unpublished data)
			a	b	
			0.022	3.02	

3. STOCKS AND AREAS

A catch-effort characterisation carried out in 2010 (MacGibbon et al, 2012) identified three main fishing areas where lookdown dory are caught. These are the east coast South Island (FMA 3), Chatham Rise (FMA 4), and west coast South Island (FMA 7). It was found that these are still the main relevant fishing areas when this work was updated in 2012 (Ballara 2013, submitted).
There is little information on stock structure, recruitment patterns, or other biological characteristics on which to base any biological fishstock boundaries. MacGibbon et al (2012) found both sexes grow to a larger size in the SubAntarctic compared with the Chatham Rise suggesting the possibility of different stocks. There is also a difference in abundance between males and females in both areas with females nearly always outnumbering males (Figure 2).

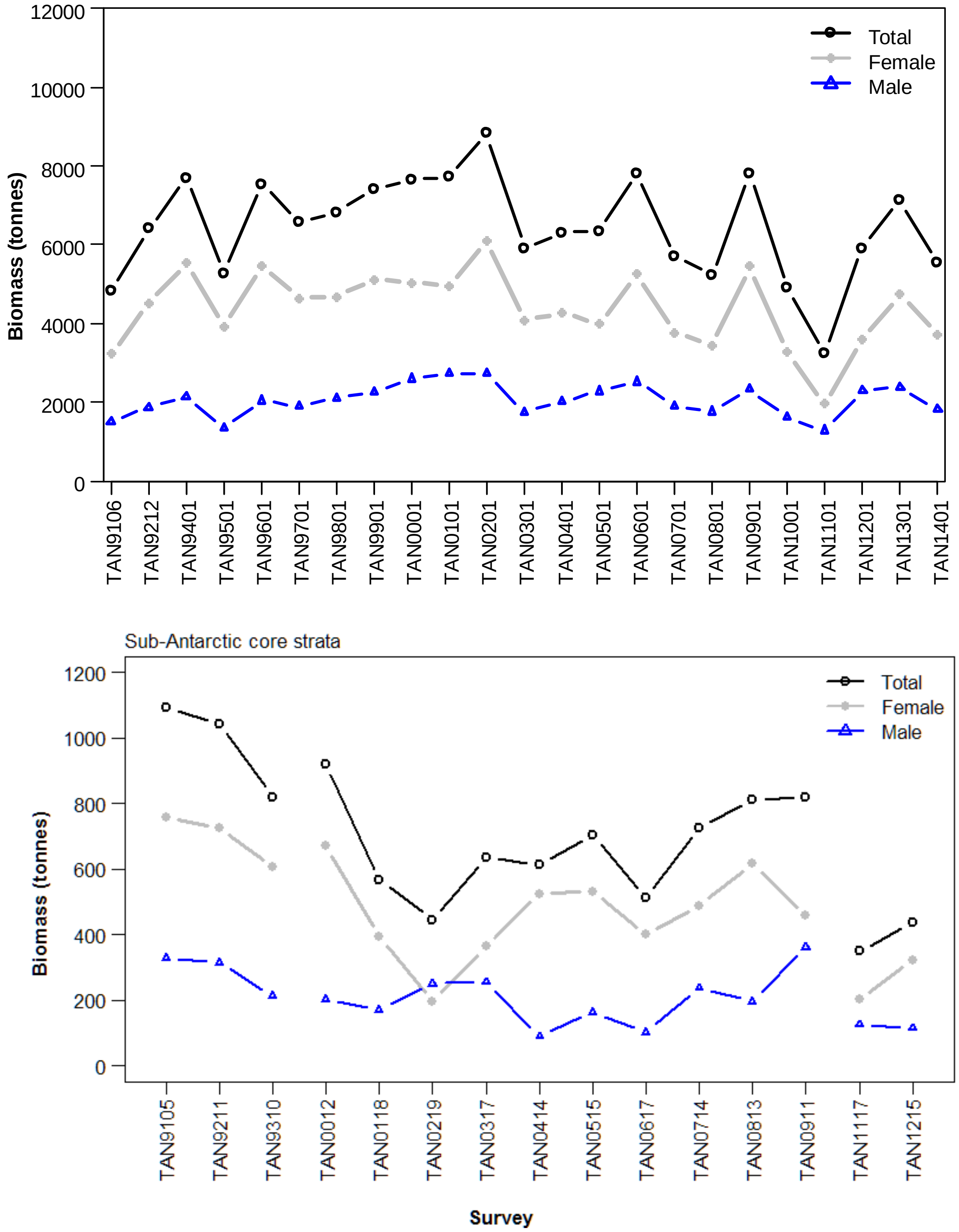


Figure 2: Doorspread biomass estimates of lookdown dory by sex from the Chatham Rise 1991 to 2014 (upper) and SubAntarctic 1991 to 1993 and 2000 to 2012 (lower), from *Tangaroa* surveys.

4. STOCK ASSESSMENT

In December 2013 the Middle Depths Working Group agreed that for the west coast South Island (FMA 7, which accounts for the vast majority of the LDO 1 catch), acceptable methods of monitoring abundance are relative biomass estimates from the west coast South Island winter trawl survey carried out by R.V. *Tangaroa*. Catch-per-unit-effort indices from daily processed commercial catches and from the scientific observer programme were also accepted as indices of abundance for the west coast of the South Island.

The Middle Depths Working Group agreed in February 2011 that relative biomass estimates of lookdown dory from middle depth trawl surveys on the Chatham Rise and the Sub-Antarctic were suitable for monitoring major changes in lookdown dory abundance for LDO 3. Standardised CPUE indices from a mixed target species trawl fishery on the ECSI and Chatham Rise area were not accepted by the Working Group.

4.1 Estimates of fishery parameters and abundance

Lookdown dory biomass is usually in the top 10 species on the Chatham Rise and CVs are relatively precise (usually < 15%) (Table 7). Females have consistently comprised more of the biomass than males (Figure 2). Biomass indices on the Sub-Antarctic have higher but still acceptable CVs (generally < 30%). Relative biomass has been lower in the last two surveys. Biomass indices from the west Coast South Island are considerably lower than those for the Chatham Rise and SubAntarctic but are still thought to be reliable measures of abundance.

Table 7: Biomass indices (t) and coefficients of variation (cv) for lookdown dory from *Tangaroa* trawl surveys (Assumptions: areal availability, vertical availability and vulnerability = 1). NB: estimates are for the core strata only for the respective time series.

Trip code	Date	Reference	Biomass (t)	% c.v.
Chatham Rise*				
TAN9106	Dec 1991–Feb 1992	Horn (1994a)	4 797	5.6
TAN9212	Dec 1992–Feb 1993	Horn (1994b)	6 439	5.2
TAN9401	Jan 1994	Schofield & Horn (1994)	7 664	7.2
TAN9501	Jan–Feb 1995	Schofield & Livingston (1995)	5 270	6.5
TAN9601	Dec 1995–Jan 1996	Schofield & Livingston (1996)	7 540	8
TAN9701	Jan 1997	Schofield & Livingston (1997)	6 568	7.6
TAN9801	Jan 1998	Bagley & Hurst (1998)	7 019	6
TAN9901	Jan 1999	Bagley & Livingston (2000)	7 417	8.2
TAN0001	Dec 1999–Jan 2000	Stevens et al (2001)	7 655	7
TAN0101	Dec 2000–Jan 2001	Stevens & Livingston (2002)	7 713	6.5
TAN0201	Dec 2001–Jan 2002	Stevens & Livingston (2003)	8 821	11.1
TAN0301	Dec 2002–Jan 2003	Livingston et al (2004)	5 853	7
TAN0401	Dec 2003–Jan 2004	Livingston & Stevens (2005)	6 304	8
TAN0501	Dec 2004–Jan 2005	Stevens & O'Driscoll (2006)	6 351	9.3
TAN0601	Dec 2005–Jan 2006	Stevens & O'Driscoll (2007)	7 818	8.5
TAN0701	Dec 2006–Jan 2007	Stevens et al (2008)	5 714	7.7
TAN0801	Dec 2007–Jan 2008	Stevens et al (2009a)	5 230	9.3
TAN0901	Dec 2008–Jan 2009	Stevens et al (2009b)	7 789	8.7
TAN1001	Jan 2010	Stevens et al (2011)	4 896	9.7
TAN1101	Jan 2011	Stevens et al (2012)	3 257	21.4
TAN1201	Jan 2012	Stevens et al (2013)	5 913	13.2
TAN1301	Jan 2013	Stevens et al (2014)	7 141	11
TAN1401	Jan 2014	Stevens et al (in preparation)	5 560	6.9
SubAntarcticic				
TAN0012	Nov–Dec 2000	O'Driscoll et al (2001)	877	15.2
TAN0118	Nov–Dec 2001	O'Driscoll & Bagley (2003a)	566	19.7
TAN0219	Nov–Dec 2002	O'Driscoll & Bagley (2003b)	446	22.1
TAN0317	Nov–Dec 2003	O'Driscoll & Bagley (2004)	636	23.7
TAN0414	Nov–Dec 2004	O'Driscoll & Bagley (2006a)	614	27.9
TAN0515	Nov–Dec 2005	O'Driscoll & Bagley (2006b)	703	19.1
TAN0617	Nov–Dec 2006	O'Driscoll & Bagley (2008)	509	35.3
TAN0714	Nov–Dec 2007	Bagley et al (2009)	725	20
TAN0813	Nov–Dec 2008	O'Driscoll & Bagley (2009)	811	24.7
TAN0911	Nov–Dec 2009	Bagley & O'Driscoll (2012)	820	25.1
TAN1117	Nov–Dec 2011	Bagley et al 2013	327	34.9
TAN1215	Nov–Dec 2012	Bagley & et al 2014	436	29.1
WCSI core				
TAN0007	Jul–Aug 2000	O'Driscoll et al (2004)	169	14.4
TAN1210	Jul–Aug 2012	O'Driscoll et al (2013) Ballara, S.L.;	155	11.9
TAN1310	Aug 2013	O'Driscoll et al (2014) Ballara, S.L.;	198	11.7
WCSI all				
TAN1210	Jul–Aug 2012	O'Driscoll et al (2013) Ballara, S.L.;	181	10.8
TAN1310	Aug 2013	O'Driscoll et al (2014) Ballara, S.L.;	228	12.1

Length frequencies of Chatham Rise lookdown dory suggest that recruitment is variable (MacGibbon et al, 2012, Ballara, submitted). Generally, when a strongly recruiting year class is present, the male length frequencies are often bimodal and females show two or three modes. Length frequency plots show that females are usually more numerous than males with a mean ratio for the time series of 1.15 females to every male (range 0.98-1.52). Males don't grow as large as females, with few males growing larger than 40 cm.

Length frequencies from the summer Sub-Antarctic series are less informative and no tracking of cohorts is possible. Overall, scaled population numbers are much lower for both sexes here than on the Chatham Rise but, again, females are more numerous than males with a mean ratio for the time series of 1.8 females for every male (range 0.55-3.9). Females also grow to a larger size than males and both sexes grow to a larger size on the Sub-Antarctic than on the Chatham Rise, which suggests that it may be a separate biological stock. This could also potentially be due to real differences in fishing pressure.

CPUE indices for lookdown dory on the WCSI were developed using the daily processed catch data and a smaller subset of observed vessels in the hoki and hake target fisheries. Both series show a similar trend, flat since 1995 (Figures 3 and 4).

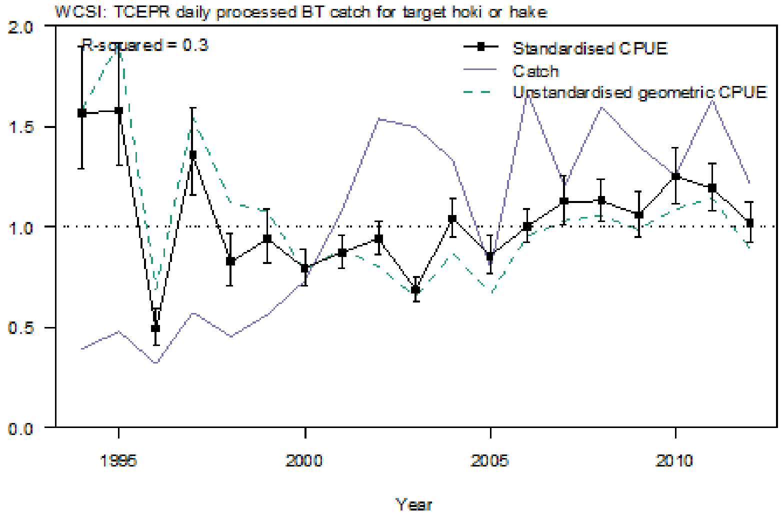


Figure 3: Log normal CPUE indices for WCSI daily processed catch, bottom trawl target hoki or hake, showing catches (scaled to same mean as indices), and lognormal standardised and un-standardised indices. Bars indicate 95% confidence intervals. Year defined as June–September.

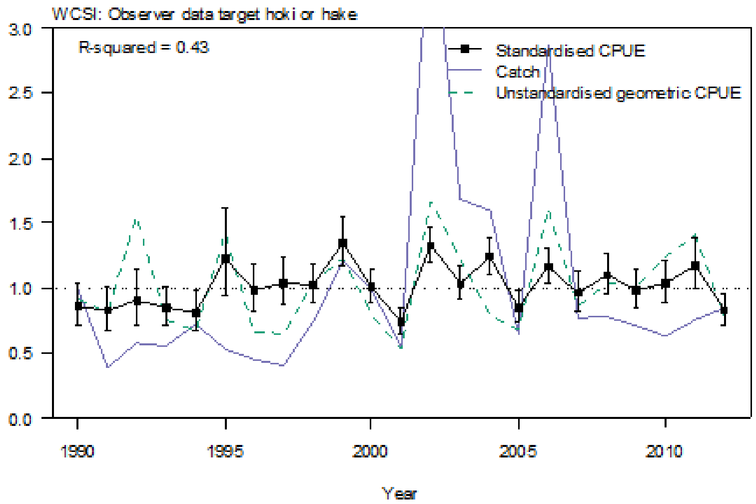


Figure 4: CPUE lognormal indices for WCSI observer programme data, target hoki or hake, bottom and midwater trawl, showing catches (scaled to same mean as indices), and lognormal standardised and un-standardised indices. Bars indicate 95% confidence intervals. Year defined as June–September.

4.2 Yield estimates and projections
MCY cannot be estimated.

CAY cannot be estimated.

4.4 Other yield estimates and stock assessment results
No information is available.

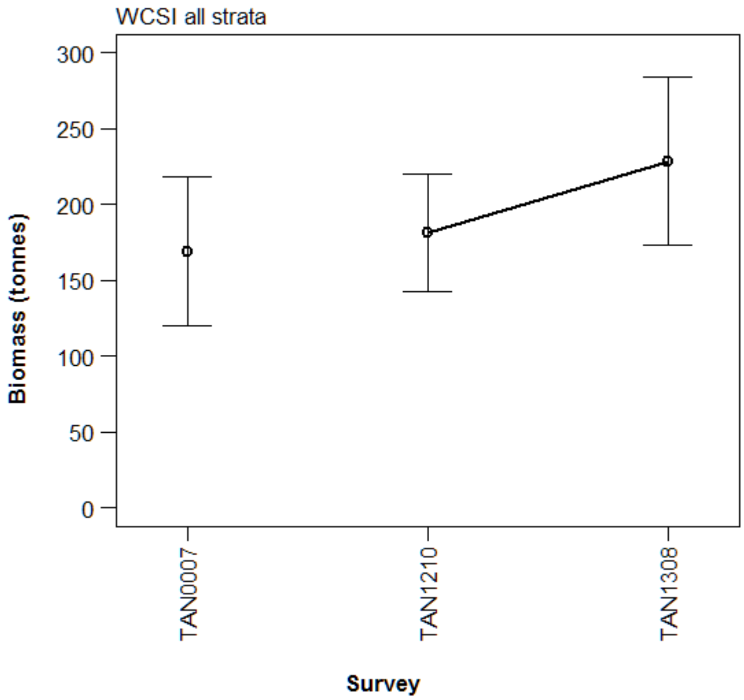
5. STATUS OF THE STOCK

There are no known sustainability concerns in the lookdown dory fishery. For LDO 1, the area which accounts for the vast majority of the lookdown dory catch is thought to be well monitored by trawl surveys which are currently too short to suggest any pattern, but CPUE indices suggest that abundance has been stable since the mid-1990s. For LDO 3, trawl surveys on the Chatham Rise and Sub-Antarctic indicate abundance has fluctuated in both areas

LDO 1

- **LDO 1 (west coast South Island, west and east coast North Island)**

Stock Status	
Year of Most Recent Assessment	2013
Reference Points	Target: Not established but 40% B_0 assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown for Soft limit Unlikely (< 40%) to be below the Hard Limit
Historical Stock Status Trajectory and Current Status	



Doorspread biomass estimates for lookdown dory (error bars are ± two standard deviations) from the winter WCSI *Tangaroa* surveys 2000, and 2012–2013.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Within LDO 1, FMA 7 biomass indices from the trawl survey time series are similar for 2000 and 2012, with an increase in 2013. This time series is only three points, but is thought to cover an appropriate depth and geographical range for lookdown dory. CPUE indices have been relatively flat since the mid-1990s.
Recent Trend in Fishing Mortality or Proxy	Unknown

Projections and Prognosis	
Stock Projections or Prognosis	Stock size is unlikely (< 40%) to change much at current catch levels in FMA 7.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Evaluation of agreed CPUE indices and trawl survey indices thought to index abundance within FMA 7 of LDO 1. The vast majority of the LDO 1 catch is taken in FMA 7, catches in other areas of LDO 1 are minor.	
Main data inputs	-	
Period of Assessment	Latest assessment: 2013	Next assessment: 2016
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

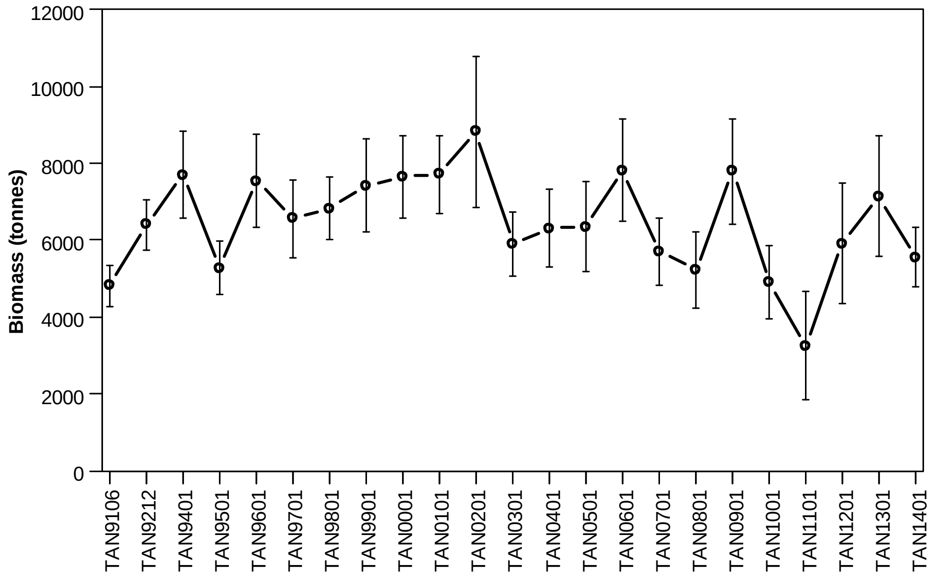
Qualifying Comments

Fishery Interactions
In LDO 1, lookdown dory are taken primarily as bycatch in the bottom trawl west coast South Island hoki and hake target fisheries. Smaller catches are reported by midwater trawl. Interactions are the same as those for the hoki fishery. The east coast North Island scampi fishery also catches lookdown dory. A variety of other target fisheries also report catching lookdown dory but in very small amounts. A small amount of lookdown dory is targeted on the west coast of the South Island by smaller trawlers.

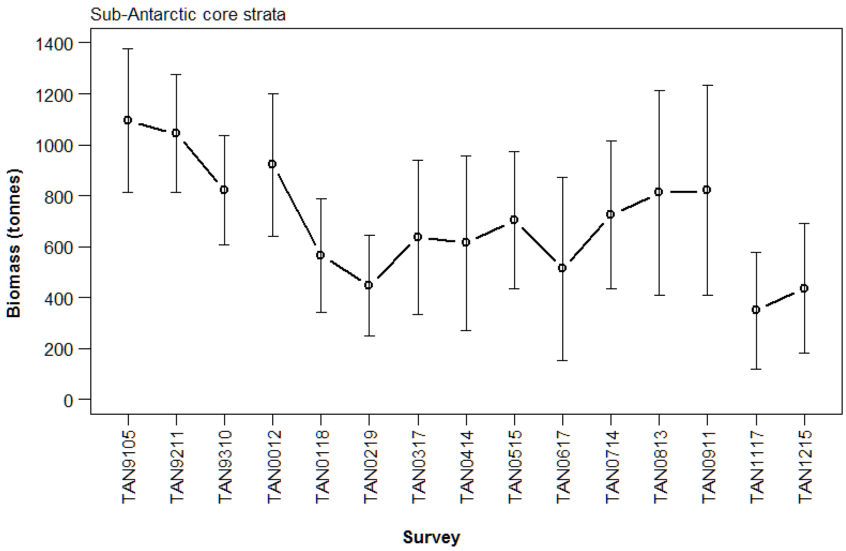
- **LDO 3 (Chatham Rise & Sub-Antarctic)**

Stock Status	
Year of Most Recent Assessment	2013
Reference Points	Target: Not established but 40% B_0 assumed Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown for Soft limit Unlikely (< 40%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Doorspread biomass estimates of lookdown dory (error bars are ± two standard deviations) from the Chatham Rise, from *Tangaroa* surveys from 1991 to 2013.



Doorspread biomass estimates of lookdown dory (error bars are ± two standard deviations) from the SubAntarctic, from *Tangaroa* surveys from 1991 to 1993, 2000 to 2009, and 2011–12.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Within LDO 3, FMAs 3 & 4 biomass indices have been fairly flat throughout the time series of Chatham Rise trawl surveys with the exception of 2010 and 2011 which show a decline. The 2012–14 surveys are more in line with previous years. For FMAs 5 & 6 biomass indices from the Sub-Antarctic series declined to 2002, steadily increased until 2009, and has dropped to the lowest estimates in the time series in 2011 and 2012.
Recent Trend in Fishing Mortality or Proxy	Unknown

Projections and Prognosis	
Stock Projections or Prognosis	Stock size is Unlikely (< 40%) to change much at current catch levels in FMAs 5 & 6.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 2: Partial quantitative stock assessment	
Assessment Method	Evaluation of agreed trawl survey indices thought to index FMA 3 & 4, and FMA 5 & 6 abundance	
Main data inputs	-	
Period of Assessment	Latest assessment: 2013	Next assessment: 2016
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
There is some indication that lookdown dory on the Chatham Rise may be a different stock to the Sub-Antarctic (i.e. different maximum sizes, evidence of some spawning activity in the Sub-Antarctic, as well as more extensively on the Chatham Rise)

Fishery Interactions
In LDO 3 lookdown dory are mainly caught as bycatch in the hoki target bottom trawl fishery but also in many other middle depth fisheries. Interactions are the same as those for the hoki fishery.

7. FOR FURTHER INFORMATION

Anderson, O F; Bagley, N W; Hurst, R J; Francis, M P; Clark, M R; McMillan, P J (1998) Atlas of New Zealand fish and squid distribution from research bottom trawls. *NIWA Technical Report 42. 303 p.*

Anderson, O F; Gilbert, D J; Clark, M R (2001) Fish discards and non-target catch in the trawl fisheries for orange roughy and hoki in New Zealand waters for the fishing years 1990–91 to 1998–99. *New Zealand Fisheries Assessment Report 2001/16. 57* p.

Bagley, N W; O'Driscoll, R L (2012) Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2009 (TAN0911). *New Zealand Fisheries Assessment Report 2012/05.* 70 p.

Ballara, S L (2014). Fishery characterisation and standardised CPUE analyses for lookdown dory, *Cyttus traversi* (Hutton, 1872) (Zeidae), 1989–90 to 2011–12. *New Zealand Fisheries Assessment Report 2014/62.*

Bull, B; Livingston, M E; Hurst, R J; Bagley, N (2001) Upper-slope fish communities on the Chatham Rise, New Zealand, 1992–99. *New Zealand Journal of Marine and Freshwater Research 35 (3):* 795–815.

Clark, M R; King, K J (1989) Deepwater fish resources off the North Island, New Zealand: results of a trawl survey, May 1985 to June 1986. *New Zealand Fisheries Technical Report 11. 56 p.*

Forman, J S; Dunn, M R (2010) The influence of ontogeny and environment on the diet of lookdown dory, *Cyttus traversi*. *New Zealand Journal of Marine and Freshwater Research*. 44: 329–42.

Francis, M P; Hurst, R J; McArdle, B; Bagley, N W; Anderson, O F (2002) New Zealand demersal fish assemblages. *Environmental Biology of Fishes 62(2):* 215–234.

Hurst, R J; Bagley, N W; Anderson, O F; Francis, M P; Griggs, L H; Clark, M R; Paul, L J; Taylor, P R (2000) Atlas of juvenile and adult fish and squid distributions from bottom and midwater trawls and tuna longlines in New Zealand waters. *NIWA Technical Report 84*. 162 p.

James, G D (1976) Cyttus traversi Hutton: Juvenile form of *C. ventralis* Barnard and Davies (Pisces: Zeidae*). Journal of the Royal Society of New Zealand 6(4):* 493–498.

Livingston, M E; Bull, B; Stevens, D W; Bagley, N W (2002) A review of hoki and middle depth trawl surveys of the Chatham Rise, January 1992–2001. *NIWA Technical Report 113*. 146 p.

Livingston, M E; Clark, M; Baird, S J (2003) Trends in incidental catch of major fisheries on the Chatham Rise for fishing years 1989–90 to 1998–99. *New Zealand Fisheries Assessment Report 2003/52.* 74 p.

Livingston, M E; Stevens, D W (2005) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2004 (TAN0401). *New Zealand Fisheries Assessment Report 2005/21. 62 p*.

MacGibbon, D J; McGregor, V; Hurst, R J (2012) Fishery characterisation and standardised CPUE analyses for lookdown dory, *Cyttus traversi* (Hutton, 1872) (Zeidae), 1989–90 to 2008–09**.** *New Zealand Fisheries Assessment Report 2012/07.* 143 p.

May, J L; Maxwell, J G H (1986) Trawl fish from temperate waters of Australia. CSIRO Division of Fisheries Research, Tasmania. 492 p.

Nelson, J S (1994) *Fishes of the world*. Third edition. J. Wiley, New York. 600 p.

O'Driscoll, R L; Bagley, N W (2001) Review of summer and autumn trawl survey time series from the Southland and Sub-Antarctic area 1991–98. *NIWA Technical Report 102.* 115 p.

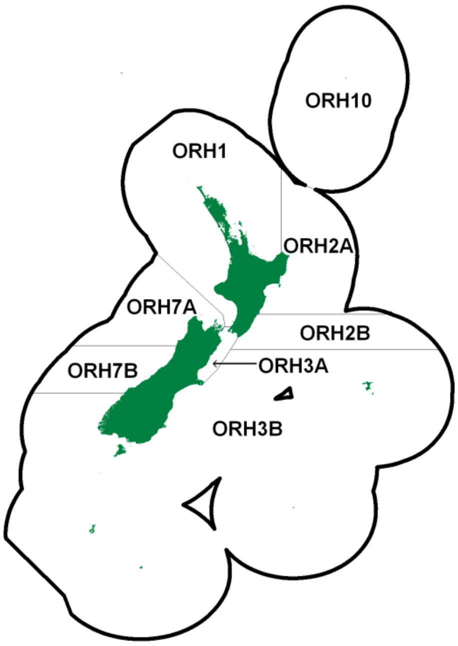
O'Driscoll, R L; Booth, J D; Bagley, N W; Anderson, O F; Griggs, L H; Stevenson, M L; Francis, M P (2003) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. *NIWA Technical Report 119*. 377 p.

Stewart, B D; Smith, D (1992) Development of methods to age commercially important dories and oreos. *Newsletter of the Australian Society for Fish Biology 22 (2):* 53–54.

Tracey, D M; Horn, P L; Andrews, A H; Marriott, P M; Dunn, M R (2007) Age and growth, and an investigation of age validation of lookdown dory (*Cyttus traversi*). Final Research Report for Ministry of Fisheries Project LDO2004-01 Objective 1. 36 p. (Unpublished report held by MPI Wellington.)

ORANGE ROUGHY (ORH)

(*Hoplostethus atlanticus*)



1. INTRODUCTION

Orange roughy was introduced into the Quota Management System (QMS) on 1 October 1986. The main orange roughy fisheries have been treated separately for assessment and management purposes, and individual reports have been produced for each of six areas consisting of one or more stocks as follows:

1. Northern North Island (ORH 1)
    - Mercury-Colville stock
    - Other stocks
2. Cape Runaway to Banks Peninsula (ORH 2A, 2B, & 3A)
    - East Cape stock
    - Mid-East Coast stock
3. Chatham Rise and Puysegur (ORH 3B)
    - Northwest Chatham Rise stock
    - East and South Chatham Rise stock
    - Puysegur stock
    - Other minor stocks or subareas
4. Challenger Plateau (ORH 7A)
5. West coast South Island (ORH 7B)
6. Outside the EEZ
    - Lord Howe
    - Northwest Challenger
    - Louisville
    - West Norfolk
    - South Tasman

Four new stock assessments were conducted in 2014: Mid-East Coast, Northwest Chatham Rise, East and South Chatham Rise, and Challenger Plateau. All assessments used similar methods and relied on the use of ageing data and recent acoustic surveys of spawning plumes. The methods, which were common to the assessments, are described later in this introduction and a brief summary of the main results is also provided.

2. BIOLOGY

Orange roughy inhabit depths between 700 m and at least 1500 m within the New Zealand EEZ. They are most abundant between about 800 m and 1200 m. Their maximum depth range is unknown.

Orange roughy are slow-growing, long-lived fish. On the basis of otolith ring counts and radiometric isotope studies, orange roughy may live up to 120–130 years. Age determination from otolith rings has been validated by length-mode analysis for juveniles up to four years of age (Mace et al 1990), and adult ages have been validated using radiometric techniques in a study by Andrews & Tracey (2003).

Orange roughy otoliths have a marked transition zone in banding which is believed to be associated with the onset of maturity (Francis & Horn 1997). The estimates of transition-zone maturity range from 23 to 31.5 years for fish from various New Zealand fishing grounds (Horn et al 1998, Seafood Industry Council/NIWA unpublished data). However, spawning fish appear to be an older subset of the transition-zone mature fish as evidenced by the older ages and the larger sizes of fish caught on the spawning grounds. The age at which 50% of fish are spawning was estimated in the 2014 stock assessment models to range from 32–41 years (see Section 4.2). Orange roughy in New Zealand waters reach a maximum size of about 50 cm standard length (SL), and 3.6 kg in weight, but the maximum size appears to vary among local populations. Average size is around 35 cm SL, although there is variation between areas.

Spawning occurs once each year between June and early August in several areas within the New Zealand EEZ, from the Bay of Plenty in the north, to the Auckland Islands in the south. Spawning occurs in dense aggregations at depths of 700–1000 m and is often associated with bottom features such as pinnacles and canyons. Spawning fish are also found outside the EEZ on the Challenger Plateau, Lord Howe Rise, and Norfolk Ridge to the west, and the Louisville Ridge to the east.

Fecundity is relatively low, with females carrying on average about 40 000–60 000 eggs. The eggs are large (2–3 mm in diameter), are fertilised in the water column, and then drift upwards towards the surface and remain planktonic until they hatch close to the bottom after about 10 days. Details of larval biology are poorly known.

Orange roughy juveniles are first available to bottom trawls at age about 6 months, when they exhibit a mean length of about 2 cm. Juveniles have been found in large numbers in only one area, at a depth of 800–900 m about 150 km east of the main spawning ground on the north Chatham Rise.

Orange roughy also form aggregations outside the spawning period, presumably for feeding. Their main prey species include mesopelagic and benthopelagic prawns, fish and squid, with other organisms such as mysids, amphipods and euphausiids occasionally being important.

Natural mortality (M) has been estimated to be 0.045 yr^{-1}. This was based on otolith age data from a 1984 research survey of the Chatham Rise that used an estimation technique based on mean age. A similar estimate was obtained in 1998 from a lightly fished population in the Bay of Plenty.

Biological parameters used in the following assessments (Tables 1 and 2) were estimated by Doonan (1994) with modifications of A_r, A_m, S_r, and S_m for the 1998 stock assessment meetings by Francis & Horn (1997), Horn et al (1998), and Doonan et al (1998), and further modifications for the 2006 assessment by Hicks (2006).

Biases in reading ages from otoliths were identified, leading to a recommendation by reviewers of orange roughy workshops in October 2005 and February 2006 that no age data should be used in assessments until the biases were quantified and corrected. Stemming from this recommendation, a new ageing methodology was developed for orange roughy in 2007, associated with an international ageing workshop for this species (Tracey et al. 2007). In the 2014 stock assessments, age-frequency data were only used if the otoliths had been read using the new ageing protocol.
It is believed that ages derived from otoliths collected during the 1984 and 1990 trawl surveys of the East Chatham Rise, which were aged under the old NIWA protocol do not contain serious biases. The

single-sex growth curve, the length-weight parameters and the maturity ogive based on transition zones, which are all based on ageing using the old-protocol data are still believed to be valid. The estimates of these biological parameters (Table 1) were used for both the East Chatham Rise and the Northwest Chatham Rise stock assessments, although the otoliths used were collected from the East Chatham Rise only (of which most were from the Spawning Box). The transition-zone maturity estimates were not used in the 2014 stock assessments as maturity was estimated in each of the models.

Table 1: Biological parameters as used for orange roughy assessments. -, not estimated.

Parameter	Symbol	Male	Female	Both sexes
Natural mortality	M	-	-	0.045 yr^{-1}
Age of recruitment	A_r (a_{50})	-	-	$=A_m$
Gradual recruitment	S_r (a_{to95})	-	-	$=S_m$
Age at maturity	A_m (a_{50})	-	-	Table 2
Gradual maturity	S_m (a_{to95})	-	-	Table 2
von Bertalanffy parameters				
- Chatham Rise (default)	L_∞	36.4 cm	38.0 cm	-
- Northwest Chatham Rise	L_∞	-	-	37.78 cm
- East Chatham Rise	L_∞	-	-	37.78 cm
- Ritchie Bank	L_∞	-	-	37.63 cm
- Challenger Plateau	L_∞	33.4 cm	35.0 cm	-
- All areas (default)	k	0.070 yr^{-1}	0.061 yr^{-1}	-
- Northwest Chatham Rise	k	-	-	0.059 yr^{-1}
- East Chatham Rise	k	-	-	0.059 yr^{-1}
- Ritchie Bank	k	-	-	0.065 yr^{-1}
- All areas (default)	t_0	-0.4 yr	-0.6 yr	-
- East Chatham Rise	t_0	-	-	-0.491
- Northwest Chatham Rise	t_0	-	-	-0.491
- Ritchie Bank	t_0	-	-	-0.5
Length-weight parameters				
- default	a	-	-	0.0921
- East and Northwest Chatham Rise	a			0.0800
- default	b	-	-	2.71
- East and Northwest Chatham Rise	b			2.75
Recruitment variability	σ_R	-	-	1.1
Recruitment steepness		-	-	0.75

Table 2: Estimates of A_m and S_m by area for New Zealand orange roughy from transition zone observations.

			A_m			S_m
Area	M	F	Both sexes	M	F	Both sexes
Chatham Rise (default)	-	-	29	-	-	3
Northwest Chatham Rise	-	-	28.51	-	-	4.56
East Chatham Rise	-	-	28.51	-	-	4.56
Ritchie Bank	-	-	31.5	-	-	7.11
Challenger Plateau	-	-	23	-	-	3
Puysegur Bank	-	-	27	-	-	3
Bay of Plenty	26	27	-	4	5	-

The method of Francis (1992) was used to estimate reference points and yields for orange roughy stocks. The differing parameter values in Tables 1 and 2 by stock meant that yield estimates varied across stocks (Table 3).

Table 3: Estimates of *MCY*, E_{CAY} and *MAY* for New Zealand orange roughy.

Area	*MCY* (%B_0)	E_{CAY}	*MAY* (%B_0)
Bay of Plenty (ORH 1)	1.47	0.063	1.94
Ritchie Bank (ORH 2A)	1.46	0.062	1.92
Chatham Rise (ORH 3B)	1.51	0.064	1.99
Puysegur Bank (ORH 3B)	1.47	0.062	1.94
Challenger Plateau (ORH 7A)	1.40	0.060	1.84

For all these stocks, the mean biomass when fishing using an *MCY* policy was estimated to be 51% of B_0, and for a *CAY* policy it was 30% of B_0 (these values varied by less than 1% between the various stocks).

The reference points and yields given above are not used in the 2014 stock assessments. In these assessments, MCMC estimates of deterministic reference points and yields were made for the target biomass range of 30-40% B_0. However, the lower bound of this range was taken from the above results (the mean biomass under a CAY policy).

3. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2013 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. This summary is from the perspective of the deepwater trawl fisheries for orange roughy; an issue-by-issue analysis is available in the 2012 Aquatic Environment and Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644).

3.1 Role in the ecosystem

Orange roughy are the dominant demersal fish at depths of 750–1100 m on the north and east Chatham Rise, the east coast of the North Island south of about East Cape, and the Challenger Plateau (Clark et al 2000; Doonan & Dunn 2011; Tracey et al 1990). An analysis of New Zealand demersal fish assemblages using research trawl data showed that orange roughy was the most frequently occurring species (found in more than 40 % of tows) in the mid slope assemblage (Francis et al 2002). Fishing has reduced the abundance of orange roughy since the 1980s, and the effects of removing, for example, an average of about 18 000 t per year from ORH 3B between 1979–80 and 2009–10 are largely unknown. There are likely to have been ecosystem implications (Tracey et al 2012).

3.1.1 Trophic interactions

The main prey species of orange roughy include mesopelagic and benthopelagic prawns, fish and squid, with other organisms such as mysids, amphipods and euphausiids occasionally being important (Rosecchi et al 1988). Koslow (1997) showed that orange roughy have a faster metabolism than deepwater fishes that are typically dispersed over the flat seafloor, and their food consumption is higher. Ontogenetic shifts occur in their feeding preferences with the smaller fish (up to 20 cm) feeding on crustaceans, and larger fish (31 cm and above) feeding on teleosts and cephalopods (Stevens et. al 2011). Relative proportions of the three prey groups were similar between areas. Bulman & Koslow (1992) found that teleosts were more important than crustaceans by weight in the prey of Australian orange roughy, and that this dominance increased in adult-sized fish. Dunn & Forman (2011) inferred from diet analysis that juveniles feed more on the benthos compared with the benthopelagic foraging of adults. Where they co-occur, orange roughy and black oreo may compete for teleost and crustacean prey.

Predators of orange roughy are likely to change with fish size. Larger smooth oreo, black oreo and orange roughy were observed with healed soft flesh wounds, typically in the dorso-posterior region. Wound shape and size suggest they may be caused by one of the deepwater dogfishes (Dunn et al 2010). Giant squid and sperm whales have also been found to prey on orange roughy (Gaskin & Cawthorn 1967, Jereb & Roper 2010)

3.1.2 Ecosystem Indicators

Tuck et al (2009) used data from the Sub-Antarctic and Chatham Rise middle-depth trawl surveys to derive indicators of fish diversity, size, and trophic level. However, fishing for orange roughy occurs mostly deeper than the depth range of these surveys and is only a small component of fishing in the areas considered by Tuck et al (2009).

3.2 Incidental catch (fish and invertebrates)

Anderson (2011) summarised the bycatch of orange roughy and oreo trawl fisheries from 1990–91 to 2008–09. For orange roughy trawls since 2005–06, orange roughy accounted for about 84% of the total observed catch and the remainder comprised mainly oreos (10%), hoki (0.4%), and cardinalfish (0.3%). About 240 other species or species groups were recorded by observers, including various deepwater dogfishes (1.8%), rattails (1.0%), morid cods (0.8%), and slickheads (0.3%). Total annual bycatch in the orange roughy fishery has been as high as 27 000 t but has declined with the TACC and was less than 4000 t between 2005–06 and 2008–09 (non-commercial species comprising only 5–10% of the total). Total annual discards also decreased over time, from about 3400 t in 1990–91 to about 300 t in 2007–08 and, since about 2000, has been almost entirely of non-QMS species (rattails, shovelnose spiny dogfish, and other deepwater dogfishes).

Invertebrate species are caught in low numbers in the orange roughy fishery (Anderson 2011). Squid (mostly warty squid, *Moroteuthis* spp.) were the largest component of invertebrate catch, followed by various groups of coral, echinoderms (mainly starfish), and crustaceans (mainly king crabs, family Lithodidae). Tracey et al (2011) analysed the distribution of nine groups of protected corals based on bycatch records from observed trawl effort from 2007–08 to 2009–10, primarily from 800–1000 m depth. For the orange roughy target fishery, about 10% of observed tows in FMAs 4 and 6 included coral bycatch, but a higher proportion of tows in northern waters included coral (28% in FMA 1, 53% in FMA 9, Tracey et al 2011).

3.3 Incidental Catch (seabirds, mammals, and protected fish)

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp but not brought onboard the vessel, Middleton & Abraham 2007, Brothers et al 2010).

3.3.1 Marine mammal interactions

Trawlers targeting orange roughy have occasionally incidentally captured NZ fur seals (which were classified as “Not Threatened” under the New Zealand Threat Classification System in 2010, Baker et al 2010). Between 2002–03 and 2011–13, there were 6 observed captures of fur seals in the orange roughy trawl fisheries, with an estimated total capture of fur seals for all orange roughy tows between 2002-03 and 2012-13 of 11. (Table 4). All observed fur seal captures occurred in the Sub-Antarctic region. There have been no reported captures of fur seals in the last six years. The average rate of capture for 2002-03 to 2012-13 is 0.06 per 100 tows (range 0 to 0.28), a very low rate compared with other New Zealand trawl fisheries by between one and two orders of magnitude.

Table 4: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in the orange roughy trawl fisheries, 2002–03 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2011–12 are based on data version 20130304 and preliminary estimates for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures		
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.	% included
2002–03	4 895	939	19.2	0	0.00	0	0 – 3	100.0
2003–04	4 866	795	16.3	1	0.13	2	2 – 5	100.0
2004–05	5 001	1 063	21.3	3	0.28	5	4 – 9	100.0
2005–06	4 949	900	18.2	1	0.10	2	1 – 6	100.0
2006–07	4 058	1 192	29.4	1	0.08	1	1 – 2	100.0
2007–08	3 689	1 618	43.9	0	0.00	0	0 – 3	100.0
2008–09	3 544	1 435	40.5	0	0.00	1	0 – 6	100.0
2009–10	2 922	1 139	39.0	0	0.00	0	0 – 4	100.0
2010–11	1 889	495	26.2	0	0.00	0	0 – 1	100.0
2011–12	1 588	437	27.5	0	0.00	0	0 – 1	100.0
2012–13†	1 592	184	11.6	0	0.00	-	-	-

† Provisional data, no model estimates available.

3.3.2 Seabird interactions

Annual observed seabird capture rates in the orange roughy trawl fisheries have ranged from 0.00 to 1.79 per 100 tows between 2002-03 and 2012-13 (Table 5). The average over this period is 0.48 per 100 tows, a very low rate relative to other trawl fisheries by between one and two orders of magnitude.

Table 5: Number of tows by fishing year and observed seabird captures in orange roughy trawl fisheries, 2002–03 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Abraham et al (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2011–12 are based on data version 20130304 and preliminary estimates for 2012–13 are based on data version 20140131.

	Fishing effort			Observed captures		Estimated captures		
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.	% included
2002–03	4 895	939	19.2	0	0.00	22	7 – 59	100.0
2003–04	4 866	795	16.3	3	0.38	21	9 – 40	100.0
2004–05	5 001	1 063	21.3	19	1.79	46	29 – 77	100.0
2005–06	4 949	900	18.2	2	0.22	26	12 – 49	100.0
2006–07	4 058	1 192	29.4	1	0.08	11	4 – 22	100.0
2007–08	3 689	1 618	43.9	2	0.12	12	5 – 22	100.0
2008–09	3 544	1 435	40.5	6	0.42	16	9 – 26	100.0
2009–10	2 922	1 139	39.0	13	1.14	27	19 – 49	100.0
2010–11	1 889	495	26.2	2≠	0.40≠	10	3 – 21	100.0
2011–12	1 588	437	27.5	0	0.00	6	1 – 14	100.0
2012–13†	1 592	184	11.6	2	1.09	-	-	-

† Provisional data, no model estimates available.
≠ The two captures reported in the database v20130304 are updated to zero in version v20140131 which is likely to reduce the estimates of recent captures somewhat when these data are available; the associated capture rate will also be zero for this year.

Salvin’s albatross was the most frequently captured albatross (38% of observed albatross captures, n=9) but seven different species have been observed captured since 2002–03. Cape petrels were the most frequently captured other taxon (57%, n=18 of non-albatross other birds, Table 6). Seabird captures in the orange roughy fisheries have been observed mostly around the Chatham Rise and off the east coast South Island. These numbers should be regarded as only a general guide on the distribution of captures because the observer coverage is not uniform across areas and may not be representative.

Table 6: Number of observed seabird captures in orange roughy fisheries, 2002–03 to 2012–13, by species and area. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard & Abraham 2013 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for orange roughy. Other data, version 20140131.

Species	Risk Ratio	Chatham Rise	East Coast South Island	Subantarctic	Stewart Snares Shelf	West Coast South Island	Total
Salvin's albatross	Very high	8	0	1	0	0	9
Southern Buller's albatross	Very high	3	0	0	0	0	3
Chatham Island albatross	Very high	4	0	0	0	0	4
NZ white capped albatross	Very high	4	0	0	0	0	4
Gibson's albatross	High	1	0	0	0	0	1
Northern royal albatross	Medium	1	0	0	0	0	1
Southern royal albatross	Medium	1	0	0	0	0	1
Unidentified	-	1	0	0	0	0	1
Total albatrosses	**N/A**	**23**	**0**	**1**	**0**	**0**	**24**
Cape petrel	High	9	9	0	0	0	18
Northern giant petrel	Medium	1	0	0	0	0	1
Grey petrel	Medium	2	0	0	0	0	2
Common diving petrel	-	2	0	0	0	0	2
White-faced storm petrel	-	1	0	0	0	0	1
Total other birds	**N/A**	**15**	**9**	**0**	**0**	**0**	**24**

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the orange roughy, oreo, and cardinalfish trawl fisheries. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Department of Internal

Affairs, 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being "paired streamer lines", "bird baffler" or "warp deflector" as defined in the notice).

3.4 Benthic interactions

Orange roughy, oreo, and cardinalfish are taken using bottom trawls and accounted for about 14% of all tows reported on TCEPR forms to have been fished on close to the bottom between 1989–90 and 2004–05 (Baird et al 2011). Black et al (2013) estimated that, between 2006–07 and 2010–11, 98% of orange roughy catch was reported on TCEPR forms. Tows are located in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2009) classes J, K (mid-slope), M (mid-lower slope), N, and O (lower slope and deeper waters) (Baird & Wood 2012), and 94% were between 700 and 1 200 m depth (Baird et al 2011). Deepsea corals in the New Zealand region are abundant and diverse and, because of their fragility, are at risk from anthropogenic activities such as bottom trawling (Clark & O'Driscoll 2003, Clark & Rowden 2009, Williams et al 2010). All deepwater hard corals are protected under Schedule 7A of the Wildlife Act 1953. Baird et al (2012) mapped the likely coral distributions using predictive models, and concluded that the fisheries that pose the most risk to protected corals are these deepwater trawl fisheries.

Trawling for orange roughy, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review 2013 (MPI, 2013).

The NZ EEZ contains 17 Benthic Protection Areas (BPAs) that are closed to bottom trawl fishing and include about 52% of all seamounts over 1500 m elevation and 88% of identified hydrothermal vents.

3.5 Other considerations

Fishing during spawning may disrupt spawning activity or success. Morgan et al (1999) concluded that Atlantic cod (*Gadus morhua*) "exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae". Morgan et al (1997) also reported that "Following passage of the trawl, a 300-m-wide "hole" in the [cod spawning] aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl." There is no research on the disruption of spawning orange roughy by fishing in New Zealand.

3.5.2 Genetic effects

Fishing, environmental changes, including those caused by climate change or pollution, could alter the genetic composition or diversity of a species. There are no known studies of the genetic diversity of orange roughy from New Zealand. Genetic studies for stock discrimination are reported under "stocks and areas".

3.5.3 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management (HPSFM) does not have a policy definition (MPI, 2013) although work is currently underway to generate one. Mace et al (1990) identified only one area of high abundance for juvenile orange roughy at 800–900 m depth about 150 km east of the main spawning ground on the north Chatham Rise. Orange roughy from 9 cm SL have also been located on the Challenger Plateau and O'Driscoll et al (2003) show other areas where immature fish are relatively common. Dunn et al (2009) showed that orange roughy juveniles are generally found close to the seabed, and in shallower water than the adults, starting off at depths of around 850–900 m and spreading deeper, and over a wider depth range, as they grow. Dunn & Forman (2011) also suggested that juveniles start on flat grounds shallower than the adults, that they shift deeper as they grow, and that seamounts and other features tend to be dominated by the largest orange roughy. It is not known if there are any direct linkages between the congregation of orange roughy around features and the corals found on those features. Bottom trawling for orange roughy has the potential to affect features of the habitat that could qualify as habitat of particular significance to fisheries management.

4. SUMMARY OF 2014 STOCK ASSESSMENTS

Stock assessments were undertaken for the Mid-east coast (MEC), Northwest Chatham Rise (NWCR), East and South Chatham Rise (ESCR) and ORH7A in 2014. In this section, the methods that were common to these four stock assessments are described and the main results are summarised.

4.1 Methods used in 2014

The methods used in 2014 were different from those used in previous orange roughy assessments in a number of respects. The major differences were in the application of a more stringent data quality threshold, in model structure, and in the use of age data to estimate year class strengths.

4.1.1 Data quality and model structure

A high threshold was imposed on data before they were used in an assessment. This resulted in the exclusion of a number of biomass estimates that had previously been used. In particular, CPUE indices were not used in any of the assessments because they were considered unlikely to be monitoring stock-wide abundance (e.g., non-spawning season catch rates from a single hill feature or complex within a large area cannot be monitoring stock wide abundance as the fishery would not have been sampling a large proportion of the stock; at best, such CPUE indices may index localised abundance; during the spawning season catches from a single hill or aggregation may be sampling a large proportion of the stock but the catch rates will depend on how the aggregation is fished rather than how much biomass is present). Also, estimates of biomass from egg surveys were not used as it was found that the available estimates were from surveys where the assumptions of the survey design were not met and/or there were major difficulties in analysing the survey data. Finally, acoustic-survey estimates of biomass were only used when mainly single-species aggregations were surveyed with suitable equipment. Estimates of spawning orange roughy biomass were accepted for plumes on the flat surveyed using hull-mounted transducers or towed systems, or for plumes on underwater features using towed systems only (otherwise the dead zone can be too large for reliable comparison).

Model structure was similar across the four assessed stocks. In each case, the base models were single-sex, single-area models with separate categories for age and maturity. Maturity was estimated within the model from age-frequencies of spawning fish and, if available, from female proportion spawning at age data from pre-spawning wide-area trawl surveys (available for NWCR and MEC). All mature fish were assumed to spawn each year as this was consistent with the estimates of female proportion spawning at age (see the NWCR and MEC assessments). This is a major contrast to earlier assessments where acoustic and egg survey estimates of spawning biomass were scaled up using estimates of transition-zone mature biomass before being used in an assessment. In the 2014 assessments, acoustic estimates of *spawning* biomass were used directly without scaling.

The use of age data was crucial to the success of the 2014 assessments. Model-based assessments of orange roughy stocks were abandoned in recent years because the model results were found to be insensitive to the data; i.e. results did not change whether or not recent abundance indices were included because the model assumptions - particularly the assumption of deterministic recruitment - overwhelmed the data. Age data were generally not used in these assessments because the (old) ageing methodology was considered unreliable, resulting in the unrealistic assumption of deterministic recruitment being used. This resulted in modelled biomass trajectories showing strong increasing trends as catches were scaled back but which were not supported by the fishery-independent abundance indices. The new ageing methodology (Tracey et al. 2007) has provided more reliable age data, which in turn has led to the abandonment of the deterministic recruitment assumption and models that fit trends in recent abundance indices.

4.1.2 Acoustic *q* priors

The major sources of recent abundance information in the models are acoustic surveys of spawning biomass. For each survey, the spawning biomass estimate was included in the appropriate assessment as an estimate of *relative* spawning biomass rather than *absolute* spawning biomass (the latter being used in previous assessments). The reason that the estimates are not used as absolute estimates of biomass is because there are two major potential sources of bias: (i) the estimates may be biased low or high because the estimate of orange roughy target strength is incorrect, and (ii) the survey is unlikely to have covered all of the spawning stock biomass. The unknown proportionality constant, or *q*, for each survey was estimated in the model using an informed prior for each *q*. Each prior was constructed from two components: orange roughy target strength and survey availability.

The target strength (TS) prior was derived from the estimates of Macaulay et al (2013) and Kloser et al (2013) who both obtained TS estimates (at 38 kHz) from visually verified orange roughy as they were herded by a trawl net (the "AOS" was mounted on the head of the net and acoustic echoes and stereo photos were obtained simultaneously). Macaulay et al (2013) estimated a TS (for 33.9 cm fish) of -52.0 dB with a 95% CI of -53.3 to -50.9 dB; Kloser et al (2013) gave a point estimate of -51.1 dB and gave a range, that allowed for the artificial tilt angles of the herded fish, from -52.2 to -50.7 dB. The prior was taken to be normal with a mean of -52.0 dB with 99% of the distribution covered by ± 1.5 dB (which covers both ranges). This results in a tight distribution for informed acoustic q priors, reflecting the high confidence in the target strength estimates.

For surveys that covered "most" of the spawning stock biomass (e.g., ESCR where in some years surveys covered the Old plume[1], the Rekohu plume, and the "Crack"), availability was modelled with a Beta(8,2) distribution (this has a mean of 0.8 – i.e., it is assumed *a priori* that 80% of the spawning stock biomass is being indexed). The acoustic *q* prior is the combination of the availability and TS priors (assuming they are independent). This was approximately normal with a mean of 0.8 and a CV of 19%. For surveys that were considered to have covered less than "most" of the spawning biomass, a similar prior was used for the *q* except that a lower mean value was assumed for the "availability" component of the prior (see individual assessments for how the mean was derived in these cases). When a higher CV was applied, the median estimates of biomass and stock status were slightly higher, and the confidence intervals were wider with a much higher upper bound.

4.1.3 Year class strength estimation

The number of year class strengths (YCSs) estimated within each model depended on the timing and number of age frequency observations available. In general a YCS was estimated provided that it was observed in at least one age frequency when it was neither "too old" nor "too young". "Old" YCSs were not estimated because it was considered that there was too little information about these cohorts as only a few of them remained. "Too young" YCSs were not estimated because the selectivity for these ages is low and consequently the YCS estimates would be unreliable.

The Haist parameterisation for estimating YCS was used for all models (Bull et al 2012). In the 2013 MEC assessment it was found that the alternative Francis parameterisation unduly restricted YCS estimates as evidenced by poor fits to the trawl survey biomass indices. In contrast, the Haist parameterisation, using uniform priors, resulted in an excellent fit to the abundance indices at the MPD stage and an adequate fit at the MCMC stage. The YCS estimates were primarily driven by the composition data (age and length frequencies), but if they unduly penalised, the estimates are restricted to a space which does not allow the trawl biomass indices to be fitted well. In the 2014 assessments a "nearly uniform" prior was used with the Haist parameterisation: LN(mode = 1, log-space s.d. = 4).

4.1.4 Model runs

As far as was appropriate, a consistent set of sensitivity runs was conducted for each assessment. In addition to a base model, there were runs that estimated natural mortality (*M*); halved and doubled the recent acoustic biomass estimates (to show that the model was sensitive to recent biomass indices); assumed deterministic recruitment (to show the importance of estimating year class strengths); increased/decreased the mean of acoustic *q* priors; and two sensitivities that simultaneously increased/decreased *M* and decreased/increased the mean of the acoustic *q* priors by 20% (a lower stock status occurs when *M* is decreased and when the mean of the acoustic *q* priors is increased; similarly an increased stock status occurs for changes in the other direction). The runs estimating *M* ("EstM") and those with the 20% changes in *M* and the mean of acoustic *q* priors ("LowM-Highq" and "HighM-Lowq") were taken through to MCMC.

[1]For clarity, what was previously described as the 'Spawning plume' located in the Spawning Box has been renamed the 'Old-plume' so as to differentiate it from the Rekohu plume, which is also a spawning plume.

4.1.5 Fishing intensity

Fishing intensity for each year of the assessment was measured in units of 100 – ESD (Equilibrium Stock Depletion). This quantity was estimated by running the model to deterministic equilibrium, given the exploitation rate and fishing pattern associated with each year. The equilibrium level of the spawning biomass will be the ESD for that year (e.g., if the stock is fished at a very high fishing intensity, the equilibrium spawning stock biomass will be close to zero: ESD = 0% B_0; if the stock is being very lightly fished, then ESD = 100% B_0). The quantity (100 – ESD) ranges from 0–100 with 100 denoting any pattern and level of fishing that would eventually force the stock down to zero spawning biomass. In general, the fishing intensity associated with a deterministic equilibrium of x% B_0 is denoted as $U_{x\%B0}$. To aid with the interpretation of fishing intensity in both the fishing intensity and "snail trail" plots (which have fishing intensity on the right hand y-axis), the value $U_{x\%B0}$ has been replaced with an associated exploitation rate proxy on the left hand y-axis. Exploitation rate, expressed as a percentage, is the number of fish caught from every 100 available fish. The exploitation rate labels represent a median exploitation rate, as each $U_{x\%B0}$ maps to a range of exploitation rates, rather than to a single number.

4.1.6 Projections

Projections were generally conducted over a 5-year time period at the level of the current catch and at the long-term yield associated with $U_{35\%B0}$ (the fishing intensity associated with the mid-point of the target biomass range of 30-40% B_0. In each case, the random YCSs were brought in immediately after the last estimated YCS and were resampled from the last 10 years of estimates (this is done because YCSs are correlated rather than being independent from year to year). For long-term projections (e.g., for MEC to estimate T_{min}, the number of years required for the stock to be rebuilt when there is no fishing), the YCSs were resampled from all estimated YCSs to ensure that the resampled YCSs will average to near 1 (so that there is no implied regime shift). Projections were done for the base model and, as a "worse-case scenario", for the *LowM-Highq* model.

4.2 Summary of 2014 stock assessment results

The main results of the 2014 stock assessments are summarised below: these include estimated natural mortality, maturity ogive parameter estimates, year class strength, virgin biomass, and stock status; deterministic B_{MSY} and MSY, and deterministic long-term yields at $U_{35\%B0}$ (35% B_0 being the mid-point of the target biomass range).

For each of the four stock assessments the median estimate of natural mortality (*M*) from the "EstM" model was lower than the assumed value in the base model of 0.045 (Table 7). This was despite a fairly tight informed prior on *M* with a mean of 0.045 and CV=0.15. In each stock assessment there appears to be very little information in the data on the value of *M*; this information can only come from the right-hand limb of age frequencies, where the relative proportion of old fish is related to *M*, but it is also confounded by fishing mortality, selectivity, and year class strength. It seems premature to move to a new value of *M* for the base models. However, as more age data are gathered the estimates of *M* may improve.

Table 7: Estimates of natural mortality for each stock assessed in 2014. These are MCMC estimates from the "EstM" models which are identical to the base models except that *M* is estimated using an informed prior N(mean = 0.045, CV = 0.15)

Stock	*M* (median)	95% CI
NWCR	0.041	0.033–0.051
ESCR	0.037	0.027–0.048
MEC	0.032	0.028–0.037
ORH7A	0.038	0.031–0.047

Estimates of the 50% maturity parameter (a_{50}) for the four stocks range from 32–41 years (Table 8). This is considerably older than the estimates of transition-zone maturity which range from 23–33 years (see Table 2). The slopes of the estimated maturity curves are also much shallower than those for transition-zone maturity (10–13 years from Table 8 compared to 3–7 years in Table 2).

Table 8: Base model, median MCMC estimates of maturity for each stock assessed in 2014. a_{50} is the age, in the virgin population, at which 50% of the fish are mature; a_{to95} is the number of years that need to be added to a_{50} to get the age at which 95% of the fish are mature.

Stock	a_{50} (years)	a_{to95} (years)
NWCR	37	13
ESCR	41	12
MEC	35	10
ORH7A	32	10

There were some similarities in the estimates of year class strength (YCS) across the four stocks (Figure 1). The MEC assessment used the most age data and therefore it had the largest number of YCS estimated. Early YCS were generally estimated to be above average and recent YCS estimated to be below average. This same pattern was evident for ORH7A and ESCR (though over a shorter duration and of slightly lesser magnitude – see Figure 1). The NWCR was the only assessment where the pattern of recruitment was consistent with average (deterministic) recruitment (Figure 1).

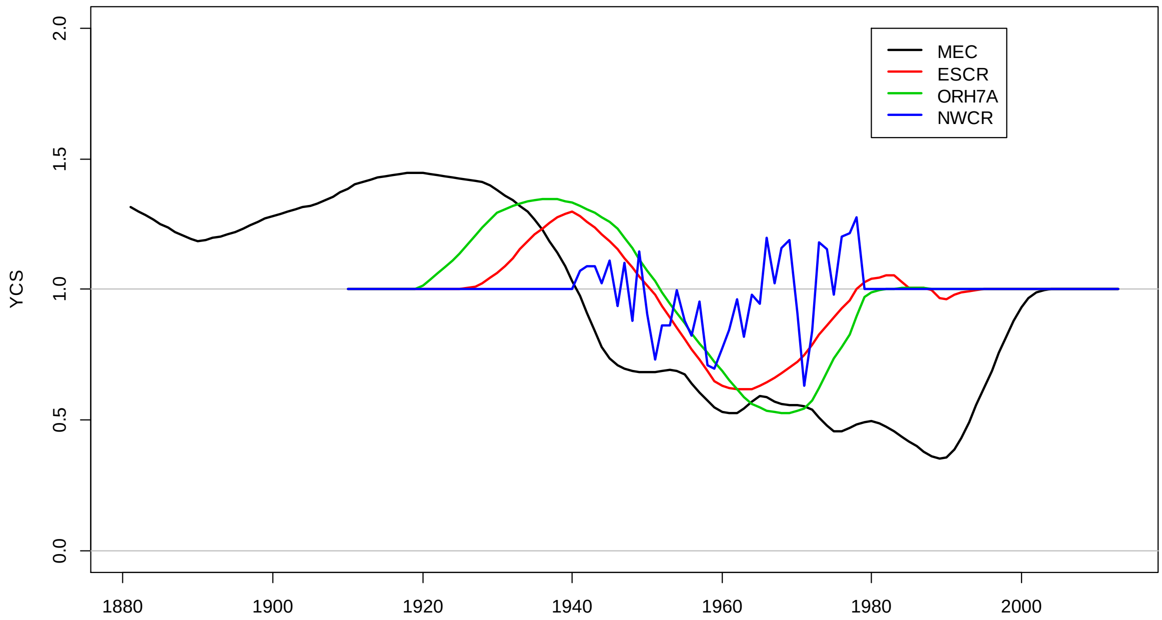


Figure 1: MCMC base models: smoothed (where possible) median estimates of year class strength (YCS) for the four stocks assessed in 2014. A lowess smoother (f = 0.15) was applied to the MCMC median estimates for each cohort.

The estimated size of the four stocks varies considerably for both virgin and current biomass (Table 9). The ESCR stock had by far the largest virgin biomass, B_0, estimated at over 300,000 t while the other stocks are smaller, with estimates of less than 100,000 t (Table 9). In terms of current biomass, three of the four stocks have median current biomass estimates within the 30–40% B_0 target range (Table 9, Figure 2). The fourth stock, the MEC stock, has a median estimate below the soft limit of 20% B_0.

Table 9: Base case models, median MCMC estimates of virgin biomass (B_0), current biomass (B_{2014}) and current stock status (B_{2014}/B_0).

Stock	B_0 (000 t)	B_{2014} (000 t)	B_{2014} (% B_0)
NWCR	66	24	37
ESCR	320	93	30
MEC	95	14	14
ORH7A	88	37	42

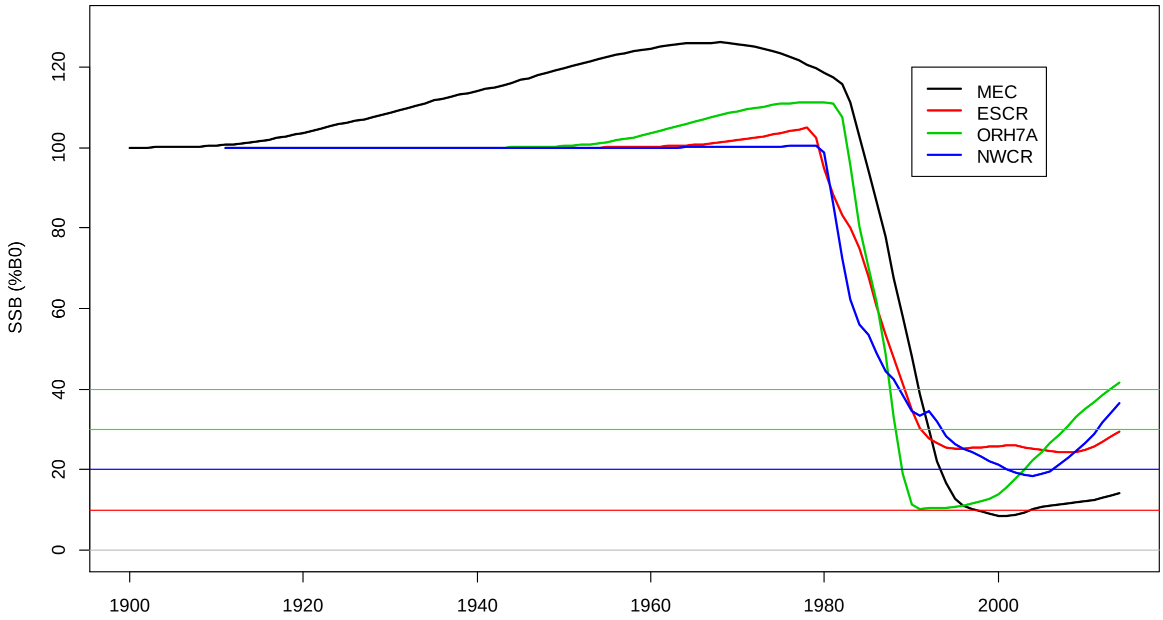


Figure 2: MCMC base models: median estimates of stock status trajectory for the four stocks assessed in 2014. The biomass target range of 30–40% B_0 is shown by green lines, and the soft and hard limits by blue and red line respectively.

For each assessment, long-term deterministic projections were conducted for each posterior sample to determine the ESD and yield curves as a function of fishing intensity. This enabled estimation of deterministic reference points and yields (Table 10). Deterministic estimates of B_{MSY} are similar for all four stocks, falling within in the range 21.5-24.5% B_0 (Table 10). In each case, the expectation is that very little yield will be is lost if the equilibrium biomass level increases from deterministic B_{MSY} to 35% B_0 (the mid-point of the biomass target range). The estimated long-term yields when fishing at U_{35} (the fishing intensity that forces the stock to deterministic equilibrium at 35% B_0) range from 1300–2100 t for the smaller stocks and is 7180 t for the ESCR stock (Table 10). These yield estimates are unrealistic in that they are derived using deterministic recruitment and maintaining an exact level of fishing intensity. More realistic estimates of long-term yield, such as those derived from a management strategy evaluation, would likely be lower.

Table 10: Base model, median MCMC estimates of deterministic B_{MSY}, MSY, deterministic long-term yield at $U_{35\%B0}$, and the exploitation rate corresponding to $U_{35\%B0}$.

Stock	B_{MSY} (%B_0)	MSY (%B_0)	$U_{35\%B0}$ yield (%B_0)	$U_{35\%B0}$ exploitation rate (%)	$U_{35\%B0}$ long-term yield (t)
NWCR	23.7	2.1	2.0	5.3	1320
ESCR	21.8	2.4	2.3	5.3	7180
MEC	22.5	2.3	2.2	5.1	2080
ORH7A	24.5	2.1	2.0	5.4	1740

5. FUTURE RESEARCH

More age information is needed for all stocks. For most areas, this may simply necessitate reading otoliths that have previously been collected. Increasing the number of years with age-composition data should enable better estimation of year class strengths, and should increase the number of YCSs able to be estimated.

For those stocks where the proportion spawning at age is used (e.g. MEC), investigate alternatives for estimating the proportion spawning at age given the sparse data; for example, consider making it asymptotic at a younger age.

The design and implementation of the Challenger (ORH 7A) combined trawl and acoustic survey needs to be reviewed to ensure that it is fit for purpose for future years.

6. FOR FURTHER INFORMATION

Abraham, E R; Thompson, F N (2011) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report* No. 80.

Abraham, E R; Thompson, F N; Berkenbusch, K (2013) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Ministry for Primary Industries, Wellington).

Abraham, E R; Thompson, F N; Oliver, M D (2010) Summary of the capture of seabirds, mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report* No.45. 149 p.

Anderson, O F (2011) Fish and invertebrate bycatch and discards in orange roughy and oreo fisheries from 1990–91 until 2008–09. *New Zealand Aquatic Environment and Biodiversity Report* No. 67.

Anderson, O F; Dunn, M R (2007) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B and 7B to the end of the 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2007/29*. 71 p.

Anderson, O F; Gilbert, D J; Clark, M R (2001) Fish discards and non-target catch in the trawl fisheries for orange roughy and hoki in New Zealand waters for the fishing years 1990–91 to 1998–99. *New Zealand Fisheries Assessment Report 2001/16*. 57 p.

Andrews, A H; Tracey, D M (2003) Age validation of orange roughy, oreos, and black cardinalfish. Final Research Report for Ministry of Fisheries Research Project DEE2000/02. 25 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Baird, S J (2004a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999–2000. *New Zealand Fisheries Assessment Report 2004/41*. 56 p.

Baird, S J (2004b) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000–01. *New Zealand Fisheries Assessment Report 2004/58*. 63 p.

Baird, S J (2004c) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001–02. *New Zealand Fisheries Assessment Report 2004/60*. 51 p.

Baird, S J (2005) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/2*. 50 p.

Baird, S J; Smith, M H (2007) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report* No. 14. 98 p.

Baird, S J; Tracey, D; Mormede, S; Clark, M (2012) The distribution of protected corals in New Zealand waters DOC12303 / POP2011-06. NIWA Client Report No: WLG2012-43. Prepared for Marine Conservation Services, Department of Conservation and Te Papa Atawhai 93 p. http://www.doc.govt.nz/conservation/marine-and-coastal/commercial-fishing/conservation-services-programme/meetings-and-project-updates/27-november-2012/

Baird, S J; Wood, B A (2012) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. *New Zealand Aquatic Environment and Biodiversity Report 89*. 43 p.

Baird, S J; Wood, B A; Bagley, N.W. (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989–90 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report 73*. 143 p.

Baker, C S; Chilvers, B L; Constantine, R; DuFresne, S; Mattlin, R H; van Helden, A; Hitchmough, R (2010) Conservation status of New Zealand marine mammals (suborders *Cetacea* and *Pinnipedia*), 2009. *New Zealand Journal of Marine and Freshwater Research* 44: 101–115.

Ballara, S L; Anderson, O F (2009) Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report* No. 38. 102 p.

Black, J; Wood, R; Berthelsen, T; Tilney, R (2013) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2009–2010. *New Zealand Aquatic Environment and Biodiversity Report* No. 110. 57 p.

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30-2012/03/21. *NIWA Technical Report 135*. 280 p.

Bulman, C M; Koslow, J A (1992). Diet and food consumption of a deep-sea fish, orange roughy *Hoplostethus atlanticus* (Pisces: Percichthyidae). of southeastern Australia. *Marine Ecology Progress Series 82*, 115–129.

Clark, M R (1999) Fisheries for orange roughy (*Hoplostethus atlanticus*) on seamounts in New Zealand. *Oceanologica Acta* 22(6): 593–602.

Clark, M R (2006) Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2006/56*. 38 p.

Clark, M R (2008) Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, northwest Challenger Plateau, west Norfolk Ridge, south Tasman Rise and Louisville Ridge to the end of the 2005–06 fishing year. *New Zealand Fisheries Assessment Report 2008/12*. 45 p.

Clark, M R; Anderson, O F; Francis, R I C C; Tracey, D M (2000) The effects of commercial exploitation on orange roughy (*Hoplostethus atlanticus*) from the continental slope of the Chatham Rise, New Zealand, from 1979 to 1997. *Fisheries Research*, *45*(3), 217–238.

Clark, M R; Fincham, D J; Tracey, D M (1994) Fecundity of orange roughy (*Hoplostethus atlanticus*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research* 28: 193–200.

Clark, M; O'Driscoll, R (2003) Deepwater fisheries and aspects of their impact on seamount habitat in New Zealand. *Journal of Northwest Atlantic Fisheries Science* 31: 441–458.

Clark, M. R., Rowden, A. A. (2009). Effect of deepwater trawling on the macro-invertebrate assemblages of seamounts on the Chatham Rise, New Zealand. *Deep Sea Research Part I: Oceanographic Research Papers, 56(9)*, 1540–1554.

Department of Internal Affairs. (2006). Seabird Scaring Devices – Circular Issued Under Authority of the Fisheries (Commercial Fishing) Amendment Regulations 2006 (No. F361). *New Zealand Gazette 6 April 2006* : 842–846.

Doonan, I J (1994) Life history parameters of orange roughy; estimates for 1994. New Zealand Fisheries Assessment Research Document: 1994/19. 14 p. (Unpublished document held in NIWA library, Wellington.)

Doonan, I J; Dunn, M R (2011) Trawl survey of Mid-East Coast orange roughy, March-April 2010. *New Zealand Fisheries Assessment Report 2011/20*. 62 p.

Doonan, I J; Francis, R I C C; Horn, P; Tracey, D M (1998) Update of biological parameters for orange roughy. Report to Deepwater Stock Assessment Working Group, 98/16. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Doonan, I J; Tracey, D M (1997) Natural mortality estimates for orange roughy in ORH 1 (Bay of Plenty). New Zealand Fisheries Assessment Research Document 1997/26. 9 p. (Unpublished document held in NIWA library, Wellington.)

Dunn, M R; Forman, J S (2011) Hypotheses of spatial stock structure in orange roughy *Hoplostethus atlanticus* inferred from diet, feeding, condition, and reproductive activity. *PLoS ONE 6(11): e26704*.

Dunn, M R; Rickard, G J; Sutton, P J H; Doonan, I J (2009) Nursery grounds of the orange roughy around New Zealand. *ICES Journal of Marine Science* 66: 871–885.

Dunn, M R; Stevens, D W; Forman, J S; Connell, A (2013) Trophic Interactions and Distribution of Some Squaliforme Sharks, Including New Diet Descriptions for *Deania calcea* and *Squalus acanthias*.*PLoS ONE 8(3):*e59938.doi:10.1371/journal.pone.0059938

Dunn, M R; Szabo, A; McVeagh, M S; Smith, P J (2010) The diet of deepwater sharks and the benefits of using DNA identification of prey. *Deep-Sea Research I 57* 923–930.

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27 p. (Unpublished document held in NIWA library, Wellington.)

Francis, M P; Hurst, R J; McArdle, B H; Bagley, N W; Anderson, O F (2002) New Zealand demersal fish assemblages. *Environmental Biology of Fishes*, *65*(2), 215–234.

Francis, R I C C; Horn, P L (1997) The transitions zone in otoliths of orange roughy (*Hoplostethus atlanticus*) and its relationship to the onset of maturity. *Marine Biology* 129: 681–687.

Francis, R I C C; Robertson, D A; Clark, M R; Doonan, I J; Coburn, R P; Zeldis, J R (1993) Assessment of the ORH 3B orange roughy fishery for the 1993/94 fishing year. New Zealand Fisheries Assessment Research Document 1993/7. 44 p. (Unpublished document held in NIWA library, Wellington.)

Gaskin, D E; Cawthorn, M W (1967) Diet and feeding habits of the sperm whale (*Physeter catodon* L.) in the Cook Strait region of New Zealand. *New Zealand Journal of Marine and Freshwater Research 1*: 156–179.

Hallet, C S; Daley, R K (2011) Feeding ecology of the southern lanternshark (*Etmopterus baxteri)* and the brown lanternshark (*E. unicolor*) off southeastern Australia. *ICES Journal of Marine Science* 68: 157–165.

Hermsen, J M; Collie, J S; Valentine, P C (2003) Mobile fishing gear reduces benthic megafaunal production on Georges Bank. *Marine Ecology Progress Series* 260: 97–108.

Hicks, A C (2006) Growth, length-weight, and maturity estimates for the Northeast Chatham Rise. WG-Deepwater-06/13. (Unpublished .report held by Ministry for Primary Industries, Wellington.)

Hiddink, J G; Jennings, S; Kaiser, M J; Queiros, A M; Duplisea, D E; Piet, G J (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Sciences* 63:721–36.

Hilborn, R; Walters, C J (1992) *Quantitative fisheries stock assessment: choice, dynamics, and uncertainty*. Chapman and Hall, New York, 570 p.

Horn, P L; Tracey, D M; Clark, M R (1998) Between-area differences in age and length at first maturity of orange roughy (*Hoplostethus atlanticus*). *Marine Biology* 132 (2): 187–194.

Jennings, S; Dinmore, T A; Duplisea, D E; Warr, K J; Lancaster, J E (2001) Trawling disturbance can modify benthic production processes. *Journal of Animal Ecology*, *70*: 459–475.

Jereb, P; Roper, C F E (2010) (eds) *Cephalopods of the world. An annotated and illustrated catalogue of cephalopod species known to date*. Volume 2. Myopsid and Oegopsid Squids. *FAO Species Catalogue for Fishery Purposes. No. 4, Vol. 2*. Rome, FAO. 2010. 605 p.

Kloser, R J; Macaulay, G J; Ryan, T E; Lewis, M (2013) Identification and target strength of orange roughy (*Hoplostethus atlanticus*) measured in situ. *Journal of the Acoustical Society of America, 134*: 97–108.

Koslow, J A (1997) Seamounts and the Ecology of Deep-sea Fishes. *American Scientist. Vol. 85*. 168–176.

Leathwick, J R; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J; Hadfield, M; Currie, K; Goh, A (2012) Benthic-optimised marine environment classification for New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 88.* 54 p.

Macaulay, G J; Kloser, R J; Ryan, T E (2013) *In situ* target strength estimates of visually verified orange roughy. *ICES Journal of Marine Science, 70*: 215–222.

Mace, P M; Fenaughty, J F; Coburn, R P; Doonan, I J (1990) Growth and productivity of orange roughy (*Hoplostethus atlanticus*) on the north Chatham Rise. *New Zealand Journal of Marine and Freshwater Research* 24: 105–119.

MacKenzie, D; Fletcher, D (2006) Characterisation of seabird captures in commercial trawl and longline fisheries in New Zealand 1997/98 to 2003/04. Final Research Report for Ministry of Fisheries project ENV2004/04. (Unpublished report held by Ministry for Primary Industries, Wellington.) 102 p.

Morgan, M J; Wilson, C E; Crim, L W (1999) The effect of stress on reproduction in Atlantic cod. *Journal of Fish Biology*, *54*(3), 477–488.

MPI (2013) Aquatic Environment and Biodiversity Annual Review 2013. Complied by the Fisheries Management Science Team, Ministry for Primary Industries, Wellington, New Zealand. 538 p.

O'Driscoll, R L; Booth, J D; Bagley, N W; Anderson, O F; Griggs, L H; Stevenson, M L; Francis, M P (2003) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. *NIWA Technical Report* 119. 377 p.

O'Driscoll, R L; MacGibbon, D; Fu, D; Lyon, W; Stevens, D W (2011) A review of hoki and middle depth trawl surveys of the Chatham Rise, January 1992–2010. *New Zealand Fisheries Assessment Report 2011/47*. 814 p.

Pankhurst, N W (1988) Spawning dynamics of orange roughy, *Hoplostethus atlanticus*, in mid-slope waters of New Zealand. *Environmental biology of fishes* 21: 101–116.

Paul, L J; Tracey, D M; Francis, R I C C (2002) Age validation of deepwater fish species, with particular reference to New Zealand orange roughy and oreos: a literature review. Final Research Report for Ministry of Fisheries Research Project DEE200002. 33 p. (Unpublished report held by Ministry for Primary Industries, Wellington)

Ramm, K (2012) Conservation Services Programme Observer Report: 1 July 2010 to 30 June 2011. FINAL REPORT. Conservation Services Programme, Department of Conservation, November 2012. (Unpublished report held by Department of Conservation, Wellington.)

Reiss, H, Greenstreet, S P R, Siebe, K, Ehrich, S, Piet, G J, Quirijns, F, Robinson, L, Wolff, W J, Kronke, I (2009) Effects of fishing disturbance on benthic communities and secondary production within an intensely fished area. *Marine Ecology Progress Series 394:201–213*.

Rice, J (2006) Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. *Canadian Science Advisory Secretariat Research Document 2006/057*. 35 p. (available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf).

Richard, Y; Abraham, E R (2013) Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report* No. 109. 58 p.

Rossechi, E; Tracey, D M; Weber, W R (1988) Diet of orange roughy, *Hoplosthethus atlanticus* (Pisces: Trachichthyidae), on the Challenger Plateau, New Zealand. *Marine Biology* 99: 293–306.

Stevens, D W; Hurst, R J; Bagley, N W (2011) Feeding habits of New Zealand fishes: a literature review and summary of research trawl database records 1960 to 2000. *New Zealand Aquatic Environment and Biodiversity Report* No. 85.

Thompson, F N; Abraham, E R; Oliver, M D (2010). Estimation of fur seal bycatch in New Zealand sea lions trawl fisheries, 2002–03 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 56*. 29 p.

Thompson, F N; Berkenbusch, K; Abraham, E R (2013) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. *New Zealand Aquatic Environment and Biodiversity Report No. 105*. 73 p.

Tracey, D M; McMillan, P J; Armstrong, J M; Banks, D A (1990) Orange roughy trawl survey: Challenger Plateau and west coast South Island, 1983. *New Zealand Fisheries Technical Report No. 22*. 34 p.
Tracey, D; Baird, S J; Sanders, B M; Smith, M H (2011) Distribution of protected corals in relation to fishing effort and assessment of accuracy of observer identification. NIWA Client Report No: WLG2011-33 prepared for Department of Conservation, Wellington. 74 p.
Tracey, D; Clark, M; Bull, B; Mackay, K (2004) Fish species composition on seamounts and adjacent slope in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research* 38: 163–182.
Tracey, D M; Clark, M R; Anderson, O F; Kim, S W (2012) Deep-Sea Fish Distribution Varies between Seamounts: Results from a Seamount Complex off New Zealand. *PLoS ONE 7(6)*: e36897. oi:10.1371/journal.pone.0036897
Tracey, D M; Horn, P L (1999) Background and review of ageing orange roughy (*Hoplostethus atlanticus*, Trachichthyidae) from New Zealand and elsewhere. *New Zealand Journal of Marine and Freshwater Research* 33: 67–86.
Tracey, D; Horn, P; Marriott, P; Krusic-Golub, K; Gren, C; Gili, R; Mieres L C (2007). Orange Roughy Ageing Workshop: otolith preparation and interpretation. Draft report to DWFAWG.
Tuck, I; Cole, R; Devine, J (2009) Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 42.* 188 p.
Williams, A; Schlacher, T A; Rowden, A A; Althaus, F; Clark, M R; Bowden, D A; Stewart, R; Bax, N J; Consalvey, M; Kloser, R J (2010) Seamount megabenthic assemblages fail to recover from trawling impacts. *Marine Ecology, 31*: 183–199.
Zeldis, J R; Grimes, P J; Ingerson, J K V (1994) Ascent rates, vertical distribution, and a thermal history model of development of orange roughy (*Hoplostethus atlanticus*) eggs in the water column. *Fishery Bulletin (United States)* 93: 373–385.

ORANGE ROUGHY NORTHERN NORTH ISLAND (ORH 1)

1. FISHERY SUMMARY

1.1 Commercial fisheries

This region extends northwards from west of Wellington around to Cape Runaway. Prior to 1993–94 there was no established fishery, and reported landings were generally small (Table 1). A new fishery developed in winter 1994, when aggregations were fished on two hill complexes in the western Bay of Plenty. In 1996 catches were also taken off the west coast of Northland. Figure 1 shows the historical landings and TACC values for ORH 1.

A TACC of 190 t was set from 1989–90. Prior to that there had been a 10 t TAC and various levels of exploratory quota. From 1995–96, ORH 1 became subject to a five year adaptive management programme, and the TACC was increased to 1190 t. A catch limit of 1000 t was applied to an area in the western Bay of Plenty (Mercury-Colville 'box'), with the former 190 t TACC applicable to the remainder of ORH 1. In 1994 and 1995, research fishing was also carried out under Special Permit (not included in the TACC). For the period June 1996–June 1997, a Special Permit was approved for exploratory fishing. This allowed an additional 800 t (not included in the TACC) to be taken in designated areas, although catches were limited from individual features (hills and seamounts etc).

Table 1: Reported landings (t) and TACCs (t) from 1982–83 to 2013–14. - no TACC. The reported landings do not include catches taken under an exploratory special permit of 699 t in 1998–99 and 704 t in 1999–2000. QMS data from 1986-present.

	Reported landings			
Fishing year	West coast	North-east coast	Total	TACC
1982–83*	< 0.1	0	< 0.1	-
1983–84*	0.1	0	0.1	-
1984–85*	< 0.1	96	96	-
1985–86*	< 1	2	2	-
1986–87*	0	< 0.1	< 0.1	10
1987–88	0	0	0	10
1988–89	0	19	19	10
1989–90	37	49	86	190
1990–91	0	200	200	190
1991–92	+	+	112	190
1992–93	+	+	49	190
1993–94	0	189	189	190
1994–95	0	244	244	190
1995–96	55	910	965	1 190
1996–97	+	+	1 021	1 190
1997–98	+	+	511	1 190
1998–99	+	+	845	1 190
1999–00	+	+	771	1 190
2000–01	+	+	858	800
2001–02	+	+	1 294	1 400
2002–03	+	+	1 123	1 400
2003–04	+	+	986	1 400
2004–05	+	+	1 151	1 400
2005–06	+	+	1 207	1 400
2006–07	+	+	1 036	1 400
2007–08	+	+	1 104	1 400
2008–09	+	+	905	1 400
2009–10	+	+	825	1 400
2010–11	+	+	772	1 400
2011–12	+	+	1 114	1 400
2012-13	+	+	1 171	1 400
2013-14	+	+	1 055	1 400

* FSU data.
\+ Unknown distribution of catch.

Reported catches have varied considerably between years, and the location of the catch in the late 1980s/early 1990s is uncertain, as some may have been taken from outside the EEZ, as well as misreported from other areas. Research fishing carried out under Special Permit in 1994 and 1995 resulted in catches of 45.2 t and 200.7 t, respectively (not included in Table 1).

Based on an evaluation of the results of an Adaptive Management Programme (AMP) for the Mercury-Colville box initiated in 1995, the AMP was concluded and the TACC was reduced to 800 t for the 2000–01 fishing year. Catch limits of 200 t were established in each of four areas in ORH 1, with an individual seamount feature limit of 100 t. From 1 October 2001, ORH 1 was reintroduced into the AMP with different design parameters for the five years, and the TACC was increased from 800 to 1400 t and allocated an allowance of 70 t for other mortality caused by fishing. The AMP was discontinued in 2007.

In recent years the fishery has also developed off the west coast and sizeable catches have been taken off the Tauroa Knoll and West Norfolk Ridge.

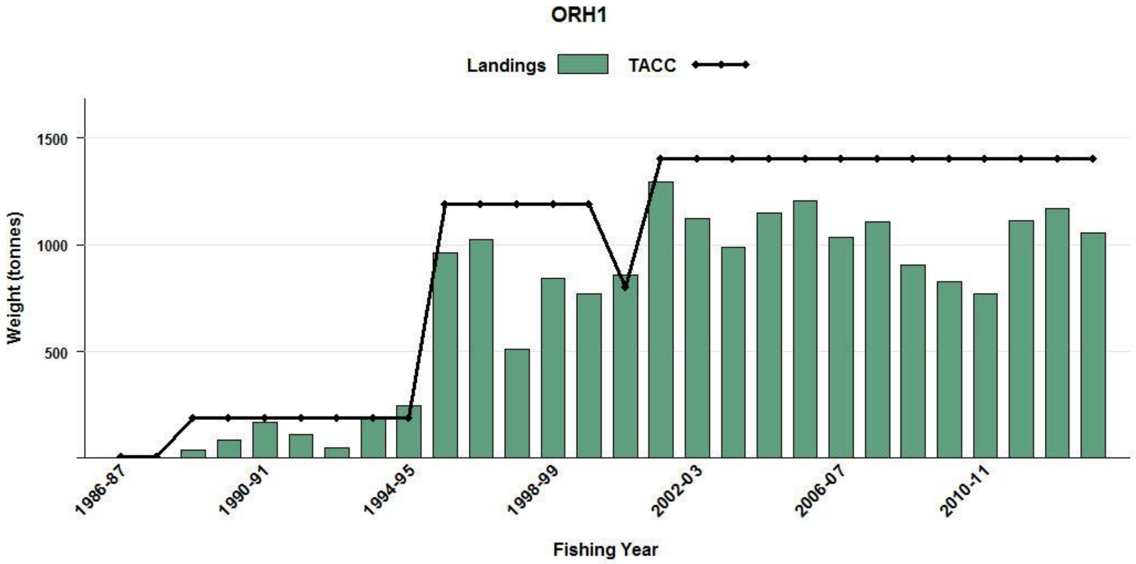


Figure 1: Reported commercial landings and TACC for ORH 1 (Auckland East). Note that this figure does not show data prior to entry into the QMS.

1.2 Recreational fisheries
There is no known non-commercial fishery for orange roughy in this area.

1.3 Customary non-commercial fisheries
No customary non-commercial fishing for orange roughy is known in this area.

1.4 Illegal catch
No quantitative information is available on the level of illegal catch in this area.

1.5 Other sources mortality
There may be some overrun of reported catch because of fish loss with trawl gear damage and ripped nets. In other orange roughy fisheries, a level of 5% has been estimated.

2. STOCKS AND AREAS

Orange roughy are distributed throughout the area. Spawning is known from several hills in the western Bay of Plenty as well as from features in the western regions of ORH 1. Stock status/affinities within the QMA are unknown. The Mercury-Colville grounds in the Bay of Plenty are about 120 n. miles from fishing grounds at East Cape (ORH 2A North), and spawning occurs at a similar time. Hence, it is likely that these are separate stocks. The Mercury and Colville Knolls in the Bay of Plenty are about 25 miles apart and may form a single stock. Stock affinities with other fishing hills in the southern and central Bay of Plenty are unknown. The Tauroa Knoll and outer Colville Ridge seamounts are distant from other commercial grounds, and these fish may also represent separate stocks.

3. STOCK ASSESSMENT

An assessment for the Mercury-Colville box was carried out in 2001 and is repeated here. A deterministic stock reduction technique (*after* Francis 1990) was used to estimate virgin biomass (B_0) and current biomass ($B_{current}$) for the Mercury-Colville orange roughy stock. The model was fitted to the biomass indices using maximum likelihood and assuming normal errors. In common with other orange roughy assessments, the maximum exploitation rate was set at 0.67. The model treats sexes separately, and assumes a Beverton-Holt stock-recruit relationship. Confidence intervals of the biomasss estimates were derived from bootstrap analysis (Cordue & Francis 1994).

3.1 Estimates of fishery parameters and abundance

A series of trawl surveys of the Mercury-Colville box to estimate relative abundance were agreed under an Adaptive Management Programme. The first survey was carried out in June 1995 with a second survey in winter 1998 (Table 2). The biomass index of the latter survey was much lower than 1995, and because of warmer water temperatures it was uncertain whether the 1998 results were directly comparable to the 1995 results. They were not incorporated in the decision rule for the adaptive management programme. A third survey was carried out in June 2000, with the results suggesting that the abundance of orange roughy in the box had decreased considerably and was at low levels. However, these estimates are uncertain because of the suggestion that environmental factors may have influenced the distribution of orange roughy. The abundance indices from trawl survey and commercial catch-effort data used in the assessment are given in Table 2. The trawl survey indices had CVs of 0.27, 0.39 and 0.29 for 1995, 1998, and 2000 respectively.

Table 2: Biomass indices and reported catch used in estimation of B_0. Values in square brackets are included for completeness; they are not used in the assessment.

Year	1993–94	1994–95	1995–96	1996–97	1997–98	1998–99	1999–00
Trawl survey	-	76 200	-	-	[2 500]	-	3 800
CPUE	8.3	9.1	5.4	4.2	[0.5]	1.5	(2.0)
Catch (t)	230	440	915	895	295	140	250

The CPUE series is mean catch per tow (sum of catches divided by number of tows, target ORH) from Mercury Knoll in the month of June. This is the only month when adequate data exist from the fishery to compare over time. A CV of 0.30 was assigned to the CPUE data.

Catch history information is derived from TCEPR records, scaled to the reported total catch for ORH 1. Overrun of reported catch (e.g., burst bags, inappropriate conversion factors) was assumed to be zero, as even if there was some, it is likely that it was similar between years. The catch in 1999–00 was assumed to be 250 t.

Assessments were carried out for three alternative sets of biomass indices (Table 3).

Table 3: Three alternative sets of biomass indices used in the stock assessment.

Alternative	Trawl survey indices	CPUE indices
1	1995, 2000	All except 1998
2	1995, 2000	None
3	1995, 2000	All except 1998 and 2000

Biological parameters used are those for the Chatham Rise stock, except for specific Bay of Plenty values for the maturity and recruitment ogives (Annala et al 2000).

3.2 Biomass estimates

The estimated virgin biomass (B_0) is very similar for all three alternative assessments (Table 4). With alternative 1 the estimated B_0 is 3200 t, with a current biomass of 15% B_0. For both alternatives 2 and 3, the estimated B_0 is 3000 t, which is B_{min}, the minimum stock size which enables the catch history to be taken given a maximum exploitation rate of 0.67.

Table 4: Biomass estimates (with 95% confidence intervals in parentheses) for stock assessments with the three alternatives of Table 3. B_0 is virgin biomass; B_{MSY} is interpreted as B_{MAY}, which is 30%B_0; $B_{current}$ is mid-season 1999–00; and B_{beg} is the biomass at the beginning of the 2000–01 fishing year. Estimates are rounded to the nearest 100 t (for B_0), 10 t (for other biomasses), or 1%.

Biomass	Alternative 1		Alternative 2		Alternative 3	
B_0 (t)	3 200	(3 000, 3 600)	3 000	(3 000, 3 500)	3 000	(3 000, 3 300)
B_{MSY} (t)	960	(900, 1080)	900	(900, 1050)	900	(900, 990)
$B_{current}$ (t)	490	(290, 890)	290	(290, 790)	290	(290, 590)
$B_{current}$ (%B_0)	15	(10, 25)	10	(10, 23)	10	(10, 18)
B_{beg} (t)	480	(270, 900)	270	(270, 800)	270	(270, 590)

The model fits the CPUE data reasonably well but estimates a smaller decline than is implied by the two trawl survey indices.

3.3 Yield estimates and projections

Yield estimates were determined using the simulation method described by Francis (1992) and the relative estimates of *MCY*, E_{CAY} and *MAY*, as given by Annala et al (2000).

Yield estimates are all much lower than recent catches (Table 5). Estimates of current yields ($MCY_{current}$ and *CAY*) lie between 16 t and 35 t; long-term yields ($MCY_{long-term}$ and *MAY*) lie between 44 t and 67 t.

Table 5: Yield estimates (t) for stock assessments with the three alternatives of Table 3.

Yield	Alternative 1		Alternative 2		Alternative 3	
MCY_{curren}	35	(22, 53)	22	(22, 51)	22	(22, 44)
$MCY_{long-term}$	47	(44, 53)	44	(44, 51)	44	(44, 49)
CAY	29	(16, 54)	16	(16, 48)	16	(16, 36)
MAY	67	(58, 70)	58	(58, 68)	58	(58, 64)

CSP for this stock is just under 100 t for any B_0 between 3000 t and 3600 t.

4. ANALYSIS OF ADAPTIVE MANAGEMENT PROGRAMME

The ORH 1 TACC was increased from 800 to 1400 t in October 2001/02 under the Adaptive Management Programme. The objectives of this AMP were to determine stock size, geographical extent, and long-term sustainable yield of the ORH 1 stock. This is a complex AMP, with ORH 1 divided into four sub-areas (see Figure 2), each with total catch and "feature" catch limits (Table 6) (a "feature" was defined as being within a 10 n. mile radius of the shallowest point).

Table 6: Description of control rules implemented in the ORH 1 AMP.

ORH 1 Subarea	Proposed Catch Limit	Feature Limit (t/fishing year)
Area A	200 t	100 t
Area B	500 t	150 t
Area C	500 t	150 t
Area D	200 t	75 t

Feature limits also serve as limits to the total catch in any area due to the limited number of available productive features. The Mercury-Colville "Box" (located within Area D) has been given a specific limit of 30 t per year to allow for the bycatch of orange roughy when fishing for black cardinalfish. The catch of orange roughy in the Mercury-Colville "Box" is included in the overall limit for Area D.

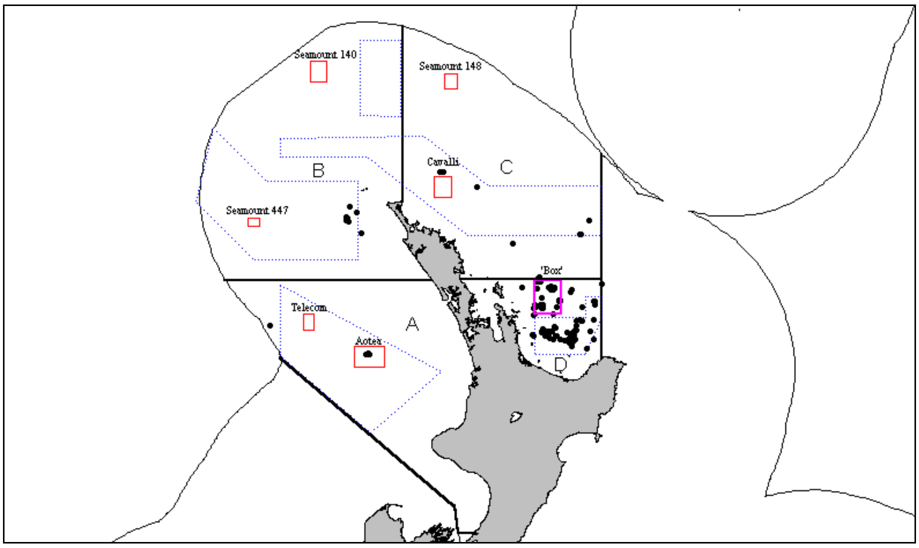


Figure 2: Four sub-management areas for the ORH 1 AMP (labelled A-D). Dotted lines enclose the exploratory fishing areas defined in the special permit issued on 6 July 1998. Solid lines enclose seamount closures and the Mercury-Colville Ohena 'box' (labelled at their top). Trawls (dots) where orange roughy were reported as the target species and caught during 1997–98 and 1998–99 are shown. Note that the lines separating Areas A and D from Areas B and C are incorrectly drawn at 36° S latitude rather than 35°30' S latitude.

From 1 October 2007 the stock is no longer part of the Adaptive Management Programme but stakeholders have agreed to continue with the sub-area and feature limits within the overall ORH 1 TACC.

Review of ORH 1 AMP in 2007

In 2007 the AMP FAWG reviewed the performance of the AMP after the full 5-year term.

Fishery Characterisation

- In most years, the total catch has been less than the TACC (Table 7).
- The area splits into A, B, C and D only occurred in 2001.
- Main fishery is in area B; the fishery in area A only began in 2002.
- Two main goals of the AMP:
  - Reduce fishing in area D, in particular the Mercury-Colville "box".
  - Look for new fishing areas, distributing effort across the QMA, with feature limits to reduce the possibility of localised overfishing.

Table 7: Estimated target catches by sub-area, scaled to landings, reported landings, and TACC for ORH 1. The scaling factor is calculated as reported catch/estimated (all target) catch (source: Anderson 2007b)

	Sub-area target catch (t)				Total target	Reported	TACC	Scaling
	A	B	C	D	catch(t)	landings (t)	(t)	factor
1998	0.5	5.6	0.0	491.0	497	511	1 190	0.99
1999	5.2	575.2	165.0	724.5	1 470	1 543	1 190	0.99
2000	0.8	644.6	164.8	597.5	1 408	1 476	1 190	1.03
2001	8.5	166.3	99.4	164.6	439	858	800	1.11
2002	122.7	440.5	265.8	227.1	1 056	1 294	1 400	1.06
2003	196.7	508.1	237.9	72.2	1 015	1 123	1 400	0.98
2004	223.2	421.7	117.0	110.1	872	986	1 400	1.01
2005	277.0	389.8	173.4	174.1	1 014	1 151	1 400	1.13
2006	151.0	473.2	372.6	186.0	1 183	1 201	1 400	1.13

CPUE Analysis

- Unstandardised CPUE is in kg/tow. The short time series, the nature of the fishery (fishing aggregations spread over a wide area in different seasons) and the impact of catch limits on features and sub-areas prevent any useful relative abundance indices from being developed at this point for ORH 1.

- Where features are less than 10 n. mile apart, catch is apportioned according to the distance to the feature. Industry in-season reporting is based on the feature closest to the start of the tow.
- Possible problems with the area A observations in 2005–06, as there seem to be more reported tows than expected given the number of vessels operating in the area.

Observer Programme

- 50% observer coverage prior to 1 October 2006 (a high level relative to that for other deepwater stocks, with a large number of samples taken relative to the size of the fishery). From 1 October 2006, 100% coverage was requested by the Minister, but this has not been fully achieved, as some ORH 1 is taken as bycatch on trips that do not predominantly target ORH.
- The size frequency data show high levels of stock variability between fisheries on features or feature groups. Size variation does not seem to be linked to exploitation rate.

Environmental Effects

- Observer data from 2000 to 2003 indicated that incidental captures of seabirds did not occur in the ORH 1 target fishery (Baird 2005). Marine mammal interactions are also not .a problem.
- Only three non-fish bycatch records have been reported from observed trips (in 1994 and 1995). All were shearwaters that landed on deck and were released alive. It was verified that observers were briefed in the same way as for other MFish trips including recording non-fish bycatch i.e. seabirds and marine mammals. Note that this does not include benthic organisms.
- The overall impact of bottom trawling on seamounts in ORH 1 is not known. A number of seamounts have been closed to fishing and the Norfolk Deep BPA is included in the industry accord relating to benthic protection areas within New Zealand's EEZ.

Sub-area D Directed Adaptive Exploratory Fishing Programme

- The purpose of this exercise was to establish whether fish populations shift between features in different years in sub-area D.
- Based on the results from the exploratory fishing from 2002 to 2005 it is evident that catches from all features contained a high proportion of ripe or ripe running females and that synchronised spawning occurs on a range of hills during winter.
- In 2006 the AMP Working Group recommended some changes to the design of the exploratory survey; however, this was not achieved during the 2006 survey.

The abbreviated checklist questions for full- and mid-term reviews are:

1. Is stock abundance adequately monitored?

   The working group concluded that CPUE does not seem to be a proportional measure of abundance for this stock. However, CPUE is used in ORH 1 as a management tool. When CPUE drops on a feature, fishers are meant to move to another feature.
2. Is logbook coverage sufficient?

   As there are Ministry fisheries observers on these vessels, fishers are not required to complete detailed logbooks for the AMP. This is the highest level of monitoring of any ORH fishery in New Zealand.
3. Are additional analyses of current data necessary?

   No. The Working Group concluded that no other information can currently be extracted from the existing data that will provide insight into the status of the ORH 1 stocks. However, a potential problem with the 2005–06 catch records from Area A still needs to be checked.
4. Based on the biomass index, is current harvest sustainable?

   Unknown. The purpose of the AMP was to spread effort in an attempt to reduce fishing pressure on any one sub-area or feature (and Area D in particular). ORH 1 is a large area, with orange roughy aggregations spread across a number of areas and features. The amount of fishing in some areas appears to be low, but without any indication of current abundance, there is no way to determine if this level of fishing is in fact sustainable, or if current feature limits will avoid overexploitation of localised areas.
5. Where is stock, based on weight of evidence, in relation to B_{MSY}?

Unknown. In 2001, when the AMP was initiated, the Working Group stated that the stock was likely to be above B_{MSY}; while the information collected since that time has not improved the understanding about the status of the stock, the intent of the AMP design for ORH 1 was to spread effort to reduce the likelihood of the biomass declining below B_{MSY}.

ORH 1 is unlikely to be a single biological stock, and probably includes a number of constituent stocks. The Working Group concluded that it is not possible to estimate B_{MSY} for any of the individual stocks, let alone aggregate up to an estimate for ORH 1 as a whole. Moreover, a better understanding is not possible in the near future. B_{MSY} is difficult to estimate in situations involving an unknown number of constituent stocks.

6. Are the effects of fishing adequately monitored?

   Yes, there is good observer coverage. The Working Group noted that one consequence of deliberately spreading effort was to increase the possible benthic impact.

7. Are rates of non-fish bycatch acceptable?

   Yes.

8. Should the AMP be reviewed by the Plenary?

   This AMP does not need to be reviewed by the Plenary.

5. STATUS OF THE STOCKS

From 1 October 2001, the TACC for ORH 1 was increased to 1400 t within the AMP, with sub-area and feature limits. From 1 October 2007 the stock is no longer part of the Adaptive Management Programme but stakeholders have agreed to continue with the sub-area and feature limits within the overall ORH 1 TACC.

In most years the total catch has been less than the TACC. However, it is not known if recent catch levels or current TACCs are sustainable in the long term. Except for the small area of the Mercury-Colville box no assessment of stock status is currently available.

An assessment of the Mercury-Colville box in 2001 indicated that biomass had been reduced to 10-15% B_0 (compared to an assumed B_{MSY} of 30% B_0). As the stock was considered to be well below B_{MSY}, a catch limit of 30 t was set for the box. The assessment indicated that a catch level of about 100 t would probably maintain the stock at the 2000 stock size (assuming deterministic recruitment) and catch levels from 16 to 35 t (consistent with *CAY* or *MCY* strategies) might allow the stock to rebuild slowly.

In other areas of ORH 1 the status of the constituent stocks is unknown. The amount of fishing in some areas appears to be low, but without any indication of current abundance, there is no way to determine if this level of fishing is in fact sustainable or if current feature limits will avoid overexploitation of localised areas.

6. FOR FURTHER INFORMATION

Anderson, O F (2007a) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1 to the end of the 2005–06 fishing year.. Deepwater-WG-07/39. 11 p. (Unpublished paper held by Ministry for Primary Industries, Wellington.)

Anderson, O F (2007b) Report to SeaFIC on the orange roughy Adaptive Management Programme in ORH 1. (Unpublished document held at NZ Seafood Industry Council Library, Wellington).

Anderson, O F; Dunn, M R (2006) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2006/20*. 59 p.

Annala, J H; Sullivan, K J; O'Brien, C J (2000) Report from the Fishery Assessment Plenary, May 2000: stock assessments and yield estimates. (Unpublished report held in NIWA library, Wellington.)

Baird, S J (2005) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/2*. 50 p.

Clark, M R (2001) A description of the orange roughy fishery in northern North Island waters (ORH 1) for 1997–98 to 1999–2000: an update of commercial catch and effort information. *New Zealand Fisheries Assessment Report 2001/76*. 23 p.

Clark, M R (1999) Fisheries for orange roughy (*Hoplostethus atlanticus*) on seamounts in New Zealand. *Oceanologica Acta* 22(6): 593–602.

Clark, M R; Field, K D (1998) Distribution, abundance and biology of orange roughy in the western Bay of Plenty: results of a trawl survey, June 1995 (SMT9501). *NIWA Technical Report* 14. 29 p.

Clark, M R; King, K J (1989) Deepwater fish resources off the North Island, New Zealand: results of a trawl survey, May 1985 to June 1986. *New Zealand Fisheries Technical Report* No. 11. 56 p.

Clark, M R; Tracey, D M (1988) Assessment of the west coast South Island and northern North Island orange roughy fisheries. New Zealand Fisheries Assessment Research Document 1988/20. 11 p. (Unpublished document held by NIWA library, Wellington.)

Cordue, P L; Francis, R I C C (1994) Accuracy and choice in risk estimation for fisheries assessment. *Canadian Journal of Fisheries and Aquatic Sciences 51*: 817–829.

Francis, R I C C (1990) A maximum likelihood stock reduction method. New Zealand Fisheries Assessment Research Document 1990/4. 8 p. (Unpublished document held in NIWA library, Wellington.)

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27 p. (Unpublished document held in NIWA library, Wellington.)

SeaFIC (2006) Report to the Adaptive Management Programme Fishery Assessment Working Group:Full Term Review of the ORH1 Adaptive Assessment Programme. AMP-WG-06 (Unpublished report held by Ministry for Primary Industries.)

Starr, P; Clark, M R; Francis, R I C C (1996) ORH 1: blueprint for controlled development of an orange roughy fishery? *Seafood New Zealand 4(2)*: 29–31.

ORANGE ROUGHY, CAPE RUNAWAY TO BANKS PENINSULA (ORH 2A, 2B, 3A)

1. FISHERY SUMMARY

1.1 Commercial fisheries

The first reported landings of orange roughy between Cape Runaway and Banks Peninsula were in 1981–82 occurring with the development of the Wairarapa fishery. Total reported catches and TACCs grouped into the three orange roughy Fishstocks from 1981–82 to 2012–13 are shown in Table 1. The historical catches and TACCs for these stocks are shown in Figure 1.

Table 1: Reported catches (t) and TACCs (t) from 1981–82 to 2013–14. QMS data from 1986–present.

Fishing Year (1 Oct–30 Sep)	QMA 2A (Ritchie + E.Cape)		QMA 2B (Wairarapa)		QMA 3A (Kaikoura)		All areas combined	
	Catches	TACC	Catches	TACC	Catches	TACC	Catches	TACC or catch limit
1981–82*	-	-	554	-	-	-	554	-
1982–83*	-	-	3 510	-	253	-	3 763	-
1983–84†	162	-	6 685	-	554	-	7 401	-
1984–85†	1 862	-	3 310	3 500	3 266	§	8 438	-
1985–86†	2 819	4 576	867	1 053	4 326	2 689	8 012	8 318
1986–87	5 187	5 500	963	1 053	2 555	2 689	8 705	9 242
1987–88	6 239	5 500	982	1 053	2 510	2 689	9 731	9 242
1988–89	5 853	6 060	1 236	1 367	2 431	2 839	9 520	10 266
1989–90	6 259	6 106	1 400	1 367	2 878	2 879	10 537	10 352
1990–91	6 064	6 106	1 384	1 367	2 553	2 879	10 001	10 352
1991–92	6 347	6 286	1 327	1 367	2 443	2 879	10 117	10 532
1992–93	5 837	6 386	1 080	1 367	2 135	2 879	9 052	10 632
1993–94	6 610	6 666	1 259	1 367	2 131	2 300	10 000	10 333
1994–95	6 202	7 000	754	820	1 686	1 840	8 642	9 660
1995–96	4 268	4 261	245	259	612	580	5 125	5 100
1996–97	3 761	4 261	272	259	580	580	4 613	5 100
1997–98	3 827	4 261	254	259	570	580	4 651	5 100
1998–99	3 335	3 761	257	259	582	580	4 174	4 600
1999–00	3 120	3 761	234	259	617	580	3 971	4 600
2000–01	1 385	1 100	190	185	479	415	2 054	1 700
2001–02	1 087	1 100	180	185	400	415	1 667	1 700
2002–03	782	680	105	99	235	221	1 122	1 000
2003–04	703	680	103	99	250	221	1 056	1 000
2004–05	1 120	1 100	206	185	416	415	1 742	1 700
2005–06	1 076	1 100	172	185	415	415	1 663	1 700
2006–07	1 131	1 100	203	185	401	415	1 736	1 700
2007–08	1 068	1 100	209	185	432	415	1 709	1 700
2008–09	1 114	1 100	173	185	414	415	1 701	1 700
2009–10	1 117	1 100	213	185	390	415	1 720	1 700
2010–11	1 113	1 100	158	185	420	415	1 690	1 700
2011–12	876	875	140	140	428	415	1 445	1 430
2012–13	727	#710	102	#106	296	#314	1 124	#1 130
2013–14	732	875	108	140	331	415	1 171	1 430

* Ministry data † FSU data. § Included in QMA 3B TAC.
\# Includes shelving (an agreement that transfers ACE to a third party to effectively reduce the catch without adjusting the TACC)

There was a major change in the ORH 2A fishery in 1993–94 with a shift of effort from the main spawning hill on Ritchie Bank to hills off East Cape. Although these hills had apparently only been lightly fished in the past, during 1993–94 52% of the total catch from ORH 2A was taken from the East Cape area (Table 2). This led to an agreement between industry and the Minister responsible for fisheries that, from 1994–95, the traditionally fished areas within ORH 2A (south of 38°23', hereafter referred to as “2A South”) would be managed separately from the new East Cape fishery (north of 38°23', “2A North”). ORH 2A South was combined with ORH 2B and ORH 3A to form the Mid-East Coast (MEC) stock for management purposes.

The catch limits for these two areas changed three times in the following four years, including a subdivision of 2A North (Table 3). Catches in the exploratory sub-area of 2A North never approached the catch limit, with only 37 t being caught in 1996–97 and less in subsequent years.

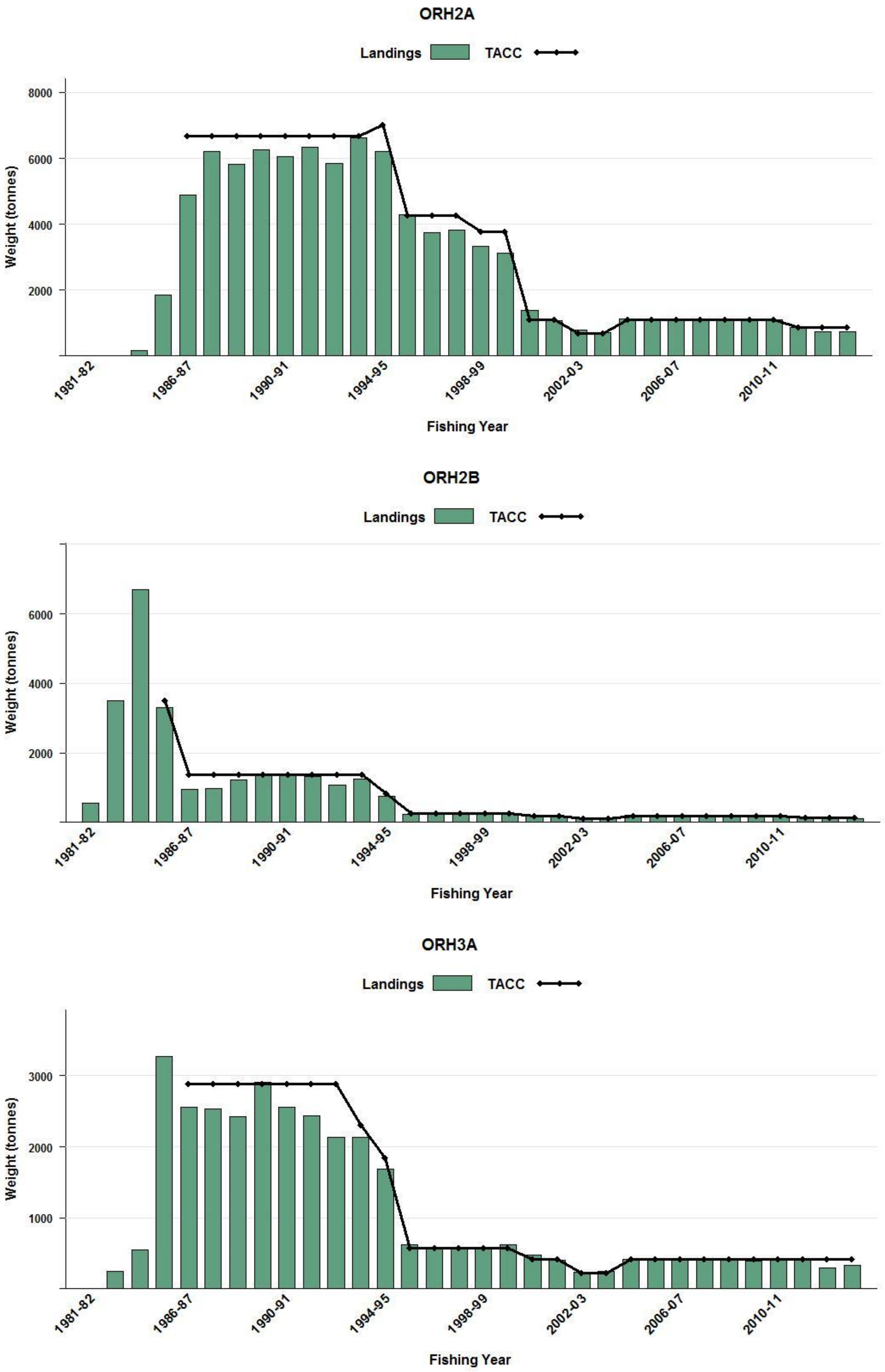


Figure 1: Reported commercial landings and TACCs for ORH 2A (Central (Gisborne)), ORH 2B (Central (Wairarapa)), and ORH 3A (Central/Challenger/South-East (Cook Strait/Kaikoura)).

For the 2000–01 fishing year, the TACC for ORH 2A was reduced to 1100 t, that for ORH 2B to 185 t, and that for ORH 3A to 415 t. Within the TACC for ORH 2A, the catch limit for all of 2A North was reduced to 200 t, without specifying separate catch limits for the East Cape Hills and the exploratory area, while the catch limit for 2A South was reduced to 900 t. This gave a catch limit for the MEC stock of 1500 t. The catch limit for MEC was reduced to 800 t (and ORH 2A South to 480 t) for the 2002–03 and 2003–04 fishing years. From 1 October 2004 there was an increase in the TACC to 1100 t, 185 t, and 415 t in 2A, 2B, and 3A respectively. Furthermore, an allowance of 58 t, 9 t, and 21 t, for other mortality was allocated to 2A, 2B, and 3A in 2004 as well.

In 2012–13 the fishing industry voluntarily shelved (an agreement that transfers ACE to a third party to effectively reduce the catch without adjusting the TACC) approximately 25% of the MEC quota, resulting in effective catch limits of 510 t, 106 t, and 314 t for 2A South, 2B, and 3A respectively.

1.2 Recreational fisheries

Recreational fishing for orange roughy is not known in this area.

1.3 Customary non-commercial fisheries

No information on customary non-commercial fishing for orange roughy is available for this area.

1.4 Illegal catch

No information is available about illegal catch in this area.

Table 2: North Mid-East Coast + East Cape (ORH 2A) catches by area, in tonnes and by percentage of the total ORH 2A catch. (Percentages up to 1993–94 and from 2007–08 calculated from Ministry data; 1994–95 to 1996–97 from NZFIB data, and 1997–98 to 2006–07 from Orange Roughy Management Co.) Mid-East Coast (MEC) stock (ORH 2A South, ORH 2B, and ORH 3A combined) catches in tonnes.

Fishing year	2A North		2A South		MEC (t)
	t	%	t	%	
1983–84	0	0	162	100	7 401
1984–85	4	< 1	1 858	99	8 434
1985–86	41	1	2 778	99	7 971
1986–87	253	5	4 934	95	8 452
1987–88	36	< 1	6 203	99	9 695
1988–89	143	2	5 710	98	9 377
1989–90	20	< 1	6 239	99	10 517
1990–91	13	< 1	6 051	99	9 988
1991–92	18	< 1	6 329	99	10 099
1992–93	30	< 1	5 807	99	9 022
1993–94	3 437	52	3 173	48	6 563
1994–95	2 921	47	3 281	53	5 721
1995–96	3 235	76	1 033	24	1 890
1996–97	2 491	66	1 270	34	2 122
1997–98	2 411	63	1 416	37	2 240
1998–99	1 901	57	1 434	43	2 273
1999–00	1 456	47	1 666	53	2 517
2000–01	302	22	1 083	78	1 752
2001–02	186	17	901	83	1 480
2002–03	173	24	546	76	886
2003–04	170	24	533	76	886
2004–05	271	24	849	76	1 471
2005–06	216	20	859	80	1 445
2006–07	229	20	902	80	1 506
2007–08	200	24	868	76	1 509
2008–09	230	21	884	79	1 471
2009–10	267	24	850	76	1 453
2010–11	207	19	906	81	1 484
2011–12	184	21	692	79	1 260
2012–13	190	26	537	74	935

Table 3: Catch limits (t) by sub-area within ORH 2A, as agreed between the industry and the Minister responsible for fisheries since 1994–95 and the catch limit for the Mid-East Coast (MEC) stock (ORH 2A South, ORH 2B, ORH 3A combined). (Note that 2A North was split, for the years 1996–97 to 1999–2000, into the area round the East Cape Hills and the remaining area, which is called the exploratory area).

Fishing year	2A North	2A South	MEC
1994–95	3 000	4 000	6 660
1995–96	3 000	1 261	2 100
1996–97	3 000*	1 261	2 100
1997–98	3 000*	1 261	2 100
1998–99	2 500*	1 261	2 100
1999–00	2 500*	1 261	2 100
2000–01	200	900	1 500
2001–02	200	900	1 500
2002–03	200	480	800
2003–04	200	480	800
2004–05	200	900	1 500
2005–06	200	900	1 500
2006–07	200	900	1 500
2007–08	200	900	1 500
2008–09	200	900	1 500
2009–10	200	900	1 500
2010–11	200	900	1 500
2011–12	200	675	1 230
2012–13	200	510	930
2013–14	200	510	930

*Catch limit for East Cape Hills including 500 t for the exploratory area.

1.5 Other sources of mortality

There has been a history of catch overruns in this area because of lost fish and discards, particularly in the early years of the fishery. In the assessments presented here total removals were assumed to exceed reported catches by the overrun percentages in Table 4.

All yield estimates and forward projections presented make an allowance for the current estimated level of overrun of 5%.

Table 4: Catch overruns (%) by QMA and year. -, no catches reported.

Year	2A (North and South)	2B	3A
1981–82	-	30	-
1982–83	-	30	30
1983–84	50	30	30
1984–85	50	30	30
1985–86	50	30	30
1986–87	40	30	30
1987–88	30	30	30
1988–89	25	25	25
1989–90	20	20	20
1990–91	15	15	15
1991–92	10	10	10
1992–93	10	10	10
1993–94	10	10	10
1994–95 and subsequent years	5	5	5

2. BIOLOGY

Biological parameters used in this assessment are presented in the Biology section at the beginning of the Orange Roughy Introduction section.

3. STOCKS AND AREAS

Two major spawning locations have been identified in ORH 2A, one at the East Cape Hills in “2A North” and the other on the Ritchie Bank in “2A South”. Spawning orange roughy were located in Wairarapa (ORH 2B) in winter 2001, but no large concentrations were found, and the significance of this spawning event is not known. Spawning orange roughy have not been located in Kaikoura (ORH 3A). The major spawning area in ORH 2A South, ORH 2B, and ORH 3A is still believed to be the Ritchie Bank, although spawning aggregations were not seen here in the 2013 AOS survey.

Results from allozyme studies showed that orange roughy from the three areas, “2A South”, Wairarapa, and Kaikoura could not be separated, but were distinct from fish on the eastern Chatham Rise. Earlier analyses that suggested there was a genetic stock boundary between East Cape and Ritchie Bank were not supported by a more recent replicate sample from East Cape. For these reasons, orange roughy in this region are currently treated as two stocks: the Mid-East Coast (MEC) stock (2A South, Wairarapa, and Kaikoura) and the East Cape (EC) stock (2A North). The relationship between these areas and the location of the main fishing grounds is shown in Figure 2.

4. STOCK ASSESSMENT

Stock assessments are reported below for East Cape from 2003 and for Mid East Coast (MEC) from 2014.

4.1 East Cape stock (2A North)

The stock assessment for the East Cape was last updated in 2003 and is summarised here (Anderson 2003b). An attempt to update the assessment with a new set of CPUE indices was made in 2006, but was rejected by the Working Group because of changes in the fishery which invalidated the utility of the CPUE series as an index of abundance. With no other abundance estimates available, an updated stock assessment was not possible.

4.1.1 Assessment Inputs

A CPUE analysis was performed in 2006, but was considered unreliable because of a change in fishing patterns and fleet size corresponding to the reduction of the catch limit to 200 t in 2000–01. The CPUE analysis was updated in 2011 and was considered more reliable by the Working Group due to the increase in the number of trawls per year since 2006. The 2011 analysis showed that standardised CPUE decreased after a peak in 2003–04, and has subsequently remained at a level similar to that in the late 1990s to early 2000s (Table 5).

Previous concerns by the Working Group that the fishery was dominated by a single vessel were alleviated somewhat by the return or entry of three other vessels to the fishery since 2003–04, but the utility of CPUE analyses in fisheries where substantial catch limit reductions have caused major changes in fishing patterns remains an issue for this stock.

The model inputs for the 2003 stock assessment were catches, an egg survey, and CPUE indices (Table 5). The biological parameters used are presented in the Biology section at the beginning of the Orange Roughy section.

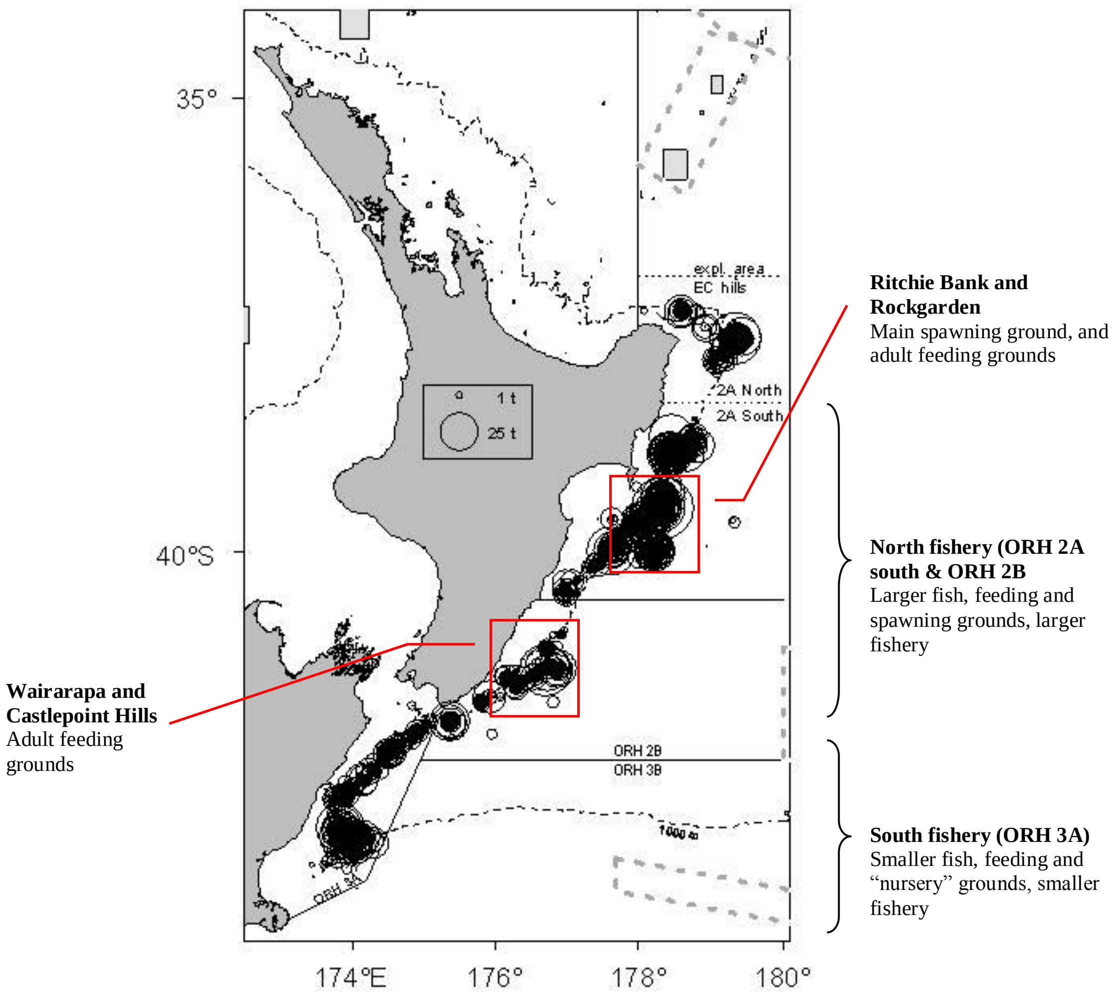


Figure 2: Catch (t) per tow of orange roughy in ORH 2A, ORH 2B, and ORH 3A for the five fishing years from 2006–07 to 2010–11 (circles, with area proportional to catch size), location of the fisheries assumed during stock assessment, and the location of the main spawning, feeding, and nursery grounds. Perimeters of Benthic Protection Areas (BPAs) closed to bottom trawling are marked with dashed grey lines, and seamounts closed to trawling are marked as shaded rectangles.

Table 5: Standardised CPUE and egg survey indices, and CVs for the East Cape stock, as used in the 2003 assessment, and an updated standardised CPUE index derived in 2011. -, no data.

	CPUE index 2003	CV(%)	Egg survey	CV(%)	CPUE index 2011	CV(%)
1993–94	1.00	12	-	-	0.95	23
1994–95	0.69	8	29 000	69	0.76	22
1995–96	0.60	8	-	-	0.61	23
1996–97	0.41	8	-	-	0.47	22
1997–98	0.25	7	-	-	0.27	23
1998–99	0.25	7	-	-	0.28	23
1999–00	0.22	9	-	-	0.23	23
2000–01	0.21	15	-	-	0.28	26
2001–02	0.22	16	-	-	0.23	27
2002–03	-	-	-	-	0.51	32
2003–04	-	-	-	-	0.50	30
2004–05	-	-	-	-	0.29	27
2005–06	-	-	-	-	0.37	28
2006–07	-	-	-	-	0.36	29
2007–08	-	-	-	-	0.27	28
2008–09	-	-	-	-	0.24	28
2009–10	-	-	-	-	0.20	27

4.1.2 Stock assessment

A stock assessment analysis for the East Cape stock was performed in 2003 using the stock assessment program, CASAL (Bull et al 2002) to estimate virgin and current biomass.

- The model was fitted using Bayesian estimation and partitioned the EC stock population by sex, maturity (the fishery was assumed to act on mature fish only) and age (age-groups used were 1–

70, with a plus group).

- The model estimated virgin biomass, B_0, and the process error for the CPUE indices. Catchability, q, was treated as a nuisance parameter by the model.
- The stock was considered to reside in a single area, and to have a single maturation episode modelled by a logistic-producing ogive where 50% of fish of both sexes were mature at age 26 and 95% at age 29.
- The catch equation used was the instantaneous mortality equation from Bull et al (2002) whereby half the natural mortality was applied, followed by the fishing mortality, then the remaining natural mortality.
- The size at age model used was the von Bertalanffy.
- No stock recruitment relationship was assumed.
- A Bayesian estimation procedure was used with a penalty function included to discourage the model from allowing the stock biomass to drop below a level at which the historical catch could not have been taken.
- Lognormal errors, with known (sampling error) CVs were assumed for the CPUE and egg survey indices. Additionally, process error variance was estimated by the model and added to the CVs from the CPUE indices.
- Confidence intervals were calculated from the posterior profile distribution of B_0 estimates, where the process error parameter was fixed at the value previously estimated.

4.1.3 Biomass estimates

Biomass estimates for this stock are given in Table 6 and the biomass trajectories, plotted against the scaled indices, are shown in Figure 3. The base case assessment of the EC stock included only the CPUE indices. An alternative assessment was carried out including the point estimate of biomass from the 1995 egg survey along with the CPUE indices. The CPUE indices agree well with the biomass estimates, with only the 1993–94 and 1997–98 indices departing from the biomass 95% confidence intervals. The egg survey biomass estimate, with the large associated CV, has little effect on the biomass trajectory.

Table 6: Estimates of virgin biomass (B_0), B_{MSY} (calculated as B_{MAY}, the mean biomass under a *CAY* policy), and B_{2003}, for the EC stock (with 95% confidence intervals in parentheses).

					B_{2003}		
Assessment	Index	B_0 (t)		B_{MSY} (t)	(t)	% B_0	
Base case	CPUE	21 100	(19 650–23 350)	6 300	5 100	24	(20–32)
Alternative	CPUE + Egg survey	21 200	(19 700–23 550)	6 380	5 200	25	(20–33)

The base case estimate of $B_{CURRENT}$ (the mid-year biomass in 2002–03) is 5100 t (24% B_0) with a 95% confidence interval of 3800 to 7550 t. This is almost twice the value of B_{2003} estimated for mid-year 1999–2000 in the previous assessment (Anderson 2000). The alternative assessment gives a very similar estimate of B_{2003}.

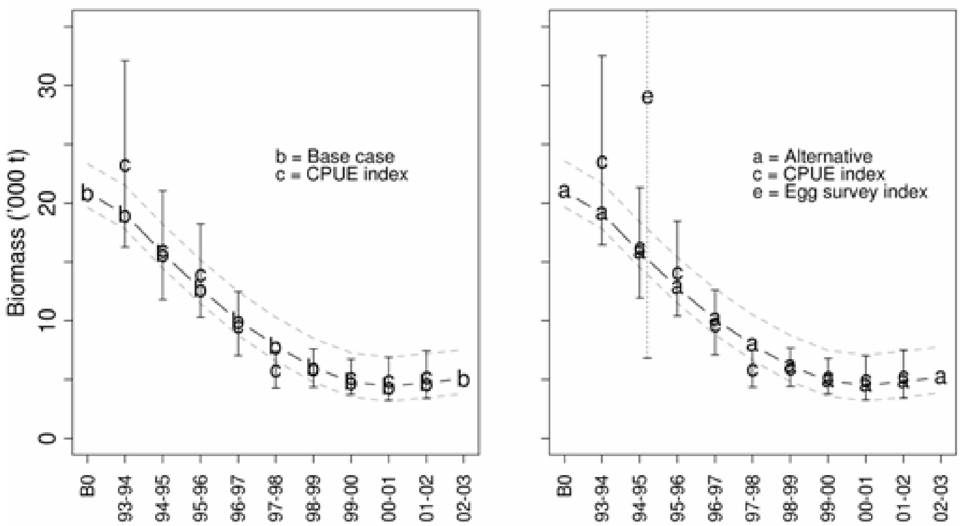


Figure 3: Estimated biomass trajectories for the base case and alternative model runs for the EC stock. Annual biomass estimates are mean posterior density (MPD) values and 95% confidence intervals (grey dashed lines) are calculated from the posterior profile distribution of B_0 estimates. The CPUE index CVs (sampling error plus process error) are shown, as is the CV calculated for the egg survey biomass estimate.

4.1.4 Yield estimates and projections

Estimates of *MCY* and *CAY* for the *EC* stock were calculated from large numbers of simulation runs using posterior profile sampling of B_0 and a series of trial harvest levels. These estimates, together with *MAY* (the mean catch with a *CAY* harvesting strategy) and *CSP* (current surplus production) are given in Table 7. *CSP* is driven by recruitment of fish spawned before the fishery began.

Table 7: Estimates of *MCY*, *CAY*, *MAY*, and *CSP* for the *EC* stock, with 95% confidence intervals in parentheses (all corrected for an assumed overrun of 5%).

Assessment	*MCY* (t)	*CAY* (t)	*MAY* (t)	*CSP* (t)
Base case	350	370	410	550
Alternative	350	370	410	550

4.2 Mid-East Coast stock (2A South, 2B, 3A)

There was no new information available that would change the accepted stock definition of the MEC orange roughy stock i.e. comprising ORH 2A South, ORH 2B, and ORH 3A.

The Mid-East Coast (MEC) stock assessment was updated in 2014 using the methods common to the four assessments performed in 2014 (see Orange Roughy Introduction). The previous model based assessment was in 2013 but that assessment used data which did not meet the quality threshold applied in 2014 (i.e., CPUE indices, wide-area acoustic survey and egg-survey estimates). In 2014, an age-structured population model was fitted to the data described in section 4.2.2 below.

4.2.1 Model structure

The model was single-sex and age-structured (1-120 years with a plus group) with maturity in the partition (i.e., fish were classified by age and as mature or immature). A single area and a single time step were used with two year-round fisheries defined by different selectivities (a “southern” fishery catching young fish (double-normal selectivity) and a “northern” fishery catching older fish (logistic selectivity). The spawning season was assumed to occur after 75% of the mortality and 100% of mature fish were assumed to spawn each year.

The catch history was constructed from the catches in Tables 1 & 2, adding the catch over-run percentages in Table 4. The northern fishery combined catches from ORH 2A South and ORH 2B, and the southern fishery used ORH 3A. Natural mortality was assumed to be fixed at 0.045 and the stock-recruitment relationship was assumed to follow a Beverton-Holt function with steepness of 0.75. The remaining fixed biological parameters are given in the Orange Roughy Introduction.

4.2.2 Input data and statistical assumptions

There were three main data sources for observations fitted in the assessment: a spawning biomass estimate from an acoustic survey (2013); a trawl-survey time series of relative biomass indices (1992–1994, 2010) with associated length frequencies (1992, 1994), and age frequencies and estimates of proportion spawning at age (1993, 2010); and length and age frequencies collected from the commercial fisheries, including four spawning-season age frequencies (1989-1991, 2010).

Research surveys

The MEC area has been surveyed using acoustic and trawl methods, and egg surveys have also been conducted. Not all survey data have been used in the 2014 assessment. The egg survey estimates have some quality issues associated with them; the 1993 survey data were post-stratified and “corrected” for turn-over of fish (Zeldis et al 1997). The 1993 egg-survey estimate was used in the 2013 assessment but was not considered to be reliable enough for the 2014 assessment (which had a higher “quality threshold”). Similarly, the wide-area acoustic survey estimates from 2001 and 2003 (Doonan et al 2003, 2004a) were rejected in 2014 as being not sufficiently reliable (in particular, the biomass estimates primarily came from mixed species marks and “orange roughy” marks identified subjectively; rather than being from easily identified spawning plumes).

Trawl survey data

A time series of pre-spawning season, random, stratified, trawl surveys were conducted in March–April on *RV Tangaroa* in 1992-94 and 2010 (Grimes et al 1994, 1996a, 1996b; Doonan & Dunn 2011). The 2010 survey was specifically designed to be comparable with the earlier surveys and to produce an abundance index for the MEC home grounds (Doonan & Dunn 2011). In addition to the relative biomass indices (Table 8), the survey data were analysed to produce length frequencies from all years and age frequencies from 1993 and 2010 (Doonan et al 2011). Also, estimates of female proportion spawning at age were produced for the 1993 and 2010 surveys (Ian Doonan, pers. comm.).

Table 8: Biomass indices and CVs used in the stock assessment.

Year	Trawl index (t)	CV (%)	Acoustic index (t)	CV (%)
1992	20 838	29		
1993	15 102	27		
1994	12 780	14		
2010	7 074	19		
2011				
2012				
2013			4 225	20

The biomass indices were fitted as relative biomass with a double-normal selectivity (it is apparent that the trawl survey did not fully select the largest/oldest fish) and an uninformed prior on the proportionality constant (q). The length frequencies from 1992 and 1994 were fitted as multinomial, as were the age frequencies from 1993 and 2010 (length frequencies from 1993 and 2010 had been used in the production of the age frequencies). The proportion spawning at age was assumed binomial at each age. Effective sample sizes were all taken from the 2013 assessment (Cordue 2014).

Acoustic survey estimate

The only reliable acoustic estimate of spawning biomass for MEC came in 2013 when a multi-frequency "AOS" survey was conducted (acoustic and optical gear mounted on the trawl headline, e.g., see Kloser et al 2011). Four areas were visited in 2013 but the only substantial spawning plume was seen in the "Valley" (a known spawning site near Ritchie Bank). Four snapshots were taken and the estimates from 38 kHz were averaged to produce a biomass index (Table 8).

The "standard" assumption in the 2014 stock assessments, for acoustic estimates from spawning plumes, is that they collectively cover "most" of the spawning biomass where "most" is taken to be 80%. However, for MEC, only one spawning plume was found and it was in a very small area. There are many potential sites in the MEC for spawning plumes. For these reasons, "most" was taken to be 60% in the base model (and sensitivities were done at 40% and 80%). That is, the acoustic estimate was fitted as relative biomass with an informed prior: lognormal (mean = 0.6, CV = 19%) for the base model.

Commercial age and length frequencies

As in 2011 and 2013, composition data were also used: length frequency samples from the northern commercial fishery (ORH 2A South and ORH 2B) for 16 years between 1988–89 and 2009–10, and from the southern commercial fishery (ORH 3A) for nine years between 1989–90 and 2008–09, and age frequency samples from commercial landings of the spawning fishery in ORH 2A south in 1989, 1990, 1991. The otoliths from the 1989–91 samples were re-aged for the 2013 assessment using the new ageing protocol (Tracey et al 2007). In addition, age samples taken from a single vessel in the 2010 spawning season were also used. These had been aged with the new protocol but because they were from a single vessel and a fishery 20 years later than in 1990 the age frequency was fitted with its own selectivity. The age frequencies from 1989-91 were assumed to be from spawning fish (i.e., no selectivity fitted). The composition data were all assumed to be multinomial and effective samples sizes from the 2013 assessment were used (except the southern fishery length frequencies were down-weighted following the iterative reweighting procedure of Francis (2011)).

4.2.3 Model runs and results

In the base model, natural mortality (M) was fixed at 0.045. There were numerous MPD sensitivity runs and six main sensitivities are presented in this report: estimate *M*; down-weight the trawl indices; separate selectivity for spawning age frequencies; mean acoustics *q* prior = 0.4; and the LowM-Highq and HighM-Lowq "standard" runs (see Orange Roughy Introduction).

In the base model, the main parameters estimated were: virgin biomass (B_0), the maturity ogive, the two fishery selectivities, the trawl survey selectivity, the 2010 age frequency selectivity, and year class strengths (YCS) from 1881 to 1996 (with the Haist parameterisation and "nearly uniform" priors on the free parameters). Additional estimated parameters included the CV of the length-at-age parameters and the proportionality constants (*q*s)for the trawl survey time series and the 2013 acoustics estimate.

Model diagnostics

The MPD fits to the biomass indices were excellent (Figure 4), although the MCMC fit was only just adequate for the trawl survey indices, particularly to the 2010 index (Figure 5). The poorer MCMC fit to the 2010 trawl index when compared to the MPD fit occurred because the MPD pattern of YCS did not match the posterior distribution of the same quantities, showing much greater year-to-year variation than seen in the MCMC posterior (Figure 6). This result highlights the difference between MPD estimates and MCMC estimates: the MPD finds the single vector of parameters which give the best fit to the data, while the MCMC procedure finds the parameter space that best explains the data. There is no reason why the MPD has to be in the "middle" of the posterior distribution, here we have an example where the MPD estimates are in the tail of the posterior distribution.

The MCMC fit to the acoustics index had also degraded when compared to the MPD fit (see Figures 4 and 5), as well as estimating a lower acoustics *q* (Figure 7). The cause of this is the same as for the 2010 trawl index; the MPD spawning biomass trajectory almost exactly matched the 2013 acoustic estimate but, given the less variable MCMC YCS trajectory, the resulting MCMC biomass trajectory was shifted higher (and the acoustic *q* shifted lower to compensate).

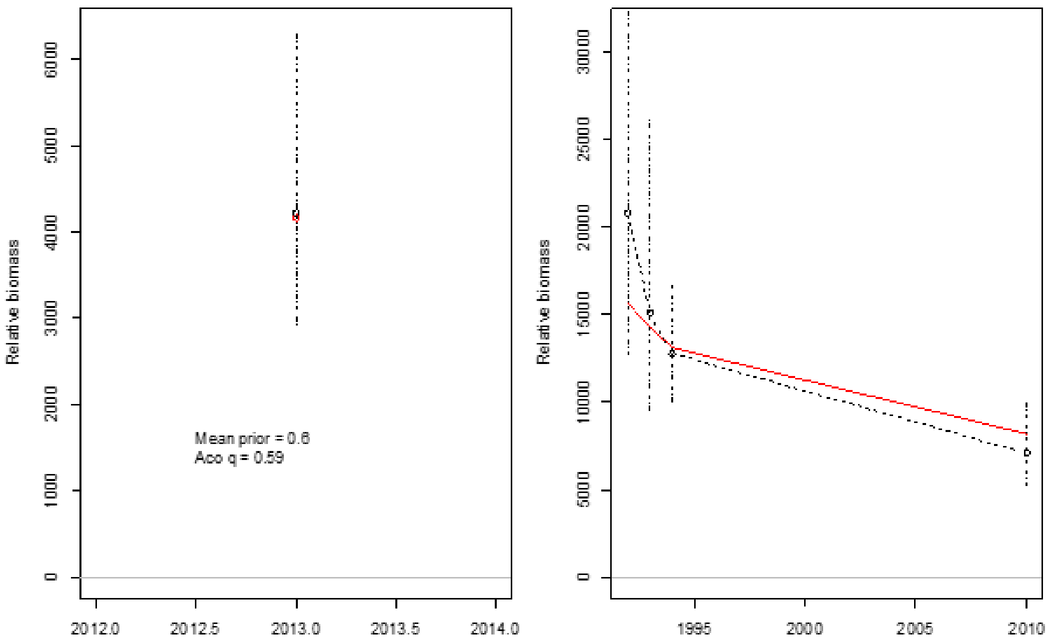


Figure 4: MPD fit to biomass indices: left: acoustic-survey spawning biomass index (fitted with an informed *q* prior, mean = 0.6; MPD estimated *q* = 0.59); right: *Tangaroa* trawl-survey indices. Vertical lines are 95% CIs.

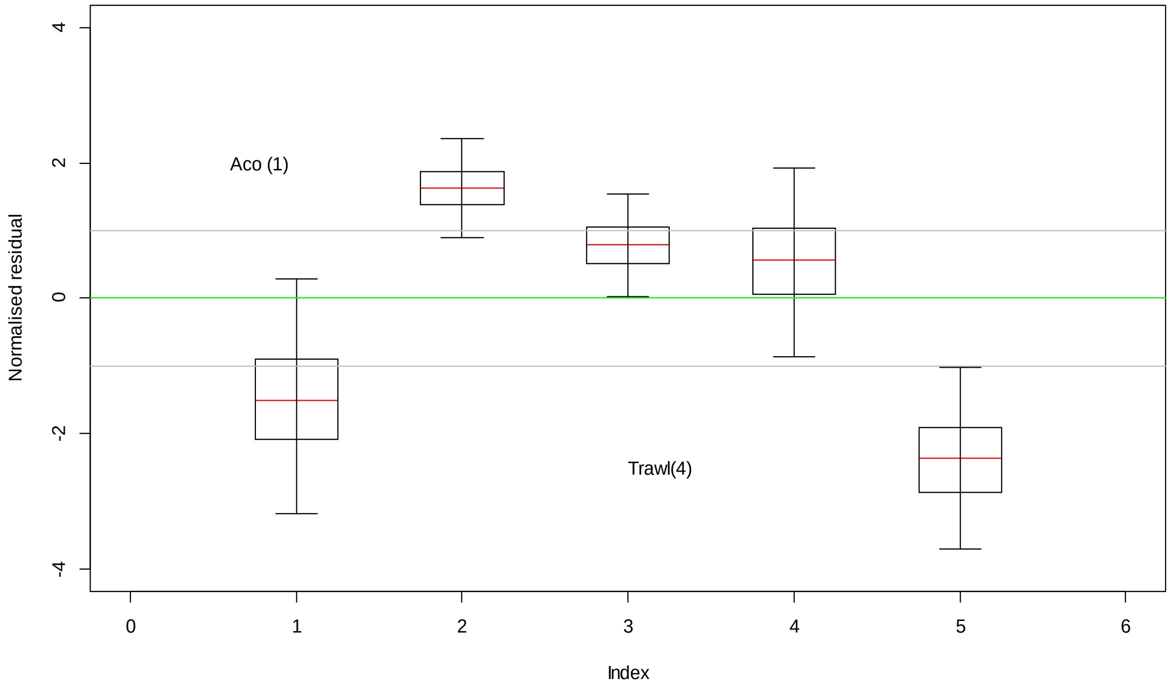


Figure 5: MCMC base: normalised residuals for the biomass indices. The box covers 50% of the distribution for each index and the whiskers extend to 95% of the distribution. "Aco" denotes the acoustic estimate (2013). "Trawl" denotes the *Tangaroa* trawl-survey time series (1992-94, 2010).

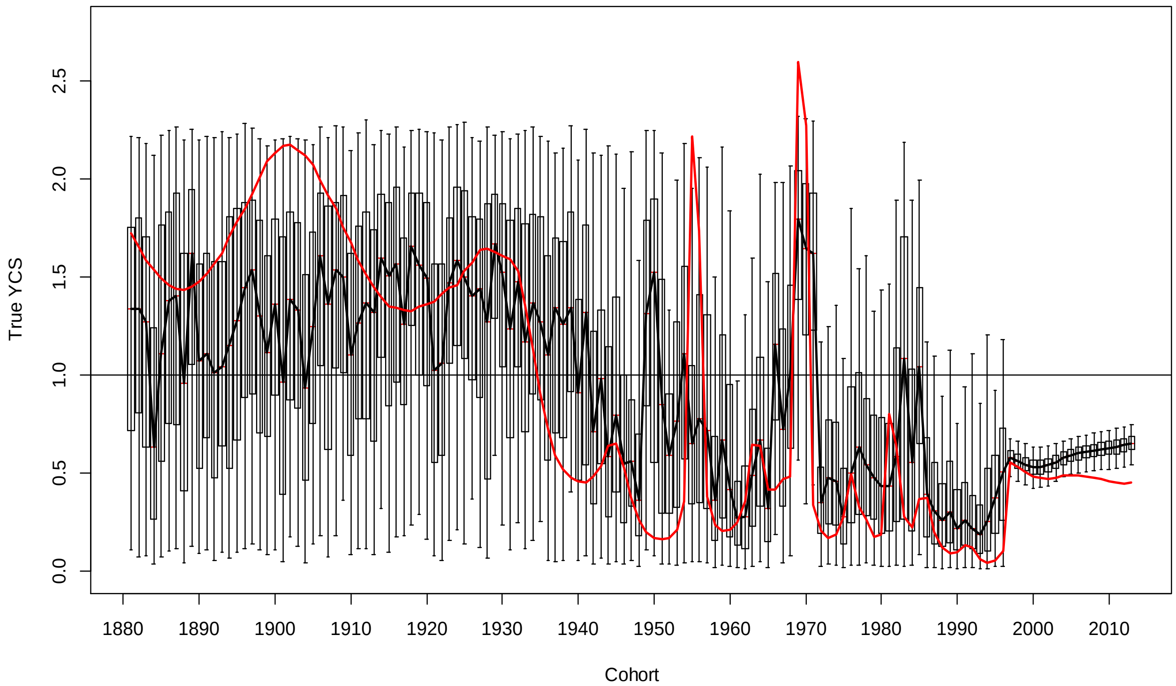


Figure 6: Base model: MCMC estimated "true" YCS (R_y/R_0) (in black). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The MPD estimates are shown in red.

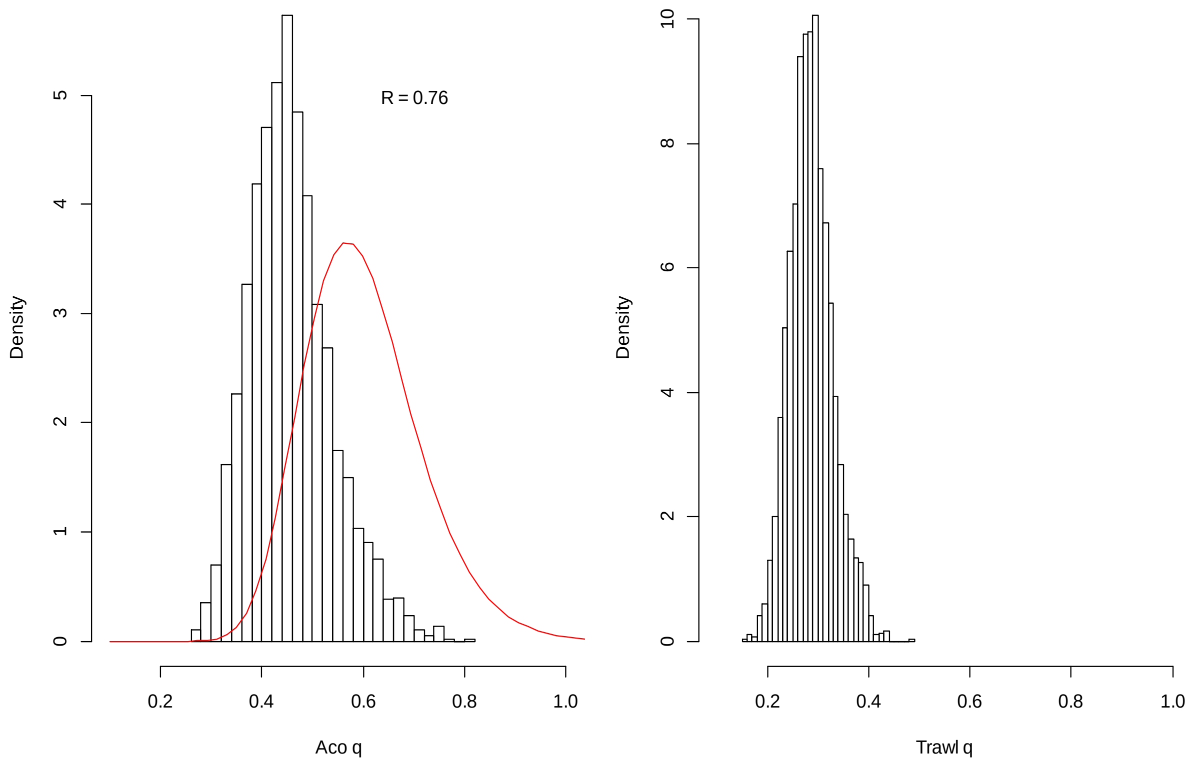


Figure 7: Base model MCMC diagnostics: prior and posterior distributions for the acoustic *q* (prior in red, posterior black histogram) (left); posterior distribution for the trawl-survey *q* (the prior was uninformed) (right). R = 0.76 is the ratio of the mean of the acoustic *q* posterior to the mean of the prior.

The MPD fits to the commercial length frequencies were adequate (Figures 8 and 9). They could never be very good because the length frequencies show a great deal of year-to-year variability, as evidenced by the annual mean lengths (Figure 10). The model predictions of annual mean length are necessarily fairly smooth from year-to-year; as they are only able to track the main trend but not the annual jumps (Figure 10).

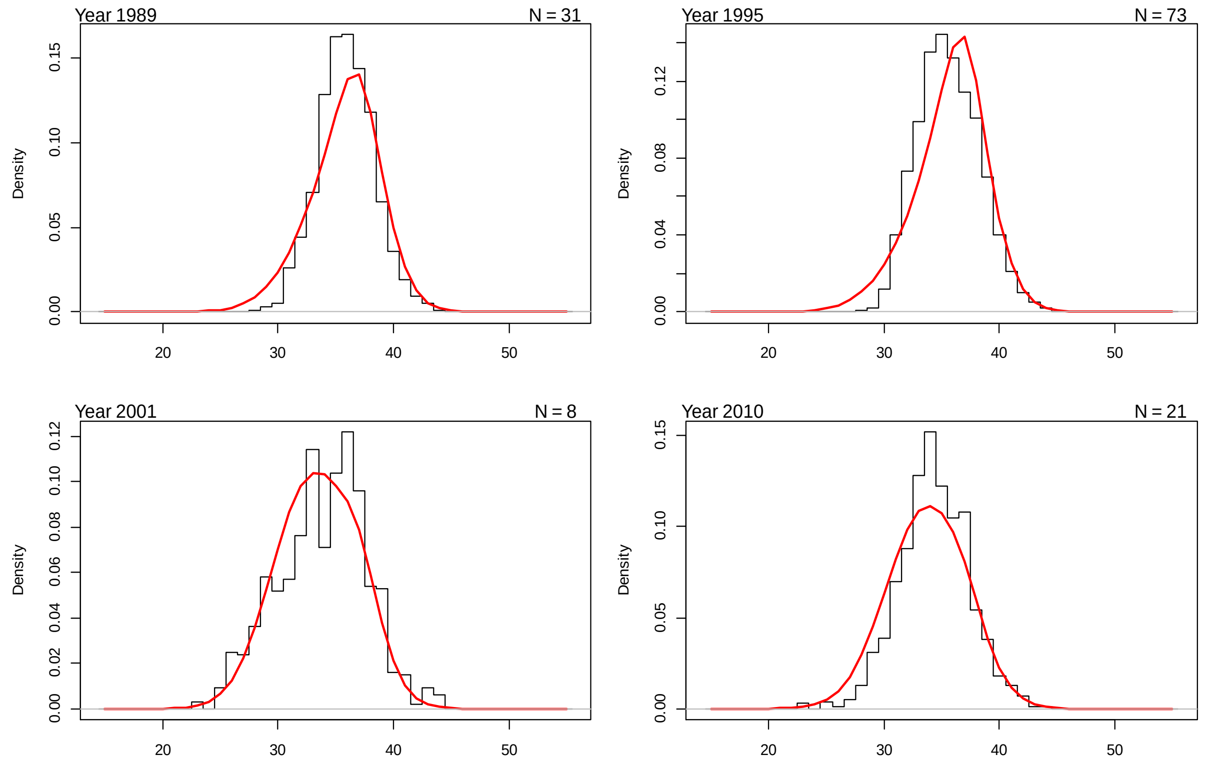


Figure 8: Example MPD fits to northern fishery length frequencies (N is the assumed effective sample size in the given year; x-axis is fish length (cm)). Observations are black lines; model predictions are the red lines.

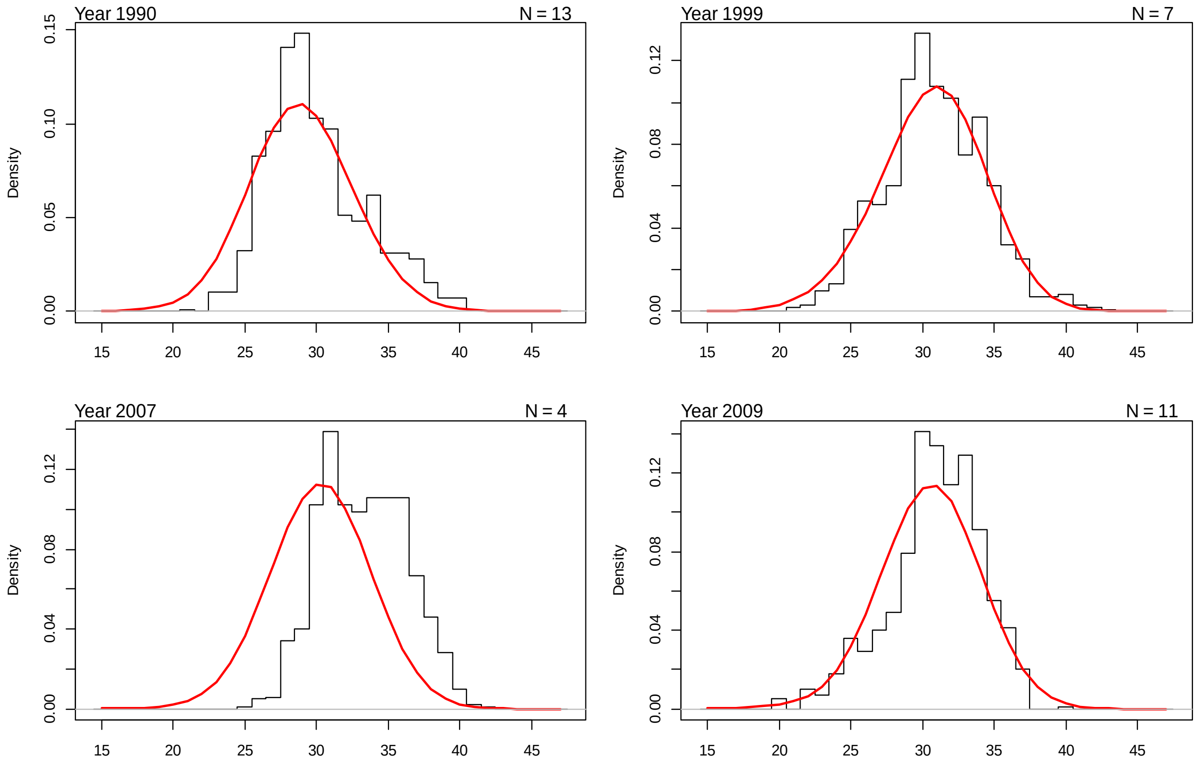


Figure 9: Example MPD fits to southern fishery length frequencies (N is the assumed effective sample size in the given year; x axis is fish length (cm)). Observations are black lines; model predictions are the red lines.

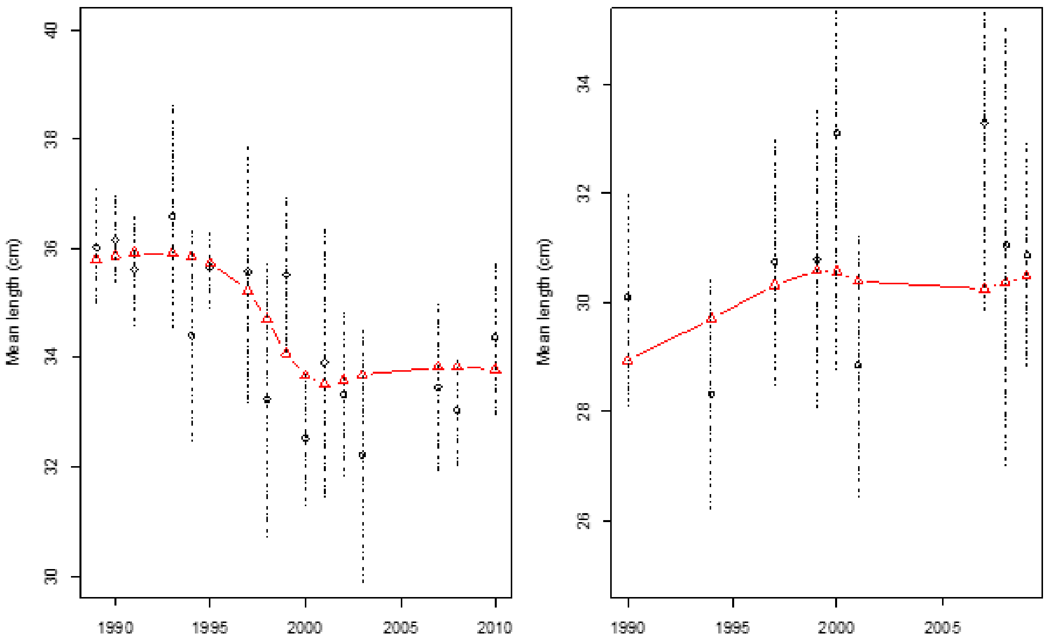


Figure 10: Annual mean lengths from the commercial length frequencies (northern fishery on the left, southern on the right) with 95% CIs (black, circles, dashed vertical lines) and the base model predictions (red, triangles, solid lines).

The MPD fits to the trawl-survey length frequencies and estimates of proportion spawning at age are good (Figure 11). It is notable that the model fits the different shape of the proportion spawning estimates in 1993 and 2010 (Figure 11). The spawning-season age frequencies are only adequately fitted (Figure 12). There is a misfit for the young ages (except for 2010 which had its own selectivity) as these data compete with the proportion spawning-at-age data to define the maturity ogive (see Figure 11 – young fish are spawning according to the proportion spawning data). In response to the misfit in Figure 12, a sensitivity run was done where the 1989-91 spawning age frequencies were allowed to have a logistic selectivity. This improved the fit substantially and raised the model estimate of the 2014 stock status from 14 to 17% B_0. The base model was preferred to be consistent across the four orange roughy stocks assessed in 2014, with the maturity ogive used to define the spawning-season selectivity and age frequencies.

The fit to the trawl-survey age frequencies is excellent, which should be expected given the large effective sample size of N = 200 (Figure 13). A number of sensitivity runs were done with alternative data weighting, including down-weighting the trawl-survey age frequencies, which demonstrated that the model was robust to a wide range of assumptions. For example, the only runs that made a substantial difference to the MPD estimates of stock status were doubling the acoustic index (10.2% B_0 compared to the base estimate of 6.5% B_0) and assuming deterministic recruitment (25.8% B_0); the other 16 runs had MPD estimates in the range 4–9% B_0.

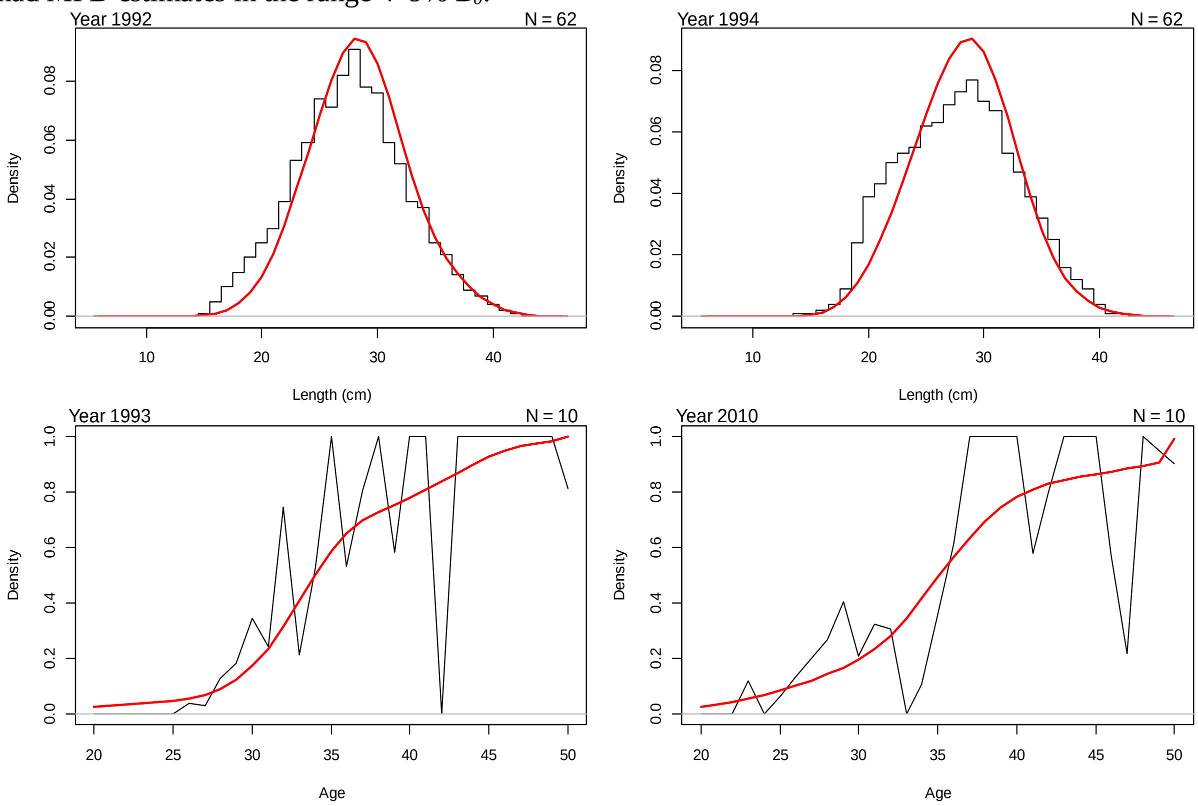


Figure 11: Base, MPD fits to trawl-survey length frequencies (N is the assumed effective sample size in the given year) and proportion spawning-at-age (N =10 is the binomial sample size assumed for each age). Observations are black lines; model predictions are the red lines.

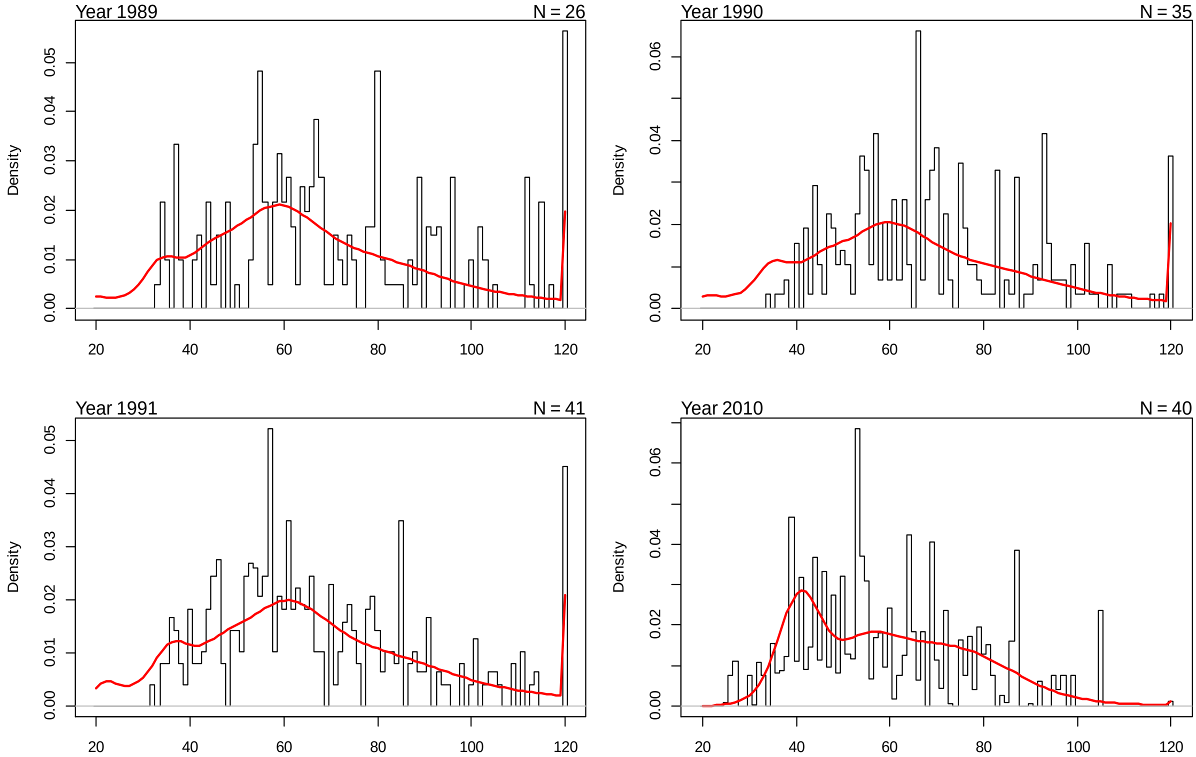


Figure 12: Base, MPD fit to spawning-season age frequencies (N is the assumed effective sample size in the given year). Observations are black lines; model predictions are the red lines.

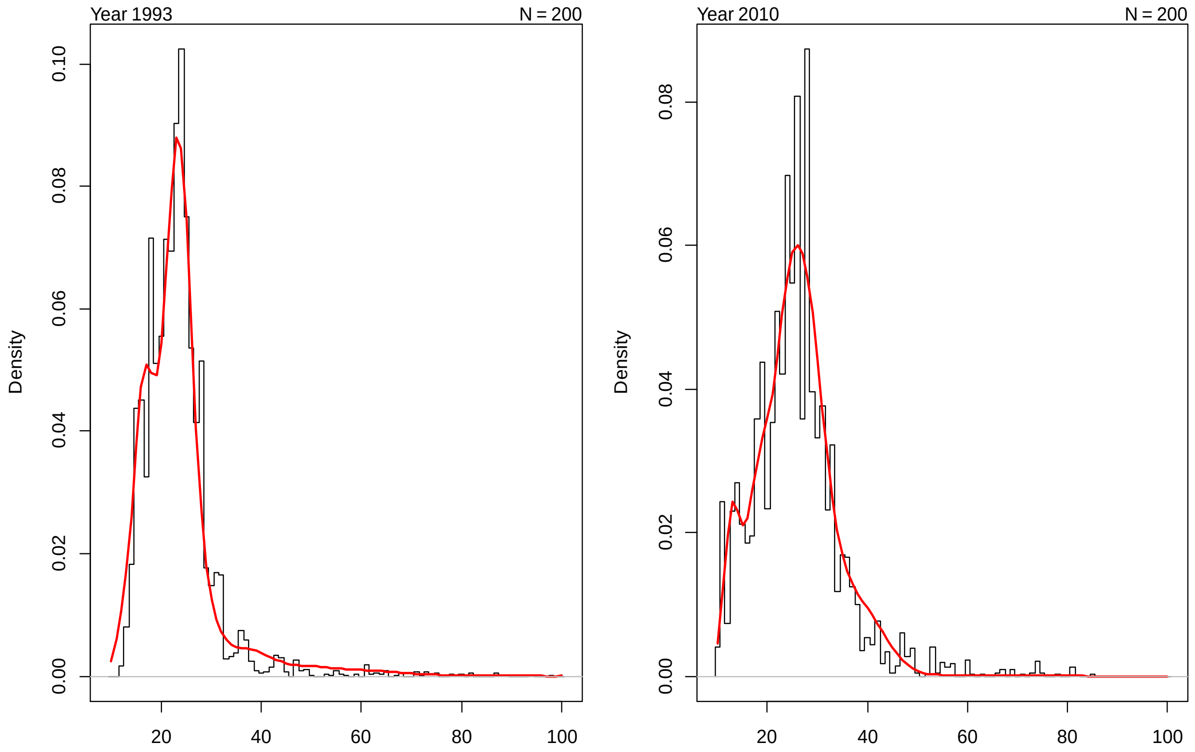


Figure 13: Base, MPD fit to trawl-survey age frequencies (N = 200 is the assumed effective sample size). Observations are black lines; model predictions are the red lines.

MCMC results

MCMC convergence diagnostics were very good for the base model and sensitivities. Virgin biomass (B_0) was estimated to be about 100,000 t for all runs (Table 9). Current stock status was similar for the base and the estimate-*M* run (Table 9). The slightly lower stock status when *M* was estimated reflects the lower estimate of M (0.032 rather than 0.045). Down-weighting the trawl indices (by adding process error CV of 20%) reduced the magnitude of the normalised residuals and raised the median estimate of 2014 stock status from 14 to 16% B_0 (Table 9). Giving the 1989–91 spawning age frequencies a selectivity improved the fit to younger age fish, decreased the estimate of B_0 from 95 000 t to 91 000 t and increased estimated stock status from 14 to 17% B_0 (Table 9). The reduction in the mean of the acoustic q from 0.6 to 0.4 increased the median estimate of stock status to 19% B_0, but the median estimate was still below the soft limit (Table 9). The two "bounding runs" where M and the mean of the acoustic q were shifted by 20%, still had median estimates under the soft limit, with the "LowM-Highq" run at the hard limit (Table 9). Other sensitivities not reported here included several where the effective sample size on age frequencies was appreciably increased or decreased; in all cases, this had little impact on the estimates of stock status.

Table 9: MCMC estimates of virgin biomass (B_0) and stock status (B_{2014} as $\%B_0$) for the base model, and the six following sensitivity runs: a) estimating natural mortality; b) down-weighting the trawl indices by adding 20% process error to the CV; c) adding a selectivity to spawning age frequencies for 1989–91; d) reducing the mean acoustic catchability coefficient, q, from 0.6 to 0.4; e) decreasing M and increasing acoustic q by 20%; and f) increasing M and decreasing acoustic q by 20%.

Assessment	***M***	**B_0 (000 t)**	**95% CI**	**B_{2014} (%B_0)**	**95% CI**
Base model	0.045	95	87–104	14	9–21
a) Estimate M	0.032	104	96–112	11	7–16
b) Down-weight trawl	0.045	97	88–108	16	11–22
c) Spawn AF selectivity	0.045	91	83–102	17	12–24
d) Mean aco. q = 0.4	0.045	100	92–112	19	13–26
e) LowM-Highq	0.036	96	90–103	10	7–15
f) HighM-Lowq	0.054	99	89–114	19	13–27

The estimated fishery selectivities showed the northern fishery taking fish over 30 years with the southern fishery primarily taking fish from 20-40 years (Figure 14). The trawl-survey selectivity primarily sampled fish from 10-70 years with peak selection from 20-30 years (Figure 14). The 2010 age frequency appears to have been a subset of spawning fish focussed on those from about 50-90 years (Figure 14).

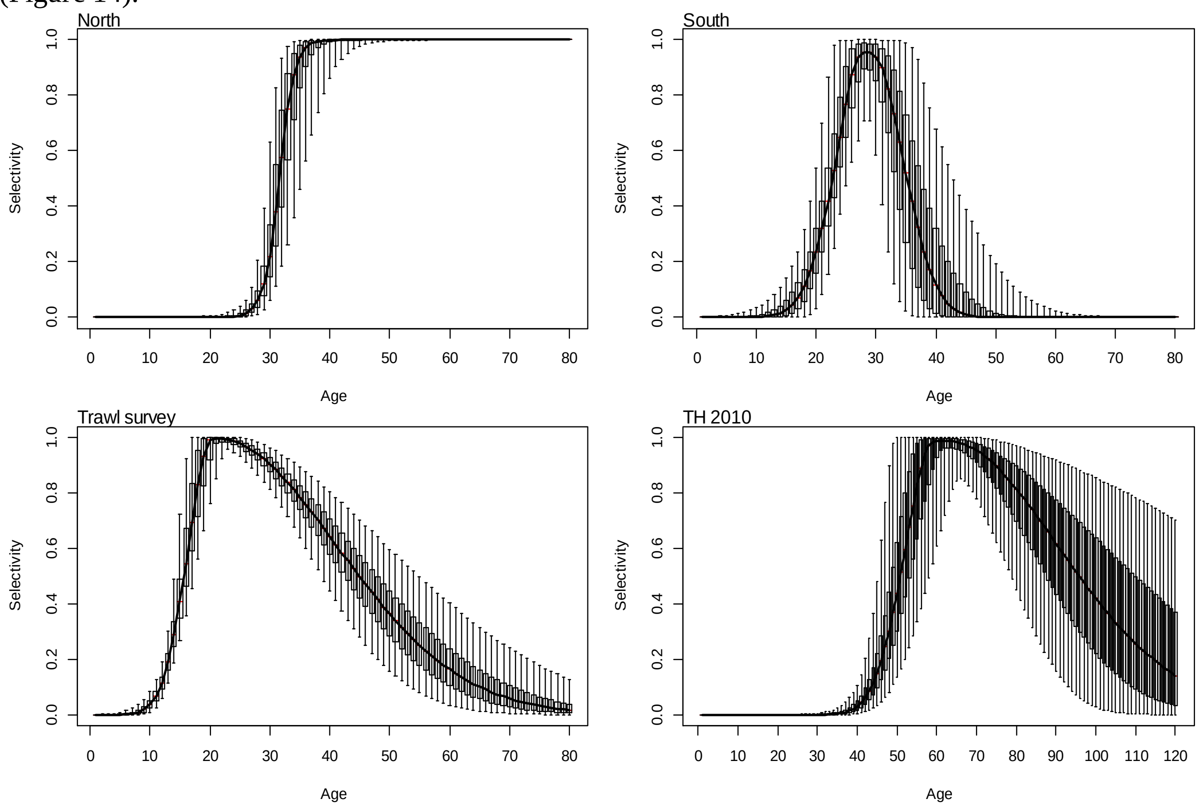


Figure 14: Base, MCMC estimated selectivities (northern and southern fisheries, the trawl survey, and the 2010 age frequency). The box at each age covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The estimated YCS show strong variation across cohorts and exhibit a long-term trend, with recruitment well below average since the early 1970s (Figure 15). The most recent 10 years of estimates, 1986–

1995 (those resampled for short-term projections) are well below average.

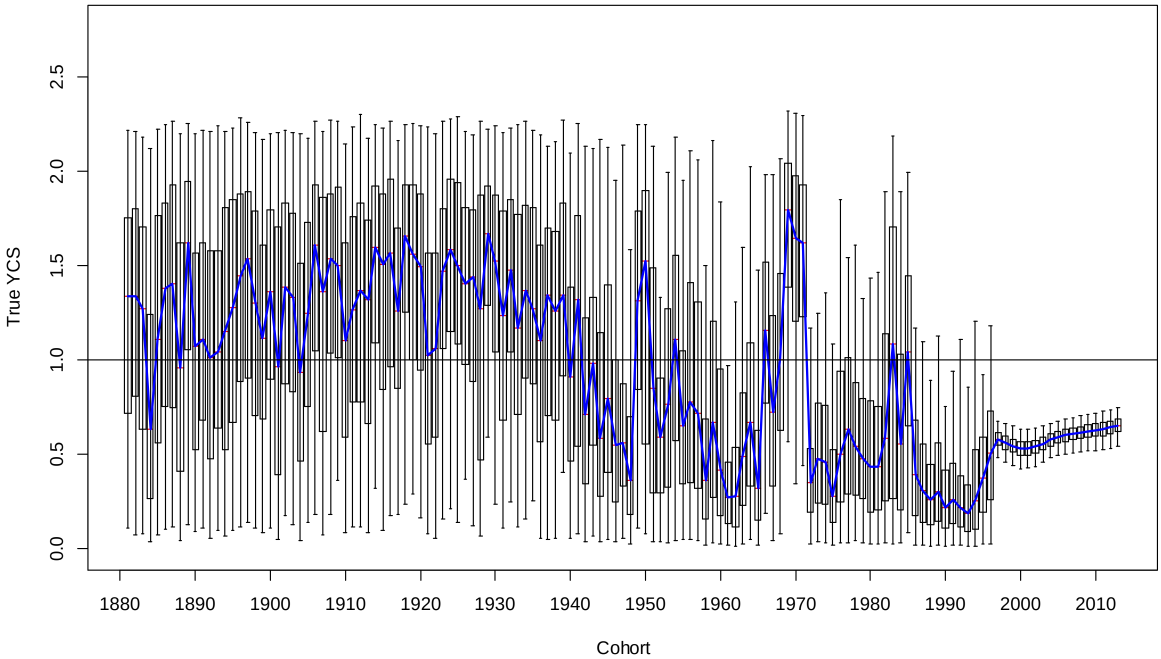


Figure 15: Base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The stock status trajectory shows an increasing trend before the start of fishery as the above average recruitment estimated by the model feeds into the spawning biomass (Figure 16). Then there is a steep decline from the start of fishery until the year 2000 when the biomass reached 10% B_0, after which there was a slow increase (Figure 16).

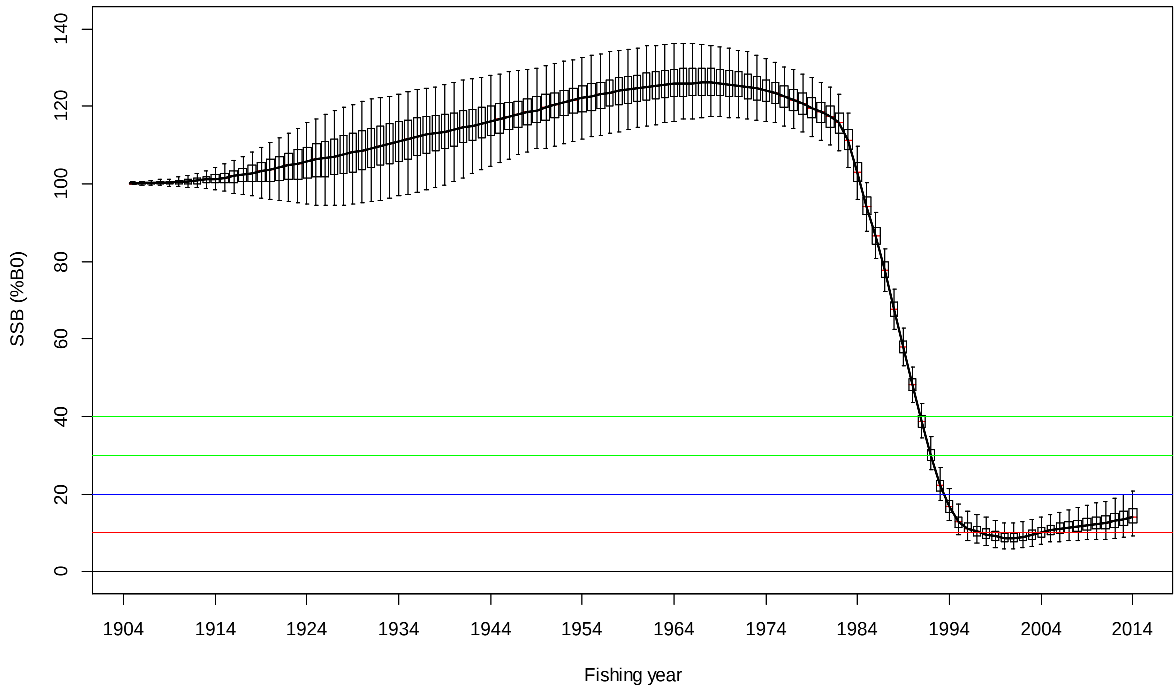


Figure 16: Base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit, 10% B_0 (red), soft limit, 20% B_0 (blue), and biomass target range, 30–40% B_0 (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity in each year. Fishing intensity is represented in term of the median exploitation rate and the Equilibrium Stock Depletion (ESD). For the latter, a fishing intensity of $U_{x\%B0}$ means that fishing (forever) at that intensity will cause the SSB to reach deterministic equilibrium at x% B_0 (e.g., fishing at $U_{30\%B0}$ drives the SSB to a deterministic equilibrium of 30% B_0). Fishing intensity in these units is plotted as 100–ESD so that fishing intensity ranges from 0 ($U_{100\%B0}$) up to 100 ($U_{0\%B0}$).

Estimated fishing intensity was above the target range ($U_{30\%B0}$–$U_{40\%B0}$) from 1984 to 2012 (Figure 17). In the last two years, fishing intensity has decreased to within the target range.

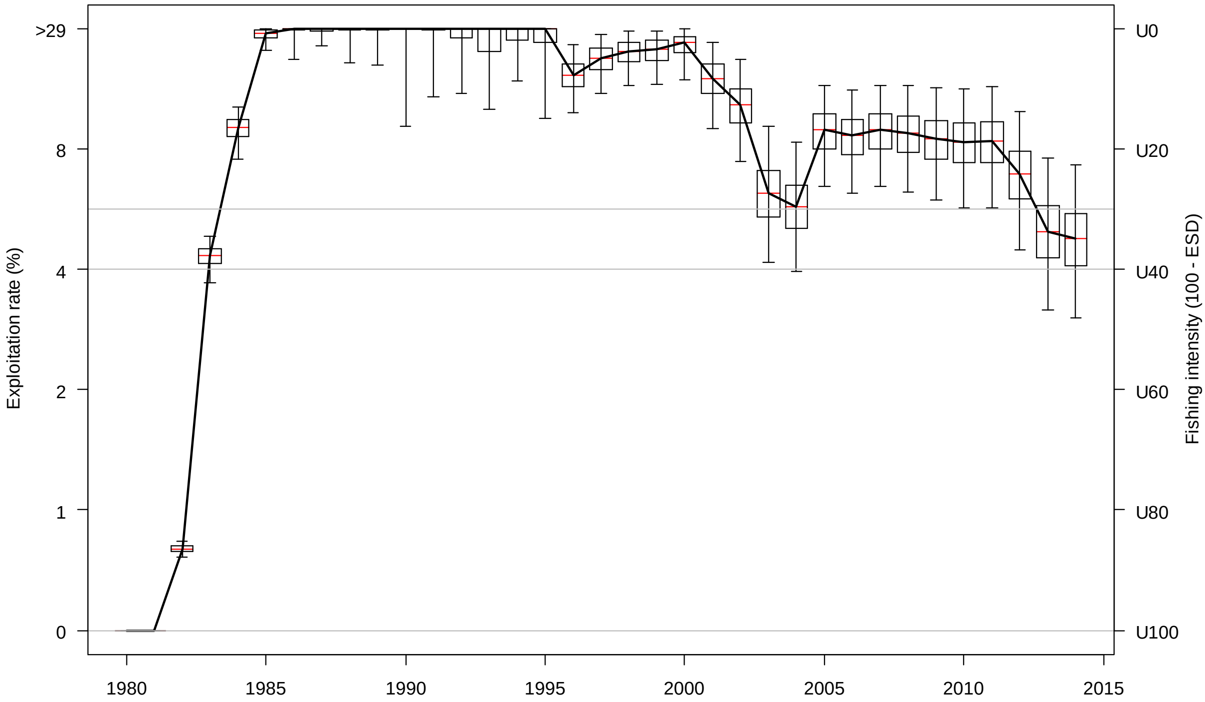


Figure 17: Base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30-40% B_0 is marked by horizontal lines.

Biological reference points, management targets and yield

MCMC estimates of deterministic B_{MSY} and associated values were produced for the base model. The yield at 35% B_0 (the mid-point of the target range) was also estimated. There is little variation in the reference points and associated values across the MCMC samples (Table 10).

There are several reasons why deterministic B_{MSY} is not a suitable target for use in fisheries management. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge (current biomass must be known exactly in order to calculate the target catch) and annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders). Second, it assumes perfect knowledge of the stock-recruit relationship, which is often poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard.

Table 10: Base, MCMC estimates of deterministic equilibrium spawning stock biomass (SSB) and long-term yield (% B_0 and tonnes) for U_{MSY} and $U_{35\%B0}$. The equilibrium SSB at U_{MSY} is deterministic B_{MSY} and the yield is deterministic MSY.

Fishing intensity		SSB (% B_0)	Yield (% B_0)	Yield (t)
U_{MSY}	Median	22.5	2.3	2214
	95% CI	21.8–23.0	2.3–2.4	2048–2415
$U_{35\%B0}$	Median	35.0	2.2	2075
	95% CI	35.0–35.0	2.2–2.2	1916–2264

Projections

Five year projections were conducted (with resampling from the last 10 estimated YCS) for catch at the current catch limit of 930 t (with a 5% catch over-run assumed). Projections were done just for the base model. At the current catch limit (930 t), SSB is predicted to increase slowly over the next five years but still be well below the soft limit in 2019 (Figure 18). The estimated minimum time to rebuild (assuming zero catch and requiring a 70% probability of being above the lower bound of the 30–40% B_0 target range), is 21 years (T_{min}) (Figure 19).

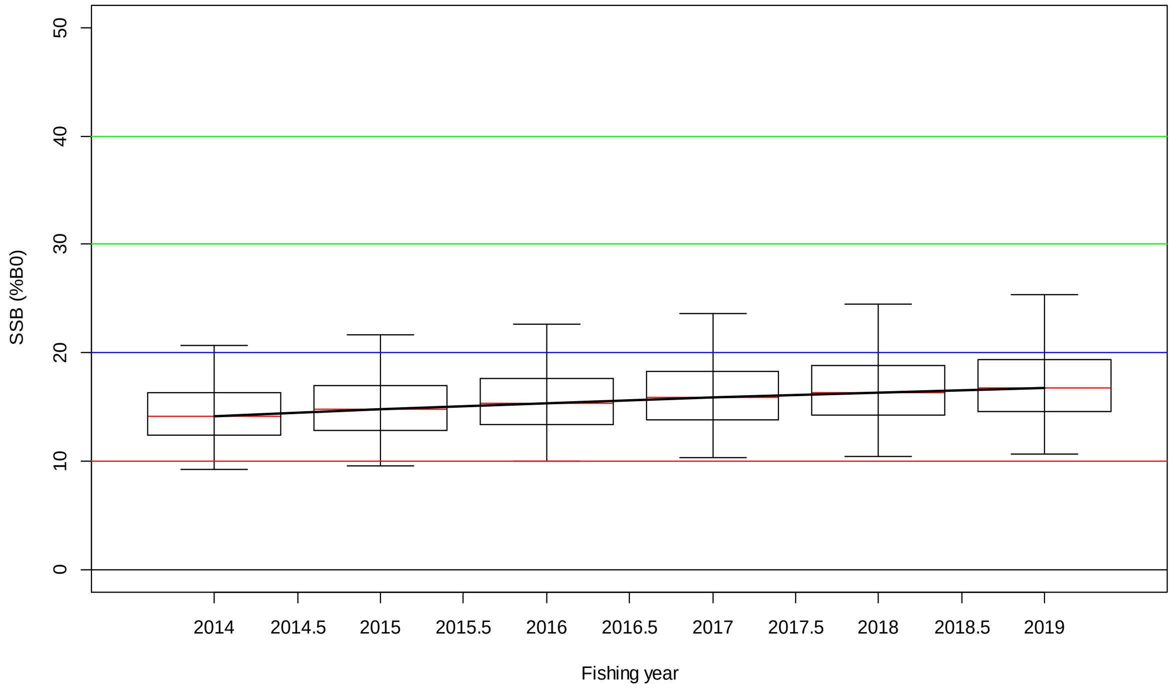


Figure 18: Base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. An annual catch at the current catch limit of 930 t was assumed (with a 5% catch over-run in each year). The target range (30–40% B_0) is indicated by horizontal green lines, with the soft limit (20% B_0) in blue and the hard limit (10% B_0) in red.

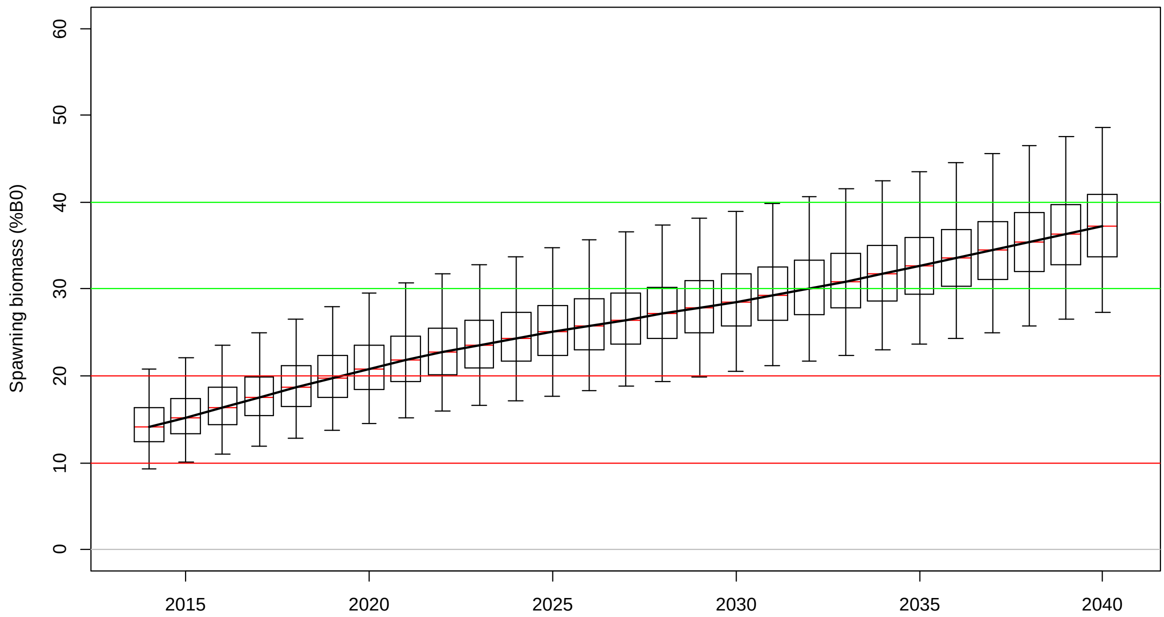


Figure 19: Base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The annual catch used in these projections is zero tonnes. The target range (30–40% B_0) is indicated by horizontal green lines, with the soft limit (20% B_0) in blue and the hard limit (10% B_0) in red.

5. STATUS OF THE STOCKS

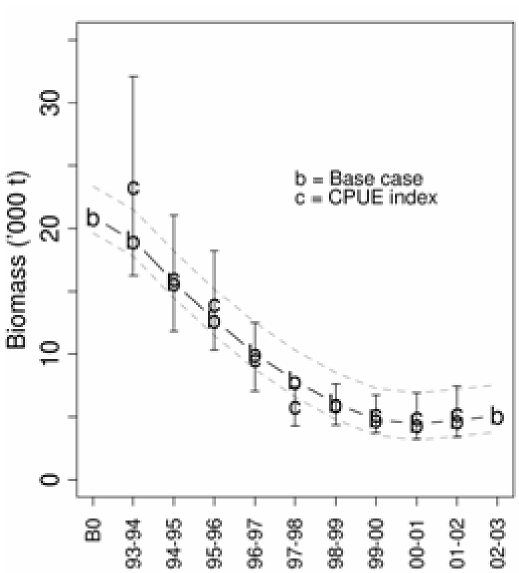
Stock Structure Assumptions
Orange roughy in ORH 2A, 2B and 3A are treated as two biological stocks based on the location of spawning grounds. These stocks are managed and assessed separately however some mixing has been shown to occur. The 2A North stock spawns around the East Cape hills off of the North Island. The 2A South, 2B and 3A stock is assumed to spawn on the Ritchie Bank.

For orange roughy stocks, the current management target is a biomass range from 30–40% B_0.

- **ORH East Cape Stock (2A North)**

Stock Status	
Year of Most Recent Assessment	2003
Assessment Runs Presented	A base case with one alternative
Reference Points	Management Target: 30% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2003} was 24% B_0, which was Unlikely (< 40%) to be at or above the target
Status in relation to Limits	B_{2003} was Unlikely (< 40%) to be below the Soft Limit, and Very Unlikely (< 10%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Estimated biomass trajectory for the base model run for the EC stock. Annual biomass estimates are mean posterior density (MPD) values and 95% confidence intervals (grey dashed lines) are calculated from the posterior profile distribution of B_0 estimates. The CPUE index CVs (sampling error plus process error) are shown.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass declined in the early 1990s but appeared to stabilise at around 5000 t.
Recent Trend in Fishing Mortality or Proxy	*F* has declined along with the agreed catch limit and remains stable at the current catch level of 200 t.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2003)	
Stock Projections or Prognosis	The estimated *CAY* (370 t) and *MAY* (410 t) were both greater than the catch limit of 200 t, and this suggested the stock would start to rebuild.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)

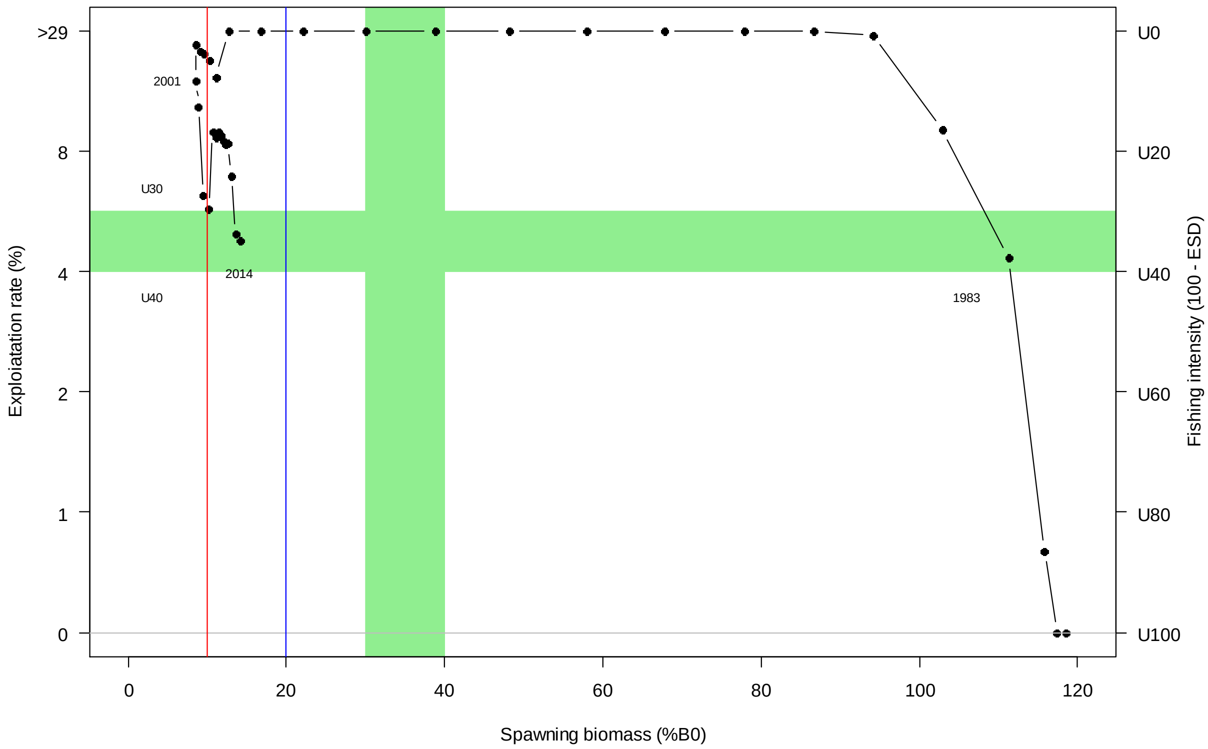
Assessment Methodology		
Assessment Type	Type 1 - Quantitative stock assessment	
Assessment Method	Statistical catch-at-age model implemented in CASAL with Bayesian estimation of posterior distributions	
Main data inputs	- Catch data - Standardised CPUE data - 1994–95 ORH egg survey	
Period of Assessment	Latest assessment: 2003	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
The most recent assessment (2003) is now 11 years out-of-date. In recent years, the ability of stock assessment models that assume deterministic recruitment for orange roughy stocks to reflect current or projected stock status has been called into question.

Fishery Interactions
The main bycatch species are cardinalfish and alfonsino. Low productivity bycatch species include deepwater sharks, deepsea skates and corals. Protected species bycatch includes seabirds and corals.

- **ORH Mid-East Coast Stock (2A South, 2B, 3A)**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base model only
Reference Points	Management Target: Biomass range 30–40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Fishing intensity range $U_{30\%B0}$–$U_{40\%B0}$
Status in relation to Target	B_{2014} was estimated to be 14% B_0 Very Unlikely (< 10%) to be at or above the lower end of the management target range
Status in relation to Limits	B_{2014} is Likely (> 60%) to be below the Soft Limit B_{2014} is Unlikely (< 40%) to be below the Hard Limit
Status in relation to Overfishing	Fishing intensity in 2014 was estimated at $U_{35\%B0}$ Overfishing is About as Likely as Not (40-60%) to be occurring

Historical Stock Status Trajectory and Current Status

Historical trajectory of spawning biomass (%B_0), median exploitation rate (%) and fishing intensity (100-ESD) (base model, medians of the marginal posteriors). The biomass target range of 30-40% B_0 and the corresponding exploitation rate (fishing intensity) range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red. Note that the Y-axis is non-linear.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated spawning biomass has been slowly increasing since about 2000.
Recent Trend in Fishing Intensity or Proxy	Estimated fishing intensity has been declining in recent years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	At the current catch limit, the stock is projected to increase slowly over the next 5 years but still be below the soft limit in 2019. The minimum rebuild period to reach 30% B_0 with 70% probability is estimated to be 21 years with no catch.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	For the current catch and catch limit (in the short term): Soft Limit: Very Likely (> 90%) Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	For the current catch and catch limit: As Likely as Not (40-60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	

Main data inputs (rank)	- Acoustic biomass estimate (2013) - Trawl-survey biomass indices (1992–94, 2010), age frequencies (1993, 2010), length frequencies (1992, 1994), proportion spawning at age (1993, 2010) - Spawning-season age frequencies (1989–91, 2010) - Commercial length-frequencies (1989–90 to 2009–10)	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- CPUE indices - 2002 spawning-season age frequency - Wide-area acoustic estimates - Egg survey estimates	3 – Low Quality (unlikely to be indexing stock-wide abundance) 2 – Mixed Quality (needs to be re-aged) 2 – Mixed Quality (too much potential bias due to target identification and mixed species issues) 2 – Mixed Quality (too much potential bias due to survey design assumptions not being meet)
Changes to Model Structure and Assumptions	A more stringent data quality threshold was imposed on data inputs (e.g., wide-area acoustics, egg survey, and CPUE indices not used).	
Major Sources of Uncertainty	-The proportion of the spawning stock biomass that was indexed by the 2013 acoustic survey (little survey effort has been expended in this area relative to other orange roughy grounds). -Patterns in year class strengths are based on only 5 years of age composition data.	

Qualifying Comments
- Estimates of stock biomass are sensitive to the means of the *q* priors. In addition, when higher CVs were used for the informed acoustic *q* priors, the median estimates of biomass and stock status were slightly higher and the confidence intervals were wider with a much higher upper bound.

Fishery Interactions
Fish bycatch is estimated to make up about 20% of the total catch in this fishery. The main bycatch species are alfonsino, smooth oreo and hoki. Low productivity bycatch species include deepwater sharks, deepsea skates and corals. Observed incidental captures of protected species include corals and very small numbers of seabirds.

6. FOR FURTHER INFORMATION

Anderson, O F (2000) Assessment of the East Cape hills (ORH 2A North) orange roughy fishery for the 2000–01 fishing year. *New Zealand Fisheries Assessment Report 2000/19*. 29 p.

Anderson, O F (2003a) A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2003/21*. 25 p.

Anderson, O F (2003b) CPUE analysis and stock assessment of the East Cape hills (ORH 2A North) orange roughy fishery for 2003. *New Zealand Fisheries Assessment Report 2003/24*. 20 p.

Anderson, O F (2005) CPUE analysis and stock assessment of the South Chatham Rise orange roughy fishery for 2003–04. *New Zealand Fisheries Assessment Report*. 2005/07.

Anderson, O F; Dunn, M R (2007a) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2003–04 fishing year. *New Zealand Fisheries Assessment Report. 2006/20.*

Anderson, O F; Dunn, M R (2007b) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2004–05 fishing year. *New Zealand Fisheries Assessment Report. 2007/29.*

Anderson, O F; Francis, R I C C; Hicks, A C (2002) CPUE analysis and assessment of Mid-East Coast orange roughy stock (ORH 2A South, 2B, 3A). *New Zealand Fisheries Assessment Report 2002/56*. 23 p.

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J (2002) CASAL (C++ algorithmic stock assessment laboratory): CASAL user manual v1.02.2002/10/21. *NIWA Technical Report 117*. 199 p.

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30-2012/03/21. *NIWA Technical Report 135*. 280 p.

Clark, M; Anderson, O; Dunn, M (2003) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2003/60*. 51 p.

Clark, M R; Taylor, P; Anderson, O F; O'Driscoll, R (2002) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2000–01 fishing year. *New Zealand Fisheries Assessment Report. 2002/62*.

Cordue, P L (2012) Fishing intensity metrics for use in overfishing determination. *ICES Journal of Marine Science, 69*: 615–623

Cordue, P.L. (2014). A 2013 stock assessment of Mid-East Coast orange roughy. *New Zealand Fisheries Assessment Report 2014/32*.

Doonan, I J (1994) Life history parameters of orange roughy: estimates for 1994. New Zealand Fisheries Assessment Research Document 1994/19. 13 p. (Unpublished document held by NIWA library, Wellington.)

Doonan, I J; Coburn, R P; Hart, A C (2004a) Acoustic estimates of the abundance of orange roughy for the Mid-East Coast fishery, June 2003. *New Zealand Fisheries Assessment Report 2004/54*. 21 p.

Doonan, I.J.; Dunn, M.R. (2011). Trawl survey of Mid-East Coast orange roughy, March-April 2010. *New Zealand Fisheries Assessment Report 2011/20*.

Doonan, I J; Hicks, A C; Coombs, R F; Hart, A C; Tracey, D (2003) Acoustic estimates of the abundance of orange roughy in the Mid-East Coast fishery, June–July 2001. *New Zealand Fisheries Assessment Report 2003/4*. 22 p.

Doonan, I J; Horn, P L; Krusic-Golub, K (2013) Comparison of age between 1993 and 2010 for mid-east coast orange roughy (ORH 2Asouth, 2B & 3A). *New Zealand Fisheries Assessment Report 2013/44*.

Doonan, I J; Tracey, D M; Grimes, P J (2004b) Relationships between macroscopic staging and microscopic observations of oocyte progression in orange roughy during and after the mid-winter spawning period, Northwest Hills, Chatham Rise, July 2002. *New Zealand Fisheries Assessment Report 2004/6*. 28 p.

Dunn, M R (2005) CPUE analysis and assessment of the Mid-East Coast orange roughy stock (ORH 2A South, 2B, 3A) to the end of the 2002–03 fishing year. *New Zealand Fisheries Assessment Report 2005/18*. 35 p.

Dunn, M; Anderson, O F; McKenzie, A (2005) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2002–03 fishing year. *New Zealand Fisheries Assessment Report. 2005/19*.

Field, K D; Francis, R I C C; Zeldis, J R; Annala, J H (1994) Assessment of the Cape Runaway to Banks Peninsula (ORH 2A, 2B, and 3A) orange roughy fishery for the 1994–1995 fishing year. New Zealand Fisheries Assessment Research Document 1994/20. 24 p. (Unpublished document held by NIWA library, Wellington.)

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27 p. (Unpublished document held by NIWA library, Wellington.)

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences. 68*: 1124–1138.

Francis, R I C C; Clark, M R; Coburn, R P; Field, K D; Grimes, P J (1995) Assessment of the ORH 3B orange roughy fishery for the 1994–95 fishing year. New Zealand Fisheries Assessment Research Document 1995/4. 43 p. (Unpublished document held by NIWA library, Wellington.)

Francis, R I C C; Field, K D (2000) CPUE analysis and assessment of the Mid-East Coast orange roughy stock (ORH 2A South, 2B, 3A). *New Zealand Fisheries Assessment Report 2000/29*. 20 p.

Francis, R I C C; Horn, P L (1997) Transition zone in otoliths of orange roughy (*Hoplostethus atlanticus*) and its relationship to the onset of maturity. *Marine Biology* 129: 681–687.

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1*. 37 p.

Grimes, P (1994) Trawl survey of orange roughy between Cape Runaway and Banks Peninsula, March–April 1992 (TAN9203). *New Zealand Fisheries Data Report 42*. 36 p.

Grimes, P (1996a) Trawl survey of orange roughy between Cape Runaway and Banks Peninsula, March–April 1993 (TAN9303). *New Zealand Fisheries Data Report 76*. 31 p.

Grimes, P (1996b) Trawl survey of orange roughy between Cape Runaway and Banks Peninsula, March–April 1994 (TAN9403). *New Zealand Fisheries Data Report 82*. 31 p.

Hart, A; Doonan, I J; Coombs, R F (2003) Classification of acoustic fish marks for the 2001 Mid-East Coast orange roughy fishery, June–July 2001. *New Zealand Fisheries Assessment Report. 2003/18*.

Kloser, R J; Macaulay, G; Ryan, T; Lewis, M (2011) Improving acoustic species identification and target strength using frequency difference and visual verification: example for a deep-sea fish orange roughy. DWWG 2011-52. (Unpublished report held by the Ministry for Primary Industries, Wellington).

Tracey, D; Ayers, D (2005) Biological data from the orange roughy abundance surveys in the Mid-East Coast fishery. *New Zealand Fisheries Assessment Report. 2005/10*.

Tracey, D; Horn, P; Marriott, P; Krusic-Golub, K; Gren, C; Gili, R; Mieres, L C (2007) Orange Roughy Ageing Workshop: otolith preparation and interpretation. Draft report to DWWG. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Zeldis, J R; Francis, R I C C; Field, K D; Clark, M R; Grimes, P J (1997) Description and analyses of the 1995 orange roughy egg surveys at East Cape and Ritchie Bank (TAN9507), and reanalyses of the 1993 Ritchie Bank egg survey. New Zealand Fisheries Assessment Research Document 1997/28. 34 p. (Unpublished document held by NIWA library, Wellington.)

ORANGE ROUGHY, CHATHAM RISE AND SOUTHERN NEW ZEALAND (ORH 3B)

1. FISHERY SUMMARY

1.1 Commercial fisheries

Orange roughy are found in waters deeper than 750 m throughout Quota Management Area 3B. Historically, the main fishery has been concentrated on the Chatham Rise. Annual reported orange roughy catches in ORH 3B ranged between 24 000–33 000 t in the 1980s, progressively decreased from 1989–90 to 1995–96 because of a series of TACC reductions, were stable over the mid-1990s–mid-2000s and decreased further from 2005–2006 as TACCs were further reduced (Table 1 and Figure 1).

Table 1: Annual reported catches and TACCs of orange roughy from ORH 3B. (Catches from 1978–79 to 1985–86 are from Robertson & Mace 1988) and from 1986–87 to 2013–14 from Fisheries Statistics Unit and Quota Monitoring System data). ‡

Fishing year	Reported catch (t)	TACC (t)	Agreed catch limit (t) *β*
1979–80†	11 800	-	-
1980–81†	31 100	-	-
1981–82†	28 200	23 000	-
1982–83*	32 605	23 000	-
1983–84*	32 535	30 000	-
1984–85	29 340	30 000	-
1985–86	30 075	29 865	-
1986–87	30 689	38 065	-
1987–88	24 214	38 065	-
1988–89	32 785	38 300	-
1989–90	31 669	32 787	-
1990–91	21 521	23 787	-
1991–92	23 269	23 787	-
1992–93	20 048	21 300	-
1993–94	16 960	21 300	-
1994–95	11 891	14 000	-
1995–96	12 501	12 700	-
1996–97	9 278	12 700	-
1997–98	9 638	12 700	-
1998–99	9 372	12 700	-
1999–00	8 663	12 700	-
2000–01	9 274	12 700	-
2001–02	11 325	12 700	-
2002–03	12 333	12 700	-
2003–04	11 254	12 700	-
2004–05	12 370	12 700	-
2005–06	12 554	12 700	-
2006–07	11 271	11 500	-
2007–08	10 291	10 500	-
2008–09	8 758	9 420	-
2009–10	6 662	7 950	-
2010–11	3 486	4 610	3 860
2011–12	2 765	3 600	2 850
2012–13	2 515	3 600	2 850
2013–14	4 492	4 500	-

† Catches for 1979–80 to 1981–82 are for an April–March fishing year.
* Catches for 1982–83 and 1983–84 are 15 month totals to accommodate the change over from an April–March fishing year to an October–September fishing year. The TACC for the interim season, March to September 1983, was 16 125 t.
‡ Catches from 1984–85 onwards are for a 1 October–30 September fishing year.
β Agreed, non-regulatory catch limits between industry and MPI, which includes ‘shelving’ (an agreement that transfers ACE to a third party to effectively reduce the catch without adjusting the TACC).

There have been major changes in the distribution of catch and effort over the history of this fishery (Table 2). Initially, it was confined to the Chatham Rise and, until 1982, most of the catch was taken from areas of relatively flat bottom on the northern slopes of the Rise (in the Spawning Box), between mid-June and mid-August, when the fish form large aggregations for spawning (Figure 2).

From 1983 to 1989 about one third of the catch was taken from the south and east Chatham Rise, where new fishing grounds developed on and around knolls and hill features. Much of the catch from these areas was taken outside the spawning season as the fishery extended to most months of the year.

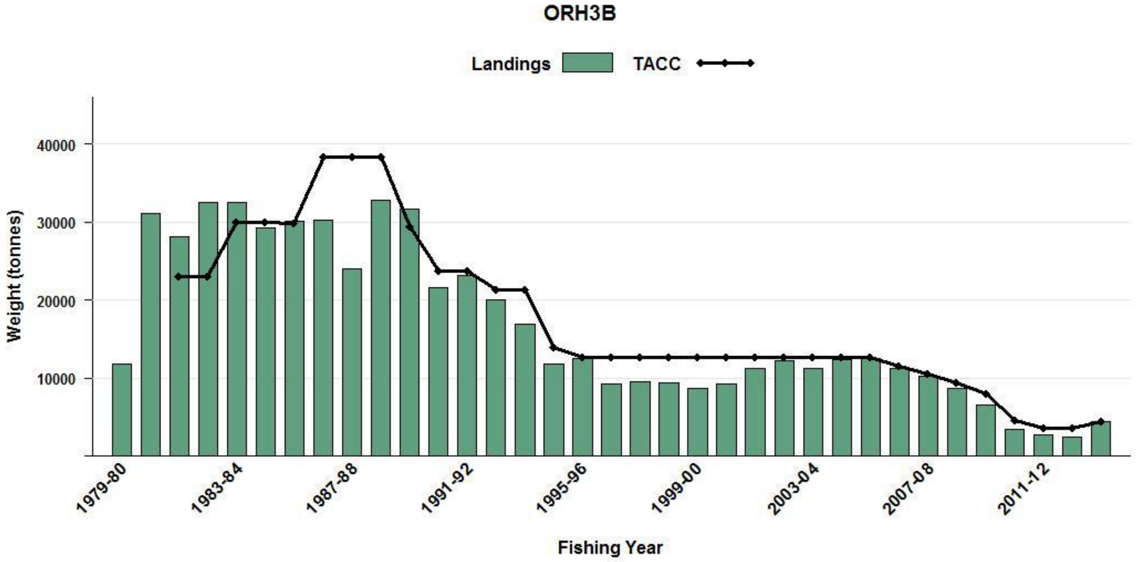


Figure 1: Reported commercial landings and TACCs for ORH 3B. Note that this figure does not show data prior to entry into the QMS.

Table 2: ORH 3B catches by area, to the nearest 10 t or 100 t, and by percentage (to the nearest percent) of the total ORH 3B reported catch. Catches are equivalent to those shown in Table 1, but allocated to area using the ratio of estimated catches, and revised such that all years are from 1 October–30 September. Note that catches for the East Rise are given by the sum of Spawning Box and Rest of East Rise.

Year	Northwest Rise		South Rise		Spawning box		Rest of East Rise		Non-Chatham	
	t	%	t	%	t	%	t	%	t	%
1978–79	0	0	0	0	11 500	98	300	2	0	0
1979–80	1 200	4	800	3	27 900	90	1 200	4	0	0
1980–81	8 400	30	3 700	13	16 000	57	100	0	0	0
1981–82	7 000	28	500	2	16 600	67	800	3	0	0
1982–83	5 400	35	4 800	31	4 600	30	600	4	0	0
1983–84	3 300	13	5 100	21	15 000	61	1 500	6	0	0
1984–85	1 800	6	7 900	27	18 400	63	1 100	4	0	0
1985–86	3 700	12	5 300	18	17 000	56	4 100	13	0	0
1986–87	3 200	10	4 900	16	20 200	66	2 400	8	0	0
1987–88	1 600	7	6 800	28	13 500	56	2 300	10	0	0
1988–89	3 800	12	9 200	28	16 700	51	3 100	9	0	0
1989–90	3 300	10	11 000	35	16 200	51	1 100	3	200	1
1990–91	1 500	7	6 900	32	6 100	28	6 100	29	900	4
1991–92	300	1	2 200	9	1 000	4	12 000	51	7 800	34
1992–93	3 800	19	5 400	27	100	0	4 700	23	6 100	30
1993–94	3 500	21	5 100	30	0	0	4 900	29	3 500	20
1994–95	2 400	20	1 600	13	500	5	3 500	30	3 800	32
1995–96	2 400	19	1 300	10	1 600	13	2 200	17	5 000	40
1996–97	2 200	24	1 400	15	1 700	19	1 900	21	1 900	21
1997–98	2 300	23	1 700	17	2 400	24	2 200	22	1 600	16
1998–99	2 700	28	1 200	13	1 100	11	2 500	27	1 900	21
1999–00	2 100	24	1 100	13	1 500	17	3 100	36	800	9
2000–01	2 600	27	1 700	18	1 200	13	2 300	24	1 500	17
2001–02	2 200	19	1 100	10	3 100	28	3 600	31	1 300	12
2002–03	2 200	19	1 500	13	3 200	27	3 900	33	1 500	7
2003–04	2 000	18	1 400	12	4 300	38	2 600	23	1 000	9
2004–05	1 600	13	1 700	14	4 100	33	3 000	24	2 000	16
2005–06	1 400	11	1 300	10	3 900	31	3 900	31	2 100	16
2006–07	700	7	1 200	11	4 200	37	3 700	32	1 500	16
2007–08	800	8	1 300	13	3 800	37	2 700	26	1 600	16
2008–09	750	8	1 170	14	3 400	39	2 150	25	1 290	15
2009–10	720	11	940	14	3 120	47	1 260	19	620	9
2010–11	40	1	460	13	1 860	53	740	21	380	11
2011–12	70	3	300	11	1 520	55	770	28	100	3
2012–13	110	4	290	12	1 450	58	590	24	70	3
2013-14										

In the early 1990s, effort within the Chatham Rise further shifted from the Spawning Box to eastern and northwestern parts of the Rise. The Spawning Box was closed to fishing from 1992–93 to 1994–95. In more recent years, catches from the main fishing grounds on the Chatham Rise have declined due to TACC reductions.

The early 1990s also saw the Puysegur fishery develop, followed by other fishing grounds near the Auckland Islands and on the Pukaki Rise, which was also a focus for the fishery south of the Chatham Rise.

Since 1992–93, the distribution of the catch within ORH 3B has been affected by a series of catch-limit agreements between the fishing industry and the Minister responsible for fisheries. Initially, the agreement was that at least 5000 t be caught south of 46° S. Subsequently, the catch limits, and the designated sub-areas to which they apply, have changed from year to year.

The TACC was reduced to 3600 t in 2011–12 (Table 1). The agreed catch limit for the East and South Chatham Rise is currently 3100 t (Table 3). A three-year staged process to reduce F to F_{MSY} was initiated on 1 October 2008. Under this approach, the catch limit was to be set at 4.5% ($F_{MSY} = M$) of the estimated current biomass in each year from 1 October 2010. However, for 2013–14 the TACC was increased to 4500 t (Table 1) in response to the increased biomass estimates following the discovery of the Rekohu plume.

The catch limit for the Sub-Antarctic has been substantially undercaught since 2009–10. However, the combined East and South Rise sub-area catch limits were exceeded by 450 t in 2005–06 and by 350 t in 2006–07 (100 t were taken against the allowance for research surveys). Taking the research allowance into account, catch limits for the combined east and south Rise sub-area have not been exceeded in subsequent years. Since 2004–05, 250 t of the ORH 3B TACC has been set aside for industry research surveys (Table 3), although this has sometimes been used in areas outside the East and South Chatham Rise.

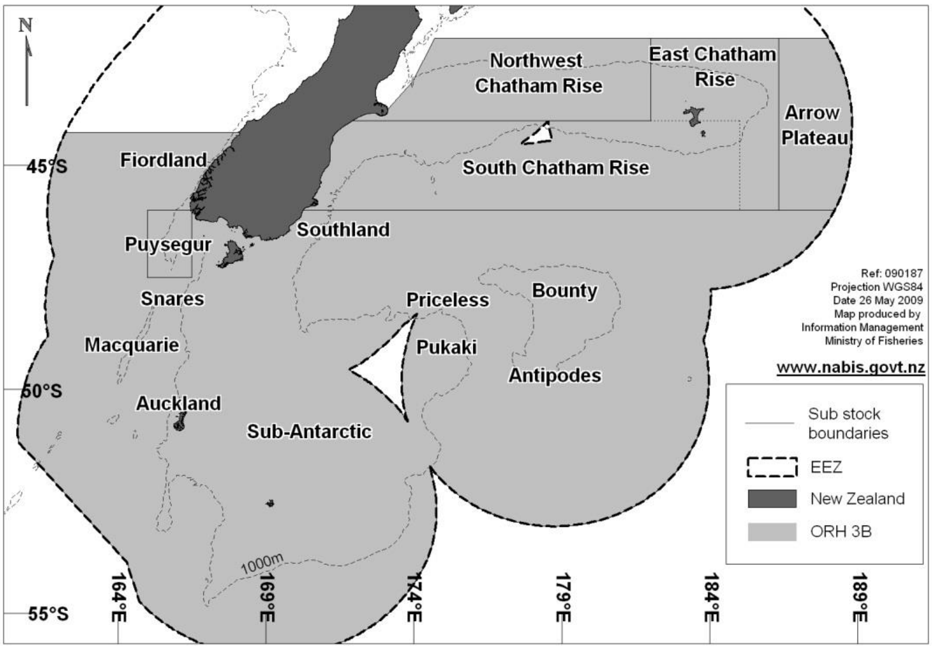


Figure 2: ORH 3B sub-areas and the approximate position of other named fisheries outside of the Chatham Rise. The Spawning Box is in the western part of the East Rise (to the west of the vertical broken line at 175°W). The East and South Rise are currently managed as a single unit. The Arrow Plateau has been designated a Benthic Protected Area. The Sub-Antarctic is all areas below 46°S on the east coast, and 44°16’S on the west coast, except Puysegur.

Table 3: Catch limits (t) by designated sub-area within ORH 3B, as agreed between the industry and the Ministers responsible for fisheries since 1992–93. Note that East Rise includes the Spawning Box, closed between 1992–93 and 1994–95. Sub-area boundaries have varied somewhat between years. * South Rise included in East Rise catch limit. ** Arrow Plateau included in Sub-Antarctic.

Year	Northwest Chatham Rise	East Chatham Rise	South Chatham Rise	Puysegur	Arrow Plateau	Sub-Antarctic
1992–93	3 500	4 500	6 300	5 000	-	2 000
1993–94	3 500	4 500	6 300	5 000	-	2 000
1994–95	2 500	3 500	2 000	2 000	3 000	1 000
1995–96	2 250	4 950	*	1 000	**	4 500
1996–97	2 250	4 950	*	500	**	5 000
1997–98	2 250	4 950	*	0	1 500	4 000
1998–99	2 250	4 950	*	0	1 500	4 000
1999–00	2 250	4 950	*	0	1 500	4 000
2000–01	2 250	4 950	*	0	1 500	4 000
2001–02	2 000	7 000	1 400	0	1 000	1 300
2002–03	2 000	7 000	1 400	0	1 000	1 300
2003–04	2 000	7 000	1 400	0	1 000	1 300
2004–05†	1 500	7 250	1 400	0	1 000	1 300
2005–06†	1 500	7 250	1 400	0†	1 000	1 300
2006–07	750	8 650‡	*	0	0	1 850
2007–08†	750	7 650#	*	0	0	1 850
2008–09†	750	6 570§	*	0	0	1 850
2009–10†	750	5 100	*	0	0	1 850
2010–11	750*β*	2 960†	*	150	0	500
2011–12	750*β*	1 950†	*	150	0	500
2012–13	750 *β*	1 950†	*	150	0	500
2013–14	750	3 100	*	150	0	500

† an additional 250 t set aside for industry research surveys.
‡ 8650 t allocated to the East and South Chatham Rise combined, with no more than 2000 t from the South Rise, and no more than 7250 t from the East Rise.
# Combined East and South Rise catch not to exceed 7650 t; East Rise not to exceed 6500 t; South Rise catch not to exceed 1750 t.
§ In 2008–09, the catch from the spawning plume was not to exceed 3285 t.
β From 2010–11 to 2012–13, quota owners have agreed to avoid fishing the Northwest Rise.

Outside the Spawning Box, catches increased in the 1990s and catch rates have been highly variable, sustained largely by the discovery of new fishing areas. Flat areas on the Northwest Rise and several major hills on the South Rise were important in the late 1980s, but currently do not support their previous levels of catch, now accounting for less than 5% of the estimated catch. High catch rates can still occur, but these are less frequent than observed in the early years of the fishery. Catches from the Northwest Rise fell to near zero in 2010–11 as a result of an agreement among quota owners to avoid fishing in this area (Table 2). This agreement was extended to the 2011–12 and 2012–13 fishing years.

Between 1991–92 and 2000–01, more than half of the Chatham Rise catch came from four hill complexes: the Andes, Smith City and neighbours, Graveyard, and Big Chief and neighbours. All of these have shown a decline in unstandardised catch rate since the early years of the fishery, and in recent years, catch rates in these hill complexes have remained relatively low. After 2000–01, the proportion of the catch from these hill complexes decreased, as a greater proportion of the catch came from the Spawning Box (about 39% in 2008–09). In addition, large catches have been made in recent years outside of the spawning season, in recently developed areas of the southeast Rise. Catches from the Spawning Box taken during the spawning season (which peaks in July) have been relatively high since 2001–02, although unstandardised catch rates have been variable.

The first fishery to be developed south of the Chatham Rise was on Puysegur Bank, where spawning aggregations of orange roughy were found during a joint Industry-Ministry exploratory fishing survey in 1990–91. The fishery developed rapidly, but from 1993–94 catch limits were substantially under-caught. Catch limits were subsequently reduced from the initial level of 5000 t, and the industry implemented a catch limit of 0 t beginning in the 1997–98 fishing year (reported catches in 2004–05 and 2005–06 were taken during industry surveys). No fishing in this area occurred in 2010–11 in spite of an increase in the catch limit to 150 t (Table 3).

Exploratory fishing on the Macquarie Ridge south of Puysegur in 1993 led to the development of a fishery off the Auckland Islands. Total catch rose to around 900 t in 1994–95, but then dropped to less than 200 t by 1999–00, and catches have since been infrequent.
In 1993–94, catches were taken on the 'Arrow Plateau', and became the first major fishery to develop on the easternmost section of the Chatham Rise. A catch limit of 3000 t was put in place for 1994–95, with an additional limit of 500 t for each hill. Only a few hills in this area have been fished successfully, and the catch has never reached the catch limit, which was reduced to 1000 t by the early 2000s (Table 3). The Arrow Plateau was closed to orange roughy fishing when it was designated a Benthic Protected Area in 2007.

In 1995–96, large catches were reported on the southeast Pukaki Rise, with a catch total of over 3000 t. However, the catches dropped rapidly and the fishery effectively ceased within a few years. From 2001–02, a fishery developed on the northeast Pukaki Rise, including the area known as Priceless, where catches were mostly taken at the start of the fishing year. Catches at Priceless reached the feature limit of 500 t for each of the six years up to 2006–07, but catches and catch rates declined substantially from 2007–08, and have remained low since. Areas of the northeast Pukaki Rise outside of Priceless were developed in 2004–05 and also showed a rapid decline in catches and catch rates. By 2007–08, the fishery in the sub-Antarctic was limited to the Auckland Islands and northeast Pukaki Rise areas. Since 2008–09, the fishery has extended over a relatively wide area, but catches and catch rates have been low.

Catches of orange roughy have also been taken off the Bounty Islands (around 100–200 t per year from 1997–98 to 2004–05, but infrequently since then), off the Snares Islands (up to around 500 t per year, but infrequently in recent years), areas of the Macquarie Ridge (100–500 t per year from 2000–01 to 2004–05, and in 2008–09), and off Fiordland (around 500 t in 2000–01, but subsequent catches rapidly decreased).

1.2 Recreational fisheries
No recreational fishing for orange roughy is known in this quota management area.

1.3 Customary non-commercial fisheries
No customary non-commercial fishing for orange roughy is known in this quota management area.

1.4 Illegal catch
No information is available on illegal catch in this quota management area.

1.5 Other sources of mortality
There has been a history of catch overruns on the Chatham Rise because of lost fish and discards, and discrepancies in tray weights and conversion factors. In assessments, total removals from each part of the Chatham Rise were assumed to exceed reported catches by the overrun percentages in Table 4.

Table 4: Catch overruns (%) by year.

Year	1978–79	1979–80	1980–81	1981–82	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88
Overrun	30	30	30	30	30	30	30	28	26	24

Year	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95 and subsequently
Overrun	22	20	15	10	10	10	5

For Puysegur and other southern fisheries there is no reason to believe that, if there was an overrun in catches, this shows any trend over time. For this reason, it was assumed that there was no overrun for this area.

Within the TAC an allowance of 5% of the TACC is allocated for other sources of mortality (currently 225 t).

2. BIOLOGY

Biological parameters used in this assessment are presented in the Biology section at the beginning of the Orange Roughy section.

3. STOCKS AND AREAS

For the purposes of this report the term "stock" refers to a biological unit with a single major spawning ground, in contrast to a "Fishstock" which refers to a management unit.

Genetically two main stocks are recognised within ORH 3B (Chatham Rise and Puysegur; Smith & Benson 1997) and these are considered to be distinct from stocks in adjacent areas (Cook Canyon and Ritchie Bank). However, it is likely, because of their geographical separation and discontinuities in the distribution of orange roughy, that concentrations of spawning fish on the Arrow Plateau, near the Auckland Islands, and west of the Antipodes Islands also form separate stocks.

Genetic data have been applied to define stock boundaries, both within ORH 3B, and between it and adjacent areas. Mitochondrial DNA shows that there are considerable differences between Puysegur fish and fish from the geographically adjacent areas Cook Canyon and Chatham Rise. Allozyme frequency studies suggest that Chatham Rise fish are distinct from those on the Ritchie Bank (ORH 2A). These data also suggest multiple stocks within the Chatham Rise, but do not indicate clear stock boundaries. Although there is significant heterogeneity amongst allozyme frequencies from different areas of the Rise, these frequencies varied as much in time (samples from the same location at different times) as in space (samples from different locations at the same time).

Chatham Rise
The stock structure of orange roughy on the Chatham Rise was comprehensively reviewed in 2008 (Dunn & Devine 2010). This review evaluated all available data as no single dataset seemed to provide definitive information about likely stock boundaries. The data analysed included: catch distribution and CPUE patterns; location of spawning and nursery grounds; inferred migrations; size, maturity and condition data; genetic studies, and habitat and natural boundaries.

There is evidence that a separate stock exists on the Northwest Rise. The Northwest Rise contains a large spawning ground on the Graveyard Hills, and also nursery grounds around, and primarily to the west of, the Graveyard Hills. There is a gap in the distribution of early juveniles (under 15 cm SL) between the Graveyard area and the Spawning Box at approximately 178°W. A research trawl survey found post-spawning adult fish to the west, but not to the east, of the Graveyard Hills, and a westerly post-spawning migration was inferred. Analyses of median length from commercial and research trawls found that orange roughy on the Northwest Chatham Rise and Graveyard Hills were smaller than those on the East Rise. A substantial decline in the size of 50% maturity after 1992 was found for both the Graveyard Hills and the Northwest Rise, but not for other areas. The only information that does not support the Northwest Rise being a separate stock is an indication from patterns in commercial catch rates that some fish arriving to spawn in the Spawning Box may come from the west (Coburn & Doonan 1994, 1997). Catch data and genetic studies do not shed any further light on stock structure. Oceanographic models suggest that a gyre to the east of the Graveyard may provide a mechanism for a separation between the Northwest Chatham Rise and the East Rise. Based on the available data, the Northwest Chatham Rise is considered to be a separate stock.

The separation of the Northeast Hills and Andes as separate stocks from the Spawning Box and Eastern Flats was based on observations of simultaneous spawning aggregations occurring on these hills, and because stock assessment models indicated a mismatch between the standardised CPUE trends. On the other hand, the occurrence of a continuous nursery ground throughout the area; similar trends in size of 50% maturity in each area; the essentially continuous habitat with similar environmental conditions and inferred post-spawning migrations from the Spawning Box towards the east Rise all suggest that all of these areas are a single stock. Analyses of median lengths from commercial catches showed no obvious differences between areas. In addition, the spawning aggregations found on the Northeast Hills and Andes appear to have been minor compared to that in the Spawning Box. The spawning aggregation on the Northeast Hills is also associated with an increase in mean length and catch rates, suggesting that fish spawning on these hills are not resident, and thus are not separate from the surrounding area. Based on the available data the Northeast Hills and Andes are therefore considered to be from the same stock as the Spawning Box and Eastern Flats.

The only evidence to separate the eastern area of the South Rise (Big Chief and surrounds) from the East Rise is the lack of spawning migrations inferred from an absence of a seasonal effect in standardised CPUE analyses. The evidence that the Big Chief area is the same stock as the East Rise includes the fact that the nursery grounds and habitat are continuous; there were no splits between the areas identified from analyses of median length; and the fisheries are similar. The reports of spawning fish around Big Chief have been infrequent, and so are considered equivocal on stock structure. The Big Chief area is therefore considered part of the East Rise stock.

There is weak evidence that the area of the South Rise west of and including Hegerville is a separate stock. The evidence includes median length analyses which indicated a split in this area, and an oceanographic front at 177°W. However, very few catches of spawning orange roughy have been reported in this area, and there appears to be no substantial nursery ground. Both of these factors support the idea that this area does not have a separate stock. In the area to the west of the suggested split the fish are relatively small during spawning, and relatively large during non-spawning. Combined with a standardised CPUE which shows a decline in abundance around July (peak spawning), and a somatic condition factor which declines during September–November (post-spawning), this supports a hypothesis of adult fish leaving the area to spawn elsewhere.

The South Rise could provide feeding habitat for the stock, which is estimated to have had an initial biomass of over 300 000 t, an amount that was probably too large to inhabit only the East Rise. There is more evidence to support orange roughy in this area being part of the East Rise stock than there is to the contrary. The current hypothesis is that the area to the west of the current convergence may be relatively marginal habitat, where larger juvenile, maturing and adult orange roughy were once predominant, and there is little spawning and few juveniles because the water is relatively cold.

Based on these analyses, the Chatham Rise has been divided into two areas: the Northwest, and the East and South Rise combined (Figure 2). The centre of the Northwest stock is the Graveyard Hills. The centre of the East and South Rise stock is the Spawning Box during spawning, and the southeast corner of the Rise during non-spawning.

4. STOCK ASSESSMENT

No model-based stock assessments were conducted for ORH 3B stocks from 2007 to 2013 inclusive. This was primarily because the 2006 stock assessment, which assumed deterministic recruitment, showed an increasing trend in biomass which was not supported by recent biomass indices. Deterministic recruitment was assumed because ageing data were considered to be unreliable. With the successful assessment of the MEC stock in 2013, which used age data from the new ageing methodology (Tracey et al. 2007), there has been a return to model-based assessment in 2014. In addition to an update of the MEC stock assessment, three further stocks have also been assessed, including two stocks in ORH 3B (the Northwest Chatham Rise, the East and South Chatham Rise). There are no other reliable assessments for stocks within ORH 3B. Recruitment in all of these assessments has been derived from limited age data.

4.1 Northwest Chatham Rise

A Bayesian stock assessment was conducted for the Northwest Chatham Rise (NWCR) stock in 2014. This used age-structured population model fitted to acoustic-survey estimates of spawning biomass, a trawl-survey estimate of proportion-at-age and proportion-spawning-at-age, and a limited number of length frequencies from the commercial fishery.

4.1.1 Model structure

The model was single-sex and age-structured (1-100 years with a plus group), with maturity estimated separately (i.e., fish were classified by age and as mature or immature). A single-time step was used and the single fishery was assumed to be year-round on mature fish. Spawning was taken to occur after 75% of the mortality and 100% of mature fish were assumed to spawn each year.

The catch history was constructed from the Northwest catches in Table 2 using the catch over-run percentages in Table 4. Natural mortality was assumed to be fixed at 0.045 and the stock-recruitment relationship was assumed to follow a Beverton-Holt function with steepness of 0.75. The remaining fixed biological parameters are given in Table 2 of the Orange Roughy Introduction section.

4.1.2 Input data and statistical assumptions

There were three main data sources for observations fitted in the assessment: acoustic-survey spawning biomass estimates from the main spawning hills (Graveyard and Morgue); an age frequency and an estimate of proportion-spawning-at-age taken from a 1994 wide-area trawl survey; and length frequencies collected from the commercial fishery from 1989–2005.

Acoustic estimates

Three types of acoustic-survey estimates were available for use in the assessment: AOS estimates (from a multi-frequency towed system, e.g., see Kloser et al. 2011); 38 kHz estimates from a towed-body system; and 38 kHz estimates from a hull-mounted system. The reliability of the data from the different systems in each year was considered and estimates from the AOS and towed-body systems were used in the base model (Table 5). An alternative treatment of the available acoustic data was to include additional survey estimates from 2002 and 2004 (Table 5). All of the data in Table 5 were used in the sensitivity run labelled “Extra acoustics”.

Table 5: Acoustic survey estimates of spawning biomass used in the base model (excludes 2002 and 2004) and the sensitivity run “Extra acoustics” (uses all data). “GY” = Graveyard, “M” = Morgue, “O” = other hills. The CVs are those used in the model and do not include any process error.

Year	System	Frequency	Areas	Snapshots	Estimate (t)	CV (%)
1999	Towed-body	38 kHz	GY+M+O	1	8126	22
2002	Towed-body	38 kHz	GY+O	2	9414	20
2004	Hill-mounted	38 kHz	GY	6	2717	16
2012	AOS	38 kHz	GY	3	5550	17
	AOS	38 kHz	M	4	9087	11
2013	AOS	120 kHz	GY	1	7379	31

The acoustic estimates in 1999 and 2012 (total = 14 637 t, CV 17%) were assumed to represent “most” of the spawning biomass in each year. This was modelled by treating the acoustic estimates as relative biomass and estimating the proportionality constant (*q*) with an informed prior. The prior was normally distributed with a mean of 0.8 (i.e., “most” = 80%) and a CV of 19% (see orange roughy Introduction). The 2013 Graveyard estimate was modelled as relative biomass with an informed prior on the *q* with a mean of 0.3 (derived from the relative proportions of the Graveyard and Morgue estimates in 2012 with the 80% assumption).

Trawl survey data

A wide-area trawl survey of the northwest flats was conducted in late May and early June of 1994 (72 stations; Tracey and Fenaughty 1997). An age-frequency for the trawl-selected biomass was estimated using 300 otoliths selected using the method of Doonan et al (2013). The female proportion spawning-at-age was also estimated. These data were fitted in the model: age frequency (multinomial with an effective sample size of 60); proportion-spawning-at-age (binomial with effective sample size at each age equal to the number of female otoliths at age).

Length frequencies

The length frequencies from the previous assessment in 2006 were used: nine years of length-frequency data from the period 1989-97 were combined into a single length-frequency that was centred on the 1993 fishing year. Eight years of length-frequency data from the period 1998-2005 were combined into a single length-frequency that was centred on the 2002 fishing year. The effective sample size was set at 1/6 of the number of tows for each period: 19 for the "1993" period and 35 for the "2002" period (A. Hicks pers. comm.). The data were assumed to be multinomial.

4.1.3 Model runs and results

In the base model, the acoustic estimates from 1999, 2012, and 2013 were used and natural mortality (*M*) was fixed at 0.045. There were five main sensitivity runs: estimate *M*; add the extra acoustic data and fix *M*; add the extra acoustic data and estimate *M*; and the LowM-Highq and HighM-Lowq "standard" runs (see orange roughy Introduction).

In the base model, the main parameters estimated were: virgin (unfished, equilibrium) biomass (B_0), maturity ogive, trawl-survey selectivity, CV of length-at-mean-length-at-age for ages 1 and 100 years (linear relationship assumed for intermediate ages), and year class strengths (YCS) from 1940 to 1979 (with the Haist parameterisation and "nearly uniform" priors on the free parameters).

Model diagnostics

The model provided good MPD fits to the data (Figures 3 & 4). The acoustic indices, free to "move" somewhat as they are relative, were very well fitted with the normalised residuals close to zero except in 2013 (Figure 3, top right). The estimated acoustic *q*s were not very different from the mean of the informed priors (Figure 3, bottom). The same is not quite true for the MCMCs, because, although the posteriors for the acoustic *q*s are not very different from the priors, there has clearly been some movement (Figure 5).

Numerous MPD sensitivity runs were performed. These showed that the main drivers of the estimated stock status were natural mortality (*M*) and the means of the acoustic *q* priors (lower *M* and higher mean *q* give lower stock status; higher *M* and lower mean *q* give higher stock status).

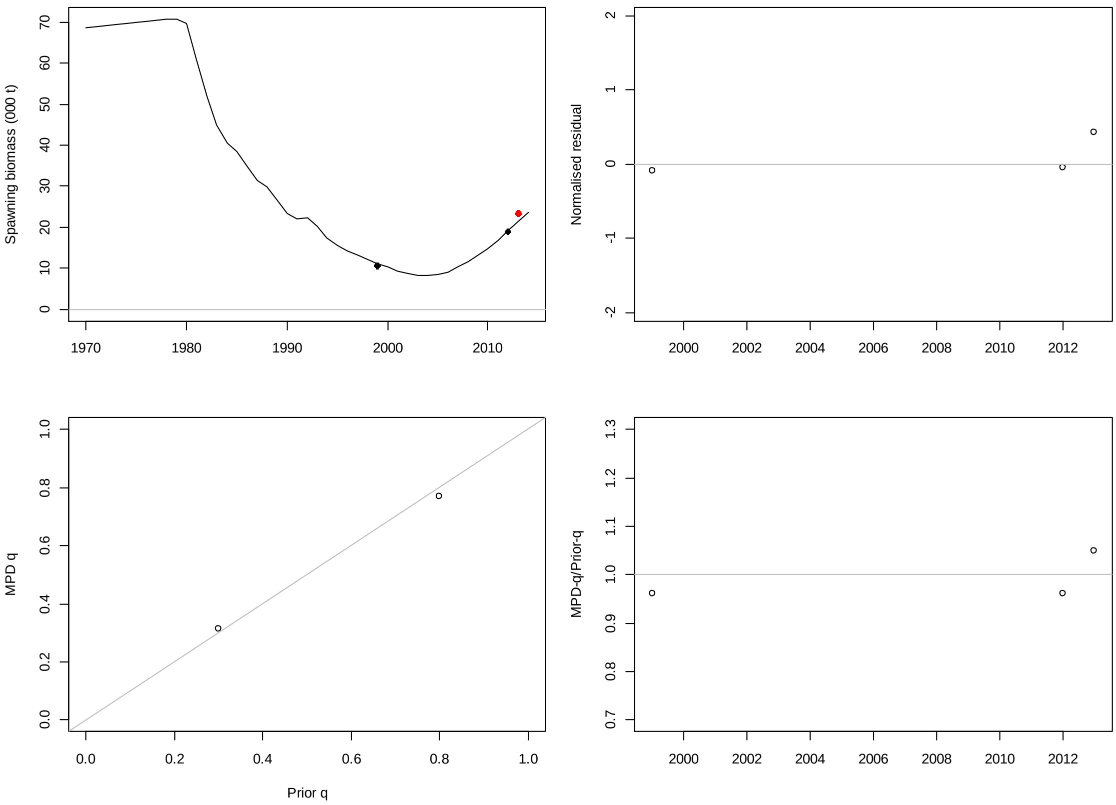


Figure 3: NWCR, base, MPD: fits to the acoustic indices: (top) spawning biomass trajectory and unscaled acoustic indices; normalised residuals; (bottom) estimated *q*s as a function of the mean of the *q* prior; the ratio of the estimated *q* to the mean of the *q* prior.

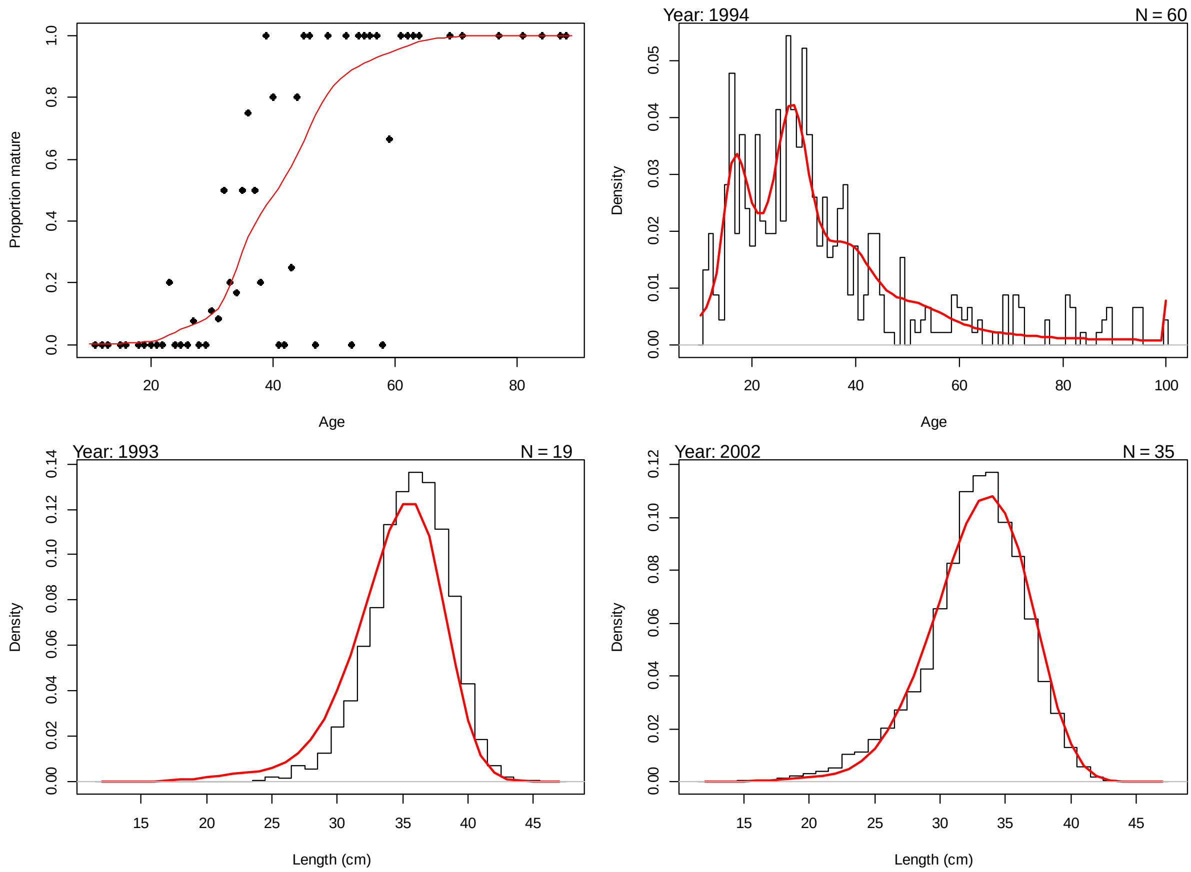


Figure 4: NWCR, base, MPD fits: (observations in black; predictions in red): (top) proportion mature at age; trawl survey age frequency ; (bottom) commercial length frequencies (N is the effective sample size).

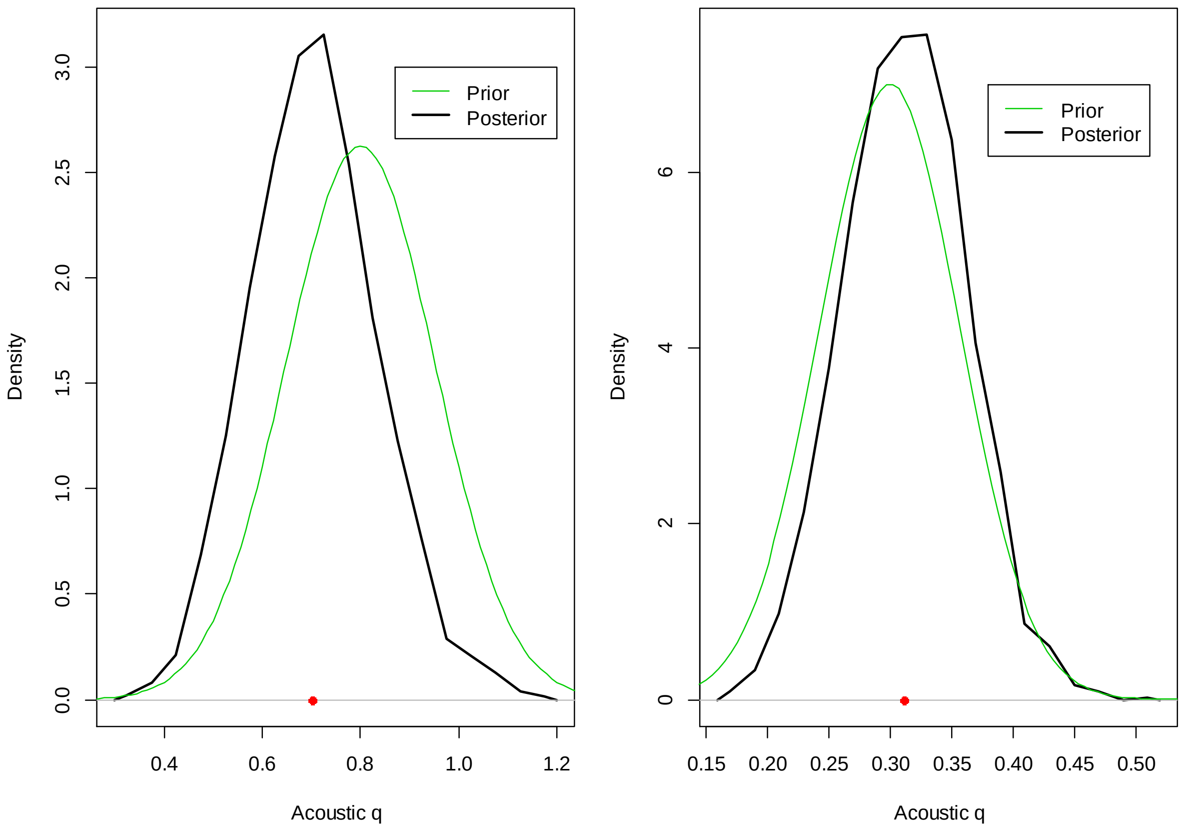


Figure 5: NWCR base, MCMC diagnostics: prior and posterior distributions for the two acoustic *q*s (left, mean *q*-prior = 0.8; right, mean q-prior = 0.3). The red dot shows the median of the posterior.

MCMC Results

For the base model, and the sensitivity runs, MCMC convergence diagnostics were excellent. Virgin biomass, B_0, was estimated to be between 64 000–68 000 t for all runs (Table 6). Current stock status was similar across the base and the first three sensitivity runs (Table 6). The slightly lower stock status when *M* was estimated reflects the lower estimates of *M* (0.040 rather than 0.045). For the two "bounding" runs, where *M* and the mean of the acoustic *q* priors were shifted by 20%, median current stock status was estimated outside of the biomass target range of 30–40% B_0 for both runs (Table 6).

Table 6: NWCR, MCMC estimates of virgin biomass (B_0) and stock status (B_{2014} as %B_0) for the base model and five sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2014} (%B_0)	95% CI
Base	0.045	66	61-76	37	30-46
Extra acoustics	0.045	64	60-69	34	29-41
Estimate M	0.041	68	61-78	34	26-45
Extra & Est. M	0.040	67	60-74	32	25-40
LowM-Highq	0.036	68	64-76	28	23-36
HighM-Lowq	0.054	66	59-78	46	38-56

For the base model, the stock is now considered to be fully rebuilt according to the Harvest Strategy Standard (at least a 70% probability that the lower end of the management target range of 30–40% B_0 has been achieved).

The estimated YCS showed little variation across cohorts (Figure 6). The variation in the more recent (true) YCS is due to variation in depletion levels across the MCMC samples (and hence different levels of recruitment were generated from the stock-recruitment function).

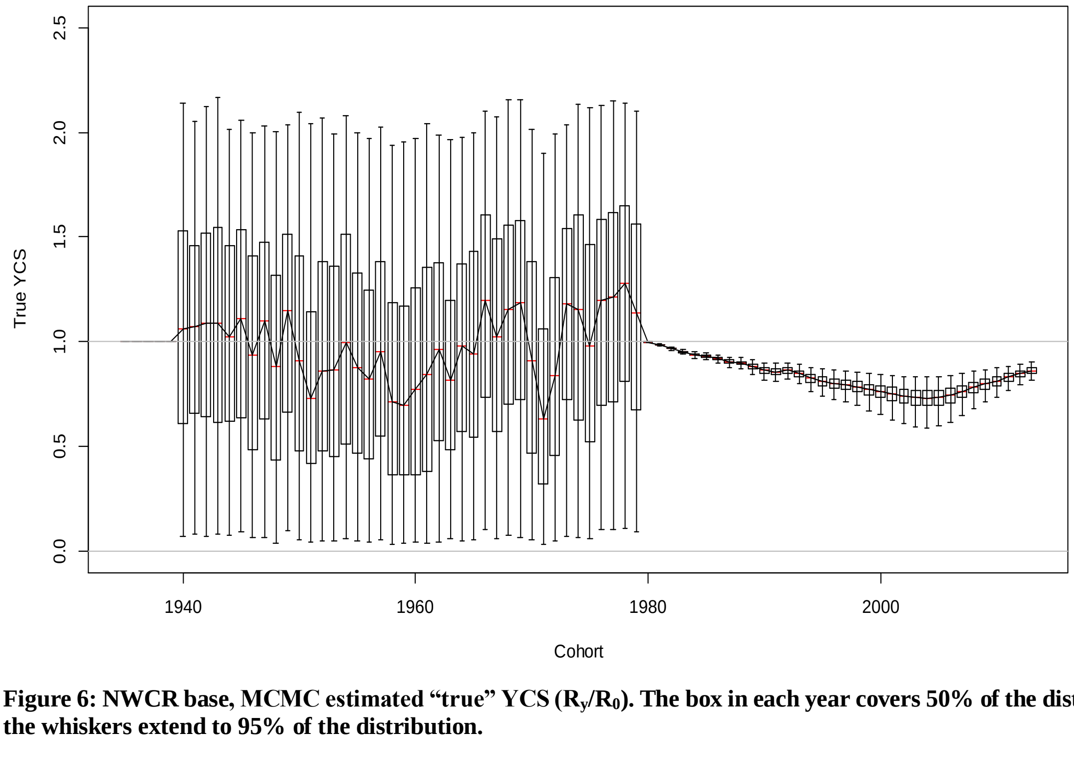


Figure 6: NWCR base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The estimated spawning-stock biomass (SSB) trajectory showed a declining trend from 1980 (when the fishery started) through to 2004 when the biomass was About as Likely as Not (40-60%) to be below the soft limit (Figure 7). Since 2005 the estimated biomass has increased steadily.

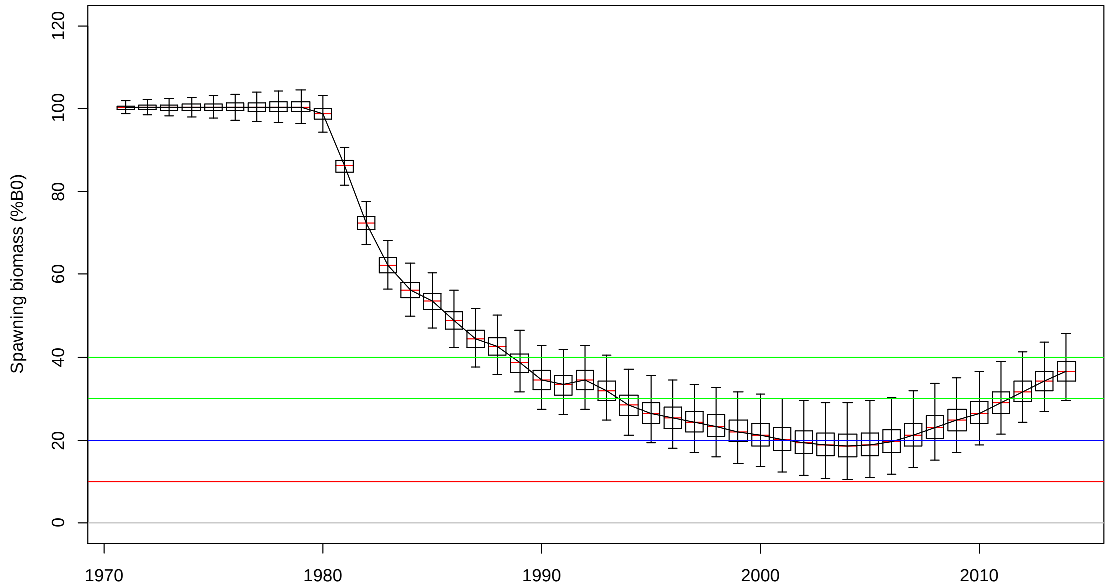


Figure 7: NWCR base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit (red), soft limit (blue), and biomass target range (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity by year. Fishing intensity is represented in term of the median exploitation rate and the Equilibrium Stock Depletion (ESD). For the latter, a fishing intensity of $U_{x\%B0}$ means that fishing (forever) at that intensity will cause the SSB to reach deterministic equilibrium at x% B_0 (e.g., fishing at $U_{30\%B0}$ forces the SSB to a deterministic equilibrium of 30% B_0). Fishing intensity in these units is plotted as 100–ESD so that fishing intensity ranges from 0 ($U_{100\%B0}$) up to 100 ($U_{0\%B0}$).

Estimated fishing intensity was above $U_{20\%B0}$ for most of the history of the fishery; it was briefly in the target range ($U_{30\%B0}$–$U_{40\%B0}$) from 2006-2010 before dropping substantially when the industry agreed to curtail fishing the NWCR in 2011 (Figure 8).

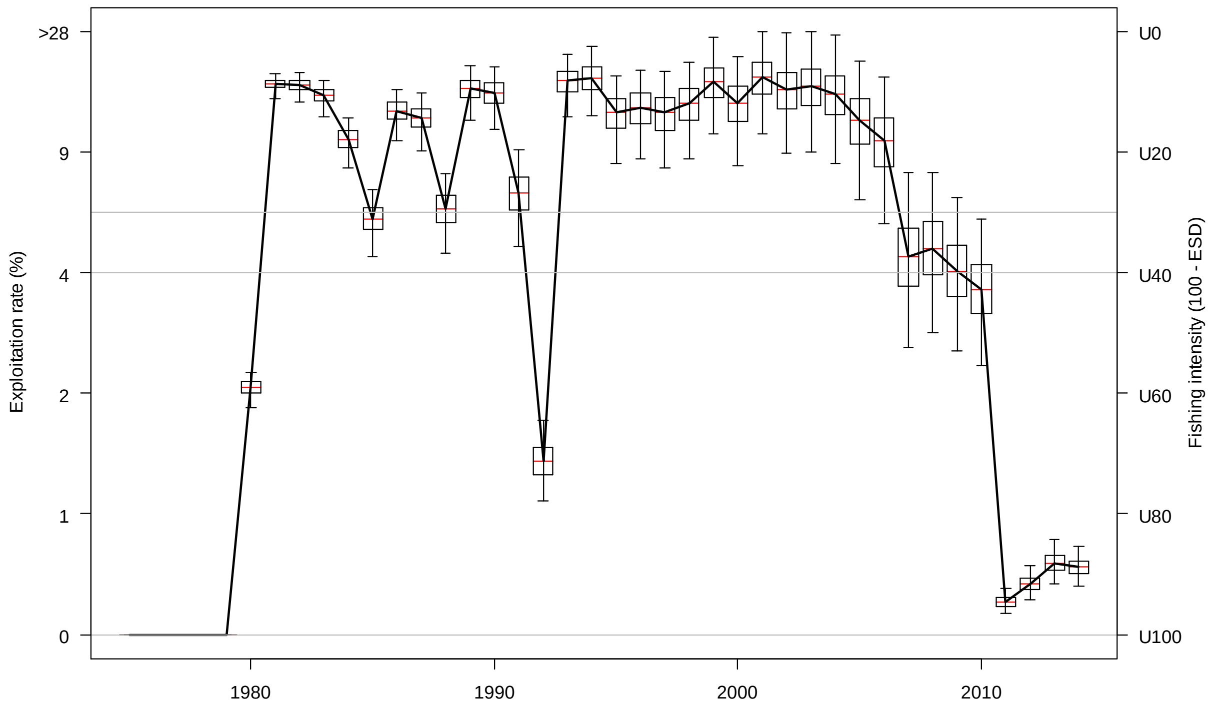


Figure 8: NWCR base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30-40% B_0 is marked by horizontal lines.

Biological reference points, management targets and yield MCMC estimates of deterministic B_{MSY} and associated values were produced for the base model. The yield at 35% B_0 (the mid-point of the target range) was also estimated. There is very little variation in the reference points and associated values across the MCMC samples (Table 7).

There are several reasons why deterministic B_{MSY} is not a suitable target for use in fisheries management. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge (current biomass must be known exactly in order to calculate the target catch) and annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders). Second, it assumes perfect knowledge of the stock-recruit relationship, which is often poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard.

Table 7 : NWCR base, MCMC estimates of deterministic equilibrium SSB and long-term yield (% B_0 and tonnes) for U_{MSY} and $U_{35\%B0}$. The equilibrium SSB at U_{MSY} is deterministic B_{MSY} and the yield is deterministic MSY.

Fishing intensity		SSB (%B_0)	Yield (%B_0)	Yield t)
U_{MSY}	Median	23.7	2.1	1391
	95% CI	23.2-24.7	2.0-2.2	1277–1593
$U_{35\%B0}$	Median	35.0	2.0	1322
	95% CI		1.9-2.1	1214–1512

The estimate of yield associated with $U_{35\%B0}$ for the 2014-15 fishing year is 1414 t (95% CI 1069-1984 t).

Projections

Five year projections were conducted (with resampling from the last 10 estimated YCS) for two different constant catch assumptions: 750 t (the current catch limit); and 1400 t (the current estimated yield at $U_{35\%B0}$). In each case a 5% over-run was assumed. Projections were done for the base model and also for the LowM-Highq model (as a “worst case” scenario).

At the current catch limit (750 t), SSB is predicted to increase over the next five years even for the LowM-Highq model (Figure 9). At the catch associated with $U_{35\%B0}$ (1400 t), SSB is predicted to rise slightly and then stay steady for both models (Figure 10). For both models and both constant catch scenarios, the estimated probability of SSB going below the soft or hard limits is virtually zero (the maximum is 0.01 for the soft limit in the latter years for LowM-Highq at 1400 t).

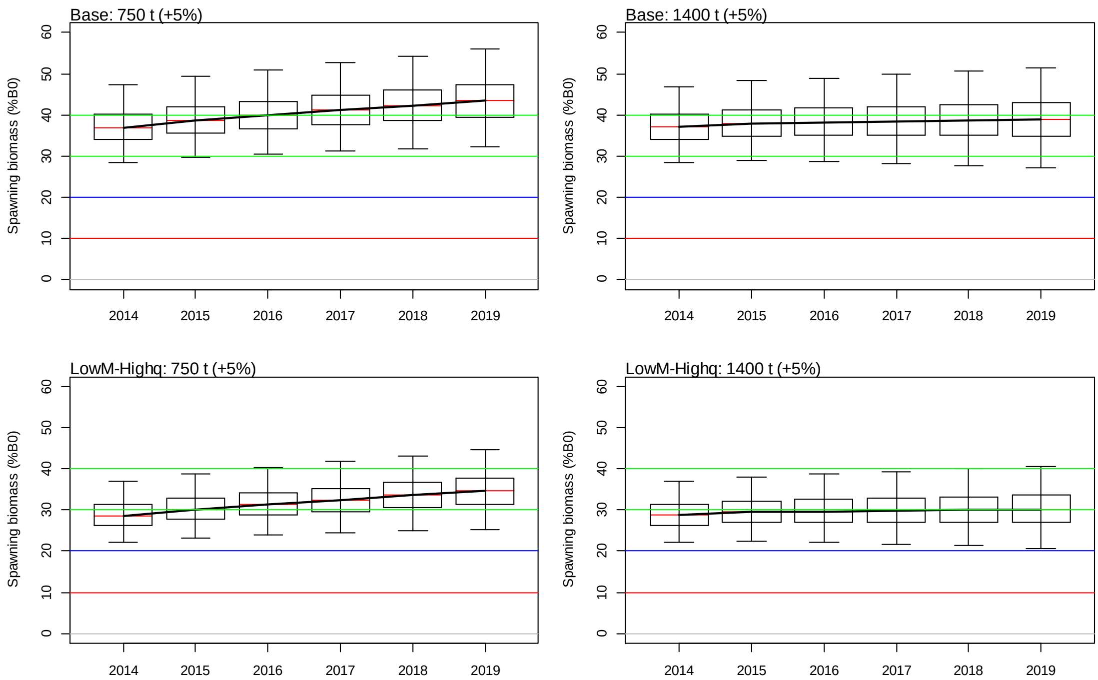


Figure 9: NWCR base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The projections are for the model and annual catch indicated (a 5% over-run was included in each year). The target range is indicated by horizontal green lines.

4.2 East and South Chatham Rise

A Bayesian stock assessment was conducted for the East and South Chatham Rise (ESCR) stock in 2014. This used an age-structured population model fitted to acoustic-survey estimates of spawning biomass, trawl-survey biomass indices, age frequencies from spawning aggregations, and length frequencies from trawl surveys and commercial fisheries.

4.2.1 Model structure

The model was single-sex and age-structured (1-100 years with a plus group), with maturity estimated separately (i.e., fish were classified by age and as mature or immature). A single-time step was used and four year-round fisheries, with logistic selectivities, were modelled: Box & flats, Eastern hills, Andes, and South Rise. These fisheries were chosen following Dunn (2007) who assessed the Box & flats, Eastern hills, and Andes as separate stocks and hence had already prepared length frequency data for those fisheries. No length frequencies were available from the South Rise fishery and its selectivity was assumed to be the same as the Andes (so effectively there were three fisheries in the model). Spawning was taken to occur after 75% of the mortality and 100% of mature fish were assumed to spawn each year.

The catch history was constructed using the catches given in Dunn (2007) from 1979-80 to 2002-2003 and from a new data extract from MPI for 2003-04 to 2012-13 (with total ORH 3B reported catch apportioned across areas using catch proportions from estimated catch on TCEPR forms). The over-run percentages in Table 4 were applied. Natural mortality was assumed fixed at 0.045 and the stock-recruitment relationship was assumed to follow a Beverton-Holt function with steepness of 0.75. The remaining fixed biological parameters are given in Table 2 of the Orange Roughy Introduction section.

In one sensitivity run, which assumed that the spawning plume first found near Rekohu canyon in 2010 had always existed, a spatially-explicit model structure was used. There were four areas to allow for the three known spawning sites (Rekohu, Old-plume[1], the Crack) and an additional area to hold the remaining spawning fish. The areas were only used at (an instantaneous) spawning time to allow the fitting of area-specific data (acoustic estimates and age frequencies). The four year-round fisheries were unchanged.

4.2.2 Input data and statistical assumptions

There were four main data sources for observations fitted in the assessment: acoustic-survey spawning biomass estimates from the Old-plume (2002–2013), Rekohu (2011–2013) and the Crack (2011, 2013); age frequencies from the spawning areas (2012 and 2013); trawl survey biomass indices and length frequencies; and early length frequencies collected from the commercial fisheries.

Acoustic estimates

The Old plume was acoustically surveyed as early as 1996, but the survey estimates are only considered to represent a consistent time series from 2002–2012 (see Cordue 2008; Hampton et al. 2008, 2009, 2010; Doonan et al. 2012). Like the Rekohu plume, that was first noted in 2010 and first surveyed in 2011, the Old plume occurs on an area of flat bottom and can be adequately surveyed using a hull-mounted transducer. In 2011 and 2013, an additional spawning area was surveyed; known as the Crack (also known as Mt. Muck), it is an area of rough terrain which requires a towed-body or trawl-mounted system to be used to reduce the height of the shadow or dead zone (i.e., with the transducer at a depth of about 500–700 m).

The estimates selected by the DWFAWG for use in the stock assessment are shown in Table 8. In 2013 there were a variety of estimates to choose from as surveys were conducted with a hull-mounted system and a multi-frequency AOS system mounted on a trawl net. In order to make the estimates as comparable as possible across years only the 38 kHz estimates were used and those from the hull-mounted system were weather-adjusted in the same way as earlier estimates (see presentations from Kloser and Ryan to the DWFAWG meetings in 2013 and 2014).

---

[1] For clarity, what was previously described as the Spawning plume' located in the Spawning Box has been renamed the ‘Old-plume’ so as to differentiate it from the Rekohu plume, which is also a spawning plume.

Table 8: Acoustic estimates of average pluming spawning biomass in the three main spawning areas as used in the assessment. All estimates were obtained from surveys on *FV San Wataki* from 38 kHz transducers. Each estimate is the average of a number of snapshots as reflected by the estimated CVs.

	Old plume		Rekohu		Crack	
	Estimate (t)	CV (%)	Estimate (t)	CV (%)	Estimate (t)	CV (%)
2002	63 950	6				
2003	44 316	6				
2004	44 968	8				
2005	43 923	4				
2006	47 450	10				
2007	34 427	5				
2008	31 668	8				
2009	28 199	5				
2010	21 205	7				
2011	16 422	8	28 113	18	6 794	21
2012	19 392	7	27 121	10		
2013	16 312	25	29 890	14	5 471	15

A key question that needed to be answered in order to use the acoustic data appropriately is: how long has the Rekohu plume been in existence? If the Rekohu plume has always existed (and was not discovered until 2010) then it would be one of three major spawning sites and could be modelled as such along with the Old plume and the Crack. This would imply that the Old-plume time series was tracking a consistent part of the spawning biomass (and its decline over time was therefore an important indicator of stock status). If, on the other hand, the Rekohu plume had very recently formed, this would imply that the Old-plume time series was a biomass index only up until the year before the Rekohu plume came into existence.

In the base model, it is assumed that the Old-plume time series cannot be relied on to provide a consistent index for any part of the spawning biomass. In 2011 and 2013, the estimates of average spawning biomass across the three areas were summed to form comparable indices for each year. The 2012 estimates from Rekohu and the Old-plume were summed to provide a 2012 index with a different proportionality constant or *q* than the preceding or following years. The Old-plume indices from 2002–2010 were used, but each point in the time series was given its own *q*. Informed priors were used for all of the *q*s in the Old-plume series, for the 2012 biomass index and the indices comprising 2011 and 2013 observations.

For 2011 and 2013, it was assumed that "most" of the biomass was being indexed so the "standard" acoustic *q* prior was used: lognormal (mean = 0.8, CV = 19%) (see orange roughy Introduction). The mean of the *q* prior for 2012 was derived from the observed biomass proportions across the three areas and the assumption that 80% of the spawning biomass was indexed in 2011 and 2013, which gave a mean of 0.7 for the 2012 index., a reflection that this index did not include an estimate for the Crack. For 2002 to 2010 the means of the *q* priors were assumed to decrease linearly from 0.7 (2002) down to 0.30 (2010), reflecting the gradual increase in the relative importance of the Rekohu plume. The linear sequence was derived by assuming 0.7 in 2002 (i.e., assuming that the Rekohu plume did not exist and only the Crack was missing from the survey estimate) and using the observed biomass proportions in 2011 with the 80% assumption (which gave the Old-plume being about 25% of the total spawning biomass). To reflect the increased uncertainty in the acoustic *q*s in years other than 2011 and 2013, the priors were given an increased CV of 30%.

For the sensitivity run where the Rekohu plume was assumed to have always existed, the specification of priors was done by splitting the two parts of the standard acoustic *q* prior. The proportion of spawning biomass indexed across all three areas combined was assigned a *Beta* (8,2) prior (which has a mean of 0.8). This is the availability part of the standard acoustic *q* prior. A single *q* was assumed for the spawning biomass estimates in each area and this was given the target strength part of the standard acoustic *q* prior (which has a mean of 1).

Trawl survey data

Research trawl surveys of the Spawning Box during July were completed from 1984 to 1994, using three different vessels: *FV Otago Buccaneer*, *FV Cordella*, and *RV Tangaroa* (Figure 10). A consistent area was surveyed using fixed station positions (with some random second phase stations each year).

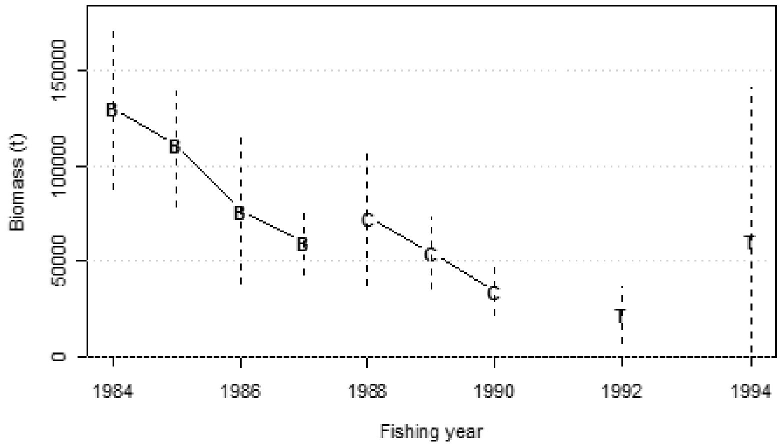


Figure 10: The Spawning Box trawl survey biomass indices (assuming a catchability of 1 for each vessel), with 95% confidence intervals shown as vertical lines. Vessels indicated as B, *FV Otago Buccaneer*; C, *FV Cordella*; T, *RV Tangaroa*.

The biomass indices were fitted as relative indices with a separate time series for each vessel (with uninformed priors on the *q*s). The second point in the Tangaroa time series, although very large (driven by a single high catch), has a large CV and so is unlikely to have had much effect on the assessment results.

Data from two wide-area surveys by *Tangaroa* in 2004 and 2007 were also used. These surveys covered the area which extends from the western edge of the Spawning Box around to the northern edge of the Andes. The area surveyed did not include the Old-plume, the Northeast Hills, or the Andes. The survey used a random design over sixteen strata grouped into five sub-areas. The trawl net used was the full-wing and relatively fine mesh ‘ratcatcher’ net. The surveys covered the same survey area as the Spawning Box trawl surveys from 1984 to 1994 as well as additional strata to the east. In 2007, the survey ran from 4–27 July and 62 trawl tows were completed. In 2004, the survey ran from 7–29 July and 57 trawl tows were completed.

The surveys had almost identical estimates of total biomass in each year (17 000 t) with low CVs (10% and 13% respectively). They were fitted as relative biomass with an uninformed prior on the *q*.

Length frequencies

The length frequencies from all of the trawl surveys were fitted in the model as multinomial random variables. Effective sample sizes (N) were taken from Dunn (2007) for the Spawning Box surveys and were assumed equal to the number of tows for the wide-area surveys (across all surveys the effective Ns ranged from about 20–80).

Length frequencies from the commercial fisheries developed by Dunn (2007) were also fitted in the model. These were fitted as multinomial with effective sample sizes ranging from 8–38.

Age frequencies

Age frequencies were developed for the Old-plume and Rekohu plume in 2012 and 2013 and also for the Crack in 2013 (Ian Doonan, NIWA, pers. comm.). Approximately 300 otoliths were randomly selected from each area in 2012 and 250 from each area in 2013. In 2012, the fish in the Old-plume were noted to be generally older than those in the Rekohu plume. This pattern was also apparent in 2013 (Figure 11). The fish from the Crack, showed a mixture of ages from new spawners (20–30 years) through to much older fish (80–100 years) (Figure 11). In the base model, the age frequencies were combined across areas and fitted as multinomial with effective sample sizes of 50 and 60 respectively (reflecting the low number of trawls from which samples were taken).

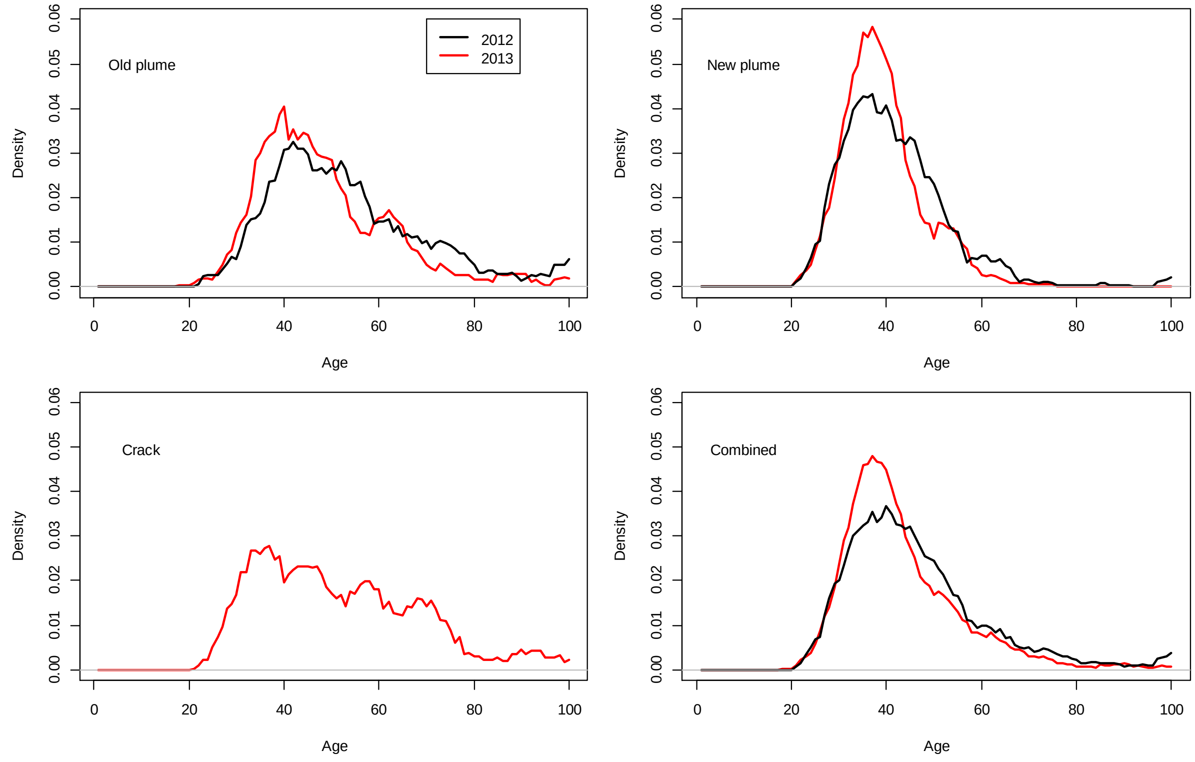


Figure 11: ESCR: *smoothed* spawning season age frequencies for the Old-plume (2012, 2013), Rekohu plume (2012, 2013), the Crack (2013) and for all three areas combined (2012, 2013).

4.2.3 Model runs and results

In the base model, the Old-plume time series was assumed to be unreliable in terms of trend and therefore each point from 2002 to 2010 was given its own *q*; also, natural mortality (*M*) was fixed at 0.045. There were several important sensitivity runs: assume that the Rekohu plume had always existed; assume that it first occurred in 2007; assume it first occurred in 2010; estimate *M*; adjust M and the mean of the priors by 20% (the standard LowM-Highq and HighM-Lowq runs, see orange roughy Introduction).

In the base model, the main parameters estimated were: virgin (unfished, equilibrium) biomass (B_0), maturity ogive, trawl-survey selectivities, fisheries selectivities, CV of length-at-mean-length-at-age for ages 1 and 100 years (linear relationship assumed for intermediate ages), and year class strengths (YCS) from 1930 to 1990 (with the Haist parameterisation and "nearly uniform" priors on the free parameters). There were also the numerous acoustic and trawl-survey *q*s.

Model diagnostics

The base model provided good MPD fits to the data. The MPD fits to the acoustic indices were excellent with normalised residuals all very small (Figure 12). Most of the MPD estimated *q*s were lower than the corresponding means of the priors, but the lowest ratio was only about 0.7 (Figure 12). The posteriors for the acoustic *q*s were shifted to the left of the priors for 2011 & 2013 and also for 2012, but remained well within the prior distribution (Figure 13). For the Old-plume time series, posteriors were sometimes shifted to the left of the priors but also sometimes to the right (e.g., see Figure 13 for 2002 and 2003) and the ratio of the mean of the posterior to the mean of the prior had a limited range from 0.85 (2003) to 1.2 (2006). The normalised residuals of the acoustic indices for the base MCMC model were also excellent, showing no apparent trend (Figure 14).

The MPD fits to the trawl indices were good but the model-predicted biomass had a shallower decline than that estimated from the indices from the *Buccaneer* and *Cordella* surveys (Figure 15). Also, the model does not fit the very large increase in the *Tangaroa* Spawning Box survey (Figure 15).

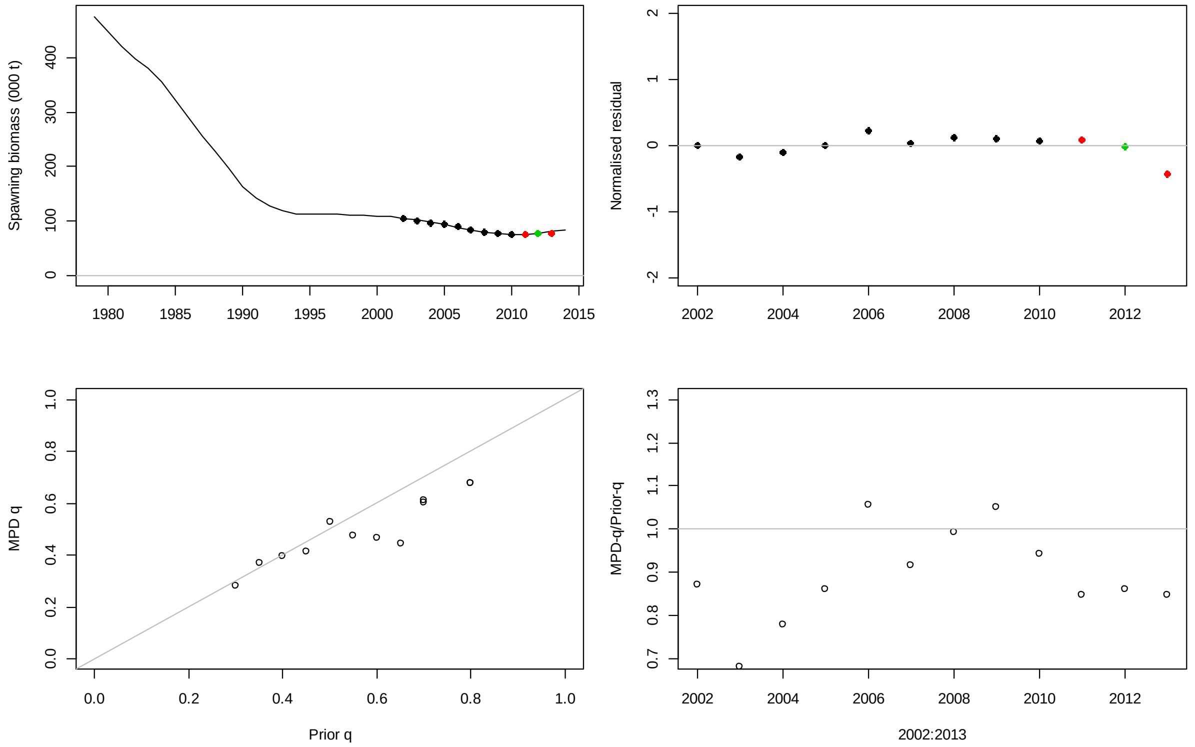


Figure 12: ESCR, MPD, base: fit to the acoustic indices: (top) spawning biomass trajectory and unscaled acoustic indices; normalised residuals; (bottom) estimated *q*s as a function of the mean of the *q* prior; the ratio of the estimated *q* to the mean of the *q* prior.

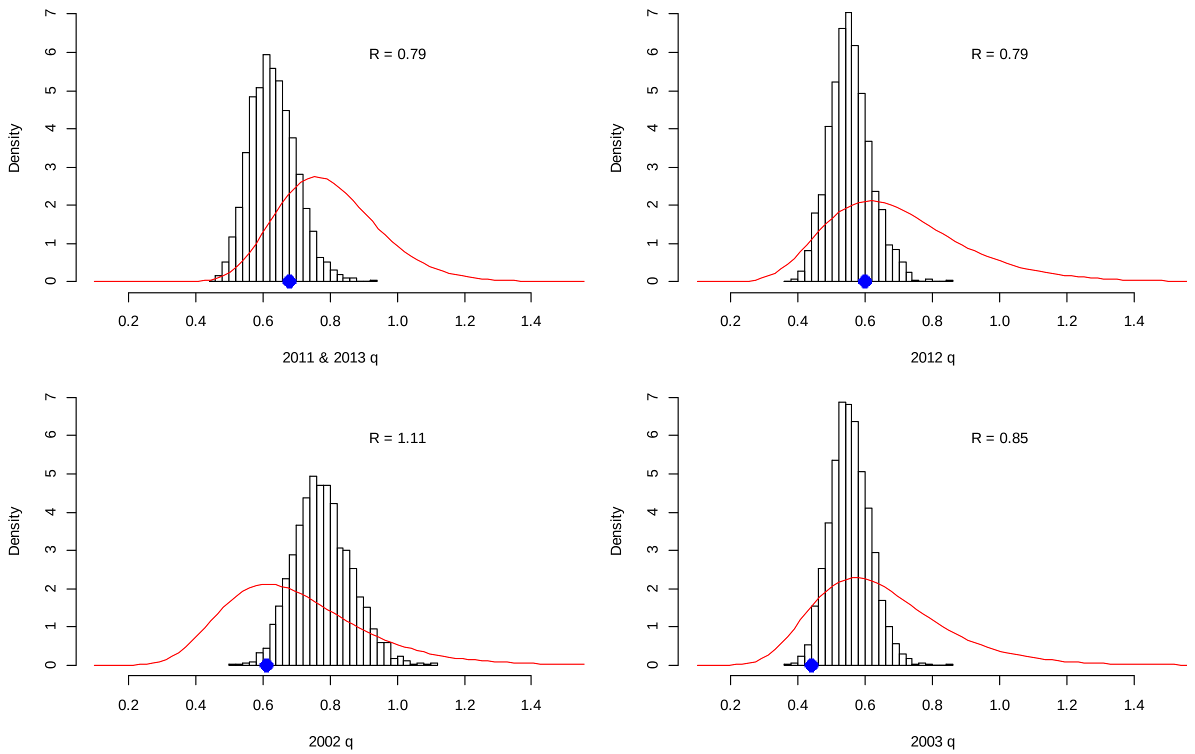


Figure 13: ESCR, MCMC base: prior (in red) and posterior distributions for a selection of acoustic *q*s. The blue dot is the MPD estimate and R is the ratio of the mean of the posterior to the mean of the prior.

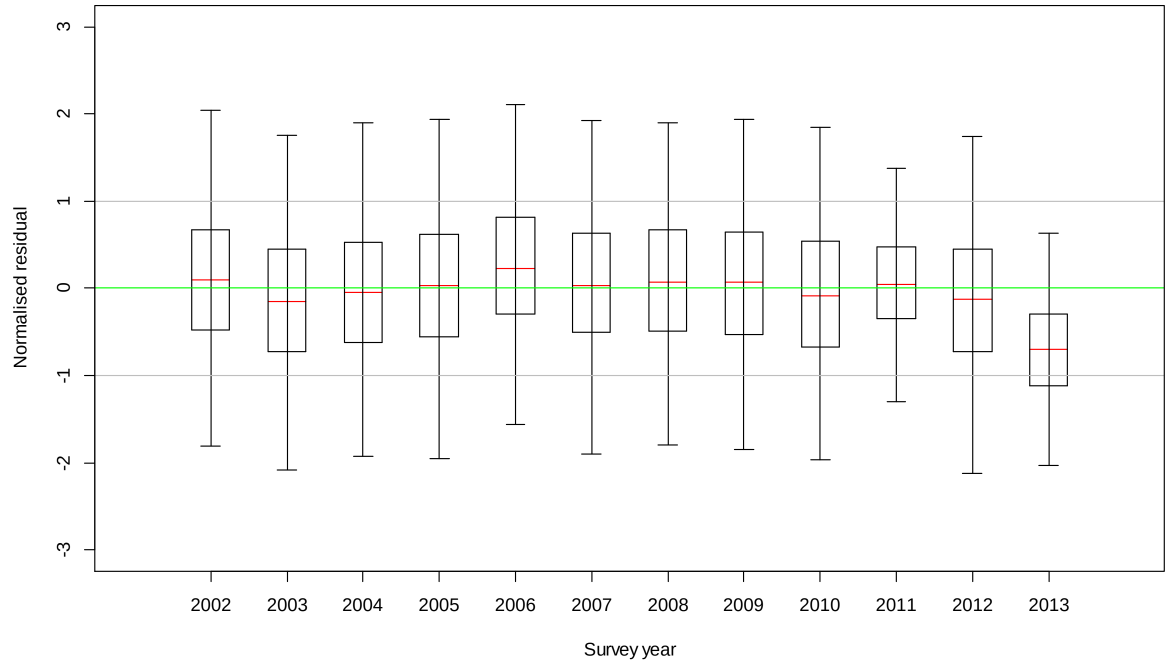


Figure 14: ESCR, MCMC base: normalized residual for the acoustic indices. The box covers 50% of the distribution for each index and the whiskers extend to 95% of the distribution.

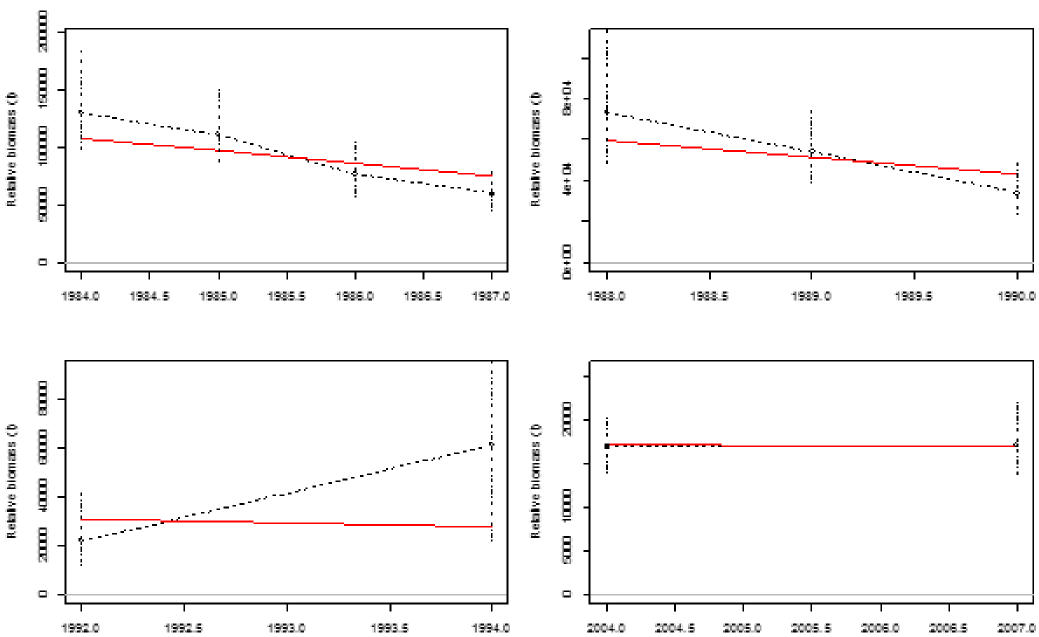


Figure 15: ESCR, MPD base: fits (in red) to the trawl-survey biomass indices (from top to bottom and left to right: *Buccaneer, Cordella, Tangaroa,* wide-area *Tangaroa*).

The fits to the age frequencies are as good as can be expected given the inconsistent shape of the age frequencies in the two consecutive years (Figure 16). The inconsistency is not caused by having the Crack included in 2013 and not 2012; the problem is too many 30-40 year old fish in 2013 (whereas the Crack had a wide mix of ages).

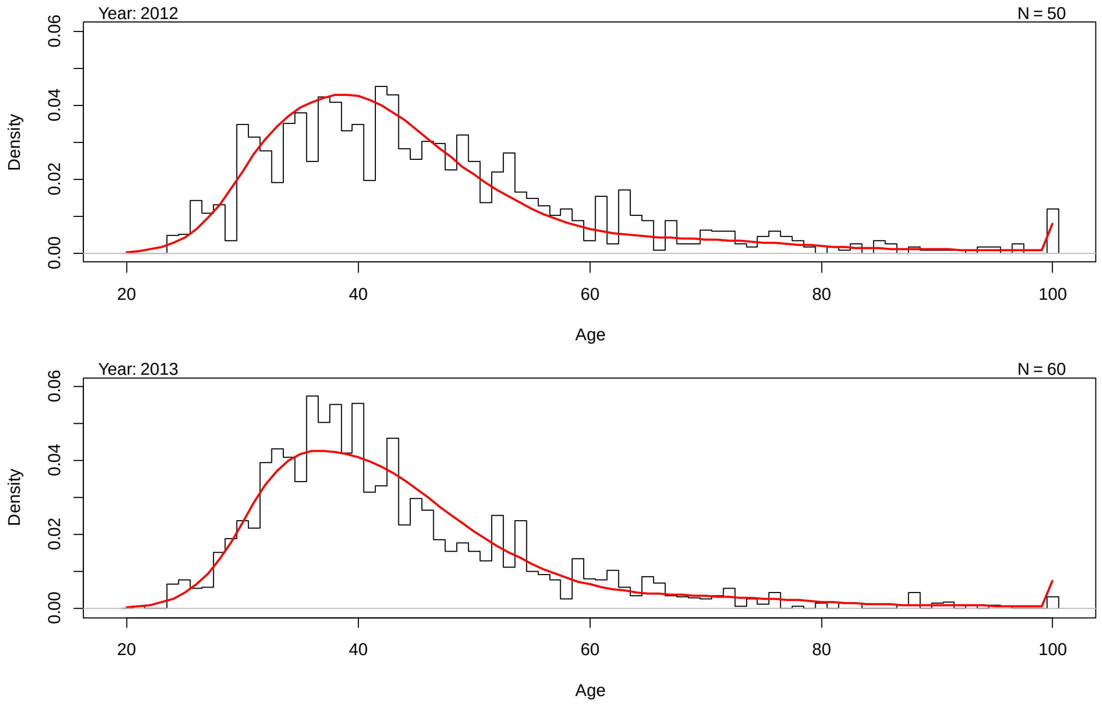


Figure 16: ESCR, MPD base: fits (in red) to the spawning season age frequencies. N is the effective sample size.

The MPD fits to the commercial length frequencies were excellent except the 1990 Box and flats length frequency (see Figure 17). Likewise the fits to the trawl survey length frequencies were excellent (e.g., see Figure 18). The long tail to the left, which was present in all of the trawl-survey length frequencies from the Spawning Box, was easily fitted in the 2014 models, as selectivities were fitted for mature and immature fish. The three Spawning Box trawl surveys all had a common immature selectivity which allowed a small proportion of the immature fish to be selected (and hence to fit the left-hand tail). The *Tangaroa* wide-area trawl survey also had separate mature and immature selectivities which allowed a much larger proportion of immature fish to be selected and hence allowed a very good fit to the broad mode of the length frequencies (Figure 18).

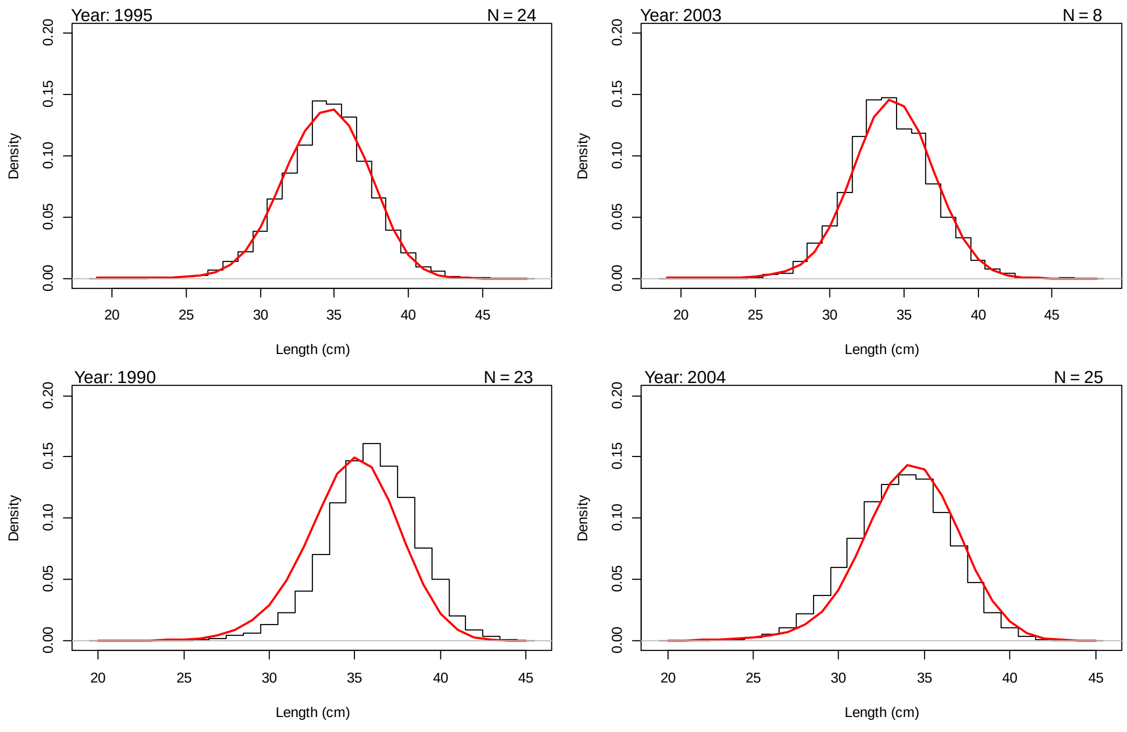


Figure 17: ESCR, MPD base: fits (in red) to the commercial length frequencies for the Eastern hills (top) and the Box and flats (bottom). N is the effective sample size.

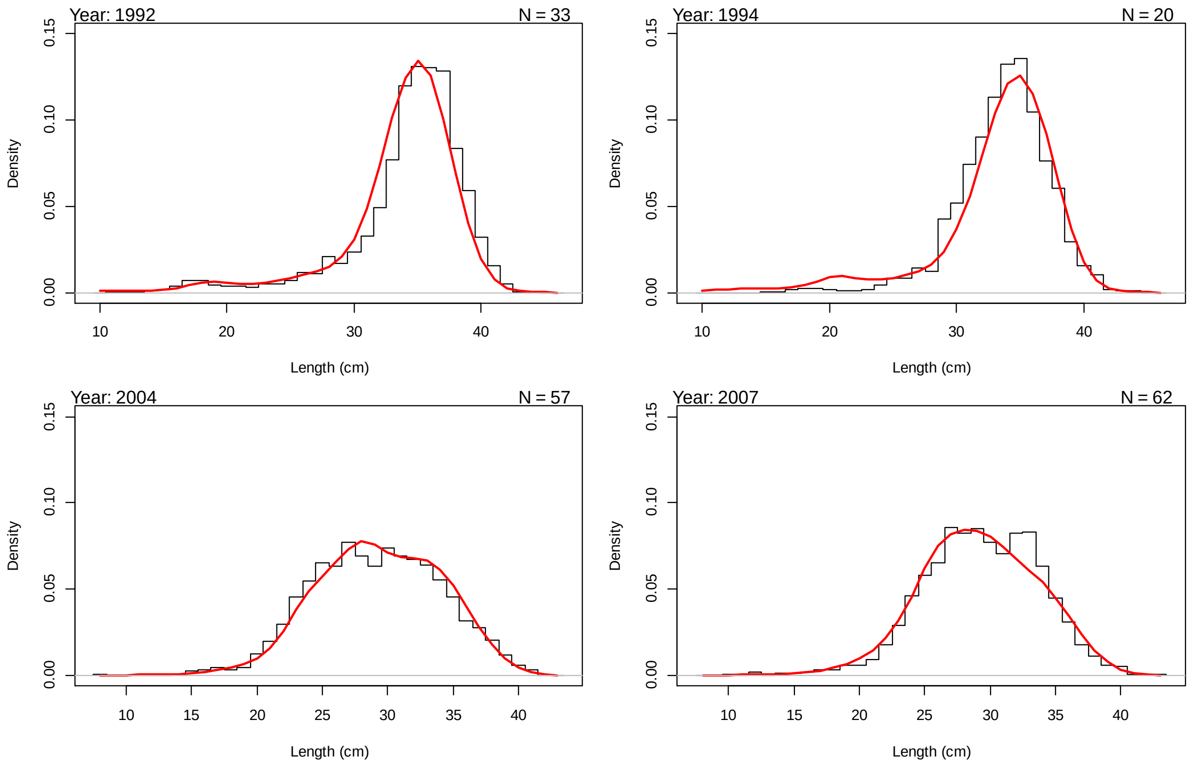


Figure 18: ESCR, MPD base: fits (in red) to the *Tangaroa* length frequencies for the Spawning Box (top) and the wide-area surveys (bottom). N is the effective sample size.

Numerous sensitivity runs were conducted at the MPD stage. Model estimates were robust to changes in effective sample sizes for composition data. The model was also robust to changes in *M* (0.03, 0.06 compared to base of 0.045) or changes in the mean of the acoustic *q* priors for 2011 & 2013 (0.6, 0.9 compared to base of 0.8). Major differences in the MPD estimate of current stock status occurred when the acoustic indices were halved or doubled, also and when deterministic recruitment was assumed (respectively: 14% B_0, 39% B_0, and 35% B_0, compared to the base estimate of 24% B_0).

The sensitivities that explored the timing of the appearance of the Rekohu plume provided another validation for the robustness of the base model estimates. The "Always" model (which assumed that the Rekohu plume had always existed) provided an adequate fit to the data, but the results lacked credibility in three respects: (i) the posterior distribution for the acoustic *q* was pushed a long way to the right of the prior (Figure 19), (ii) as was the posterior for the proportion of spawning biomass being indexed by the three spawning areas combined (Figure 19), and (iii) the model estimated that the Rekohu plume had contained over 100,000 t of spawning biomass up until the early 1980s (Figure 20), which seemed unlikely, given the high level of fisheries exploration at that time (it also seemed unlikely that the fleet would have missed the 40-50,000 t estimated to have existed in the early 1990s when the spawning box (Old plume) was closed and the fleet may have been actively searching for other aggregations). These three factors combined caused the DWFAWG to conclude that the "Always" run was not a credible alternative to the base model.

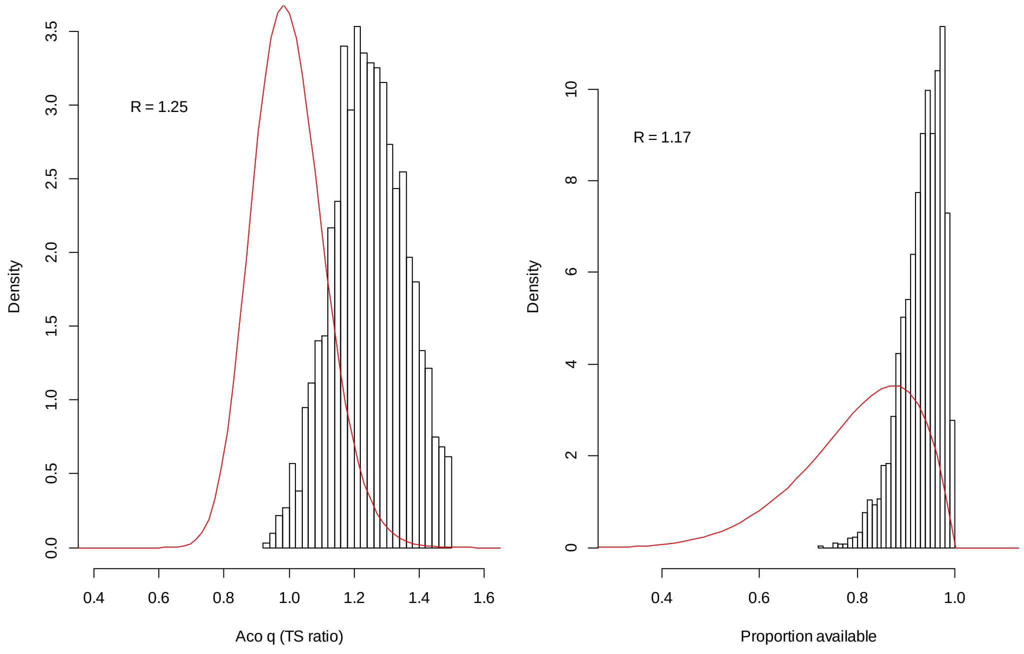


Figure 19: ESCR, MCMC: "Always" sensitivity run: prior (in red) and posterior distributions for the acoustic *q* (left) and the proportion of spawning biomass available to the Old-plume, Rekohu plume, and the Crack combined (right). R is the ratio of the mean of the posterior to the mean of the prior.

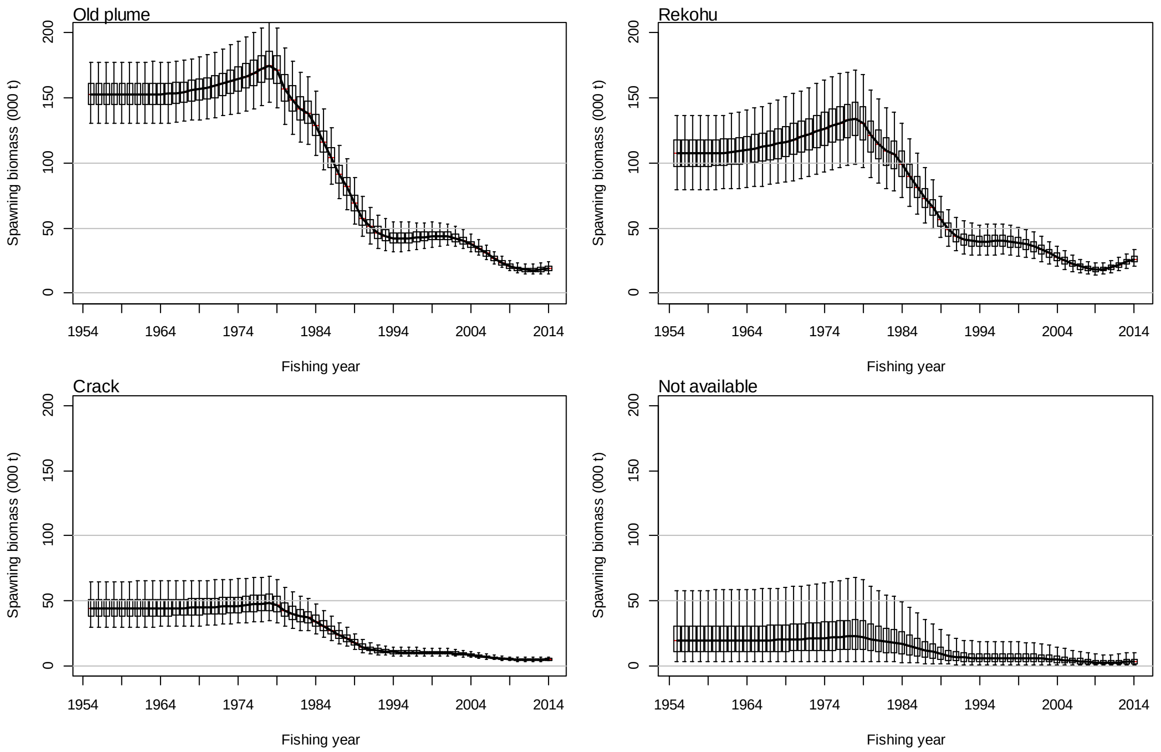


Figure 20: ESCR, MCMC: "Always" sensitivity model: spawning biomass trajectories for each area in the model including the Rekohu plume which is assumed, in this run, to have always existed. The box covers 50% of the distribution in each year and the whiskers extend to 95% of the distribution.

The sensitivities that assumed the first occurrence of the Rekohu plume in 2007 or 2010 were also critically examined to see if they were able to adequately explain the data, as well as being consistent with other ancillary information. It was found that a creation year of 2010 did not allow enough time for the Rekohu plume to build up to the levels of biomass observed in 2011 (unless fish spawning outside the three surveyed areas suddenly began joining the Rekohu plume, another assumption thought unlikely by the DWFAWG). However, a creation year of 2007 did provide sufficient time to allow for the Rekohu plume to build up to the size observed in 2011, without the need to assume that existing spawning fish would change their spawning sites. The Rekohu 2007 model also fitted the data adequately. The Rekohu 2007 model was taken through to MCMC but it was not considered as a base model because there was no evidence to support the assumption that the Rekohu plume first occurred in 2007.

MCMC results

For the base model, MCMC convergence diagnostics were adequate once the three chains (with random starting values near the MPD estimate) had been run for 15 million iterations. These chains were much longer than those normally required and it appeared that the slow convergence was due to a high correlation between B_0 and the age at 50% maturity. Some technical changes were made to improve chain convergence; they were successful and gave identical results to the base model without the changes. The technical changes were used in the sensitivity runs to avoid running chains out to 15 million.

Virgin biomass, B_0, was estimated to be about 320,000 t for the base model with median estimates ranging from 310,000–360,000 t for the four sensitivity runs presented (Table 9). Current stock status was similar across the base and the first two sensitivity runs (Table 9). The lower stock status when M was estimated reflects the lower estimates of M (0.036 rather than 0.045). For the two “bounding” runs, where M and the mean of the acoustic q priors were shifted by 20%, current stock status was estimated well below the biomass target range of 30–40% B_0 for the pessimistic *LowM-Highq* run and primarily within the target range for the optimistic *HighM-Lowq* run (Table 9).

Table 9: ESCR, MCMC estimates of virgin biomass (B_0) and stock status (B_{2014} as %B_0) for the base model and four sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2014} (%B_0)	95% CI
Base	0.045	320	280-350	30	25-34
Estimate M	0.036	360	300-410	26	20-32
Rekohu 2007	0.045	310	280-340	26	22-30
LowM-Highq	0.036	340	320-370	22	19-26
HighM-Lowq	0.054	310	280-350	38	32-43

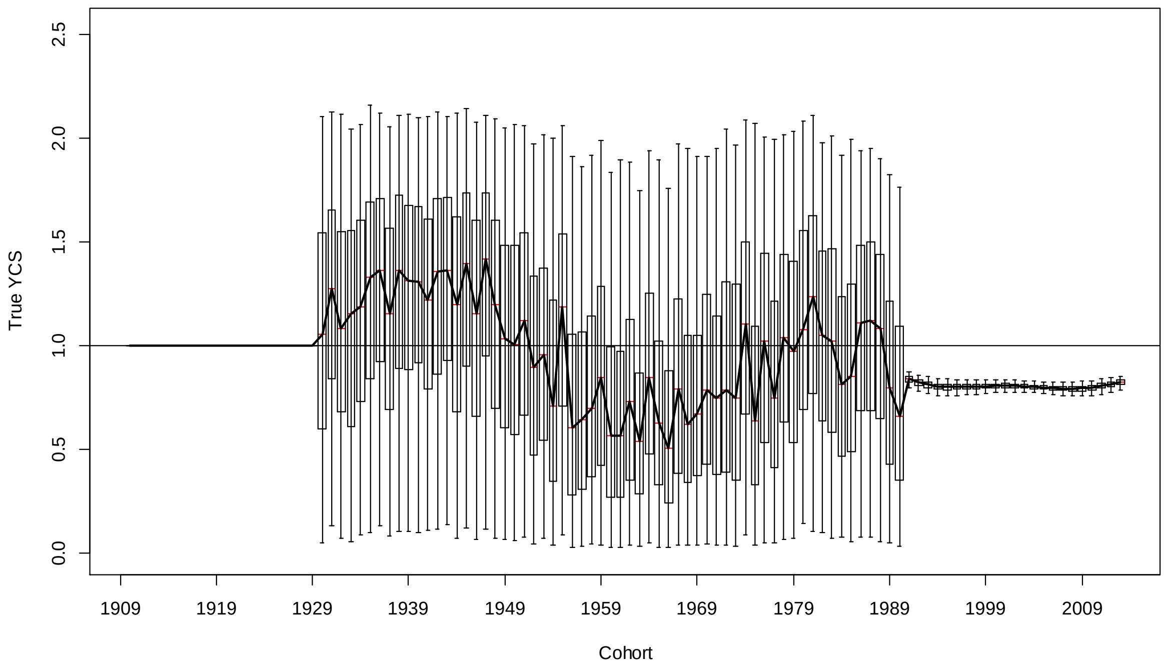


Figure 21: ESCR base, MCMC estimated “true” YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The estimated YCS show little variation across cohorts but do exhibit a long-term trend (Figure 21). The most recent 10 years of estimates (those resampled for short-term projections) are a little above average.

The stock status trajectory shows a steady decline from the start of fishery until the mid 1990s where it remains in the 20-30% range until an upturn in about 2010 (Figure 22)

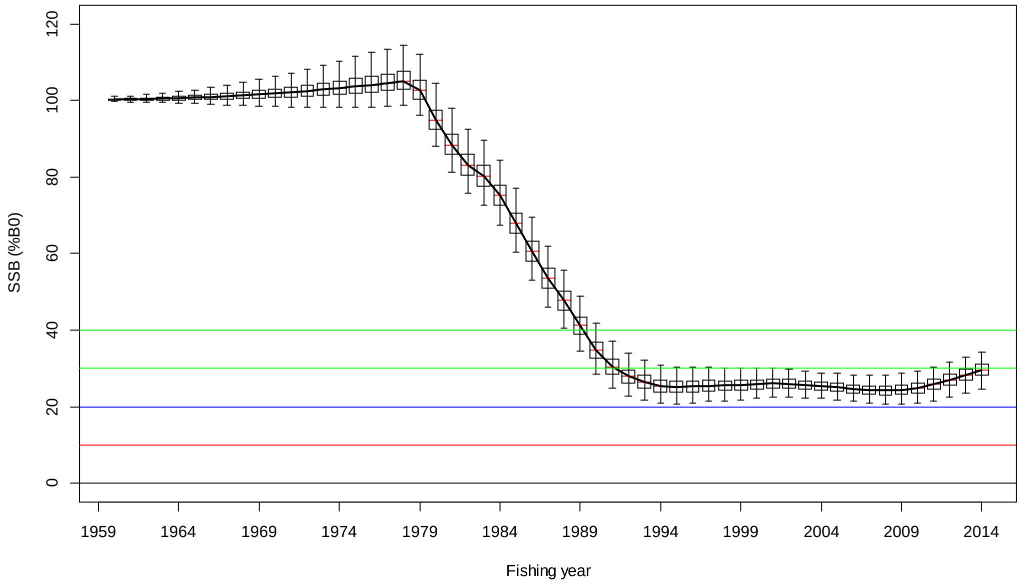


Figure 22: ESCR base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit 10% B_0 (red), soft limit 20% B_0 (blue), and biomass target range 30–40% B_0 (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity by year. Fishing intensity is represented in term of the median exploitation rate and the Equilibrium Stock Depletion (ESD). For the latter, a fishing intensity of $U_{x\%B0}$ means that fishing (forever) at that intensity will cause the SSB to reach deterministic equilibrium at x% B_0 (e.g., fishing at $U_{30\%B0}$ forces the SSB to a deterministic equilibrium of 30% B_0). Fishing intensity in these units is plotted as 100–ESD so that fishing intensity ranges from 0 ($U_{100\%B0}$) up to 100 ($U_{0\%B0}$).

Estimated fishing intensity was within or above the target range ($U_{30\%B0}$–$U_{40\%B0}$) for most of the history of the fishery; it has been below the target range since 2010 (Figure 23).

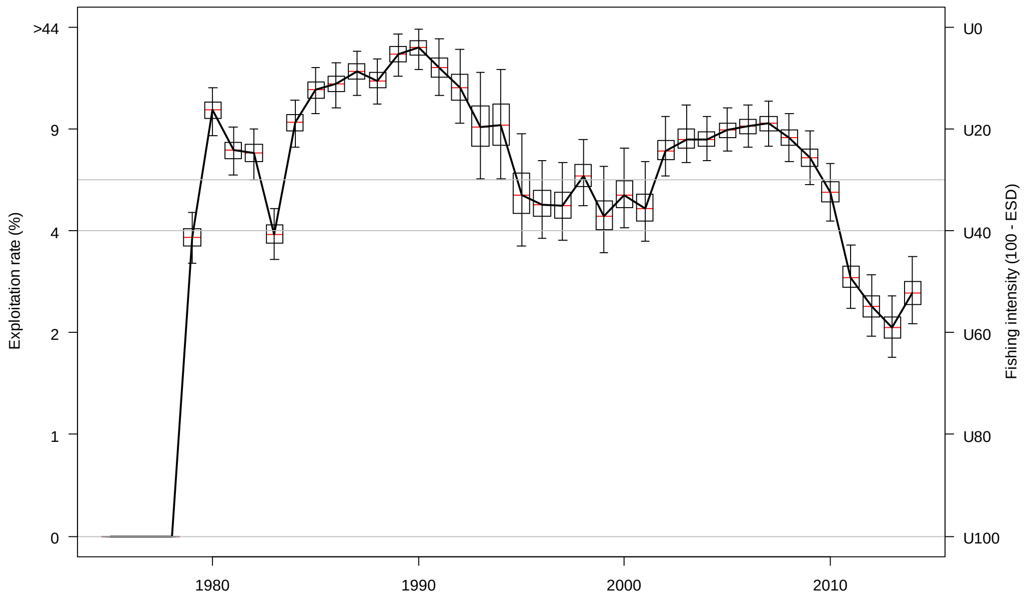


Figure 23: ESCR base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30–40% B_0 is marked by horizontal lines.

Biological reference points, management targets and yield

MCMC estimates of deterministic B_{MSY} and associated values were produced for the base model. The yield at 35% B_0 (the mid-point of the target range) was also estimated. There is little variation in the reference points and associated values across the MCMC samples (Table 10).

There are several reasons why deterministic B_{MSY} is not a suitable target for use in fisheries management. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge (current biomass must be known exactly in order to calculate the target catch) and annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders). Second, it assumes perfect knowledge of the stock-recruit relationship, which is often poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard.

Table 10: ESCR base, MCMC estimates of deterministic equilibrium SSB and long-term yield (% B_0 and tonnes) for U_{MSY} and $U_{35\%B0}$. The equilibrium SSB at U_{MSY} is deterministic B_{MSY} and the yield is deterministic MSY.

Fishing intensity		SSB (%B_0)	Yield (%B_0)	Yield (t)
U_{MSY}	Median	21.8	2.4	7716
	95% CI	20.2-23.4	2.3-2.7	7264–8237
$U_{35\%B0}$	Median	35.0	2.3	7175
	95% CI		2.1-2.5	6740–7666

Projections

Five year projections were conducted (with resampling from the last 10 estimated YCS) for two different constant catch assumptions: 3100 t (the current catch limit); and 6400 t (the current estimated yield at $U_{35\%B0}$). In each case a 5% catch over-run was assumed. Projections were done for the base model and also for the LowM-Highq model (as a "worst case" scenario).

At the current catch limit (3100 t), SSB is predicted to increase steadily over the next five years for both models (Figure 24). At the catch associated with $U_{35\%B0}$ (6400 t), SSB is predicted to rise slightly for both models (Figure 24). For both models and both constant catch scenarios the estimated probability of SSB going below the hard limit is zero over the next five years. There is also zero probability for the base model of going below 20% B_0 under either catch scenario. For the LowM-Highq model there is a small but non-zero probability that the SSB is already below 20% in 2014 but this decreases over time for both catch scenarios (Figure 24).

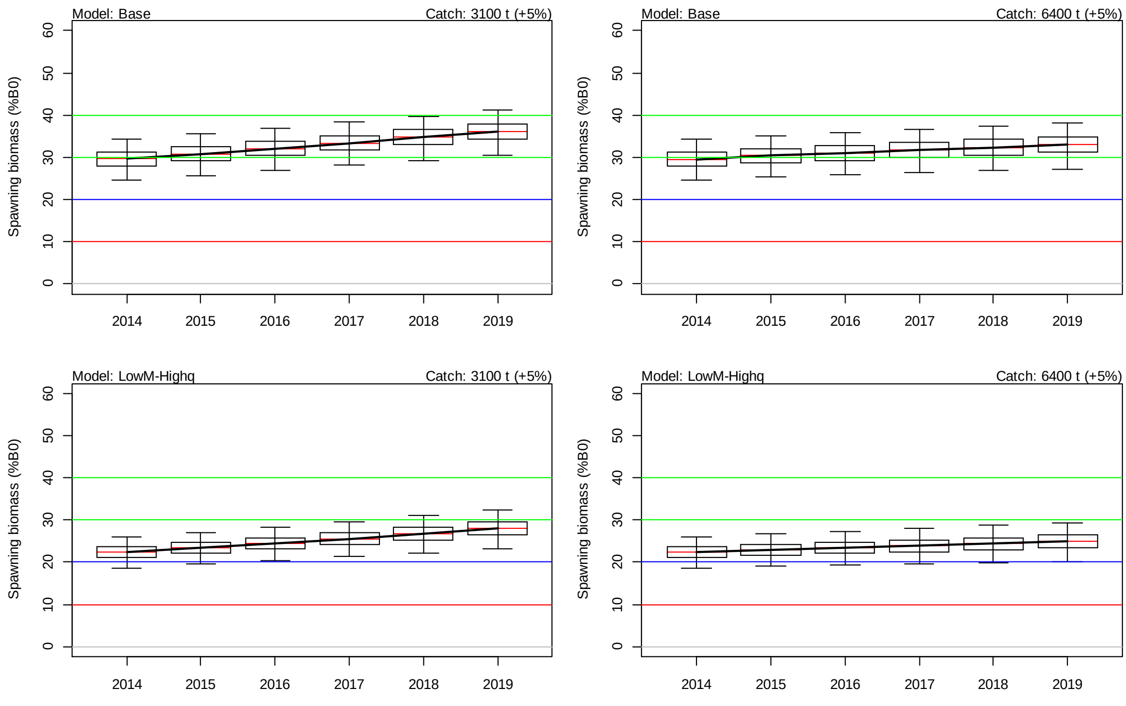


Figure 24: ESCR base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The projections are for the model and annual catch indicated (a 5% catch over-run was included in each year). The 30–40% B_0 target range is indicated by horizontal green lines and the hard limit 10% B_0 and soft limit 20% B_0 by red and blue lines respectively.

5. STATUS OF THE STOCKS

For orange roughy stocks, the management target is a biomass range from 30–40% B_0.

5.1 Chatham Rise

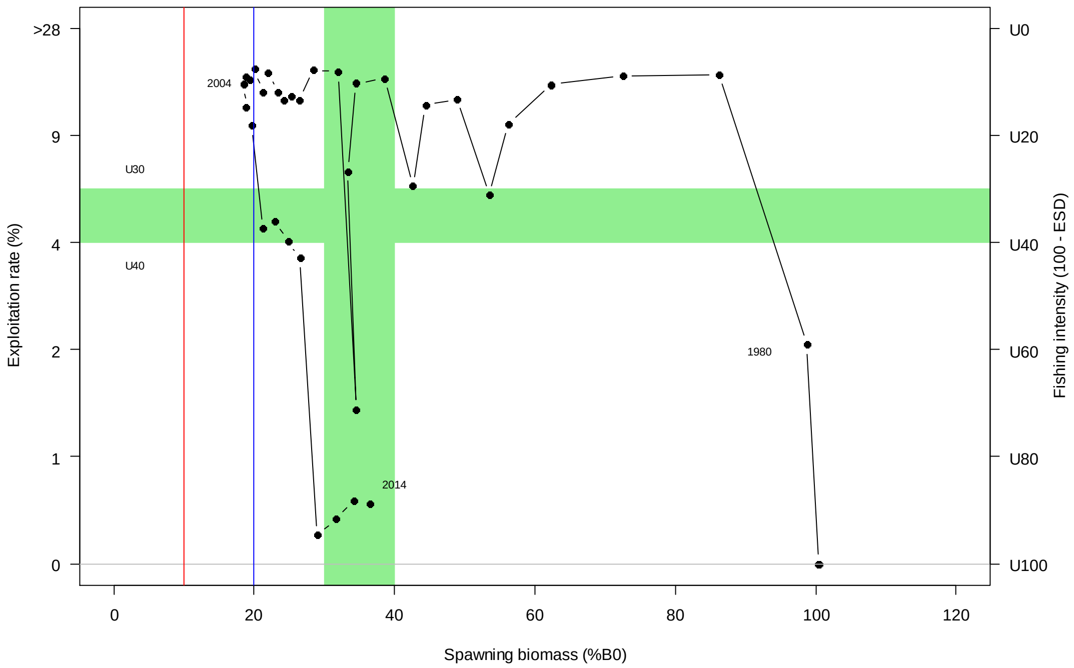
Stock Structure Assumptions

Chatham Rise orange roughy are believed to comprise two biological stocks; these are assessed and managed separately: one on the Northwest of the Chatham Rise and the other ranging throughout the East and South Rise. This assumed stock structure is based on the presence of two main areas where spawning takes place simultaneously, and observed and inferred migration patterns of adults and juveniles. These two biological stocks form the bulk of the ORH 3B Fishstock. They are geographically separated from all other ORH 3B biological stocks.

Northwest Chatham Rise

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base model only
Reference Points	Management Target: Biomass range 30–40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Fishing intensity range $U_{30\%B0}$–$U_{40\%B0}$
Status in relation to Target	B_{2014} was estimated at 37% B_0. Likely (> 60%) to be at or above the lower end of the management target range
Status in relation to Limits	B_{2014} is Very Unlikely (< 10%) to be below the Soft Limit B_{2014} is Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Fishing intensity in 2014 was estimated at $U_{89\%B0}$ Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status



Historical trajectory of spawning biomass (%B_0), median exploitation rate (%) and fishing intensity (100-ESD) (base model, medians of the marginal posteriors). The biomass target range of 30-40 % B_0 and the corresponding exploitation rate range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red. Note that the Y-axis is non-linear.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass reached its lowest point in 2004 and has increased consistently since then. According to the Harvest Strategy Standard, the stock is now considered to be fully rebuilt (at least a 70% probability that the lower end of the management target range of 30–40% B_0 has been achieved).
Recent Trend in Fishing Intensity or Proxy	Fishing intensity decreased sharply from 2010 to 2011 and has remained well below the overfishing threshold since then.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Biomass is expected to increase or stay steady over the next 5 years at annual catches of up to 1400 t.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	At both current catch (110 t) or current catch limit (750 t): Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	At current catch: Exceptionally Unlikely (< 1%) At current catch limit: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2014	Next assessment: unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	-Acoustic estimates of spawning biomass on Graveyard (1999, 2012-13) and Morgue (1999, 2012).	1 – High Quality
	-Trawl survey age frequency and proportion-spawning-at-age (1994).	1 – High Quality
	-17 years of length frequency data.	1 – High Quality
Data not used (rank)	-CPUE	3 – Low Quality: unlikely to be indexing stock-wide abundance
	-Trawl surveys of hills (1990-2002)	3 – Low Quality: unlikely to be indexing stock-wide abundance
	-Wide-area acoustic survey estimates	2 – Medium or Mixed Quality: large potential bias due to mixed-species
	-Chatham Rise trawl survey deepwater stations (2010-2014)	2 – Medium or Mixed Quality: variable indices
	-Egg survey estimate	3 – Low Quality: survey design assumptions not met

Changes to Model Structure and Assumptions	The previous assessment was in 2006. -Model now based on spawning biomass rather than transition-zone mature biomass. -Age data included to enable estimation of year class strengths rather than assuming deterministic recruitment. - A more stringent data quality threshold was imposed on data inputs (e.g., CPUE indices not used, egg survey and wide-area acoustic estimates also excluded).
Major Sources of Uncertainty	-The largest source of uncertainty is the proportion of the NWCR spawning stock that is indexed by the acoustic survey in each year. -Patterns in year class strengths are based on only one year of age composition data. -The time series of abundance indices is short and restricted to the period of lower stock status.

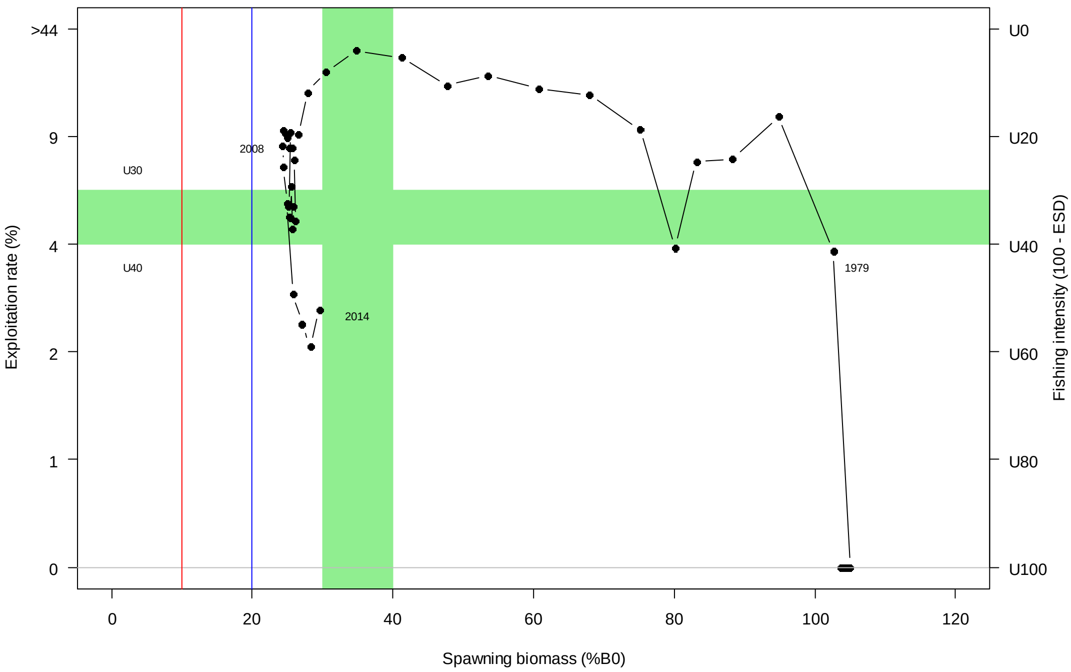
Qualifying Comments
Estimates of stock biomass are sensitive to the means of the *q* priors. In addition, when higher CVs were used for the informed acoustic *q* priors, the median estimates of biomass and stock status were slightly higher and the confidence intervals were wider with a much higher upper bound.

Fishery Interactions
Main bycatch species are smooth oreo, black oreo, rattails, deepwater dogfish and hoki, with lesser bycatches of Johnson's cod and ribaldo. Low productivity bycatch species include deepwater sharks, skates and corals. Overall, bycatch usually comprises about 20% of the total catch. Observed incidental captures of protected species include corals, low numbers of seabirds and occasional NZ fur seals.

East and South Chatham Rise

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base model only
Reference Points	Management Target: Biomass range 30–40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Fishing intensity range $U_{30\%B0}$–$U_{40\%B0}$
Status in relation to Target	B_{2014} was estimated to be 30% B_0 About as Likely as Not (40–60%) to be at or above the lower end of the management target range
Status in relation to Limits	B_{2014} is Unlikely (< 40%) to be below the Soft Limit B_{2014} is Very Unlikely (< 10%) to be below the Hard Limit
Status in relation to Overfishing	Fishing intensity in 2014 was estimated at $U_{52\%B0}$ Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Historical trajectory of spawning biomass (%B_0), median exploitation rate (%) and fishing intensity (100-ESD) (base model, medians of the marginal posteriors). The biomass target range of 30-40 % B_0 and the corresponding exploitation rate range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red. Note that the Y-axis is non-linear.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The spawning biomass is estimated to have been slowly increasing over the last four years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity (exploitation rate) is estimated to have been below the lower end of the target range in the last four years.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Biomass is expected to increase or stay steady over the next 5 years at annual catches of up to 6400 t.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	At current catch or catch limit (3100 t) Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2014	Next assessment: 2015
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	-Four short time series of biomass indices from research trawl surveys -Acoustic indices from research surveys of spawning plumes (Old-plume, Rekohu plume, Crack)	1 – High Quality 1 – High Quality

	-Age frequencies from the spawning plumes in 2012 and 2013 -Length frequencies from commercial fisheries	1 – High Quality 1 – High Quality
Data not used (rank)	-CPUE -Acoustic surveys of hills (hull-mounted transducers) -Wide-area acoustic survey estimates -CR deepwater trawl survey stations (2010-2014)	3 – Low Quality: unlikely to be indexing stock-wide abundance 3 – Low Quality: major species identification and dead zone issues 2 – Medium or Mixed Quality: large potential bias due to mixed-species 2 – Medium or Mixed Quality: variable indices
Changes to Model Structure and Assumptions	The most recent model-based assessment was in 2006. Subsequent assessments have been based on an expert assessment of data, principally acoustic biomass estimates. -The current assessment is fully quantitative and based on spawning biomass rather than transition-zone mature biomass. -Age data have been included to enable estimation of year class strengths rather than assuming deterministic recruitment. - A more stringent data quality threshold was imposed on data inputs (e.g. CPUE indices and wide-area acoustic estimates not used)	
Major Sources of Uncertainty	-The largest source of uncertainty is the proportion of the ESCR spawning stock that is indexed by the acoustic survey in each year. -Stock status is dependent on the timing of the appearance of the Rekohu spawning plume, which is unknown. -Patterns in year class strengths are based on only 2 years of age composition data.	

Qualifying Comments
-Estimates of stock biomass are sensitive to the means of the *q* priors. In addition, when higher CVs were used for the informed acoustic *q* priors, the median estimates of biomass and stock status were slightly higher and the confidence intervals were wider with a much higher upper bound. -There were some concerns about a potential lack of convergence in the MCMCs.

Fishery Interactions
Main bycatch species are smooth oreo, black oreo, deepwater dogfish, hoki and rattails, with lesser bycatches of slickhead, Johnson's cod and morids. Low productivity bycatch species include deepwater sharks and dogfish and also corals. Overall, bycatch usually comprises about 25% of the total catch, the majority of which are QMS species. Observed incidental captures of protected species include corals, low numbers of seabirds and occasional NZ fur seals.

5.2 Southern ORH 3B fisheries

Puysegur

The 1998 assessment for this stock (Annala et al 1998) was uncertain because the three time series of biomass indices on which it was based are all very short. However, all three series (two of trawl surveys and one of CPUE) suggested that the biomass was reduced substantially up to 1998. The point estimate of biomass from this assessment was probably below B_{MSY}, but it was uncertain. Estimates of *MCY* and *CAY* were 420 t or less. The fishery was voluntarily closed in 1997–98 in order to maximise the rate of rebuilding. It was re-opened in 2010–11 with a catch limit of 150 t (Table 3).

Auckland Islands (Pukaki South)

The Deepwater Working Group examined the data on orange roughy catch and effort from the Auckland Islands area in 2006, and found that there had been relatively little fishing activity in this area in the previous few years. There were insufficient data to conduct a standardised CPUE analysis, and it was believed that unstandardised CPUE did not provide a suitable index of relative abundance. Therefore, a stock assessment could not be carried out.

Other fisheries

In 2006 the Deepwater Working Group examined the data on orange roughy catch and effort from other parts of ORH 3B – the Bounty Islands, Pukaki Rise, Snares Island and the Arrow Plateau – and agreed that there were insufficient data to carry out standardised CPUE analyses for any of these areas.

6. FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J; O'Brien, C J; Iball, S D (Comps) (1998) Report from the Fishery Assessment Plenary, May 1998: stock assessments and yield estimates. 409 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Bull, R; Doonan, I J; Tracey, D M; Coombs, R F (2000) An acoustic estimate of orange roughy abundance on the Northwest Hills, Chatham Rise, June–July 1999. New Zealand. Fisheries Assessment Research Document 2000/20. 36 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Bull, B; Francis, R I C C; Dunn, A; McKenzie, A; Gilbert, D J; Smith, M H (2003) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.01-2003/08/01. *NIWA Technical Report 124*. 223 p.

Clark, M R; Anderson, O F; Dunn, M (2003) Descriptive analysis of catch and effort data from New Zealand orange roughy fisheries in ORH 1, 2A, 2B, 3A, 3B, and 7B to the end of the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2003/60*. 51p.

Clark, M R; Anderson, O F; Francis, R I C C; Tracey, D M (2000) The effects of commercial exploitation on orange roughy (*Hoplostethus atlanticus*) from the continental slope of the Chatham Rise, New Zealand, from 1979 to 1997. *Fisheries Research* 45(3): 217–238.

Coburn, R P; Doonan, I J (1994) Orange roughy fishing on the North East Chatham Rise: a description of the commercial fishery, 1979–1988. *New Zealand Fisheries Technical Report* 38.

Coburn, R P; Doonan, I J (1997) The fishery for orange roughy on the northeast Chatham Rise, 1988–99 to 1993–94. *New Zealand Fisheries Technical Report 48*. 28 p.

Coombs, R F; Barr, R (2007) *In situ* measurements of orange roughy (*Hoplostethus atlanticus*) target strength. *ICES Journal of Marine Science* 64: 1220–1234.

Cordue, P L (2008) Review of estimates of Chatham Rise orange roughy biomass from plume surveys. Report prepared for the New Zealand Ministry of Fisheries. 39 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Cordue, P L (2010) Linear-model derived bottom-referenced weather corrections for the CR ORH plume time series (2002–2009). Report to the DWWG, DWWG2010-30, New Zealand Ministry of Fisheries. 71 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Doonan, I J (1991) Orange roughy fishery assessment, CPUE analysis - linear regression, NE Chatham Rise 1991. New Zealand Fisheries Assessment Research Document 1991/9. 48 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Doonan, I J (1994) Life history parameters of orange roughy; estimates for 1994. New Zealand Fisheries Assessment Research Document 1994/19. 13 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Doonan, I (2009) Re-analysis of the spawning plume biomass, towbody acoustics surveys 1998 & 2000. Deepwater Working Group document 2009/16. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Doonan, I; Bull, B (2001) Absolute biomass for 1999, NE and East Chatham Rise. WG-Deepwater-01/27. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Doonan, I; Bull, B; Dunford, A; Coombs, R; Tracey, D; Hart, A (2001) Acoustic estimates of the biomass of aggregations of orange roughy in the Spawning Box and on the Northeastern and Eastern Hills, Chatham Rise, JuIy 2000. *New Zealand Fisheries Assessment Report 2001/70*. 31 p.

Doonan, I J; Dunn, M; Dunford, A; Hart, A C; Tracey, D (2006) Acoustic estimates of orange roughy abundance on the Northeastern and Eastern Chatham Rise, July 2004: wide-area survey and hill survey. *New Zealand Fisheries Assessment Report 2006/58*. 45 p.

Doonan, I J; Dunn, M; Hart, A C (2009) Abundance estimates of orange roughy on the Northeastern and Eastern Chatham Rise, July 2007: wide-area trawl survey and hill acoustic survey (TAN0709). *New Zealand Fisheries Assessment Report 2009/20*. 38 p.

Doonan, I; Hart, A C (2003) Notes on the abundance of mature orange roughy on the NW Chatham Rise and Graveyard Hills, ORH 3B, 20 June - 7 July 2002. WG-Deepwater- 03/01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Doonan, I.J.; Hart A.C.; Bagley, N.; Dunford, A. (2012). Orange roughy abundance estimates of the north Chatham Rise Spawning Plumes (ORH3B), *San Waitaki* acoustic survey, June-July 2011. *New Zealand Fisheries Assessment Report 2012/28*. 35 p.

Dunn, M R (2007) CPUE analysis and assessment of the Northeast Chatham Rise orange roughy stock (part of ORH 3B) to the end of 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2007/8*. 75 p.

Dunn, M R; Anderson, O F; Doonan, I J (2008) Evaluation of stock status for orange roughy on the east and south Chatham Rise for 2008. *New Zealand Fisheries Assessment Report 2008/65*. 30 p.

Dunn, M R; Devine, J A (2010) An holistic approach to determining stock structure of orange roughy on the Chatham Rise. *New Zealand Fisheries Assessment Report 2010/17*. 65 p.

Dunn, M R; Rickard, G J; Sutton, P J H; Doonan, I J (2009) Nursery grounds of orange roughy around New Zealand. *ICES Journal of Marine Science* 66: 871–885.

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 26 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Francis, R I C C (1995) The longevity of orange roughy: a reinterpretation of the radiometric data. New Zealand Fisheries Assessment Research Document 1995/2. 13 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Francis, R I C C (1996) Orange roughy sex ratios and catch rate distributions in the Chatham Rise Spawning Box. New Zealand Fisheries Assessment Research Document 1996/13. 27 p. (Unpublished document held by NIWA library.)

Francis, R I C C (2006) Some recent problems in New Zealand orange roughy assessments. *New Zealand Fisheries Assessment Report 2006/43*. 65 p.

Francis, R I C C (2001a) Orange roughy CPUE on the South and east Chatham Rise. *New Zealand Fisheries Assessment Report 2001/26*. 30 p.

Francis, R I C C (2001b) Stock Assessment of orange roughy on the South Chatham Rise. *New Zealand Fisheries Assessment Report 2001/27*. 25 p.

Francis, R I C C (2001c) Stock assessment for 2001 of orange roughy on the northeast Chatham Rise. *New Zealand Fisheries Assessment Report 2001/41*. 32 p.

Francis, R I C C; Bull, B (2000) Assessment of the northwest Chatham Rise orange roughy stock (part of ORH 3B). *New Zealand Fisheries Assessment Report 2000/21*. 17 p.

Francis, R I C C; Clark, M R; Coburn, R P; Field, K D; Grimes, P J (1995) Assessment of the ORH 3B orange roughy fishery for the 1994–95 fishing year. New Zealand Fisheries Assessment Research Document 1995/4. 43 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Francis, R I C C; Clark, M R; Grimes, P J (1997) Calculation of the recruited biomass of orange roughy on the northwest Chatham Rise using the 1996 Graveyard Hill egg survey (TAN9608). New Zealand Fisheries Assessment Research Document 1997/29. 18 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Francis, R I C C; Horn, P L (1997) Transition zone in otoliths of orange roughy (*Hoplostethus atlanticus*) and its relationship to the onset of maturity. *Marine Biology* 129: 681–687.

Francis, R I C C; Hurst, R J; Renwick, J A (2001) An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1*. 37 p.

Hampton, I; Soule, M; Nelson, J (2008) Standardisation of acoustic estimates of orange roughy biomass in the North Chatham Rise Spawning Plume between 1996 and 2007, made with vessel-mounted transducers. 26 p. (Unpublished report held by the Ministry for Primary Industries, Wellington).

Hampton, I; Soule, M; Nelson, J (2009) Corrections to time series of acoustic estimates of orange roughy spawning biomass in the Spawning Plume in area ORH3B from vessel-mounted transducers, 1996 to 2008. 29 p. WG-Deepwater-09/14. (Unpublished report held by the Ministry for Primary Industries, Wellington).

Hampton, I; Soule, M A; Nelson, J C (2010) Standardised acoustic estimates of orange roughy biomass in the Spawning Plume in area ORH 3B from vessel-mounted and towed transducers, 1996–2009. (Unpublished report held by the Ministry for Primary Industries, Wellington).

Hicks, A C (2006) Changes in lengths from the commercial catch in the Spawning Box. WG-Deepwater-06/ (Unpublished report held by the Ministry for Primary Industries, Wellington).

Hilborn, R; Walters, C J (1992) *Quantitative fisheries stock assessment: choice, dynamics, and uncertainty*. Chapman and Hall, New York, 570 p.

Horn, P L; Tracey, D M; Clark, M R (1998) Between-area differences in age and length at first maturity of the orange roughy *Hoplostethus atlanticus*. *Marine Biology* 132 (2): 187–194.

Kloser, R J; Horne, J K (2003) Characterizing uncertainty in target-strength measurements of a deepwater fish: orange roughy (*Hoplostethus atlanticus*). *ICES Journal of Marine Science* 60: 516–523.

Kloser, R J; Macaulay, G; Ryan, T; Lewis, M (2011) Improving acoustic species identification and target strength using frequency difference and visual verification: example for a deep-sea fish orange roughy. DWWG 2011-52. (Unpublished report held by the Ministry for Primary Industries, Wellington).

Macaulay, G; Kloser, R J; Ryan, T (2009) Visually verified *in situ* target strength measurements of orange roughy from the Chatham Rise, July 2007. Final Research Report for Ministry of Fisheries Research Project ORH2006-01A, Objective 2. (Unpublished report held by the Ministry for Primary Industries, Wellington). 45 p.

Mace, P M; Fenaughty, J M; Coburn, R P; Doonan, I J (1990) Growth and productivity of orange roughy (*Hoplostethus atlanticus*) on the north Chatham Rise. *New Zealand Journal of Marine and Freshwater Research* 24: 105–119.

McKenzie, A (2003) Standardised CPUE analysis and stock assessment of the northwest Chatham Rise orange roughy stock (part of ORH 3B). *New Zealand Fisheries Assessment Report 2003/61*. 24 p.

McKenzie, A (2005) Standardised CPUE analysis and stock assessment of the northwest Chatham Rise orange roughy stock (part of ORH 3B). Final Research Report for Ministry of Fisheries Project (ORH2003-02). 42 p (Unpublished report held by Ministry for Primary Industries, Wellington).

Robertson, D A; Mace, P M (1988) Assessment of the Chatham Rise orange roughy fishery for 1987/88. New Zealand Fisheries Assessment Research Document 1988/37. 5 p. (Unpublished report held by NIWA library, Wellington.)

Smith, M H (2006) Northwest Chatham Rise mature biomass estimate for the stock assessment. WG-Deepwater-06/17. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Smith, P J; Benson, P G (1997) Genetic diversity in orange roughy from the east of New Zealand. *Fisheries Research* 31(3): 197–213.

Soule, M A; Hampton, I; Nelson, J C; Tilney, R L (2010) Acoustic survey of orange roughy on the North Chatham Rise (ORH 3B), New Zealand. June/July 2010. Report prepared for New Zealand Deepwater Group Ltd.

Soule, M A; Nelson, J C; Hampton, I (2007) Acoustic survey of orange roughy in the spawning plume on the North Chatham Rise, New Zealand. DWWG-2008/83. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Taylor, P (2001) Assessment of orange roughy fisheries in southern New Zealand for 2000. *New Zealand Fisheries Assessment Report 2001/24*. 30 p.

Tracey, D; Horn, P; Marriott, P; Krusic-Golub, K; Gren, C; Gili, R; Mieres, L C (2007) Orange Roughy Ageing Workshop: otolith preparation and interpretation. (Unpublished report to the Deepwater Fisheries Assessment Working Group; held by the Ministry for Primary Industries, Wellington.)

ORANGE ROUGHY CHALLENGER PLATEAU (ORH 7A)

1. FISHERY SUMMARY

1.1 Commercial fisheries

Historically, the fishery mainly occurred in the south-western region of the Challenger Plateau, both inside and outside the EEZ. Fish were caught throughout the year, with most effort in winter when the orange roughy form aggregations for spawning. Domestic vessels caught most of the quota. Total catches peaked at 10 000–12 000 t annually from 1986–87 to 1988–89 (Table 1). Total catch and ORH 7A catch were less than 2100 t annually from 1990–91 until the closure in 2000–01 (Table 1, Figure 1), when the TACC for this stock was reduced to 1 t.

Recent surveys have shown an increase in biomass in the area. On 1 October 2010 the TACC was increased from 1 t to 500 t, with a 25 t allowance for other mortality, raising the TAC to a total of 525 t.

Table 1: Reported catches (t) and TACs (t) from 1980–81 to 2012–13. QMS data from 1986-present.

Fishing year	Inside EEZ	Outside EEZ	Total catch	TACC
1980–81†	1	32	33	-
1981–82†	3 539	709	4 248	-
1982–83†	4 535	7 304	11 839	-
1983–84†	6 332	3 195	9 527	-
1984–85†	5 043	74	5 117	-
1985–86†	7 711	42	7 753	-
1986–87†	10 555	937	11 492	10 000
1987–88	10 086	2 095	12 181	12 000
1988–89	6 791	3 450	10 241	12 000
1989–90	3 709	600	*4 309	2 500
1990–91	1 340	17	1 357	1 900
1991–92	1 894	17	1 911	1 900
1992–93	1 412	675	2 087	1 900
1993–94	1 594	138	1 732	1 900
1994–95	1 554	82	1 636	1 900
1995–96	1 206	463	1 669	1 900
1996–97	1 055	253	1 308	1 900
1997–98	+	+	1 502	1 900
1998–99	+	+	1 249	1 425
1999–00	+	+	629	1 425
2000–01	+	+	0.2	1
2001–02	+	+	0.1	1
2002–03	+	+	4	1
2003–04	+	+	< 0.1	1
2004–05	+	+	< 1#	1
2005–06	+	+	< 1#	1
2006–07	+	+	< 0.1	1
2007–08	+	+	< 0.1	1
2008–09	+	+	0.12#	1
2009–10	+	+	< 0.1#	1
2010–11	+	+	476	500
2011–12	+	+	511	500
2012–13	+	+	513	500
2013–14	+	+	497	500

†FSU data
*This is a minimum value, because of unreported catches by foreign vessels fishing outside the EEZ.
+Unknown distribution of catch between inside and outside the EEZ
Catches taken during winter trawl and acoustic surveys were approximately 200 t each year.

1.2 Recreational fisheries

There is no known recreational fishing for orange roughy in this area.

1.3 Customary non-commercial fisheries

There is no known customary non-commercial fishing for orange roughy in this area.

1.4 Illegal catch

There is no quantitative information available on illegal catch.

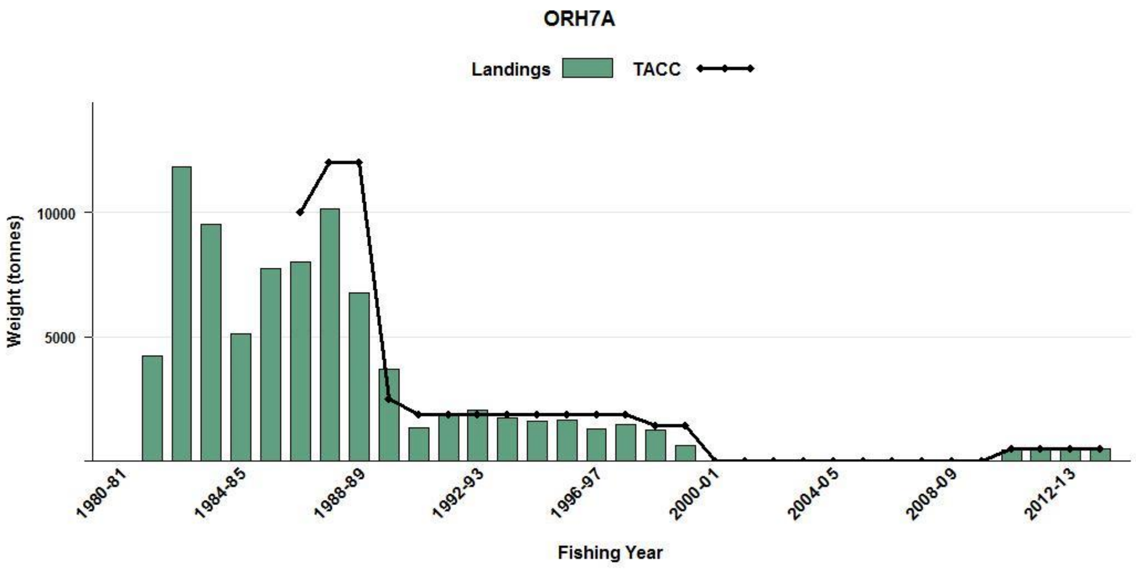


Figure 1: Reported commercial landings and TACC for ORH 7A. Note that this figure does not show data prior to entry into the QMS.

1.5 Other sources of mortality

In previous stock assessments, catch overruns from various sources (including lost and/or discarded fish, use of nominal tray weights and low conversion factors) have been estimated as: 1980–81 to 1987–88, 30%; 1988–89, 25%; 1989–90, 20%; 1990–91, 15%; 1991–92 to 1992–93, 10%; 1993–94 onwards, 5%.

2. BIOLOGY

Biological parameters used in this assessment are presented in the Biology section at the beginning of the Orange Roughy Introduction section.

3. STOCKS AND AREAS

There is no new information on orange roughy stock structure beyond that presented in previous assessment documents.

Orange roughy on the southwest Challenger Plateau (Area 7A, including Westpac Bank) are regarded as a single separate stock. Size structure, parasite composition, flesh mercury levels, allozyme frequency and mitochondrial DNA studies show differences to other major fisheries. Spawning occurs at a similar time to fish on the Chatham Rise, Puysegur Bank, Ritchie Banks, Cook Canyon and Lord Howe Rise.

4. STOCK ASSESSMENT

A model-based Bayesian stock assessment was carried out for this stock in 2014. It was the first model-based assessment since 2005 (MFish 2006) when a Bayesian model was used to update the 2000 assessment (Annala et al 2000, Field & Francis 2001). From 2010 to 2013, assessments were conducted using an ad hoc approach which combined the virgin biomass estimate from the 2000 assessment and current biomass estimates from annual combined acoustic and trawl surveys (see Clark et al 2006, NIWA & FRS 2009, Doonan et al 2010, Hampton et al 2012, Hampton et al 2013, Cordue 2010, 2012, 2013).

The 2014 assessment for this stock was one of four orange roughy assessments carried out in 2014 which all used similar methods (see Orange Roughy Introduction). An age-structured population model was fitted to combined acoustic and trawl-survey estimates of spawning biomass, two trawl-survey time series of spawning biomass, and three trawl-survey age frequencies.

4.1 Model structure

The model was single-sex and age-structured (1-100 years with a plus group), with maturity estimated separately (i.e., fish were classified by age and as mature or immature). Two time steps were used: a full year of natural mortality followed by an instantaneous spawning season and fishery on the spawning fish. The fishery selectivity was uniform across ages (for spawning fish) and 100% of mature fish were assumed to spawn each year.

The catch history was constructed from the total catches in Table 1 and the over-run percentages in Section 1.5. Natural mortality was assumed to be fixed at 0.045 and the stock-recruitment relationship was assumed to follow a Beverton-Holt function with steepness of 0.75. The remaining fixed biological parameters are given in the Orange Roughy Introduction.

4.2 Input data and statistical assumptions

There were three main data sources for observations fitted in the assessment: spawning biomass estimates from combined acoustic and trawl surveys (2006, 2009–2013); an early trawl survey time series of relative spawning biomass (1987–1989); and three age frequencies from the trawl surveys (1987, 2006, and 2009).

4.2.1 Research surveys

Trawl surveys of orange roughy on the Challenger Plateau were conducted regularly from 1983 to 1990. However, a variety of vessels and survey strata were used which makes comparisons problematic (Dunn et al 2010). Wingtip biomass estimates in 1983–1986 ranged from 100 000–185 000 t but the 1989 and 1990 survey estimates much lower at approximately 10 000 t. From these early trawl surveys a “comparable area” time series, defined by Clark & Tracey (1994) and covering the period 1987–89, was selected for use in the assessment to provide some information on the early rate of spawning biomass decline (Table 2).

In 2005, a new series of combined trawl and acoustic surveys was begun using the *FV Thomas Harrison* with a survey area comparable to that used from 1987–1990 (Clark et al 2005). The survey was repeated in 2006 (with an enlarged survey area) and was then conducted annually from 2009–2013 (Clark et al 2006, NIWA & FRS 2009, Doonan et al 2010, Hampton et al 2012, Hampton et al 2013). It was apparent from the later surveys that the 2005 survey did not cover an appropriate area as the spawning biomass distribution had shifted somewhat in the intervening years. The surveys from 2006 onwards appear to have covered the bulk of the spawning biomass. The data from these surveys have been analysed to produce three types of indices used in this assessment: combined acoustic and trawl survey spawning biomass; acoustic estimates of spawning plumes; trawl survey indices of spawning biomass.

Combined acoustic and trawl survey indices

The method of Cordue (2010, 2012) was used to produce combined acoustic and trawl survey indices for 2010 and 2013 (Table 2). This method used an estimate of orange roughy trawl vulnerability to allow the trawl survey estimates to be combined with the acoustic estimates (trawl estimates are essentially scaled down by a vulnerability distribution with a mean of 1.66). The method accounts for observation error and potential bias in orange roughy target strength by combining priors and “error distributions” centred on the observations (Cordue 2010, 2012). Strata 9-11 were excluded from the estimates as they covered hills and/or very rough terrain (i.e., were not included because orange roughy are probably not equally vulnerable to the trawl gear on the hills and on the flat).

The 2010 and 2013 surveys were used in this way for different reasons. In 2010, the survey specifically excluded spawning plumes from the trawl survey strata and the plumes were surveyed acoustically. In other years, plumes were not explicitly excluded from the trawl survey area and a number of random trawl stations did obtain very high catch rates in the vicinity of plumes. The 2010 design was specifically aimed at combining the acoustic and trawl survey estimates.

The 2013 survey had three trawl stations with very high catch rates in two strata which were near where spawning plumes were surveyed. As a consequence, the trawl survey index had a very high CV of 51%. It seemed preferable to replace the trawl estimates from the two "plume" strata with the corresponding acoustic estimates and combine them with the remaining trawl estimates (following Cordue 2012) which gave a combined index with a lower CV of 35% (Table 2).

The estimates were used as relative biomass with a lognormal informed prior on the *q*. The total survey area was assumed to cover 90% of the spawning biomass and the three excluded strata (9-11) were estimated to account for 15% of the surveyed biomass (from years in which they were surveyed). The mean of the informed prior was therefore 0.9 × 0.85 = 0.77. The CV was chosen so that the CVs for the prior and the observation were equal in 2010 and the combined CV from observation error and the prior were equal to 0.3 (2010) and 0.35 (2013) (the CVs of the distribution-estimates of spawning biomass). This gave a prior CV of 0.21.

Acoustic estimate for two plumes in 2009

Two spawning plumes were acoustically surveyed on 4–5 July 2009. The main plume was covered by two snapshots and had a much higher average biomass than was seen in a comparable survey conducted during the previous few days (28 June–2 July): 16 800 t compared to 6700 t. A second plume was also surveyed with a single snapshot (6300 t) and the combined estimate was 23 100 t (Table 2). This unusual event led to the conclusion that "most" of the 2009 spawning biomass was present in the two surveyed plumes.

This was modelled by treating the acoustic estimate as relative biomass and estimating the proportionality constant (*q*) with an informed prior. The acoustic *q* prior described in the Orange Roughy Introduction was used: a mean of 0.8 (i.e., "most" = 80%) and a CV of 19%.

Trawl survey indices

The spawning biomass estimates from the *Thomas Harrison* trawl surveys in 2006, 2009–2012 (Table 2) were used as relative biomass with an informed prior. They excluded the rough terrain strata 9-11 and the mean of the informed prior was: 0.9 × 0.85 × 1.66 = 1.27 (allowing for total-survey availability (0.9), exclusion of strata 9-11 (0.85) and trawl vulnerability – mean of estimated vulnerability distribution = 1.66). Given the problematic nature of these trawl surveys (fish pluming and moving within the area), a process error CV of 20% was added to the estimated CVs (Table 2).

Table 2: Biomass indices used in the stock assessment. The model CV is the observation error used in the base model. A 20% process error CV has been added to the sample CV for the trawl indices. The CV for the combined acoustics and trawl estimates has been split between the informed *q*-prior (CV = 21%) and the observation error in the model.

Series	Year	Biomass index (t)	CV (%)	Model CV (%)
Amaltal Explorer	1987	75 040	26	33
	1988	28 954	27	34
	1989	11 062	11	23
Thomas Harrison	2006	13 987	27	34
	2009	34 864	24	31
	2011	18 425	26	33
	2012	22 451	18	27
	2013	18 993	51	55
Acoustics & trawl	2010	14 766	30	21
	2013	13 637	35	28
Two plumes	2009	23 095	25	25

Age frequencies

Age frequencies were available from three of the trawl surveys for use in the assessment. A previous analysis produced age frequencies for the 1987 *Amaltal Explorer* survey and the 2009 *Thomas Harrison* survey (Doonan et al 2013), although that study was based on a relatively small number of otoliths, it showed that the 2009 age frequency had much younger fish than the 1987 age frequency. For the stock assessment, the existing age frequencies were augmented with an increased number of otoliths (for a total of about 300 for each survey) and a new age frequency (from about 300 otoliths) was produced for the 2006 *Thomas Harrison* survey.

The age frequencies were assumed to be multinomial and were assigned effective sample sizes of 300/5 = 60 (with the sample size reflecting the number of trawl stations rather than the number of otoliths).

4.3 Model runs and results

In the base model, natural mortality (*M*) was fixed at 0.045. There were numerous MPD sensitivity runs but three main sensitivities are presented in this report: estimate *M*; and the LowM-Highq and HighM-Lowq runs (see the Orange Roughy Introduction section for specifications).

In the base model the main parameters estimated were: virgin biomass (B_0), the maturity ogive, and year class strengths (YCS) from 1925 to 1985 (with the Haist parameterisation and “nearly uniform” priors on the free parameters). There were also the proportionality constants (*q*) for the two trawl survey time series, the combined acoustic and trawl estimates (2010, 2013) and the two-plumes estimate in 2009.

4.3.1 Model diagnostics

The model provided good MPD fits to the biomass indices although the 2009 trawl index had a large positive residual (Figure 2, top right). The large positive residual in 2009 was balanced by negative residuals in the other years. In a sensitivity run, taken through to MCMC, the 2009 index was removed. This had no effect on the stock status estimates for the MPD or MCMC runs but it did provide an improved fit to the other biomass indices (the 2009 index is not influential in terms of important derived estimates but does affect the residual pattern). The MCMC normalised residuals for the biomass indices show a similar pattern to the MPD fit, but the only large residuals are for the *Amaltal Explorer* time series (Figure 3). The magnitude of the *Amaltal Explorer* residuals could be reduced by adding more process error, but this would not affect any of the important assessment estimates (the same results are obtained if the *Amaltal* time series is removed altogether).

The MPD fit to the age frequencies was very good (Figure 4).

The biomass indices with the informed priors are free to “move” somewhat as they are relative. The MPD estimated *q*s were not very different from the mean of the informed priors (Figure 5, blue dots). The same is not true for the MCMC runs, as the *Thomas Harrison q* and the combined acoustics and trawl *q* have both moved to the left appreciably (Figure 5, right-hand plots). Although they have moved, the posteriors are still well within the distribution of the priors, leaving the estimated *q*s credible.

Numerous MPD sensitivity runs were performed. These showed that the main drivers of the estimated stock status were natural mortality (*M*) and the means of the informed *q* priors (lower *M* and higher mean *q* give lower stock status; higher *M* and lower mean *q* give higher stock status). The base model was robust to changes in the relative weights of the different data sets. Large changes in estimated 2014 stock status only occurred when deterministic recruitment was assumed (49% B_0 compared to 32% B_0 for the base) or when recent biomass indices were halved or doubled (respectively 18% B_0 and 50% B_0).

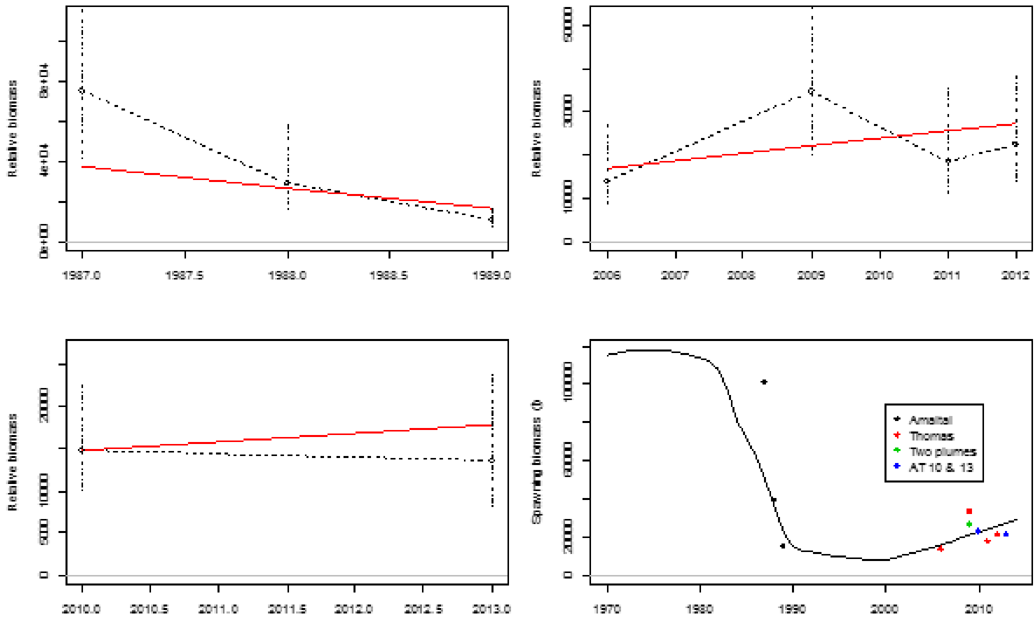


Figure 2: MPD fit to biomass indices: top left: *Amaltal Explorer*; top right: *Thomas Harrison*; bottom left: combined acoustics and trawl; bottom right: indices scaled to spawning biomass (using MPD estimated *qs*). Vertical lines are 95% CIs (model CVs).

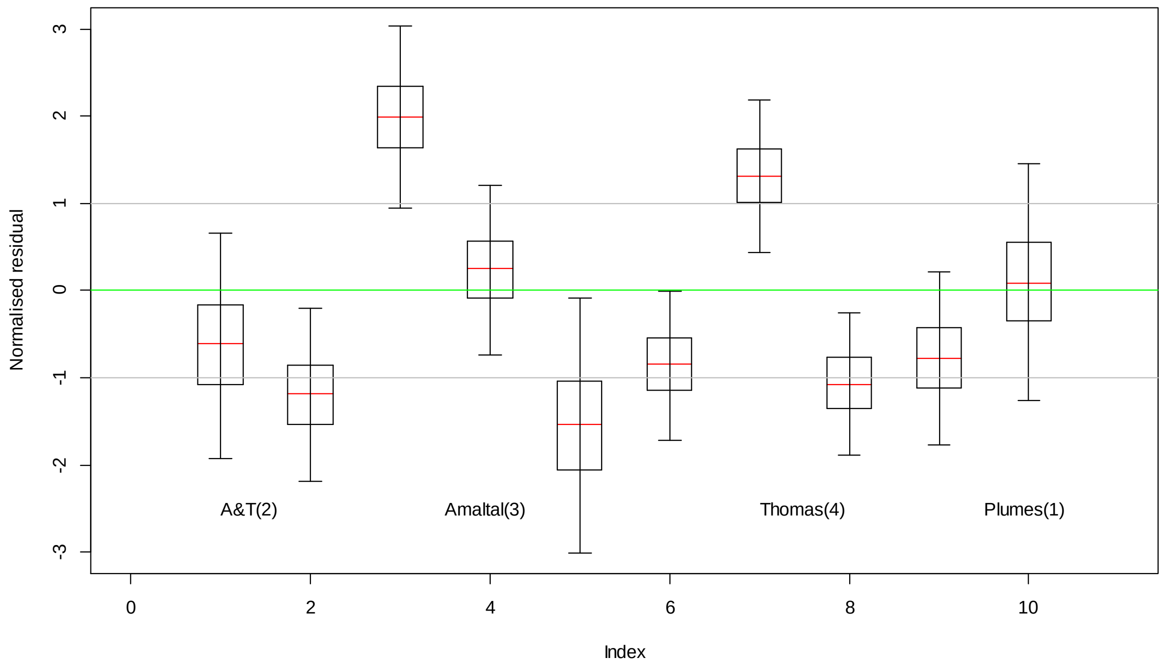


Figure 3: MCMC base: normalised residuals for the biomass indices. The box covers 50% of the distribution for each index and the whiskers extend to 95% of the distribution. "A&T" denotes combined acoustics and trawl (2010, 2013); "Amaltal" the *Amaltal Explorer* series; "Thomas" the *Thomas Harrison* series; and "Plumes" the two-plumes estimate from 2009.

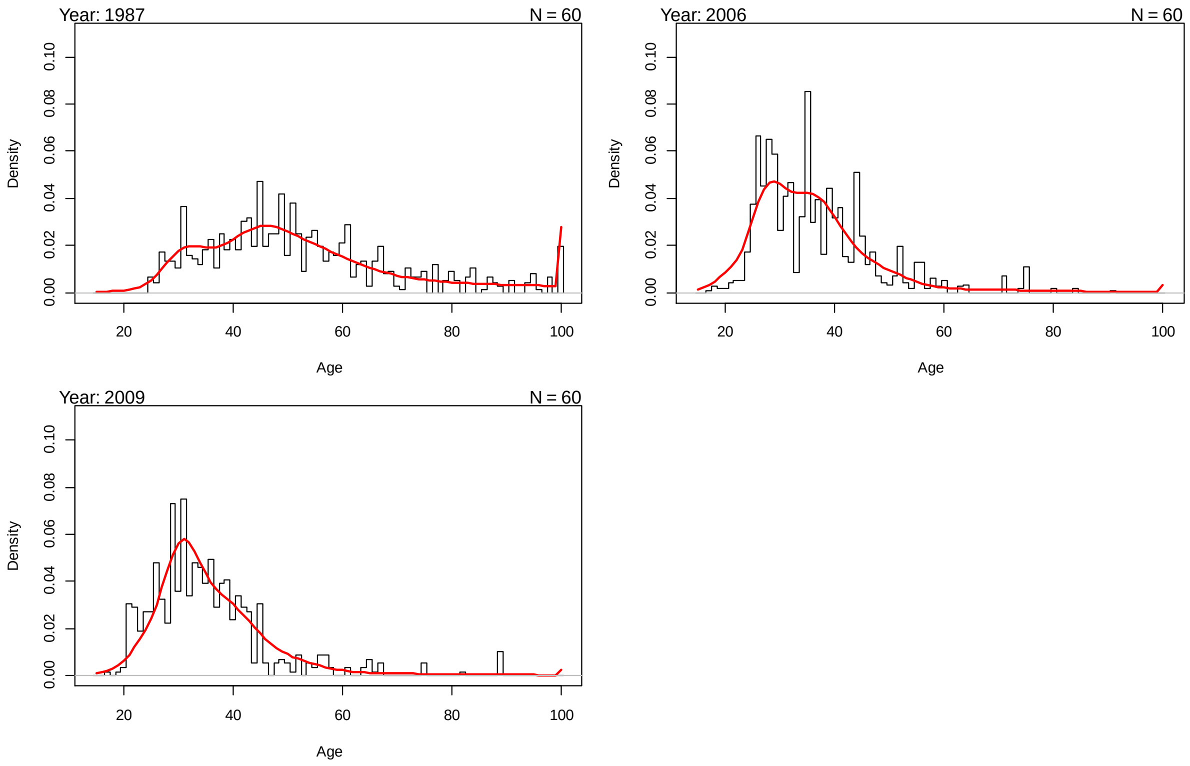


Figure 4: MPD fit to spawning-season trawl-survey age frequencies for the 1987, 2006 and 2009 surveys (N = 60 is the assumed effective sample size). Observations are square-topped black lines; model predictions are the smooth red lines.

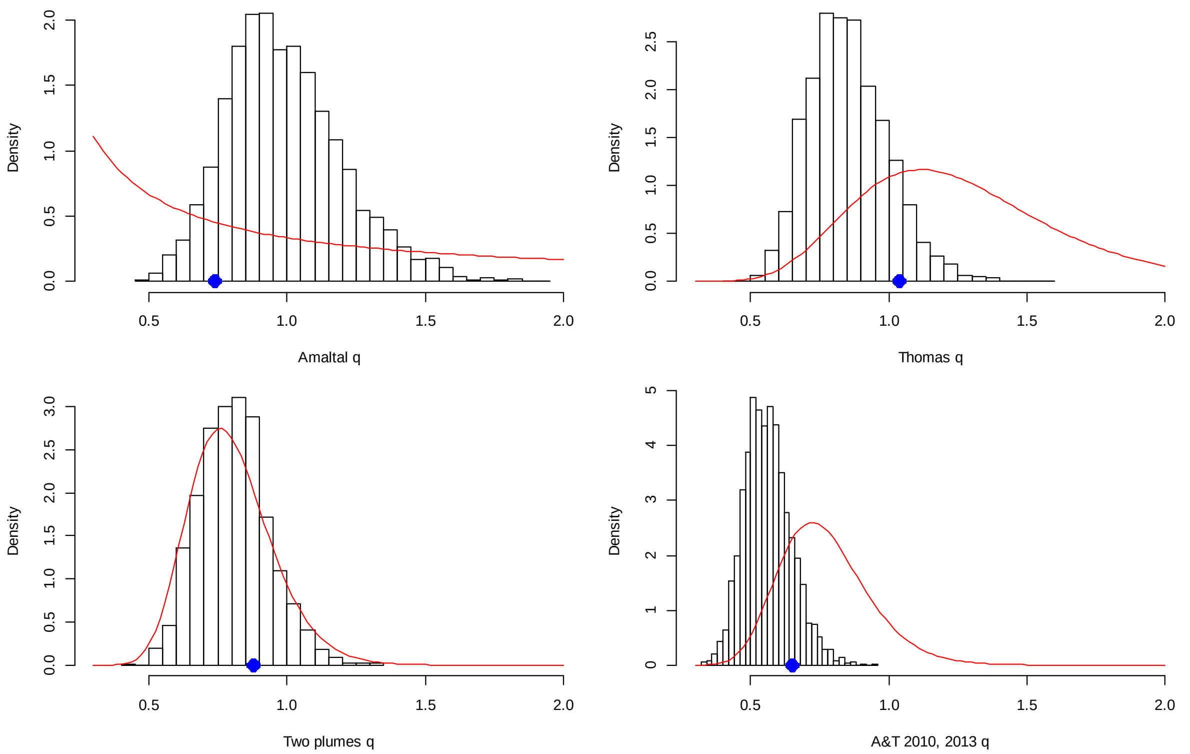


Figure 5: Base model MCMC diagnostics: prior and posterior distributions for the biomass time series *qs* (prior in red, posterior black histograms; the blue dot is the MPD estimate. "Amaltal q" denotes the *Amaltal Explorer* series; "Thomas q" the *Thomas Harrison* series; "Two plumes q" the two-plumes estimate from 2009; and "A&T 2010, 2013 q" denotes combined acoustics and trawl for those years).

MCMC results

For the base model, and the sensitivity runs, MCMC convergence diagnostics were excellent. Virgin biomass (B_0) was estimated to be about 90 000 t for all runs (Table 3). Current stock status was similar for the base and the estimate-*M* run (Table 3). The slightly lower stock status when *M* was estimated reflects the lower estimate of *M* (0.039 rather than 0.045). For the two runs, where *M* and the mean of the informed *q* priors were shifted either up or down by 20%, median current stock status was estimated within the biomass target range of 30–40% B_0 for the *LowM-Highq* run but well above the range for the *HighM-Lowq* run (Table 3).

Table 3: MCMC estimates of virgin biomass (B_0) and stock status (B_{2014} as %B_0) for the base model and three sensitivity runs.

	M	B_0 (000 t)	95% CI	B_{2014} (%B_0)	95% CI
Base	0.045	88	82-96	42	35-49
Estimate M	0.039	92	84-100	38	30-47
LowM-Highq	0.036	90	85-97	33	27-40
HighM-Lowq	0.054	88	81-97	51	44-59

The estimated YCS show little variation across cohorts but exhibit a long-term trend (Figure 6). The most recent 10 years (1976–1985) of estimates (those resampled for short-term projections) are about average.

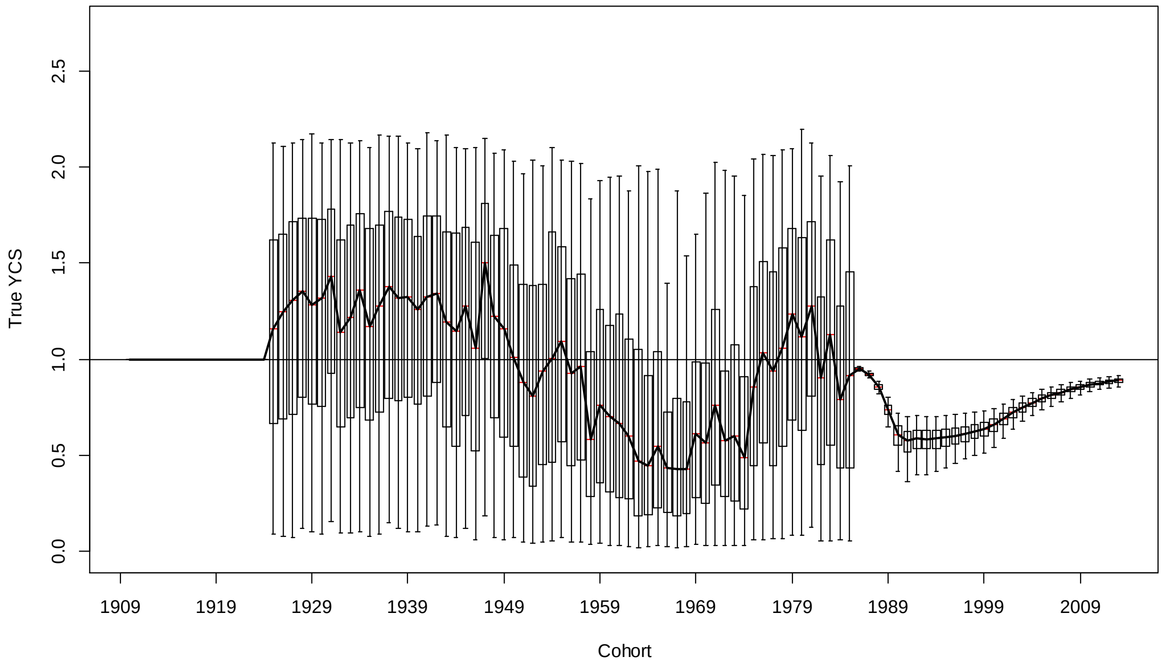


Figure 6: Base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

The stock status trajectory showed a steep decline to about 10% B_0 in 1990, reflecting the large removals during the initial fish-down phase of this fishery (Figure 7). From 1990 stock status remained at about 10% B_0 until a strong upturn in 2000 (Figure 7). Rebuilding has taken only 14 years to reach the top of the 30-40% biomass target range because the fishery was closed in 2001 and reopened in 2011, with relatively limited catches since then (see Table 1).

For the base model, the stock is now considered to be fully rebuilt according to the Harvest Strategy Standard (at least a 70% probability that the lower end of the management target range of 30–40% B_0 has been achieved).

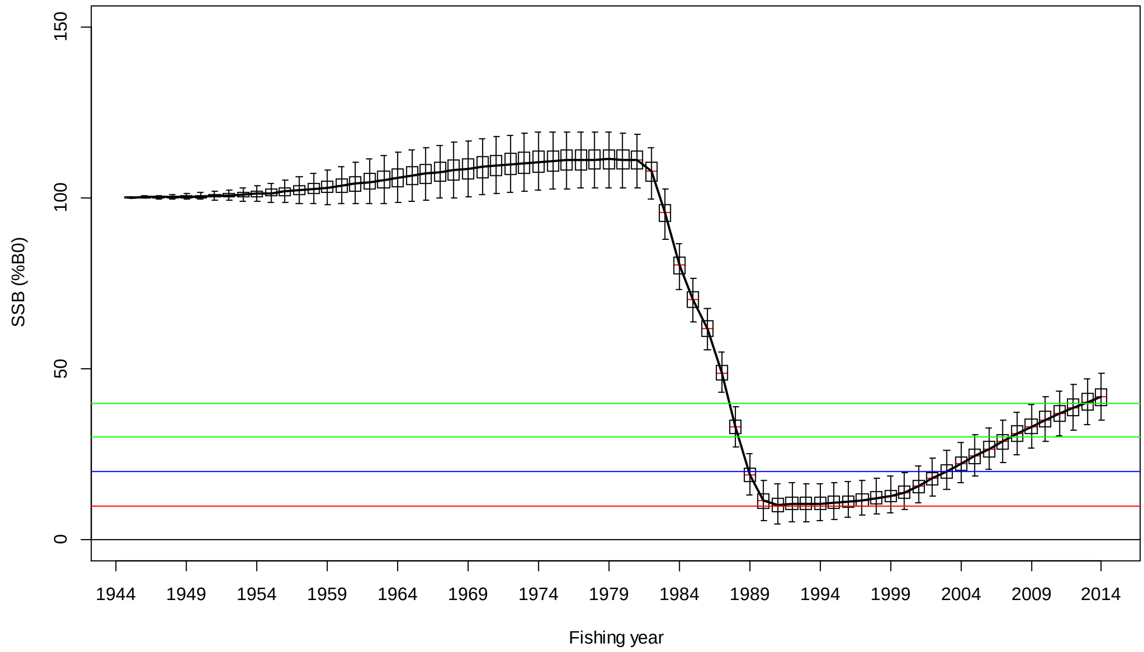


Figure 7: Base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The hard limit 10% B_0 (red), soft limit 20% B_0 (blue), and biomass target range 30–40% B_0 (green) are marked by horizontal lines.

Fishing intensity was estimated in each year for each MCMC sample to produce a posterior distribution for fishing intensity by year. Fishing intensity is represented in term of the median exploitation rate and the Equilibrium Stock Depletion (ESD). For the latter, a fishing intensity of $U_{x\%B0}$ means that fishing (forever) at that intensity will cause the SSB to reach deterministic equilibrium at x% B_0 (e.g., fishing at $U_{30\%B0}$ drives the SSB to a deterministic equilibrium of 30% B_0). Fishing intensity in these units is plotted as 100–ESD so that fishing intensity ranges from 0 ($U_{100\%B0}$) up to 100 ($U_{0\%B0}$).

Estimated fishing intensity was within or above the target range ($U_{30\%B0}$–$U_{40\%B0}$) up until the closure of the fishery in 2001. Since then, it has been well below the target range (Figure 8).

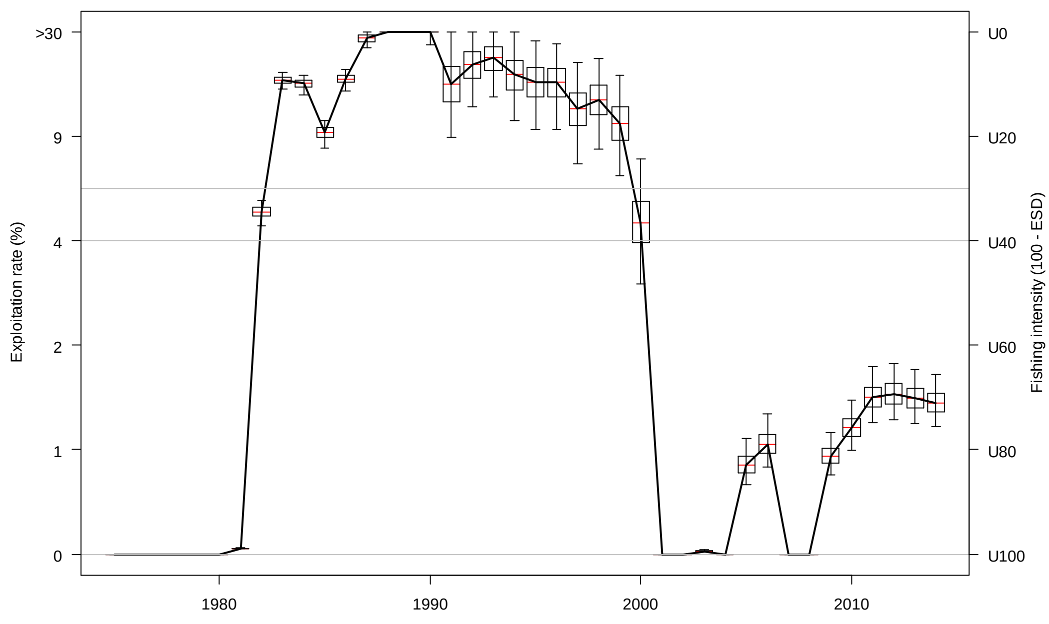


Figure 8: Base, MCMC estimated fishing-intensity trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The fishing-intensity range associated with the biomass target of 30-40% B_0 is marked by horizontal lines.

Biological reference points, management targets and yield

MCMC estimates of deterministic B_{MSY} and associated values were produced for the base model. The yield at 35% B_0 (the mid-point of the target range) was also estimated. There is little variation in the reference points and associated values across the MCMC samples (Table 4).

There are several reasons why deterministic B_{MSY} is not a suitable target for use in fisheries management. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge (current biomass must be known exactly in order to calculate the target catch) and annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders). Second, it assumes perfect knowledge of the stock-recruit relationship, which is often poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard.

Table 4: Base, MCMC estimates of deterministic equilibrium SSB and long-term yield (% B_0 and tonnes) for U_{MSY} and $U_{35\%B0}$. The equilibrium SSB at U_{MSY} is deterministic B_{MSY} and the yield is deterministic MSY.

Fishing intensity		SSB (%B_0)	Yield (%B_0)	Yield (t)
U_{MSY}	Median	24.5	2.1	1853
	95% CI	22.9-24.9	2.1-2.1	1728–2009
$U_{35\%B0}$	Median	35.0	2.0	1764
	95% CI	35.0-35.0	2.0-2.0	1645–1912

The estimate of long–term yield associated with $U_{35\%B0}$ for the 2014-15 fishing year is 2128 t (95% CI 1673–2694 t).

Projections

Five-year projections were conducted (with resampling from the last 10 estimated YCS, 1976–1985) for two different constant catch assumptions: 500 t (the current TACC); and 2100 t (the current estimated yield at $U_{35\%B0}$). In each case a 5% catch over-run was assumed. Projections were done for the base model and for the *LowM-Highq* sensitivity model (as a "worst case" scenario).

At the current TACC (500 t), SSB is predicted to increase steadily over the next five years for both models (Figure 9). At the catch associated with $U_{35\%B0}$ (2100 t), SSB is predicted to decrease slightly for both models (Figure 9). For both models and both constant catch scenarios the estimated probability of SSB going below either the soft limit (20% B_0) or hard limit (10% B_0) is zero. For the *LowM-Highq* model there is a small probability (1.5% and 3% respectively) of the SSB falling below 20% B_0 in 2018 or 2019 under a 2100 t catch (Figure 9).

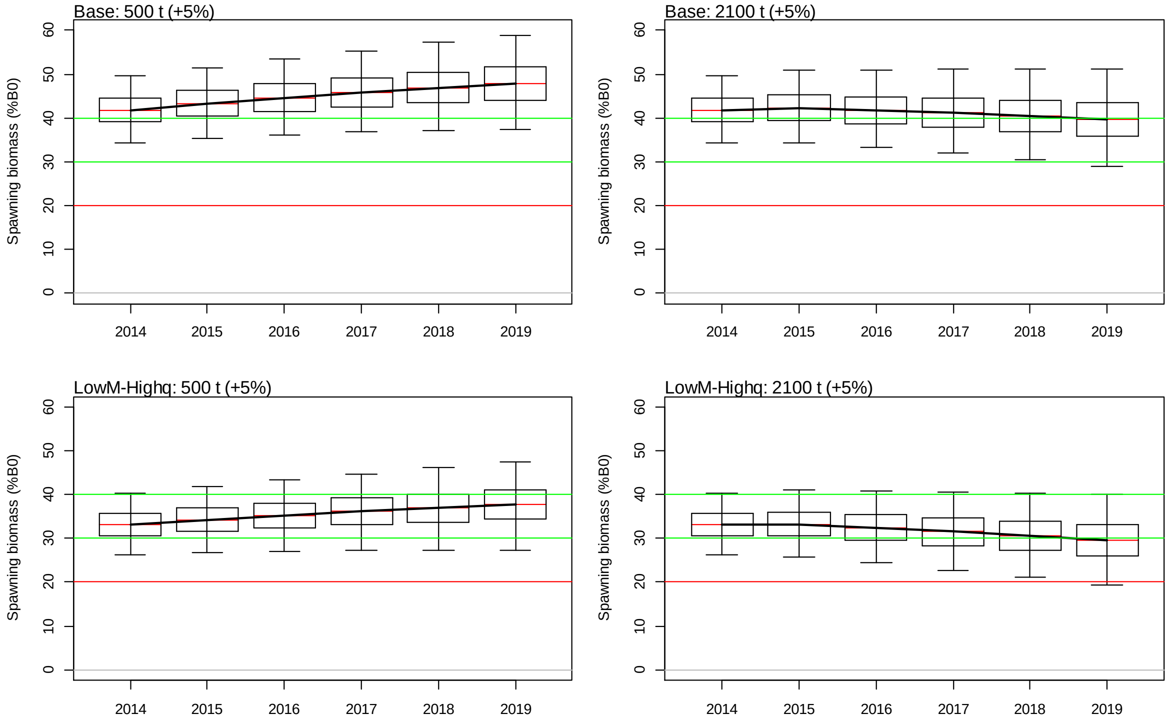
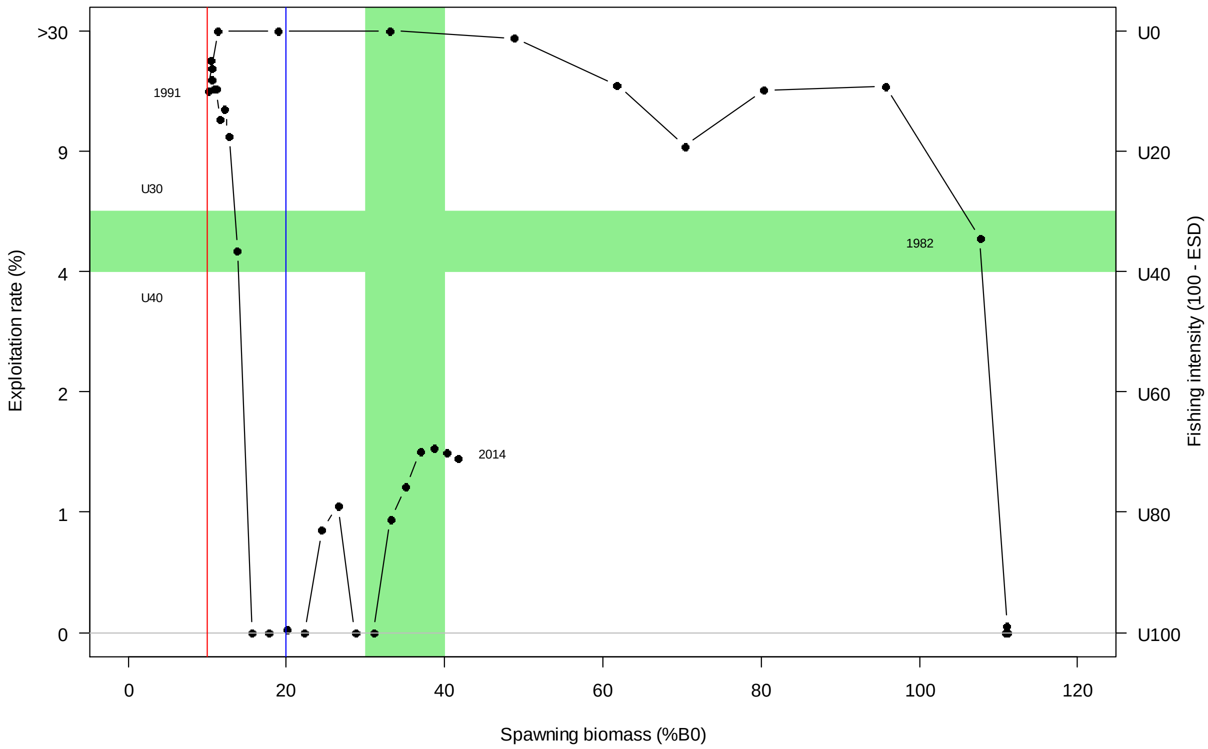


Figure 9: Base, MCMC projections. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The projections are for the model and annual catch indicated (a 5% catch over-run was included in each year). The target biomass range(30–40% B_0) is indicated by horizontal green lines, the hard limit (10% $B_{0)}$ by a red line and the soft limit (20% $B_{0)}$ by a blue line.

5. STATUS OF THE STOCK

Orange roughy on the southwest Challenger Plateau (Area 7A, including Westpac Bank) are regarded as a single separate stock.

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base model only
Reference Points	Management Target: Biomass range 30–40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Fishing intensity range $U_{30\%B0}$–$U_{40\%B0}$
Status in relation to Target	B_{2014} was estimated to be 42% B_0 Very Likely (> 90%) to be at or above the lower end of the management target range and About as Likely as Not (40–60%) to be at or above the upper end of the management target range
Status in relation to Limits	B_{2014} is Very Unlikely (< 10%) to be below the Soft Limit B_{2014} is Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Fishing intensity in 2014 was estimated at $U_{71\%B0}$ Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status

Historical trajectory of spawning biomass (%*B₀*), median exploitation rate (%) and fishing intensity (100-ESD) (base model, medians of the marginal posteriors). The biomass target range of 30-40% B_0 and the corresponding exploitation rate (fishing intensity) range are marked in green. The soft limit (20% B_0) is marked in blue and the hard limit (10% B_0) in red. Note that the Y-axis is non-linear.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The spawning biomass is estimated to have been steadily increasing since just before the fishery closure in 2000–2001. According to the Harvest Strategy Standard, the stock is now considered to be fully rebuilt (at least a 70% probability that the lower end of the management target range of 30–40% B_0 has been achieved).
Recent Trend in Fishing Intensity or Proxy	The fishery was closed in 2000-01 and re-opened in 2010-11, with fisheries surveys conducted since 2005. Fishing intensity has been low and fairly constant since 2010-11.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Biomass is expected to increase at the current TACC (500 t) or decrease slightly over the next 5 years at annual catches of up to 2100 t.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	-Combined acoustic and trawl survey estimates of spawning biomass (2010, 2013)	1 – High Quality
	-Acoustic survey estimate of spawning biomass from two plumes in 2009	1 – High Quality
	-Two trawl survey time series: 1987-1989 and 2006, 2009-2012	1 – High Quality
	-Age frequencies from the trawl surveys in 1987, 2006, and 2009	1 – High Quality
Data not used (rank)	-CPUE	3 – Low Quality: unlikely to be indexing stock-wide abundance
	-Acoustic surveys of hills (hull-mounted transducers)	2 – Medium or Mixed Quality: species identification and dead zone problems
	-Early trawl surveys with different vessels covering different areas	2 – Medium or Mixed Quality: not a consistent time series
Changes to Model Structure and Assumptions	-The previous model-based assessment was in 2005. Recent assessments have been based on an ad hoc method. -The current assessment is fully quantitative and based on spawning biomass rather than transition-zone mature biomass. -Age data were included to enable estimation of year class strengths rather than assuming deterministic recruitment. - A more stringent data quality threshold was imposed on data inputs (e.g. CPUE indices were not used).	
Major Sources of Uncertainty	-The proportion of the stock that is indexed by the combined acoustic and trawl survey. -Patterns in year class strengths are based on only 3 years of age composition data.	

Qualifying Comments
- Estimates of stock biomass are sensitive to the means of the *q* priors. In addition, when higher CVs were used for the informed acoustic *q* priors, the median estimates of biomass and stock status were slightly higher and the confidence intervals were wider with a much higher upper bound.

Fishery Interactions
Historically, the main bycatch species were deepwater dogfish, spiky oreos and ribaldo. Since the fishery re-opened with a low level of catch and effort and fishing during the spawning season, bycatch levels have been relatively low at about 4%. The bycatch of low productivity species includes deepwater sharks, deepsea skates and corals. With limited fishing effort, there have been no observed incidental captures of protected species other than corals since 2002–03.

6. FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J; O'Brien, C J (Comps.) (2000) Report from the Fishery Assessment Plenary, May 2000: stock assessments and yield estimates. 495 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Clark, M R (1991) Assessment of the Challenger Plateau (ORH 7A) orange roughy fishery for the 1991/92 fishing year. New Zealand Fisheries Assessment Research Document 1991/2. 19 p. (Unpublished document held in NIWA library, Wellington.)

Clark, M R (1992) Assessment of the Challenger Plateau (ORH 7A) orange roughy fishery for the 1992/93 fishing year. New Zealand Fisheries Assessment Research Document 1992/6. 14 p. (Unpublished document held in NIWA library, Wellington.)

Clark, M R; O'Driscoll, R L; Macaulay, G (2005) Distribution, abundance, and biology of orange roughy on the Challenger Plateau: results of a trawl and acoustic survey, June–July 2005 (THH0501). NIWA Client Report WLG2005-64.

Clark, M R; O'Driscoll, R L; Macaulay, G; Bagley, N W; Gauthier, S (2006) Distribution, abundance, and biology of orange roughy on the Challenger Plateau: results of a trawl and acoustic survey, June–July 2006. NIWA Client Report WLG2006-83.

Clark, M R; Tracey, D M (1994) Changes in a population of orange roughy, *Hoplostethus atlanticus*, with commercial exploitation on the Challenger Plateau, New Zealand. *Fishery Bulletin, U.S.* 92: 236–253.

Cordue, P L (2010) Estimation of absolute biomass from the 2009 trawl and acoustic survey of Challenger orange roughy. ISL Client Report. *For* Deepwater Group Ltd. 24 p.

Cordue, P L (2012) Estimation of absolute biomass from the time series of trawl and acoustic surveys of Challenger orange roughy. ISL Client Report. *For* MAF. 30 p. (Unpublished document held by Ministry for Primary Industries, Wellington.)

Cordue, P L (2013) Estimating absolute orange roughy biomass for the southwest Challenger Plateau: 2005-2012. DWWG document 2013_25 Draft Report to MPI on ORH 7A.15 p. (Unpublished document held by Ministry for Primary Industries, Wellington.)

Doonan, I J; Horn, P L; Krusic-Golub, K (2013) Comparison of Challenger Plateau (ORH 7A) orange roughy age estimates between 1987 and 2009. *New Zealand Fisheries Assessment Report 2013/2*. 19 p.

Doonan, I J; Parkinson, D; Gauthier, S (2010) Abundance, distribution, and biology of orange roughy on the southwest Challenger Plateau (area ORH 7A): results of a trawl and acoustic survey, June-July 2010. NIWA Client Report WLG2010-63.

Dunn, M R; Cordue, P L; Langley, A; Stokes, K (2010) Review of data and potential stock assessment approaches for orange roughy on the Challenger Plateau (ORH 7A). Draft New Zealand Fisheries Assessment Report. 41 p.

Field, K D (1999) Assessment of the Challenger Plateau (ORH 7A) orange roughy fishery for the 1998–99 fishing year. New Zealand Fisheries Assessment Research Document 1999/9. 19 p. (Unpublished document held in NIWA library, Wellington.)

Field, K D; Clark, M R (1996) Assessment of the ORH 7A orange roughy fishery for the 1996–97 fishing year. New Zealand Fisheries Assessment Research Document 1996/20. 16 p. (Unpublished document held in NIWA library, Wellington.)

Field, K D; Francis, R I C C (2001) CPUE analysis and stock assessment of the Challenger Plateau orange roughy stock (ORH 7A) for the 2000–01 fishing year. *New Zealand Fisheries Assessment Report 2001/25*. 19 p.

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27 p. (Unpublished document held in NIWA library, Wellington.)

Francis, R I C C; Clark, M R; Coburn, R P; Field, K D; Grimes, P J (1995) Assessment of the ORH 3B orange roughy fishery for the 1994–95 fishing year. New Zealand Fisheries Assessment Research Document 1995/4. 44 p. (Unpublished document held in NIWA library, Wellington.)

Francis, R I C C; Robertson, D A; Clark, M R; Coburn, R P (1992) Assessment of the ORH 3B orange roughy fishery for the 1992–93 fishing year. New Zealand Fisheries Assessment Research Document 1992/4. 46 p. (Unpublished document held in NIWA library, Wellington.)

Hampton, I (2010) Re-analysis of data from acoustic surveys of orange roughy on the Challenger Plateau (Area ORH7A) in 2005, 2006 and 2009. DWWG document 2010/38. 9 p. (Unpublished document held by Ministry for Primary Industries, Wellington.)

Hampton, I; Boyer, D C; Leslie, R W; Nelson, J C (2014) Acoustic and trawl estimates of orange roughy (*Hoplostethus atlanticus*) biomass on the southwest Challenger Plateau, June/July 2012. *New Zealand Fisheries Assessment Report.* 2014/15. 43 p.

Hampton, I; Boyer, D C; Leslie, R W; Nelson, J C; Soule, M A; Tilney, R L (2013) Acoustic and trawl estimates of orange roughy (*Hoplostethus atlanticus*) biomass on the southwest Challenger Plateau, June/July 2011. *New Zealand. Fisheries Assessment Report.* 2013/48. 45p.

MFish (2006). Ministry of Fisheries, Science Group (Comps.) 2006: Report from the Fishery Assessment Plenary, May 2006: stock assessments and yield estimates. 875 p. (Unpublished report held in NIWA library, Wellington).

NIWA & FRS (2009) Abundance, distribution, and biology of orange roughy on the southwest Challenger Plateau (area ORH7A): results of a trawl and acoustic survey, June–July 2009. NIWA Client Report: 2009-59. FRS Client Report. 73 p.

Tracey, D; Horn, P; Marriott, P; Krusic-Golub, K; Gren, C; Gili, R; Mieres, L C (2007) Orange Roughy Ageing Workshop: otolith preparation and interpretation. Draft report to DWWG. (Unpublished document held by Ministry for Primary Industries, Wellington.)

ORANGE ROUGHY WEST COAST SOUTH ISLAND (ORH 7B)

1. FISHERY SUMMARY

1.1 Commercial fisheries
From 1 October 2007 the TACC for this stock was reduced to 1 t. Previously the fishery was centred on an area near the Cook Canyon in statistical areas 033, 034 and 705. Up until 1996–97 approximately 80% of the catch was taken in winter (June–July) when fish form aggregations for spawning. From 1997–98 onwards about 50% of the catch was taken in winter. Reported domestic landings and TACCs are shown in Table 1, while the historical landings and TACC for ORH 7B are depicted in Figure 1.

Table 1: Reported landings (t) of orange roughy and TACCs (t) for ORH 7B from 1983–84 to present. QMS data from 1986–present.

Fishing year	Reported landings	TACC
1983–84*	2	-
1984–85*	282	-
1985–86*	1 763	1 558
1986–87*	1 446	1 558
1987–88	1 413	1 558
1988–89	1 750	1 708
1989–90	1 711	1 708
1990–91	1 683	1 708
1991–92	1 604	1 708
1992–93	1 139	1 708
1993–94	701	1 708
1994–95	290	1 708
1995–96	446	430
1996–97	425	430
1997–98	330	430
1998–99	405	430
1999–00	284	430
2000–01	161	430
2001–02	95	110
2002–03	90	110
2003–04	119	110
2004–05	106	110
2005–06	77	110
2006–07	125	110
2007–08	6.0	1
2008–09	1.4	1
2009–10	< 0.1	1
2010–11	0.1	1
2011–12	< 0.1	1
2012-13	0.3	1
2013-14	0.6	1

*FSU data.

Catches in the early-mid 1990s (especially 1994–95) were well below the TACC. The TACC was reduced to 430 t for the 1995–96 fishing year, then was reduced further to 110 t from 1 October 2001, followed by a further reduction to 1 t in the 2007–08 fishing year.

1.2 Recreational fisheries
There is no known recreational fishery for orange roughy in this area.

1.3 Customary non-commercial fisheries
There is no known customary non-commercial fishing for orange roughy in this area.

1.4 Illegal catch
There is no quantitative information available on illegal catch.

1.5 Other sources of mortality
There is no quantitative information available on other sources of mortality in this fishery.

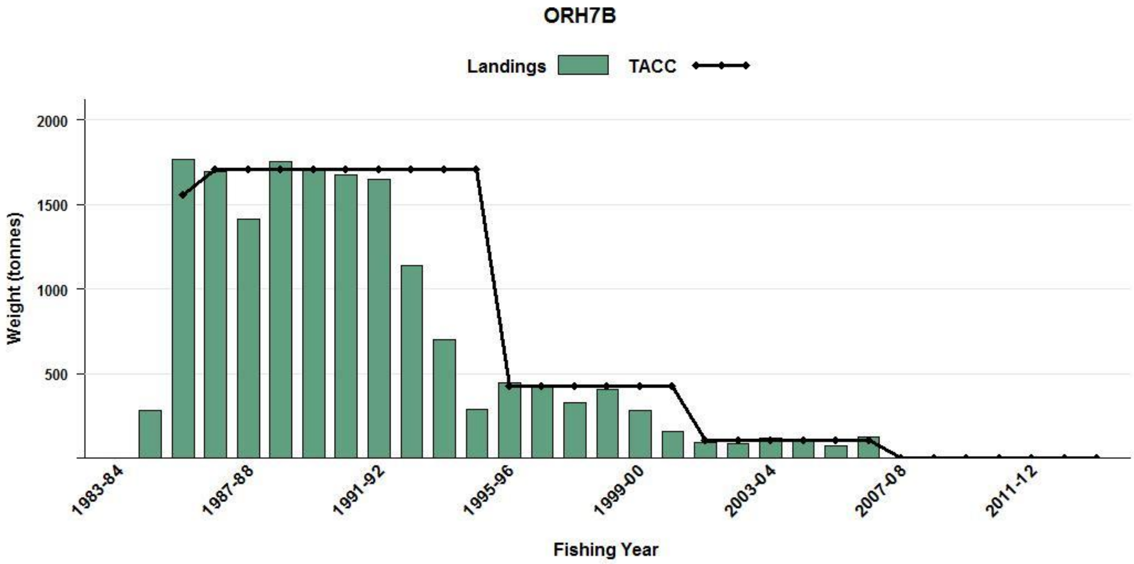


Figure 1: Reported commercial landings and TACC for ORH 7B (Auckland East). Note that this figure does not show data prior to entry into the QMS.

2. STOCKS AND AREAS

There is no new information which would alter the stock boundaries given in previous assessment documents.

Orange roughy in this fishery are thought to be a single stock. Genetic studies have shown that samples of Cook Canyon orange roughy are significantly different from Challenger Plateau and Puysegur Bank samples. Moreover, the size structure and parasite composition differ from fish on the Challenger Plateau. Spawning occurs at a similar time to fish on the Challenger Plateau and the Puysegur Bank.

3. STOCK ASSESSMENT

The previous assessment for this stock was carried out in 2004 and is summarised in the 2006 Plenary Report. Biomass was estimated to be 17% B_0 (95% confidence interval 14–23%) when CPUE was assumed to be directly proportional to abundance.

An updated assessment was attempted in 2007 with the addition of catch data up to 2005–06 and new standardised CPUE indices. The Working Group rejected the assessment on the basis of the poor fit to the CPUE data. The effect was similar to the result from the 2004 assessment; namely a slow rebuild in recent years, which was not supported by the CPUE data.

3.1 Estimates of fishery parameters and abundance
Commercial catch and effort data are available from 1985 and were examined using both an unstandardised and a standardised analysis. Unstandardised catch rates have declined substantially over the course of the fishery but have shown no clear trend in recent years (Table 2).

The standardised CPUE analysis has been divided into two series to address reporting form changes: (i) using TCEPR data from 1985–86 through to 1996–97, and (ii) using CELR data from 1990–91 through to 2005–06. In addition, in order to increase vessel linkage across years, it was decided to use all months of data not just that from the winter fishery (June–July) as has been done for previous standardisations.

Table 2: Summary of groomed data from TCEPR and CELR forms.

Fishing year	Number of vessel days	Number of tows	Total estimated catch (t)	Mean daily catch rate (t/tow)	Mean daily catch rate (t/h)
1985–86	138	357	1 544	4.5	2.9
1986–87	132	405	1 250	4.0	2.7
1987–88	132	420	1 250	3.4	2.3
1988–89	133	368	827	2.5	1.6
1989–90	123	356	1 282	4.5	5.6
1990–91	208	632	1 657	2.8	3.3
1991–92	238	810	1 601	2.0	1.4
1992–93	258	784	1 128	1.5	2.3
1993–94	298	708	660	1.1	0.9
1994–95	162	361	320	0.9	1.6
1995–96	66	150	275	2.2	1.7
1996–97	90	182	244	1.3	7.5
1997–98	96	228	170	0.7	0.3
1998–99	188	566	359	0.6	0.2
1999–00	213	647	259	0.4	0.1
2000–01	149	442	162	0.4	0.1
2001–02	117	282	76	0.3	0.1
2002–03	97	292	112	0.4	0.2
2003–04	90	252	118	0.4	0.2
2004–05	121	393	102	0.3	0.1
2005–06	87	257	73	0.3	0.2

The standardised analysis for the TCEPR data used catch per tow in a linear regression model. Indices from this model (Table 3, Figure 2) show a steep decline after the first two years, followed by a more gradual decline and a slight increase in catch rates in 1995–96 and 1996–97.

Table 3: Standardised CPUE indices (relative year effect) based on TCEPR data with number of vessel tows from 1985–86 to 1996–97.

Year	CPUE index	CV	Number of tows	Year	CPUE index	CV	Number of tows
1985–86	1.99	0.20	153	1991–92	0.48	0.23	231
1986–87	2.13	0.23	150	1992–93	0.29	0.23	230
1987–88	1.11	0.26	212	1993–94	0.14	0.25	341
1988–89	0.58	0.22	310	1994–95	0.13	0.27	172
1989–90	0.61	0.22	236	1995–96	0.51	0.33	37
1990–91	0.76	0.23	238	1996–97	0.41	0.26	104

The standardised analysis for the CELR data used daily catch in a linear regression model. Indices from this model (Table 4, Figure 2) show a steep decline for the first four years, followed by an increase to a peak in 1995–96, and subsequent low catch rates after then.

Table 4: Standardised CPUE indices (relative year effect) based on CELR data with number of days from 1990–91 to 2005–06.

Year	CPUE index	CV	Number of days	Year	CPUE index	CV	Number of days
1990–1991	2.17	0.27	110	1999–2000	0.34	0.27	131
1991–1992	1.11	0.27	108	2000–2001	0.34	0.28	88
1992–1993	0.74	0.27	126	2001–2002	0.33	0.28	73
1993–1994	0.28	0.28	81	2002–2003	0.61	0.26	67
1994–1995	0.53	0.30	46	2003–2004	0.59	0.25	75
1995–1996	1.16	0.33	29	2004–2005	0.35	0.24	114
1996–1997	0.53	0.38	19	2005–2006	0.36	0.26	80
1997–1998	0.36	0.30	52				
1998–1999	0.39	0.28	112				

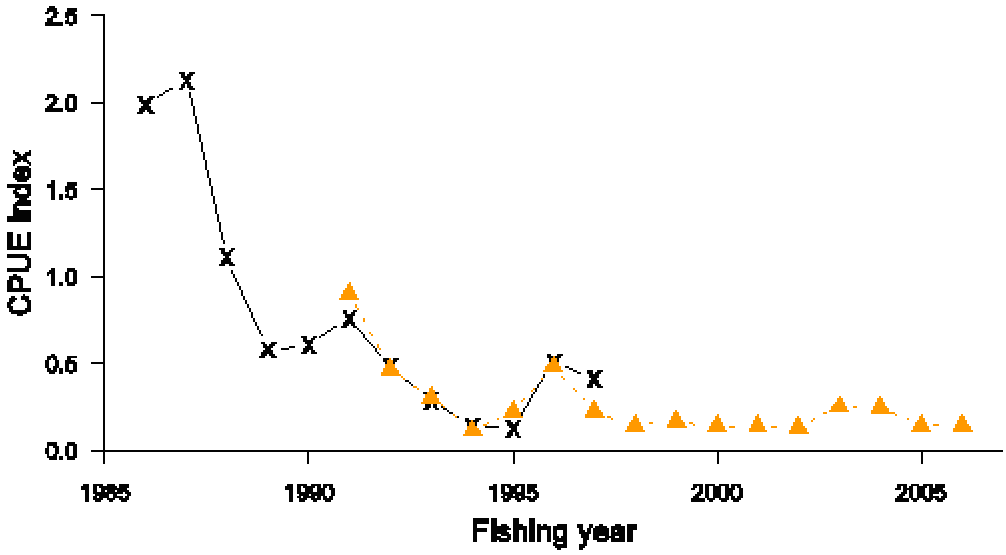


Figure 2: The CPUE indices based on: (i) TCEPR data (solid line and crosses) covering 1985–86 to 1996–97, and (ii) CELR data (triangles and dashed line) covering 1990–91 to 2005–06. The CELR index has been scaled so that it has the same mean value as the TCEPR index in the years that they overlap.

3.2 Biomass estimates

No estimates of current biomass are available. Based on previous stock assessments using CPUE data the TACC was cut back severely from about 1700 t in 1994–95 to 110 t in 2000–01. By the late 1990s the stock was believed to be well below B_{MSY} where it continued until at least 2004 (17% B_0 in the 2004 assessment, Figure 3). Despite the large reduction in annual removals from the stock after 2001–02, catch rates did not increase over the subsequent 5 years.

An updated assessment was attempted in 2007 with the addition of catch data up to 2005–06 and new standardised CPUE indices (Figure 2) based on TCEPR data (1986 to 1997) and a separate CELR series (1991 to 2006). These data were incorporated in a Bayesian stock assessment with deterministic recruitment to estimate stock size. The Working Group rejected the assessment on the basis of the poor fit to the recent CPUE data. The model was insensitive to the recent CPUE data and predicted a rebuild (driven by the recruitment assumptions) that is not supported by any observations in the fishery.

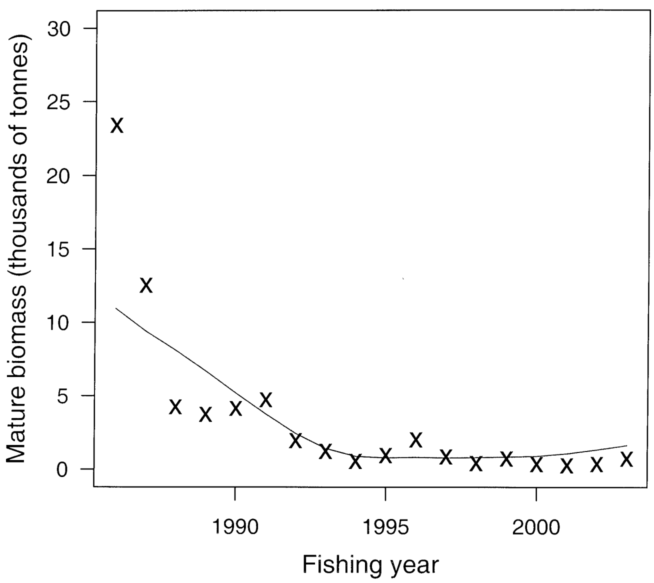


Figure 3: Biomass trajectory derived from Maximum Posterior Density (MPD) estimate of the model parameters (2004 stock assessment). The biomass trajectory is shown by the solid line; crosses denote the CPUE index scaled to biomass.

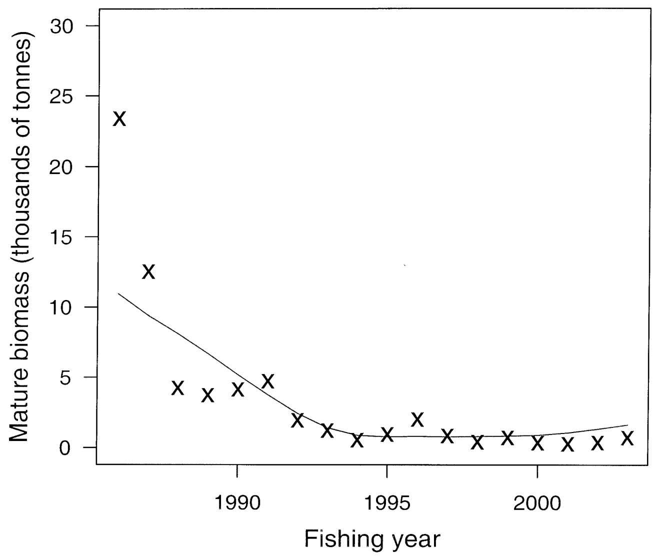
4. STATUS OF THE STOCK

Stock Structure Assumptions

The ORH 7B stock has been treated as a single spawning stock located around the Cook Canyon area. It is assessed and managed separately from other stocks and is assumed to be non-mixing with orange roughy stocks outside of the Cook Canyon area.

Stock Status	
Year of Most Recent Assessment	2004
Assessment Runs Presented	One base case
Reference Points	Target: 30% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2004} was estimated to be 17% B_0, Very Unlikely (< 10%) to be at or above the target
Status in relation to Limits	B_{2004} was Likely (> 60%) to be below the Soft Limit and Unlikely (< 40%) to be below the Hard Limit

Historical Stock Status Trajectory and Current Status



Biomass trajectory derived from Maximum Posterior Density (2004 stock assessment model)

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown, but biomass is thought to be very low.
Recent Trend in Fishing Mortality or Proxy	The fishery has been effectively closed since October 2007.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2004)	
Stock Projections or Prognosis	Stable at current catch level
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Already below the Soft Limit Hard Limit: Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Type 1 - Quantitative stock assessment	
Assessment Method	Age-structured model with Bayesian estimation of posteriors.	
Main data inputs	- Catch history - CPUE indices (1985–2003)	
Period of Assessment	Latest assessment: 2004	Next assessment: Unknown
Changes to Model Structure and Assumptions	- CPUE indices based on mean catch per hour as opposed to previous measure of mean catch per tow	
Major Sources of Uncertainty	- Recruitment assumed to be deterministic - CPUE assumed to be directly proportional to stock biomass in base model	

Qualifying Comments (2010)
A further assessment was attempted in 2007 with updated information; however, this was rejected by the working group as the model was insensitive to the CPUE data. The model indicated that the stock had been rebuilding since the mid 1990s, a trend not supported by any observations in the fishery. The fishery was closed from 1 October 2007 and stock size is expected to increase.

Fishery Interactions
Historically, the main bycatch species were oreos and deepwater dogfish. Bycatch species of concern included deepwater sharks, deepsea skates, seabirds and corals. The fishery is currently closed.

5. FOR FURTHER INFORMATION

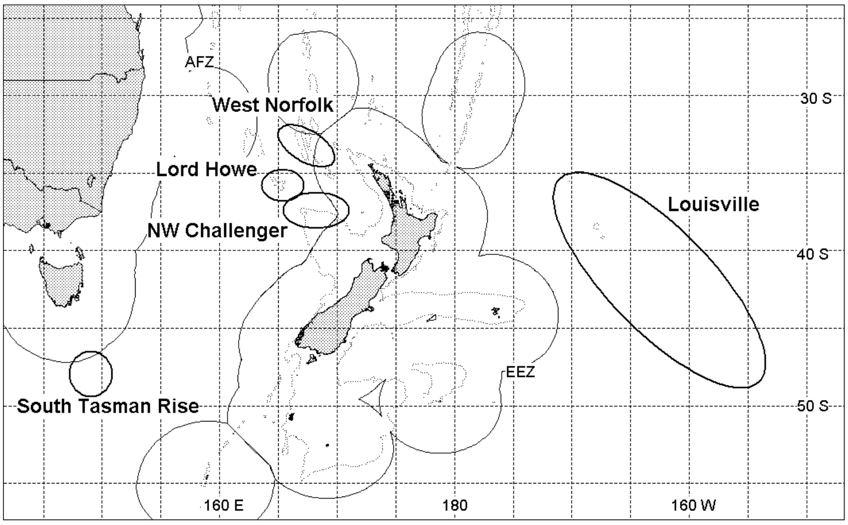
Annala, J H; Sullivan, K J; O'Brien, C J; Smith, N W McL; Graying, S M (Comps.) (2003) Report from the Fishery Assessment Plenary, May 2003: stock assessments and yield estimates. 616 p. (Unpublished report held in NIWA Greta Point library, Wellington.)

Clark, M R; Tracey, D M (1988) Assessment of the west coast South Island and northern North Island orange roughy fisheries. New Zealand. Fisheries Assessment Research Document 1988/20. 11 p. (Unpublished report held in NIWA library, Wellington.)

Clark, M R; Field, K D (1995) Assessment of the ORH 7B orange roughy fishery for the 1995–96 fishing year. New Zealand Fisheries Assessment Research Document 1995/19. 15 p. (Unpublished report held in NIWA library, Wellington.)

O'Driscoll, R L (2001) Assessment of the west coast South Island orange roughy fishery (ORH 7B) for the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2001/31*. 29p.

ORANGE ROUGHY OUTSIDE THE EEZ (ORH ET)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Fisheries outside the EEZ in the New Zealand region occur on ridge systems and seamount chains in the Tasman Sea and southwest Pacific Ocean. There are five main fishing areas: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge (see figure above).

Fisheries outside the EEZ developed firstly on the "Westpac Bank" close to the main fishing grounds on the southwest Challenger Plateau in the early-mid 1980s. This is included in the stock area of ORH 7A, and so is not covered here. Further exploration in the region resulted in the development of commercial fisheries on the Lord Howe Rise in 1987–88, Northwest Challenger Plateau in 1988–89, Louisville Ridge in 1993–94, South Tasman Rise in 1997–98, and West Norfolk Ridge in 2001–02 (Table 1).

Table 1: Estimated catches (t) of orange roughy for ORH ET fisheries from 1987–88 to 2006–07. (Data from New Zealand (FSU, QMS), Australia (AFMA), and various sources for other countries. Note the fishing year for South Tasman Rise is March to February, all others are October to September).

Fishing year	Lord Howe	NW Challenger	Louisville	West Norfolk	South Tasman	Total ET
1987–88	4 000	5	0	0	0	4 005
1988–89	2 430	297	0	0	0	2 727
1989–90	927	425	0	0	0	1 352
1990–01	282	123	0	0	0	405
1991–02	859	620	0	0	0	1 479
1992–03	2 300	2 463	0	0	0	4 763
1993–04	840	1 731	689	0	0	3 260
1994–05	761	1 138	13 252	0	0	15 151
1995–06	5	500	8 816	0	0	9 321
1996–07	139	332	3 209	0	5	3 685
1997–08	26	397	1 404	0	3930	5 757
1998–09	440	961	3 164	0	705	5 270
1999–00	52	473	1 369	0	4 110	6 004
2000–01	428	1 228	1 598	10	830	4 094
2001–02	120	2 075	1 004	649	170	3 729
2002–03	272	1 010	1 296	94	110	2 782
2003–04	324	654	1 419	90	3	2 490
2004–05	430	464	1 510	277	55	2 736
2005–06	240	201	675	727	12	1 855
2006–07	40	96	323	552	0	1 011

Catch totals include data from New Zealand and Australian vessels available from tow by tow fishing records, with estimated catches added for vessels from Japan, USSR, Korea, Norway, South Africa and China. Catch statistics are likely to be incomplete.

These fisheries have historically been unregulated, with the exception of the South Tasman Rise area, where catches by Australian and New Zealand vessels have at times been restricted by a TAC imposed under a Memorandum of Understanding between the two countries. The South Tasman Rise fishery is now formally closed.

South Pacific Regional Fisheries Management Organisation (SPRFMO) Convention Area

Regulation for these was implemented following adoption of the SPRFMO interim measures in May 2007, specific high sea fishing permits for the SPRFMO Area have been issued since 2007–08. Table 2 shows the number of vessels that fished and orange roughy catch by area. Since 2007, an orange roughy catch limit has been applied, being the average annual catch between 2002 and 2006, of 1852 t.

Table 2: Annual catch(t) and effort data for orange roughy from New Zealand vessels for the SPRFMO Area. Note that year is calendar year.

Year	Number of Vessels	Number of tows	Lord Howe	Challenger	Louisville	West Norfolk	Other	All areas
2007	8	415	34	36	280	515	0	866
2008	4	208	380	31	0	426	0	837
2009	6	545	403	261	0	233	31	928
2010	7	1 170	385	420	584	79	6	1 474
2011	7	1 158	1	680	285	113	-	1 079
2012	6	652	121	255	288	49	8	721

Lord Howe Rise

Commercial quantities of orange roughy were found by Japanese vessels in winter 1988, and New Zealand vessels joined the fishery the following year. A number of countries fished the Rise in the late 1980s, but since then it has been largely a New Zealand and Australian fishery. Tows were relatively long at the start of the fishery, when most fishing effort was on the flat ground of the broad platforms. However, shorter tows latterly became more common, associated with a shift onto rough ground and small hill features in the area. Levels of catch and effort decreased to low levels in the mid 1990s, but in recent years have tended to increase (Tables 2 & 3).

Table 3: Catch and effort data from New Zealand vessels for the Lord Howe Rise.

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)	Mean catch rate (t/nmile)
1988–89	181	766	3.0	4.2	5.2	1.5
1989–90	63	127	2.9	2.0	1.0	0.3
1990–91	14	52	2.9	3.7	2.0	0.7
1991–92	70	479	1.7	6.8	7.6	2.5
1992–93	825	1 363	1.3	1.7	3.6	1.2
1993–94	1 263	777	0.9	0.6	1.9	0.8
1994–95	110	61	1.2	0.6	0.5	0.2
1995–96	26	5	0.7	0.2	0.5	0.2
1996–97	179	44	0.8	0.2	0.8	0.3
1997–98	57	15	0.3	0.3	1.8	0.5
1998–99	138	48	1.0	0.3	0.5	0.2
1999–00	121	34	1.1	0.3	1.3	0.5
2000–01	136	145	0.7	1.1	2.9	1.0
2001–02	191	110	0.7	0.6	2.3	0.7
2002–03	280	208	0.5	0.7	4.2	1.4
2003–04	207	180	0.7	0.9	4.7	1.6
2004–05	218	255	0.6	1.2	6.4	2.0
2005–06	71	123	0.4	1.7	15.8	5.2
2006–07	40	34	0.5	0.8	3.4	1.1

A reduced data set has been examined for 22 vessels that have fished for several years in the area until 2005–06 (Table 4). CPUE peaked in 1991–92, declined rapidly to low levels from 1994–95 to 1998–99, and increased over the last 5 years of the period.

Northwest Challenger Plateau

New Zealand and Norwegian vessels began working the northwestern margins of the Challenger Plateau in the late 1980s. Fishing initially was on relatively flat bottom but from 1990 onwards developed more on small hill and pinnacle features, and mean tow length became relatively short (Table 5). Effort declined during the mid 1990s but increased substantially in 2000–01. Tow length increased also, as the fishery moved eastwards along the northern flanks of the Plateau in towards the EEZ. The hill fishery has decreased. Effort has also extended southwards along the western margins of the Challenger Plateau, although catches there have been small.

Table 4: Unstandardised CPUE indices for core vessels from Lord Howe Rise.

Fishing year	Number of tows	Catch (t)	t/tow	t/n.mile	t/hr
1988–89	72	291	4.1	0.5	1.5
1989–90	63	128	2.0	0.3	1.0
1990–91	16	52	3.3	0.6	1.8
1991–92	76	481	6.3	2.3	7.1
1992–93	539	1 108	2.1	1.2	3.7
1993–94	897	618	0.7	0.7	1.7
1994–95	109	60	0.6	0.2	0.5
1995–96	29	5	0.2	0.2	0.5
1996–97	184	45	0.2	0.3	0.8
1997–98	58	15	0.3	0.5	1.7
1998–99	49	3	0.1	0	0.1
1999–00	77	28	0.4	0.7	1.9
2000–01	127	146	1.2	1.1	3.2
2001–02	162	106	0.7	0.8	2.6
2002–03	269	206	0.8	1.4	4.4
2003–04	148	144	0.9	1.5	4.4
2004–05	87	170	2.0	3.8	12.0
2005–06	40	97	2.4	7.4	22.8

Table 5: Catch and effort data from New Zealand vessels for Northwest Challenger.

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)	Mean catch rate (t/nmile)
1988–89	33	107	3.2	3.3	1.5	0.5
1989–90	40	25	2.4	0.6	0.6	0.2
1990–91	4	1	0.2	0.3	1.5	0.4
1991–92	56	230	0.5	4.1	12.8	3.7
1992–93	1 370	2 250	0.8	1.6	3.9	1.2
1993–94	1 499	1 394	1.1	0.9	1.4	0.5
1994–95	877	1 138	0.8	1.3	5.7	2.0
1995–96	270	500	1.0	1.9	10.0	3.4
1996–97	385	332	0.8	0.9	3.5	1.2
1997–98	215	228	0.7	1.1	6.0	2.0
1998–99	707	838	0.8	1.2	4.2	1.4
1999–00	598	335	1.0	0.6	2.6	0.9
2000–01	1 002	944	2.6	0.9	1.5	0.5
2001–02[1]	2 431	1 863	3.9	0.8	1.4	0.5
2002–03[1]	1 979	948	3.8	0.5	0.9	0.3
2003–04	869	495	3.5	0.6	1.0	0.3
2004–05	1 007	442	4.7	0.4	0.7	0.2
2005–06	399	200	5.2	0.5	0.6	0.2
2006–07	77	36	4.6	0.5	0.4	0.1

[1] Aggregated daily data are included in the vessel, tow, and catch totals, excluded from catch rate.

Table 6: CPUE indices for core vessels from all seasons for Northwest Challenger.

			Unstandardised CPUE		
Fishing year	Number of tows	Catch (t)	t/tow	t/nmile	% zero catch
1992–93	474	819	1.7	0.9	20
1993–94	1 115	1 343	1.2	0.6	42
1994–95	869	1 136	1.3	2.0	39
1995–96	266	499	1.9	3.5	36
1996–97	379	330	0.9	1.2	41
1997–98	211	227	1.1	2.0	35
1998–99	463	622	1.3	1.3	25
1999–00	430	190	0.4	0.6	29
2000–01	997	940	0.9	0.5	15
2001–02	2 098	1 633	0.6	0.5	10
2002–03	1 822	896	0.5	0.3	12
2003–04	786	464	0.6	0.3	9
2004–05	828	385	0.5	0.3	7
2005–06	324	164	0.5	0.2	4

Unstandardised CPUE for vessels that fished the area for several years through until 2005–06 has declined over time (Table 6). Average catch per tow was less than 1 t after 2000, even though the success of catching orange roughy (expressed as % of zero catch trawls) improved.

Catch rates in the hill fishery (winter, tow duration less than 30 minutes), decreased from a peak at around 4 t/tow in the mid 1990s to less than 1 t.

West Norfolk Ridge

This fishery developed from exploratory fishing inside the EEZ on the West Norfolk Ridge (ORH 1). In 2001–02 Australian vessels were involved as well as New Zealand vessels. Annual catches have typically been about 200–300 t (Table 7).

Table 7: Catch and effort data from New Zealand vessels for the West Norfolk Ridge orange roughy fishery.

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)	Mean catch rate (t/nmile)
2000–01	1	0.2				
2001–02	297	586	0.3	2.0	9.0	3.0
2002–03	91	35	0.3	0.4	2.4	0.8
2003–04	90	88	0.5	1.0	2.3	0.8
2004–05	248	274	0.4	1.1	4.5	1.5
2005–06	337	727	0.4	2.2	19.7	6.6
2006–07	215	543	0.3	2.5	12.7	4.0

Fishing has been spread over the year, although highest catch rates have occurred in June and July, especially in 2005–06 and 2006–07.

Louisville Ridge

The Louisville Ridge is a chain of more than 60 seamounts extending for over 4000 km southeast from the Kermadec Ridge. Fishing began in 1993–94 in the central part of the ridge, and spread both northwest and southeast in subsequent years. The fishery has comprised largely New Zealand vessels, although vessels from Australia, China, Russia, Ukraine, Korea and Japan are known to have fished the ridge also (mainly in the first few years). The New Zealand catch peaked in 1994–95 at over 11 000 t but has subsequently reduced (Tables 2 & 8). Catch rates between 1993-94 and 2005-06 varied with a general decline in all areas (Table 9).

Table 8: Catch and effort data from New Zealand vessels for the Louisville Ridge.

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)	Mean catch rate (t/nmile)
1993–94	134	189	1.4	1.4	1.5	0.6
1994–95	4 294	11 340	0.7	2.6	10.6	4.2
1995–96	4 024	8 764	0.7	2.2	7.4	3.0
1996–97	1 849	3 209	0.8	1.7	5.3	2.1
1997–98	787	1 404	0.5	1.8	14.2	4.8
1998–99	1 093	3 025	0.5	2.7	14.2	5.2
1999–00	918	1 369	0.5	1.5	11.4	3.8
2000–01	749	1 598	0.5	2.1	18.0	2.3
2001–02	889	1 004	0.6	1.1	7.4	2.4
2002–03	736	1 296	0.4	1.8	13.8	4.6
2003–04	1 336	1 419	0.4	1.1	8.7	2.9
2004–05	745	1 510	0.4	2.0	17.2	5.6
2005–06	581	669	0.6	1.2	6.2	2.0
2006–07	283	323	0.5	1.1	8.5	2.6

Table 9: Average catch rate (tonnes per tow) of orange roughy in winter months (June to August) by New Zealand vessels from the Louisville Ridge, by sub-area from 1993–94 to 2005–06.

	Full Area	North	Central	South
1993–94	1.9	-	1.9	-
1994–95	2.7	3.9	2.6	11.0
1995–96	3.6	6.0	2.1	3.9
1996–97	2.1	1.4	2.0	3.5
1997–98	2.0	1.9	2.4	0.7
1998–99	2.7	2.1	2.9	1.7
1999–00	1.8	2.1	1.6	2.8
2000–01	2.3	2.6	2.0	1.9
2001–02	1.3	0.9	2.3	3.9
2002–03	1.9	1.7	1.2	5.3
2003–04	1.1	0.7	1.4	1.8
2004–05	2.1	1.8	1.6	2.9
2005–06	1.1	1.0	1.0	1.6

CPUE, from individual seamounts shows variable patterns. The fishery on some seamounts has lasted only a few years, while on others it has continued, or fluctuated over time. Seamounts in the northwestern and southeastern sections of the Ridge have not sustained consistent catches, and some localised depletion may have occurred.

South Tasman Rise

Exploratory fishing south of Tasmania located aggregations of orange roughy on the South Tasman Rise just outside the Australian Fishing Zone (AFZ) in late 1997. The fishery rapidly increased in the next four years (Table 10), with Australian and New Zealand vessels working several small hill features on the Rise. However, New Zealand vessels have not fished the South Tasman Rise since 2000–01. Effort dropped continuously from 2001–02, and mean catch per tow in 2004–05 was about 1 t/tow. Note that insufficient vessels have fished since 2005–06 to enable presentation of catch or effort summaries.

Table 10: Catch and effort data from the South Tasman Rise (combined Australian and New Zealand data).

Fishing year	Number of tows	Total recorded catch (t)	Mean tow length (h)	Mean catch rate (t/tow)	Mean catch rate (t/h)
1996–97	61	4	0.6	0.1	0.5
1997–98	1 132	3 930	0.7	3.5	17.4
1998–99	1 332	1 705	0.6	1.3	10.4
1999–00	1 086	3 360	0.5	3.1	21.1
2000–01	1 155	830	0.4	0.7	6.7
2001–02	201	170	0.8	1.0	3.5
2002–03	164	110	0.5	0.9	7.9
2003–04	67	2	0.3	0.1	0.4
2004–05	47	55	0.3	1.2	14.7

The fishery was formally regulated by a Memorandum of Understanding between Australia and New Zealand from December 1998. A precautionary TAC of 2100 t was applied, increased to 2400 t in 2000–01, and then progressively reduced to 600 t for 2004–05. The fishery was closed to all trawling in 2007.

1.2 Summary of trends in commercial fisheries

Since the high seas fishing permits for the SPRFMO Convention Area were implemented in 2007–08 the number of bottom trawl vessels actively fishing has varied from 4–8 vessels. Catch levels have decreased for all fisheries since they began, but after a period in the late 1990s–early 2000s when the total catch by New Zealand vessels was relatively consistent at 2000–2500 t. Trends in catch and effort have been difficult to interpret given changes in the vessel composition over time and the areas fished between years.

Mean catch rates for the Lord Howe Rise have been variable in recent years as the fishery has moved to hill features. The fishery appears to have become more consistent from year to year following a period of low catch and effort in the mid 1990s. The Louisville Ridge fishery has been the largest of those in the New Zealand region, but catch and effort levels have declined substantially since 2004–05. The patterns on individual seamounts differ, with some appearing stable, while others have declined. The West Norfolk Ridge fishery developed rapidly in 2001−02, and after an initial decrease in catch and effort, these increased in 2004–05 as new sites were fished. Catches increased substantially in 2005–06, and relatively large catches and high catch rates continued in 2006–07. The fishery on the South Tasman Rise decreased to very low levels during the early 2000s, and was closed in 2007. New Zealand vessels have not fished the Rise since 2001.

1.3 Recreational fisheries
There is no known non-commercial fishery for orange roughy in these areas.

1.4 Customary non-commercial fisheries
No customary non-commercial fishing for orange roughy is known in these areas.

1.5 Illegal catch
In most of these areas, there were no regulations regarding limits on catch in international waters prior to 2007. The South Tasman Rise region has been subject to catch restrictions for Australian and New Zealand vessels under a Memorandum of Understanding between the two countries. In 1999–2000 vessels registered in South Africa and Belize fished the region. The estimated catch of at least 750 t has been included in the catch total for that year. No other information is available on any possible illegal catch on the South Tasman Rise, or the Westpac Bank region of ORH 7A.

1.6 Other sources of mortality
There may be some overrun of reported catch because of fish loss with trawl gear damage, ripped nets, discards, and conversion factor inaccuracies. In a number of other orange roughy fisheries, a current level of 5% has been applied (higher in the past). No corrections are made here because of limited information on the sources which may differ with each fishery.

2. STOCKS AND AREAS

The five fishing grounds are all regarded as separate stocks.

The Lord Howe Rise and Northwest Challenger Plateau fisheries are based on fish that have a different size structure, different age/size at maturity, similar timing of spawning, and a geographical separation of about 120 n. miles. Their genetic make-up differs from fish on the southwest Challenger Plateau (ORH 7A). Morphometric differences have also been shown between orange roughy from Lord Howe and Puysegur Bank areas.

Orange roughy on the South Tasman Rise are regarded as a straddling stock with fish inside the AFZ.

The Louisville Ridge is a long seamount chain, and little is known about stock structure within the area. There are several known spawning sites, and it would seem likely that there could be multiple stocks or sub-populations along the ridge.

The fishery on the West Norfolk Ridge outside the EEZ is continuous with that carried out on ridge peaks and seamount features inside the EEZ.

3. STOCK ASSESSMENT

There are currently no accepted stock assessments for these orange roughy fisheries outside the EEZ. Several have been attempted (for Lord Howe, Northwest Challenger Plateau, and Louisville Ridge) based on catch per unit effort data, but these have not been accepted as sufficiently robust by the Deepwater Fishery Assessment Working Group. This was generally on account of highly variable levels of effort and catch between years within each of the fisheries, which can make the use of CPUE as an index of abundance uncertain.

4. STATUS OF THE STOCKS

The status of the stocks is unknown. Catch and effort levels have decreased substantially in some of the grounds in the last few years, and unstandardised CPUE has declined in a number of areas. However, it is not known if recent catch levels are sustainable, or whether they will allow the stocks to move towards a size that will support the *MSY*.

5. FOR FURTHER INFORMATION

Anderson, O F (2006) A summary of biological information on the New Zealand fisheries for orange roughy (*Hoplostethus atlanticus*) for the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2006/16*. 25 p.

Clark, M R (2003) Estimation of orange roughy biomass on the Louisville Ridge: application of "Seamount Meta-analysis" results. Final Research Report to the Ministry of Fisheries for ORH2002/03. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Clark, M R (2004) Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2002–03 fishing year. *New Zealand Fisheries Assessment Report 2004/51* 36 p.

Clark, M R (2006a) Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2006/25*. 37 p.

Clark, M R (2006b) Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2004–05 fishing year. *New Zealand Fisheries Assessment Report 2006/56*. 38 p.

Clark, M R (2008) Descriptive analysis of orange roughy fisheries in the New Zealand region outside the EEZ: Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise, and Louisville Ridge to the end of the 2005–06 fishing year. *New Zealand Fisheries Assessment Report 2008/12*. 45 p.

Clark, M R; Anderson, O F (2001) The Louisville Ridge orange roughy fishery: an update of commercial catch-effort data and CPUE analysis of the fishery to the end of the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report 2001/74*. 31 p.

Clark, M R; Anderson, O F (2003) The Louisville Ridge orange roughy fishery: an analysis of commercial catch-effort data and stock assessment of the fishery to the end of the 2000–01 fishing year. *New Zealand Fisheries Assessment Report 2003/3*. 26 p.

Clark, M R; O'Driscoll, R L (2002) Descriptive analysis of orange roughy fisheries in the Tasman Sea outside the New Zealand EEZ: Lord Howe Rise, Northwest Challenger Plateau, and South Tasman Rise from 1986–87 to the end of the 2000–01 fishing year. *New Zealand Fisheries Assessment Report 2002/59*. 26 p.

Clark, M; Tilzey, R (1996) A summary of stock assessment information for orange roughy fisheries on the Lord Howe Rise: 1996. Bureau of Resource Sciences, Canberra. 23 p. (Available from BRS, P.O. Box E11, Canberra, Australia).

Clark, M; Tilzey, R (2001) A summary of commercial catch and effort information for the orange roughy (*Hoplostethus atlanticus*) fishery on the South Tasman Rise from 1987 to 1999. *New Zealand Fisheries Assessment Report 2001/3*. 16 p.

O'Driscoll, R L (2001) CPUE analysis of orange roughy fisheries outside the New Zealand EEZ: Lord Howe Rise and Northwest Challenger Plateau, to the end of the 1999–2000 fishing year. *New Zealand Fisheries Assessment Report 2001/36*. 26 p.

O'Driscoll, R L (2003) Catch-per-unit-effort analysis of orange roughy fisheries outside the New Zealand EEZ: Lord Howe Rise and Northwest Challenger Plateau to the end of the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2003/36*. 38 p.

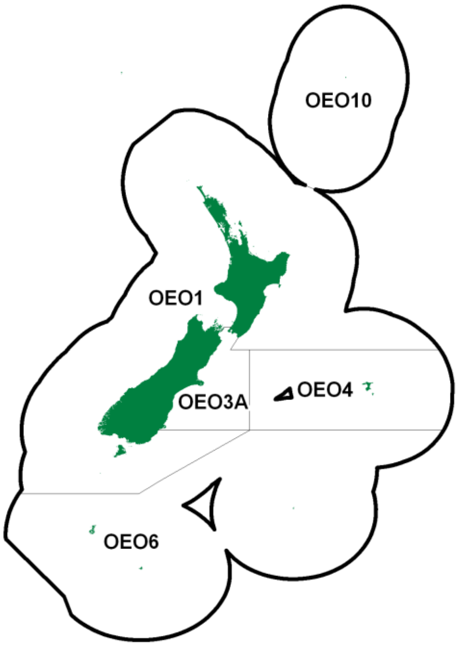
Smith, P J; Robertson, S; Horn, P; Bull, B; Anderson, O; Stanton, B R; Oke, C S (2002) Multiple techniques for determining stock relationships between orange roughy, *Hoplostethus atlanticus*, fisheries in the eastern Tasman Sea. *Fisheries Research* 58: 119–140.

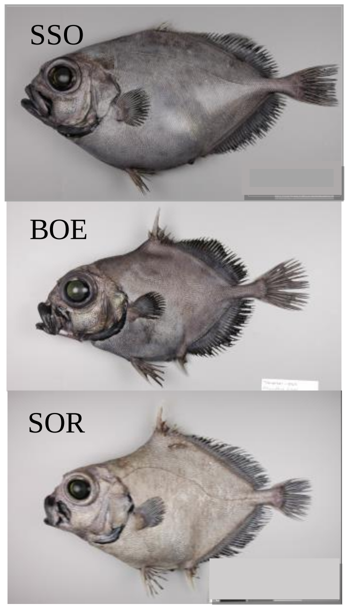
Tilzey, R (2000) South Tasman Rise trawl fishery. *In*: Caton, A.,McLoughlin, K. (eds) Fishery status reports 1999: resource assessments of Australian Commonwealth fisheries. BRS, Canberra.

Wayte, S; Bax, N; Clark, M; Tilzey, R (2003) Analysis of orange roughy catches on the South Tasman Rise, 1997–2002. Report provided to the Orange Roughy Assessment Group. 14 p. (Unpublished report held by CSIRO, Hobart.)

OREOS (OEO)

(*Allocyttus niger*, *Allocyttus verucosus*, *Neocyttus rhomboidalis* and *Pseudocyttus maculatus*)





1. INTRODUCTION

The main black oreo and smooth oreo fisheries have been assessed separately and individual reports produced for each as follows:

1. OEO 3A black oreo and smooth oreo
2. OEO 4 black oreo and smooth oreo
3. OEO 1 and OEO 6 black oreo and smooth oreo

2. BIOLOGY

2.1 Black oreo

Black oreo have been found within a 600 m to 1300 m depth range. The geographical distribution south of about 45° S is not well known. It is a southern species and is abundant on the south Chatham Rise, along the east coast of the South Island, the north and east slope of Pukaki Rise, the Bounty Platform, the Snares slope, Puysegur Bank and the northern end of the Macquarie Ridge. They most likely occur all around the slope of the Campbell Plateau.

Spawning occurs from late October to at least December and is widespread on the south Chatham Rise. Mean length at maturity for females, estimated from Chatham Rise trawl surveys (1986–87, 1990, 1991–93) using macroscopic gonad staging, is 34 cm TL.

They appear to have a pelagic juvenile phase, but little is known about this phase because only about 12 fish less than 21 cm TL have ever been caught. The pelagic phase may last for 4–5 years with lengths of up to 21–26 cm TL.

Unvalidated age estimates were obtained for Chatham Rise and Puysegur-Snares samples in 1995 and 1997 respectively using counts of the zones (assumed to be annual) observed in thin sections of otoliths. These estimates indicate that black oreo is slow growing and long lived. The maximum estimated age was 153 years (45.5 cm TL fish). Australian workers used the same methods, i.e., sections of otoliths,

and reported similar results A von Bertalanffy growth curve was fitted to the Puysegur samples only (Table 1). Estimated age at maturity for females was 27 years.
A first estimate of natural mortality (*M*), 0.044 (yr^{-1}), was made in 1997 using the Puysegur growth data only. This estimate is uncertain because it appeared that the otolith samples were taken from a well fished part of the Puysegur area.

Black oreo appear to settle over a wide range of depths on the south Chatham Rise, but appear to prefer to live in the depth interval 600–800 m that is often dominated by individuals with a modal size of 28 cm TL.

2.2 Smooth oreo

Smooth oreo occur from 650 m to about 1500 m depth. The geographical distribution south of about 45° S is not well known. It is a southern species and is abundant on the south Chatham Rise, along the east coast of the South Island, the north and east slope of Pukaki Rise, the Bounty Platform, the Snares slope, Puysegur Bank and the northern end of the Macquarie Ridge. They most likely occur all around the slope of the Campbell Plateau.

Spawning occurs from late October to at least December and is widespread on the south Chatham Rise in small aggregations. Mean length at maturity for females, estimated from Chatham Rise trawl surveys (1986–87, 1990, 1991–93) using macroscopic gonad staging, is 40 cm TL.

They appear to have a pelagic juvenile phase, but little is known about this phase because only about six fish less than 16 cm TL have ever been caught. The pelagic phase may last for 5–6 years with lengths of up to 16–19 cm TL.

Unvalidated age estimates were obtained for Chatham Rise and Puysegur-Snares fish in 1995 and 1997 respectively using counts of the zones (assumed to be annual) observed in thin sections of otoliths. These estimates indicate that smooth oreo is slow growing and long lived. The maximum estimated age was 86 years (51.3 cm TL fish). Australian workers used the same methods, i.e., sections of otoliths, and reported similar results. A von Bertalanffy growth curve was fitted to the age estimates from Chatham Rise and Puysegur-Snares fish combined and the parameters estimated for the growth curve are in Table 1. Estimated age at maturity for females was 31 years.

An estimate of natural mortality, 0.063 (yr^{-1}), was made in 1997. The estimate was from a moderately exploited population of fish from the Puysegur region. The Puysegur fishery started in 1989–90 and by August–September 1992 (when the otoliths were sampled) about 24% of the smooth oreo catch from 1989–90 to 1995–96 had been taken. Future estimates of *M* should, if possible, be made from an unexploited population.

There are concentrations of recently settled smooth oreo south and south west of Chatham Island, although small individuals (16–19 cm TL) occur widely over the south Chatham Rise at depths of 650–800 m.

Table 1: Biological parameters used for black oreo and smooth oreo stock assessments. Values not estimated are indicated by (-). [Continued on next page].

Fishstock			Estimate
1. Natural Mortality - *M* (yr^{1})			
	Females	Males	Unsexed
Black oreo	0.044	0.044	0.044
Smooth oreo	0.063	0.063	
2. Age at recruitment - A_r (yr)			
Black oreo	-	-	-
Smooth oreo	21	21	
3. Age at maturity A_M (yr)			
Black oreo	27	-	-
Smooth oreo	31	-	

Table 1 [Continued].

Fishstock Estimate

4. von Bertalanffy parameters

	Females			Males			Unsexed		
	$L_{¥(cm, TL)}$	$k(yr^{1})$	t_0 (yr)	$L_{¥(cm, TL)}$	$k(yr^{1})$	t_0 (yr)	$L_{¥(cm, TL)}$	$k(yr^{1})$	t_0 (yr)
Black oreo	39.9	0.043	-17.6	37.2	0.056	-16.4	38.2	0.05	-17.0
Smooth oreo	50.8	0.047	-2.9	43.6	0.067	-1.6			

5. Length-weight parameters (Weight = a(length)^b (Weight in g, length in cm fork length))

	Females		Males		Unsexed	
	a	b	a	b	a	b
Black oreo	0.008	3.28	0.016	3.06	0.0078	3.27
Smooth oreo	0.029	2.90	0.032	2.87		

6. Length at recruitment (cm, TL)

	Females	Males	Unsexed
Black oreo	-	-	-
Smooth oreo	34	-	

7. Length at maturity (cm, TL)

	Females	Males	Unsexed
Black oreo	34	-	-
Smooth oreo	40	-	-

8. Recruitment variability (σ_R)

	Females	Males	Unsexed
Black oreo	0.65	0.65	0.65
Smooth oreo	0.65	0.65	

9. Recruitment seeepness

	Females	Males	Unsexed
Black oreo	0.75	0.75	0.75
Smooth oreo	0.75	0.75	

10. Fishing mortality (F_{max} (yr^{-1}))

	Females	Males	Unsexed
Black oreo	0.9	0.9	-
Smooth oreo	0.9	0.9	

11. Max exploitation (E_{max} (yr^{-1}))

	Females	Males	Unsexed
Black oreo	-	-	0.67

3. STOCKS AND AREAS

3.1 Black oreo

Stock structure of Australian and New Zealand samples was examined using genetic (allozyme and mitochondrial DNA) and morphological counts (fin rays, etc.). It was concluded that the New Zealand samples constituted a stock distinct from the Australian sample based on "small but significant difference in mtDNA haplotype frequencies (with no detected allozyme differences), supported by differences in pyloric caeca and lateral line counts". The genetic methods used may not be suitable tools for stock discrimination around New Zealand.

A New Zealand pilot study examined stock relationships using samples from four management areas (OEO 1, OEO 3A, OEO 4 and OEO 6) of the New Zealand EEZ. Techniques used included genetic (nuclear and mitochondrial DNA), lateral line scale counts, settlement zone counts, parasites, otolith microchemistry, and otolith shape. Lateral line scale and pyloric caeca counts were different between samples from OEO 6 and the other three areas. The relative abundance of three parasites differed significantly between all areas. Otolith shape from OEO 3A samples was different to that from OEO 1 and OEO 4, but OEO 1, OEO 4 and OEO 6 otolith samples were not morphologically different. Genetic, otolith microchemistry, and settlement zone analyses showed no regional differences.

3.2 Smooth oreo

Stock structure of Australian and New Zealand samples was examined using genetic (allozyme and mitochondrial DNA) and morphological counts (fin rays, etc.). No differences between New Zealand and Australian samples were found using the above techniques. A broad scale stock is suggested by these results but this seems unlikely given the large distances between New Zealand and Australia. The genetic methods used may not be suitable tools for stock discrimination around New Zealand.

A New Zealand pilot study examined stock relationships using samples from four management areas (OEO 1, OEO 3A, OEO 4 and OEO 6) of the New Zealand EEZ. Techniques used included genetic (nuclear and mitochondrial DNA), lateral line scale counts, settlement zone counts, parasites, otolith microchemistry, and otolith shape. Otolith shape from OEO 1 and OEO 6 was different to that from OEO 3A and OEO 4 samples. Weak evidence from parasite data, one gene locus and otolith microchemistry suggested that northern OEO 3A samples were different from other areas. Lateral line scale and otolith settlement zone counts showed no differences between areas.

These data suggest that the stock boundaries given in previous assessment documents should be retained until more definitive evidence for stock relationships is obtained, i.e., retain the areas OEO 1, OEO 3A, OEO 4, and OEO 6 (see the figure on the first page of the Oreos assessment report above).

The four species of oreos (black oreo, smooth oreo, spiky oreo, and warty oreo) are managed with separate catch limits for black and smooth in some areas. Each species could be managed separately. They have different depth and geographical distributions, different stock sizes, rates of growth, and productivity.

4. FISHERY SUMMARY

4.1 Commercial fisheries

Commercial fisheries occur for black oreo (BOE) and smooth oreo (SSO). Oreos are managed as a species group, which also includes spiky oreo (SOR). The Chatham Rise (OEO 3A and OEO 4) is the main fishing area, but other fisheries occur off Southland on the east coast of the South Island (OEO 1/OEO 3A), and on the Pukaki Rise, Macquarie Ridge, and Bounty Plateau (OEO 6). In the past oreo catch has been taken as bycatch of the more valuable orange roughy fisheries but target fisheries are now much more common in most areas for smooth or black oreo.

Total reported landings of oreos and TACs are shown in Table 2, while Figure 1 depicts the historical landings and TACC values for the main OEO stocks. OEO 3A and OEO 4 were introduced into the QMS in 1982–83, while OEO 1 and OEO 6 were introduced later in 1986–87. Total oreo catch from OEO 4 exceeded the TAC from 1991–92 to 1994–95 and was close to the TAC from 1995–96 to 2000–01 (Table 2). Catch remained high in OEO 4 while the orange roughy fishery has declined. The OEO 4 TAC was reduced from 7000 to 5460 t in 2001–02 but was restored to 7000 t in 2003–04. The oreo catch from OEO 3A was less than the TAC from 1992–93 to 1995–96, substantially so in 1994–95 and 1995–96. The OEO 3A TAC was reduced from 10 106 to 6600 t in 1996–97. A voluntary agreement between the fishing industry and the Minister of Fisheries to limit catch of smooth oreo from OEO 3A to 1400 t of the total oreo TAC of 6600 t was implemented in 1998–99. Subsequently the total OEO 3A TAC was reduced to 5900 t in 1999–00, 4400 in 2000–01, 4095 in 2001–02 and 3100 t in 2002–03. Catch from the Sub-Antarctic area (OEO 6) increased substantially in 1994–95 and exceeded the TAC in 1995–96. The OEO 6 TAC was increased from 3000 to 6000 t in 1996–97. There was also a voluntary agreement not to fish for oreos in the Puysegur area which started in 1998–99. OEO 1 was fished under the adaptive management programme up to the end of 1997–98. The OEO 1 TAC reverted back to pre-adaptive management levels from 1998–99.Catches have declined since then, and from 1 October 2007 the TACC was reduced to 2500 t, and other sources of mortality were allocated 168 t.

Reported estimated catches by species from tow by tow data recorded in catch and effort logbooks (Deepwater, TCEPR, and CELR) and the ratio of estimated to landed catch reported are given in Table 3.

Table 2: Total reported landings (t) for all oreo species combined by Fishstock from 1978–79 to 2013–14 and TACs (t) from 1982–83 to 2013–14.

Fishing	OEO 1		OEO 3A		OEO 4		OEO 6		Totals	
year	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1978–79*	2 808	-	1 366	-	8 041	-	17	-	12 231	-
1979–80*	143	-	10 958	-	680	-	18	-	11 791	-
1981–82*	21	-	12 750	-	9 296	-	4 380	-	25 851	-
1982–83*	162	-	8 576	10 000	3 927	6 750	765	-	26 514	-
1983–83#	39	-	4 409	#	3 209	#	354	-	13 680	17 000
1983–84†	3 241	-	9 190	10 000	6 104	6 750	3 568	-	8 015	#
1984–85†	1480	-	8 284	10 000	6 390	6 750	2 044	-	22 111	17 000
1985–86†	5 390	-	5 331	10 000	5 883	6 750	126	-	18 204	17 000
1986–87†	532	4 000	7 222	10 000	6 830	6 750	0	3 000	16 820	17 000
1987–88†	1 193	4 000	9 049	10 000	8 674	7 000	197	3 000	15 093	24 000
1988–89†	432	4 233	10 191	10 000	8 447	7 000	7	3 000	19 159	24 000
1989–90†	2 069	5 033	9 286	10 106	7 348	7 000	0	3 000	19 077	24 233
1990–91†	4 563	5 033	9 827	10 106	6 936	7 000	288	3 000	18 703	25 139
1991–92†	4 156	5 033	10 072	10 106	7 457	7 000	33	3 000	21 614	25 139
1992–93†	5 739	6 044	9 290	10 106	7 976	7 000	815	3 000	21 718	25 139
1993–94†	4 910	6 044	9 106	10 106	8 319	7 000	983	3 000	23 820	26 160
1994–95†	1 483	6 044	6 600	10 106	7 680	7 000	2 528	3 000	23 318	26 160
1995–96†	4 783	6 044	7 786	10 106	6 806	7 000	4 435	3 000	18 291	26 160
1996–97†	5 181	6 044	6 991	6 600	6 962	7 000	5 645	6 000	23 810	26 160
1997–98†	2 681	6 044	6 336	6 600	7 010	7 000	5 222	6 000	24 779	25 644
1998–99†	4 102	5 033	5 763	6 600	6 931	7 000	5 287	6 000	21 249	25 644
1999–00†	3 711	5 033	5 859	5 900	7 034	7 000	5 914	6 000	22 083	24 633
2000–01†	4 852	5 033	4 577	4 400	7 358	7 000	5 932	6 000	22 518	23 933
2001–02†	4 197	5 033	3 923	4 095	4 864	5 460	5 737	6 000	22 719	22 433
2002–03†	3 034	5 033	3 070	3 100	5 402	5 460	6 115	6 000	18 721	20 588
2003–04†	1 703	5 033	2 856	3 100	6 735	7 000	5 811	6 000	17 621	19 593
2004–05†	1 025	5 033	3 061	3 100	7 390	7 000	5 744	6 000	17 105	21 133
2005–06†	850	5 033	3 333	3 100	6 829	7 000	6 463	6 000	17 220	21 133
2006–07†	903	5 033	3 073	3 100	7 211	7 000	5 926	6 000	17 475	21 133
2007–08†	947	2 500	3 092	3 100	7 038	7 000	5 902	6 000	17 113	21 133
2008–09†	582	2 500	2 848	3 100	6 907	7 000	5 540	6 000	16 979	18 600
2009–10†	464	2 500	3 550	3 350	7 047	7 000	5 730	6 000	15 877	18 600
2010–11†	381	2 500	3 370	3 350	7 061	7 000	3 610	6 000	16 791	18 850
2011–12†	581	2 500	3 324	3 350	6 858	7 000	2 325	6 000	14 422	18 860
2012–13	652	2 500	3 245	3 350	6 944	7 000	136	6 000	13 088	18 860
2013-14	386	2 500	3 473	3 350	7 024	7 000	367	6 000	11 251	18 860

Source: FSU from 1978–79 to 1987–88; QMS/MFish/MPI from 1988–89 to 2013–14. *, 1 April to 31 March. #, 1 April to 30 September. Interim TACs applied. †, 1 October to 30 September. Data prior to 1983 were adjusted up due to a conversion factor change

Table 3: Reported estimated catch (t) by species (smooth oreo (SSO), black oreo (BOE) by Fishstock from 1978–79 to 2007–08 and the ratio (percentage) of the total estimated SSO plus BOE, to the total reported landings (from Table 2. -, less than 1. No catch split available for 2008–09.

	SSO				BOE				Total estimated	Estimated landings (%)
Year	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6		
1978–79*	0	0	0	0	9	0	0	0	9	-
1979–80*	16	5 075	114	0	118	5 588	566	18	11 495	98
1980–81*	1	1 522	849	2	66	8 758	5 224	215	16 637	64
1981–82*	21	1 283	3 352	2	0	11 419	5 641	4 378	26 096	98
1982–83*	28	2 138	2 796	60	6	6 438	1 088	705	13 259	97
1983–83#	9	713	1 861	0	1	3 693	1 340	354	7 971	100
1983–84†	1 246	3 594	4 871	1 315	1 751	5 524	1 214	2 254	21 769	99
1984–85†	828	4 311	4 729	472	544	3 897	1 651	1 572	18 004	99
1985–86†	4 257	3 135	4 921	72	1 060	2 184	961	54	16 644	99
1986–87†	326	3 186	5 670	0	163	4 026	1 160	0	14 531	96
1987–88†	1 050	5 897	7 771	197	114	3 140	903	0	19 072	100
1988–89†	261	5 864	6 427	-	86	2 719	1 087	0	16 444	86
1989–90†	1 141	5 355	5 320	-	872	2 344	439	-	15 471	83
1990–91†	1 437	4 422	5 262	81	2 314	4 177	793	222	18 708	87
1991–92†	1 008	6 096	4 797	2	2 384	3 176	1 702	15	19 180	88
1992–93†	1 716	3 461	3 814	529	3 768	3 957	1 326	69	18 640	78
1993–94†	2 000	4 767	4 805	808	2 615	4 016	1 553	35	20 599	88
1994–95†	835	3 589	5 272	1 811	385	2 052	545	230	14 719	81
1995–96†	2 517	3 591	5 236	2 562	1 296	3 361	364	1 166	20 093	84
1996–97†	2 203	3 063	5 390	2 492	2 578	3 549	530	1 950	21 755	88
1997–98†	1 510	4 790	5 868	2 531	1 027	1 623	811	1 982	20 142	95
1998–99†	2 958	2367	5 613	3 462	820	3 147	844	1 231	20 442	93
1999–00†	2 533	1 733	5 985	4 306	970	3 943	628	1 043	21 142	94

Table 3 [Continued]:

	SSO				BOE				Total estimated	Estimated landings (%)
Year	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6		
2001–02†	2 973	1 769	3 806	4 470	697	2 378	515	983	17 591	94
2002–03†	2 521	1 395	4 105	3 941	481	1 636	868	1 640	16 587	94
2003–04†	1 046	1 244	5 082	3 767	458	1 590	973	1 496	15 656	92
2004–05†	665	1 447	5 848	3 840	234	1 594	851	1 580	16 059	93
2005–06†	529	1 354	5 145	3 289	265	1 770	763	2 616	15 731	90
2006–07†	530	1 220	5 863	2 214	263	1 651	795	3 071	15 607	91
2007–08†	407	1 482	6 150	2 182	429	1 521	592	3 022	15 785	93

Source: FSU from 1978–79 to 1987–88 and MFish from 1988–89 to 2006–07 * 1 April to 31 March. #, 1 April to 30 September. †, 1 October to 30 September.

Descriptive analyses of the main New Zealand oreo fisheries were updated with data from 2006–07 in 2008. Standardised CPUE analyses of black and smooth oreo have been updated as follows:

- smooth oreo in OEO 3A in 2009;
- black oreo in OEO 4 in 2009;
- black oreo in OEO 6 (Pukaki) in 2009;
- smooth oreo OEO 6 (Bounty) in 2008;
- black oreo in OEO 3A in 2008;
- smooth oreo in OEO 4 in 2007;
- smooth oreo in Southland (OEO 1 and OEO 3A)in 2007;
- smooth oreo OEO 6 (Pukaki) in 2006.

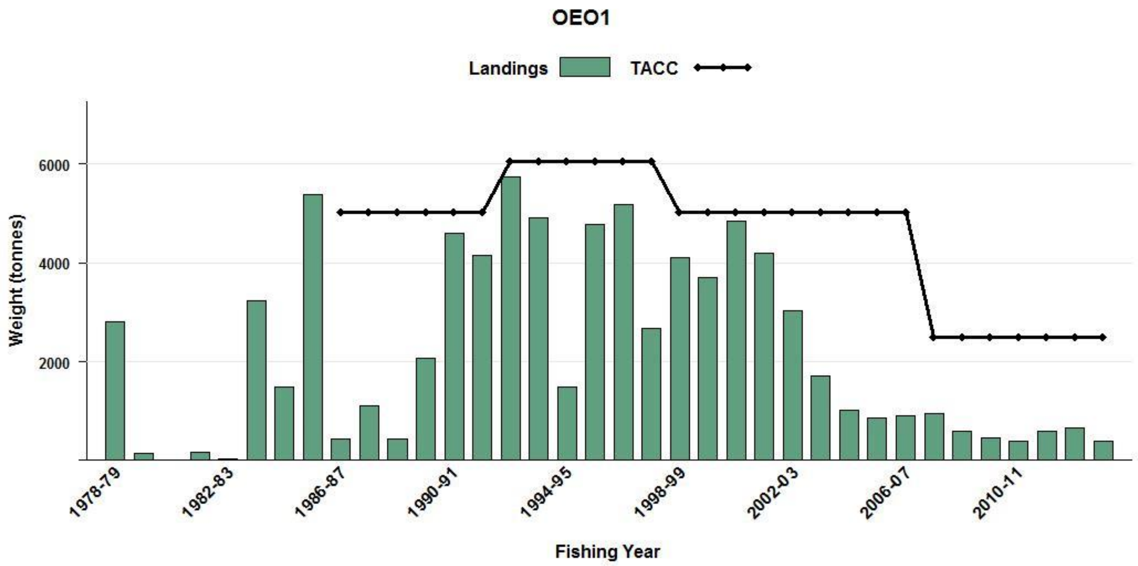


Figure 1: Reported commercial landings and TACC for the four main OEO stocks. OEO 1 (Central East - Wairarapa, Auckland, Central Egmont, Challenger, Southland, South East Catlin Coast). [Continued on next page].

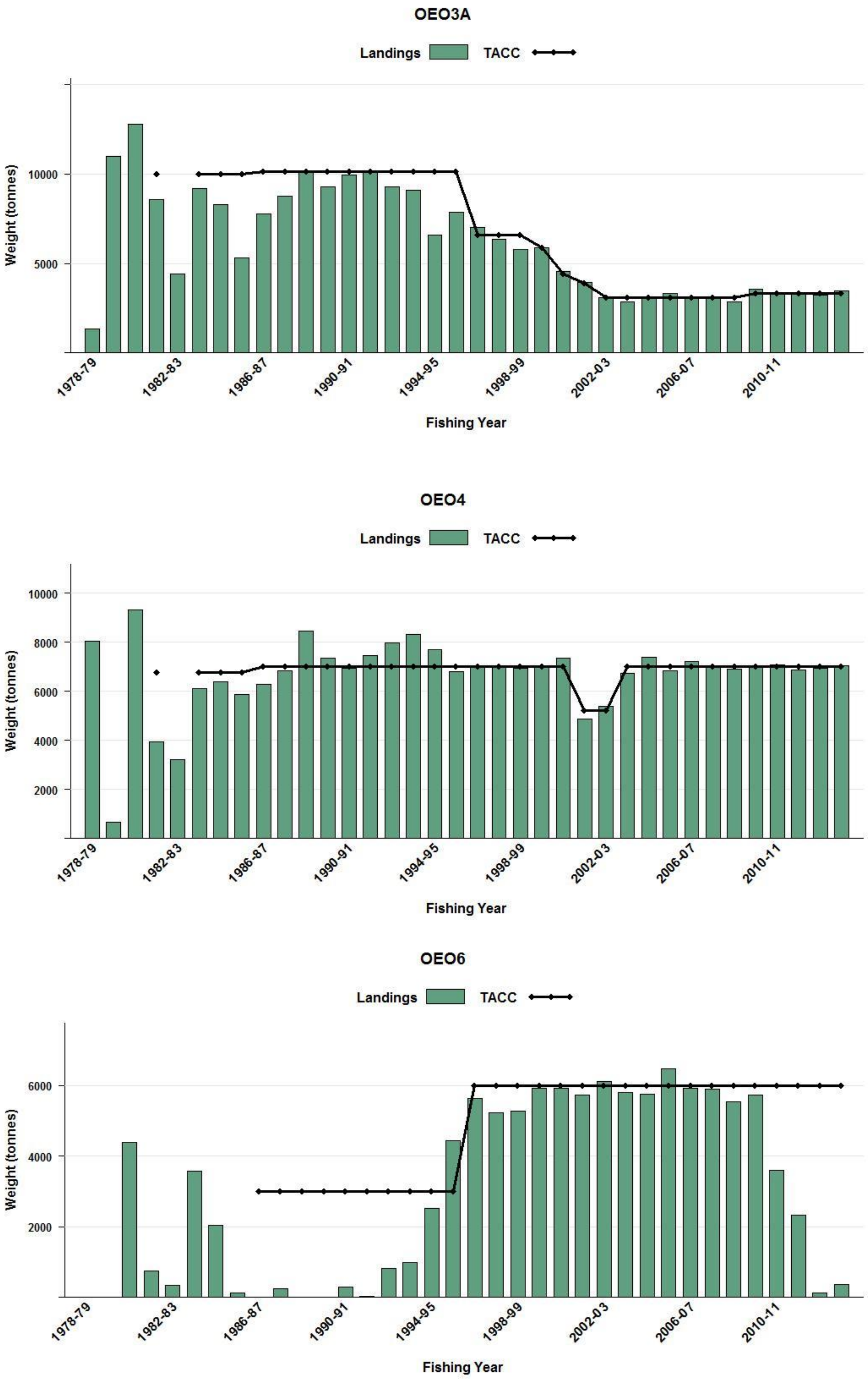


Figure 1 [Continued]: Figure 1: Reported commercial landings and TACC for the four main OEO stocks. From top to bottom: OEO 3A (South East Cook Strait/Kaikoura/Strathallan), OEO 4 (South East Chatham Rise), and OEO 6 (Sub-Antarctic).

4.2 Recreational fisheries
There are no known recreational fisheries for black oreo and smooth oreo.

4.3 Customary non-commercial fisheries
There is no known customary non-commercial fishing for black oreo and smooth oreo.

4.4 Illegal catch
Estimates of illegal catch are not available.

4.5 Other sources of mortality
Dumping of unwanted or small fish and accidental loss of fish (lost codends, ripped codends, etc.) were features of oreo fisheries in the early years. These sources of mortality were probably substantial in those early years but are now thought to be relatively small. No estimate of mortality from these sources has been made because of the lack of hard data and because mortality now appears to be small. Estimates of discards of oreos were made for 1994–95 and 1995–96 from MFish observer data. This involved calculating the ratio of discarded oreo catch to retained oreo catch and then multiplying the annual total oreo catch from the New Zealand EEZ by this ratio. Estimates were 207 and 270 t for 1994–95 and 1995–96 respectively.

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2013 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. An issue-by-issue analysis is available in the 2012 Aquatic Environment and Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644).

5.1 Role in the ecosystem
Smooth and black oreo dominate trawl survey relative abundance estimates of demersal fish species at 650–1200 m on the south and southwest slope of the Chatham Rise (e.g., Hart & McMillan 1998). They are probably also dominant at those depths on the southeast slope of the South Island and other southern New Zealand slope areas including Bounty Plateau, and Pukaki Rise. They are replaced at depths of about 700–1200 m on the east and northern slope of Chatham Rise by orange roughy. The south Chatham Rise oreo fisheries are relatively long-standing, dating from Soviet fishing in the 1970s but the effects of extracting approximately 6000 t per year of smooth oreo from the south Chatham Rise (OEO 4) ecosystem between 1983–84 and 2012–13 are unknown.

5.1.1 Trophic interactions
Smooth oreo feed mainly on salps (80%), molluscs (9%, of which 8% are squids but also including octopods), and teleosts (5%) (percentage frequency of occurrence in stomachs with food, Stevens et al 2011). Black oreo feed on teleosts (48%), crustaceans (36%), salps (24%), and cephalopods (mainly squid, 6%) (Stevens et al 2011). Diet varies with fish size but salps remained the main prey for smooth oreo in the largest fish with small numbers of Scyphozoa, fish and squids. Salps were the main prey for smaller black oreo but amphipods and natant decapod crustaceans were important for intermediate sized fish (Clark et al 1989). Smooth oreo and black oreo occur with orange roughy at times. Orange roughy diet was mainly crustaceans (58%), teleosts (41%), and molluscs (10%, particularly squids) (frequency of occurrence, Stevens et al 2011) suggesting little overlap with the salp-dominated diet of smooth oreo. Where they co-occur, orange roughy and black oreo may compete for teleost and crustacean prey.

Predators of oreos probably change with fish size. Larger smooth oreo, black oreo and orange roughy were observed with healed soft flesh wounds, typically in the dorso-posterior region. Wound shape and size suggest they may be caused by one of the deepwater dogfishes (Dunn et al 2010).

5.1.2 Ecosystem indicators
Tuck et al. (2009) used data from the Sub-Antarctic and Chatham Rise middle-depth trawl surveys to derive indicators of fish diversity, size, and trophic level. However, fishing for oreos occurs mostly deeper than the depth range of these surveys and is only a small component of fishing in the areas considered by Tuck et al. (2009).

5.2 Incidental catch (fish and invertebrates)
Anderson (2011) summarised the bycatch of oreo trawl fisheries from 1990–91 to 2008–09. Since 2002, oreo species (mainly smooth oreo and black oreo) accounted for about 92% of the total estimated catch from all observed trawls targeting oreos. Orange roughy (3.5%) was the main bycatch species, with no other species or group of species accounting for more than 0.6% of the total catch. Hoki were the next most common bycatch species, followed by rattails, deepwater dogfishes, especially Baxter's dogfish (*Etmopterus baxteri*) and seal shark (*Dalatias licha*), slickheads, and basketwork eel (*Diastobranchus capensis*), all of which were usually discarded. Ling were also frequently caught, but only comprised about 0.3% of the total catch. In total, over 250 species or species groups were identified by observers in the target fishery. Total annual fish bycatch in the oreo fishery since 1990–91 ranged from about 270 t to 2200 t and, apart from some higher levels in the late 1990s, did not show any obvious trends. Bycatch was split almost evenly between commercial and non-commercial species although, since 2002, about 60% of the bycatch was of commercial species.

The main invertebrate bycatch includes corals (almost 0.4% of the total catch, Anderson 2011), squids and octopuses, king crabs, and echinoderms. Tracey et al (2011) analysed the distribution of nine groups of protected corals based on bycatch records from observed trawl effort from 2007–08 to 2009–10, primarily from 800–1000 m depth. For the oreo target fishery, the highest catches were reported from the north and south slopes of the Chatham Rise, east of the Pukaki Rise, and on the Macquarie Ridge.

5.3 Incidental catch (seabirds, mammals, and protected fish)
For protected species, capture estimates presented here *include* all animals recovered to the deck of fishing vessels (alive, injured or dead), but do not include any cryptic mortality (e.g., a seabird struck by a warp but not brought on board the vessel, Middleton & Abraham 2007, Brothers et al 2010). Ramm (2011, 2012a, 2012b) summarised observer data for combined bottom trawl fisheries for orange roughy, oreos, cardinalfish and listed annual captures of seabirds, and mammals from 2008–09 to 2010–11.

5.3.1 Marine mammal interactions
There have been no observed incidental captures of New Zealand sea lions by trawlers targeting oreos from 2002–03 to date, but occasional captures of New Zealand fur seals are observed (which were classified as "Not Threatened" under the New Zealand Threat Classification System in 2010, Baker et al 2010). Between 2002–03 and 2012–13, there were 8 observed captures of New Zealand fur seals in oreo trawl fisheries, all prior to 2008–09. In the 2011–12 fishing year there were no observed captures (Table 4) but there were 2 (95% c.i. 0–10) estimated captures, with the estimates made using a statistical model (Thompson et al 2013). All observed fur seal captures occurred in the Sub-Antarctic region. The average rate of capture for the last ten years was less than 0.00 per 100 tows (range 0–0.38). This is a very low rate compared with that in the hoki fishery (1.28–5.63 per 100 tows

Table 4: Number of tows by fishing year and observed and model-estimated total New Zealand fur seal captures in oreo trawl fisheries, 2002–03 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and preliminary data for 2012–13 are based on data version 20140131.

		Observed				Estimated		
	Tows	No.obs	%obs	Captures	Rate	Captures	95%c.i.	%inc.
2002–03	2 834	302	10.7	0	0.00	3	0 – 14	100.0
2003–04	2 542	372	14.6	1	0.27	4	0 – 16	100.0
2004–05	2 571	495	19.3	1	0.20	11	0 – 61	96.3
2005–06	2 306	365	15.8	1	0.27	7	1 – 28	100.0
2006–07	2 255	1 079	47.8	1	0.09	2	1 – 5	100.0
2007–08	2 499	1 050	42.0	4	0.38	6	4 – 15	96.8
2008–09	2 167	893	41.2	0	0.00	2	0 – 11	96.2
2009–10	2 541	964	37.9	0	0.00	2	0 – 10	96.8
2010–11	1 899	612	32.2	0	0.00	2	0 – 12	100.0
2011–12†	1 660	428	25.8	0	0.00	2	0 – 10	100.0
2012–13†	1 278	157	12.3	0	0.00	-	-	-

† Provisional data, no model estimates available.

5.3.2 Seabird interactions

Annual observed seabird capture rates ranged from 0.1 to 3.5 per 100 tows in the combined orange roughy, oreo, and cardinalfish trawl fisheries between 1998–99 and 2007–08 (Baird 2001, 2004 a,b,c, 2005, Abraham et al 2009, Abraham & Thompson 2011). However, in the oreo trawl fisheries only, capture rates have not been above 1 bird per 100 tows since 2005–06 and have fluctuated without obvious trend at this low level (Table 5). In the 2011–12 fishing year there was 1 observed bird capture in the oreo trawl fisheries, a rate of 0.23 birds per 100 observed tows with estimated captures of 8 (3-16) per 100 tows (Abraham et al 2013, Table 5). The average capture rate in the oreo trawl fisheries over the last ten years was only 0.34 birds per 100 tows, a low rate relative to trawl fisheries for squid (13.78), scampi (5.57) and hoki (2.16), birds per 100 tows over the same period.

Table 5: Number of tows by fishing year and observed seabird captures in orange roughy, oreo, and cardinalfish trawl fisheries, 2002–03 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Abraham et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and preliminary data for 2012–13 are based on data version 20140131.

			Fishing effort		Observed captures		Estimated captures	
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.	% included
2002–03	2 834	302	10.7	0	0.00	13	4–27	100.0
2003–04	2 542	372	14.6	0	0.00	13	4–27	100.0
2004–05	2 571	495	19.3	1	0.20	24	94–53	96.3
2005–06	2 306	365	15.8	5	1.37	20	10–38	100.0
2006–07	2 255	1 079	47.8	0	0.00	7	2–18	100.0
2007–08	2 499	1 050	42.0	3	0.29	11	4–21	96.8
2008–09	2 167	893	41.2	2	0.22	8	3–17	96.2
2009–10	2 541	964	37.9	6	0.62	11	5–20	96.8
2010–11	1 899	612	32.2	4	0.65	15	8–26	100.0
2011–12	1 660	428	25.8	1	0.23	8	3–16	100.0
2012 –13†	1 278	157	12.3	0	0.00	-	-	-

† Provisional data, no model estimates available.

Table 6: Number of observed seabird captures in oreo trawl fisheries, 2002–03 to 2012–13, by species and area. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard & Abraham 2013 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for oreo. Other data, version 20130304.

Species	Risk Ratio	Chatham Rise	East Coast South Island	Subantarctic	Stewart-Snares Shelf	West Coast South Island	Total
Salvin's albatross	Very high	3	3	3	0	0	9
Chatham Island albatross	Very high	3	0	1	0	0	4
Total albatrosses	**N/A**	**6**	**3**	**4**	**0**	**0**	**13**
Cape petrel	High	0	1	0	0	0	1
White chinned petrel	Medium	0	1	0	0	0	1
Grey petrel	Medium	0	0	1	0	0	1
Sooty shearwater	Very low	0	3	0	1	0	4
NZ White-faced storm petrel	-	1	0	0	0	0	1
Total other birds	N/A	**1**	**5**	**1**	**1**	**0**	**8**

Salvin’s albatross was the most frequently captured albatross (46% of observed albatross captures) but only two different species have been observed captured since 2002–03 (Table 6). Sooty shearwaters were the most frequently captured other taxon (50%, Table 6). Seabird captures in the oreo trawl fisheries were observed mostly off the east coast South Island. These numbers should be regarded as only a general guide on the distribution of captures because the observer coverage may not be representative.

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the orange roughy, oreo, and cardinalfish trawl fisheries. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Department of Internal Affairs 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being “paired streamer lines”, “bird baffler” or “warp deflector” as defined in the Notice).

5.4 Benthic interactions

Orange roughy, oreos, and cardinalfish are taken using bottom trawls and accounted for about 14% of all tows reported on TCEPR forms to have been fished on or close to the bottom between 1989–90 and 2004–05 (Baird et al 2011). Black et al (2013) estimated that, between 2006–07 and 2010–11, 97% of oreo catch was reported on TCEPR forms. Tows are located in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2009) classes J, K (mid-slope), M (mid-lower slope), N, and O (lower slope and deeper waters) (Baird & Wood 2012), and 94% were between 700 and 1 200 m depth (Baird et al 2011). Deepsea corals in the New Zealand region are abundant and diverse and, because of their fragility, are at risk from anthropogenic activities such as bottom trawling (Clark & O’Driscoll 2003, Clark & Rowden 2009, Williams et al 2010). All deepwater hard corals are protected under Schedule 7A of the Wildlife Act 1953. Baird et al (2012) mapped the likely coral distributions using predictive models, and concluded that the fisheries that pose the most risk to protected corals are these deepwater trawl fisheries.

Trawling for orange roughy, oreo, and cardinalfish, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review (Ministry for Primary Industries 2012).

The New Zealand EEZ contains 17 Benthic Protection Areas (BPAs) that are closed to bottom trawl fishing and include about 52% of all seamounts over 1500 m elevation and 88% of identified hydrothermal vents.

5.5 Other considerations

5.5.1 Spawning disruption

Fishing during spawning may disrupt spawning activity or success. Morgan et al (1999) concluded that Atlantic cod (*Gadus morhua*) "exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae". Morgan et al (1997) also reported that "Following passage of the trawl, a 300-m-wide "hole" in the [cod spawning] aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl." There is no research on the disruption of spawning smooth oreo and black oreo by fishing in New Zealand, but spawning of both species appears to be over a protracted period (October to February) and over a wide area (O'Driscoll et al 2003). Fishing continues during the spawning period, possibly because localised spawning schools of smooth oreo, in particular, may provide good catch rates.

5.5.2 Genetic effects

Fishing, environmental changes, including those caused by climate change or pollution, could alter the genetic composition or diversity of a species. There are no known studies of the genetic diversity of smooth or black oreo from New Zealand. Genetic studies for stock discrimination are reported under "stocks and areas".

5.5.3 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management does not have a policy definition currently although work is currently underway to generate one. O'Driscoll et al. (2003) identified the south Chatham Rise as important for smooth oreo spawning, and the north, east and south slope as important for juveniles. The south Chatham Rise is also important for black oreo spawning and juveniles. Deepsea corals such as the reef-forming scleractinian corals and gorgonian sea fan corals are thought to provide prey and refuge for deep-sea fish (Fosså et al 2002, Stone 2006, Mortensen et al 2008). Large aggregations of deepwater species like orange roughy, oreos, and cardinalfish occur above seamounts with high densities of such "reef-like" taxa, but it is not known if there are any direct linkages between the fish and corals. Bottom trawling for orange roughy, oreos, and cardinalifish has the potential to affect features of the habitat that could qualify as habitat of particular significance to fisheries management.

6. FOR FURTHER INFORMATION

Abraham, E.R.; Thompson, F.N. (2009). Capture of protected species in New Zealand trawl and longline fisheries, 1998–99 to 2006–07. *New Zealand Aquatic Environment and Biodiversity Report No. 32*. 197 p.

Abraham, E R; Thompson, F N (2011) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 80*.

Abraham, E R; Thompson, F N; Berkenbusch, K (2013) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Ministry for Primary Industries, Wellington).

Anderson, O F (2011) Fish and invertebrate bycatch and discards in orange roughy and oreo fisheries from 1990–91 until 2008–09. *New Zealand Aquatic Environment and Biodiversity Report No. 67*. 61 p.

Baird, S J (2001) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1998–99. *New Zealand Fisheries Assessment Report 2001/14*.43 p.

Baird, S J (2004a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999–2000. *New Zealand Fisheries Assessment Report 2004/41*. 56 p.

Baird, S J (2004b) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000–01. *New Zealand Fisheries Assessment Report 2004/58*. 63 p.

Baird, S J (2004c) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001–02. *New Zealand Fisheries Assessment Report 2004/60*. 51 p.

Baird, S J (2005) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/2*. 50 p.

Baird, S J; Smith, M H (2007) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report No. 14*. 98 p.

Baird, S J; Wood, B A (2012) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. *New Zealand Aquatic Environment and Biodiversity Report 89*. 43 p.

Baird, S J; Wood, B A; Bagley, N W (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989–90 to 2004–05. *New Zealand Aquatic Environmental and Biodiversity Report No. 73*. 48 p.

Baker, C S; Chilvers, B L; Constantine, R; DuFresne, S; Mattlin, R H; van Helden, A; Hitchmough, R (2010) Conservation status of New Zealand marine mammals (suborders Cetacea and Pinnipedia), 2009. *New Zealand Journal of Marine and Freshwater Research 44*: 101–115.

Ballara, S L; Anderson, O F (2009) Fish discards and non-target fish catch in the trawl fisheries for arrow squid and scampi in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 38*. 102 p.

Black, J; Wood, R; Berthelsen, T; Tilney, R (2013) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2009–2010. *New Zealand Aquatic Environment and Biodiversity Report No. 110*. 57 p.

Clark, M R; Anderson, O F; Gilbert, D J (2000) Discards in trawl fisheries for southern blue whiting, orange roughy, hoki, and oreos in waters around New Zealand. *NIWA Technical Report 71*. 73 p.

Clark, M R; King, K J; McMillan, P J (1989) The food and feeding relationships of black oreo, *Allocyttus niger*, smooth oreo, *Pseudocyttus maculatus*, and eight other fish species from the continental slope of the south-west Chatham Rise, New Zealand. *Journal of Fish Biology* 35: 465–484.

Clark, M; O'Driscoll, R (2003) Deepwater fisheries and aspects of their impact on seamount habitat in New Zealand. *Journal of Northwest Atlantic Fishery Science 31*: 441–458.

Clark, M R; Rowden, A A (2009) Effect of deepwater trawling on the macro-invertebrate assemblages of seamounts on the Chatham Rise, New Zealand. *Deep Sea Research I 56*: 1540–1554.

Coburn, R P; McMillan, P J (2006) Descriptions of the black oreo and smooth oreo fisheries in OEO 1, OEO 3A, OEO 4, and OEO 6 from 1977–78 to the 2004–05 fishing years. *New Zealand Fisheries Assessment Report 2006/60*. 70 p.

Coburn, R P; McMillian, P J; Gilbert, D J (2007) Inputs for a stock assessment of smooth oreo, Pukaki Rise (part of OEO 6). *New Zealand Fisheries Assessment Report 2007/23*. 32 p.

Department of Internal Affairs. (2006) Seabird Scaring Devices – Circular Issued Under Authority of the Fisheries (Commercial Fishing) Amendment Regulations 2006 (No. F361). *New Zealand Gazette 6 April 2006* : 842–846.

Doonan, I J; McMillan, P J; Hart, A C (1997) Revision of smooth oreo life history parameters. New Zealand Fisheries Assessment Research Document 1997/9. 11 p. (Unpublished document held in NIWA library, Wellington.)

Doonan, I J; McMillian, P J; Hart, A C (2008) Ageing of smooth oreo otoliths for stock assessment. *New Zealand Fisheries Assessment Report 2008/08*. 29 p.

Doonan, I J; McMillan, P J; Kalish, J M; Hart, A C (1995) Age estimates for black oreo and smooth oreo. New Zealand Fisheries Assessment Research Document. 1995/14. 26 p. (Unpublished document held in NIWA library, Wellington.)

Dunn, M R; Szabo, A; McVeagh, M S; Smith, P J (2010) The diet of deepwater sharks and the benefits of using DNA identification of prey. *Deep-Sea Research I 57* 923–930.

Fosså J H; Mortensen P B; Furevik D M (2002) The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. *Hydrobiologia* 471: 1–12.

Hart, A C; McMillan, P J (1998) Trawl survey of oreos and orange roughy on the south Chatham Rise, October–November 1995 (TAN9511). *NIWA Technical Report 27*. 48 p.

Hart, A C; McMillan, P J (2006) A summary of observer biological information on the New Zealand black oreo and smooth oreo fisheries from 1979–80 to 2004–05. *New Zealand Fisheries Assessment Report 2006/55*. 39 p.

Hermsen, J M; Collie, J S; Valentine, P C (2003) Mobile fishing gear reduces benthic megafaunal production on Georges Bank. *Marine Ecology Progress Series 260*: 97–108.

Hiddink, J G; Jennings, S; Kaiser, M J; Queiros, A M; Duplisea, D E; Piet, G J (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Sciences 63*: 721–36.

Jennings, S; Dinmore, T A; Duplisea, D E; Warr, K J; Lancaster, J E (2001) Trawling disturbance can modify benthic production processes. *Journal of Animal Ecology 70*: 459–475.

Leathwick, J R; Rowden, A; Nodder, S; Gorman, R; Bardsley, S; Pinkerton, M; Baird, S J; Hadfield, M; Currie, K; Goh, A (2009) Benthic-optimised marine environment classification for New Zealand waters. Final Research Report for Ministry of Fisheries project BEN2006/01. 52 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

McKenzie, A (2007) Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6). *New Zealand Fisheries Assessment Report 2007/34*. 27 p.

McMillan, P J; Doonan, I J; Hart, A C (1997) Revision of black oreo life history parameters. New Zealand Fisheries Assessment Research Document 1997/8. 13 p. (Unpublished document held in NIWA library, Wellington.)

Middleton, D A J; Abraham, E R (2007) The efficacy of warp strike mitigation devices: Trials in the 2006 squid fishery. Final Research Report for research project IPA2006/02. (Unpublished report held by Ministry for Primary Industries, Wellington).

Ministry for Primary Industries (2012) Aquatic Environment and Biodiversity Annual Review 2012. Compiled by the Fisheries Management Science Team, Ministry for Primary Industries, Wellington, New Zealand. 390 p.

Morgan, M J; Deblois, E M; Rose, G A (1997) An observation on the reaction of Atlantic cod (*Gadus morhua*) in a spawning shoal to bottom trawling. *Symposium on the Biology and Ecology of Northwest Atlantic Cod, St. John's, NF (Canada)*, 24–28 Oct 1994.

Morgan, M J; Wilson, C E; Crim, L W (1999) The effect of stress on reproduction in Atlantic cod. *Journal of Fish Biology 54*: 477–488.

Mortensen, P B; Buhl-Mortensen, L; Gebruk, A V; Krylova, E M (2008) Occurrence of deep-water corals on the Mid-Atlantic Ridge based on MAR-ECO data. *Deep Sea Research Part II: Topical Studies in Oceanography 55*: 142–152.

O'Driscoll, R L; Booth, J D; Bagley, N W; Anderson, O F; Griggs, L H; Stevenson, M L; Francis, M P (2003) Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. *NIWA Technical Report 119*. 377 p.

Ramm, K C (2011) Conservation Services Programme Observer Report for the period 1 July 2008 to 30 June 2009. Available at: www.doc.govt.nz/documents/science-and-technical/2008-09-csp-observer-report.pdf

Ramm, K (2012a) Conservation Services Programme Observer Report: 1 July 2009 to 30 June 2010. Department of Conservation, Wellington. 130 p.

Ramm, K (2012b) Conservation Services Programme Observer Report: 1 July 2010 to 30 June 2011. Department of Conservation, Wellington. 121 p.

Reiss, H; Greenstreet, S P R; Siebe, K; Ehrich, S; Piet, G J; Quirijns, F; Robinson, L; Wolff, W J; Kronke, I (2009) Effects of fishing disturbance on benthic communities and secondary production within an intensively fished area. *Marine Ecology Progress Series 394*: 201–213.

Rice, J (2006) Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. Canadian Science Advisory Secretariat Research Document 2006/057. 35 p. (available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf).

Richard, Y; Abraham, E R (2013) Risk of commercial fisheries to New Zealand seabird populations. *New Zealand Aquatic Environment and Biodiversity Report No. 109*. 62 p.

Richard, Y; Abraham, E R; Filippi, D (2011) Assessment of the risk to seabird populations from New Zealand commercial fisheries. Final Research Report for Ministry of Fisheries research projects IPA2009-19 and IPA2009-20. (Unpublished report held by Ministry for Primary Industries, Wellington.). 66 p.

Smith, P; McMillan, P; Proctor, C; Robertson, S; Knuckey, I; Diggles, B; Bull, B (1999) Stock relationships of smooth oreo in New Zealand waters. Final Research Report for Ministry of Fisheries Research Project DEE9801. 76 p.

Smith, P; Proctor, C; Robertson, S; McMillan, P; Bull, B; Diggles, B (2000) Stock relationships of black oreo in New Zealand waters. Final Research Report for Ministry of Fisheries Research Project DEE9801. Objective 1 (Part two). 79 p.

Stevens, D W; Hurst, R J; Bagley, N W (2011) Feeding habits of New Zealand fishes: a literature review and summary of research trawl database records 1960 to 2000. *New Zealand Aquatic Environment and Biodiversity Report No. 85*. 218 p.

Stewart, B D; Smith, D C (1994) Development of methods to age commercially important dories and oreos. Final Report to the Fisheries Research and Development Corporation.

Stone, R P (2006) Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. *Coral Reefs 25*: 229–238.

Thompson, F N; Berkenbusch, K; Abraham, E R (2013) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. *New Zealand Aquatic Environment and Biodiversity Report No. 105*. 73p.

Tracey, D M; Rowden, A A; Mackay, K A; Compton, T (2011) Habitat-forming cold-water corals show affinity for seamounts in the New Zealand region. *Marine Ecology Progress Series 430*: 1–22.

Tuck, I; Cole, R; Devine, J (2009) Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 42*. 188 p.

Ward, R D; Elliot, N G; Yearsley, G K; Last, P R (1996) Species and stock delineation in Australasian oreos (Oreosomatidae). Final Report to Fisheries Research and Development Corporation. 144 p.

Williams, A; Schlacher, T A; Rowden, A A; Althaus, F; Clark, M R; Bowden, D A; Stewart, R; Bax, N J; Consalvey, M; Kloser, R J (2010) Seamount megabenthic assemblages fail to recover from trawling impacts. *Marine Ecology 31 (Suppl. 1)*: 183–199.

OREOS — OEO 3A BLACK OREO AND SMOOTH OREO

1. FISHERY SUMMARY

This is presented in the Fishery Summary section at the beginning of the Oreos report.

2. BIOLOGY

This is presented in the Biology section at the beginning of the Oreos report.

3. STOCKS AND AREAS

This is presented in the Stocks and Areas section at the beginning of the Oreos report.

4. STOCK ASSESSMENT

The smooth oreo stock assessment is unchanged from 2009. The black oreo stock assessment for 2008 has been withdrawn but the CPUE series has been updated to 2012.

4.1 Introduction

The following assumptions were made in the stock assessment analyses to estimate biomasses and yields for black oreo and smooth oreo.

(a) The acoustic abundance estimates were unbiased absolute values.
(b) The CPUE analyses provided indices of abundance for either black oreo or smooth oreo in the whole of OEO 3A. Most of the oreo commercial catches came from the CPUE study areas. Research trawl surveys indicated that there was little habitat for, and biomass of, black oreo or smooth oreo outside those areas.
(c) The ranges used for the biological values covered their true values.
(d) The maximum fishing mortality (F_{MAX}) was assumed to be 0.9, varying this value from 0.5 to 3.5 altered B_0 for smooth oreo in OEO 3A by only about 6% in the 1996 assessment.
(e) Recruitment was deterministic and followed a Beverton and Holt relationship with steepness of 0.75.
(f) Catch overruns were 0% during the period of reported catch.
(g) The populations of black oreo and smooth oreo in OEO 3A were discrete stocks or production units.
(h) The catch histories were accurate.

4.1.1 Black oreo

The last accepted assessment was in 2008. A three-area population model was used to accommodate the structure of the catch and length data, with age-dependent migration between areas. However, new age data collected within each area suggest that, based on 2013 analyses, assumptions made by this model are incorrect. Specifically, differences in the size distribution between areas now seem likely to be due to differential growth rates, rather than to movement. The model applied in 2008 was therefore considered inadequate and has been withdrawn. No stock assessment is presented here; a new approach needs to be developed.

4.1.2 Smooth oreo

A new assessment of smooth oreo in OEO 3A was completed in 2009. This used a CASAL age-structured population model employing Bayesian methods. Input data included research and observer-collected length data, one absolute abundance estimate from a research acoustic survey carried out in 1997 (TAN9713), and three relative abundance indices from standardised catch per unit effort analyses.

4.2 Black oreo

Partition of the main fishery into 3 areas

The main fishery area was split into three areas: a northern area that contained small fish and was generally shallow (Area 1), a southern area that contained large fish in the period before 1993 and which was generally deeper (Area 3), and a transition area (Area 2) that lay between Areas 1 and 3 (Figure 1).

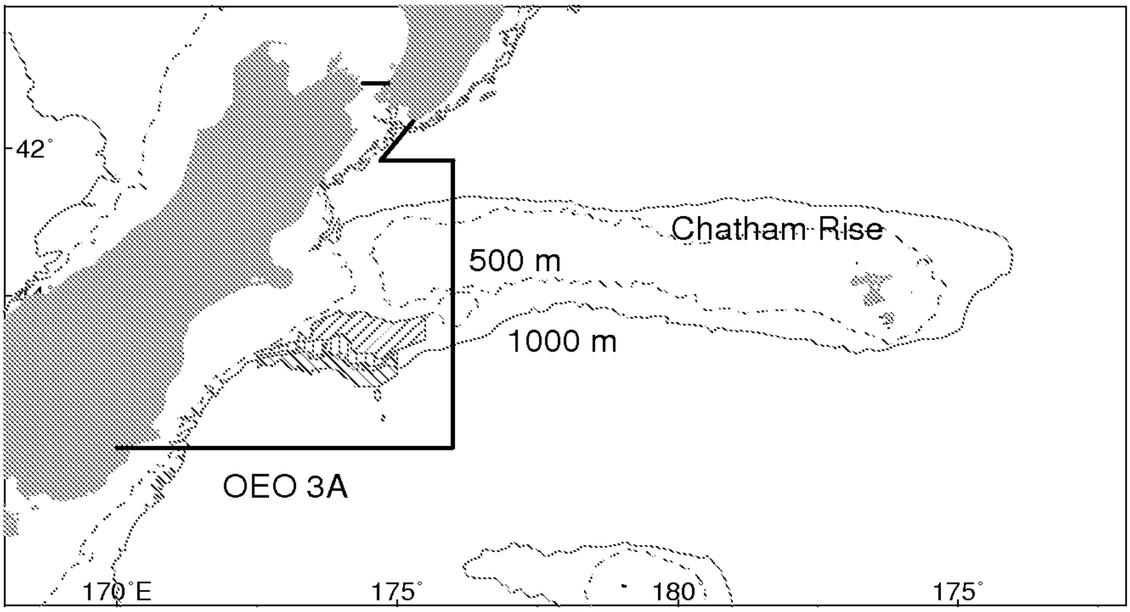


Figure 1: The three spatial areas used in the CASAL model and 2002 acoustic abundance survey. Area 1 at the top with right sloping shading; Area 2 in the middle with vertical shading; Area 3 at the bottom with left sloping shading. The thick dark line encloses management area OEO 3A.

The boundary between Areas 1 and 2 was defined in terms of the northern edge of the area that enclosed 90% of the total catch from the fishery. Areas 2 and 3 contained most of the fishery while Area 1 consisted of lightly fished and unfished ground. The boundary between Areas 2 and 3 was defined by the 32.5 cm contour in mean fish length for data before 1993 so that the fishery is split into an area containing smaller fish and another that has larger fish. The population outside the main fishery was assumed to follow the same relative dynamics.

Rejection of spatial model based on migration

The previous model reconciled the differences in commercial length distribution by using three areas. No age data were incorporated and instead lengths were used as a proxy for age. The dynamics were assumed to be recruitment in the shallow area (Area 1), with migration from Area 1 to Area 2, and also from Area 2 to Area 3, i.e., a one way movement to generally deeper water. The differences in the length distributions between areas drove the estimated migration rates by age. The stock assessment predicted that mature fish in the relatively unfished area (Area 1) comprised about 25% B_0 and so there were no sustainability concerns as this area was largely not fished.

To test the above migration hypothesis, otoliths sampled from acoustic survey mark identification trawls were aged and age distributions estimated for Area 1 and for the combined Areas 2 and 3 (Doonan, pers. comm.). The results showed deficiencies in the use of length data as a proxy for age in the stock assessment model. The age frequency in Area 1 was similar to that from Areas 2 and 3, but the model predicted them to be very different. Growth in Areas 2 and 3 appears to be faster than in Area 1 and this may drive the observed differences in length distributions. The migration model assumed the same growth in all areas. Maturity may be related to length rather than age, but it is age-based in the model. For these reasons, the Working Group rejected the stock assessment model in 2013. No formal stock assessment is presented here.

4.2.1 Estimates of fishery parameters and abundance

Catches by area

Catches were partitioned into the three areas by scaling up the estimated catch of black oreo from each area to the total reported catch (see tables 2 and 3 in the Fishery Summary section at the beginning of the Oreos report) and are given in Table 1.

Table 1: Estimated black oreo catch (tonnes) for each fishing year in the three spatial model areas.

Year	Area 1	Area 2	Area 3	Total
1972–73	110	2 010	1 320	†3 440
1973–74	130	2 214	1 456	†3 800
1974–75	170	2 970	1 960	†5 100
1975–76	40	736	484	†1 260
1976–77	130	2 260	1 490	†3 880
1977–78	190	3 350	2 210	†5 750
1978–79	27	750	30	806
1979–80	39	2 189	4 762	6 990
1980–81	793	7 813	4 090	12 696
1981–82	12	7 616	3 851	11 479
1982–83	57	3 384	2 577	6 018
1983–84	682	5 925	3 192	9 800
1984–85	148	1 478	2 218	3 844
1985–86	13	814	1 112	1 938
1986–87	33	1 863	1 908	3 805
1987–88	49	2 399	1 439	3 888
1988–89	244	3 532	811	4 588
1989–90	696	1 164	1 288	3 148
1990–91	753	1 947	1 330	4 030
1991–92	289	1 250	1 816	3 355
1992–93	180	2 221	1 717	4 117
1993–94	339	2 509	1 353	4 200
1994–95	139	1 894	845	2 878
1995–96	231	2 744	1 099	4 074
1996–97	418	2 095	1 035	3 548
1997–98	257	874	1 267	2 397
1998–99	138	2 047	572	2 756
1999–00	133	2 246	906	3 285
2000–01	89	1 804	761	2 653
2001–02	58	1 447	620	2 126
2002–03	82	997	236	1 314
2003–04	233	775	464	1 471
2004–05	61	766	360	1 187
2005–06	55	1 315	312	1 682
2006–07	48	914	698	1 659
2007–08	53	926	629	1 607
2008–09	59	920	671	1 649
2009–10	115	973	885	1 973
2010–11	38	859	762	1 659
2011–12	31	534	910	1 475

† Soviet catch, assumed to be mostly from OEO 3A and to be 50:50 black oreo: smooth oreo.

Observer length frequencies by area

Catch at length data collected by observers in Areas 1, 2, and 3 were extracted from the *obs_lfs* database (Table 2). Derived length frequencies for each group were calculated from the sample length frequencies weighted by the catch weight of each sample.

Table 2: Number of observed commercial tows where black oreo was measured for length frequency. A total of 60 tows were excluded because they had fewer than 30 fish measured, extreme mean lengths or missing catch information.

Year	Area 1	Area 2	Area 3	Other
1985–86	0	1	0	0
1986–87	0	2	6	0
1987–88	0	6	3	0
1988–89	30	8	4	2
1989–90	12	6	1	0
1990–91	2	5	7	1
1991–92	0	10	1	0
1992–93	0	0	0	0
1993–94	8	16	2	5
1994–95	0	4	2	2
1995–96	2	3	2	6
1996–97	0	1	1	2
1997–98	13	2	5	0
1998–99	2	1	0	3
1999–00	7	94	11	6
2000–01	3	110	22	2
2001–02	8	23	8	5
2002–03	3	17	4	4
2003–04	9	1	2	3
2004–05	3	5	3	1
2005–06	0	38	7	7
2006–07	6	1	2	5
2007–08	0	9	5	7
2008–09	4	16	9	3
2009–10	4	14	4	2
2010–11	1	15	7	2
2011–12	3	6	1	0

Research acoustic survey length frequencies by area

The 1997, 2002, 2006 and 2011 acoustic survey abundance at length data were converted to a length frequency using the combined sexes fixed length-weight relationship (“unsexed” in table 1, Biology section above) to convert the abundance to numbers at length (Table 3).

Absolute abundance estimates from the 1997, 2002, 2006 and 2011 acoustic surveys

Absolute estimates of abundance for black oreo are available from four acoustic surveys of oreos carried out from 10 November to 19 December 1997 (TAN9713), 25 September to 7 October 2002 (TAN0213), 17–30 October 2006 (TAN0615) and 17 November to 1 December 2011 (SWA1102). The 1997 survey covered the “flat” with a series of random north-south transects over six strata at depths of 600–1200 m. Seamounts were also sampled using parallel and “starburst” transects. Targeted and some random (background) trawling was carried out to identify targets and to determine species composition. The 2002 survey was limited to flat ground with 77 acoustic transect and 21 mark identification tows completed. The 2006 (78 transects and 22 tows) and 2011 (72 transects and 25 tows) surveys were very similar to the 2002 survey and covered the main area of the black oreo fishery. The estimated total abundance (immature plus mature) for each survey by area is shown in Table 4.

Table 3: Research length frequency proportions for the model area for the 1997, 2002, 2006 and 2011 acoustic surveys. - no data for 1997 to 2006, lengths below 25 cm and greater than 38 were pooled.

	1997			2002			2006			2011		
Length (cm)	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
22	-	-	-	-	-	-	-	-	-	0.001	0.001	0.000
23	-	-	-	-	-	-	-	-	-	0.007	0.008	0.002
24	-	-	-	-	-	-	-	-	-	0.021	0.019	0.007
25	0.015	0.013	0.009	0.022	0.016	0.008	0.009	0.017	0.015	0.031	0.029	0.010
26	0.035	0.027	0.019	0.039	0.030	0.013	0.026	0.035	0.032	0.027	0.027	0.019
27	0.113	0.061	0.029	0.051	0.038	0.018	0.066	0.073	0.055	0.044	0.047	0.032
28	0.165	0.090	0.038	0.085	0.062	0.029	0.118	0.105	0.077	0.083	0.086	0.055
29	0.153	0.104	0.064	0.117	0.091	0.044	0.152	0.143	0.113	0.112	0.114	0.072
30	0.143	0.105	0.065	0.139	0.119	0.060	0.175	0.153	0.132	0.153	0.154	0.107
31	0.131	0.119	0.089	0.123	0.122	0.086	0.156	0.157	0.154	0.159	0.157	0.125
32	0.102	0.121	0.105	0.137	0.133	0.127	0.117	0.136	0.169	0.121	0.119	0.153
33	0.046	0.094	0.098	0.112	0.123	0.141	0.073	0.089	0.119	0.121	0.118	0.175
34	0.041	0.086	0.097	0.065	0.084	0.138	0.059	0.056	0.076	0.069	0.067	0.126
35	0.029	0.058	0.083	0.054	0.064	0.100	0.032	0.026	0.037	0.026	0.029	0.057
36	0.015	0.043	0.091	0.021	0.052	0.104	0.014	0.009	0.014	0.018	0.018	0.034
37	0.006	0.037	0.080	0.015	0.025	0.049	0.001	0.001	0.004	0.005	0.005	0.018
38	0.006	0.042	0.131	0.020	0.041	0.083	0.003	0.001	0.003	0.002	0.002	0.005
39	-	-	-	-	-	-	-	-	-	0.000	0.000	0.002
40	-	-	-	-	-	-	-	-	-	0.000	0.000	0.000
41	-	-	-	-	-	-	-	-	-	0.000	0.000	0.000
42	-	-	-	-	-	-	-	-	-	0.000	0.000	0.000

Table 4: Total (immature plus mature) black oreo abundance estimates (t) and CVs for the 1997, 2002, 2006 and 2011 acoustic surveys for the three model areas in OEO 3A.

Acoustic survey	Area 1	Area 2	Area 3	Total
1997	148 000 (29)	10 000 (26)	5 240 (25)	163 000 (26)
2002	43 300 (31)	15 400 (27)	4 710 (38)	64 000 (22)
2006	56 400 (37)	16 400 (30)	5 880 (34)	78 700 (30)
2011	138 100 (27)	36 800 (30)	7 400 (34)	182 300 (25)

Relative abundance estimates from standardised CPUE analysis

Standardised CPUE indices were obtained for each area. Because of the apparent changes in fishing practice attributable to the introduction of GPS, the data were split into pre- and post-GPS series. There were also major changes in the fishery from 1998–99 to 2001–02 when there were TACC reductions and the start of a voluntary industry catch limit on smooth oreo (1998–99). Two post-GPS series were therefore developed. The first of these was from 1992–93 to 1997–98 (early series) and the second was from 2002–03 onwards (late series) with data from the intervening years ignored. Since there are no new data for either the pre-GPS series or the post-GPS early series, these are left unchanged from previous standardisation results. Only the post-GPS late series is updated here, using data that now extends from 2002–03 to 2011–12.

Only data within a pre-defined spatial area were considered useful for assessing abundance (Figure 2).

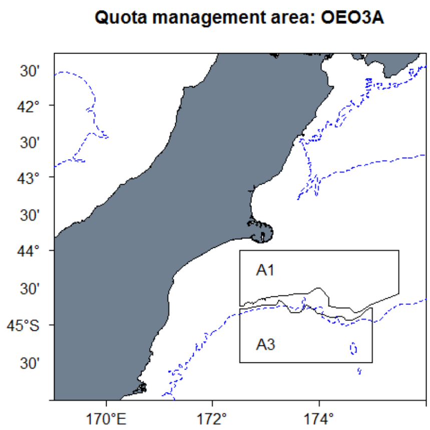


Figure 2: Spatial areas from which CPUE data were collected for inclusion in the standardisation. Areas A1 and A3 are shown, with A2 being the area between the two.

This area corresponds to the main fishing area and overlaps with the acoustic survey area (Figure 1). Tows were initially selected for inclusion in the CPUE standardisation if they targeted or caught black oreo within this area.

Uncertainty was assessed by bootstrapping the data, re-estimating the indices for each iteration, and estimating the coefficient of variation (CV) for each year/area from this distribution. The indices and CV estimates are listed in Table 5 and shown in Figure 3.

Table 5: OEO 3A black oreo pre-GPS and post-GPS time series of standardised catch per unit effort indices and bootstrapped CV estimates (%). Values for each series have been renormalized to a geometric mean of one. -, no estimate.

Fishing	Pre-GPS						Post-GPS					
Year	Area1		Area2		Area3		Area1		Area2		Area3	
	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1979–80	-	-	1.45	39	1.52	125	-	-	-	-	-	-
1980–81	-	-	1.84	17	2.55	15	-	-	-	-	-	-
1981–82	-	-	1.71	22	2.15	9	-	-	-	-	-	-
1982–83	-	-	1.41	8	1.80	14	-	-	-	-	-	-
1983–84	-	-	0.99	8	1.04	19	-	-	-	-	-	-
1984–85	-	-	0.95	27	0.99	12	-	-	-	-	-	-
1985–86	-	-	0.63	31	0.66	33	-	-	-	-	-	-
1986–87	-	-	0.81	22	0.88	36	-	-	-	-	-	-
1987–88	-	-	0.45	20	0.49	23	-	-	-	-	-	-
1988–89	-	-	0.72	21	0.23	44	-	-	-	-	-	-
1989–90	-	-	-	-	-	-	-	-	-	-	-	-
1990–91	-	-	-	-	-	-	-	-	-	-	-	-
1991–92	-	-	-	-	-	-	-	-	Early series			
1992–93	-	-	-	-	-	-	-	-	1.62	14	2.46	20
1993–94	-	-	-	-	-	-	-	-	1.17	17	1.20	15
1994–95	-	-	-	-	-	-	-	-	0.96	13	0.82	17
1995–96	-	-	-	-	-	-	-	-	0.89	15	0.68	22
1996–97	-	-	-	-	-	-	-	-	1.06	18	0.96	17
1997–98	-	-	-	-	-	-	-	-	0.58	47	0.64	63
1998–99	-	-	-	-	-	-	-	-	-	-	-	-
1999–00	-	-	-	-	-	-	-	-	-	-	-	-
2000–01	-	-	-	-	-	-	-	-	-	-	-	-
2001–02	-	-	-	-	-	-	Late series					
2002–03	-	-	-	-	-	-	0.62	90	1.11	24	0.9	38
2003–04	-	-	-	-	-	-	0.99	45	1.15	27	1.05	37
2004–05	-	-	-	-	-	-	1.33	63	0.85	32	0.8	56
2005–06	-	-	-	-	-	-	1.1	63	1.34	23	0.99	31
2006–07	-	-	-	-	-	-	0.51	78	1.05	27	1.49	24
2007–08	-	-	-	-	-	-	1.52	44	0.67	66	0.84	33
2008–09	-	-	-	-	-	-	0.65	73	0.84	44	0.75	30
2009–10	-	-	-	-	-	-	1.17	29	1.02	26	1.06	30
2010–11	-	-	-	-	-	-	1.38	52	0.89	30	0.9	22
2011–12	-	-	-	-	-	-	1.37	44	1.28	24	1.49	18

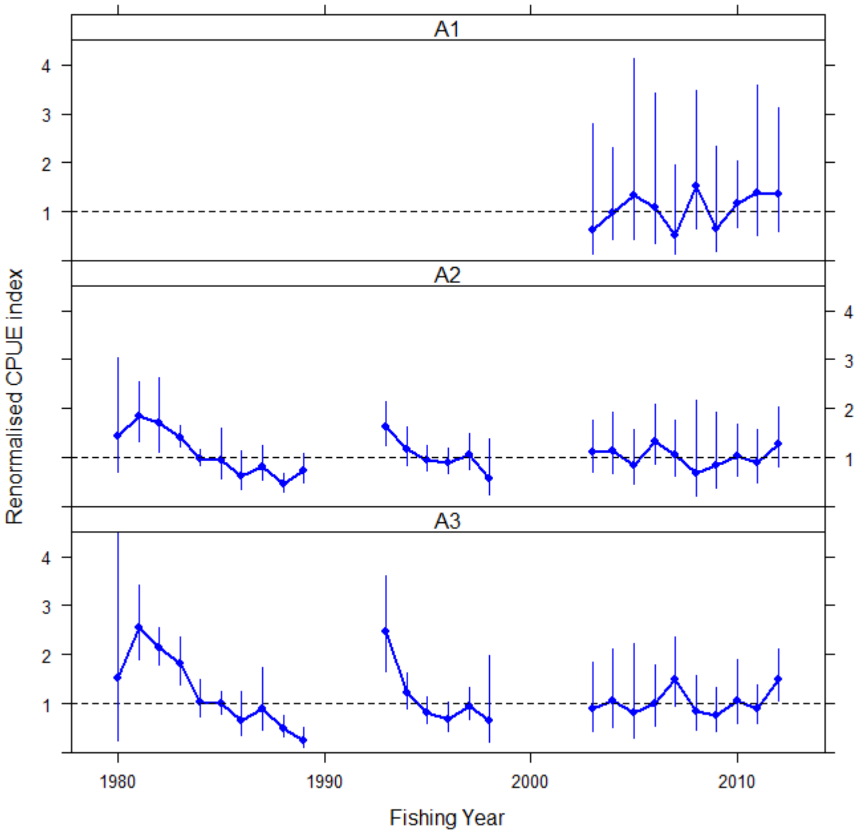


Figure 3: Standardised commercial CPUE series for black oreo in each area within OEO 3A. Pre-GPS and post-GPS (early and late) series are shown, each renormalized to a geometric mean of one. Error bars represent the 95% confidence intervals assuming a log-normal error distribution and using the CVs listed in Table 5.

4.3 Smooth oreo

2009 assessment

The stock assessment analyses were conducted using the CASAL age-structured population model employing Bayesian statistical techniques. The 2005 assessment was updated by including five more years of catch, CPUE and observer length data, and used two new series of post-GPS standardised CPUE, one before and the second after major TACC and catch limit changes. The modelling took account of the sex and maturity status of the fish and treated OEO 3A as a single smooth oreo fishery, i.e., no sub-areas were recognised. The base case model used the 1997 absolute acoustic abundance estimate, pre-GPS and early and late post-GPS series of standardised CPUE indices, and the mean natural mortality estimate (0.063 yr^{-1}). Acoustic and observer length frequencies were used in a preliminary model run to estimate selectivity and the base case fixed these selectivity estimates but did not use the length frequencies. Other cases investigated the sensitivity of the model to data sources including:

- Use of the upper and lower 95% confidence interval values for estimates of natural mortality (0.042–0.099 yr^{-1});
- Use of only the left hand limb of the 1994 observer length frequency (plus the 1997 acoustic survey length frequency) with growth not estimated by the model.

4.3.1 Estimates of fishery parameters and abundance

Catch history

The estimated catches were scaled up to the total reported catch (see tables 2 and 3 in the Fishery Summary section at the beginning of the Oreos report) and are given in Table 6.

Table 6: Reconstructed catch history (t)

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1972–73	†3 440	1981–82	1 288	1990–91	5 054	1999–00	1 789
1973–74	†3 800	1982–83	2 495	1991–92	6 622	2000–01	1 621
1974–75	†5 100	1983–84	3 979	1992–93	4 334	2001–02	1 673
1975–76	†1 260	1984–85	4 351	1993–94	4 942	2002–03	1 412
1976–77	†3 880	1985–86	3 142	1994–95	4 199	2003–04	1 254
1977–78	†5 750	1986–87	3 190	1995–96	4 022	2004–05	1 457
1978–79	650	1987–88	5 905	1996–97	3 239	2005–06	1 445
1979–80	5 215	1988–89	6 963	1997–98	4 733	2006–07	1 306
1980–81	2 196	1989–90	6 459	1998–99	2 474	2007–08	1 526

† Soviet catch, assumed to be mostly from OEO 3A and to be 50 : 50 black oreo : smooth oreo.

Observer length frequencies

Observer length data were extracted from the observer database. These data represent proportional catch at length and sex. All length samples were from the CPUE study area (see Figure 4). Only samples where 30 or more fish were measured, and the catch weight and a valid depth were recorded, were included in the analysis. Data from adjacent years were pooled because of the paucity of data in some years. The pooled length frequencies were applied in the model at the year that the median observation of the grouped samples was taken (Table 7).

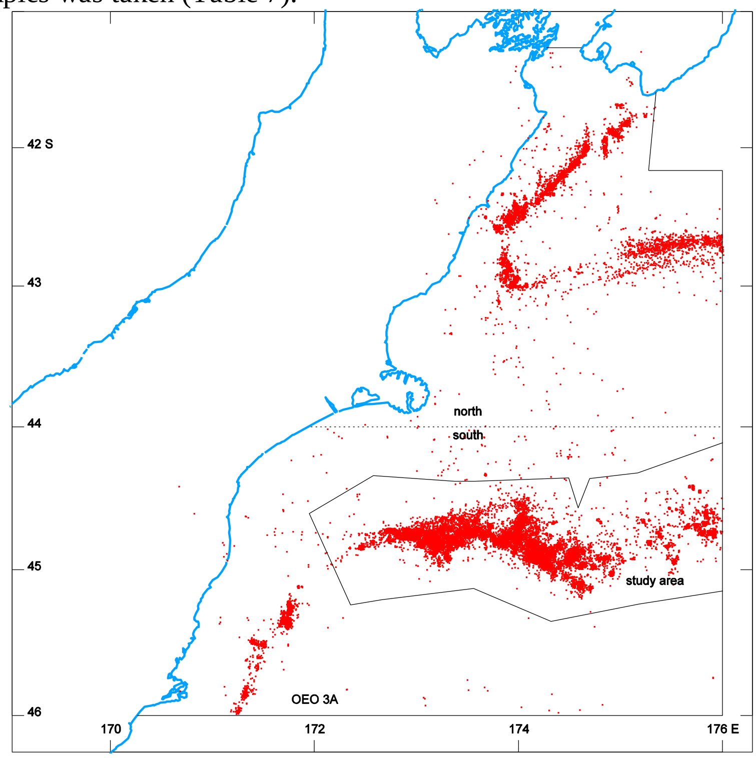


Figure 4: Locations of all tows in OEO 3A with a reported catch of smooth oreo from 1979–80 to 2002–03 (dots). The study area is shown along with the line chosen to split north from south Chatham rise catches.

Table 7: Observer length frequencies; numbers of length samples (tows sampled), number of fish measured, groups of pooled years, and the year that the length data were applied in the stock assessment model. -, not applicable.

Year	Number of length samples	Number of fish measured	Year group code	Year the grouped data were applied
1979–80	32	3 499	1	Applied
1980–81	0	0	-	-
1981–82	0	0	-	-
1982–83	0	0	-	-
1983–84	0	0	-	-
1984–85	0	0	-	-
1985–86	1	106	2	-
1986–87	4	387	2	-
1987–88	10	1 300	2	Applied
1988–89	14	1 512	2	-
1989–90	0	0	-	-
1991–92	9	919	3	-
1992–93	0	0	-	-
1993–94	13	1 365	4	Applied

Table 7 [Continued].

Year	Number of length samples	Number of fish measured	Year group code	Year the grouped data were applied
1994–95	7	752	4	-
1995–96	2	207	4	-
1996–97	3	365	5	-
1997–98	13	1 720	5	-
1998–99	5	770	5	-
1999–00	77	7 595	5	Applied
2000–01	93	9 389	6	Applied
2001–02	20	3 030	7	Applied
2002–03	14	1 427	8	Applied
2003–04	4	321	8	-
2004–05	9	840	8	-
2005–06	26	3 207	9	Applied
2006–07	2	205	9	-
2007–08	8	816	9	-

Length frequency data from the 1997 acoustic survey

Length data collected during the 1997 survey were used to generate a population length frequency by sex. A length frequency was generated from the trawls in each mark-type and also for the seamounts. These frequencies were combined using the fraction of smooth oreo abundance in each mark-type. The overall frequency was normalised over both male and female frequencies so that the sum of the frequencies over both sexes was 100%. The CV for each length class was given by the regression, log(CV) = 0.86 + 8.75/log(proportion). This regression was estimated from the CVs obtained by bootstrapping the data and provides a smoothed estimate of the CVs. The estimated length frequency is in Figure 5.

Absolute abundance estimates from the 1997 acoustic survey

Absolute estimates of abundance for smooth oreo are available from the acoustic survey on oreos carried out from 10 November to 19 December 1997 (TAN9713) using the same approach as described for OEO 3A black oreo. The abundance estimates used in the 1999 OEO 3A smooth oreo assessment were revised in 2005 using new target strength estimates for smooth oreo, black oreo and a number of bycatch species. The revised estimate was 25 200 t with a CV of 23% (the 1999 estimate was 35 100 t with a CV of 27%). There is uncertainty in the estimates of biomass because the acoustic estimate includes smooth oreo in layers that are a mixture of species for which the acoustic method has potential bias problems.

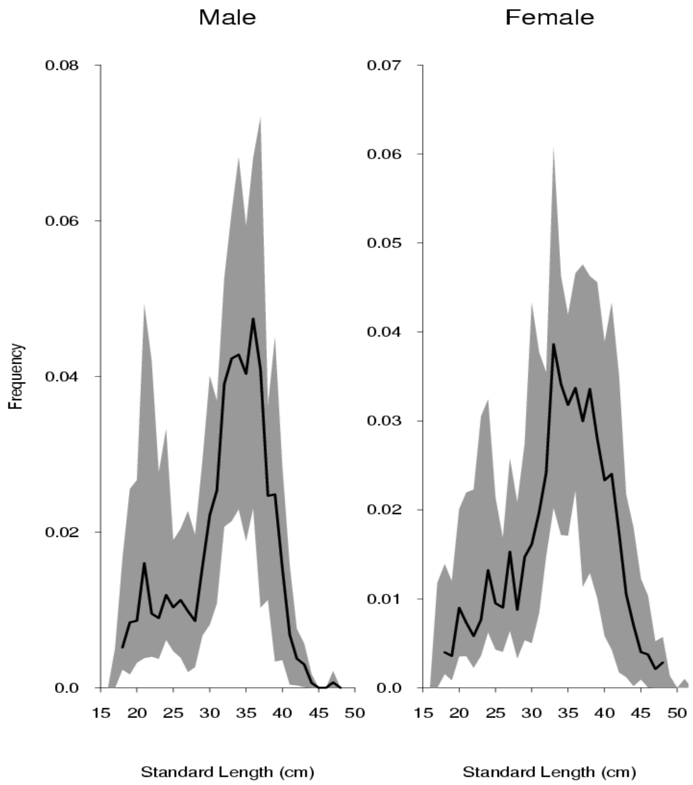


Figure 5: Population length frequency derived from the 1997 acoustic survey data. The bold line is the estimated value and the shaded area is the spread from 300 bootstraps.

Relative abundance estimates from standardised CPUE analysis

The CPUE study area is shown in Figure 5. Three analyses were carried out; a pre-GPS analysis (unchanged from 2005) that included data from 1980–81 to 1988–89 and two post-GPS analyses that included data from 1992–93 to 1997–98 and 2002–03 to 2007–08. The years from 1998–99 to 2001–02 were not included because a voluntary smooth oreo of catch limit (1400 t) was introduced and substantial oreo TACC reductions were made during that time (6600 down to 3100 t). The pre-GPS series shows a downward trend down, and declines to approximately a third of the initial level over the nine-year period. The early post-GPS also has a downward trend but the late post-GPS series has an upward trend and then flattens out. The base case stock assessment used all three indices (Table 8).

Fishing Industry members of the Deepwater Fishery Assessment Working Group expressed concern about the accuracy of the historical Soviet catch and effort data (pre-GPS series) and felt that it was inappropriate to use those data in the stock assessment.

Table 8: CPUE indices by year and jackknife CV (%) estimates from the pre-GPS and the two post-GPS analyses.

	Pre-GPS							Post-GPS
Year	Index	CV	Year	Index	CV	Year	Index	CV
1980–81	1.00	27	1992–93	1.00	24	2002–03	0.55	23
1981–82	0.82	26	1993–94	0.88	11	2003–04	0.77	22
1982–83	0.72	62	1994–95	0.74	14	2004–05	0.99	22
1983–84	0.59	61	1995–96	0.48	17	2005–06	0.96	31
1984–85	0.72	22	1996–97	0.56	15	2006–07	1.00	20
1985–86	0.61	19	1997–98	0.50	19	2007–08	0.92	21
1986–87	0.46	16						
1987–88	0.42	16						
1988–89	0.26	28						

4.3.2 Biomass estimates

The posterior distributions from the MCMC on the base case are shown in Figure 6. The probability that the current mature biomass (2008–09) and the biomass 5 years out (2013–14) are above 20% B_0 is 1 for both.

Biomass estimates derived from the MCMC are in Table 9. Total mature biomass for 2008–09 was estimated to be 36% of the initial biomass (B_0). Sensitivity case results for the base case using the lower and upper 95% confidence interval value estimates for *M* gave estimates of current biomass between 26% and 49% of B_0. The sensitivity case that used the left hand limb of the 1994 observer length frequency (plus the 1997 acoustic survey length frequency) with growth not estimated by the model gave estimates of current biomass for the mean estimate of *M* (0.063 yr^{-1}) of 30 % of B_0 while estimates using the lower and upper 95% confidence interval value estimates for *M* gave estimates of 2008 biomass between 12% and 59% of B_0.

Projections were carried out for five years with the current catch limit of 1400 t. The trajectory shows increasing biomass (Figure 6).

4.3.3 Other factors

Because of differences in biological parameters between the species, it would be appropriate to split the current TACC for black oreo and smooth oreo. The WG noted that separate species catch limits are in place to reduce the risk of over- or under-fishing either smooth oreo or black oreo.

The model estimates of uncertainty are unrealistically low. Uncertainties that are not included in the model include:

- the assumption that recruitment is deterministic;
- that the acoustic index is assumed to be an absolute estimate of abundance;
- the selectivity in the base case is fixed at the MPD estimate from the preliminary case where all length data is used;
- uncertainty in the estimate of *M*.

In addition, the growth is fixed and known. The WG has previously noted the impact of the different ages of maturity for males and females. Due to the fact that males mature at a much smaller size than females (age at 50% maturity is 18–19 years for males and 25–26 for females), the sex ratio needs to be taken into account when assessing the sustainability of any particular catch level.

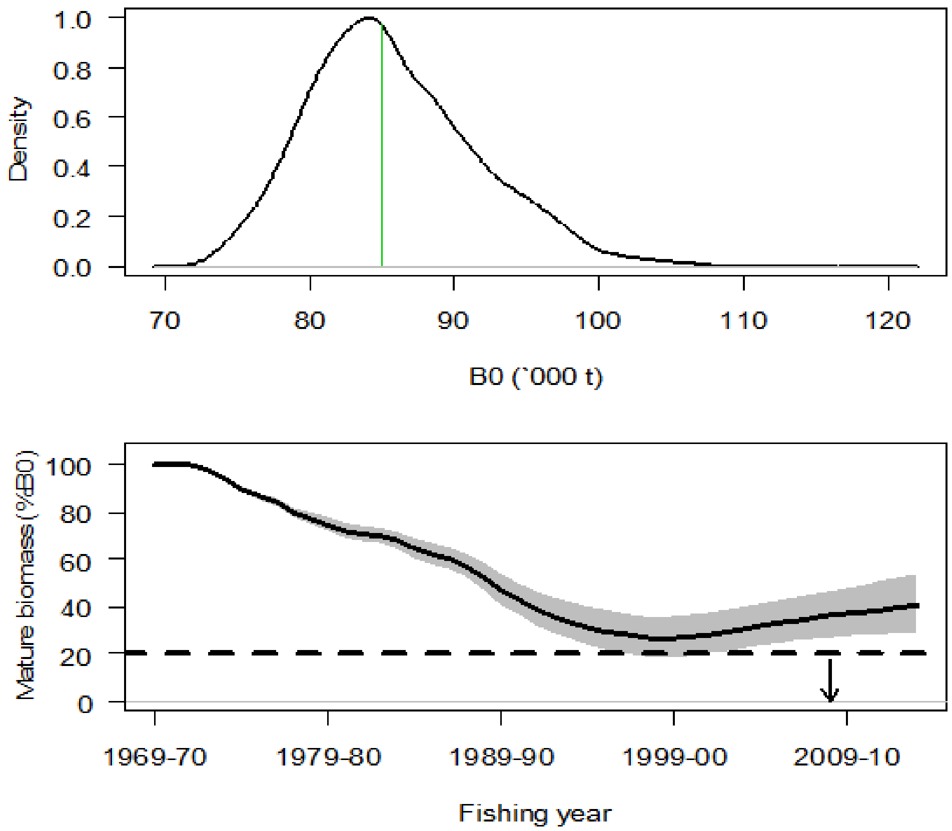


Figure 6: Smooth oreo OEO 3A: posterior distribution for the virgin biomass (top plot) and the mature biomass trajectories as a percentage of virgin biomass (bottom plot) from the MCMC analysis of the "NoLF" case with M = 0.063 (base case). In the top plot, the vertical line is the median of the distribution. In the bottom plot, the grey area is the point-wise 95% confidence intervals of the trajectories and the solid line is the median.

Table 9 (a): Base case (in bold) and sensitivity to M values (biomass estimates). Bcurr is 2008.

	***M* = 0.063**			†*M* = 0.042			†*M* = 0.099		
	Median	**CI.05**	**CI.95**	Median	CI.05	CI.95	Median	CI.05	CI.95
B_0	**85 000**	**77 300**	**96 500**	97 700	90 100	110 000	68 500	60 300	79 600
B_cur	**30 900**	**22 400**	**43 000**	26 300	18 000	38 800	33 800	25 000	45 500
B_cur(%B_0)	**36**	**29**	**45**	27	20	35	49	41	57

(b) Sensitivity (biomass estimates). In these runs the left hand limb of the 1994 observer length was fitted, the 1997 acoustic survey length frequency was included and growth was not estimated by the model:

	†*M* = 0.063			†*M* = 0.042			†*M* = 0.099		
	Median	CI.05	CI.95	Median	CI.05	CI.95	Median	CI.05	CI.95
B_0	77 400	74 800	80 200	82 800	81 600	84 200	82 300	76 700	89 200
B_cur	23 100	19 900	26 400	10 200	8 480	12 100	48 800	42 900	56 200
B_cur(%B_0)	30	27	33	12	10	14	59	56	63

5. STATUS OF THE STOCKS

The smooth oreo stock assessment is unchanged from 2009. The stock status of black oreo sessment is updated using CPUE data up to 2011–12.

Stock Structure Assumptions
The two oreo stocks in FMA 3A are assessed separately but managed as a single stock. For both the black oreo and smooth oreo stocks it is assumed that there is potential mixing with stocks outside of the OEO 3A area.

- **OEO 3A (Black Oreo)**

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Age-structured CASAL spatial assessment model rejected by the Working Group; CPUE accepted
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\% B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Catch has decreased with TACC since the early 1990s and remained low and relatively constant over the last 10 years.
Other Abundance Indices	CPUE since 2002–03 has stabilised in all three areas after significant declines in the two deeper areas in the 1980s and 1990s.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	CPUE	
Assessment Dates	Latest assessment: 2013	Next assessment: 2014?
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	CPUE abundance	1 – High Quality
Data not used (rank)		
Changes to Model Structure and Assumptions	The three area model with migration based on age is thought to be flawed and the previous model has been withdrawn.	

Major Sources of Uncertainty	-

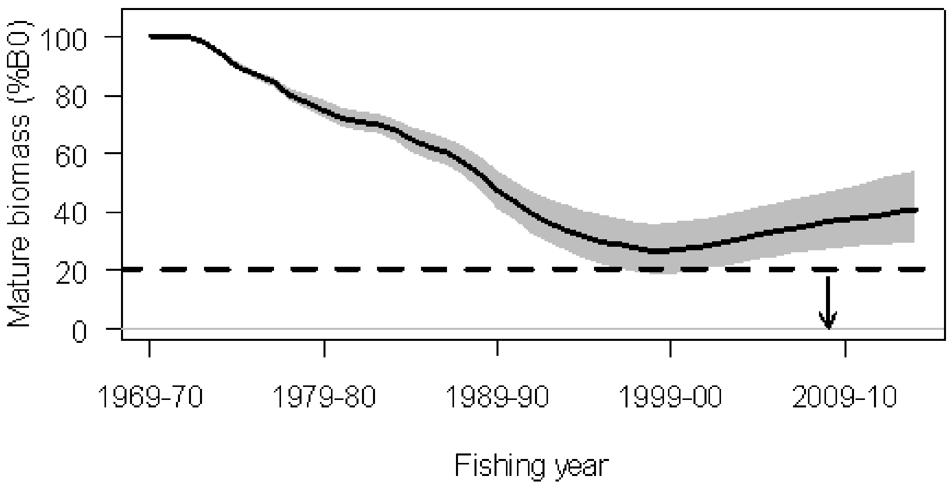
Qualifying Comments
-

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries, mostly in other areas e.g. OEO 4. The main bycatch species in the OEO 3A black oreo target fishery include smooth oreo, hoki, javelinfish, Baxter's dogfish, pale ghost shark, ridge scaled rattail, and basketwork eel. Bycatch species that may be vulnerable to overfishing include deepwater sharks and rays. Protected species catches include seabirds and deepwater corals.

- **OEO 3A (Smooth Oreos)**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	One base case and 5 sensitivity runs
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	For the base case, B_{2009} was estimated at 36% B_0, About as Likely as Not (40–60%) to be at or above the target.
Status in relation to Limits	B_{2009} is Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Mature biomass trajectories as a percentage of virgin biomass from the base case. The grey area is the point-wise 95% confidence intervals of the trajectories and the solid line is the median.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is projected to have been increasing since the late 1990s.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2009)	
Stock Projections or Prognosis	The biomass is expected to increase over the next 5 years given the current catch limit of 1400 t.

Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)

Assessment Methodology		
Assessment Type	Level 1 - Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Main data inputs	- One acoustic absolute abundance estimate (1997) - three standardised CPUE indices (1981–82 to 1988–89, 1992–93 to 1997–98, 2002–03 to 2007–08) - Natural mortality estimate (0.063) - Selectivity estimated from acoustic and observer length frequencies New information from previous (2005) assessment: - Updated with additional catch, CPUE, observer length data collected since last assessment - two new standardised post-GPS CPUE series	
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- The single acoustic index (1997) is assumed to be an absolute estimate of abundance - Sex ratio needs to be taken into account, as males mature at a much smaller size than females. - Recruitment is assumed to be deterministic. - Uncertainty in the estimates of natural mortality (*M*) - Selectivity is fixed in the base case at the MPD estimate from the preliminary study	

Qualifying Comments
-

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries, mostly in other areas e.g. OEO 4. The main bycatch species in the OEO 3A smooth oreo target fishery include black oreo, hoki, javelinfish, Baxter's dogfish, pale ghost shark, ridge scaled rattail and basketwork eel. Bycatch species vulnerable to overfishing include deepwater sharks and rays. Protected species catches include seabirds and deepwater corals.

6. FOR FURTHER INFORMATION

Coburn, R P; Doonan, I J; McMillan, P J (1999) Black oreo abundance indices from standardised catch per unit of effort data for OEO 3A. New Zealand Fisheries Assessment Research Document 1999/32. 18 p. (Unpublished document held by NIWA library, Wellington.)

Coburn, R P; Doonan, I J; McMillan, P J (2006) Smooth oreo OEO 3A abundance estimates from standardised catch per unit of effort data, 1979–80 to 2002–03. *New Zealand Fisheries Assessment Report 2006/35*. 38 p.

Coburn, R P; McMillan, P J; Gilbert, D J (2007) Inputs for a stock assessment of smooth oreo, Pukaki Rise (part of OEO 6). *New Zealand Fisheries Assessment Report 2007/23*. 32 p.

Cordue, P L (1996) A model-based method for bounding virgin biomass using a catch history, relative biomass indices, and ancillary information. New Zealand Fisheries Assessment Research Document 1996/8. 48 p. (Unpublished document held by NIWA library, Wellington.)

Doonan, I J; Coburn, R P; McMillan, P J (2009) Assessment of OEO 3A black oreo for 2006–07. *New Zealand Fisheries Assessment Report 2009/12*. 46 p.

Doonan, I J; Coburn, R P; McMillan, P J; Hart, A C (2004) Assessment of OEO 3A black oreo for 2002–03. *New Zealand Fisheries Assessment Report 2004/52*. 54 p.

Doonan, I J; Coombs, R F; McMillan, P J; Dunn, A (1998) Estimate of the absolute abundance of black and smooth oreo in OEO 3A and 4 on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project OEO9701. 47 p. (Unpublished document held by Ministry for Primary Industries, Wellington.)

Doonan, I J; McMillan, P J (2001) A non-parametric age selectivity ogive for OEO 3A black oreo for 2001–02. *New Zealand Fisheries Assessment Report 2001/40*. 17 p.

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (1996) Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1996. New Zealand Fisheries Assessment Research Document 1996/17. 21 p. (Unpublished document held by NIWA library, Wellington.)

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (1997) Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1997. New Zealand Fisheries Assessment Research Document 1997/21. 26 p. (Unpublished document held by NIWA library, Wellington.)

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (1999a) Assessment of OEO 3A smooth oreo for 1999–2000. New Zealand Fisheries Assessment Research Document 1999/45. 21 p. (Unpublished document held by NIWA library, Wellington.)

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (1999b) Assessment of OEO 3A black oreo for 1999–2000. New Zealand Fisheries Assessment Research Document 1999/52. 30 p. (Unpublished document held by NIWA library, Wellington.)

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (2003) Assessment of OEO 4 smooth oreo for 2002–03. *New Zealand Fisheries Assessment Report 2003/50*. 55 p.

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C; Cordue, P L (1995) Assessment of smooth oreo for 1995. New Zealand Fisheries Assessment Research Document 1995/12. 31 p. (Unpublished document held by NIWA library, Wellington.)

Doonan, I J; McMillan, P J; Hart, A C (2008) Ageing of smooth oreo otoliths for stock assessment. *New Zealand Fisheries Assessment Report 2008/08*. 29 p.

Doonan, I J; McMillan, P J; Hart, A H (2012) Comparison of the fraction of mature black oreo between Area 1 and Area 2&3 (OEO 3A). Draft New Zealand Fisheries Assessment Report. . (Unpublished document held by Ministry for Primary Industries, Wellington.)

Doonan, I J; McMillan, P J; Hart, A C; Coombs, R F (2003) Smooth oreo abundance estimates from the October–November 2001 acoustic survey of the south Chatham Rise (OEO 4). *New Zealand Fisheries Assessment Report 2003/26*. 21 p.

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27 p. (Unpublished document held by NIWA library, Wellington.)

McKenzie, A (2007) Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6). *New Zealand Fisheries Assessment Report 2007/34*. 27 p.

McMillan, P J; Doonan, I J; Hart, A C; Coburn, R P (1998) Oreo stock assessment. Final Research Report for Ministry of Fisheries Research Project OEO9702. 16 p. (Unpublished document held by Ministry for Primary Industries, Wellington.)

McMillan, P J; Hart, A C (1991) Assessment of black and smooth oreos for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 1991/10. 29 p. (Unpublished document held by NIWA library, Wellington.)

Smith, M H; Doonan, I J; McMillan, P J; Hart, A C (2006) Black oreo abundance estimates from the September–October 2002 acoustic survey of the south Chatham Rise (OEO 3A). *New Zealand Fisheries Assessment Report 2006/33*. 20 p.

OREOS – OEO 4 BLACK OREO AND SMOOTH OREO

1. FISHERY SUMMARY

This is presented in the Fishery Summary section at the beginning of the Oreos report.

2. BIOLOGY

This is presented in the Biology section at the beginning of the Oreos report.

3. STOCKS AND AREAS

This is presented in the Stocks and Areas section at the beginning of the Oreos report.

4. STOCK ASSESMENT

4.1 Introduction

In 2014, the stock assessment was updated for smooth oreos in OEO 4.

4.2 Black oreo

Investigations were carried out in 2009 using age-based single sex single step preliminary models in CASAL. The data used in these models were four standardised CPUE indices (pre– and post–GPS in the east and west), and observer length frequencies. Growth and maturity were also estimated in some of the runs.

4.2.1 Estimates of fishery parameters and abundance

Absolute abundance estimates from the 1998 acoustic survey

Absolute estimates of abundance were available from an acoustic survey on oreos which was carried out from 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812). Transects on flat ground were surveyed to a stratified random design and a random sample of seamounts were surveyed with either a random transect (large seamounts) or a systematic “star” transect design. For some seamounts the flat ground nearby was also surveyed to compare the abundance of fish on and near the seamount either by extending the length of the star transects or by extra parallel transects. Acoustic data were collected concurrently for flat and seamounts using both towed and hull mounted transducers. The OEO 4 survey covered 59 transects on the flat and 29 on seamounts. A total of 95 tows were carried out for target identification and to estimate target strength and species composition. In situ and swimbladder samples for target strength data were collected and these have yielded revised estimates of target strength for both black oreo and smooth oreo.

Acoustic abundance estimates for recruit black oreo from seamounts and flat for the whole of OEO 4 are in Table 1. About 59% of the black oreo abundance came from the background mark-type. This mark-type is not normally fished by the commercial fleet and this implies that the abundance estimate did not cover the fish normally taken by the fishery. In addition the scaling factor to convert the acoustic area estimate to the trawl survey area estimate was 4.3, i.e., the acoustic survey area only had about 23% of the abundance. The magnitude of this ratio suggests that the size of the area surveyed was borderline for providing a reliable abundance estimate.

Table 1: OEO 4 recruit black oreo seamount, flat, and total acoustic abundance estimates (t) and recruit CV (%) based on knife-edge recruitment (23 years).

	Abundance (t)	CV (%)
Seamount	127	91
Flat	13 800	56
Total	13 900	55

Relative abundance estimates from standardised CPUE analyses – 2009 analysis

The CPUE analysis method involved regression based methods on the positive catches only. Sensitivities were run where the positive catch tow data and the zero catch tow data were analysed separately to produce positive catch and zero catch indices. All data were included, whether they were target or bycatch fisheries, with the target offered to the model (and not accepted).

The best data-split was investigated using the Akaike Information Criteria (AIC) on a number of potential regressions. Four indices were subsequently used, pre- and post-GPS in the east and west areas respectively. These two areas are very distinct: the west consists of flat fishing and the east of hill fishing, the west area was fished 10 years prior to the east, and there has been a move by the fishery since the early 1990s from the west to the east. However, despite of all these differences, the two series present almost identical patterns of decline in relative standardised CPUEs from the time their exploitation started in earnest (1980 in the west and 1992 in the east) which would suggest that for this fishery CPUE might be a reasonable index of abundance (because less influenced by technology, fishing patterns, hills or flats etc).

The standardised CPUE series and CVs are described in Table 2. Over comparable time periods and data sets, the trends from the updated series were similar to those from the 2000 analyses (Coburn *et al.* 2001). The west CPUE reduced to between 5% of 1980 value and 15% of 1981 value by 1990. The post-GPS west series is either flat or slightly increasing. The east CPUE reduced to 4% of 1984 value and 21% of 1985 value by 1990 even though catches were low. The post-GPS east series showed a further steep initial decline with total reduction to 15% of 1993 values by 2008.

Table 2: OEO 4 black oreo standardised CPUE analyses in 2009 (expressed in t / tow).

	Pre-GPS east		Pre-GPS west			Post-GPS east		Post-GPS west	
fishing year	index	cv	index	cv	fishing year	index	cv	index	cv
1980			8.97	0.17	1993	0.71	0.15	0.73	0.41
1981			4.00	0.11	1994	0.63	0.13	0.45	0.32
1982			2.24	0.10	1995	0.31	0.15	0.41	0.31
1983			2.20	0.09	1996	0.21	0.15	0.28	0.27
1984	0.47	0.95	1.54	0.10	1997	0.24	0.12	0.61	0.27
1985	0.41	0.28	1.51	0.07	1998	0.20	0.11	0.45	0.23
1986	0.38	0.32	1.28	0.10	1999	0.16	0.12	0.46	0.23
1987	0.65	0.30	0.67	0.10	2000	0.17	0.12	0.68	0.25
1988	0.10	0.18	0.54	0.13	2001	0.14	0.08	0.62	0.24
1989	0.02	0.20	0.48	0.12	2002	0.18	0.07	0.47	0.29
					2003	0.13	0.06	0.49	0.24
					2004	0.13	0.06	0.93	0.24
					2005	0.14	0.07	0.91	0.26
					2006	0.13	0.07	0.68	0.26
					2007	0.12	0.07	1.00	0.27
					2008	0.10	0.09	0.88	0.24

Relative abundance estimates from trawl surveys

The estimates, and their CVs, from the four standard *Tangaroa* south Chatham Rise trawl surveys are treated as relative abundance indices (Table 3).

Table 3: OEO 4 black oreo research survey abundance estimates (t). N is the number of stations. Estimates were made using knife-edge recruitment set at 33 cm TL. Previously knife-edge recruitment was set at 27 cm and estimates of abundance based on that value are also provided for comparison.

Year	Mean abundance		CV (%)	N
	27 cm	33 cm		
1991	34 407	13 065	40	105
1992	29 948	12 839	46	122
1993	20 953	6 515	30	124
1995	29 305	9 238	30	153

Observer length frequencies

Observer length frequencies were available for about 20% of the yearly catch from 1989 to 2008. Analyses conducted on these data indicated they were not representative of the spatial spread of the fishery. When stratified by depth, the length frequencies had double-modes, centred around 28 cm and 38 cm, with inconsistent trends in the modes between years. Alternative stratification by subarea, hill, etc, did not resolve the problem; some tows showed bimodality. These patterns in length frequencies were an issue because the yearly shifts in length frequencies and double mode cannot be representative of the underlying fish population since black oreo is a slow growing long-lived fish. They are more likely linked with discrete spatial sub-groups of the population.

A similar double mode was reported for some strata in the same area from the 1994 Tangaroa trawl survey (Tracey & Fenaughty 1997). It is likely that there is further spatial stock structure that is currently unaccounted for.

4.2.2 Biomass estimates

The 2009 stock assessment of OEO 4 black oreo was inconclusive as assessment models were unable to represent the observer length frequency structure, and were considered unreliable. The CPUE was fitted satisfactorily under a two-stock model but could not be fitted in a single homogeneous stock model. However, the WG agreed that:

1. The CPUE indices are consistent with a two-stock structure or at least a minimally-mixing single stock.
2. The updated CPUE estimates were probably a reasonable indicator of abundance (at the spatial scale of the east and west analyses).

4.2.3 Estimation of Maximum Constant Yield (MCY)

In 2000, MCY was estimated using the equation, MCY = $c*Y_{AV}$ (Method 4). There was no trend in the annual catches, nominal CPUE, or effort from 1982–83 to 1987–88 so that period was used to calculate the MCY estimate (1200 t). The MCY calculation was not updated in 2009.

4.2.4 Estimation of Current Annual Yield (CAY)

CAY cannot be estimated because of the lack of current biomass estimates.

4.3 Smooth oreo

Biomass and yield estimates for smooth oreo were made using a CASAL age-structured population model with Bayesian estimation, incorporating stochastic recruitment, life history parameters (Table 1 of the Biology section at the beginning of the Oreos report), and catch history up to 2012-13. In early assessments (Doonan et al. 2008, 2003, 2001), the stock area was split at 178° 20′ W into a west and an east fishery based on an analysis of commercial catch, standardised CPUE, and research trawl and acoustic result, and data fitted in the model included acoustic survey abundance estimates, standardised CPUE indices, observer length data, and the acoustic survey length data. In 2012, the Deepwater Working Group decided that using CPUE to index abundance should be discontinued, due to changes in fishing patterns over time within the stock area. With no CPUE indices, the 2012 assessment was simplified to a single area model using only the observations of vulnerable biomass from acoustic surveys carried out in 1998, 2001, 2005, and 2009.

The 2014 stock assessment updated the 2012 assessment model using the same single area model structure and used an additional observation of abundance from the research acoustic survey carried out in 2012. The assessment also revised the previous assessments by including the age frequency estimates from the 1998 and 2005 acoustic surveys and by estimating relative year class strengths.

Oreo catch data showed marked changes in fishing patterns over time. Large catches first started in the west and then progressed east over time and appeared to represent successive exploitation of new areas. Previously exploited areas in the west did not later sustain high catches. The target species and the type of fishing also changed over time with smooth oreo the target species in the west on flat, dropoff, and seamounts from the late 1970s, with a gradual change to target fishing for orange roughy on seamounts in the east from the late 1980s. Since the late 1990s, there has been an increase in target fishing for smooth oreo in the east, with more fish being caught as a target species than as bycatch. Given the above, the Deepwater Working Group decided in 2012 that using CPUE to index abundance should be discontinued.

To limit the extra uncertainty in “layer” marks which contained the pre-recruited fish, the abundance data were re-worked into vulnerable abundance of adult sized fish (school marks). Selectivities for both the commercial fishery and acoustic survey were assumed to be length-based and knife-edged at 33 cm derived from the distribution of the observer length commercial data Acoustic abundance data were fitted as relative abundances using a log-normal likelihood with no additional process error. The model assumed a fixed M (0.063).

The 2014 assessment used the same model structure as that in 2012, but it also used a separate logistic selectivity for fitting the age frequency data from the acoustic surveys and this was estimated within the model.

Year class strengths (YCS) were estimated for 1955–2000 (based on the range of age estimates in the age frequency data). YCS were assumed to be fixed at 1 in previous assessments as no age data were used. A number of prior distributions on YCS were investigated. The base case used a prior that is close to being uniform (parameterised as a lognormal distribution with a mode of 1 and sigma of 4), which places minimum constraint on the YCS (Haist parameterisation).

Informed priors were assumed for the survey catchability coefficient q. For the time series based on fished marks, a lognormal prior with mean of 0.83 and CV of 0.3 was used. The choice of the priors was based on limited information on target strength, the QMA scaling-factor, and the proportion of vulnerable biomass in the vulnerable acoustic marks (Fu & Doonan 2013).

A brief description of the base case and sensitivity runs presented are summarised in Table 4. The Deepwater Working Group recommended that MCMC runs be carried out for the base case and models 5.1, 5.2 and 5.4 to address the uncertainty in survey q and acoustic abundance estimate, the following assumptions were made in the stock assessment analyses:

(a) Recruitment followed a Beverton & Holt relationship with steepness of 0.75.
(b) Catch overruns were 0% during the period of reported catch.
(c) The population of smooth oreo in OEO 4 was a discrete stock or production unit.
(d) The catch history was accurate.

Bayesian procedures were used in the assessment to estimate the uncertainties in model estimates of biomass for all model runs using the following procedure:

1. Model parameters were estimated using maximum likelihood and the prior probabilities;
2. Samples from the joint posterior distribution of parameters were generated with the Monte Carlo Markov Chain procedure (MCMC) using the Hastings-Metropolis algorithm;
3. A marginal posterior distribution was found for each quantity of interest by integrating the product of the likelihood and the priors over all model parameters; the posterior distribution was described by its median, 5th and 95th percentiles for parameters of interest.

Bayesian estimates were based on results from a 30 million long MCMC. After a burn-in of 25 million, the last 5 million of the chain was sampled at each 1000th value. Posterior distributions were obtained from samples combined over three independent chains.

Table 4: Descriptions of the model runs of the 2014 smooth oreo assessment. LN, lognormal distribution with mean and CV given in the bracket. All use Haist parameterisation for YCS.

Model run	Description
5.0 (base case)	estimated *q* with a LN (0.83, 0.3) prior, nearly uniform prior on YCS, *M* fixed at 0.063, adult abundance indices (school marks)
5.1	5.0, but estimated *q* with a LN(1, 0.3) prior, M fixed at 0.05
5.2	5.0, but estimated *q* with a LN(0.6, 0.3) prior, M fixed at 0.07
5.4	5.0, but excluded the 2012 large school mark in stratum 52 in the acoustic abundance

4.3.1 Estimates of fishery parameters and abundance

The 2014 assessment incorporated the catch history and the adult acoustic abundance indices based on either the length cut-off of 33 cm or fished marks. The updated CPUE indices, observer length data, and acoustic length data were not included in the 2014 assessment model.

Catch history

A catch history for OEO 4 was developed by scaling the estimated catch to the QMS values, Table 5.

Table 5: Catch history for OEO 4 smooth oreo (t)

Year	OEO 4	Year	OEO 4
1978–79	1 321	1996–97	6 359
1979–80	112	1997–98	6 248
1980–81	1 435	1998–99	6 030
1981–82	3 461	1999–00	6 357
1982–83	3 764	2000–01	6 491
1983–84	5 759	2001–02	4 291
1984–85	4 741	2002–03	4 462
1985–86	4 895	2003–04	5 656
1986–87	5 672	2004–05	6473
1987–88	7 764	2005–06	5955
1988–89	7 223	2006–07	6363
1989–90	6 789	2007–08	6422
1990–91	6 019	2008–09	6090
1991–92	5 508	2009–10	6118
1992–93	5 911	2010–11	6518
1933–94	6 283	2011–12	6357
1994–95	6 936	2012–13	5964
1995–96	6 378		

Absolute abundance estimates from the 1998, 2001, 2005, 2009, and 2012 acoustic surveys

Absolute estimates of abundance were available from five acoustic surveys:

(i) 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812);
(ii) 16 October to 14 November 2001 using *Tangaroa* for acoustic work (voyage TAN0117) and *Amaltal Explorer* (voyage AEX0101) for trawling;
(iii) 3–22 November 2005 using *Tangaroa* for acoustic work (voyage TAN0514) and 3–20 November 2005 using *San Waitaki* (SWA0501) for mark identification trawling;
(iv) 2–18 November 2009 using *Tangaroa* for acoustic work (voyage TAN0910) and 2–18 November 2009 using *San Waitaki* (SWA0901) for mark identification trawling.
(v) 8–26 November 2012 using *Tangaroa* for acoustic work (voyage TAN01214) and 8–26 November 2012 using *San Waitaki* (SWA1201) for mark identification trawling.

Acoustic abundance estimates were made for total smooth oreo from seamounts and flat for the whole of OEO 4. The 1998 and 2001 estimates for the mixed species mark-types were adjusted to match the larger contribution for non-smooth oreo species in these mark types from the trawl net used in 2005.

One of the major uncertainties in the assessment is from the large contribution to the total acoustic abundance estimate from smooth oreo estimated to be in the LAYER mark-type (72% of the total abundance for the 1998 survey, 47% for the 2001 survey, 45% for the 2005 survey, 61% for the 2009 survey, 49% for the 2012 survey). The contribution of large (greater than 31 cm) smooth oreo to the total backscatter in these LAYER marks was typically less than 10% of the total LAYER abundance, with the remainder composed of a number of associated bycatch species and smaller smooth oreo in 1998 and 2001. The layer acoustic abundance may be biased due to misspecification of the contribution made by other fish species present in the layers, thus adding to the overall uncertainty in the biomass estimates from the assessment. The contribution of large smooth oreo to the total backscatter in the SCHOOL mark-types was typically greater than 75% in 1998 and 2001. Therefore, the acoustic smooth oreo abundance estimates from the schools were considered to be better estimated than the equivalent acoustic estimates from the layers.

.

Abundance of vulnerable smooth oreo was estimated using two different methods. The first method was based on the acoustic mark types, where vulnerable biomass was the sum over two flat mark types: DEEP SCHOOLS and SHALLOW SCHOOLS, with the hill biomass added on. The second method was based on the length cut-offs on the total biomass, where the ratio of vulnerable to total biomass was calculated from the length data collected from the surveys using a vulnerable cut-off length determined from a mid-point on the left hand limb of the commercial length distribution. Estimates were therefore produced for a length cut-off of 33 cm (the 2012 assessment also considered a length cut-off of 34 cm as a sensitivity analysis). These estimates were made for smooth oreo in the whole of OEO 4 (Table 6).

One major source of uncertainty in the 2012 survey estimates was that about 25% of the total estimate came from one school mark on the flat. The species composition of this mark was not able to be verified by trawling. Excluding this mark, i.e., assuming they are not smooth oreo, reduced the total abundance for smooth oreos to 64 860 t with a reduced CV of 31%.

Table 6: Estimated smooth oreo abundance (t) and CV (in brackets, %) from acoustic surveys in 1998, 2001, 2005, and 2009, and 2012, including estimates for total abundance and vulnerable abundance. The vulnerable abundance estimates were based either on vulnerable acoustic marks (shallow and deep schools, plus hills), or a length cut-off of 33 cm.

	Total		Adult (school mark)		Adult (>33cm)	
Year	Abundance (t)	CV (%)	Abundance (t) *	CV (%)	Abundance (t)	CV (%)
1998	146 000	33	65 679	26	99 619	33
2001	218 200	22	81 633	26	142 348	19
2005	115 500	28	63 237	25	90 316	22
2009	66 500	36	26 953	26	63 471	30
2012	88 558	42	58 603	30	69 925	42

* When the single large mark was removed from the adult (school mark) estimate for 2012, the abundance was reduced to 36,550 t, with an assumed CV of 30%.

Age frequencies from the 1998 and 2005 acoustic surveys

Population age frequency distributions for smooth oreo in OEO 4 were determined by estimating ages from otoliths and data collected on two acoustic surveys carried out in 1998 and 2005 (Doonan 2008b). All of the sampled otoliths (n = 546) from the 1998 survey and randomly selected otoliths (n = 500) from the 1800 otoliths collected during the 2005 survey were read.

The age frequency distribution was estimated using the aged otoliths from tows in each mark-type weighted by the catch rates and the proportion of abundance in the mark-type. Age frequencies were estimated by sex and combined over sexes. The variance was estimated by bootstrapping the tows within mark-types for the 1998 survey and within mark-type and stratum for the 2005 survey (Doonan 2008b). The ageing error was estimated by comparing age estimates from two readers and also by using repeated readings from the same reader. The age frequencies had a mean weighted CV of 36% (1998) and 45% (2005). The ageing error was estimated to be about 8.5%. The age frequencies data (male and female combined) were included in order to estimate year class strength.

Observer length frequencies
Observer length data were extracted from the observer database. These data were stratified by season (October-March and April-September) and into west and east parts. The length frequencies were combined over strata by the proportion of catch in each stratum.

The scaled length were used to determine the length cut-offs for estimating the adult abundance, but were not otherwise included in the assessment model

Relative abundance estimates from standardised CPUE analyses
The CPUE analysis was not updated for the 2014 assessment.

4.3.2 Biomass estimates
When carrying out MCMC simulations to obtain posterior samples, the survey *q* was estimated as a free parameter (it was estimated as a nuisance parameter in the MPD). This allowed the uncertainly associated with *q* to be incorporated into model results because estimates of stock sizes were integrated over possible values of *q*.

The estimates of biomass for base case and sensitivity models are summarised in **Error! Reference source not found.**. For the base case (model 5.0), the median of B_0 was estimated to be 131 000 t, with a 90% credible interval between 115 000 and 156 000 t. The estimate of 2013 stock status was 27% B_0, with a 90% confidence interval between 16 and 41%. The biomass trend showed a steeper decline after the mid-2000s (Figure 1). Estimated probability of B_{2013} being above the target biomass (40% B_0) was 0.067, and being below the soft (20% B_0) and hard (10% B_0) limit was 0.167 and 0.003, respectively (Table 8).

Biomass estimates were sensitive to the assumed *q* and *M*. If the assumed prior mean of *q* was 20% higher, and *M* was 20% lower (model 5.1) than in the base case, B_{2013} was estimated to be 18% B_0, with a 90% confidence interval between 11 and 29%; if the prior mean of *q* was 20% lower, and *M* was 20% higher than the base case (model 5.2), B_{2013} was estimated to be 36% B_0, with a 90% confidence interval between 21 and 56%. The location and shape of the posterior distribution of survey *q* appeared to be strongly driven by the assumed prior, suggesting that the signal in the acoustic estimates is not strong enough to determine *q* (Figure 2).

Excluding the uncertain large mark in stratum 52 from the 2012 survey led to much more pessimistic estimates of stock status (Model 5.4), with B_{2013} estimated to be 20% B_0 (90% CI of 12–36%).

For the base case, estimated YCS appeared noisy with associated large variability (Figure 3–left). Overall they suggested that there was a period of relatively low recruitment before 1970, relatively high recruitment between 1970 and 1985, and the recruitment in more recent years was below the long term average. Estimated exploitation rates appear to have steadily increased over time, especially after 2000 (Figure 3, right). The current median exploitation rate was estimated to be 0.16, which is significantly higher than $U_{40\%B0}$ (estimated to be 0.057).

4.3.3 Yield estimates and projections
The five year projection for the base case, with future annual catch assumed to be 6000 t for 2014–2018 suggested that the biomass is likely to decrease, and the median of spawning biomass in 2018 (B_{2018}) was estimated to be 22 400 t, or 18% B_0. The estimated probability of B_{2018} being above 40% B_0 was 0.003, and being below the soft (20% B_0) and hard (10% B_0) limit was 0.616 and 0.16, respectively (Table 8).

Table 7: Estimates of mature biomass for OEO 4 smooth oreo for MCMC models 5.0 (base case), 5.1, 5.2, and 5.4. AcAq, catchability coefficient for relative indices of vulnerable biomass; U2013, current exploitation rate.

			MCMC 5.0			**MCMC 5.1**
	5%	Median	95%	5%	Median	95%
B_0	115 000	131 000	156 000	126 000	138 000	159 000
B_{2013}	18 000	35 000	62 000	13 000	25 000	45 000
B_{2013} (%B_0)	0.16	0.27	0.41	0.11	0.18	0.29
ACAq	0.65	0.94	1.36	0.79	1.11	1.55
U_{2013}	0.09	0.16	0.29	0.12	0.21	0.38
			MCMC 5.2			**MCMC 5.4**
	5%	Median	95%	5%	Median	95%
B_0	112 000	132 000	185 000	113 950	127 000	152 000
B_{2013}	23 000	43 000	99 050	13 000	27 000	53 000
B_{2013} (%B_0)	0.21	0.34	0.56	0.12	0.22	0.36
ACAq	0.44	0.75	1.10	0.64	0.95	1.33
U_{2013}	0.06	0.13	0.24	0.10	0.20	0.39

Table 8: Summary of current and projected biomass indicators for the base case (5.0), with future annual catch assumed to be 6000 t for 2014–2018: spawning biomass as a percentage of B_0, the probability of spawning being above the target biomass (40% B_0), below the soft limit (20% B_0), and below the hard limit (10% B_0), and the probability of exploitation rate (U_t) being above $U_{40\%B0}$.

	B_t %B_0 (90% CI)	Pr(B_t > 40%B_0)	Pr(B_t < 20%B_0)	Pr(B_t < 10%B_0)	Pr (U_t >$U_{40\%B0}$)
2013	27 (16–41)	0.067	0.167	0.003	1.000
2018	18 (6–32)	0.003	0.616	0.160	1.000

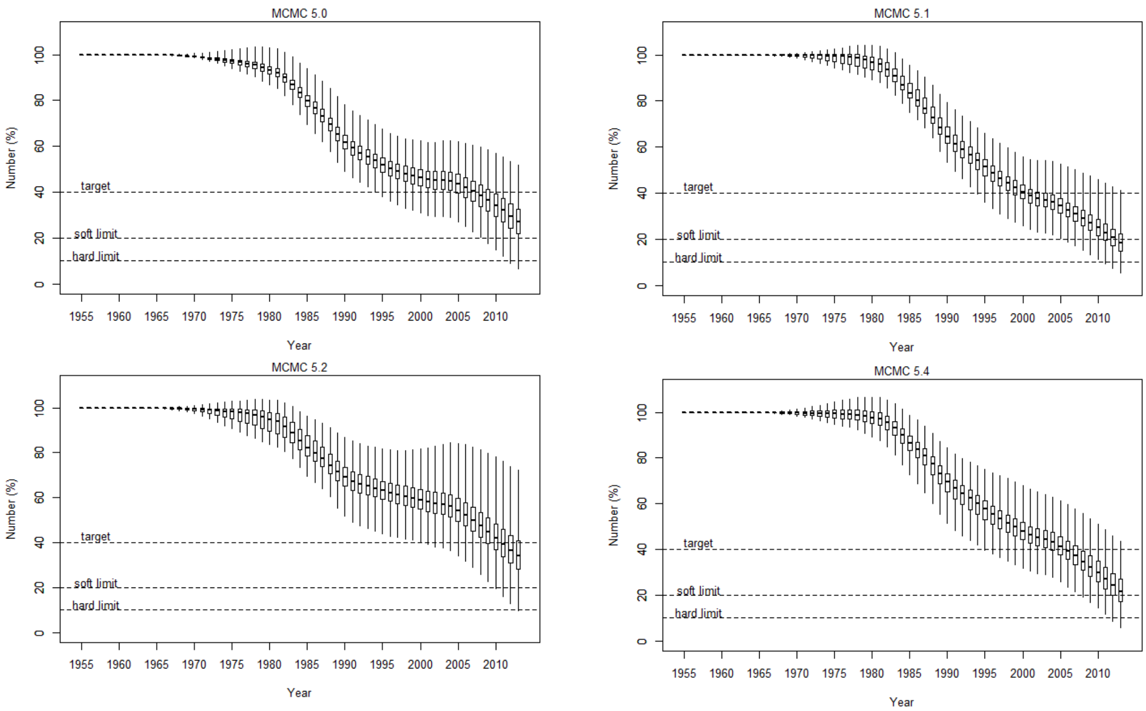


Figure 1: Bayesian posterior distribution of mature biomass mature biomass as a percentage of B_0 (right) for models 5.0, 5.1, 5.2, and 5.4. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

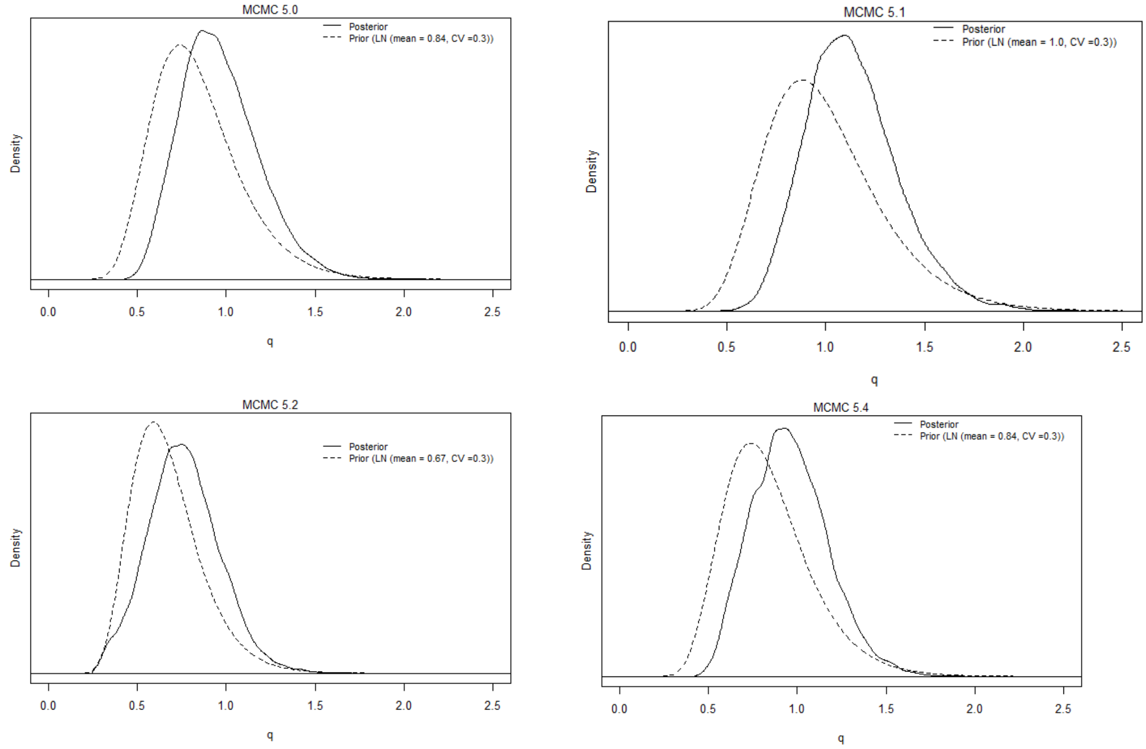


Figure 1: Estimated Bayesian posterior distribution and the assumed prior distribution for survey *q* for models 5.0, 5.1, 5.2, and 5.4.

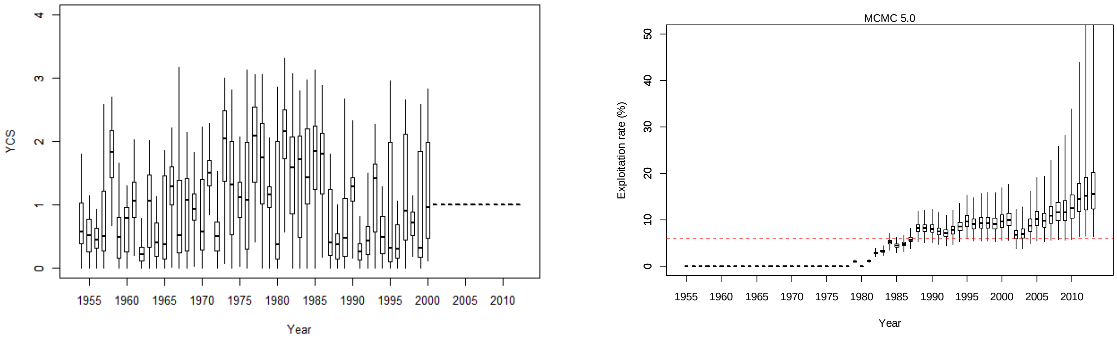


Figure 2: Estimated Bayesian posterior distributions of year class strength (left) and exploitation rates (right) for the base case. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. YCS were estimated for 1955–2000, and fixed at 1 for other years.

4.3.4 Other factors

The Working Group considered that there were a number of other factors that should be considered in relation to the stock assessment results presented here:

- There are also a number of factors that are outside the model and the analyses that add uncertainty to the model estimates of biomass. These include the sensitivity of the acoustic biomass estimate to the low value of the target strength of smooth oreo, and uncertainty in the estimates of *M* and growth rates.

- Age frequencies estimated from the 1998 and 2005 acoustic surveys suggest the possibility of poor recruitment to 1 year olds from 1986 up to 1995, the youngest cohort that would be seen in the 2005 acoustic data (Doonan & McMillan 2011). These cohorts would enter the fishery (at about age 23 years) from 2009 to 2018. However, age data from the 1993 and 1994 trawl surveys on the eastern end of the south Chatham Rise were ambiguous (Doonan & McMillan 2011).

- Another major source of uncertainty was in the 2012 survey estimates in which a significant proportion of the biomass was from a mark which was identified as smooth oreo. The species composition of this mark was not able to be verified by trawling. Excluding this mark would reduce the 2012 adult school abundance estimate by 38%, and as a result, reduce the estimate of current spawning stock biomass to 22% B_0.

4.3.5 Future research needs

- Only two years of age composition data are included in the smooth oreo assessment. More otoliths from previous surveys should be read to improve the estimation of year class strengths.
- As the acoustic survey time series lengthens, and the number of species identification trawls increases, the uncertainty in the assessment is likely to be reduced.
- Better mark identification, particularly for very large schools, is needed to improve the survey biomass estimates. The strategy used in the acoustic surveys should be modified to maintain contact with any very large school until it can be trawled. It may also be useful to sub-stratify the area ("hotspot") that tends to have very large schools.

5. STATUS OF THE STOCKS

There is an updated stock assessment in 2014 for the smooth oreo stock.

Stock Structure Assumptions
The two oreo stocks on the Chatham Rise are assessed separately but managed as a single stock. For black oreos the population has been found to be genetically similar to other oreo stocks and it is likely that some mixing occurs. Smooth oreos are assumed to be distinct from OEO1+6 stocks but may mix with the 3A stock.

- **OEO4 (Black Oreos)**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	No quantitative stock assessment model
Reference Points	Target(s): 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status <No plot available>	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has been stable for the last 5 years, after initial substantial decline during the 1980s and 1990s.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown

Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 2 – Partial quantitative stock assessment	
Assessment Method	Age-based model in CASAL	
Main data inputs	- 4 standardised CPUE indices (pre/post GPS and east/west) - Observer length frequencies	
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	- Assessments unable to represent observer length frequency data. - CPUE could be fitted to a two-stock model but not a homogenous model. - A portion of the abundance estimates were based on data from areas not normally covered by the trawl fishery, and the surveyed area was scaled by a factor of 4.3 – the area surveyed was borderline for providing a reliable abundance estimate.	

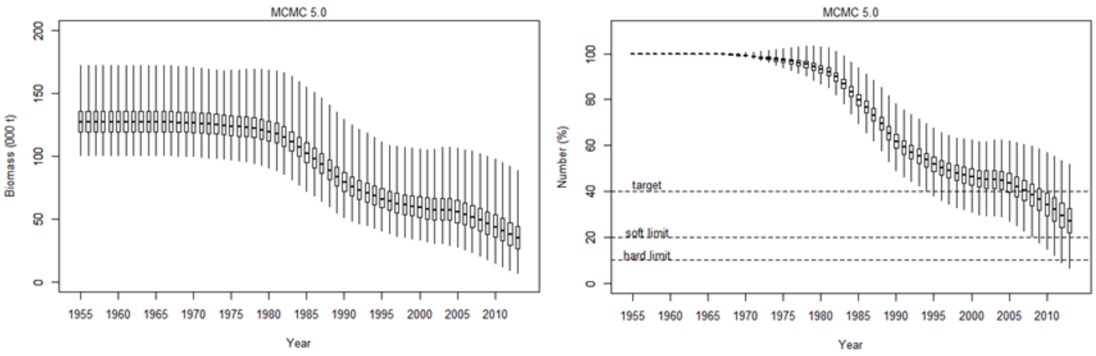
Qualifying Comments
The WG agreed that the stock might be split into east and west areas that were independent or at least minimally mixing for future assessments.

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

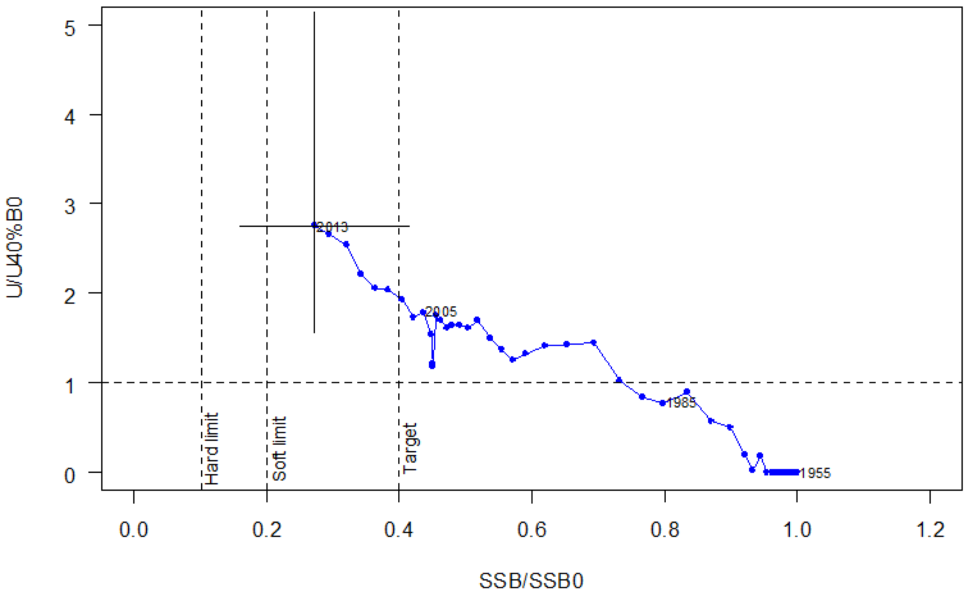
- **OEO4 (Smooth Oreos)**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base case model fitted to vulnerable acoustic abundance estimates based on school marks, and age frequencies from acoustic surveys
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%}$
Status in relation to Target	B_{2013} was estimated at 27% B_0 for the base case model. B_{2013} is Very Unlikely (< 10%) to be at or above the target
Status in relation to Limits	B_{2013} is Unlikely (< 40%) to be below the Soft limit and Very Unlikely (< 10%) to be below Hard Limits.
Status in relation to Overfishing	Overfishing is Very Likely (> 90%) to be occurring.

Historical Stock Status Trajectory and Current Status



Spawning stock biomass trajectory for model 5.0 in number (left) and in percentage (right).



Trajectory of exploitation rate as a ratio $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1955 to 2013 for MCMC 5.0 (base case). The vertical lines at 10%, 20%, and 40% B_0 represent the hard limit, the soft limit, and the target respectively. $U_{\%40B0}$ is the exploitation rate at which the spawning stock biomass would stabilise at 40% B_0 over the long term. Each point on trajectory represents the estimated annual stock status: the value on x axis is the mid-season spawning stock biomass (as a ratio of B_0) and the value on the y axis is the corresponding exploitation rate (as a ratio $U_{\%40B0}$) for that year. The estimates are based on MCMC medians and the 2013 90% CI is shown by the cross line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass appears to be steadily decreasing,
Recent Trend in Fishing Intensity or Proxy	Estimated exploitation rates have steadily increased over recent years
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	Relatively low recruitment before 1970, relatively high recruitment between 1970 and 1985, and below the long term average in more recent years

Projections and Prognosis	
Stock Projections or Prognosis	Assuming a future catch of 6000 t results in a reduction in the median estimate of spawning stock biomass to 22 400 t, or 17.6% B_0 in 2018.

Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Likely (> 60%) Hard Limit: Unlikely (<`40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Likely (> 90%)

Assessment Methodology and Evaluation		
Assessment Type	Type 1 – Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment : 2014	Next assessment: 2018
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Five acoustic abundance data (1998, 2001, 2005, 2009, 2012)	1 – High Quality
	- Age frequencies from acoustic surveys (1998, 2005)	1 – High Quality
	- Acoustic length data	1 – High Quality
	- Observer length data (not used, except to provide a length cut-off for vulnerable fish)	2 – Medium or Mixed Quality: conflicts with M and growth information in the model
Data not used (rank)	- Commercial CPUE	3 – Low Quality: substantial changes in fishing patterns over time
Changes to Model Structure and Assumptions	- added age data and used stochastic recruitment rather than deterministic	
Major sources of Uncertainty	- uncertainties in the prior for the survey catchability (q): • estimated target strength • scaling factor from the trawl survey area to acoustic area • scaling factor from acoustic area to the QMA area • proportion of vulnerable biomass in the fished marks - mark identification of very large schools - lack of age composition data	

Qualifying Comments
The estimates derived from the model are determined largely by the prior for the survey catchability due to the limited observations.

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

6. FOR FURTHER INFORMATION

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J (2002) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v1.02.2002/10/21. *NIWA Technical Report 117*. 199 p.

Coburn, R P; Doonan, I J; McMillan, P J (2001a) Smooth oreo abundance indices from standardised catch per unit of effort data for OEO 4. *New Zealand Fisheries Assessment Report 2001/11*. 39 p.

Coburn, R P; Doonan, I J; McMillan, P J (2001b) Black oreo abundance indices from standardised catch per unit of effort data for OEO 4. *New Zealand Fisheries Assessment Report 2001/39*. 24 p.

Doonan, I J; Coombs, R F; McMillan, P J; Dunn, A (1998) Estimate of the absolute abundance of black and smooth oreo in OEO 3A and 4 on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project OEO9701. 47p.

Doonan, I J; McMillan, P J (2011) Final Research Report for Ministry of Fisheries Research Project OEO2009-01. 10 p. (Unpublished report held by MPI Wellington.)

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (1996) Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1996. New Zealand Fisheries Assessment Research Document 1996/17. 21p. (Unpublished document held by NIWA library.)

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (1997) Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1997. New Zealand Fisheries Assessment Research Document 1997/21. 26p. (Unpublished document held by NIWA library.)

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (2001) Assessment of OEO 4 black oreo for 2000–01. *New Zealand Fisheries Assessment Report 2001/30*. 32p.

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (2001) Assessment of OEO 4 smooth oreo for 2000–01. *New Zealand Fisheries Assessment Report 2001/21*. 37 p.

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (2003) Assessment of OEO 4 smooth oreo for 2002–03. *New Zealand Fisheries Assessment Report 2003/50*. 55 p.

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (2008) Assessment of OEO 4 smooth oreo for 2006–07. *New Zealand Fisheries Assessment Report 2008/40*. 45 p.

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C; Cordue, P L (1995) Assessment of smooth oreo for 1995. New Zealand Fisheries Assessment Research Document 1995/12. 31p. (Unpublished document held by NIWA library.)

Doonan, I J; McMillan, P J; Hart, A C (2001) The use of mean length data for stock assessments of black oreo and smooth oreo in OEO 4. *New Zealand Fisheries Assessment Report 2001/34*. 16 p.

Doonan, I J; McMillan, P J; Hart, A C (2008) Ageing of smooth oreo otoliths for stock assessment. *New Zealand Fisheries Assessment Report 2008/8*. 29 p.

Francis, R I C C (1999) The impact of correlations in standardised CPUE indices. New Zealand Fisheries Assessment Research Document 1999/42. 30p. (Unpublished document held by NIWA library.)

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (MCY) and current annual yield (CAY). New Zealand Fisheries Assessment Research Document 1992/8. 27p. (Unpublished document held by NIWA library.)

Fu, D; Doonan, I J (2013) Assessment of OEO 4 smooth oreo for 2009–10. *New Zealand Fisheries Assessment Report 2013/22*. 35 p.

McMillan, P J; Doonan, I J; Coburn, R P; Hart, A C (1996) Is the south Chatham Rise trawl survey providing an index of smooth oreo abundance in OEO 4?. New Zealand Fisheries Assessment Research Document 1996/16. 18p. (Unpublished document held by NIWA library.)

McMillan, P J; Doonan, I J; Hart, A C; Coburn, R P (1998) Oreo stock assessment. Final Research Report for Ministry of Fisheries Research Project OEO9702. 16p. (Unpublished document held by MPI Wellington.)

McMillan, P J; Hart, A C (1991) Assessment of black and smooth oreos for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 1991/10. 29p. (Unpublished document held by NIWA library.)

OREOS - OEO 1 AND OEO 6 BLACK OREO AND SMOOTH OREO

1. FISHERY SUMMARY

This is presented in the Fishery Summary section at the beginning of the Oreos report.

2. BIOLOGY

This is presented in the Biology section at the beginning of the Oreos report.

3. STOCKS AND AREAS

This is presented in the Stocks and Areas section at the beginning of the Oreos report.

4. STOCK ASSESSMENT

4.1 Introduction

New assessments for Pukaki Rise black oreo and Pukaki Rise smooth oreo were attempted in 2013 but were rejected by the Working Group and are only briefly discussed here. The previously reported assessments for Southland (OEO 1/OEO 3A) and Bounty Plateau smooth oreo (only MPD results) are repeated.

4.2 Southland smooth oreo fishery

This assessment was updated in 2007 and applies only to the study area as defined in Figure 1 and does not include areas to the north (Waitaki) and east (Eastern canyon) of the main fishing grounds.

This fishery is mostly in OEO 1 on the east coast of the South Island but catches occur at the northern end of the fishery straddle and cross the boundary line between OEO 1 and OEO 3A at 46ºS. This is an old fishery with catch and effort data available from 1977–78. Smooth oreo catch from Southland was about 480 t (mean of 2003–04 to 2005–06). There is an industry catch limit of 400 t smooth oreo implemented after the previous (2003) assessment. There were no fishery-independent abundance estimates, so relative abundance estimates from pre- and post-GPS standardised CPUE analyses and length frequency data collected by Ministry (SOP) and industry (ORMC) observers were used.

The following assumptions were made in this analysis.

1. The CPUE analysis indexed the abundance of smooth oreo in the study area of OEO 1/3A.
2. The length frequency samples were representative of the population being fished.
3. The ranges used for the biological values covered their true values.
4. Recruitment was deterministic and followed a Beverton-Holt relationship with steepness of 0.75.
5. The population of smooth oreo in the study area was a discrete stock or production unit.
6. Catch overruns were 0% during the period of reported catch.
7. The catch histories were accurate.
8. The maximum fishing pressure (U_{MAX}) was 0.58.

An age-structured CASAL model employing Bayesian statistical techniques was developed. A two-fishery model was employed with a split into deep and shallow fisheries because of a strong relationship found between smaller fish in shallow water and large fish in deeper water. The boundary between deep and shallow was 975 m. The 2007 analysis used five extra years of catch and observer length frequency data compared to the 2003 assessment. The model was partitioned by the sex and maturity status of the fish and used population parameters previously estimated from fish sampled on the Chatham Rise and Puysegur Bank fisheries. The maturity ogive used was estimated from Chatham Rise research samples.

4.2.1 Estimates of fishery parameters and abundance

Catch history

A catch history (Table 1) was derived using declared catches of OEO from OEO 1 (see table 2 in the Fishery Summary section at the beginning of the Oreos report) and tow-by-tow records of catch from the study area (Figure 1). The tow-by-tow data were used to estimate the species ratio (SSO/BOE) and therefore the SSO taken. It was assumed that the reported landings provided the best information on total catch quantity and that the tow-by-tow data provided the best information on the species and area breakdown of catch.

Table 1: Catch history of smooth oreo from Southland rounded to the nearest 10 t.

Fishing year	Shallow	Deep	Fishing year	Shallow	Deep
1977–78	210	0	1992–93	410	250
1978–79	10	0	1993–94	220	150
1979–80	40	0	1994–95	80	150
1980–81	0	0	1995–96	600	500
1981–82	0	0	1996–97	440	70
1982–83	0	0	1997–98	320	230
1983–84	480	660	1998–99	480	620
1984–85	170	510	1999–00	650	480
1985–86	480	3 760	2000–01	400	610
1986–87	30	160	2001–02	580	1 470
1987–88	130	860	2002–03	130	1 320
1988–89	0	240	2003–04	330	420
1989–90	210	430	2004–05	140	290
1990–91	410	420	2005–06	120	140
1991–92	530	380			

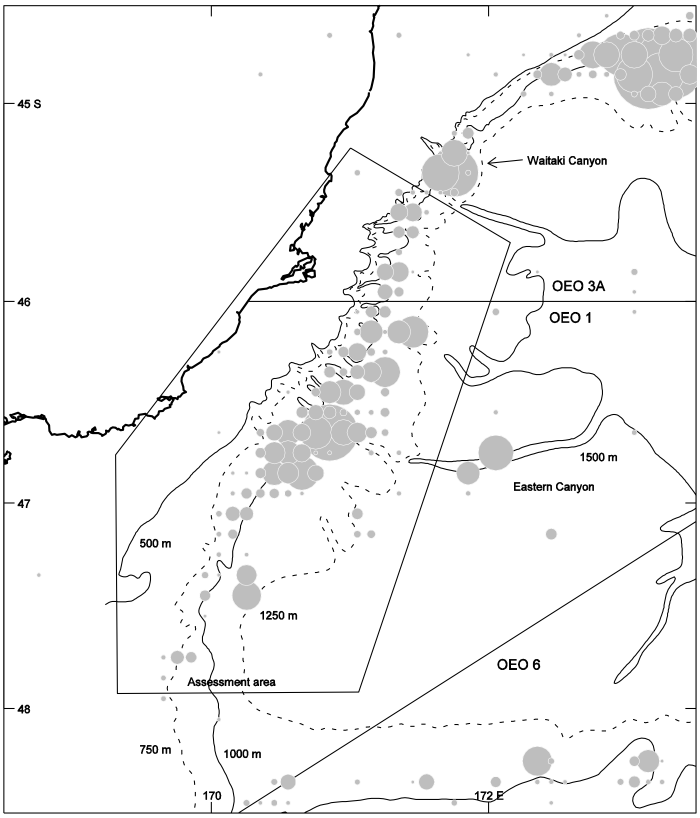


Figure 1: Smooth oreo estimated catch from all years up to (and including) 2005–06. The area was divided into cells that are 0.1 degrees square and catches were summed for each cell. Circles proportional in area to the catch are plotted centred on the cells. Catches less than 10 tonnes per cell are not shown. Circles are layered so that smaller circles are never hidden by larger ones. The assessment area and bottom topography are also shown.

Length data

All SOP records where smooth oreo were measured from within the assessment area are shown in Table 2: 78 samples were shallow and 51 deep. Only 13 shallow and 4 deep samples were collected before 1999–2000 (Table 2). Composite length frequency distributions were calculated for each year. Each sample was weighted by the catch weight of the tow from which the sample was taken. This was modified slightly by estimating the number of fish that would be in a unit weight of catch and multiplying by that.

Table 2: Summary of length frequency data for smooth oreo available for the study area. Year group, year applied, and the total number of length frequency samples for the shallow and deep year groups.

Year group	Year applied	No. of lfs
Shallow		
a=1993–94 to 1997–98	1995–96	13
b=1999–2000	1999–00	30
c=2000–01 to 2001–02	2001–02	22
d=2002–03 to 2005–06	2004–05	13
Deep		
e=1997–98 to 2001–02	2001–02	27
f=2002–03 to 2004–05	2003–04	21

Relative abundance estimates from CPUE analyses

The standardised CPUE analyses used a two part model which separately analysed the tows which caught smooth oreo using a log-linear regression (referred to as the positive catch regression) and a binomial part which used a Generalised Linear Model with a logit link for the proportion of successful tows (referred to as the zero catch regression). The binomial part used all the tows, but considered only whether or not the species was caught and not the amount caught. The yearly indices from the two parts of the analysis (positive catch index and zero catch index) were multiplied together to give a combined index. The pre-GPS data covered the years from 1983–84 to 1987–88, was left unmodified from 2003, and was used as an index of the deep fishery as most fishing in that period was deep (Table 3). The post-GPS data covered 1992–93 to 2005–06 split into shallow and deep fisheries but the indices for the last two years (2004–05, 2005–06) were dropped because catch was constrained by the industry catch limit of 400 t for smooth oreo introduced after the 2003 assessment (Table 4).

Table 3: Smooth oreo pre-GPS combined index estimates by year, and jackknife CV estimates from analysis of all tows in the study area that targeted smooth oreo, black oreo, or unspecified oreo.

Year	Combined index	Jackknife CV (%)
1983–84	1.75	22
1984–85	1.65	29
1985–86	1.19	33
1986–87	0.48	23
1987–88	0.61	27

Table 4: Smooth oreo post-GPS combined index estimates by year, and jackknife CV estimates from analysis of all tows in the study area that targeted smooth oreo, black oreo, or unspecified oreo.

	Shallow		Deep	
Fishing year	Index (kg/tow)	Bootstrap CV (%)	Index (kg/tow)	Bootstrap CV (%)
1992–93	1 489	57	1 401	73
1993–94	956	47	916	53
1994–95	1 521	72	428	121
1995–96	1 173	37	1 862	84
1996–97	511	84	2 117	41
1997–98	1 477	39	502	59
1998–99	939	42	915	50
1999–00	842	44	611	48
2000–01	758	46	385	72
2001–02	573	44	658	53
2002–03	303	48	406	76
2003–04	480	57	719	218

4.2.2 Biomass estimates

Biomass estimates were made based on a Markov Chain Monte Carlo analysis which produced a total of about 1.4 million iterations. The first 100 000 iterations were discarded and every 1000th point was retained, giving a final converged chain of about 1300 points.

Biomass estimates for the base case are given in Table 5 and Figure 2. These biomass estimates are uncertain because of the reliance on commercial CPUE data for abundance indices.

Table 5: Biomass estimates (t) for the base case.

		5%	Median	Mean	95%	CV (%)
Free parameters						
Virgin mature biomass (B_0)		15 600	17 400	17 900	21 700	12
Selectivity, shallow	a1	17.2	19.0	19.0	21.0	6
	sL	3.9	4.8	4.8	5.8	12
	sR	5.9	8.3	8.4	11.2	20
Selectivity, deep	a50	22.1	26.0	26.2	30.8	10
	to95	1.9	7.1	7.0	11.0	37
Derived quantities						
Current mature biomass (% initial)		19	27	28	41	25
Current selected shallow biomass (% initial)		56	65	65	73	8
Current selected deep biomass (% initial)		12	20	22	36	36

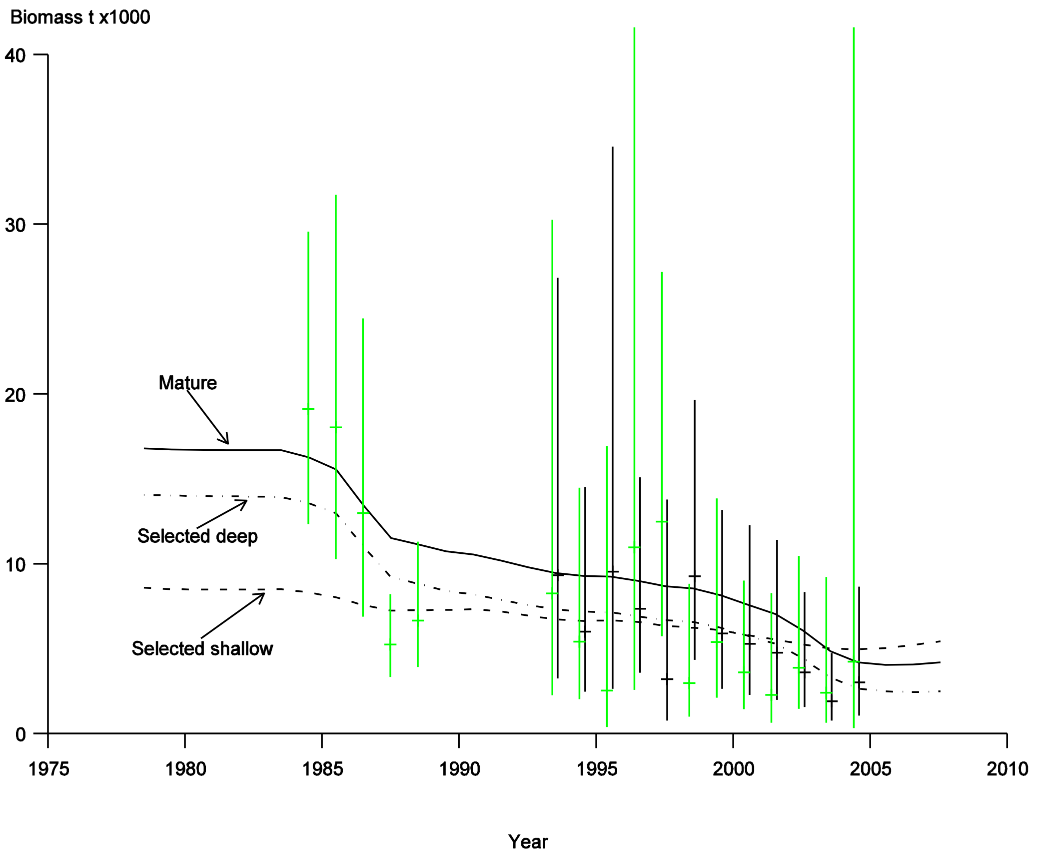


Figure 2: Estimated biomass trajectories from the 2007 base case assessment — mature biomass and selected biomass for the shallow and deep fisheries. Also shown are the CPUE indices from the pre- and post-GPS analysis for the deep fishery (in gray) and the post-GPS analyses for the shallow fishery (in black). CPUE indices are shown with +/- 2 s.e. confidence interval indicated by the vertical lines (the post-GPS CPUE data are slightly offset to avoid over plotting). The CPUE data were scaled by catchability coefficients to match the biomass scale.

4.3 Pukaki Rise smooth oreo fishery (part of OEO 6)

A second assessment for this fishery was attempted in 2013, applying only to the assessment area as defined in Figure 3. The first assessment for this fishery was in 2006–07 (Coburn et al 2007; McKenzie, 2007). This is the main smooth oreo fishery in OEO 6 with an annual catch in 2011–12 of 290 t, taken mainly by New Zealand vessels, down substantially from previous years (Table 6). There was also a small early Soviet fishery (1980–81 to 1985–86) with mean annual catches of less than 100 t. There were no fishery-independent abundance estimates, so relative abundance estimates from a post-GPS standardised CPUE analysis and length frequency data collected by Ministry and industry observers were considered. Biological parameter values estimated for Chatham Rise and Puysegur Bank smooth oreo were used in the assessment because there are no research data from Pukaki Rise. However, the CPUE analysis was not accepted as an index of abundance for smooth oreo in the Pukaki Rise (OEO 6) assessment area, principally due to the complex temporal and spatial patterns of this fishery and associated fisheries, and the small number of vessels. As a result, the assessment was not accepted by the Working Group, and only catch history, length frequencies and unstandardised catch and effort data are reported here.

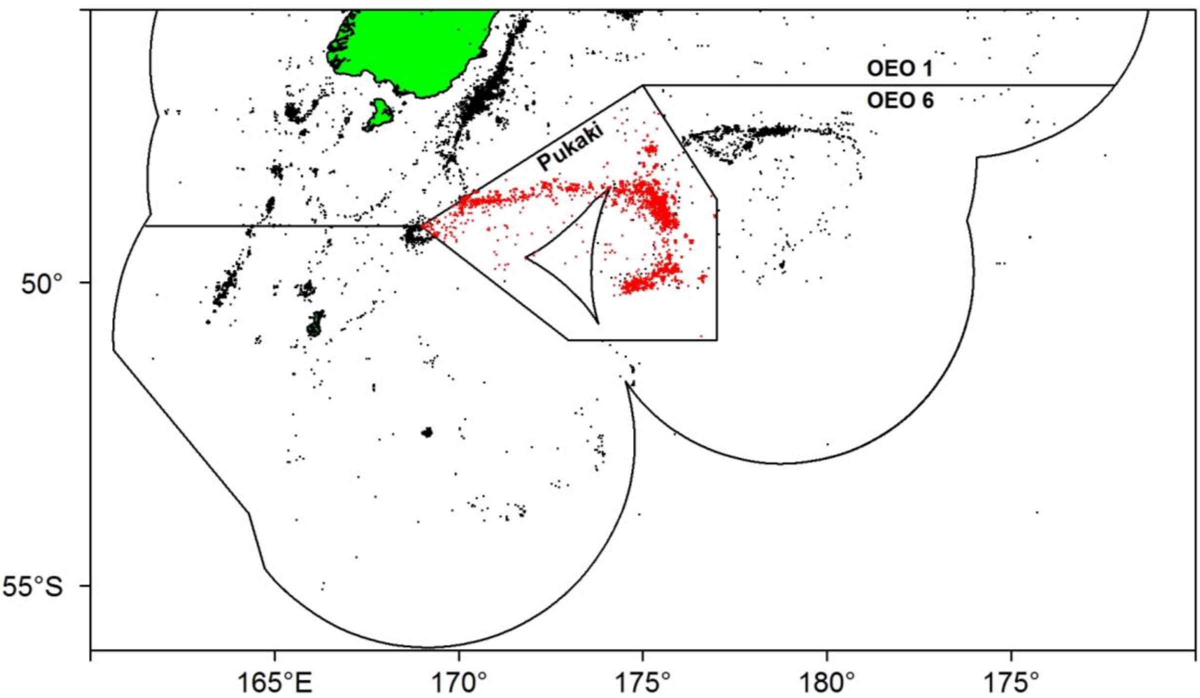


Figure 3: The Pukaki Rise fishery assessment area (polygon) abutting the north boundary of OEO 6. The dots show all tows where the target species or catch was OEO, SSO, BOE or ORH, with the red dots being those within the Pukaki assessment area.

4.3.1 Estimates of fishery parameters and abundance

Catch history

A catch history was derived using declared catches of OEO from OEO 6 (Table 2 in the "Fishery Summary" section of the Oreos report above) and tow-by-tow records of catch from the assessment area (Figure 3). The tow-by-tow data were used to estimate the species ratio (SSO/BOE) and therefore the amount of SSO taken. It was assumed that the reported landings provided the best information on total catch quantity and that the tow-by-tow data provided the best information on the species and area breakdown of catch. There may be unreported catch from before records started, although this is thought to be small. Before the 1983–84 fishing year the species catch data were combined over years to get an average figure that was then applied in each of those early years. For the years from 1983–84 onwards, each year's calculation was made independently. The catch history used in the population model is given in Table 6.

Table 6: Catch history of smooth oreo from the Pukaki Rise fishery assessment area. Catches are rounded to the nearest 10 t.

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1980–81	30	1988–89	0	1996–97	1 650	2004–05	1 370
1981–82	20	1989–90	0	1997–98	1 340	2005–06	1 470
1982–83	0	1990–91	10	1998–99	1 370	2006–07	1 790
1983–84	640	1991–92	0	1999–00	2 270	2007–08	1 260
1984–85	340	1992–93	70	2000–01	2 580	2008–09	1 200
1985–86	10	1993–94	0	2001–02	2 020	2009–10	770
1986–87	0	1994–95	130	2002–03	1 340	2010–11	820
1987–88	180	1995–96	1 360	2003–04	1 660	2011–12	290
						2012–13	136

Length data

Smooth oreo length frequency data collected by observers are available from the last 15 years (Table 7). An in-depth analysis of these data in the previous assessment (covering fishing years 1998–2005) indicated that they were reasonably representative of the fishery in terms of spatial, depth and temporal coverage in those years that had adequate data (Coburn et al 2007). The depths fished by the sampled fleet varied between years so the length data were stratified by depth resulting in shallow (less than 900 m), middle (900–990 m) and deep strata (greater than 990 m). The data from adjacent years were also grouped because some years had few samples. The resulting length frequencies are shown in Figure 4. There is a trend towards a flatter distribution over the last three grouped distributions (2000–01, 02, and 03–05).

Table 7: Summary of length frequency data for smooth oreo available for the assessment area. The table shows the number of tows sampled by year, the sample source, and the year group. -, no data.

	Year group	Number of tows sampled		
Year		ORMC	SOP	All
1997–98	98–99	-	15	15
1998–99	98–99	64	9	73
1999–00	00–01	5	36	41
2000–01	00–01	37	17	54
2001–02	01–02	42	22	64
2002–03	03–04	4	12	16
2003–04	03–04	-	19	19
2004–05	05–06	-	30	30
2005–06	05–06	-	20	20
2006–07	06–07	-	205	205
2007–08	07–08	-	124	124
2008–09	08–09	-	66	66
2009–10	09–10	-	46	46
2010–11	10–11	-	107	107
2011–12	10–11	-	21	21
Totals		152	149	301

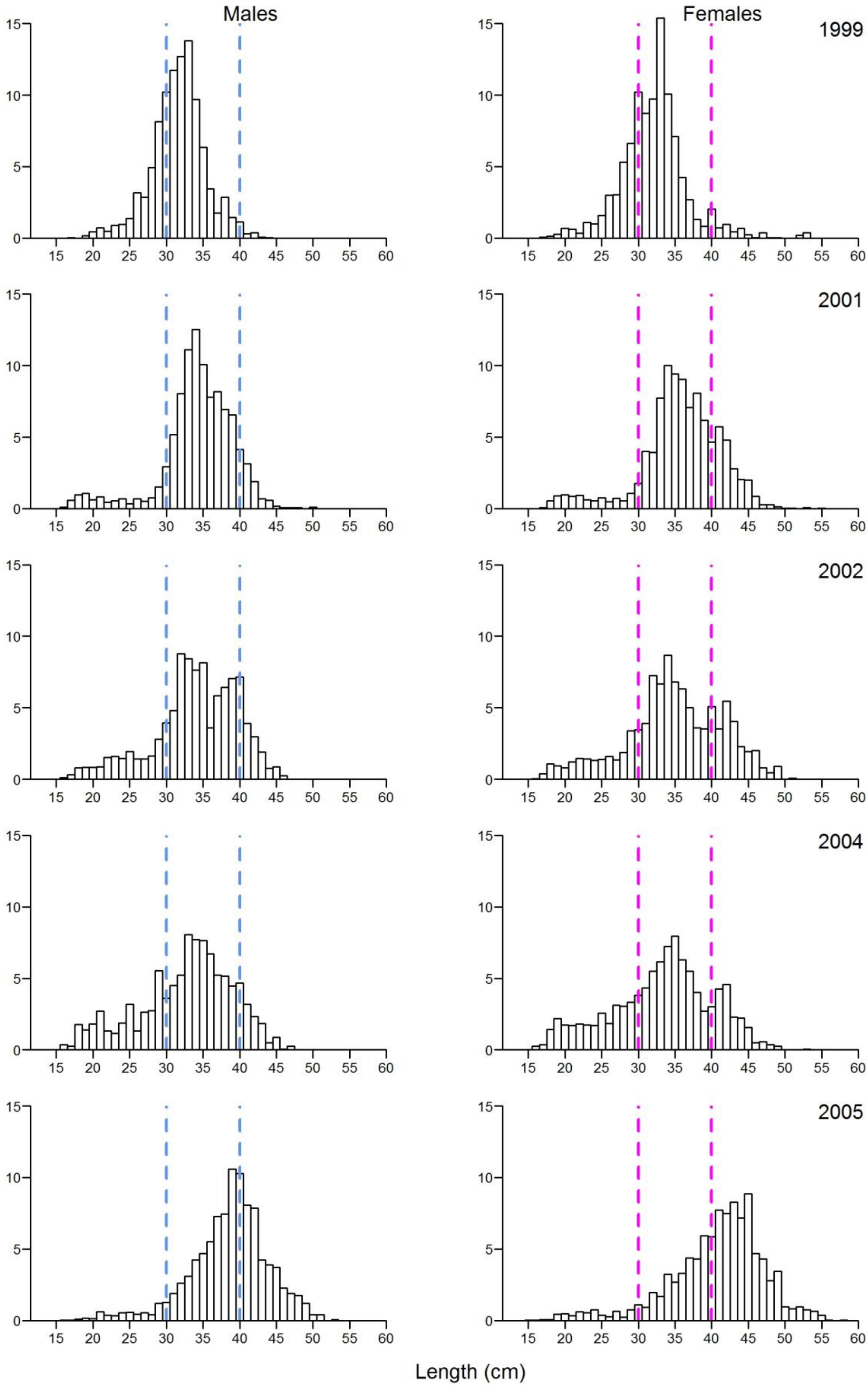


Figure 4: Length frequencies for Pukaki Rise smooth oreo, stratified by depth (see text), and grouped by years. [Continued on next page].

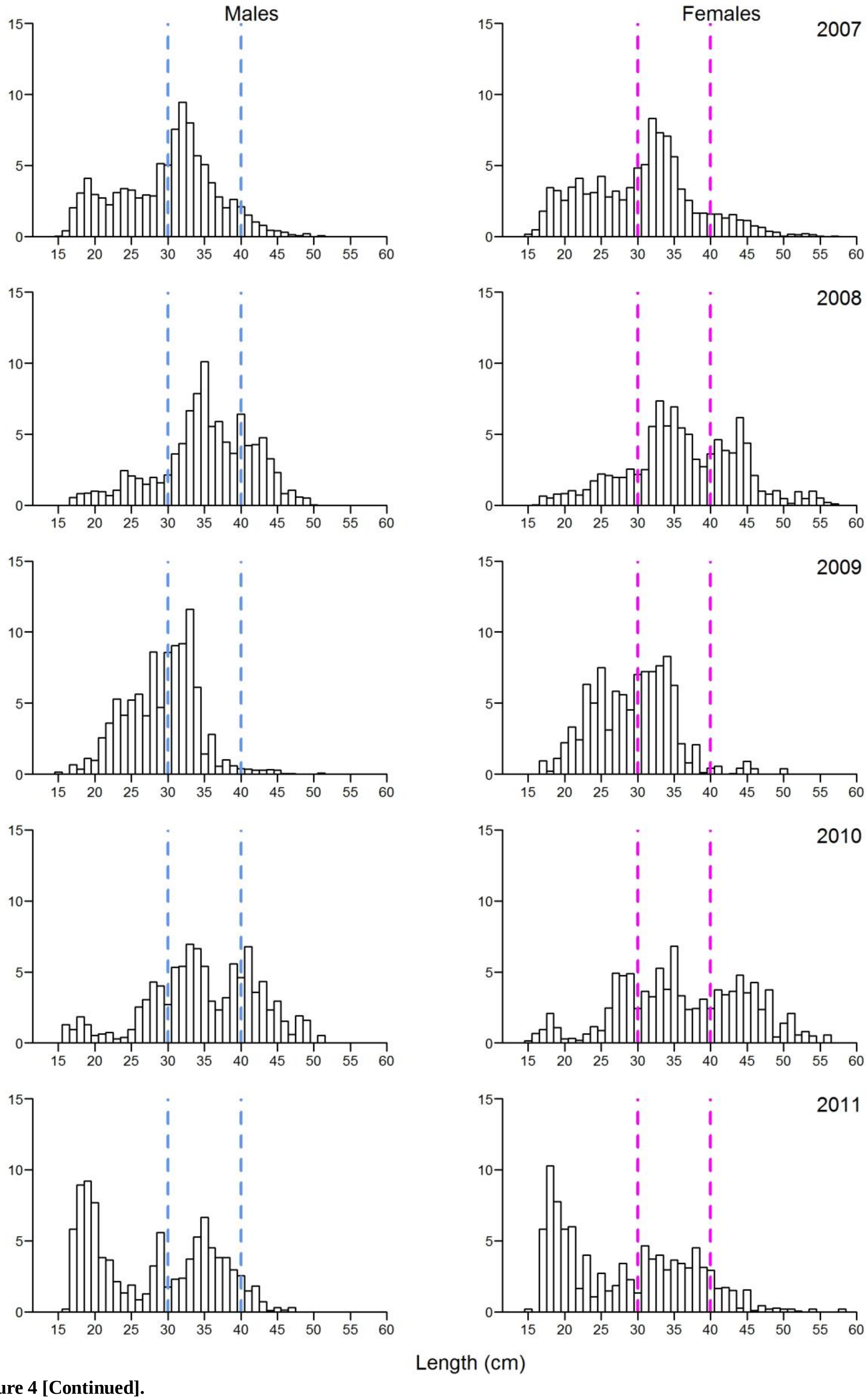


Figure 4 [Continued].

Catch and effort data

Core vessels for the fishery were defined in order to develop a standardised CPUE series, but the standardised series was rejected by the Working group. Unstandardised catch and effort data are presented in Table 8.

Table 8: Catch and effort data for vessels with three or more consecutive years with at least 10 records from 1995–96 to 2011–12.

	No. of tows	No. of vessels	Estimated catch (t)	Mean t/tow	Zero catch tows (%)	SSO target (%)
1996	193	2	810	4.20	-	6
1997	322	3	1 270	3.90	4	4
1998	264	4	1 020	3.90	6	9
1999	262	4	1 050	4	1	15
2000	528	5	2 030	3.90	32	37
2001	588	7	2 280	3.90	49	52
2002	409	5	1 920	4.70	9	9
2003	498	5	1 230	2.50	14	18
2004	512	4	1 300	2.50	9	13
2005	588	6	1 170	2	21	27
2006	656	5	1 260	1.90	13	14
2007	806	5	1 550	1.90	23	25
2008	933	2	1 110	1.20	13	16
2009	918	3	1 200	1.30	21	23
2010	948	3	740	0.80	8	11
2011	593	3	720	1.20	22	25
2012	397	2	260	0.70	10	12

4.4 Bounty Plateau smooth oreo fishery (part of OEO 6)

The first assessment for this fishery was developed in 2008 and applies only to the study area as defined in Figure 5. There were no fishery-independent abundance estimates, so relative abundance estimates from a post-GPS standardised CPUE analysis and length frequency data collected by Ministry (SOP) and industry (ORMC) observers were considered. Biological parameter values estimated for Chatham Rise and Puysegur Bank smooth oreo were used in the assessment because there are no research data from Bounty Plateau.

The following assumptions were made in this analysis.

1. The CPUE analysis indexed the abundance of smooth oreo in the Bounty Plateau (OEO 6) assessment area.
2. The length frequency samples were representative of the population being fished.
3. The biological parameters values used (from other assessment areas) are close to the true values.
4. Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
5. The population of smooth oreo in the assessment area was a discrete stock or production unit.
6. Catch overruns were 0% during the period of reported catch.
7. The catch histories were accurate.
8. The maximum exploitation rate (E_{MAX}) was 0.58.

Data inputs included catch history, relative abundance estimates from a standardised CPUE analysis, and length data from SOP and ORMC observers. The observational data were incorporated into an age-based Bayesian stock assessment (CASAL) with deterministic recruitment to estimate stock size. The stock was considered to reside in a single area, with a partition by sex. Age groups were 1–70 years, with a plus group of 70+ years.

The length-weight and length-at-age population parameters are from fish sampled on the Chatham Rise and Puysegur Bank fisheries (Table 1, Biology section). The natural mortality estimate is based on fish sampled from the Puysegur Bank fishery. The maturity ogive is from fish sampled on the

Chatham Rise, and the age at which 50% are mature is between 18 and 19 years for males and between 25 and 26 years for females.

4.4.1 Estimates of fishery parameters and abundance

Catch history

Table 9: Catch history (t) of smooth oreo from the Bounty Plateau fishery assessment area. Catches are rounded to the nearest 10 t.

Year	Catch	Year	Catch
1983–84	620	1996–97	610
1984–85	0	1997–98	650
1985–86	0	1998–99	1 200
1986–87	0	1999–00	870
1987–88	10	2000–01	550
1988–89	0	2001–02	980
1989–90	0	2002–03	1 530
1990–91	20	2003–04	1 420
1991–92	0	2004–05	2 190
1992–93	110	2005–06	1 790
1993–94	490	2006–07	670
1994–95	1 450	2007–08	670
1995–96	900		

A catch history was derived using declared catches of oreo from OEO 6 (Table 2 in the "Fishery Summary" section of the Oreos report above) and tow-by-tow records of catch from the assessment area (Figure 5). The tow-by-tow data were used to estimate the species ratio (SSO/BOE) and therefore the SSO taken. The catch history used in the population model is given in Table 9.

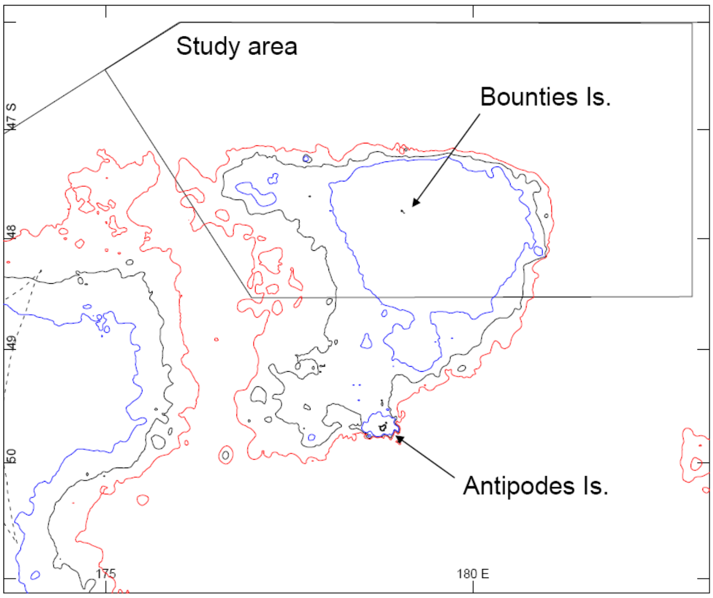


Figure 5: The Bounty Plateau fishery assessment study area.

Length data

Smooth oreo length frequency data collected by SOP and ORMC observers are available from the last twenty eight years. An in-depth analysis indicated that these data were reasonably representative of the fishery in terms of spatial, depth and temporal coverage in those years that had adequate data. Length frequencies were based on tows from the core area (a subset of the study area where about 80% of the catch is take). The data from adjacent years were grouped because some years had few samples (Table 10). The resulting length frequencies are shown in Figure 6. In the final model runs the 1994–95 year of the length frequency series was omitted as it contained very few samples.

Table 10: Core length analysis Year group, year applied and the number of length frequency samples. Smooth oreo sample catch weight, fishery catch and sample catch as percentage of the fishery.

Year group	Year applied	No. of lfs	Catch sampled (t)	Fishery catch (t)	% fishery sampled
1991–92 to 1995–96	1994–95	7	88	1 505	6
1998–99 to 1999–2000	1998–99	30	246	1 121	22
2000–2001 to 2002–03	2001–02	25	398	2 261	18
2003–04 to 2004–05	2004–05	29	261	2 280	11
2005–06	2005–06	32	379	1 121	34
2006–07 to 2007–08	2006–07	17	168	494	34

Relative abundance estimates from CPUE analyses

The small early Soviet fishery had too few data for a standardised CPUE analysis. The standardised CPUE analysis was, therefore, from the New Zealand vessel fishery and only included data from those vessels that had fished at least three years. Just a single vessel puts in significant continuous effort from 1995–2007, with the rest of the vessels' effort confined to mainly either 1995–2000 (early) or 2001–2007 (late). Because of this, in addition to the single standardised CPUE covering the entire time period, two separate standardised CPUE indices were calculated covering the early and late periods. The final indices are shown in Tables 11 and 12.

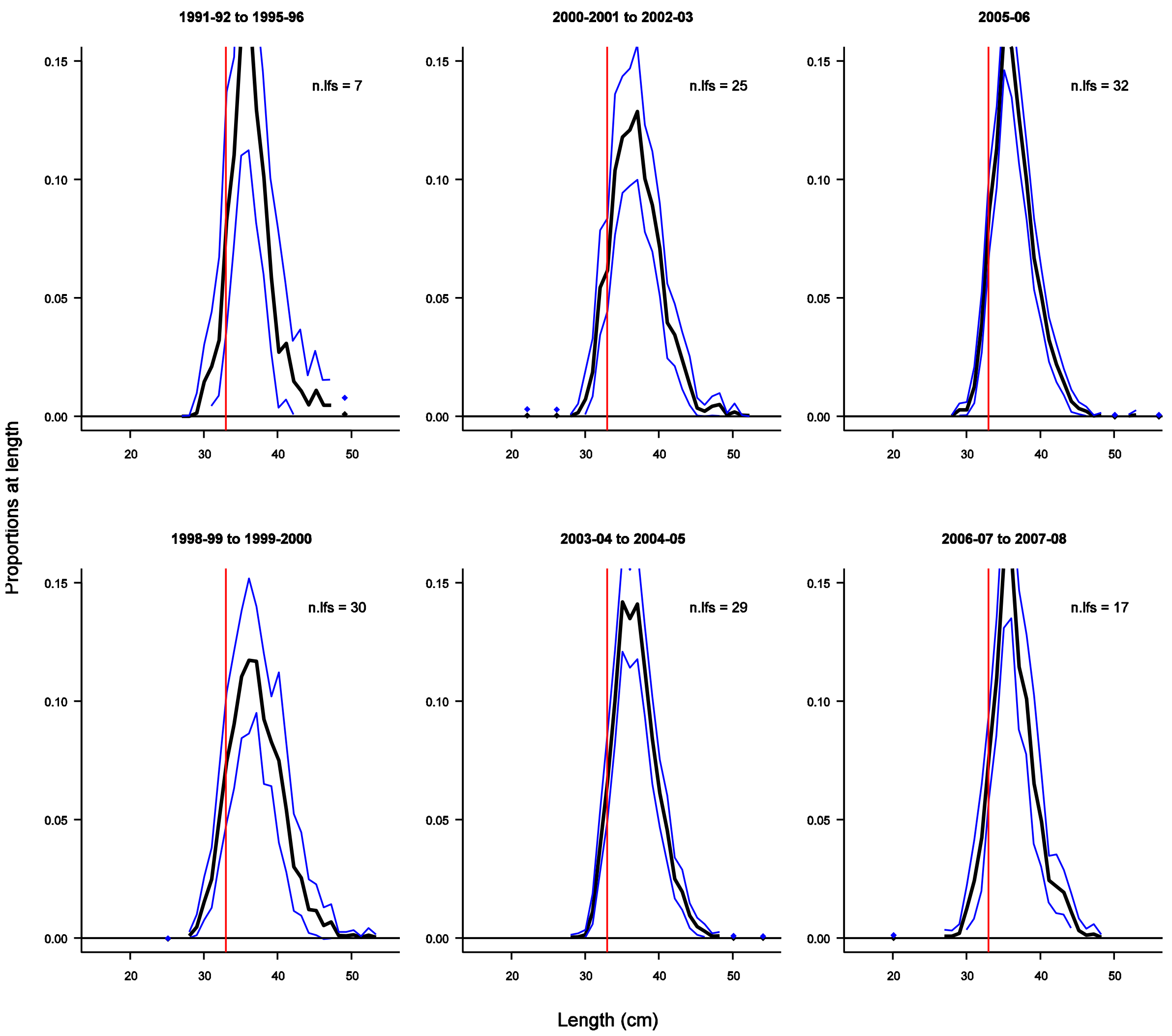


Figure 6: Length frequency distribution plots for core data only (thick lines) with 95% confidence interval (thin lines).

Table 11: Early and late period CPUE combined index estimates by year, and bootstrap CV estimates.

Year	Kg/tow	CV	Late period	Kg/tow	CV
1995–96	3551	0.423	2000–01	850	0.487
1996–97	3322	0.496	2001–02	2976	0.274
1997–98	2306	0.980	2002–03	1489	0.243
1998–99	781	0.391	2003–04	1727	0.260
1999–2000	1536	0.306	2004–05	1604	0.227
			2005–06	1386	0.310
			2006–07	966	0.232

Table 12: Single period CPUE combined index estimates by year, and bootstrap CV estimates.

Year	Kg/tow	CV
1995–96	7472	0.286
1996–97	4453	0.735
1997–98	3366	1.264
1998–99	1444	0.406
1999–2000	2835	0.286
2000–01	2817	0.436
2001–02	632	0.680
2002–03	1973	0.663
2003–04	1296	0.615
2004–05	1284	0.445
2005–06	1289	0.563
2006–07	1056	1.200

4.4.2 Biomass estimates

In all preliminary model runs the length-frequency data series were not well fitted, and gave a strong but contrasting biomass signal relative to the CPUE indices. Therefore, for final model runs, the length frequency data was down-weighted by using just the 1999 length frequency.

The base case model used early and late period CPUE indices, and the 1999 length frequency data. Current mature biomass was estimated to be 33% of a virgin biomass of 17 400 t (Figure 7).

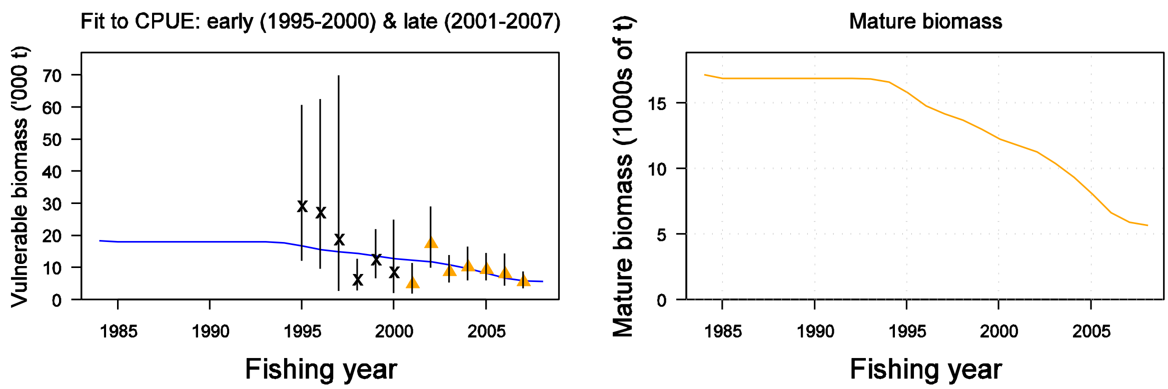


Figure 7: Model run showing the MPD fit to the CPUE data (vertical lines are the 95% confidence intervals for the indices) and the trajectory of mature biomass.

Two sensitivity model runs were carried out with the 1999 length frequency data dropped from the model, but retaining the fishery selectivity estimated using the length data. The first model run used the early and late period CPUE indices and current biomass was estimated to be 39% of a virgin biomass of 19 300 t. The second model run used the single CPUE series covering the same period and current biomass was estimated to be 17% of a virgin biomass of 13 900 t. No MCMC runs were carried out with the base case model as the sensitivity runs showed that the assessment was quite different if the CPUE analysis was not split into two series.

Biomass estimates are uncertain because of the reliance on commercial CPUE data, the use of biological parameter estimates from other oreo stocks, and because of contrasting biomass signals from using either a single or split CPUE indices.

4.4.3 Projections

No projections were made because of the uncertainty in the assessment.

4.5 Pukaki Rise black oreo stock (part of OEO 6)

A second assessment for this fishery was attempted in 2013, applying only to the assessment area as defined in Figure 8. The first assessment for this fishery was in 2009 (Doonan et al 2010). This is currently the largest black oreo fishery in the New Zealand EEZ with both current (2011–12) and mean (1994–95 to 2011–12) annual catches of 1900 t, but with annual catches of 2800–3400 t between 2005–06 and 2009–10. There was an early Soviet and Korean fishery (1980–81 to 1984–85) with mean annual catches of about 1700 t. Fishery-independent abundance estimates were not available, so a series of relative abundance indices, based on an analysis of post-GPS standardised CPUE, was developed. Length frequency data collected by Ministry (SOP) and industry (ORMC) observers were included in the model. The assessment used biological parameter values estimated for Chatham Rise and Puysegur Bank black oreo because no biological data from Pukaki Rise are available. As stated above, the Pukaki Rise smooth oreo CPUE was thought to be unreliable until further investigations have been conducted. Since the black oreo fishery is in the same area, the Working Group determined that the black oreo CPUE analysis also could not be accepted as an index of abundance of black oreo in the Pukaki Rise (OEO 6) assessment area, and as a result the assessment was rejected. Therefore, only catch history, length frequencies and unstandardised catch and effort data are reported here.

4.5.1 Estimates of fishery parameters and abundance

Catch history

A catch history for black oreo was derived (Table 13) using declared catches of OEO from OEO 6 (Table 2 in the “Fishery summary” section of the Oreos report above) and tow-by-tow records of catch from the assessment area (Figure 8). The catch history used in the assessment is given in Table 13.

Table 13: Catch history (t) of black oreo from the Pukaki Rise fishery assessment area.

Year	Catch	Year	Catch	Year	Catch
1978–79	17	1990–91	15	2002–03	1 701
1979–80	5	1991–92	27	2003–04	1 530
1980–81	283	1992–93	27	2004–05	1 588
1981–82	4 180	1993–94	10	2005–06	2 811
1982–83	1 084	1994–95	242	2006–07	3 434
1983–84	1 150	1995–96	1 352	2007–08	3 346
1984–85	1 704	1996–97	2 413	2008–09	2 818
1985–86	46	1997–98	2 244	2009–10	3 093
1986–87	0	1998–99	1 181	2010–11	1 641
1987–88	0	1999–00	1 061	2011–12	1 671
1988–89	0	2000–01	1 158		
1989–90	0	2001–02	988		

Length data

Black oreo length frequency data collected by SOP and ORMC observers are available from the last 16 years (Table 14). An analysis indicated that there was a trend in fish size across years (with smaller mean lengths in more recent years) and with depth (deeper fish being larger). The length data were considered to be representative of the fishery in terms of the spatial, depth, and temporal coverage for those years that had adequate data. The length data were stratified into two depth bins: shallow (less than 900 m), and deep (greater than 900 m). Length data from adjacent years were grouped because of the low number of samples in some years (Figure 9). There is no trend in mean length over the first six year-groups, but fish sizes appear to be generally smaller in the later year-groups, with the mode of the distributions shifting to the left between 2005–06 and 2007–08.

Table 14: Summary of length frequency data for black oreo available from the assessment area. The table shows the number of tows sampled by year, the sample source, and the year group.

		Number of tows sampled		
Year	Year group	SOP	ORMC	All
1996–97	97–98	7	0	7
1997–98	97–98	25	0	25
1998–99	99–00	7	44	51
1999–00	99–00	6	0	6
2000–01	01–02	8	18	26
2001–02	01–02	2	8	10
2002–03	03–05	7	2	9
2003–04	03–05	18	0	18
2004–05	03–05	21	0	21
2005–06	06	21	42	63
2006–07	07	154	11	165
2007–08	08	31	9	40
2008–09	08	61	9	70
2009–10	09	46	0	46
2010–11	10	57	0	57
2011–12	11–12	13	0	13
Total		477	134	611

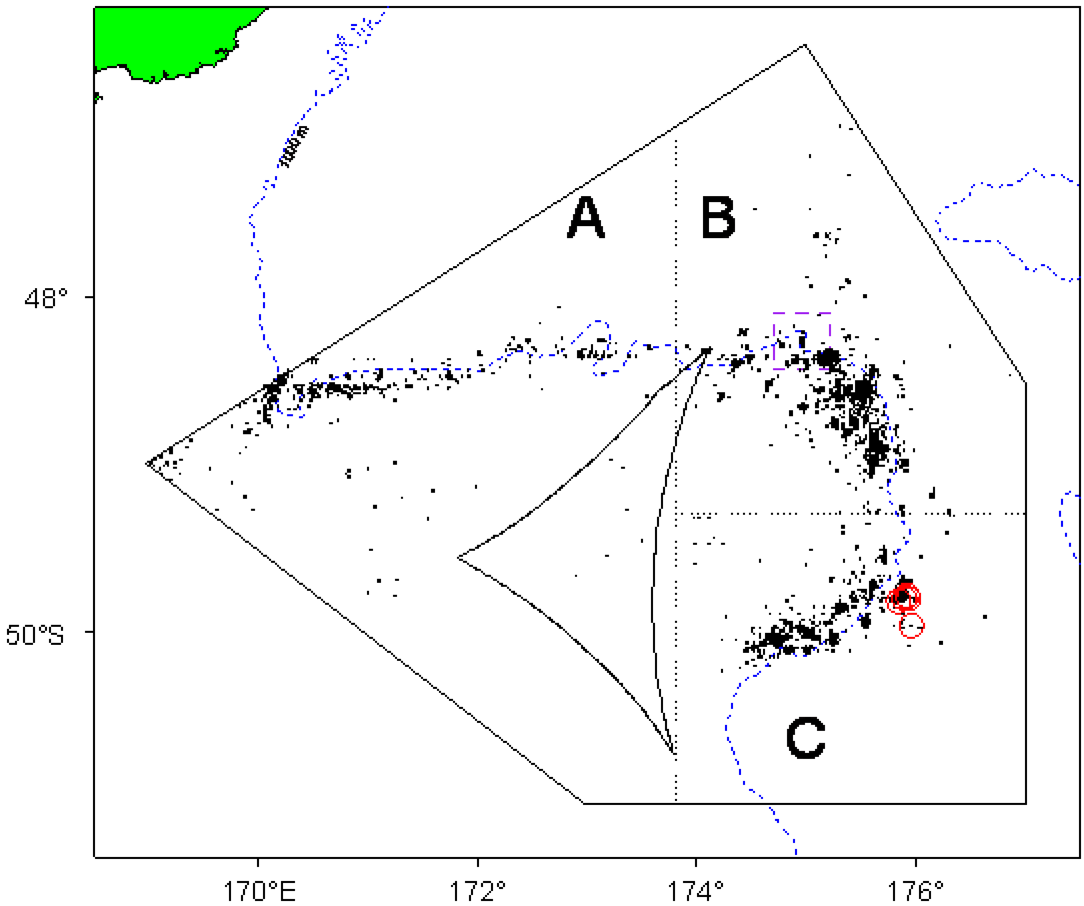


Figure 8: The Pukaki Rise fishery black oreo assessment area (polygon) abutting the boundary of OEO 6/OEO 1 in the north-west. The dots show tow positions where black oreo catch was reported between 1980–81 and 2011–12. A, B, and C are the three areas defined in the standardised CPUE analysis.

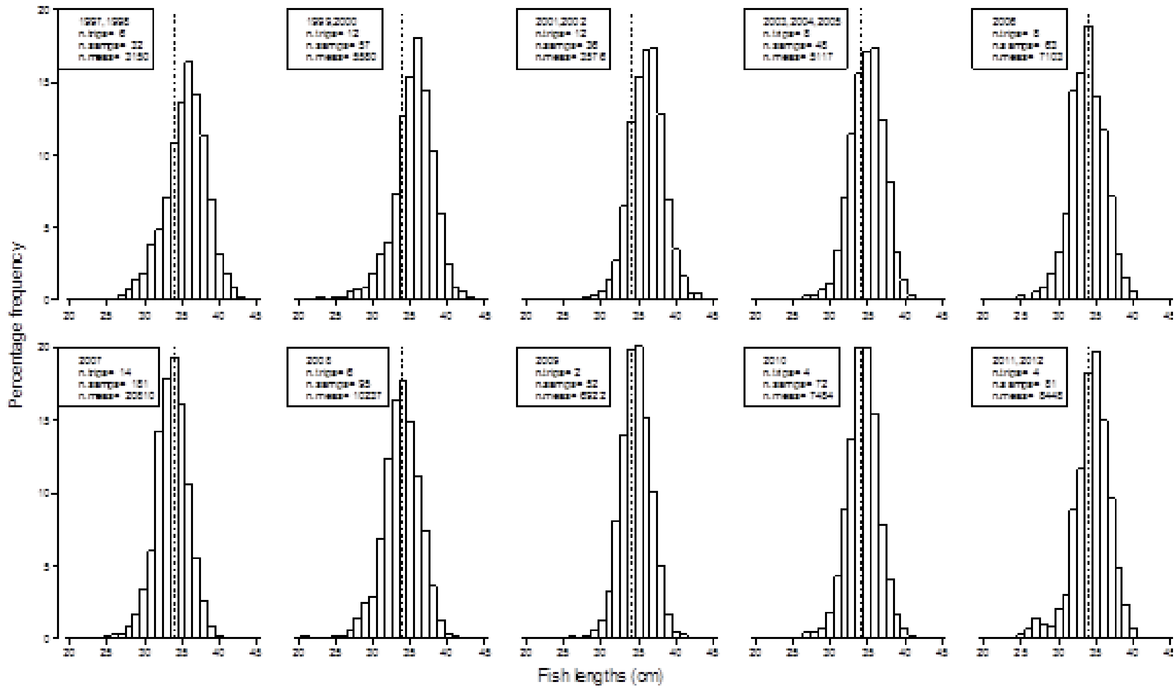


Figure 9: Observer length frequencies for Pukaki Rise black oreo, stratified by depth (see text), and grouped by years (in the legends 1997=1996–97 etc.). The vertical dashed lines indicate the approximate overall mean length as an aid to comparing the distributions.

Catch and effort data

The fishery taking Pukaki Rise black oreo divides into two distinct periods: a pre-GPS period 1980–81 to 1984–85 when much of the catch was taken by Soviet and Korean vessels, and a post-GPS period, 1995–96 to 2011–12 when most of the catch was taken by New Zealand vessels. The intervening period was characterised by low catches and the introduction of GPS technology in the fleet. Standardisation of CPUE for the pre-GPS period was attempted but rejected due to poor linkage of vessels across years and the shifting of fishing effort between areas. For the post-GPS period, the Working Group rejected CPUE as an index of abundance because of the variability in recorded target species over time and space in the overlapping Pukaki fisheries for black oreo, smooth oreo, and orange roughy. The Working Group believed that recording of target species in these fisheries was likely to have been inconsistent between vessels and skippers over time and that the practice of separately examining these fisheries according to recorded target species was inappropriate. Unstandardised catch and effort data for defined core vessels are presented in Table 15.

Table 15: Catch and effort data for vessels fishing in the eastern areas (B and C in Figure 8) with a minimum of 15 successful tows for black oreo in at least three years from 1995–96 to 2011–12.

Year	No. of tows	CPUE index	CV	Year	No. of tows	CPUE index	CV
1995–96	63	1.94	0.09	2004–05	309	0.73	0.13
1996–97	55	1.44	0.13	2005–06	481	0.88	0.09
1997–98	219	1.53	0.07	2006–07	650	0.80	0.09
1998–99	235	0.98	0.11	2007–08	795	0.62	0.12
1999–00	252	0.82	0.12	2008–09	734	0.61	0.12
2000–01	199	1.11	0.10	2009–10	979	0.33	0.21
2001–02	175	1.07	0.11	2010–11	450	0.51	0.16
2002–03	320	0.91	0.10	2011–12	430	0.72	0.12
2003–04	343	0.97	0.09				

4.5.2 Biomass estimates

No biomass estimates are reported.

4.5.3 Yield estimates and projections
No yield estimates were made.

No projections were made because the assessment was not accepted by the Working Group.

4.6 Other oreo fisheries in OEO 1 and OEO 6

4.6.1 Estimates of fishery parameters and abundance

Relative abundance estimates from trawl surveys
Two comparable trawl surveys were carried out in the Puysegur area of OEO 1 (TAN9208 and TAN9409). The 1994 oreo abundance estimates are markedly lower than the 1992 values (Table 16).

4.6.2 Biomass estimates
Estimates of virgin and current biomass are not yet available.

4.6.3 Yield estimates and projections
MCY cannot be estimated because of the lack of current biomass estimates for the other stocks.

CAY cannot be estimated because of the lack of current biomass estimates for the other stocks.

4.6.4 Other factors
Recent catch data from this fishery may be of poor quality because of area misreporting.

Table 16: OEO 1. Research survey abundance estimates (t) for oreos from the Puysegur and Snares areas. N is the number of stations. Estimates for smooth oreo were made based on a recruited length of 34 cm TL. Estimates for black oreo were made using knife-edge recruitment set at 27 cm TL.

Smooth oreo					
Puysegur area (strata 0110–0502)					
	Mean biomass	Lower bound	Upper bound	CV (%)	N
1992	1 397	736	2 058	23	82
1994	529	86	972	41	87
Snares area (strata 0801–0802)					
	Mean biomass	Lower bound	Upper bound	CV (%)	N
1992	2 433	0	5 316	59	8
1994	118	0	246	54	7
Black oreo					
Puysegur area (strata 0110–0502)					
	Mean biomass	Lower bound	Upper bound	CV (%)	N
1992	2 009	915	3 103	27	82
1994	618	0	1 247	50	87
Snares area (strata 0801–0802)					
	Mean biomass	Lower bound	Upper bound	CV (%)	N
1992	3 983	0	8 211	53	8
1994	1 564	0	3 566	64	7

5. STATUS OF THE STOCKS

Stock Structure Assumptions
Oreos in the OEO 1 and 6 FMAs are managed as a single stock but assessed as four separate stocks, separated by species and geography.

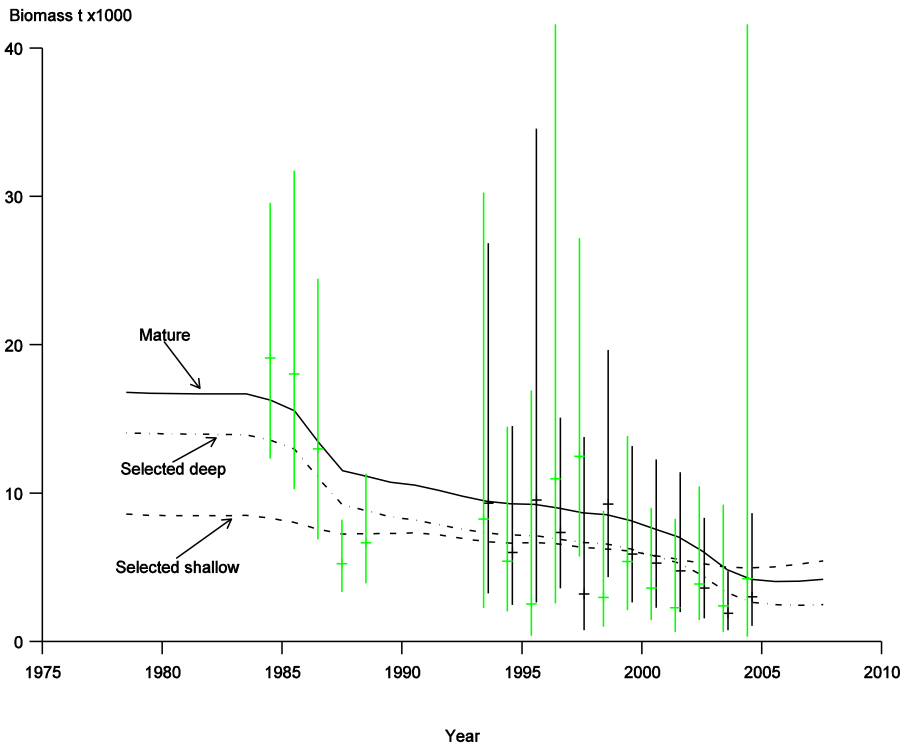
The Southland smooth oreo stock is based along the east coast of the South Island in OEO 1 but extends slightly into OEO 3. It does not include the Waitaki and Eastern canyon areas but is likely to have some level of mixing with other smooth oreo fishstocks. The Pukaki Rise smooth oreo stock comprises the major part of OEO 6 stocks and is centered on its namesake. Some mixing with other smooth oreo fishstocks is thought to occur. The Bounty Plateau smooth oreo stock is located across the Bounty Plateau and the Bounty Islands. Some mixing is thought to occur with other smooth oreo fishstocks.

The Pukaki Rise black oreo stock is the main black oreo fishstock in OEO 6 and the largest black oreo fishstock in the New Zealand EEZ. It extends the entire length of the Rise towards OEO 1. It is assessed separately to other fishstocks but managed as a part of OEO 6. Black oreo on the Pukaki Rise are thought to be non-mixing with other black oreo fishstocks.

- **OEO 1 and OEO 3A Southland (Smooth Oreo)**

Stock Status	
Year of Most Recent Assessment	2007
Assessment Runs Presented	One base case only
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2007} was estimated at 27% B_0, Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	B_{2007} was estimated to be Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status



Predicted biomass trajectories for the 2007 base case assessment— mature biomass and selected biomass for the shallow and deep fisheries. Also shown are the CPUE indices from the pre- and post-GPS analysis for the deep fishery (in gray) and the post-GPS analyses for the shallow fishery (in black). CPUE indices are shown with +/- 2 s.e. confidence interval indicated by the vertical lines (the post-GPS CPUE data are slightly offset to avoid over plotting). The CPUE data were scaled by catchability coefficients to match the biomass scale.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has been declining at a steady rate since the late 1980s.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	None because of assessment uncertainty.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Type 1 - Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Length-frequency data collected by SOP and ORMC observers - A second, earlier fishery based on Soviet vessels was included in the assessment using historical catch data. - Standardised CPUE indices were derived from the historical and modern datasets.	
Period of Assessment	Latest assessment: 2007	Next assessment: 2012
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Scarcity of observer length frequency data - Poor quality area catch data due to significant misreporting - Lack of fishery-independent abundance estimates creates reliance on commercial CPUE data.	

Qualifying Comments
-

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

- **OEO 6 Pukaki Rise (Smooth Oreo)**

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	CASAL assessment based on CPUE rejected
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%\ B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown
Historical Stock Status Trajectory and Current Status -	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is likely to have been declining since 1996.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	CPUE has steadily declined.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	No projections were made due to the uncertainties in the assessment.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

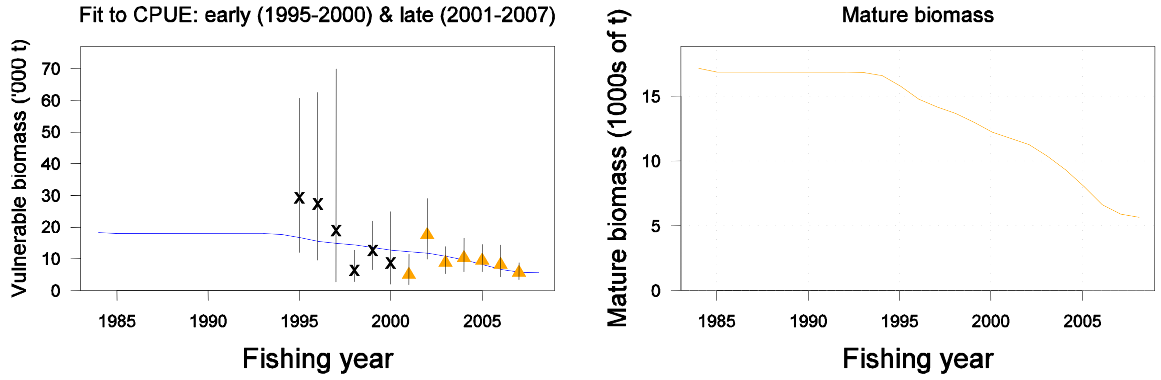
Assessment Methodology and Evaluation		
Assessment Type	Type 1 - Quantitative Stock Assessment, but rejected.	
Assessment Method	CASAL assessment based on CPUE (rejected)	
Assessment Dates	Latest assessment: 2013	Next assessment: Unknown
Overall assessment quality rank	3 – Low Quality	
Main data inputs (rank)	-	
Data not used (rank)	Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Lack of fishery-independent biomass estimates creates reliance on commercial CPUE data. - Lack of biological parameters specific to Smooth Oreo in the target area - data from Chatham Rise/Puysegur Bank had to be substituted instead.	

Qualifying Comments
Further investigations into CPUE are required.

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Low productivity bycatch species include deepwater sharks and rays. Protected species interactions occur with seabirds and deepwater corals.

- **OEO 6 Bounty Plateau (Smooth Oreo)**

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	A base case with two sensitivity runs
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Targe	B_{2008} was estimated at 33% B_0; Unlikely (< 40%) to be at or above the target.
Status in relation to Limits	B_{2008} is Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit.

Historical Stock Status Trajectory and Current Status

Model run showing the MPD fit to the CPUE data (vertical lines are the 95% confidence intervals for the indices) and the trajectory of mature biomass.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been decreasing rapidly since 1995.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	No projections were made because of the uncertainty of the assessment.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Type 1 - Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Main data inputs	- Catch history - Abundance estimates derived from a standardised CPUE - Length data from SOP and ORMC observers	
Period of Assessment	Latest assessment: 2008	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Reliance on commercial CPUE data - To estimate biological parameters, data was used from different stocks (Puysegur Bank + Chatham Rise) to the target stock - Using a single CPUE index instead of split indices gives contrasting biomass signals	

Qualifying Comments
-

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

- **OEO 6 Pukaki Rise (Black Oreo)**

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	CASAL assessment based on CPUE rejected
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%\ B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown
Historical Stock Status Trajectory and Current Status	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is likely to have been decreasing since the 1980s with a major decline starting about 1995.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	CPUE declined, but has levelled out in the last four years.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Type 1 - Quantitative Stock Assessment	
Assessment Method	CASAL assessment based on CPUE (rejected)	
Assessment Dates	Latest assessment: 2009	Next assessment: Unknown
Overall assessment quality rank	3 – Low Quality	
Main data inputs (rank)	-	
Data not used (rank)	Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Lack of fisheries-independent data causes reliance on commercial CPUE data - Lack of biological parameter estimates specific to black oreo in this assessment area	

Qualifying Comments
Further investigations into CPUE are needed.

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Low productivity bycatch species include deepwater sharks and rays. Protected species interactions occur with seabirds and deepwater corals.

6. FOR FURTHER INFORMATION

Coburn, R P; Doonan, I J; McMillan, P J (2002) CPUE analyses for the Southland black oreo and smooth oreo fisheries, 1977–78 to 1999–2000. *New Zealand Fisheries Assessment Report 2002/3.* 28 p.

Coburn, R P; Doonan, I J; McMillan, P J (2002) CPUE analyses for the major black oreo and smooth oreo fisheries in OEO 6, 1980–81 to 1999–2000. *New Zealand Fisheries Assessment Report 2002/6.* 29 p.

Coburn, R P; Doonan, I J; McMillan, P J (2003) Stock assessment of smooth oreo in the Southland fishery (OEO 1 and 3A) for 2003. *New Zealand Fisheries Assessment Report 2003/62*. 32 p.

Coburn, R P; Doonan, I J; McMillan, P J (2008) A stock assessment of smooth oreo in Southland (part of OEO 1 & OEO 3A). *New Zealand Fisheries Assessment Report 2008/37*. 43 p.

Coburn, R P; McMillan, P J; Gilbert, D J (2007) Inputs for a stock assessment of smooth oreo, Pukaki Rise (part of OEO 6). *New Zealand Fisheries Assessment Report 2007/23*. 32p

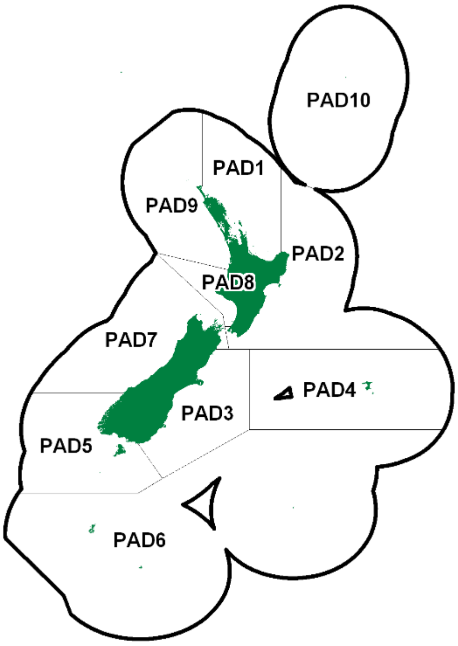
Doonan, I J; Anderson, O F; McMillan, P J (2010) Assessment of Pukaki (OEO 6) black oreo for 2008–09. *New Zealand Fisheries Assessment Report 2010/39*.

McKenzie, A (2007) Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6). *New Zealand Fisheries Assessment Report 2007/34*. 27 p.

McMillan, P J; Coburn, R P; Hart, A C; Doonan, I J (2002) Descriptions of black oreo and smooth oreo fisheries in OEO 1, OEO 3A, OEO 4, and OEO 6 from 1977–78 to the 2000–01 fishing year. *New Zealand Fisheries Assessment Report. 2002/40*.

PADDLE CRABS (PAD)

(Ovalipes catharus)
Papaka



1. FISHERY SUMMARY

1.1 Commercial fisheries

Paddlecrabs were introduced into the QMS from 1 October 2002 with recreational and customary non-commercial allowances, TACCs and TACs summarised in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs for paddle crabs, by Fishstock.

Fishstock	Recreational Allowance	Customary non-Commercial Allowance	TACC	TAC
PAD 1	20	10	220	250
PAD 2	10	5	110	125
PAD 3	8	2	100	110
PAD 4	4	1	25	30
PAD 5	4	1	50	55
PAD 6	0	0	0	0
PAD 7	4	1	100	105
PAD 8	4	1	60	65
PAD 9	20	10	100	130
PAD 10	0	0	0	0

Commercial interest in paddle crabs was first realised in New Zealand in 1977–78 when good numbers of large crabs were caught off Westshore Beach, Napier in baited lift and set-pots. Annual catches have varied, mainly due to marketing problems, and estimates are likely to be conservative. Landings increased in the early fishery, from 775 kg in 1977 to 306 t in 1985, and 403 t in 1995–96 but have since generally decreased to a total of 121 t in 2011-12. Paddle crabs are known to be discarded from inshore trawl operations targeting species such as flatfish, and this may have resulted in under-reporting of catches. Crabs are marketed live, as whole cooked crabs, or as crab meat. Attempts were made to establish a soft-shelled crab industry in New Zealand in the late 1980s.

Bycatch is commonly taken during trawl, dredge and setnetting operations. Catch rates vary considerably with method, season and area, and there is no clear seasonal trend to paddle crab landings. It is likely that catches are related to the availability of fishers and/or market demands. Commercial landings from 1989–90 until the present are shown in Table 2, while Figure 1 shows the historical landings and TACC for the six main PAD stocks.

Table 2: Reported landings (t) of paddle crabs by QMA and fishing year, from CLR and CELR$_{landed}$ data from 1989–90 to present.

QMA	PAD 1		PAD 2		PAD 3		PAD 4		PAD 5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1989–90	20	-	57	-	38	-	< 1	-	< 1	-
1990–91	34	-	37	-	26	-	0	-	6	-
1991–92	96	-	32	-	31	-	< 1	-	< 1	-
1992–93	175	-	14	-	36	-	0	-	< 1	-
1993–94	277	-	18	-	46	-	0	-	< 1	-
1994–95	237	-	6	-	36	-	< 1	-	< 1	-
1995–96	183	-	5	-	18	-	< 1	-	1	-
1996–97	165	-	25	-	36	-	0	-	1	-
1997–98	158	-	126	-	18	-	< 1	-	13	-
1998–99	195	-	197	-	21	-	< 1	-	2	-
1999–00	265	-	21	-	27	-	1	-	14	-
2000–01	32	-	10	-	17	-	0	-	0	-
2001–02	221	-	34	-	22	-	0	-	2	-
2002–03	145	220	65	110	18	100	< 1	25	< 1	50
2003–04	239	220	46	110	20	100	0	25	0	50
2004–05	163	220	44	110	30	100	0	25	0	50
2005–06	109	220	49	110	11	100	0	25	< 1	50
2006–07	53	220	21	110	13	100	0	25	3	50
2007–08	86	220	9	110	19	100	0	25	< 1	50
2008–09	36	220	14	110	37	100	0	25	1	50
2009–10	35	220	17	110	37	100	0	25	< 1	50
2010–11	49	220	18	110	47	100	0	25	<1	50
2011–12	12	220	41	110	47	100	< 1	25	< 1	50
2012–13	< 1	220	36	110	39	100	< 1	25	< 1	50
2013-14	3	220	6	110	74	100	1	25	<1	50

QMA	PAD 6		PAD 7		PAD 8		PAD 9		PAD 10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1989–90	0	-	94	-	22	-	0	-	0	-
1990–91	0	-	68	-	12	-	0	-	0	-
1991–92	0	-	83	-	21	-	0	-	0	-
1992–93	0	-	59	-	24	-	0	-	0	-
1993–94	0	-	49	-	27	-	5	-	0	-
1994–95	0	-	71	-	46	-	< 1	-	0	-
1995–96	55	-	82	-	58	-	< 1	-	< 1	-
1996–97	25	-	106	-	44	-	< 1	-	1	-
1997–98	7	-	63	-	25	-	< 1	-	< 1	-
1998–99	10	-	59	-	34	-	0	-	1	-
1999–00	14	-	45	-	50	-	0	-	< 1	-
2000–01	0	-	0	-	< 1	-	0	-	0	-
2001–02	22	-	33	-	24	-	0	-	0	-
2002–03	< 1	0	42	100	11	60	0	100	0	0
2003–04	0	0	50	100	17	60	< 1	100	0	0
2004–05	0	0	40	100	14	60	1	100	0	0
2005–06	0	0	48	100	14	60	1	100	0	0
2006–07	0	0	32	100	11	60	< 1	100	0	0
2007–08	0	0	47	100	7	60	0	100	0	0
2008–09	0	0	35	100	11	60	< 1	100	0	0
2009–10	0	0	17	100	13	60	0	100	0	0
2010–11	0	0	11	100	14	60	0	100	0	0
2011–12	0	0	7	100	14	60	< 1	100	0	0
2012–13	0	0	11	100	17	60	0	100	0	0
2013-14	0	0	4	100	13	60	0	100	0	0

QMA	Total	
	Landings	TACC
1989–90	231	-
1990–91	183	-
1991–92	264	-
1992–93	308	-
1993–94	423	-
1994–95	397	-
1995–96	403	-
1996–97	403	-
1997–98	410	-
1998–99	519	-
1999–00	437	-
2000–01	59	-
2001–02	358	-
2002–03	281	765

QMA	Total	
	Landings	TACC
2002–03	281	765
2003–04	372	765
2004–05	292	765
2005–06	232	765
2006–07	132	765
2007–08	168	765
2008–09	134	765
2009–10	120	765
2010–11	140	765
2011–12	121	765
2012–13	103	765
2013-14	101	765

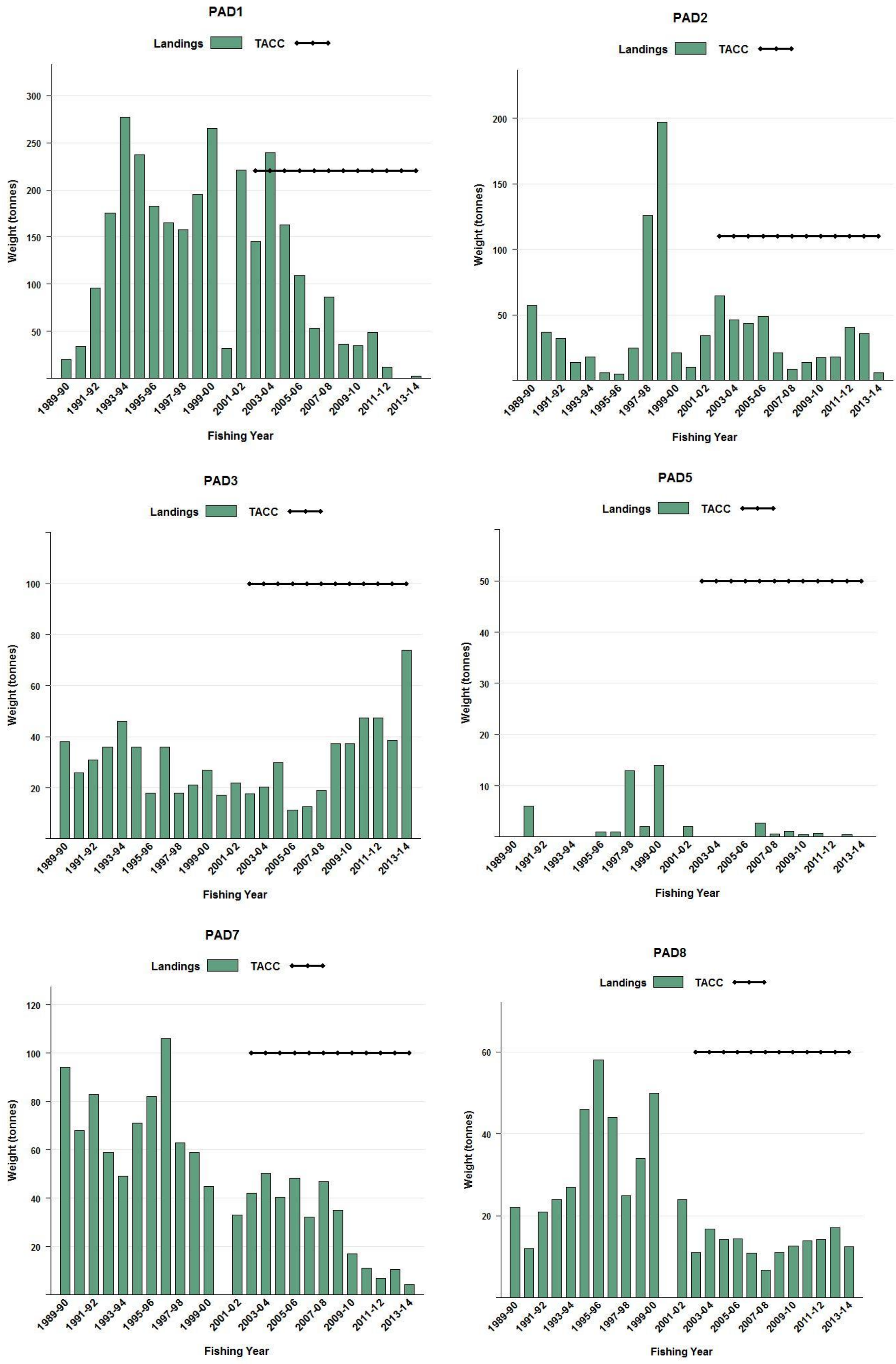


Figure 1: Reported commercial landings and TACCs for the six main PAD stocks. From top left to bottom right: PAD 1 (Auckland East), PAD 2 (Central East), PAD 3 (south East Coast), PAD 5 (Southland), PAD 7 (Challenger), and PAD 8 (Central Egmont).

1.2 Recreational fisheries

Indicative data from the 1996 National Marine Recreational Fishing Survey show that paddle crabs are seldom caught by recreational fishers (NIWA unpublished). Paddle crabs are taken as a bycatch of beach and estuarine seining and in setnets throughout much of their geographical range.

1.3 Customary non-commercial fisheries

There is no quantitative information on the current level of customary non-commercial catch.

1.4 Illegal catch

There is no quantitative information available on the current level of illegal catch.

1.5 Other sources of mortality

There is no quantitative information available on other sources of mortality, although unknown quantities of paddle crabs have been discarded from commercial fishing operations such as the inshore trawl, setnet and dredge fisheries.

2. BIOLOGY

The paddle crab is found off sandy beaches, and in harbours and estuaries throughout mainland New Zealand, the Chatham Islands, and east and south Australia. They are abundant from the intertidal zone to at least 10 m depth, although they do occur in much deeper water. Paddle crabs are mainly active in early evening or at night, when they move into the shallow intertidal zone to feed.

Paddle crabs are versatile and opportunistic predators. They feed mainly on either molluscs or crustaceans, but also on polychaetes, several fish species, cumaceans, and occasionally on algae. A high proportion of the molluscs eaten are *Paphies* species. These include: tuatua (*P. subtriangulata);* pipi (*P. australis);* and toheroa (*P. ventricosa).* The burrowing ghost shrimp *Callianassa filholi*, isopods and amphipods are important crustacean prey items. Cannibalism is common, particularly on small crabs and during the winter moulting season.

Anecdotal information suggests there has been a significant increase in paddle crab numbers since the 1970s. Concern has been expressed as to the impact of an increased number of paddle crabs on bivalve shellfish stocks in coastal waters. Feeding studies have shown that although paddle crabs do eat large adult toheroa and other shellfish, they more usually eat bivalve shellfish spat which are found in abundance.

Mating generally occurs during winter and spring (May to November) in sheltered inshore waters. Female paddle crabs can only mate when they are soft-shelled. Male crabs protect and carry pre-moult females to ensure copulation. Female crabs are thought to migrate to deeper water to spawn over the warmer months (September to March). After spawning the eggs are incubated until they hatch. *Ovalipes catharus* has an extended larval life characterised by eight zoea stages and a (crab-like) megalopa. The larvae are thought to live offshore in deeper water, migrating inshore in the megalopa stage to settle from January to May.

Two spawning mechanisms have been observed in *O. catharus*. In Wellington, Tasman Bay, and Canterbury, spawning does not appear to be synchronised and females may spawn several times during the season (non-synchronous spawning). In Blueskin Bay, Otago, paddle crabs are group-synchronous, with one clutch of eggs developing to maturity over winter, and spawned from September to February.

Annual fecundity is determined by the number of eggs per brood (brood fecundity) and the number of broods per year. Both these parameters are size dependent and highly variable. Brood fecundity estimates vary considerably geographically from between 82 000–638 000 in Wellington waters, to 100 000–1 200 000 in Canterbury waters, and 931 000–2 122 807 in Otago waters. The number of broods per year also varies geographically from 1.2–3.3 in Wellington waters, to 1.2–2.2 in Canterbury waters, and 1 brood per year in Otago waters (group synchronous spawning).

O. catharus is a relatively large and fast growing species of *Ovalipes.* In Canterbury waters, paddle crabs reach a maximum size of 130 mm carapace width (CW - males only) after 13 postlarval moults and 3 to 4 years after settlement. Other studies have reported maximum sizes up to 150 mm CW. In Wellington waters, crabs of approximately 100 mm carapace width, of either sex, would be at least 3 years old, while larger crabs could be 4 or 5 years old.

The differences in growth rate, size at first maturity, and fecundity (particularly the number of broods) appear to be largely environmentally regulated. At lower temperatures and higher latitudes, paddle crabs grow slower, mature at a larger size, have a shorter breeding season, and produce fewer broods per year.

Estimates of biological parameters relevant to stock assessment are presented in Table 3.

Table 3: Estimates of biological parameters.

Fishstock		Estimate			Source
1. Natural mortality (females only)					
(Percentage mortality at each instar stage)					
Instar	Tasman Bay (QMA 7)		Canterbury (QMA 3)		
8	15.3		15.0		Osborne (1987)
9	31.2		30.0		
10 (68–75 mm CW)	78.1		39.1		
11	30.7		38.9		
12	55.6		18.2		
13 (> 100 mm CW)	100		100		
2. weight = a + b log CW (carapace width)					
	Females		Males		
Canterbury (QMA 3)	a	b	a	b	Davidson & Marsden (1987)
	-3.32	2.79	-3.46	2.89	

3. STOCKS AND AREAS

It is not known whether biologically distinct stocks occur, although this seems unlikely given that the species is found throughout New Zealand waters, and from tagging experiments, appears to be highly migratory. There is probably also widespread larval dispersal as larvae spend two months offshore in deeper water (to at least 700 m). Genetically distinct populations may occur in isolated areas such as the Chatham Islands.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

None are available at present.

4.2 Biomass estimates

No estimates of current or virgin biomass are available. The landings, CPUE, and area data are considered too unreliable or incomplete to allow modelling.

4.3 Yield estimates and projections

MCY cannot be estimated.

CAY cannot be estimated because of the lack of current biomass estimates.

5. STATUS OF THE STOCKS

Estimates of current and reference biomass are not available. Landings have fluctuated significantly in most QMAs, mainly due to market variations. Paddle crabs are abundant throughout most of their range and the fishery is probably only lightly exploited.

6. FOR FURTHER INFORMATION

Armstrong, J H (1985) Aspects of the biology of the swimming crab, *Ovalipes catharus* (White, 1843) in the Otago region. Unpublished MSc thesis, University of Otago, Dunedin.

Clark, M R (1978) Aspects of the population biology of the swimming crab *Ovalipes catharus* (White, 1843) (Crustacea; Decapoda; Portunidae) in the Plimmerton Area, Wellington. Unpublished BSc (Hons). Zoology Department, Victoria University, Wellington. 115 p.

Davidson, R J (1987) Natural food and predatory activity of the paddle crab, *Ovalipes catharus*. Unpublished MSc thesis. Zoology Department, University of Canterbury, Christchurch, New Zealand. 110 p.

Davidson, R J; Marsden, I D (1987) Size relationships and relative growth of the New Zealand swimming crab *Ovalipes catharus* (White, 1983). *Journal of Crustacean Biology* 7: 308–317.

Haddon, M (1988) Impact of paddle crabs on shellfish. *Catch* 15: 9–11.

Kung, H T (1973) Some aspects of the biology of the swimming crab *Ovalipes catharus* (White, 1843) in Paremata Harbour, New Zealand. Unpublished MSc thesis, Victoria University, Wellington.

McLay, C L (1988) Brachyura and crab-like Anomura of New Zealand. Leigh Laboratory Bulletin No: 22, University of Auckland. 463 p.

NZFIB (1996) The New Zealand seafood industry economic review 1994–1996. New Zealand Fishing Industry Board, Wellington. 65 p.

Osborne, T A (1987) Life history and population biology of the paddle crab, *Ovalipes catharus*. Unpublished PhD thesis. Zoology Department, University of Canterbury, Christchurch, New Zealand. 156 p.

Stead, D (1983) Paddle crab investigations. *Catch* 10: 14–15.

Stead, D (1984) Crab fishery expansion possible. *Catch* 11: 13–14.

Stevens, D W (1999) A summary of biology and commercial landings and a stock assessment of paddle crabs *Ovalipes catharus* White, 1843 (Crustacea, Portunidae) in New Zealand waters. New Zealand Fisheries Research Assessment Document 1999/18. 26 p. (Unpublished document held by NIWA library, Wellington.)

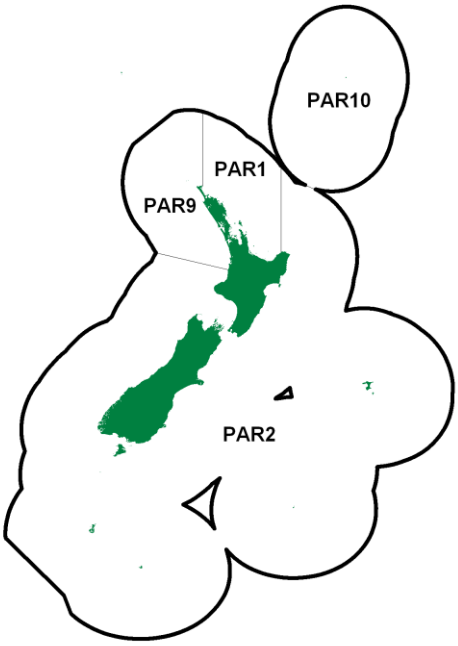
Wear, R G (1988a) Paddle crab fishery has potential in New Zealand. *Catch* 15: 11 p.

Wear, R G (1988b) Paddle crabs eat small shellfish. *Catch* 15: 12–13.

Wear, R G; Haddon, M (1987) Natural diet of the crab *Ovalipes catharus* (Crustacea, Portunidae) around central and northern New Zealand. *Marine Ecology (Progress series)* 35: 39–49.

PARORE (PAR)

(Girella tricuspidata)
Parore



1. FISHERY SUMMARY

Parore was introduced into the Quota Management System (QMS) on 1 October 2004 with the TACs, TACCs and allowances shown in Table 1.

Table 1: TACs (t), TACCs (t) and allowances (t) for parore.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
PAR 1	6	3	4	61	74
PAR 2	1	1	0	2	4
PAR 9	2	1	1	21	25
PAR 10	0	0	0	0	0
Total	9	5	5	84	103

1.1 Commercial fisheries

Parore is principally caught as a bycatch in the grey mullet, flatfish and trevally setnet fisheries in northern New Zealand. Most of the catch comes from eastern Northland and the Firth of Thames (FMA 1) and the Kaipara and Manukau Harbours (FMA 9) (Figure 1). Highest catch rates occur during September to October. Few parore are caught in the other FMAs.

Historical estimated and recent reported parore landings and TACCs are shown in Tables 2, 3 and 4.

Fishers may confuse the codes PAR (parore) and POR (porae) when reporting catches, but given that both species occur in shallow northern waters, misreporting is difficult to discern.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	PAR 1	PAR 2	PAR 9	Year	PAR 1	PAR 2	PAR 9
1931-32	0	0	0	1957	19	0	0
1932-33	0	0	0	1958	22	0	1
1933-34	0	0	0	1959	13	0	1
1934-35	0	0	0	1960	6	0	0
1935-36	0	0	0	1961	12	0	1
1936-37	0	0	0	1962	28	0	2
1937-38	0	0	0	1963	29	0	2
1938-39	1	0	0	1964	62	0	2
1939-40	0	0	0	1965	56	0	2
1940-41	0	0	0	1966	42	0	2
1941-42	0	0	0	1967	19	0	2
1942-43	15	0	0	1968	39	0	0
1943-44	13	0	0	1969	67	0	2
1944	21	0	0	1970	69	1	4
1945	41	0	0	1971	82	0	3
1946	75	0	0	1972	67	0	3
1947	31	0	0	1973	50	0	5
1948	4	0	0	1974	55	0	2
1949	7	0	0	1975	37	1	7
1950	13	0	0	1976	67	1	13
1951	7	0	0	1977	65	0	7
1952	20	0	0	1978	62	0	3
1953	11	0	0	1979	53	0	5
1954	16	0	0	1980	40	6	6
1955	12	0	1	1981	50	0	6
1956	7	0	0	1982	52	1	12

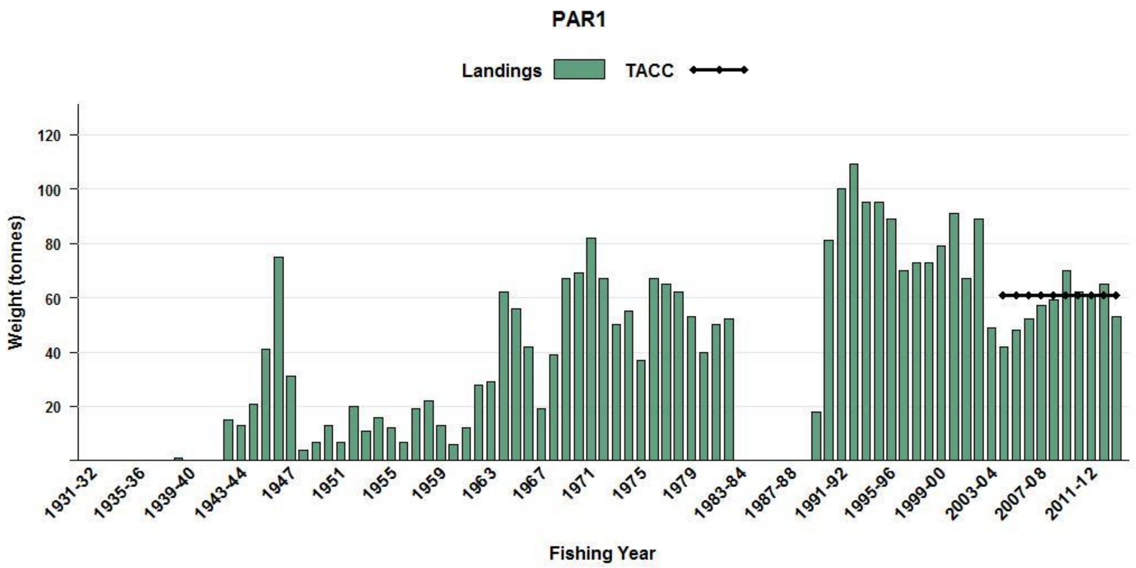
Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings

Table 3: Reported landings (t) of parore by FMA, fishing years 1989–90 to 2003–04.

	FMA 1	FMA 2	FMA 3	FMA 4	FMA 5	FMA 7	FMA 8	FMA 9
1989–90	18	< 1	0	0	< 1	< 1	0	< 1
1990–91	81	2	< 1	< 1	< 1	< 1	< 1	0
1991–92	100	< 1	< 1	0	0	2	0	0
1992–93	109	< 1	< 1	0	< 1	< 1	0	0
1993–94	95	< 1	0	< 1	0	< 1	< 1	0
1994–95	95	< 1	< 1	0	0	< 1	0	3
1995–96	89	< 1	0	0	0	< 1	< 1	9
1996–97	70	< 1	< 1	< 1	0	3	< 1	6
1997–98	73	< 1	< 1	0	0	< 1	< 1	5
1998–99	73	< 1	< 1	< 1	0	< 1	< 1	6
1999–00	79	< 1	< 1	0	< 1	< 1	< 1	4
2000–01	91	< 1	< 1	0	0	< 1	< 1	9
2001–02	67	1	< 1	0	< 1	< 1	0	3
2002–03	89	0	0	0	0	0	0	4
2003–04	49	< 1	< 1	0	0	0	< 1	6

Table 4: Reported domestic landings (t) of Parore Fishstocks and TACC, fishing years 2004–05 to 2013–14.

Fishstock	PAR 1		PAR 2		PAR 9			
FMA	1		2,3,4,5,6,7&8		9		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004–05	42	61	< 1	2	14	21	56	84
2005–06	48	61	< 1	2	15	21	63	84
2006–07	52	61	< 1	2	10	21	61	84
2007–08	57	61	< 1	2	11	21	68	84
2008–09	59	61	< 1	2	20	21	79	84
2009–10	70	61	< 1	2	22	21	92	84
2010–11	62	61	< 1	2	18	21	80	84
2011–12	61	61	< 1	2	18	21	78	84
2012–13	65	61	<1	2	18	21	83	84
2013-14	53	61	<1	2	18	21	72	84



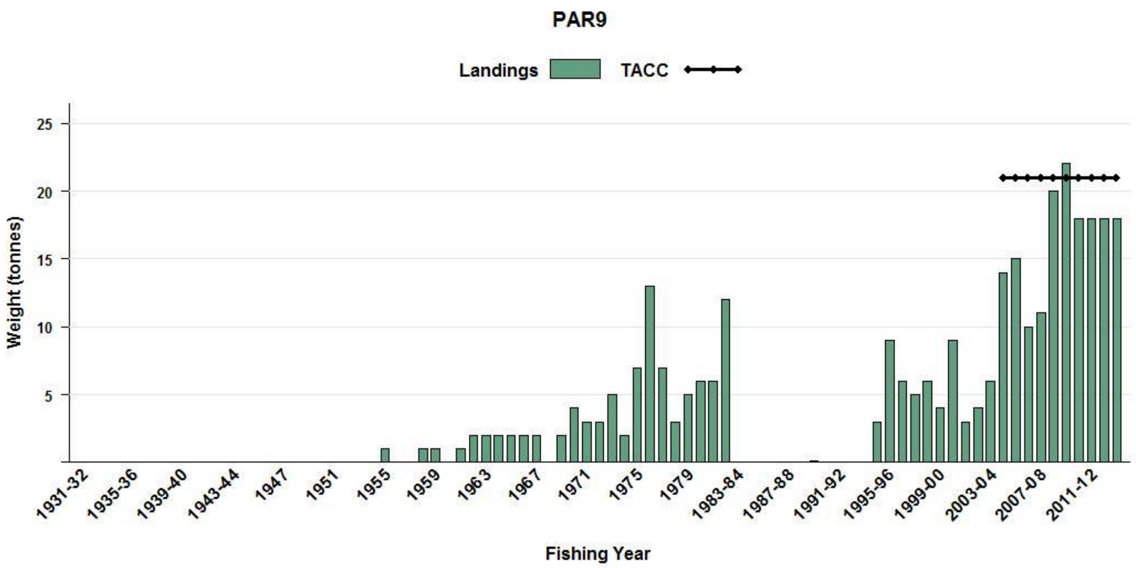


Figure 1: Reported commercial landings and TACC for the two main PAR stocks. PAR 1 (Auckland East) and PAR 9 (Auckland West).

1.2 Recreational fisheries

The National Marine Recreational Fishing surveys in 1994, 1996, and 2000 do not provide estimates of recreational catches of parore. There is likely to be some recreational catch in northern areas as a bycatch when targeting other species such as snapper, trevally, and mullet. These catches are most likely taken by setnetting, as well as being targeted opportunistically by spear fishing. Parore is considered to be a low value recreational species and current catches are likely to be low.

Non-commercial catches are likely to increase in the future as a result of the increasing human population in northern New Zealand, and the likely increase in the number of recreational fishers. Increased targeting may also occur as parore are considered good eating.

1.3 Customary non-commercial fisheries

There is no quantitative information on customary harvest levels of parore. Customary fishers are likely to catch small quantities of parore when targeting other species such as snapper, trevally, and mullet. Parore is considered to be a low value customary species and current catches are likely to be low.

2. BIOLOGY

Parore (*Girella tricuspidata*) occur along both east and west coasts of the North Island, from North Cape to Cook Strait (Anderson et al 1998). It has not been recorded around the Chatham Islands. They usually occur in schools, ranging from half a dozen to several hundred individuals. Although there is evidence that large individuals display territorial behaviour on some reef systems, work in Australia has shown that parore are capable of moving distances of hundreds of kilometres (Pollock 1981).

Parore grow to a maximum size of at least 600 mm, but most adult fish are around 300–400 mm in length. The maximum age for this species on the North Island east coast, as estimated by scale ring counts (validated by seasonal increments), is 10 years (Morrison 1990). As scales tend to provide underestimates of the age of older fish, maximum age could be considerably higher. Growth is relatively rapid in the first year of life, with fish reaching a size of about 100 mm at age one. Fish reach a length of 300 mm by age five, at which time growth slows. Growth rates of males and females, and of open coast and estuarine populations, appear similar. No growth studies have been undertaken on the west coast of the North Island, but large parore (about 600 mm) are sometimes taken in harbour set-nets as bycatch.

Parore reach sexual maturity at a length of 280 mm and spawning takes place in late spring to early summer (Morrison 1990). Larvae are neustonic, occurring near the ocean’s surface, often in association with drifting material such as seaweed clumps.

Juveniles enter estuaries in January at a length of about 11 mm. They are initially found on seagrass meadows and beds of Neptune’s Necklace (*Hormosira banksii*) on shallow reefs, but after 3–4 months move down the estuary to other habitats e.g., brown kelp beds. At approximately one year old, they move out to coastal reefs in the immediate vicinity of estuary mouths and over the following 2–3 years move to reef systems further off- and along-shore (Morrison 1990).

Parore are important herbivores in coastal systems and may play a significant role in structuring algal assemblages (Morrison 1990). Juvenile parore have been found in the stomachs of kahawai and John dory.

There is no fishery independent information to determine the stock status of parore. Biomass estimates cannot be determined for this species with existing data.

3. STOCKS AND AREAS

There is insufficient biological information available on this species to indicate the existence of separate stocks around New Zealand. However, reliance on localized nursery areas suggests that more than one biological stock may exist.

4. STOCK ASSESSMENT

There has been no scientific assessment of the maximum sustainable yield for parore stocks.

5. STATUS OF THE STOCK

Estimates of current and reference biomass are not available. It is not known if recent catch levels or TACs are sustainable. The status of PAR 1, 2 and 9 relative to B_{MSY} is unknown.

TACCs and reported landings of parore by Fishstock, for the 2013–14 fishing year, are summarised in Table 5.

Table 5: Summary of TACCs (t) and reported landings (t) of parore for the most recent fishing year.

Fishstock		FMA	2013–14 Actual TACC	2013–14 Reported landings
PAR 1	Auckland (East)	1	61	53
PAR 2	South East, Southland, Sub-Antarctic, Central, Challenger	2,3,4,5,6,7&8	2	< 0.1
PAR 9	Auckland (West)	9	21	18
Total			84	72

6. FOR FURTHER INFORMATION

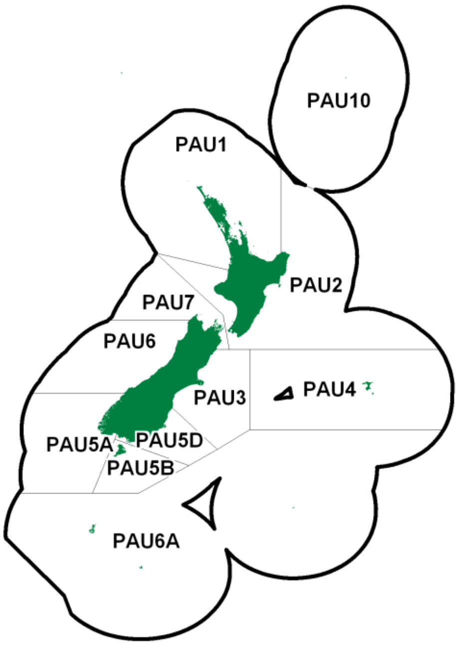
Anderson, O F; Bagley, N W; Hurst, R J; Francis, M P; Clark, M R; McMillan, P J (1998) Atlas of New Zealand fish and squid distributions from research bottom trawls. *NIWA Technical Report* 42. 303 p.

Morrison, M A (1990) Ontogenetic shifts in the ecology of the parore, *Girella tricuspidata*. Unpublished MSc thesis, University of Auckland. 66 p.

Pollock, B R (1981) Age determination and growth of luderick, *Girella tricuspidata* (Quoy and Gaimard), taken from Moreton Bay, Australia. *Journal of Fisheries Biology* 19: 475–485.

PAUA (PAU)

(*Haliotis iris, Haliotis australis*)
Paua



1. INTRODUCTION

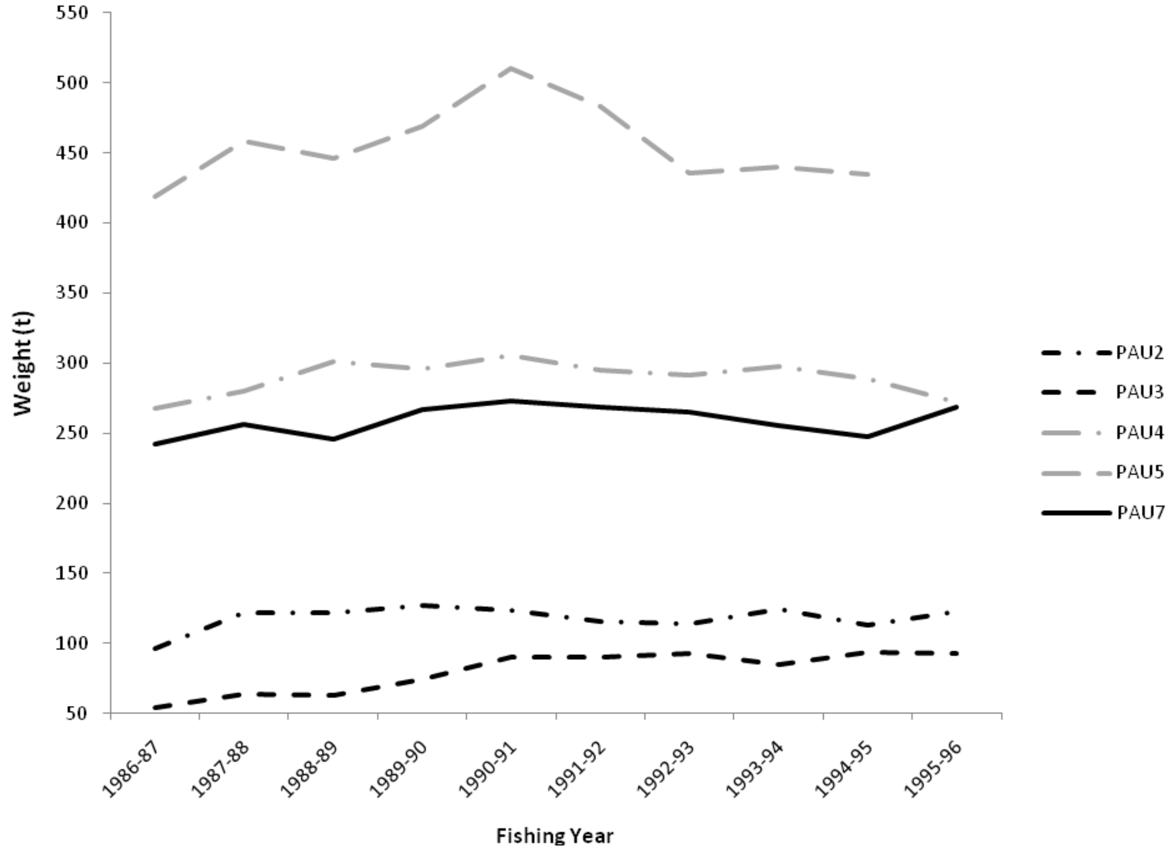
Specific Working Group reports are given separately for PAU 2, PAU 3, PAU 4, PAU 5A, PAU 5B, PAU 5D and PAU 7. The TACC for PAU 1, PAU 6 and PAU 10 is 1.93 t, 1 t and 1 t respectively. Commercial landings for PAU 10 since 1983 have been 0 t.

1.1 Commercial fisheries

The commercial fishery for paua dates from the mid-1940s. In the early years of this commercial fishery the meat was generally discarded and only the shell was marketed, however by the late 1950s both meat and shell were being sold. Since the 1986–87 fishing season, the eight Quota Management Areas have been managed with an individual transferable quota system and a total allowable catch (TAC) that is made up of; total allowed commercial catch (TACC), recreational and customary catch and other sources of mortality.

Fishers gather paua by hand while free diving (use of underwater breathing apparatus is not permitted). Most of the catch is from the Wairarapa coast southwards: the major fishing areas are in the South Island, Marlborough (PAU 7), Stewart Island (PAU 5A, 5B and 5D) and the Chatham Islands (PAU 4). Virtually the entire commercial fishery is for the black-foot paua, *Haliotis iris*, with a minimum legal size for harvesting of 125 mm shell length. The yellow-foot paua, *H. australis* is less abundant than *H. iris* and is caught only in small quantities; it has a minimum legal size of 80 mm. Catch statistics include both *H. iris* and *H. australis*.

Up until the 2002 fishing year, catch was reported by general statistical areas, however from 2002 onwards, a more finely scaled system of paua specific statistical areas were put in place throughout each QMA (refer to the QMA specific Working Group reports). Figure 1 shows the historical landings for the main PAU stocks. On 1 October 1995 PAU 5 was divided into three separate QMAs: PAU 5A, PAU 5B and PAU 5D.



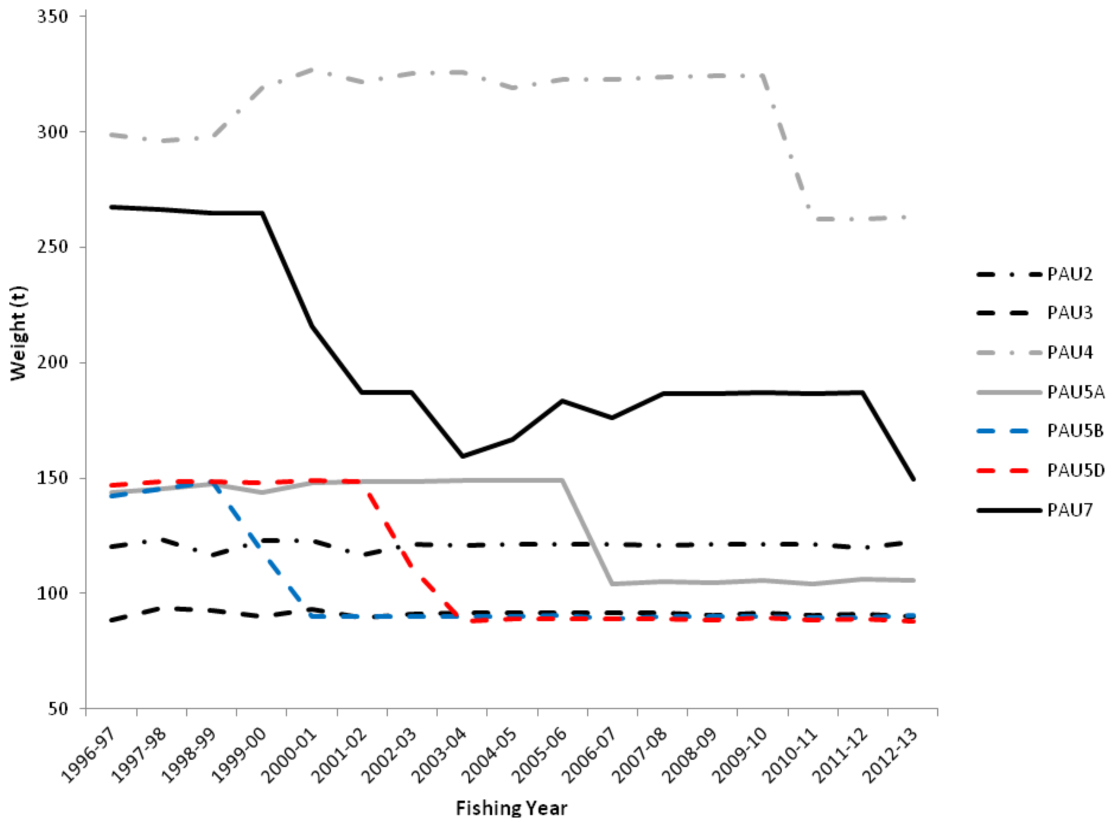


Figure 1: Historic landings for the major paua QMAs from 1983–84 to 1995–96 (top) and from 1996–97 to present (lower).

Landings for PAU 1, PAU 6, PAU 10 and PAU 5 (prior to 1995) are shown in Table 1. For information on landings specific to other paua QMAs refer to the specific Working Group reports.

Table 1: TACCs and reported landings (t) of paua by Fishstock from 1983–84 to present.

	PAU 1		PAU 5		PAU 6		PAU 10	
PAU	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	1	-	550	-	0.00	-	0.00	-
1984–85*	0	-	353	-	3.00	-	0.00	-
1985–86*	0	-	228	-	0.00	-	0.00	-
1986–87*	0.01	1.00	418.9	445	0.00	1.00	0.00	1.00
1987–88*	0.98	1.00	465	448.98	0.00	1.00	0.00	1.00
1988–89*	0.05	1.93	427.97	449.64	0.00	1.00	0.00	1.00
1989–90	0.28	1.93	459.46	459.48	0.00	1.00	0.00	1.00
1990–91	0.16	1.93	528.16	484.94	0.23	1.00	0.00	1.00
1991–92	0.27	1.93	486.76	492.06	0.00	1.00	0.00	1.00
1992–93	1.37	1.93	440.15	442.85	0.88	1.00	0.00	1.00
1993–94	1.05	1.93	440.39	442.85	0.10	1.00	0.00	1.00
1994–95	0.26	1.93	436.13	442.85	18.21H	1.00	0.00	1.00
1995–96	0.99	1.93	-	-	28.62H	1.00	0.00	1.00
1996–97	1.28	1.93	-	-	0.11	1.00	0.00	1.00
1997–98	1.28	1.93	-	-	0.00	1.00	0.00	1.00
1998–99	1.13	1.93	-	-	0.00	1.00	0.00	1.00
1999–00	0.69	1.93	-	-	1.04	1.00	0.00	1.00
2000–01	1.00	1.93	-	-	0.00	1.00	0.00	1.00
2001–02	0.32	1.93	-	-	0.00	1.00	0.00	1.00
2002–03	0.00	1.93	-	-	0.00	1.00	0.00	1.00
2003–04	0.05	1.93	-	-	0.00	1.00	0.00	1.00
2004–05	0.27	1.93	-	-	0.00	1.00	0.00	1.00
2005–06	0.45	1.93	-	-	0.00	1.00	0.00	1.00
2006–07	0.76	1.93	-	-	1.00	1.00	0.00	1.00
2007–08	1.14	1.93	-	-	1.00	1.00	0.00	1.00
2008–09	0.47	1.93	-	-	1.00	1.00	0.00	1.00
2009–10	0.20	1.93	-	-	1.00	1.00	0.00	1.00
2010–11	0.12	1.93	-	-	1.00	1.00	0.00	1.00
2011–12	0.77	1.93	-	-	1.00	1.00	0.00	1.00
2012-13	1.06	1.93	-	-	1.00	1.00	0.00	1.00
2013-14	0.71	1.93	-	-	1.00	1.00	0.00	1.00

H experimental landings
* FSU data

1.2 Recreational fisheries

There is a large recreational fishery for paua. Estimated catches from telephone and diary surveys of recreational fishers (Teirney et al 1997, Bradford 1998, Boyd & Reilly 2004, Boyd et al 2004, Wynne-Jones et al 2014) are shown in Table 2. In 1996–97 sufficient diary data were available for an estimate in PAU 5D only (Bradford 1998, NIWA unpublished data). The Marine Recreational Fisheries Technical Working Group (RFTWG) has reviewed the harvest estimates from the national surveys. Due to a methodological error in the methodology, the harvest estimates for 1991–92 to 1993–94 and 1996–97 are not considered to be reliable. The harvest estimates for the 1999–2000 and 2000–01 surveys may be very inaccurate and some implausibly high. This may be due to a number of factors including the accuracy of the mean weight used to derive total harvest weight from the estimated numbers of paua caught by diarists, and the small number of diarists harvesting the stock in some areas. However relative comparisons can be made between stocks within the surveys.

Table 2: Estimated annual harvest of paua (t) by recreational fishers*.

Fishstock	PAU 1	PAU 2	PAU 3	PAU 5	PAU5A	PAU5B	PAU 5D	PAU 6	PAU 7
1991–92	-	-	35–60	50–80	-	-	-	-	-
1992–93	-	37–89	-	-	-	-	-	0–1	2–7
1993–94	29–32	-	-	-	-	-	-	-	-
1995–96	10–20	45–65	-	20–35	-	-	-	-	-
1996–97	-	-	-	N/A	-	-	22.5	-	-
1999–00	40–78	224–606	26–46	36–70	-	-	26–50	2–14	8–23
2000–01	16–37	152–248	31–61	70–121	-	-	43–79	0–3	4–11
2011-12	12.6	81.85	16.98	-	0.42	0.82	22.45	-	14.13

*1991–1995 Regional telephone/diary estimates, 1995/96, 1999/00 and 2000/01 National Maine Recreational Fishing Surveys.

1.3 Customary fisheries

There is an important customary use of paua by Maori for food, and the shells have been used extensively for decorations and fishing devices. Limited data is available for reported customary landings in PAU 3; however no information is available for current levels of customary take for any other paua QMA. Kaitiaki are now in place in many areas and estimates of customary harvest can be expected in the future.

1.4 Illegal catch

Current levels of illegal harvests are not known. In the past, annual estimates of illegal harvest for some Fishstocks were provided by MFish Compliance based on seizures. In the current paua stock assessments, nominal illegal catches are used.

1.5 Other sources of mortality

Paua may die from wounds caused by removal desiccation or osmotic and temperature stress if they are bought to the surface. Sub-legal paua may be subject to handling mortality by the fishery if they are removed from the substrate to be measured. Further mortality may result indirectly from being returned to unsuitable habitat or being lost to predators or bacterial infection. Gerring (2003) observed paua (from PAU 7) with a range of wounds in the laboratory and found that only a deep cut in the foot caused significant mortality (40% over 70 days). In the field this injury reduced the ability of paua to right themselves and clamp securely onto the reef, and consequently made them more vulnerable to predators. The tool generally used by divers in PAU 7 is a custom made stainless steel knife with a rounded tip and no sharp edges. This design makes cutting the paua very unlikely (although abrasions and shell damage may occur). Gerring (2003) estimated that in PAU 7, 37% of paua removed from the reef by commercial divers were undersize and were returned to the reef. His estimate of incidental mortality associated with fishing in PAU 7 was 0.3% of the landed catch. Incidental fishing mortality may be higher in areas where other types of tools and fishing practices are used. Mortality may increase if paua are kept out of the water for a prolonged period or returned onto sand. To date, the stock assessments developed for paua have assumed that there is no mortality associated with capture of undersize animals.

2. BIOLOGY

Paua are herbivores which can form large aggregations on reefs in shallow subtidal coastal habitats. Movement is over a sufficiently small spatial scale that the species may be considered sedentary. Paua are broadcast spawners and spawning is thought to be annual. Habitat related factors are an important source of variation in the post-settlement survival of paua. Growth, morphometrics, and recruitment can vary over short distances and may be influenced by factors such as wave exposure, habitat structure, availability of food and population density. A summary of generic estimates for biological parameters for paua are presented in Table 3. Parameters specific to individual paua QMAs are reported in the specific Working Group reports.

Table 3: Estimates of biological parameters for paua (H. *iris*).

Fishstock		Estimate	Source
1. Natural mortality (*M*)			
All		0.02–0.25	Sainsbury (1982)
2. Weight = a (length)^b (weight in kg, shell length in mm)			
	a = 2.99E^{-08}	b = 3.303	Schiel & Breen (1991)

3. STOCKS AND AREAS

Using both mitochondrial and microsatellite markers Will & Gemmell (2008) found high levels of genetic variation within samples of *H. Iris* taken from 25 locations spread throughout New Zealand. They also found two patterns of weak but significant population genetic structure. Firstly, *H. iris* individuals collected from the Chatham Islands were found to be genetically distinct from those collected from coastal sites around the North and South Islands. Secondly a genetic discontinuity was found loosely associated with the Cook Strait region. Genetic discontinuities within the Cook Strait region have previously been identified in sea stars, mussels, limpets, and chitons and are possibly related to contemporary and/or past oceanographic and geological conditions of the region. This split may have some implications for management of the paua stocks, with populations on the south of the North Island, and the north of the South Island potentially warranting management as separate entities; a status they already receive under the zonation of the current fisheries regions, PAU 2 in the North Island, and PAU 7 on the South Island.

4. STOCK ASSESSMENT

The dates of the most recent survey or stock assessment for each QMA are listed in Table 4.

Table 4: Recent survey and stock assessment information for each paua QMA

QMA	Type of survey or assessment	Date	Comments
PAU 1	No surveys or assessments have been undertaken		
PAU 2	Relative abundance estimate using standardised CPUE index based on commercial catch	2014	Standardised CPUE showed slight oscillation without trend between 1992 and 2001 and has remained flat from 2002 until 2014.
PAU 3	Quantitative assessment using a Bayesian length based model	2013	For the 2013 stock assessment nine model runs where conducted. The Shellfish Working Group agreed on a base case model which estimated M within the model but fixed the growth parameters as providing a reliable estimate of the status of the stocks in PAU 3 with the caveat that the model most likely underestimated uncertainty in growth but adequately estimated uncertainty in natural mortality.
PAU 4	Quantitative assessment using a Bayesian length based model	2004	In February 2010 the Shellfish Working Group (SFWG) agreed that due to the lack of adequate data as input into the Bayesian length-based model, a stock assessment for PAU 4 using this model was not appropriate. Other performance indicators that could be used as reference points around which to assess the status of the stocks are being evaluated for use in PAU 4
PAU 5A	Quantitative assessment using a Bayesian length based model	2010	The 2014 stock assessment was conducted over two subareas of the QMA. The SFWG was satisfied that the stock assessment for both the Southern and Northern areas was reliable based on the available data.
PAU 5B	Quantitative assessment using a Bayesian length based model	2013	The SFWG were satisfied that the stock assessment provided a reliable estimate of the status of the stocks in PAU 5B. Sensitivity trials addressed uncertainties associated with various aspects of the input data and model assumptions.
PAU 5D	Quantitative assessment using a Bayesian length based model	2012	Four assessment runs were presented and all considered to be equally plausible. All runs showed that it was Very Unlikely the stock will fall below the soft or hard limits over the next three years at current levels of catch, and suggested that biomass would increase. However, the four runs differed in their assessment of the status of the stock relative to the target.
PAU 6	Biomass estimate	1996	This fishery has a TACC of 1 t
PAU 7	Quantitative assessment using a Bayesian length based model	2012	The SFWG agreed that the stock assessment was reliable based on the available data. Currently, spawning stock biomass is estimated at 22% B_0 Results suggest an increase to 23.4% B_0 in over the next three years at current levels of catch.
PAU 10	No surveys or assessments have been undertaken		

4.1 Estimates of fishery parameters and abundance

For further information on fishery parameters and abundance specific to each paua QMA refer to the specific Working Group report.

In 2008 standardised CPUE indices were constructed to assess relative abundance in PAU 2. In QMAs where quantitative stock assessments have been undertaken, standardised CPUE is also used as input data for the Bayesian length-based stock assessment model. There is however a large amount of literature on abalone which suggests that any apparent stability in CPUE should be interpreted with caution and CPUE may not be proportional to abundance as it is possible to maintain high catch rates despite a falling biomass. This occurs because paua tend to aggregate and in order to maximise their catch rates divers' move from areas that have been depleted of paua, to areas with higher density. The consequence of this fishing behaviour is that overall abundance is decreasing while CPUE is remaining stable. This process of hyperstability is believed to be of less concern in PAU 3, PAU 5D and PAU 7 because fishing in these QMAs is consistent across all fishable areas.

In PAU 4, 5A, 5B, 5D and 7 the relative abundance of paua has also been estimated from independent research diver surveys (RDS). In PAU 7, seven surveys have been completed over a number of years but only two surveys have been conducted in PAU 4. In 2009 and 2010 several reviews were conducted (Cordue (2009) and Haist V (2010 MPI .FRR) to assess; i) the reliability of the research diver survey index as a proxy for abundance; and ii) whether the RDS data, when used in the paua stock assessment models, results in model outputs that do not adequately reflect the status of the stocks. The reviews concluded that:

- Due to inappropriate survey design the RDS data appear to be of very limited use for constructing relative abundance indices.
- There was clear non-linearity in the RDS index, the form of which is unclear and could be potentially complex.
- CVs of RDS index 'year' effects are likely to be underestimated, especially at low densities.
- Different abundance trends among strata reduces the reliability of RDS indices, and the CVs are likely not to be informative about this.
- It is unlikely that the assessment model can determine the true non-linearity of the RDS index-abundance relationship because of the high variability in the RDS indices.
- The non-linearity observed in the RDS indices is likely to be more extreme at low densities, so the RDSI is likely to mask trends when it is most critical to observe them.
- Existing RDS data is likely to be most useful at the research stratum level.

4.2 Biomass estimates

Biomass was estimated for PAU 6 in 1996 (McShane et al 1996). However the survey area was only from Kahurangi Point to the Heaphy River.

Biomass has been estimated, as part of the stock assessments, for PAU 4, 5A, 5B, 5D and 7 (Table 4). For further information on biomass estimates specific to each paua QMA refer to the specific Working Group report.

4.3 Yield Estimates and Projections

Yield estimates and projections are estimated as part of the stock assessment process. Both are available for PAU 5A, 5D and 7. For further information on yield estimates and projections specific to each paua QMA refer to the specific Working Group report.

4.4 Other factors

In the last few years the commercial fishery have been implementing voluntary management actions in the main QMAs. These management actions include raising the minimum harvest size and subdividing QMAs into smaller management areas and capping catch in the different areas

5. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

5.1. Ecosystem role

Paua are eaten by a range of predators, and smaller paua are generally more vulnerable to predation. Smaller paua are consumed by blue cod (Carbines and Beentjes 2003), snapper (Francis 2003), banded wrasse (Russell 1983), spotties (McCardle 1983), triplefins (McCardle 1983) and octopus (Andrew & Naylor 2003). Large paua are generally well protected by their strong shells, but are still vulnerable to rock lobsters (McCardle 1983), the large predatory starfishes *Astrostole scabra* and *Coscinasterias muricata* (Andrew & Naylor 2003). Large paua are also vulnerable to predation by eagle rays (McCardle 1983), but Ayling & Cox (1982) suggested that eagle rays feed almost exclusively on Cook's turban. There are no known predators that feed exclusively on paua.

Paua feed preferentially on drift algae but at high densities they also feed by grazing attached algae. They are not generally considered to have a large structural impact upon algal communities but at high densities they may reduce the abundance of algae. There are no recognised interactions with paua abundance and the abundance or distribution of other species, with the exception of kina which, at very high densities, appear to exclude paua (Andrew et al 2000). Research at D'Urville Island and on Wellington's south coast suggests that there is some negative association between paua and kina (Andrew & MacDiarmid 1999).

5.2. Fish and invertebrate bycatch

Because paua are harvested by hand gathering, incidental bycatch is limited to epibiota attached to, or within the shell. The most common epibiont on paua shell is non-geniculate coralline algae, which, along with most other plants and animals which settle and grow on the shell, such as barnacles, oysters, sponges, bryozoans, and algae, appears to have general habitat requirements (i.e. these organisms are not restricted to the shells of paua). Several boring and spiral-shelled polychaete worms are commonly found in and on the shells of paua. Most of these are found on several shellfish species, although within New Zealand's shellfish, the onuphid polychaete *Brevibrachium maculatum* has been found only in paua shell Handley, S. (2004). This species; however, has been reported to burrow into limestone, or attach its tube to the holdfasts of algae (Read 2004). It is also not uncommon for paua harvesters to collect predators of paua (mainly large predatory starfish) while fishing and to effectively remove these from the ecosystem. The levels of these removals are unlikely to have a significant effect on starfish populations (nor, in fact, on the mortality of paua caused by predation).

5.3. Incidental catch (seabirds, mammals, and protected fish)

There is no known bycatch of threatened, endangered, or protected species associated with the hand gathering of paua.

5.44. Benthic interactions

The environmental impact of paua harvesting is likely to be minimal because paua are selectively hand gathered by free divers. Habitat contact by divers at the time of harvest is limited to the area of paua foot attachment, and paua are usually removed with a blunt tool to minimise damage to the flesh. The diver's body is also seldom in full contact with the benthos. Vessels anchoring during or after fishing have the potential to cause damage to the reef depending on the type of diving operation (in many cases, vessels do not anchor during fishing). Damage from anchoring is likely to be greater in areas with fragile species such as corals than it is on shallow temperate rocky reefs. Corals are relatively abundant at shallow depths within Fiordland, but there are seven areas within the sounds with significant populations of fragile species where anchoring is prohibited.

5.5. Other considerations

5.5.1 Genetic effects

Fishing, environmental changes, including those caused by climate change or pollution, could alter the genetic composition or diversity of a species and there is some evidence to suggest that genetic changes may occur in response to fishing of abalones. Miller et al (2009) suggested that, in *Haliotis rubra* in Tasmania, localised depletion will lead to reduced local reproductive output which may, in turn, lead to an increase in genetic diversity because migrant larval recruitment will contribute more to total larval recruitment. Enhancement of paua stocks with artificially-reared juveniles has the potential to lead to genetic effects if inappropriate broodstocks are used.

5.5.2 Biosecurity issues

Undaria pinnatifida is a highly invasive opportunistic kelp which spreads mainly via fouling on boat hulls. It can form dense stands underwater, potentially resulting in competition for light and space which may lead to the exclusion or displacement of native plant and animal species. *Undaria* may be transported on the hulls of paua dive tenders to unaffected areas. Bluff Harbour, for example, supports a large population of *Undaria*, and is one of the main ports of departure for fishing vessels harvesting paua in Fiordland, which appears to be devoid of *Undaria* (R. Naylor, personal observation). In 2010, a small population of *Undaria* was found in Sunday Cove in Breaksea Sound, and attempts to eradicate it appear to have been successful (see http://www.biosecurity.govt.nz/pests/undaria).

6. STATUS OF THE STOCKS

The status of paua stocks PAU 2, PAU 3, PAU 4, PAU 5A, PAU 5B, PAU 5D and PAU 7 are given in the relevant Working Group reports.

7. FOR FURTHER INFORMATION

Andrew, N; Francis, M (Eds.) (2003) *The Living Reef: the ecology of New Zealand's Living Reef*. Nelson, Craig Potton Publishing.

Andrew, N L; Breen, P A; Naylor, J R; Kendrick, T H; Gerring, P K (2000a) Stock assessment of paua *Haliotis iris* in PAU 7 in 1998–99. *New Zealand Fisheries Assessment Report. 2000/49*.

Andrew, N L; Naylor, J R; Gerring, P; Notman, P R (2000b) Fishery independent surveys of paua (*Haliotis iris*) in PAU 5B and 5D. *New Zealand Fisheries Assessment Report 2000/3*. 21 p.

Andrew, N L; Naylor, J R; Gerring, P (2000c) A modified timed-swim method for paua stock assessment. *New Zealand Fisheries Assessment Report 2000/4*. 23 p.

Andrew, N L; Naylor, J R; Kim, S W (2002) Fishery independent surveys of the relative abundance and size-structure of paua (*Haliotis iris*) in PAU 5B and PAU 5D. *New Zealand Fisheries Assessment Report. 2002/41*.

Andrew, N.L.; MacDiarmid, A.B., 1999. Sea urchin fisheries and potential interactions with a kina fishery in Fiordland. Conservation Advisory Science Notes No. 266, Department of Conservation, Wellington.

Annala, J H; Sullivan, K J; O'Brien, C; Iball, S (Comps.) (1998) Report from the Fishery Assessment Plenary, May 1998: Stock assessments and yield estimates. 409 p. (Unpublished report held in NIWA library, Wellington.)

Boyd, R O; Gowing, L; Reilly, J L (2004) 2000–2001 National Marine Recreational Fishing Survey: diary results and harvest estimates. Draft New Zealand Fisheries Assessment Report. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Boyd, R O; Reilly, J L (2004) 1999/2000 National Marine Recreational Fishing Survey: harvest estimates. Draft New Zealand Fisheries Assessment Report 2004. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document 1998/16. 27 p. (Unpublished report held by NIWA library, Wellington.)

Breen, P A; Andrew, N L; Kendrick, T H (2000a) Stock assessment of PAU 5B for 1998−99. *New Zealand Fisheries Assessment Report* 2000

Breen, P A; Andrew, N L; Kendrick, T H (2000b) Stock assessment of paua (*Haliotis iris*) in PAU 5B and PAU 5D using a new length-based model. *New Zealand Fisheries Assessment Report. 2000/33.*

Breen, P A; Andrew, N L; Kendrick, T H (2000c) The 2000 stock assessment of paua (*Haliotis iris*) in PAU 5B using an improved Bayesian length-based model. *New Zealand Fisheries Assessment Report. 2000/48.*

Breen, P A; Andrew, N L; Kim, S W (2001) The 2001 stock assessment of paua *Haliotis iris* in PAU 7. *New Zealand Fisheries Assessment Report. 2001/55.*

Breen, P A; Kim, S W (2004) The 2004 stock assessment of paua *Haliotis iris* in PAU 5A. *New Zealand Fisheries Assessment Report. 2004/40.*

Breen, P A; Kim, S W (2005) The 2005 stock assessment of paua *Haliotis iris* in PAU 7. *New Zealand Fisheries Assessment Report. 2005/47.*

Breen, P A; Kim, S W (2007) The 2006 stock assessment of paua (*Haliotis iris*) stocks PAU 5A (Fiordland) and PAU 5D (Otago). *New Zealand Fisheries Assessment Report. 2007/09.*

Breen, P A; Smith, A N (2008a) The 2007 stock assessment of paua (*Haliotis iris*) stock PAU 5B (Stewart Island). *New Zealand Fisheries Assessment Report. 2008/05.*

Breen, P A; Smith, A N (2008b) Data used in the 2007 stock assessment for paua (*Haliotis iris)* stock 5B (Stewart Island). *New Zealand Fisheries Assessment Report. 2008/06.*

Carbines, G.D.; Beentjes, M.P. (2003). Relative abundance of blue cod in Dusky Sound in 2002. New *Zealand Fisheries Assessment Report 2003B7*. 25 p.

Cordue, P L (2009) Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 report. 45 p.

Elvy, D; Grindley, R; Teirney, L (1997) Management Plan for Paua 5. Otago Southland Paua Management Working Group Report 57 p. (Unpublished report held by Ministry for Primary Industries, Dunedin.)

Francis, R I C C (1990) A maximum likelihood stock reduction method. New Zealand Fisheries Assessment Research Document 1990/4. 8 p. (Unpublished report held by NIWA library, Wellington.)

Gerring, P K (2003) Incidental fishing mortality of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report 2003/56*. 13 p.

Kendrick, T H; Andrew, N L (2000) Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5A, 5B, and 5D. *New Zealand Fisheries Assessment Report. 2000/47.*

McShane, P E (1992) Paua fishery assessment 1992. New Zealand Fisheries Assessment Research Document 1992/3. 26 p. (Unpublished report held by NIWA library, Wellington.)

McShane, P E (1996) Patch dynamics and effects of exploitation on abalone (*Haliotis iris*) populations. *Fisheries Research* 25: 191–199.

McShane, P E; Mercer, S; Naylor, R (1993) Paua (*Haliotis* spp.) fishery assessment 1993. New Zealand Fisheries Assessment Research Document 1993/6. 22 p. (Unpublished report held by NIWA library, Wellington.)

McShane, P E; Mercer, S F; Naylor, J R; Notman, P R (1994a) Paua fishery assessment 1994. New Zealand Fisheries Assessment Research Document 1994/16. 47 p. (Unpublished report held by NIWA library, Wellington.)

McShane, P E; Mercer, S F; Naylor, J R (1994b) Spatial variation and commercial fishing of New Zealand abalone (*Haliotis iris* and *H. australis*). *New Zealand Journal of Marine and Freshwater Research* 28: 345–355.

McShane, P E; Mercer, S F; Naylor, J R; Notman, P R (1996) Paua (*Haliotis iris*) fishery assessment in PAU 5, 6, and 7. New Zealand Fisheries Assessment Research Document. 1996/11. (Unpublished report held by NIWA library, Wellington.)

McShane, P E; Naylor, J R (1995) Small-scale spatial variation in growth, size at maturity, and yield- and egg-per-recruit relations in the New Zealand abalone *Haliotis iris*. *New Zealand Journal of Marine and Freshwater Research* 29: 603–612.

McShane, P E; Schiel, D R; Mercer, S F; Murray, T (1994c) Morphometric variation in *Haliotis iris* (Mollusca:Gastropoda): analysis of 61 populations. *New Zealand Journal of Marine and Freshwater Research* 28: 357–364.

Naylor, J R; Andrew, N L (2000) Determination of growth, size composition, and fecundity of paua at Taranaki and Banks Peninsula. *New Zealand Fisheries Assessment Report. 2000/51.*

Naylor, J R; Andrew, N L (2002) Determination of paua growth in PAU 2, 5A, 5B, and 5D. *New Zealand Fisheries Assessment Report. 2002/34.*

Naylor, J R; Andrew, N L; Kim, S W (2003) Fishery independent surveys of the relative abundance, size-structure and growth of paua (*Haliotis iris*) in PAU 4. *New Zealand Fisheries Assessment Report. 2003/08.*

Naylor, J R; Kim, S W (2004) Fishery independent surveys of the relative abundance and size-structure of paua *Haliotis iris* in PAU 5D. *New Zealand Fisheries Assessment Report. 2004/48*.

Naylor, J R; Notman, P R; Mercer, S F; Gerring, P (1998) Paua (*Haliotis iris*) fishery assessment in PAU 5, 6, and 7. New Zealand Fisheries Assessment Research Document. 1998/05. (Unpublished report held by NIWA library, Wellington.)

Pirker, J G (1992) Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165 p.

Sainsbury, K J (1982) Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. *New Zealand Journal of Marine and Freshwater Research* 16: 147–161.

Schiel, D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris. Fishery Bulletin 89:* 681–691.

Schwarz, A.; Taylor, R.; Hewitt, J.; Phillips, N.; Shima, J.; Cole, R.; Budd, R. (2006). Impacts of terrestrial runoff on the biodiversity of rocky reefs. New Zealand Aquatic Environment and Biodiversity Report No 7. 109 p.

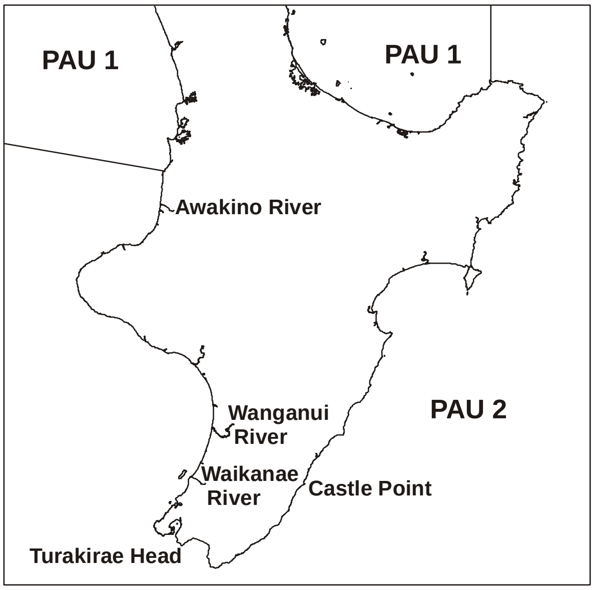
Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Wynne-Jones,J; Gray, A; Hill, L; Heinemann, A (2014) National Panel Survey of Marine Recreational Fishers 2011-12: Harvest Estimates. New Zealand Fisheries Assessment Report 2014/16.

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

PAUA (PAU 2) – Wairarapa / Wellington / Taranaki

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

PAU 2 was introduced into the Quota Management System in 1986–87 with a TACC of 100 t. As a result of appeals to the Quota Appeal Authority, the TACC was increased to 121.19 t in 1989 and has remained unchanged to the current fishing year (Table 1). There is no TAC for this QMA: before the Fisheries Act (1996) a TAC was not required. When changes have been made to a TACC after 1996, stocks have been assigned a TAC.

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 2 since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1989	-	-	-	-	100
1989–present	-	-	-	-	121.19

1.1 Commercial fisheries

The fishing year runs from 1 October through to 30 September. Most of the commercial catch comes from the Wairarapa and Wellington South coasts between Castle Point and Turakirae Head. The western area between Turakirae Head and the Waikanae River is closed to commercial fishing.

On 1 October 2001 it became mandatory to report catch and effort on PCELRs using the fine-scale reporting areas that had been developed by the New Zealand Paua Management Company for their voluntary logbook programme (Figure 1).

1.2 Recreational fisheries

The most recent recreational fishery survey "The National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates (2014)", estimated about 80 t of paua were harvested by recreational fishers in PAU 2 in 2011–12.

Because paua around Taranaki are naturally small and never reach the minimum legal size (MLS) of 125 mm, a new MLS of 85 mm was introduced for recreational fishers from 1 October 2009. The new length is on a trial basis for five years and applies between the Awakino and Wanganui rivers.

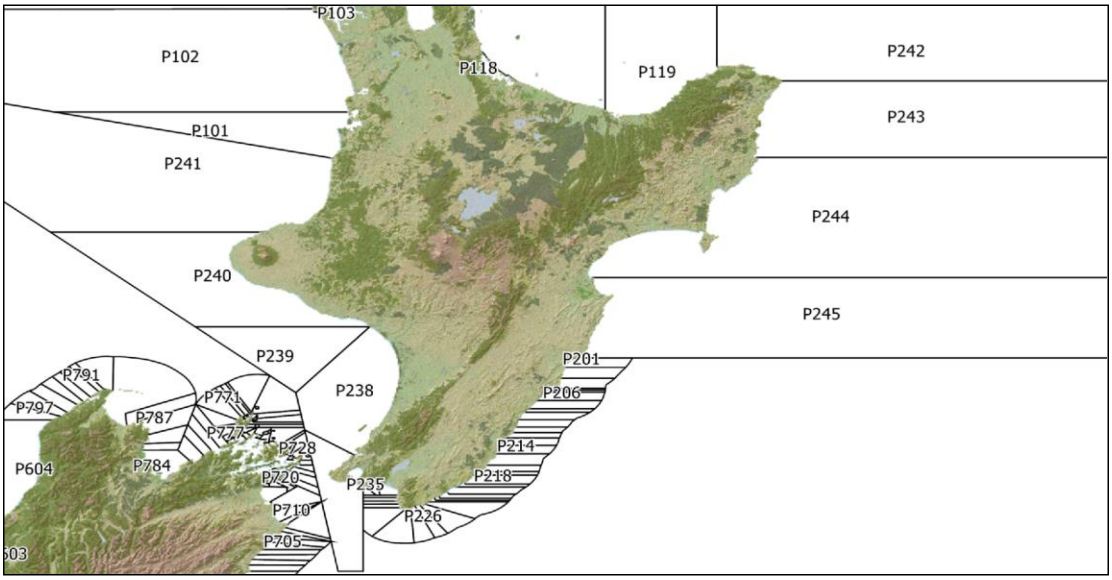


Figure 1: Map of fine scale statistical reporting areas for PAU 2.

Landings for PAU 2 are shown in Table 2.

Table 2: TACC and reported landings (t) of paua in PAU 2 from 1983–84 to present.

Year	Landings	TACC
1983–84*	110	–
1984–85*	154	–
1985–86*	92	–
1986–87*	96.2	100
1987–88*	122.11	111.33
1988–89*	121.5	120.12
1989–90	127.28	121.19
1990–91	125.82	121.19
1991–92	116.66	121.19
1992–93	119.13	121.19
1993–94	125.22	121.19
1994–95	113.28	121.19
1995–96	119.75	121.19
1996–97	118.86	121.19
1997–98	122.41	121.19
1998–99	115.22	121.19
1999–00	122.48	121.19
2000–01	122.92	121.19
2001–02	116.87	121.19
2002–03	121.19	121.19
2003–04	121.06	121.19
2004–05	121.19	121.19
2005–06	121.14	121.19
2006–07	121.20	121.19
2007–08	121.06	121.19
2008–09	121.18	121.19
2009–10	121.13	121.19
2010–11	121.18	121.19
2011–12	120.01	121.19
2012–13	122	121
2013–14	120	121

* FSU data.

1.3 Customary fisheries

For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

It is widely believed that the level of illegal harvesting is high around Wellington and on the Wairarapa coast. For further information on illegal catch refer to the introductory PAU Working Group Report.

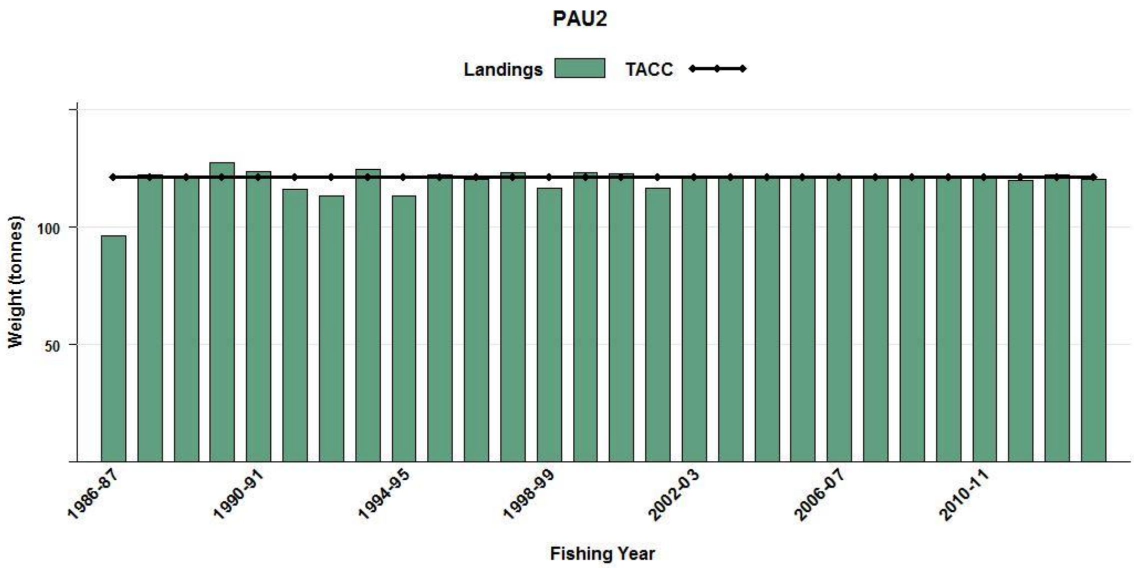


Figure 2: Historical landings and TACC for PAU 2 from 1983–84 to present. QMS data from 1986–present.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of published estimates of biological parameters for PAU 2 is presented in Table 3.

Table 3: Estimates of biological parameters (*H. iris*)

Area		Estimate	Source
1. Size at maturity (shell length)			
Wellington	50% mature	71.7 mm	Naylor et al. (2006)
Taranaki	50% mature	58.9 mm	Naylor & Andrew (2000)
2. Fecundity = a (length)^b (eggs, shell length in mm)			
Taranaki	a = 43.98	b = 2.07	Naylor & Andrew (2000)
3. Exponential growth parameters (both sexes combined)			
Wellington	g_{50}	30.58 mm	Naylor et al. (2006)
	g_{100}	14.8 mm	
Taranaki	G_{25}	18.4 mm	Naylor & Andrew (2000)
	G_{75}	2.8 mm	

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. RELATIVE ABUNDANCE INDEX

A standardised CPUE index based on commercial catch was constructed covering the 1990 to 2014 fishing years (McKenzie in press). Two separate indexes were estimated, the first was estimated from CELR data for the fishing years 1989–90 to 2001–02, and the second was estimated from PCELR data for the fishing years 2002–03 to 2013–14. FSU data covering the period from 1983 to 1988 was not used in the standardisation due to problems with this data including: 1) a high proportion of missing values for the vessel field; 2) ambiguity and inaccuracies in what is recorded for the important fishing duration field and 3) low coverage of the annual catch.

There was little evidence of serial depletion over the past 13 years (Figure 3).

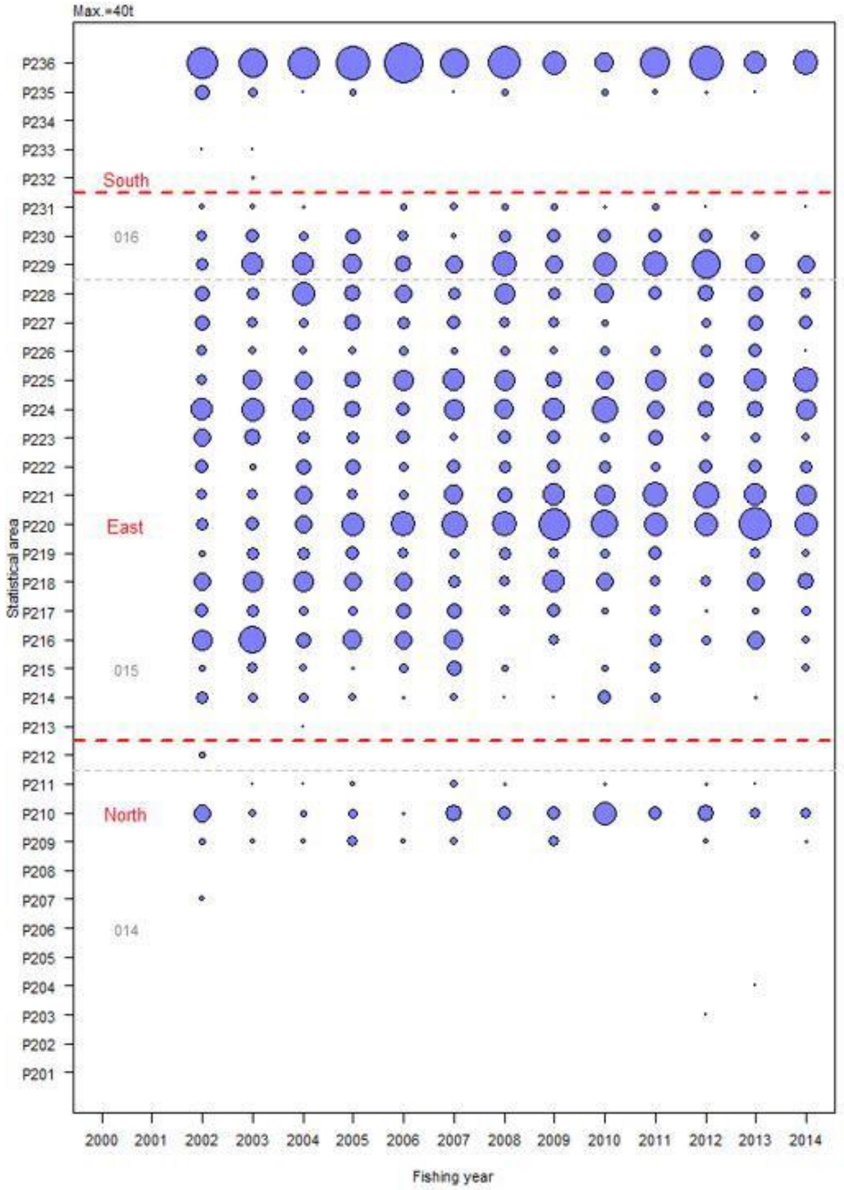


Figure 3: Annual estimated catch by fine-scale statistical area in PAU 2 for fishing years 2002–2014. The size of the circle is proportional to the catch. The red dashed lines delineate different regions.

The CPUE standardisations used the following criteria:

- To restrict the catch-effort records to those from the old statistical areas 014, 015, 016 (CELR data) and zones P201–P236 (PCELR data). These areas contain most of the commercial catch.
- For the CELR data standardisation to use a subset of the groomed data for which the recorded duration would be less ambiguous. The criteria to be used to subset the data are: (i) just one diver, or (ii) fishing duration ≥ 6 hours and number of divers ≥ 2. For this subsetted data set, offer both number of divers and duration (as a polynomial) to the model.
- Do a sensitivity CELR data standardisation where the fishing duration cut-off is 4 hours: (i) just one diver, or (ii) fishing duration ≥ 4 hours and number of divers ≥ 2.
- To use Fisher Identification Number (FIN) in standardisation procedures instead of vessel.
- Not to put in a year and area interaction in the standardisations (which would be used in a single area assessment), but to explore area differences in catch rates by doing separate standardisations where a year and area interaction is forced in at the start. For the CELR data

the smallest possible area sub-divisions are 014, 015, and 016. For the PCELR data a close, but more natural division of the areas is South, East, and North (Figure), where the large East area can be broken up further based on the strata used for length-frequencies.

4.1 CELR: the standardisation

CPUE was defined as daily catch. Year was forced into the model at the start and other predictor variables offered to the model were FIN, statistical area (014, 015, 016), month, fishing duration (as a cubic polynomial), number of divers, and a month:area interaction. Following previous standardisations, no interaction of fishing year with area was entered into the model, however, a separate standardisation is also done where a year:area interaction is forced in at the start.

The model explained 77% of the variability in CPUE with fishing duration (70%) explaining most of this followed by FIN (3%). The effects appear plausible and the model diagnostics were good.The standardised index declines for the first four years, then increases, with a drop in the last year (Table 4, Figure 4).

Table 4: Standardised CELR index, lower and upper 95% confidence intervals, and CV.

year	index	lower.CI	upper.CI	CV
1990	1.01	0.88	1.17	0.07
1991	0.94	0.81	1.07	0.07
1992	0.89	0.78	1.02	0.07
1993	0.89	0.78	1.01	0.06
1994	0.87	0.76	0.99	0.06
1995	0.91	0.80	1.03	0.06
1996	0.99	0.87	1.12	0.06
1997	0.98	0.86	1.13	0.07
1998	1.08	0.92	1.27	0.08
1999	1.19	1.02	1.39	0.08
2000	1.21	1.03	1.42	0.08
2001	1.13	0.97	1.31	0.08

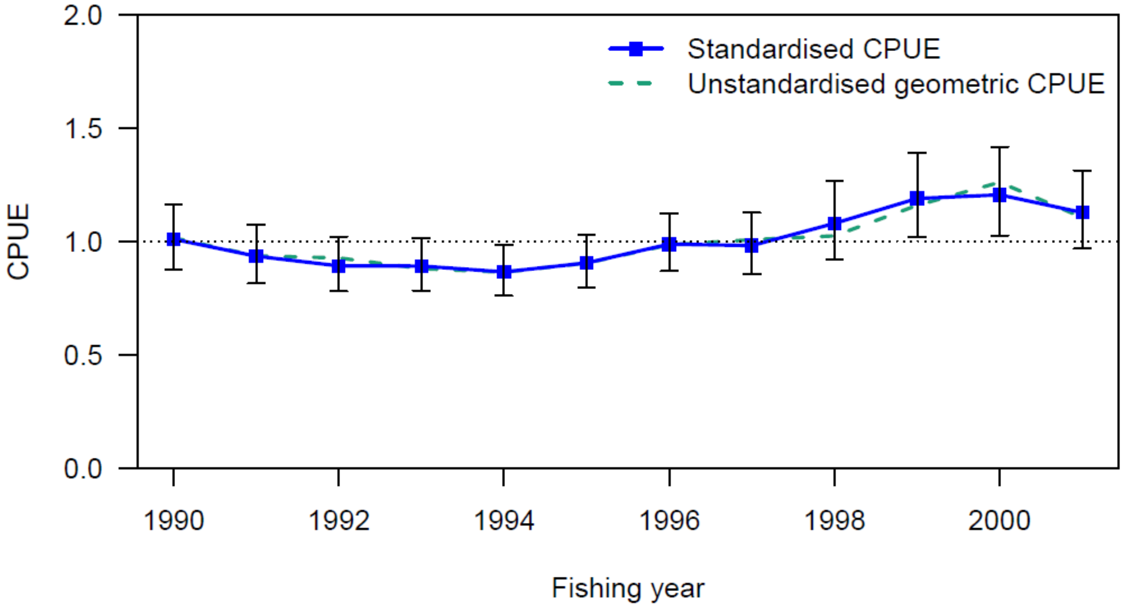


Figure 4: The standardised CPUE index with 95% confidence intervals. The unstandardised geometric CPUE is calculated as daily catch divided by daily fishing duration

As a sensitivity to the filtering criteria for the subsetted data set (in which the fishing duration field should be less ambiguous), another standardisation was done in which when the number of divers was

≥ 2 then the fishing duration has to be ≥ 4 hours (instead of 6 hours). The resulting index is very similar to that when 6 hours is used (Figure 5).

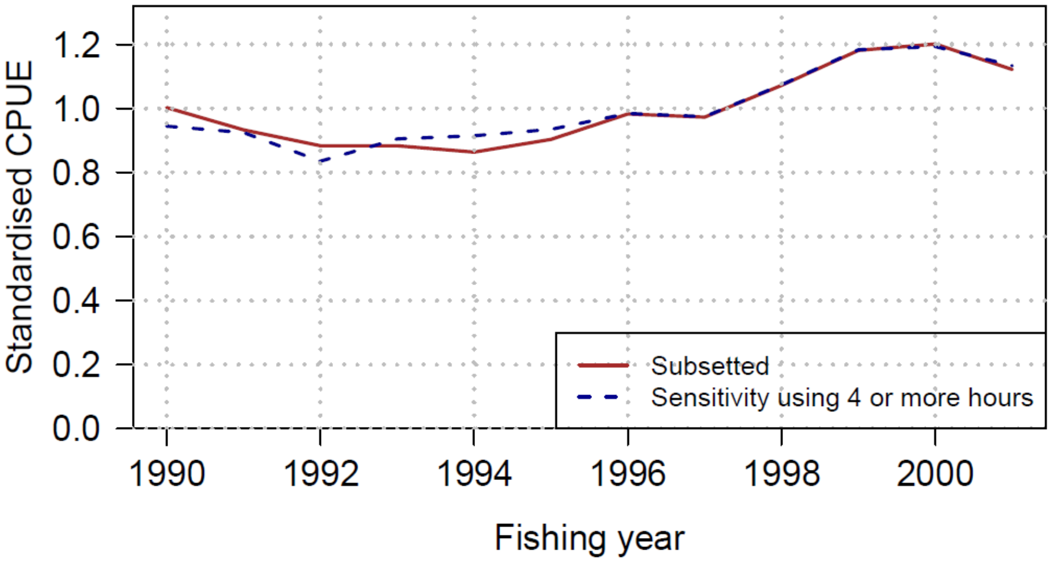


Figure 5: Sensitivity using four hours or more (for two or more divers).

4.2 PCELR: the standardisation

For the standardisation model CPUE (the dependent variable) was modelled as log of the diver catch with a normal error distribution. Fishing year was forced into the model at the start. Variables offered to the model were month, diver key, FIN, statistical area, duration (third degree polynomial), and diving condition. Following previous standardisations, no interaction of fishing year with area was entered into the model however, a separate standardisation is also done where a year:area interaction is forced in at the start.

Except for month, all variables were accepted into the model, which explained 73% of the variability in CPUE. Most of the variability was explained by duration (56%) and diver (9%). The effects appear plausible and the diagnostics were good. There is an apparent increasing effect for the catch taken after a fishing duration of 10 hours, although for the majority of records fishing duration is less than 10 hours.

The standardised index shows a slow decline from 2002 to 2012 with a slight increase since then (Table 5, Figure 6). As the standardised index shows little contrast since 2002, and there is little growth data available for PAU 2, stock assessment model estimates of biomass would be highly uncertain and not useful for management purposes. Because of this it was decided by the Shellfish Working Group that a full stock assessment should not be undertaken for PAU 2.

Table 5: Standardised index for the PCELR data set, lower and upper 95% confidence intervals and CV.

year	index	lower.CI	upper.CI	CV
2002	1.13	0.99	1.28	0.06
2003	1.05	0.94	1.16	0.05
2004	1.05	0.95	1.16	0.05
2005	1.01	0.92	1.11	0.05
2006	1.04	0.94	1.15	0.05
2007	0.95	0.86	1.05	0.05
2008	0.94	0.86	1.04	0.05
2009	0.99	0.89	1.10	0.05
2010	0.97	0.88	1.08	0.05

Table 5 [Continued]

year	index	lower.CI	upper.CI	CV
2011	0.95	0.86	1.05	0.05
2012	0.95	0.86	1.05	0.05
2013	1.01	0.90	1.12	0.05
2014	0.98	0.86	1.11	0.07

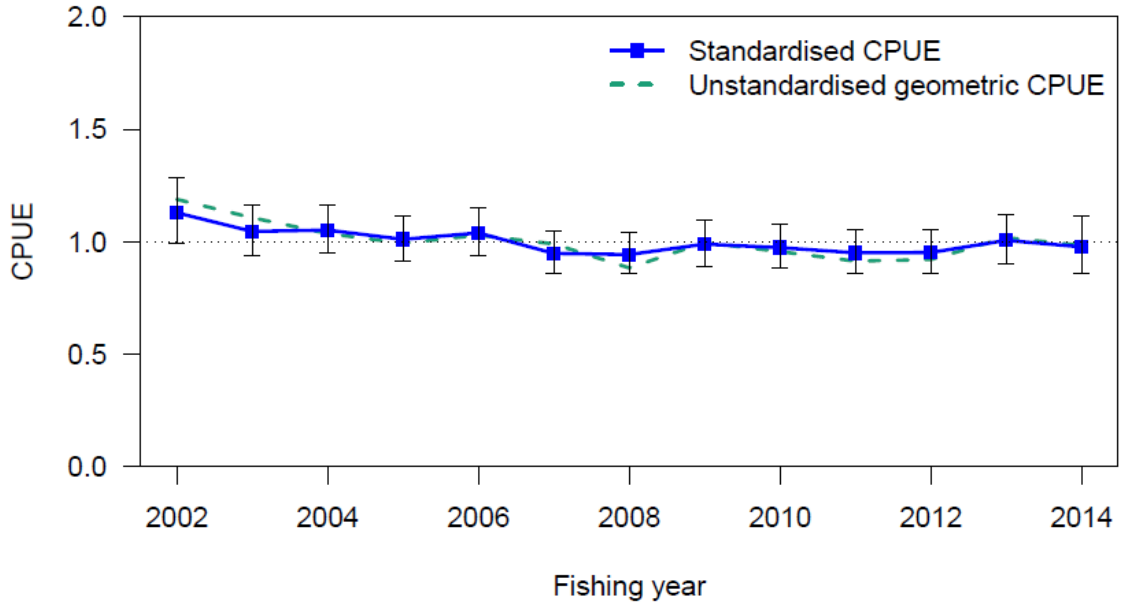


Figure 6: The standardised CPUE index for the PCELR dataset with 95% confidence intervals. The unstandardised geometric CPUE is calculated as daily catch divided by daily fishing duration.

It should be noted that a large amount of literature on abalone suggests that any apparent stability in CPUE should be interpreted with caution; and CPUE may not be proportional to abundance as it is possible to maintain high catch rates despite a falling biomass. This occurs because paua tend to aggregate and in order to maximise their catch rates divers' move from areas that have been depleted of paua, to areas with higher density. The consequence of this fishing behaviour is that overall abundance is decreasing but CPUE is remaining stable. This may not be such a large problem in PAU2 because distribution of catch has been consistent for many years and there is little evidence of serial depletion occurring (Figure 3).

5. STATUS OF THE STOCKS

Stock Structure Assumptions

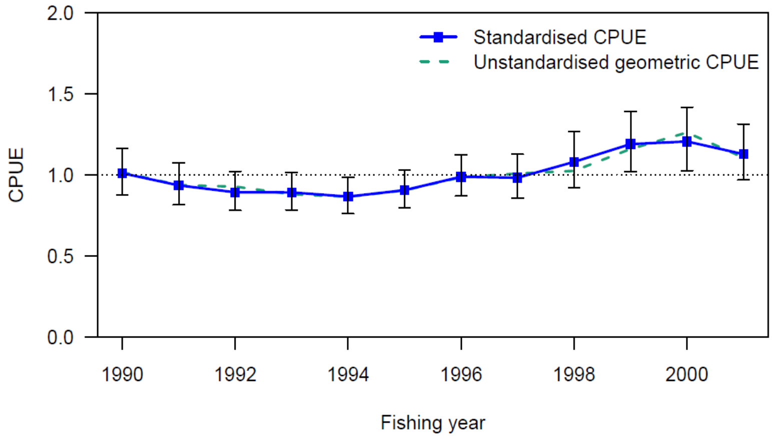
A genetic discontinuity between North Island and South Island paua populations was found approximately around the area of Cook Strait (Will & Gemmell 2008).

- **PAU 2 -** *Haliotis iris*

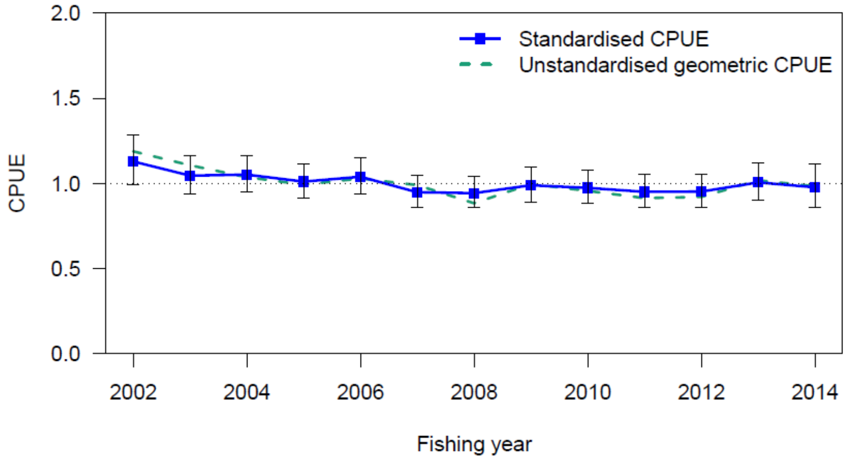
Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Standardised CPUE index
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS)

Status in relation to Target	Unknown
Status in relation to Limits	Unlikely (< 40%) to be below the Soft Limit Unlikely (< 40%) to be below the Hard Limit
Status in relation to Overfishing	Unknown: There are no data for recreational or illegal catch and both are likely to be significant.

Historical Stock Status Trajectory and Current Status



Standardised and unstandardized CPUE index for 1990–2001 with 95% confidence intervals. The unstandardised geometric CPUE is calculated as daily catch divided by daily fishing duration.



Standardised and unstandardized CPUE index for 2002–2014 using PCELR data, with 95% confidence intervals. The unstandardised geometric CPUE is calculated as daily catch divided by daily fishing duration.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	From 1989–90 to 2001–02 the standardized CPUE index oscillates without any obvious trend, and from 2002–03 until 2013–14 the index is flat.
Recent Trend in Fishing Mortality or proxy	-
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	No stock assessment has been undertaken for this stock
Probability of Current Catch or TACC causing Biomass to	Soft Limit: Unknown

remain below or to decline below Limits	Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unknown

Assessment Methodology		
Assessment Type	-	
Assessment Method	-	
Period of Assessment	Latest assessment: -	Next assessment: -
Overall assessment quality rank	-	
Main data inputs (rank)	-	-
Data not used (rank)	-	-
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
CPUE is not generally considered to be a reliable indicator of the status of paua stocks and may not reflect abundance. A large portion of PAU 2, including the Wellington south coast, is closed to commercial fishing. This means that the CPUE series collected from the commercial catch and effort data are exclusive of this large area and therefore the abundance of paua in the fishery as a whole will not be captured well by the CPUE index.

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Andrew, N L; Naylor, J R; Gerring, P (1999) A modified timed-swim method for paua stock assessment. *New Zealand Fisheries Assessment Report 2000/4*. 23 p.

Breen, P A; Kim, S W (2004) The 2004 stock assessment of paua (*Haliotis iris*) in PAU 4. *New Zealand Fisheries Assessment Report* 2004/55. 79 p.

Breen, P A; Kim, S W; Andrew, N L (2003) A length-based Bayesian stock assessment model for abalone. *Marine and Freshwater Research* 54(5): 619–634.

Chen, Y; Breen, P A; Andrew, N L (2000) Impacts of outliers and mis-specification of priors on Bayesian fish stock assessment. *Canadian Journal of Fisheries and Aquatic Science* 57: 2293–2305.

Fu, D. (2014). 2014 PAU 2 stock assessment – Model input. SFWG 14-76. (Unpublished report held by the Ministry for Primary Industries.)

Fu, D.; McKenzie, A.; Naylor. R. (2014a). Summary of input data for the 2013 PAU 3 stock assessment. *New Zealand Fisheries Assessment Report 2014/42*.

Fu, D.; McKenzie, A.; Naylor. R. (2014b). Summary of input data for the 2013 PAU 5B stock assessment. *New Zealand Fisheries Assessment Report 2014/43*.

Gerring, P K; Andrew, N L; Naylor, J R (2003) Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. *New Zealand Fisheries Assessment Report 2003/56*. 13 p.

Kendrick, T H; Andrew, N L (2000) Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5a, PAU 5B, and PAU 5D. *New Zealand Fisheries Assessment Report 2000/47*. 25

McKenzie A.(2014). Standardised CPUE analyses for paua (*Haliotis iris*) in PAU 2, 1989-90 to 2013-14 *New Zealand Fisheries Assessment Report (in press)*

McKenzie, A; Naylor, J R; Smith, N H (2009) Characterisation of PAU 2 and PAU 3. Final Research Report. 58 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Naylor, J R; Andrew, N L; Kim, S W (2003) Fishery independent surveys of the relative abundance, size-structure, and growth of paua (*Haliotis iris*) in PAU 4. *New Zealand Fisheries Assessment Report 2003/08*. 16 p.

Pirker, J G (1992) Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165 p.

Sainsbury, K J (1982) Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. *New Zealand Journal of Marine and Freshwater Research* 16: 147–161.

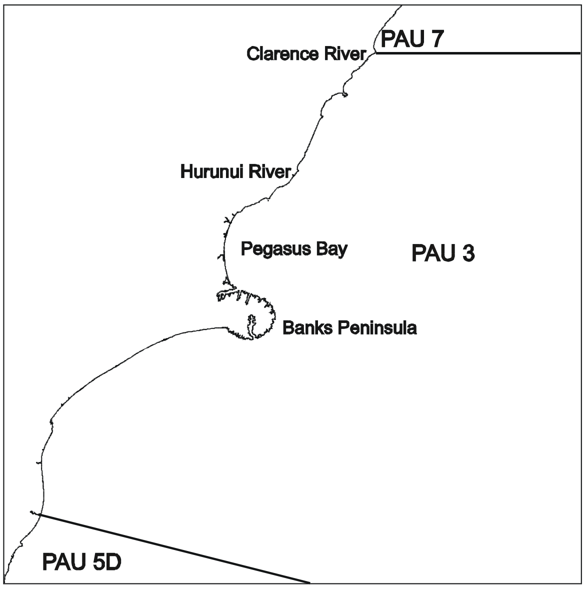
Schiel, D R (1992) The paua (abalone) fishery of New Zealand. *In*: Shepherd, S A; Tegner, M J; Guzman del Proo, S (Eds.), *Abalone of the World: Biology, fisheries, and culture.* Blackwell Scientific, Oxford.

Schiel, D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris*. *Fishery Bulletin* 89: 681–691.

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

PAUA (PAU 3) – Canterbury / Kaikoura

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

1.1 Commercial fisheries

PAU 3 was introduced into the Quota Management System in 1986–87 with a TACC of 57 t. As a result of appeals to the Quota Appeal Authority, the TACC was increased to 91.62 t in 1995 and has remained unchanged to the current fishing year (Table 1).

There is no TAC for PAU 3 (Table 1): before the Fisheries Act (1996) a TAC was not required. When changes have been made to a TACC after 1996, stocks have been assigned a TAC. No allowances have been made for customary, recreational or other mortality.

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 3 since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1995	-	-	-	-	57
1995–present	-	-	-	-	91.615

The fishing year runs from 1 October through 30 September.

Most of the commercial catch comes from the northern part of the QMA between the northern end of Pegasus Bay and the Clarence River, and from the southern side of Banks Peninsula.

On 1 October 2001 it became mandatory to report catch and effort on Paua Catch Effort Landing Returns (PCELRs) using fine-scale reporting areas that had been developed by the New Zealand Paua Management Company for their voluntary logbook programme (Figure 1). Reported landings for PAU 3 are shown in Table 2 and Figure 2.

Since 2001, a redistribution of fishing effort within PAU 3 has been undertaken by the industry as a response to fears that the more accessible northern part of the fishery was being overfished. A voluntary subdivision was agreed by PauaMAC 3 which divided PAU 3 into four management zones (

Table 3). A voluntary harvest cap is placed on each management zone and this cap is reviewed annually. Minimum harvest sizes (MHS) are also agreed for each zone in addition to the legislated Minimum Legal Size (MLS). These are also reviewed annually.

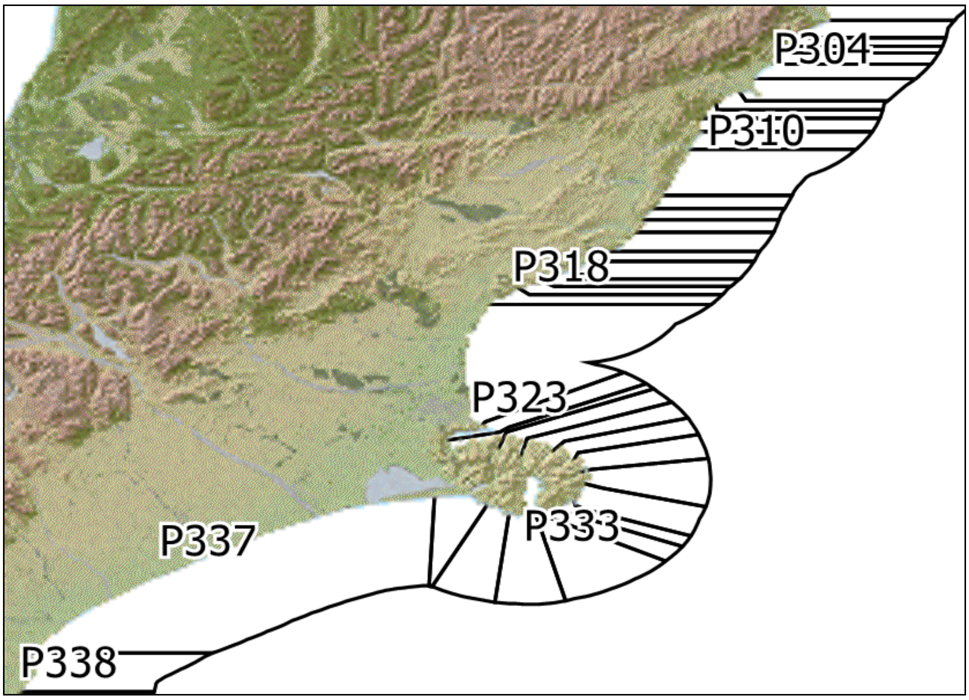


Figure 1: Map of fine scale statistical reporting areas for PAU 3.

Landings for PAU 3 are shown in Table 2.

Table 2: TACC and reported landings (t) of paua in PAU 3 from 1983–84 to present.

Year	Landings	TACC
1983–84*	114	–
1984–85*	92	–
1985–86*	51	–
1986–87*	54.02	57
1987–88*	62.99	60.49
1988–89*	57.55	66.48
1989–90	73.46	69.43
1990–91	90.68	77.24
1991–92	90.25	91.5
1992–93	94.52	91.5
1993–94	85.09	91.5
1994–95	93.26	91.5
1995–96	92.89	91.62
1996–97	89.65	91.62
1997–98	93.88	91.62
1998–99	92.54	91.62
1999–00	90.3	91.62
2000–01	93.19	91.62
2001–02	89.66	91.62
2002–03	90.92	91.62
2003–04	91.58	91.62
2004–05	91.43	91.62
2005–06	91.6	91.62
2006–07	91.61	91.62
2007–08	91.67	91.62
2008–09	90.84	91.62
2009–10	91.61	91.62
2010–11	90.4	91.62
2011–12	91.14	91.62
2012–13	90.01	91.62
2013-14	90.85	91.62

* FSU data.

Table 3: Summary of the management zones within PAU3 as initiated by PauaMac3

Management zone (since 2001)	Area	Statistical area zone
3A	Clarence to Hapuku	P301–P304
3B	Hapuku to Conway	P305–P310
3D	Conway to Waipar	P311–P321
3E	Waipara to Witaki	P322–P329

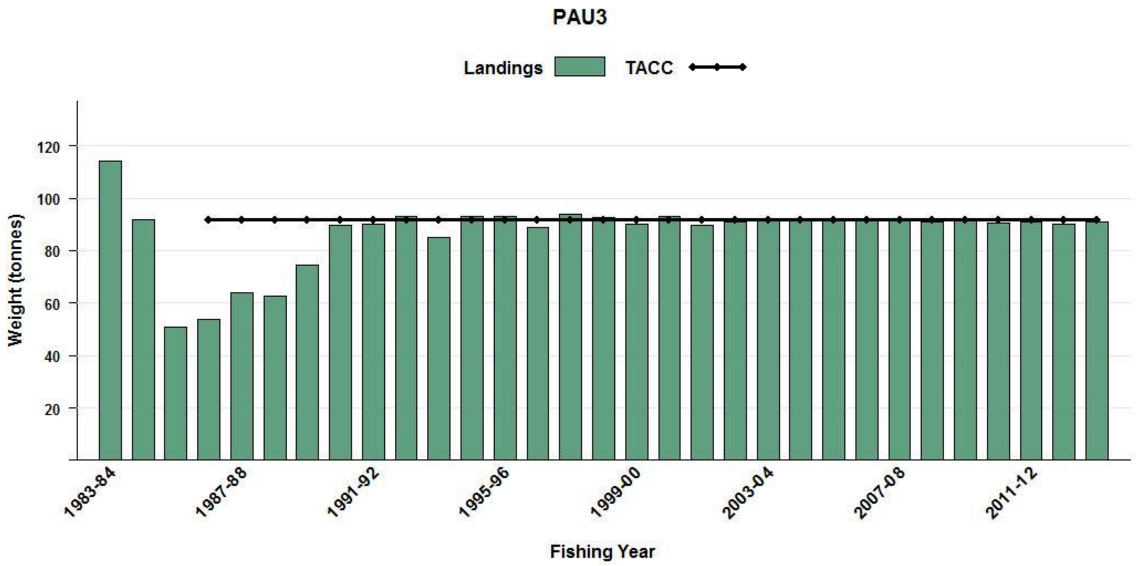


Figure 2: Reported commercial landings and TACC for PAU 3 from 1983–84 to present. QMS data from 1983–present.

1.2 Recreational fisheries

For further information on recreational fisheries refer to the introductory PAU Working Group Report. The 'National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates' estimated the recreational harvest for PAU 3 was 16.98 ton with a C.V. of 30%. For the purpose of the 2013 stock assessment, the Shellfish Working Group (SFWG) agreed to assume that the recreational catch rose linearly from 5t in 1974 to 17 t in 2013.

1.3 Customary fisheries

Estimates of customary catch for PAU 3 over the period where reliable estimates are available are shown in Table 4. Landings do not include the area between the Hurunui River and the South Shore (just north of Banks Peninsula), as Tangata Tiaki have not yet been appointed there. Many tangata whenua also harvest paua under their recreational allowance and these are not included in records of customary catch.

Table 4: Reported customary landings (t) of paua in PAU 3 from 2000–01 to 2013-14. Landings data exclude the area between the Hurunui and Pegasus Bay.

Year	Landings (t)
2000–01	1.64
2001–02	5.67
2002–03	3.84
2003–04	5.83
2004–05	1.95
2005–06	1.90
2006–07	4.56
2007–08	5.79
2008–09	8.23
2009–10	6.47
2010–11	7.45
2011–12	4.24
2012–13	12.87
2013-14	7.57

1.4 Illegal catch
For further information on illegal catch refer to the introductory PAU Working Group Report. For the purpose of the 2013 stock assessment, the SFWG agreed to assume that illegal catches rose linearly from 5t in 1974 to 15 t in 2000, and remained at 15 t between 2001 and 2013.

1.5 Other sources of mortality
The Working Group agreed that handling mortality would not be included in the model. For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of published estimates of biological parameters for PAU 3 is presented in Table 5.

Table 5: Estimates of biological parameters (*H. iris*) in PAU 3.

		Estimate	Source
1. Natural mortality (*M*)			
		0.135 (0.120-0.153)	Median (5-95% range) of posterior distribution for the base case model
2. Weight = a(length)^b (Weight in g, length in mm shell length)			
All	a	b	
	2.99×10^{-5}	3.303	Schiel & Breen (1991)
3. Size at maturity (shell length)			
		50% maturity at 82 mm (80-84)	Median (5-95% range) of posterior distribution for the base case model
		95% maturity at 102 mm (96-108)	Median (5-95% range) of posterior distribution for the base case model

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. STOCK ASSESSMENT

The stock assessment was implemented using a length-based Bayesian estimation model, with parameter point estimates based on the mode of the joint posterior distribution and uncertainty based on marginal posterior distributions generated from Markov chain-Monte Carlo (MCMC) simulations. The most recent stock assessment was conducted in 2014 for the fishing year ended 30 September 2013. The Shellfish WG determined a set of model runs where growth and natural mortality parameter values were fixed. The parameter values were thought to cover the plausible range of productivity assumptions for the stock. Markov chain-Monte Carlo (MCMC) simulations were conducted on a model agreed to by the SFWG. This particular model (6.1) estimated *M* within the model (with a lognormal prior with a mean of 0.1) but fixed the growth parameters at the medium value (g_1=20 mm, g_2=6 mm). On reviewing the results of the MCMC simulations the SFWG chose model 6.1 as the base case. The lack of comprehensive growth and length frequency data for PAU 3 and the lack of contrast in the CPUE series mean's uncertainty in the model outputs is higher than preferred.

4.1 Estimates of fishery parameters and abundance indices

Assumed prior distributions for model parameters are summarized in Table 6.

Table 6: A summary of estimated model parameters, lower bound, upper bound, type of prior, (U, uniform; N, normal; LN = lognormal), mean and C.V. of the prior.

Parameter	Prior	μ	C.V.	Bounds	
				Lower	Upper
ln($R0$)	U	–	–	5	50
M (Natural mortality)	LN	0.1	0.35	0.01	0.5
Ln(q^I) (catchability coefficient of CPUE)	U	–	–	-30	0
Ln(q^J) (catchability coefficient of PCPUE)	U	–	–	-30	0
L_{50} (Length at 50% maturity)	U	–	–	70	145
L_{95-50}(Length between 50% and 95% maturity)	U	–	–	1	50
D_{50}(Length at 50% selectivity for the commercial catch)	U	–	–	70	145
D_{95-50}(Length between 50% and 95% selectivity the commercial catch)	U	–	–	0.01	50
ϵ (Recruitment deviations)	N	0	0.4	-2.3	2.3

The observational data were:

1. A 1990-2001 standardised CPUE series based on CELR data.
2. A 2002-2012 standardised CPUE series based on PCELR data.
3. A commercial catch sampling length frequency series for 2000, 2002–2012.
4. Maturity at length data

4.1.1 Relative abundance estimates from standardised CPUE analyses

The 2013 stock assessment used two sets of standardised CPUE indices: one based on CELR data covering 1990–2001, and another based on PCELR data covering 2002–2013. For both series, standardised CPUE analyses were carried out using Generalised Linear Models (GLMs). A stepwise procedure was used to select predictor variables, with variables entering the model in the order that gave the maximum decrease in the residual deviance. Predictor variables were accepted into the model only if they explained at least 1% of the deviance.

For both the CELR and PCELR data, the Fisher Identification Number (FIN) was used in the standardisations instead of vessel, because the FIN is associated with a permit holder who may employ a suite of grouped vessels, which implies that there could be linkage in the catch rates among vessels operated under a single FIN.

For the CELR data there is ambiguity in what is recorded for estimated daily fishing duration, and therefore daily fishing duration has not been used in past standardisations as a measure of effort; instead the number of divers has been used. However, there is evidence that the fishing duration for a diver changes over time, and because of this a subset of the data was selected for which the recorded fishing duration was less ambiguous. The criteria used to subset the data were: (i) just one diver or, (ii) fishing duration >= 6 hours and number of divers >=2. This data subset was used for the CELR standardisation, using estimated daily catch and effort measured as either number of divers or fishing duration (both were offered to the standardisation model).

For the PCELR data the unit of catch was diver catch, with effort as diver duration. The diver duration measures the number of hours fished per diver day.

FIN codes were used to select a core group of fishers from the CELR data, with the requirement that there be a minimum of 6 records per year for a minimum of 2 years to qualify for the core fisher group. This retained 84% of the catch over 1990-2001. For the PCELR data the FIN was also used to select a core group of fishers, with the requirement that there be a minimum of 20 records per year for a minimum of 2 years. This retained 84% of the catch over 2002-2013.

For the CELR data, year was forced into the model and other predictor variables offered to the model were FIN, statistical area (018, 020, 022), month, fishing duration (as a cubic polynomial), number of divers, and a month:area interaction. Variables accepted into the model were fishing year, month, FIN, and fishing duration. Following previous standardisations, no interaction of fishing year with area was entered into the model as the stock assessment for PAU 3 is a single area model. However, a separate standardisation is also done where a year:area interaction is forced in. Forcing in a year:area interaction indicates that there are differences in standardised CPUE between the area 018 and the two areas 020 and 022. However, in the years where they differ there are very few records to estimate the year effects for areas 020 and 022.

For the PCELR data, fishing year was forced into the model and variables offered to the model were month, diver key, FIN statistical area, diver duration (third degree polynomial), and diving conditions. All the variables were accepted into the final model.

The standardised CPUE from the CELR data is flat from 1990 to 1994, shows a rise of 20% from 1995 to 1998, then declines for the next three years to 2001 (Figure 3–top). The standardised CPUE from the PCELR data shows a gradual decline of 10% from 2002 to 2013 (Figure 3–bottom).

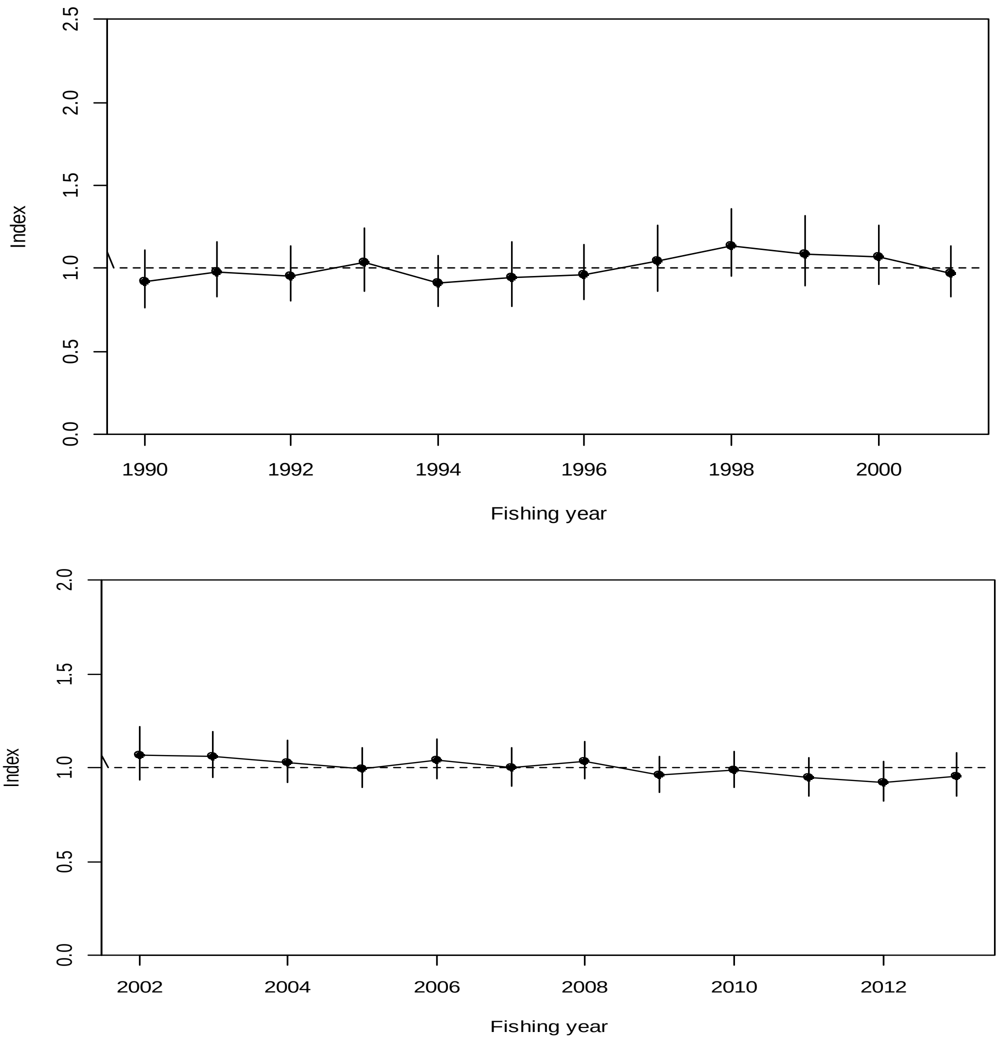


Figure 3: The standardised CPUE indices with 95% confidence intervals for the early CELR/FSU series (top panel) and the recent PCELR series (bottom panel).

4.2 Stock assessment methods

The 2013 PAU 3 stock assessment used the same length-based model as the 2012 PAU 5D assessment (Fu 2013). The model was described by Breen *et al.* (2003). This is the first assessment for PAU 3 using the length based Bayesian model (Fu 2013(in prep)).

The model structure assumed a single sex population residing in a single homogeneous area, with length classes from 70 mm to 170 mm, in 2 mm bins. Growth is length-based, without reference to age, mediated through a growth transition matrix that describes the probability of transition among length classes at each time step. Paua enter the model following recruitment and are removed by natural mortality and fishing mortality.

The models were run for the years 1965–2013. Catches were collated for 1974–2013, and were assumed to increase linearly between 1965 and 1973 from 0 to the 1974 catch level. Catches included commercial, recreational, customary, and illegal catch, and all catches occurred at the same time step.

Recruitment was assumed to take place at the beginning of the annual cycle, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. The stock-recruitment relationship is unknown for paua. A relationship may exist on small geographical scales, but not be apparent when large geographical scales are modelled (Breen et al 2003). However, the Shellfish Working Group agreed to use a Beverton-Holt stock-recruitment relationship with steepness (h) of 0.75 for this assessment.

Maturity is not required in the population partition but is necessary for estimating spawning biomass. The model estimated proportions mature from length-at-maturity data. Growth and natural mortalities were also estimated within the model. The model estimated the commercial fishing selectivity, assumed to follow a logistic curve and asymptote at 1.

The growth data available to the PAU 3 assessment were collected from several sites in Banks Peninsula. Because most of the paua measured in this experiment were stunted, incorporating these data in the assessment would under-estimate the growth for the whole stock. There were also some growth measurements from an experiment conducted in Cape Campbell (within PAU 7) which is close to the northern boundary of PAU 3, but the sample size is too small to be useful. Therefore the growth parameters were fixed in this assessment.

The growth parameter were fixed at low ($g_1=15$ mm, $g_2=4.5$ mm), median ($g_1=20$ mm, $g_2=6$ mm), and high ($g_1=25$ mm, $g_2=7.5$ mm) values. The median values were based on the estimates of growth using the tag-recapture data from Cape Campbell (Fu 2014). The low and high values were loosely based on the range of growth estimates from assessments of other paua stocks. For each fixed value of the growth parameters, natural mortality was fixed at three levels, 0.1, 0.15, and 0.2. These values were considered to have covered the plausible range of natural mortality for paua. In total nine model runs were carried out. The growth and natural mortality parameter values aimed to evaluate the sensitivity of model results to key productivity assumptions and to estimate uncertainty in stock status. Each model run was considered an equally likely scenario. The models were fitted to the data with parameters estimated at the mode of their joint posterior distribution (MPD).

Markov chain-Monte Carlo (MCMC) simulations were conducted on a model agreed to by the SFWG in order to obtain a large set of samples from the joint posterior distribution. This particular model (6.1) estimated M within the model (with a lognormal prior with a mean of 0.1) but fixed the growth parameters at the medium value (g_1=20 mm, g_2=6 mm).

The assessment calculates the following quantities from the posterior distributions: the equilibrium spawning stock biomass with recruitment equal to the average recruitment over the period for which recruitment deviations were estimated (B_0,); and the mid-season spawning and recruited biomass for 2013 (B_{2013} and B^r_{2013}) and for the projection period (B_{proj} and B^r_{proj}).

This assessment also reports the following fishery indictors:

- $B\%B_0$ Current or projected spawning biomass as a percentage of B_0
- $B\%B_{msy}$ Current or projected spawning biomass as a percentage of B_{msy}
- $\Pr(B_{proj} > B_{msy})$ Probability that projected spawning biomass is greater than B_{msy}
- $\Pr(B_{proj} > B_{2013})$ Probability that projected spawning biomass is greater than $B_{current}$
- $B\%B_0^r$ Current or projected recruited biomass as a percentage of B_0^r
- $B\%B_{msy}^r$ Current or projected recruited biomass as a percentage of B_{msy}^r
- $\Pr(B_{proj} > B_{msy}^r)$ Probability that projected recruit-sized biomass is greater than B_{msy}^r
- $\Pr(B_{proj} > B_{2013}^r)$ Probability that projected recruit-sized biomass is greater than B_{2012}^r
- $\Pr(B_{proj} > 40\%B_0)$ Probability that projected spawning biomass is greater than 40% B_0
- $\Pr(B_{proj} < 20\%B_0)$ Probability that projected spawning biomass is less than 20% B_0
- $\Pr(B_{proj} < 10\%B_0)$ Probability that projected spawning biomass is less than 10% B_0
- $\Pr(U_{proj} > U_{40\%B0})$ Probability that projected exploitation rate is greater than $U_{40\%B0}$

4.3 Stock assessment results

For the nine model runs in which growth and natural mortality were fixed B_0 ranged from 1500 t to 2900 t, and $B_{current}$ ranged from 21% to 66% of B_0 (Table 7). All model runs showed an overall deceasing trend in spawning stock biomass but this trend has become slower in recent years (Figure 4). In general, models with higher values for *M* and growth had higher estimates of initial and current biomass, and models with lower *M* and growth had lower estimates of biomass.

When *M* was fixed at 0.1, the models fitted the CSLF and CPUE data poorly. Model fits improved markedly when *M* was increased to 0.15 or 0.20. The SFWG believed that 0.15 is probably more credible than 0.2 for the natural mortality of paua. Model fits and likelihood function values did not provide a clear distinction among low, median, or high growth values. Estimates of stock depletion levels were sensitive to the assumed value of the growth parameters.

For model (6.1), the posterior of *M* had a median of 0.14 with a 90% credible interval between 0.12 and 0.15. The posterior distributions of spawning stock biomass showed a gradual declining trend (Figure 5), estimated B_0 was about 2670 t (2470–2960t) and $B_{current}$ was about 52% (45–60%) of B_0 (Table 8). The SFWG agreed for this model to be adopted as the base case model, but noted that the model underestimates uncertainty in stock biomass and status because of uncertainty in growth.

The estimates of recruitment deviations showed a period of relatively low recruitment between 1980 the 1990 and recruitment in recent years (after 2002) has been above the long term average. Exploitation rates showed a gradual upward trend since the 2000s, and the estimated exploitation rate in 2013 was about 0.16 (0.09–0.14) (Table 8).

Model projections, assuming current catch levels and using recruitments re-sampled from the recent model estimates, suggested that the spawning stock abundance will slightly decrease to about 51% (41–63) of B_0 over the next three years (Table 9). The projections indicated that the probability of the spawning stock biomass being above the target (40% B_0) over the next three years is close to 100%

Table 7: MPD estimates of B_0, B_{2013}, and U_{2013} for models 3.1–3.3, 4.1–4.3, and 5.1–5.3.

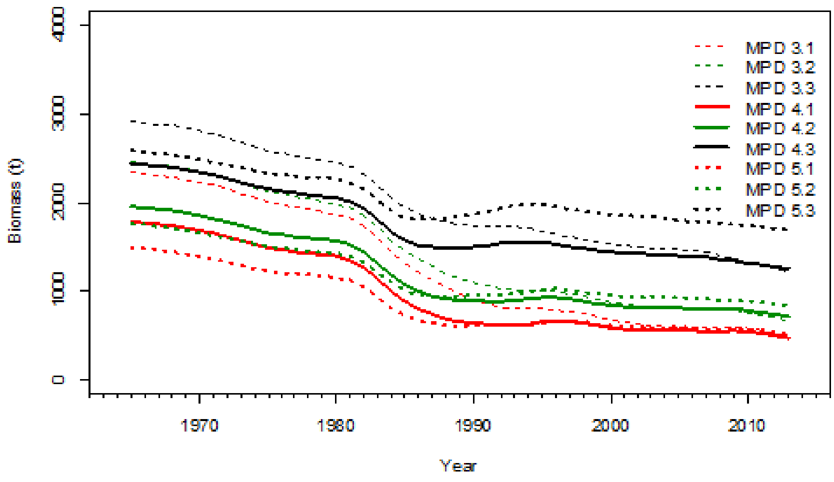
Model	M	g_1	g_2	B_0	B_{2013}	B_{2013}/B_0	U_{2013}
3.1	0.10	25	7.5	2344	488	0.21	0.32
3.2	0.10	20	6	2460	672	0.27	0.26
3.3	0.10	15	4.5	2916	1231	0.42	0.17
4.1	0.15	25	7.5	1795	474	0.26	0.39
4.2	0.15	20	6	1965	718	0.37	0.30
4.3	0.15	15	4.5	2452	1262	0.51	0.21
5.1	0.20	25	7.5	1497	520	0.35	0.40
5.2	0.20	20	6	1767	848	0.48	0.30
5.3	0.20	15	4.5	2594	1708	0.66	0.18

Table 8: Summary of the marginal posterior distributions of key biomass indicators from the MCMC chain from the base case (Model 6.1). The columns show the median, the 5th and 95th percentiles values observed in the 1000 samples. Biomass is in tonnes.

	5%	Median	95%
B_0	2470	2666	2957
B_{msy}	687	741	834
B_{2013}	1133	1390	1727
$B_{2013}\%B_0$	45	52	60
$B_{2013}\%B_{msy}$	163	187	214
$B_{msy}\%B_0$	27	28	29
rB_0	1700	1880	2100
rB_{msy}	78	126	195
rB_{2013}	502	657	874
rB_{2013}/rB_0	0.28	0.35	0.43
rB_{2013}/rB_{msy}	3.22	5.17	9.32
rB_{msy}/rB_0	0.04	0.07	0.09
MSY	116	131	155
$U_{40\%B0}$	0.39	0.56	0.79
U_{msy}	0.19	0.25	0.34
U_{2013}	0.12	0.16	0.21

Table 9: Summary of current and projected indicators for the base case with future commercial catch set to current TACC: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. $B_{()}$ (current or projected biomass), $U_{()}$(current or projected exploitation rate).

	2013	2014	2015
Bt	1390 (1088–1858)	1379 (1067–1855)	1371 (1041–1847)
$\%B_0$	52 (43.9–62.0)	51.5 (42.9–62.0)	51.3 (41.2–63.1)
$\%B_{msy}$	187 (158–218)	185 (155–220)	184 (149–224)
$Pr(>B_{msy})$	1.00	1.00	1.00
$Pr(>B_{current})$	0.35	0.32	0.32
$Pr(>40\%B_0)$	1.00	0.99	0.99
$Pr(<20\%B_0)$	0.00	0.00	0.00
$Pr(<10\%B_0)$	0.00	0.00	0.00
rB_t	657 (481–946)	643 (462–926)	626 (443–915)
$\%rB_0$	34.9 (26.7–45.5)	34.1 (25.2–44.6)	33.2 (24.1–43.9)
$\%rB_{msy}$	517 (295–1045)	504 (283–1035)	491 (273–1019)
$Pr(>rB_{msy})$	1.00	1.00	1.00
$Pr(>rB_{current})$	0.12	0.09	0.05
$Pr(U_{proj>}U_{40\%B0})$	0.03	0.04	0.05



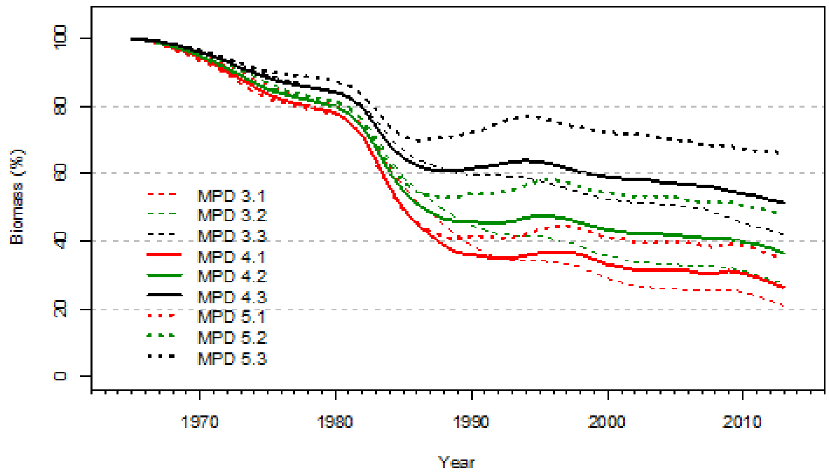


Figure 4: Estimates of spawning stock biomass (top panel) and spawning stock biomass as a ratio of B_0 (bottom panel) for MPD models 3.1, 3.2, 3.3, 4.1, 4.2, 4.3, 5.1, 5.2, and 5.3.

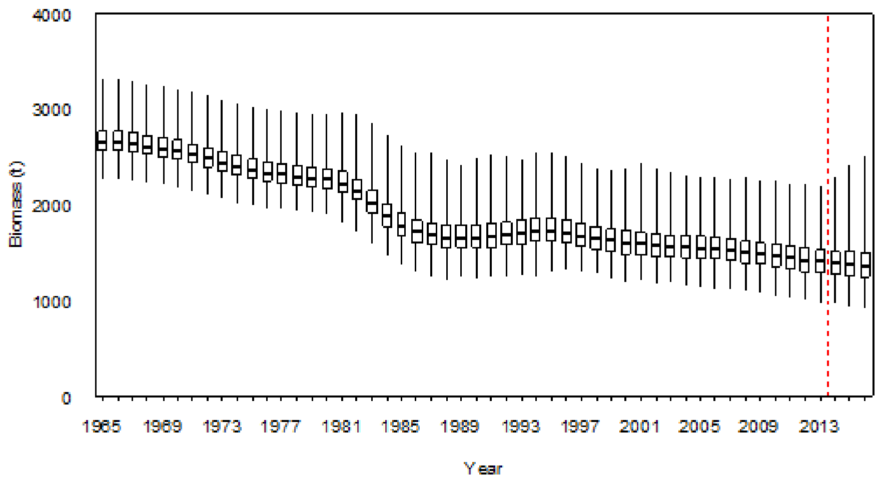


Figure 5: Posterior distributions of spawning stock biomass (top panel) and spawning stock biomass as a percentage of virgin level (bottom panel) from MCMC 6.1 (including projections). The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution [Continued on the next page]

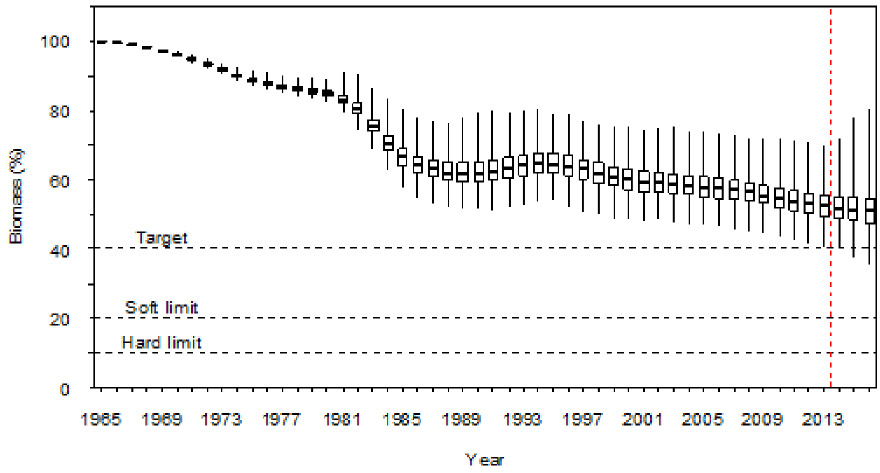


Figure 5 [Continued]:Posterior distributions of spawning stock biomass (top panel) and spawning stock biomass as a percentage of virgin level (bottom panel) from MCMC 6.1 (including projections). The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

4.4 Other factors

The assessment used CPUE as an index of abundance. The assumption that CPUE indexes abundance is questionable. The literature on abalone suggests that CPUE is difficult to use in abalone stock assessments because of serial depletion. This can happen when fishers deplete unfished or lightly fished beds and maintain their catch rates by moving to new areas. Thus CPUE stays high while the biomass is decreasing. In PAU 3, both the early and recent CPUE indices have shown a relatively flat trend (the recent CPUE decreased slightly). It is unknown to what extent the CPUE series tracks stock abundance in PAU 3. Information from commercial fishers indicates that the stock is in relatively good shape suggesting that the trend in CPUE series may be credible.

Even if the CPUE indices are credible, they are not very useful in informing estimates of B_0 in this case because they have shown a relatively flat trend. Therefore the catch sampling length frequencies are the most important observations that provide information on the initial size of the stock. The catch sampling coverage in PAU 3 is considered to be reasonably adequate and the CSLF data are likely to have been representative of the stock.

Another source of uncertainty is the catch data. The commercial catch is known with accuracy since 1985, but is probably not well estimated before that. In addition, non-commercial catch estimates are poorly determined. The estimate of illegal catch is uncertain. Anecdotal evidence suggested the recreational catch in PAU 3 is very likely to have increased substantially in recent years and could be much higher than what was assumed in the model. However, the increase in non-commercial catch (if it is true) has not been reflected in the recent CPUE indices, which showed an almost flat trend. One possible reason is that the commercial divers may have fished deeper than recreational fishers, and could be fishing on different sections of the population. If there is substantial bias in estimates of catches, the model could significantly under-estimate the stock depletion level. Therefore better information on the scale and trend in recreational catch needs to be collated for more accurate assessment of the stock status.

Another source of uncertainty is that fishing may cause spatial contraction of populations (Shepherd & Partington 1995), or that some populations become relatively unproductive after initial fishing (Gorfine & Dixon 2000). If this happens, the model will overestimate productivity in the population as a whole. Past recruitments estimated by the model might instead have been the result of serial depletion.

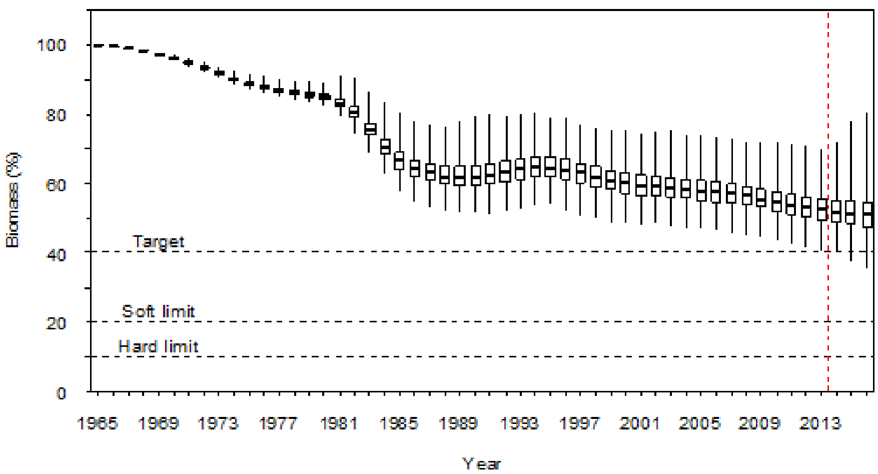
5. STATUS OF THE STOCK

Stock Structure Assumptions
PAU 3 is assumed to be a homogenous stock for purposes of the stock assessment however there is evidence to show this may not be correct (Naylor et al 2006).

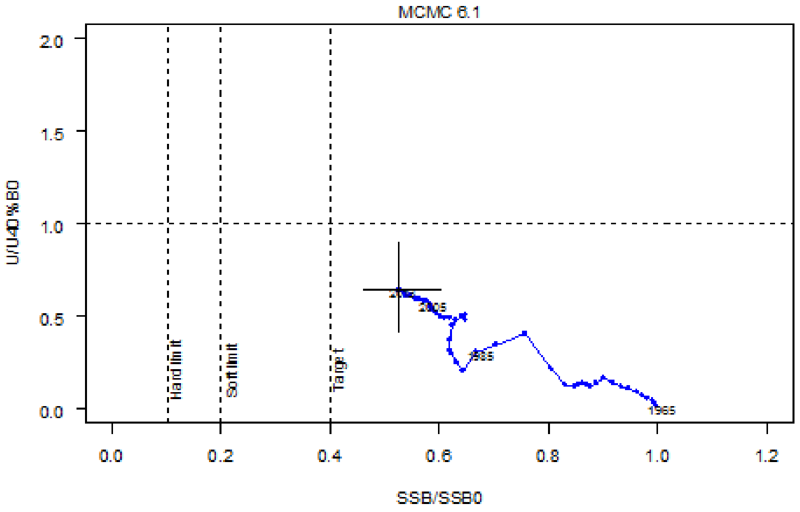
- **PAU 3 - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MCMC 6.1 base case (*M* estimated, g_1 fixed at 20 mm and g_2 fixed at 6.0 mm)
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS) Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	B_{2013} estimated to be 52% B_0 : Very Likely (> 60%) to be at or above the target
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Posterior distributions of spawning stock biomass as a percentage of virgin level from MCMC 6.1 (including projections). The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.



Trajectory of exploitation rate as a ratio U%40B0 and spawning stock biomass as a ratio of *B_0* from the start of assessment period 1965 to 2013 for MCMC 6.1 (base case). The vertical lines at 10%, 20%, 40% *B_0* represent the hard limit, the soft limit, and the target respectively. U%40B0 is the exploitation rate at which the spawning stock biomass would stabilise at 40% *B_0* over the long term. Each point on trajectory represents the estimated annual stock status: the value on x axis is the mid-season spawning stock biomass (as a ratio of B0) and the value on the y axis is the corresponding exploitation rate (as a ratio U%40B0) for that year. The Estimates are based on MCMC median and the 2013 90% CI is shown by the cross line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning stock biomass has shown an overall deceasing trend but this has become much slower in recent years.
Recent Trend in Fishing Mortality or Proxy	The exploitation rate has shown a gradual upward trend since the 2000s and was about 0.16 (0.09–0.14) in 2013.
Other Abundance Indices	Standardised CPUE remained relatively flat until the early 2000s, and has declined only slightly since then.
Trends in Other Relevant Indicators or Variables	Estimated recruitment was relatively low between 1980 and 1990 but since 2002 has been above the long term average.

Projections and Prognosis	
Stock Projections or Prognosis	The projected spawning stock abundance will slightly decrease over the next three years but will still be remaining above the target
Probability of Current Catch or TACC causing decline below Limits	Results from all model runs suggest it is very unlikely (< 10%) that current catch or TACC will cause a decline below the limits.

Assessment Methodology & Evaluation		
Assessment Type	Full quantitative stock assessment	
Assessment Method	Length based Bayesian model	
Assessment Dates	Latest: 2014	Next: 2017
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	-Catch history -CPUE indices early series	1 – High Quality for commercial catch 2 – Medium or Mixed Quality for recreational catch, which is not believed to be fully representative over the history of the fishery 2 – Medium or Mixed Quality: not

	-CPUE indices later series -Commercial sampling length frequencies -Tag recapture data (to estimate growth) -Maturity at length data	believed to proportional to abundance 1 – High Quality 1 – High Quality 2 – Medium or Mixed Quality: not believed to be fully representative of the whole QMA 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	New model	
Major Sources of Uncertainty	- Very little growth data available and growth is not well known. - CPUE may not be a reliable index of abundance. - The model treats the whole of the assessed area of PAU 3 as if it were a single stock with homogeneous biology, habitat and fishing pressures. - Recreational catch in PAU 3 is very likely to have increased substantially in recent years and could be much higher than what was assumed in the model.	

Qualifying Comments:
-The lack of comprehensive growth and length frequency data for PAU 3 and the lack of contrast in the CPUE series cause uncertainty in the model outputs. -The SFWG agreed to adopt model 6.1 as the base case model, but noted that the model underestimates uncertainty in stock biomass and stock status because of uncertainty in growth.

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Gerring, P K; Andrew, N L; Naylor, J R (2003) Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. *New Zealand Fisheries Assessment Report 2003/56*. 13 p.

Kim, S W (2004) CPUE analysis of fine-scale logbook data for PAU 3. Ministry of Fisheries Research Report PAU 2001/01 Obj. 7. (Unpublished report held by Ministry for Primary Industries, Wellington.)

McKenzie, A; Naylor, J R; Smith, N H (2009) Characterisation of PAU 2 and PAU 3. Final Research Report. 58p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Naylor, J R; Andrew, N L (2000) Determination of growth, size composition, and fecundity of paua at Taranaki and Banks Peninsula. *New Zealand Fisheries Assessment Report. 2000/51*. 25 p.

Pirker, J G (1992) Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165 p.

Poore, G C B (1972) Ecology of New Zealand abalones, *Haliotis* species (Mollusca: Gastropoda). 3. Growth. *New Zealand Journal of Marine and Freshwater Research* 6, 534–59.

Poore, G C B (1973) Ecology of New Zealand abalones, *Haliotis* species (Mollusca: Gastropoda). 4. Reproduction. *New Zealand Journal of Marine and Freshwater Research 7* (1&2), 67–84.

Sainsbury, K J (1982) Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. *New Zealand Journal of Marine and Freshwater Research 16*: 147–161.

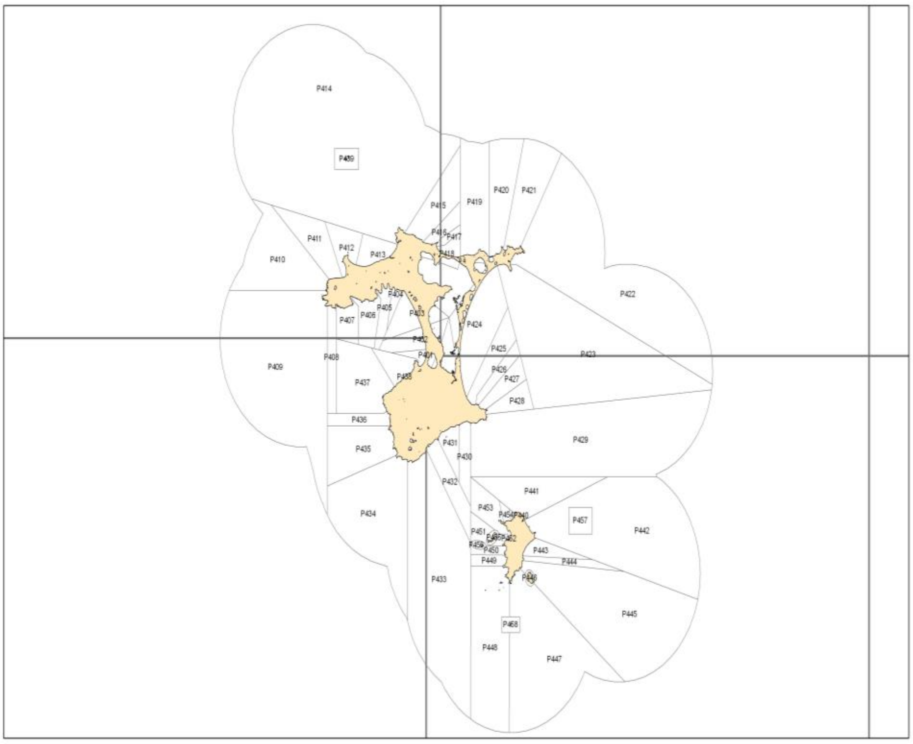
Schiel, D R (1992) The paua (abalone) fishery of New Zealand. *In:* Shepherd, S A; Tegner, M J; Guzman del Proo, S (Eds.), *Abalone of the World: Biology, fisheries, and culture*. Blackwell Scientific, Oxford.

Schiel, D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris. Fishery Bulletin* 89: 681–691.

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

PAUA (PAU 4) – Chatham Islands

(Haliotis iris)
Paua



1. FISHERY SUMMARY

PAU 4 was introduced into the Quota Management System in 1986–87 with a TACC of 261 t. As a result of appeals to the Quota Appeal Authority, the TACC was increased in 1995–96 to 326 t and has remained unchanged to the current fishing year (Table 1). There is no TAC for this QMA: before the Fisheries Act (1996) a TAC was not required. When changes have been made to a TACC after 1996, stocks have been assigned a TAC.

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 4 since introduction into the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1995	-	-	-	-	261
1995–present	-	-	-	-	326

1.1 Commercial fisheries

The fishing year runs from 1 October through to 30 September. On 1 October 2001 it became mandatory to report catch and effort on PCELRs using fine-scale reporting areas that had been developed by the New Zealand Paua Management Company for their voluntary logbook programme (see figure above).

At the beginning of the 2009–10 fishing year, reporting of catch in PAU 4 was changed from reporting in greenweight to reporting in meatweight. The TACC is still set in greenweight but fishers are now required to report greenweight catch that is estimated from the meatweight measured by the licensed fish receiver (LFR). The meatweight to greenweight conversion factor is 2.50 (equivalent to 40% meatweight recovery). The change was made to curb the practice of converting meatweight to landed greenweight after shucking to obtain artificially high recovery rates. It was also made to encourage catch spreading by making it commercially viable for fishers to harvest areas where shells are heavily fouled and meatweight recovery is low. Heavy fouling on shells is a problem that occurs in a number of areas around the Chatham Islands. Landings for PAU 4 are shown in Table 2 and Figure 1.

Table 2: TACC and reported landings (t) of paua in PAU 4 from 1983–84 to the present.

Fishstock	Landings	TACC
1983–84*	409	-
1984–85*	278	-
1985–86*	221	-
1986–87*	267.37	261
1987–88*	279.57	269.08
1988–89*	284.73	270.69
1989–90	287.38	287.25
1990–91	253.61	287.25
1991–92	281.59	287.25
1992–93	266.38	287.25
1993–94	297.76	287.25
1994–95	282.10	287.25
1995–96	220.17	326.54
1996–97	251.71	326.54
1997–98	301.69	326.54
1998–99	281.76	326.54
1999–00	321.56	326.54
2000–01	326.89	326.54
2001–02	321.64	326.54
2002–03	325.62	326.54
2003–04	325.85	326.54
2004–05	319.24	326.54
2005–06	322.53	326.54
2006–07	322.76	326.54
2007–08	323.98	326.54
2008–09	324.18	326.54
2009–10	323.57	326.54
2010–11	262.15	326.54
2011–12	262.07	326.54
2012-13	263.33	326.54
2013-14	291.98	326.54

* FSU data.

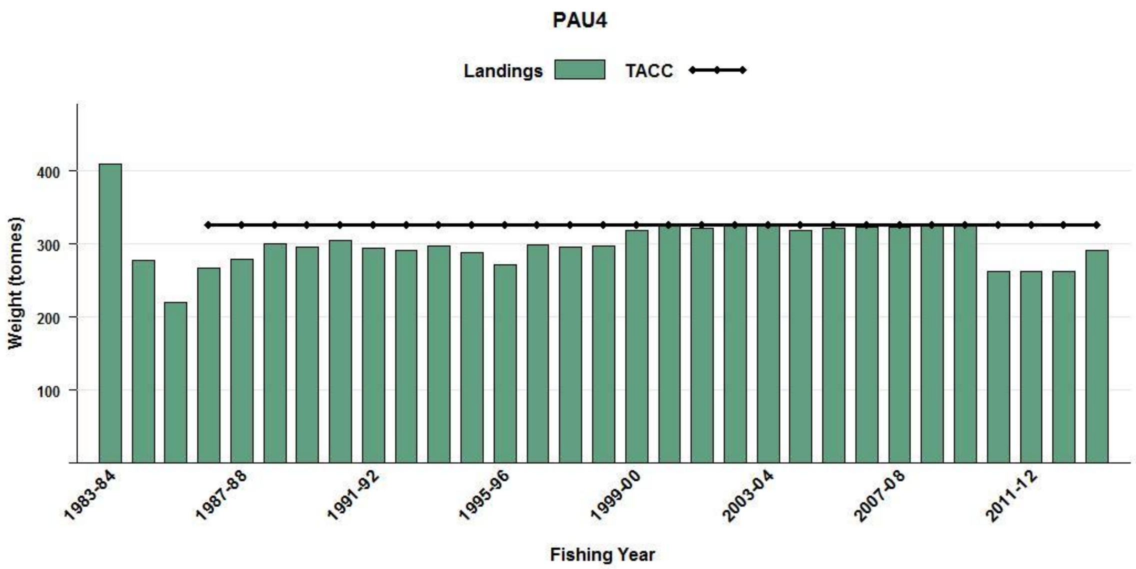


Figure 1: Reported commercial catch and TACC for PAU 4 from 1983–84 to the present.

1.2 Recreational fisheries

There are no estimates of recreational catch for PAU 4. The 1996, 1999–2000 and 2000–01 national marine recreational fishing surveys did not include PAU 4.

1.3 Customary fisheries

There are no estimates of customary catch for PAU 4. For the 2004 stock assessment this catch was assumed to be zero. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch
There are no estimates of illegal catch for PAU 4. For the 2004 stock assessment this catch was assumed to be zero. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality
For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report.

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance
A standardised CPUE analysis for PAU 4 (Fu 2010) from 1989–90 to 2007–08 was completed in February 2010.

The Shellfish Working Group (SFWG) agreed that, because of extensive misreporting of catch in PAU 4, catch and effort data from the Fisheries Statistical Unit and from the CELR and PCELR forms might be misleading in CPUE analyses and therefore, CPUE cannot be used as an index of abundance in this fishery.

4.2 Stock assessment 2004
The last stock assessment for PAU 4 was completed in 2004 (Breen & Kim 2004). A Bayesian length-based stock assessment model was applied to PAU 4 data to estimate stock status and yield. A reference period from 1991–93 was chosen: this was a period after which exploitation rates increased and then leveled off, and after which biomass declined somewhat and then stabilised. It was not intended as a target. Assessment results suggested that then-current recruited biomass was just above $B_{AV,}$ but with high uncertainty (83% to 125%). and current spawning biomass appeared higher than S_{AV}, (130%), but with cautions related to maturity ogives. Projections suggested that 2007 recruited and spawning biomasses could be above B_{AV}, but this was uncertain.

The SFWG advised that major uncertainties in the assessment required the results to be treated with great caution. The major uncertainties included very sparse research diver survey data, misreported CELR and PCELR data, growth and length frequency data most likely not being representative of the whole population and the assumption that CPUE was an index of abundance.

In February 2010 the SFWG agreed that, because of the lack of adequate data as input into the Bayesian length-based model, a stock assessment for PAU 4 using this model was not appropriate.

4.3 Biomass estimates
There are no current biomass estimates for PAU 4.

4.4 Yield estimates and projections
There are no estimates of PAU 4.

5. STATUS OF THE STOCKS

Stock Structure Assumptions
H. iris individuals collected from the Chatham Islands were found to be genetically distinct from those collected from costal sites around the North and South Islands (Will & Gemmell 2008).

- **PAU 4 - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2004
Assessment Runs Presented	None
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS) Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown
Historical Stock Status Trajectory and Current Status[8]	
In 2010 the SFWG rejected CPUE as an index of abundance, therefore the 2004 stock assessment (Breen & Kim 2004) is no longer considered reliable.	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	None
Trends in Other Relevant Indicators or Variables	None

Projections and Prognosis	
Stock Projections or Prognosis	The 2004 stock assessment is no longer considered reliable
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Full Quantitative Stock Assessment, but subsequently rejected	
Assessment Method	Length-based Bayesian model	
Assessment Dates	Last assessment: 2004	Next assessment: No fixed date
Overall assessment quality rank	3 - Low Quality	
Main data inputs (rank)	Catch history CPUE indices Tag recapture growth data Research diver abundance survey data Research diver length frequency data	3 - Low Quality 3 - Low Quality 2- Medium Quality 2- Medium Quality 2- Medium Quality
Data not used (rank)	–	
Changes to Model Structure and Assumptions	–	
Major Sources of Uncertainty	• Potential bias in RDSI • Unreliable reporting of catch and effort data • Assuming CPUE as a reliable index of abundance • Model assumes a homogeneous population • Other model assumptions may be violated	

Qualifying Comments
The 2004 full quantitative stock assessment is no longer considered reliable; i.e. the previous assessment has been rejected and there is currently no valid assessment for this stock.

Fishery Interactions

6. FOR FURTHER INFORMATION

Breen, P A; Kim, S W (2004) The 2004 stock assessment of paua (*Haliotis iris*) in PAU 4. *New Zealand Fisheries Assessment Report 2004/55*. 79 p.

Fu, D (2010) Summary of catch and effort data and standardised CPUE analyses for paua (*Haliotis iris*) in PAU 4, 1989–90 to 2007–08. Fisheries Research Report 2008/01. 50 p

Naylor, J R; Andrew, N L; Kim, S W (2003) Fishery independent surveys of the relative abundance, size-structure, and growth of paua (*Haliotis iris*) in PAU 4. *New Zealand Fisheries Assessment Report 2003/08*. 16 p.

Pirker, J G (1992) Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165 p.

Sainsbury, K J (1982) Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. *New Zealand Journal of Marine and Freshwater Research* 16: 147–161.

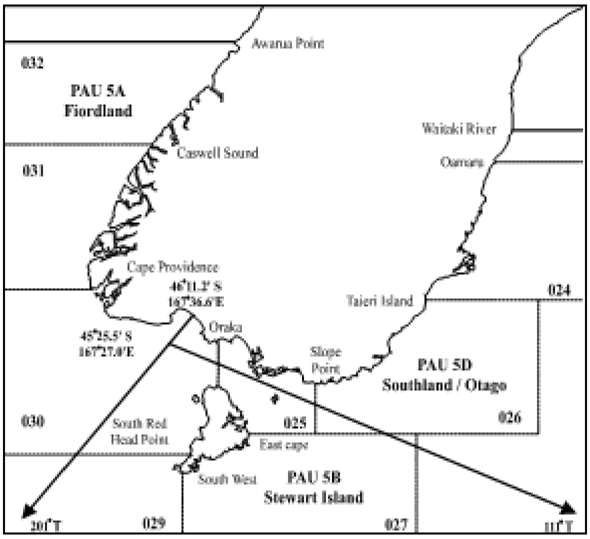
Schiel, D R (1992) The paua (abalone) fishery of New Zealand. *In:* Shepherd, S A; Tegner, M J; Guzman del Proo, S (Eds.), *Abalone of the World: Biology, fisheries, and culture.* Blackwell Scientific, Oxford.

Schiel, D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris. Fishery Bulletin* 89: 681–691.

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A. 37 p. (Unpublished report held by Ministry for Primary Industries.)

PAUA (PAU 5A) – Fiordland

(Haliotis iris)
Paua



1. FISHERY SUMMARY

Prior to 1995, PAU 5A was part of the PAU 5 QMA, which was introduced into the QMS in 1986 with a TACC of 445 t. As a result of appeals to the Quota Appeal Authority, the TACC increased to 492 t in the 1991–92 fishing year; PAU 5 was then the largest QMA by number of quota holders and TACC. Concerns about the status of the PAU 5 stock led to a voluntary 10% reduction in the TACC in 1994–95. On 1 October 1995, PAU 5 was divided into three QMAs (PAU 5A, PAU 5B, and PAU 5D; see the figure above) and the TACC was divided equally among them; the PAU 5A quota was set at 148.98 t.

There is no TAC for PAU 5A (Table 1): before the Fisheries Act (1996) a TAC was not required. When changes have been made to a TACC after 1996, stocks have been assigned a TAC. No allowances have been made for customary, recreational or other mortality

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 5 and PAU 5A since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1991*	-	-	-	-	445
1991–1994*	-	-	-	-	492
1994–1995*	-	-	-	-	442.8
1995–present	-	-	-	-	148.98

*PAU 5 TACC figures

1.1 Commercial fisheries

The fishing year runs from 1 October to 30 September.

On 1 October 2001 it became mandatory to report catch and effort on Paua Catch Effort Landing Returns (PCELRs) using fine-scale reporting areas that had been developed by the New Zealand Paua Management Company for their voluntary logbook programme (Figure 1).

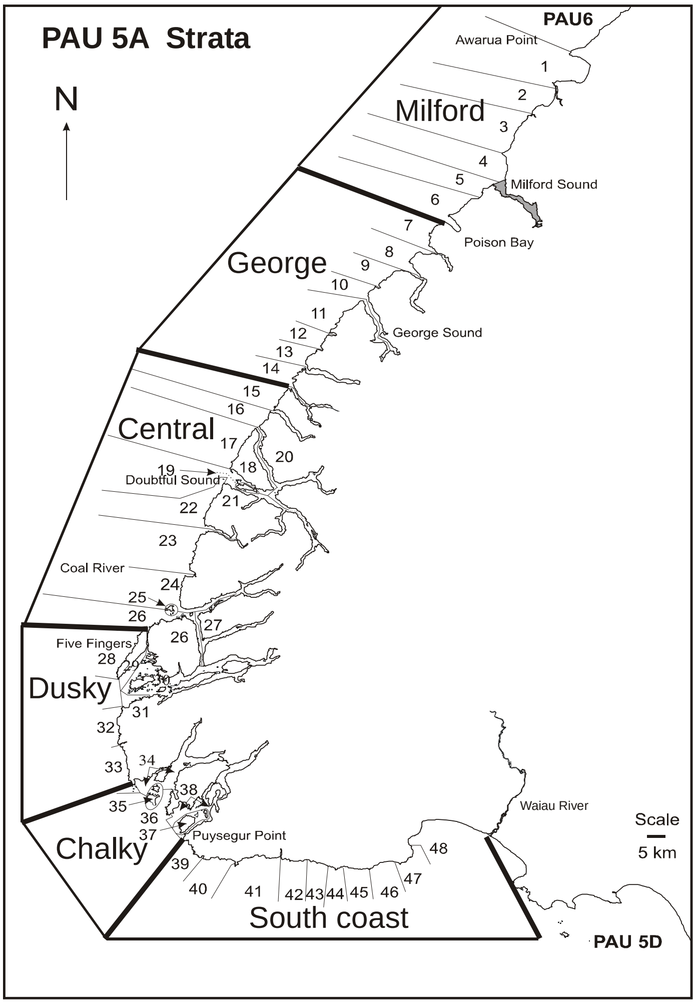


Figure 1: Map of paua statistical areas, and voluntary management strata in PAU 5A.

Landings for PAU 5A are shown in Table 2 and Figure 2. Landings for PAU 5 are reported in the introductory PAU Working Group Report.

Table 2: TACC and reported landings (t) of paua in PAU 5A from 1995–96 to the present from MHR returns.

Year	Landings	TACC
1995–96	139.53	148.98
1996–97	141.91	148.98
1997–98	145.22	148.98
1998–99	147.36	148.98
1999–00	143.91	148.98
2000–01	147.70	148.98
2001–02	148.53	148.98
2002–03	148.76	148.98
2003–04	148.98	148.98
2004–05	148.95	148.98
2005–06	148.92	148.98
2006–07	104.03	148.98
2007–08	105.13	148.98
2008–09	104.82	148.98
2009–10	105.74	148.98
2010–11	104.40	148.98
2011–12	106.23	148.98
2012–13	105.56	148.98
2013–14	102.30	148.98

1.2 Recreational fisheries

The National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates (2014), estimated about 0.42t of paua were harvested by recreational fishers in PAU 5A in 2011–12. For the purpose of the 2014 stock assessment, the SFWG agreed to assume that the recreational catch rose linearly from 1 t in 1974 to 5 t in 2006, and remained at 5 t between 2007 and 2013.

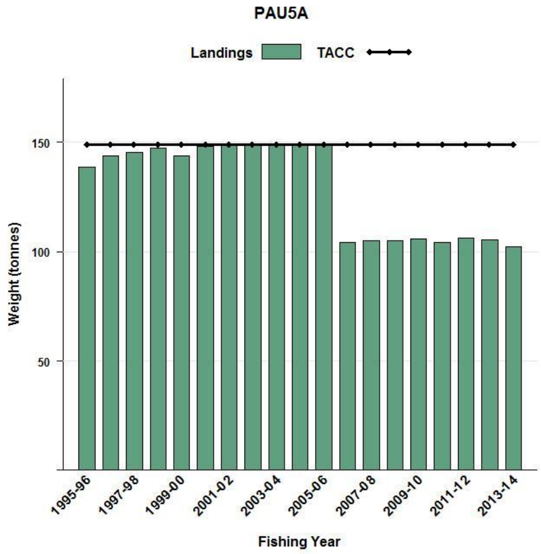


Figure 2: Landings and TACC for PAU 5A from 1995–96 to the present. For historical landings in PAU 5 prior to 1995–96, refer to Figure 1 and Table 1 in the introductory PAU Working Group Report.

1.3 Customary fisheries

Records of customary non-commercial catch taken under the South Island Regulations show that about 100 to 500 paua were collected each year from 2001–02 to 2012–13. For the purpose of the 2014 stock assessment model, the SFWG agreed to assume that customary catch has been constant at 1t.

1.4 Illegal catch

There are no estimates of illegal catch for PAU 5A. For the purpose of the 2014 stock assessment model, the SFWG agreed to assume that illegal catches have been a constant 5 t.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. Biological parameters derived using data collected from PAU 5A are summarised in Table 3. Size-at-maturity, natural mortality and annual growth increment parameters were estimated within the assessment model.

Table 3: Estimates of biological parameters (*H. iris*). All estimates are external to the model.

Stock area		Estimate	Source
<u>1. Weight = a (length)^b (weight in kg, shell length in mm)</u>			
PAU 5A	a = 2.99E-08	b = 3.303	Schiel & Breen (1991)
<u>2. Size at maturity (shell length)</u>			
PAU 5A	50% mature	93 mm	Samples from Dusky, George, and Milford areas (Fu et al 2010)
	95% mature	109 mm	
<u>3. Estimated annual growth increments (both sexes combined)</u>			Samples from Central, Dusky, George, Chalky and the South Coast (Fu et al 2010)
PAU 5A	At 75 mm	25.2 mm	
	At 120 mm	6.9 mm	

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. STOCK ASSESSMENT

Prior to 2010, stock assessments for PAU 5A had been carried out at the QMA level. In 2010 the Shellfish Working Group decided to split PAU 5A into two subareas (the southern area which included the Chalky and South Coast strata, and the northern area which included the Milford, George, Central, and Dusky strata (Figure 1)) and conduct separate stock assessments in each subarea. The division was based on the availability of data, differences in exploitation history and management initiatives. The 2014 assessment followed the same decision.

4.1 Estimates of fishery parameters and abundance

Parameters estimated in the base case model (for both the southern and northern areas) and their assumed Bayesian priors are summarized in Table 4.

Table 4: A summary of estimated model parameters, lower bound, upper bound, type of prior, (U=uniform; N= normal; LN=lognormal), mean and CV of the prior.

Parameter	Prior	μ	CV	Bounds	
				Lower	Upper
ln($R0$)	U	–	–	5	50
M (natural mortality)	LN	0.1	0.35	0.01	0.5
g_{max} (maximum growth increment)	U	–	–	1	50
$g_{50\%}$ (length at which the annual increment is half the maximum)	U	–	–	1	150
$g_{50\text{-}95\%}$ (difference in length at 50% and 95% of the maximum increment)	U	–	–	0.01	150
φ (CV of mean growth)	U	–	–	0.001	1
Ln(q^I) (catchability coefficient of CPUE)	U	–	–	-30	0
Ln(q^J) (catchability coefficient of PCPUE)	U	–	–	-30	0
L_{50} (Length at 50% maturity)	U	–	–	70	145
$L_{95\text{-}50}$(Length between 50% and 95% maturity)	U	–	–	1	50
D_{50}(Length at 50% selectivity for the commercial catch)	U	–	–	70	145
$D_{95\text{-}50}$(Length between 50% and 95% selectivity for the commercial catch)	U	–	–	0.01	50
D_s(change in commercial diver selectivity for one unit change of MHS)	U	–	–	0.01	50

For both assessments, the following observational data were included:

1. Standardised CPUE series covering 1990–2001 based on CELR data.
   Standardised CPUE series covering 2002–2014 based on PCELR data.
2. Commercial catch sampling length frequency series for 1992–1994, 1998, 2001–2014
3. Tag-recapture length increment data (all areas combined).
4. Maturity at length data (all areas combined)

4.1.1 Relative abundance estimates from standardised CPUE analyses

The 2014 stock assessment used two sets of standardised CPUE indices: one based on CELR data covering 1990–2001, and another based on PCELR data covering 2002–2014. For both series, standardised CPUE analyses were carried out using Generalised Linear Models (GLMs). A stepwise procedure was used to select predictor variables, with variables entering the model in the order that gave the maximum decrease in the residual deviance. Predictor variables were accepted in the model only if they explained at least 1% of the deviance.

For both the CELR and PCELR data, the Fisher Identification Number (FIN) was used in the standardisations instead of vessel identification. This process was followed because the FIN is associated with a permit holder who may employ a suite of grouped vessels, which implies that there could be linkage in the catch rates among vessels operated under a single FIN.

For the CELR data there is ambiguity in what is recorded for estimated daily fishing duration. On many CELR forms it is unclear if the hours of diving recorded is the total time each individual diver spent harvesting, or the total time spent harvesting by all divers. Because of this daily fishing duration has not been used in past standardisations as a measure of effort, instead the number of divers has been used. However, there is evidence that the fishing duration for a diver changes over time, and because of this a new data set was generated for which the recorded fishing duration was less ambiguous. This was done by combining a subset of the data for which the recorded daily duration was predominantly total hours of diving *for all* divers, with the rest of the data in which the daily fishing duration was incorrectly recorded as hours *per diver* (and scaling the hours recorded by the number of divers to get the correct daily fishing duration *for all* divers). The criteria used to subset the data were: (i) just one diver or (ii) fishing duration >= 8 hours and number of divers >= 2. The new combined data set was used for the CELR standardisation using estimated daily catch, and effort as either number of divers or estimated fishing duration (both were offered to the standardisation model).

For the PCELR data the unit of catch was diver catch, with effort as diver duration.

FIN codes were used to select a core group of fishers from the CELR data, with the requirement to qualify for the core fisher group that there be a minimum of 5 records per year for a minimum of 2 years (northern area), or a minimum of 5 records per year for a minimum of three years (southern area). In both cases 80% of the catch was retained over 1990–2001. For the PCELR data the FIN was also used to select a core group of fishers, with the requirement that there be a minimum of 10 records per year for a minimum of 6 years (northern area), or a minimum of 10 records per year for a minimum of 4 years (southern area). This retained 83% (northern area) or 85% (southern area) of the catch over 2002–2014.

For the CELR data, year was forced into the model and other predictor variables offered to the model were FIN, statistical area month, fishing duration (as a cubic polynomial), number of divers, and a month:area interaction. For the PCELR data fishing year was forced into the model and variables offered to the model were month, diver key, FIN statistical area, diver duration (third degree polynomial), and diving conditions.

The northern area standardised CPUE shows fluctuation with no real trend from 1990 to 2001, and is flat from 2002 to 2014 (Figure 3-top). The southern area standardised CPUE shows a decline from 1990 to 2008, then an increase from 2009 to 2014 (Figure 3-bottom).

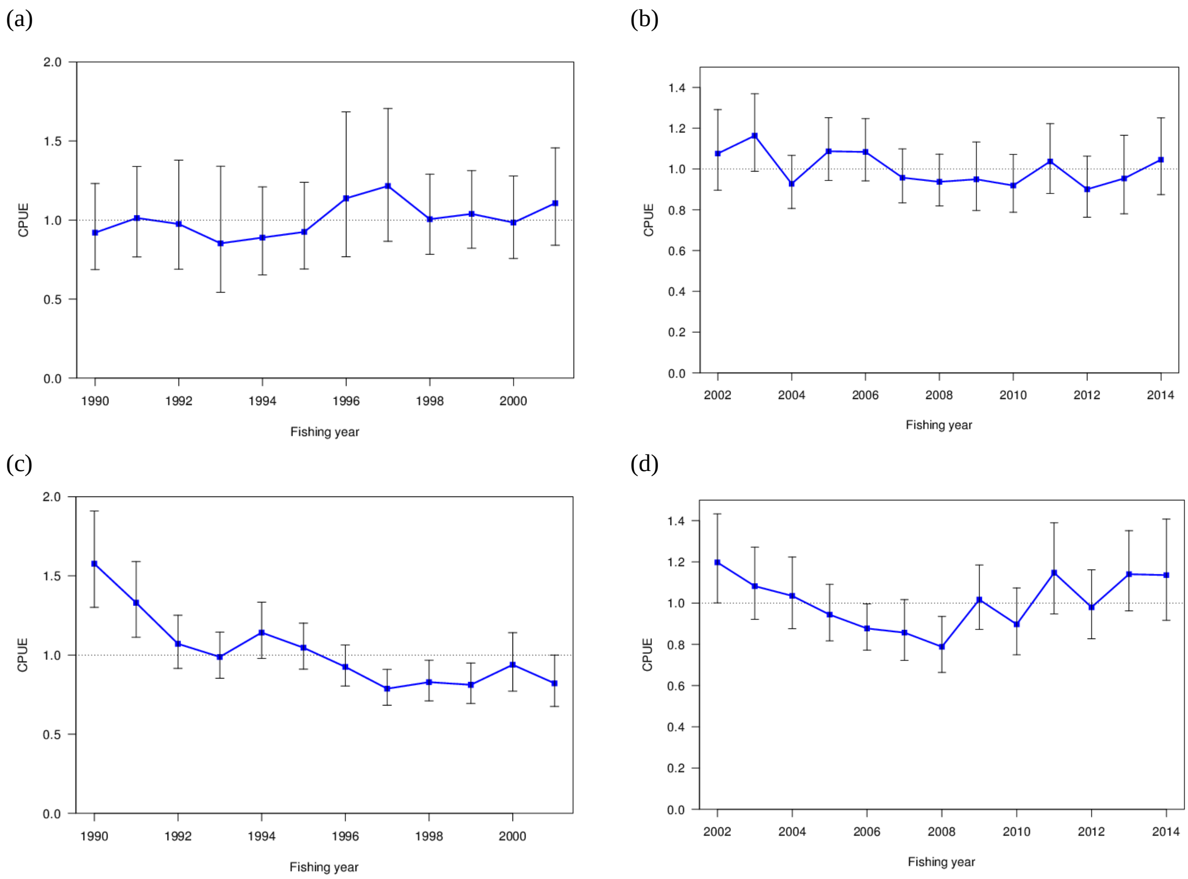


Figure 3: Standardised CPUE indices for the northern area of PAU 5A based on the CELR 1990–2001 (a) and PCELR 2002–2014 (b) and for the southern area based on CELR 1990–2001 (c) and PCELR 2002–2014 (d).

4.1.2 Relative abundance estimates from research diver surveys

The abundance of paua in PAU 5A was also estimated from research diver surveys in 1996, 2002, 2003, 2006, and 2008–2010. Not every stratum was surveyed in each year, and before 2005–06 surveys were conducted only in the area from Dusky South. These data were not included in the assessment because there is concern that the data are not a reliable index of abundance

Concerns about the reliability of this data as an estimate of relative abundance instigated several reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed i) the reliability of the research diver survey index as a proxy for abundance and ii) whether the Research Diver Survey Index (RDSI), when used in the paua stock assessment models, results in model outputs that do not adequately reflect the status of the stocks. Both reviews suggest that outputs from paua stock assessments using the RDSI should be treated with caution. For a summary of the conclusions from the reviews refer to the introductory PAU Working Group Report.

4.2 Stock assessment methods

The 2014 assessment for the southern and northern areas of PAU 5A (Fu 2015a, b) incorporated revision of the length-based model used in 2010 for PAU 5A (Fu & McKenzie 2010a, 2010b) and used in revised form for subsequent assessment in PAU 5D (Fu 2013) and PAU 5B (Fu 2014) For more information on the model structure and the data used refer to Fu et al. (2015) and Fu (2015a, b).

The model structure assumed a single-sex population residing in a single homogeneous area, with length classes from 70 mm to 170 mm in groups of 2 mm. Growth is length-based, without reference to age, mediated through a growth transition matrix that describes the probability of each length class to change at each time step. Paua entered the partition following recruitment and were removed by natural mortality and fishing mortality.

The model simulates the population from 1965 to 2014. Catches were available for 1974–2014 although catches before 1995 must be estimated from the combined PAU 5 catch, and were assumed to increase linearly between 1965 and 1973 from 0 to the 1974 catch level. Catches included commercial, recreational, customary, and illegal catch, and all catches occurred within the same time step. It was assumed that 80% of the non-commercial catch was taken from the southern area of PAU 5A, with the remainder being taken from the northern area

Recruitment was assumed to take place at the beginning of the annual cycle, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. No explicit stock-recruitment relationship was modelled in previous assessments; however, the Shellfish Working Group agreed to use a Beverton-Holt stock-recruitment relationship with steepness (h) of 0.75 for this assessment.

Maturity is not required in the population partition but is necessary for estimating spawning biomass. The model estimated proportions mature from length-at-maturity data. Growth and natural mortalities were also estimated within the model. The model estimated the commercial fishing selectivity, assumed to follow a logistic curve and to reach an asymptote. The increase in Minimum Harvest Size between since 2006 was modelled as an annual shift in fishing selectivity, which is equal to an annualised unit increase (estimated within the model), multiplied by the number of units associated with each year.

The assessment was conducted in several steps. First, the model was fitted to the data with parameters estimated at the mode of their joint posterior distribution (MPD). The fit obtained is the mode of the joint posterior distribution of parameters (MPD). Next, from the resulting fit, Markov chain-Monte Carlo (MCMC) simulations were made to obtain a large set of samples from the joint posterior distribution. From this set of samples, forward projections were made to obtain a set of agreed indicators. Sensitivity trials were explored by comparing MPD fits made with alternative model assumptions.

For the Southern area the commercial catch history estimates were made under assumptions about the split of the catch between sub-stocks of PAU 5, and between subareas within PAU 5A. The base case model run has assumed 40% of the catch in Statistical Area 030 was taken from PAU 5A between 1985 and 1996. Estimates made under alternative assumptions (a lower bound of 18% and an upper bound of 61%) were used in sensitivity trials. The maturity and growth data included in the model were based on samples collected throughout PAU 5A, and the abundance and length frequency data were from Chalky and South Coast. Catch samples before 2002 (1992–1994, 1998, and 2001) were excluded from the base case, because the sample size is low and sampling coverage is dubious. The base case also used the methods recommended by Francis (2012) to determine the weight of the proportion-at-length and abundance data, and used the inverse-logistic growth model. The RDSI and RDLF were excluded from the base case, and the CPUE shape parameter was fixed at 1 assuming a linear relationship between CPUE and abundance. Recruitment deviations were estimated for 1986–2010.

For the Northern area the commercial catch history estimates between 1984 and 2010 were based on reported catch from Statistical Area 031 and 032, and estimates before 1984 were made using assumptions about the split of the catch between subareas within PAU 5A. The split proportions were inferred from the total estimated catch between 1984 and 1995 from Statistical Areas 030, 031, and 032, assuming that 18% (upper bound), 40% (base case), or 61% (lower bound) of the annual catch in 030 was taken from PAU 5A. The catch vector estimated under the base case assumption was used in the base case model. The maturity and growth data included in the model were based on samples collected throughout PAU 5A, and the abundance and length frequency data were from Milford, George, Central, and Dusky. Catch samples collected before 2002 (1992, 1993, 1998, 2000, and 2001) were excluded from the base case. The base case also used the methods recommended by Francis (2012) to determine the weight of the proportion-at-length and abundance data, and used the inverse-logistic growth model. The RDSI and RDLF were excluded from the base case and the CPUE shape parameter was fixed at 1. Recruitment deviations were estimated for 1986–2010.

The following sensitivities were conducted for both the Southern and Northern areas. Run 1.6 used the SDNRs-based method to determine the weights of the proportion-at-length and abundance data; Run 1.7 included all the commercial length frequencies; Run 2.0 included the RDSI and RDLF data. For the Southern area, two additional sensitivities were conducted: Run 1.8 used commercial catch history that was estimated under “assumption 1” (between 1984 and 1996, 18% of the catch in Statistical Area 030 was taken from PAU 5A); Run 1.9 used commercial catch history estimated under “assumption 3” (between 1984 and 1996, 61% of the catch in Statistical Area 030 was taken from PAU 5A); For both assessments, The MCMC runs were carried out on models 1.5 (base case), 1.6, and 1.7.

The assessment calculates the following quantities from their posterior distributions: the equilibrium spawning stock biomass assuming that recruitment is equal to the average recruitment from the period for which recruitment deviation were estimated (B_0,), the mid-season spawning and recruited biomass for 2014 (B_{2014} and B^r_{2014}) and for the projection period (B_{proj} and B^r_{proj}). This assessment also reports the following fishery indictors:

- $B\%B_0$ — Current or projected spawning biomass as a percentage of B_0
- $B\%B_{msy}$ — Current or projected spawning biomass as a percentage of B_{msy}
- $\Pr(B_{proj} > B_{msy})$ — Probability that projected spawning biomass is greater than B_{msy}
- $\Pr(B_{proj} > B_{2014})$ — Probability that projected spawning biomass is greater than $B_{current}$
- $B\%B^r_0$ — Current or projected recruited biomass as a percentage of B^r_0
- $B\%B^r_{msy}$ — Current or projected recruited biomass as a percentage of B^r_{msy}
- Ucurrent — Current Exploitation
- $U_{40\%B0}$ — Exploitation that will achieve 40%B0
- MSY — Maximum Sustainable Yield
- $\Pr(B_{proj} > B^r_{msy})$ — Probability that projected recruit-sized biomass is greater than B^r_{msy}
- $\Pr(B_{proj} > B^r_{2012})$ — Probability that projected recruit-sized biomass is greater than B^r_{2012}
- $\Pr(B_{proj} > 40\%B_0)$ — Probability that projected spawning biomass is greater than 40% B_0
- $\Pr(B_{proj} < 20\%B_0)$ — Probability that projected spawning biomass is less than 20% B_0

- $\Pr(B_{proj} < 10\% B_0)$ Probability that projected spawning biomass is less than 10% B_0
- $\Pr(U_{proj} > U_{40\% B0})$ Probability that projected exploitation rate is greater than $U_{40\% B0}$

4.2.1 Stock assessment results

Southern Area

The base case fitted the two CPUE indices and the CSLF well, but the model predicted a broader distribution than the observed LF for a number of years. The use of the inverse-logistic growth model produced an adequate fit to the tag-recpature data. The estimates of recruitment deviations showed a period of relatively high recruitment in the mid-1990s and also in the 2000s. Estimated exploitation rates have declined since 2002, but have increased slightly over the last few years

The summaries of indicators from the base case are shown in Table 5. The median of the posterior of B_0 was estimated to be 1381 t. The posterior trajectory of spawning stock biomass is shown in Figure 4. Current estimates from the base case suggested that the spawning stock population in 2014 (B_{current}) was 41% (33–50%) B_0, and recruit-sized stock abundance ($B^r_{cureent}$) was 32% (24–41%) of the initial state (B^r_0).

When the CSLF data were up-weighted (MCMC 1.6), $B_{current}$ was estimated to be 35% (30–41%) of B_0. This model fitted less adequately to the tag-recapture data, with some negative bias for the larger size classes. Model results from the MCMC 1.7 were very similar to the base case and $B_{current}$ was estimated to be 42% (33–52%) B_0.

The assessment results were sensitive to the alternative catch history estimates. MPD estimates of $B_{current}$ were 34% and 46% B_0 when the upper and lower bound catch estimates were assumed, respectively.

Table 5: Summaries of the marginal posterior distributions of indicators for the base case of the southern area assessment. Columns show the 5th and 95th quantiles, median, minimum and maximum of each distribution. Biomass is in tonnes.

	Min	5%	Median	95%	Max
B_0	1135	1264	1381	1522	1765
B_{msy}	310	341	373	411	482
$B_{current}$	311	433	561	745	1153
$B_{current}/B_0$	0.25	0.33	0.41	0.50	0.68
$B_{current}/B_{msy}$	0.89	1.22	1.51	1.87	2.57
B_{msy}/B_0	0.26	0.26	0.27	0.28	0.28
B^r_0	975	1108	1228	1366	1559
B^r_{msy}	142	176	211	250	298
$B^r_{current}$	190	283	385	531	839
$B^r_{current}/B^r_0$	0.17	0.24	0.32	0.41	0.57

Table 5 [continued]

$B^r_{current} / B^r_{msy}$	0.87	1.34	1.83	2.53	3.95
B^r_{msy} / B^r_0	0.13	0.15	0.17	0.19	0.21
MSY	47	52	57	65	86
U_{msy}	0.15	0.19	0.23	0.30	0.40
$U_{40\% B_0}$	0.09	0.11	0.13	0.16	0.20
$U_{current}$	0.05	0.08	0.11	0.15	0.21

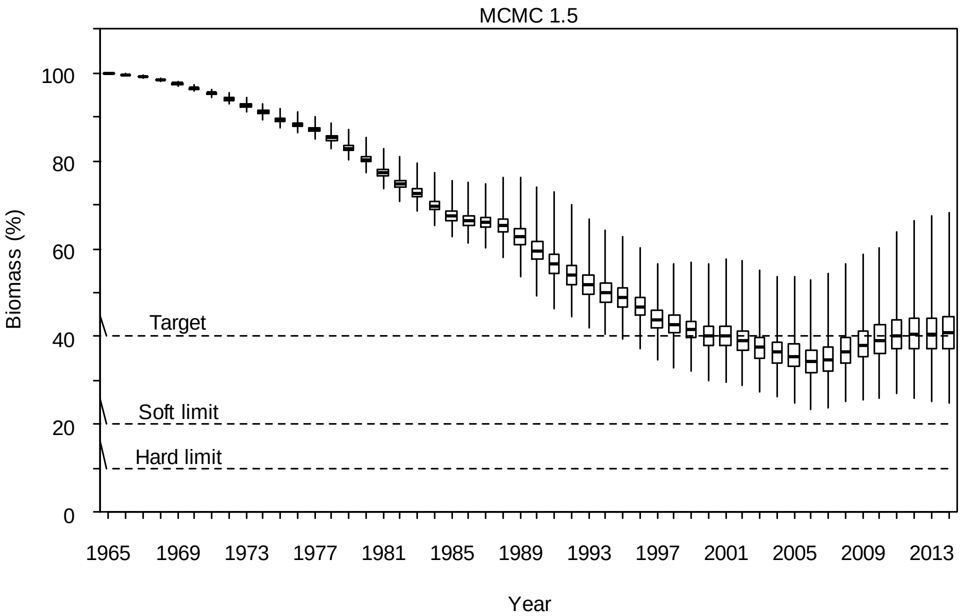


Figure 4: Posterior distributions of spawning stock biomass (including projection) as a percentage of *B_0* for the southern area assessment base case model. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

Northern area

The base case fitted the two CPUE indices well, but predicted more large paua in the length distributions than the observed LF for a number of years. The estimates of recruitment deviations showed a period of relatively high recruitment in the early 1990s and the early 2000s, but in most years, the recruitment was close to the long-term average. Estimated exploitation rates have declined since 2005.

The summaries of indicators from the base case for the northern area assessment are shown in Table 6. The median of the posterior of B_0 was estimated to be 1239 t. The posterior trajectory of spawning stock biomass is shown in Figure 5. Current estimates from the base case suggest that the spawning stock population in 2014 (B_{current}) was 47% (40–54%) B_0, and recruit-sized stock abundance ($B^r_{cureent}$) was 37% (31–45%) of the initial state (B^r_0).

When the CSLF data were up-weighted (MCMC 1.6), $B_{current}$ was estimated to be 39% (34–45%) B_0 . Model results from MCMC 1.7 were very similar to the base case, and $B_{current}$ was estimated to be 47% (39–55%) B_0 .

Table 6: Summaries of the marginal posterior distributions of indicators for the base case of the northern area assessment. Columns show the 5th and 95th quantiles, median, minimum and maximum of each distribution. Biomass is in tonnes.

	Min	5%	Median	95%	Max
B_0	1058	1144	1239	1359	1565
B_{msy}	286	307	332	363	413
$B_{current}$	383	472	576	717	958
$B_{current}/B_0$	0.34	0.40	0.47	0.54	0.62
$B_{current}$ / B_{msy}	1.27	1.49	1.74	2.03	2.35
B_{msy}/B_0	0.26	0.26	0.27	0.27	0.27
B_0^r	844	935	1026	1132	1276
B_{msy}^r	104	130	158	187	219
$B_{current}^r$	246	300	380	489	669
$B_{current}^r/B_0^r$	0.25	0.31	0.37	0.45	0.54
$B_{current}^r$ / B_{msy}^r	1.43	1.87	2.42	3.21	4.57
B_{msy}^r/B_0^r	0.11	0.14	0.15	0.17	0.19
MSY	62	66	73	83	101
U_{msy}	0.25	0.32	0.39	0.50	0.66
$U_{40\%B_0}$	0.14	0.17	0.21	0.25	0.31
$U_{current}$	0.09	0.12	0.16	0.20	0.24

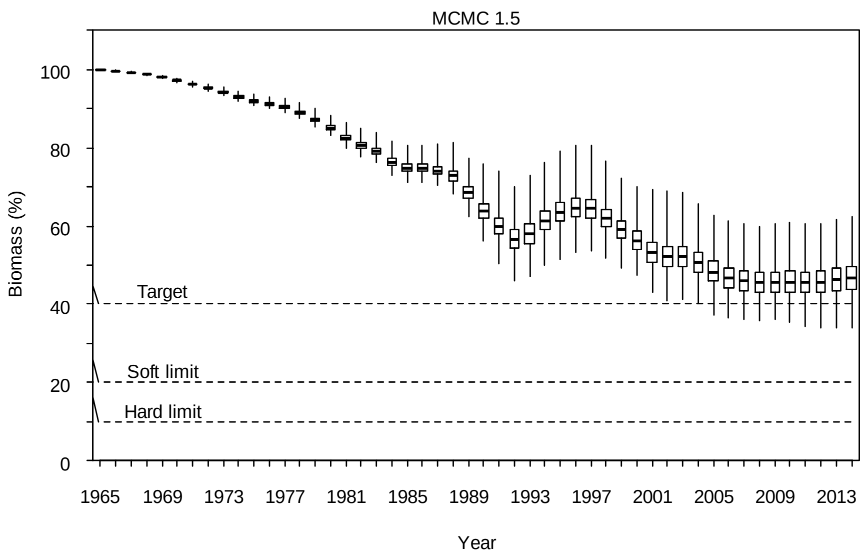


Figure 5: Posterior distributions of spawning stock biomass as a percentage of *B0* for the northern area assessment base case model. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

4.3 Yield estimates and projections

Southern Area

Assuming that the future catch remains at its current level, projections suggested that the spawning stock abundance will increase to 48% (0.38–0.61) over the next three years, and the probability of the spawning biomass being above the target (40%) will increase from 55% in 2014 to 67% in 2017 (Table 7). Assuming a 10% increase in the catch, the biomass will only increase slightly over the next three years; assuming a 20% increase in catch; the projected biomass will remain relatively stable.

Table 7: Summary of key indicators from the projection for the base case (1.5) MCMC of the southern area assessment with future commercial catch assumed to be the same the current catch: projected biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass.

	2014	2015	2016	2017
$B_{proj}\%B_0$	0.41 (0.32–0.53)	0.41 (0.32–0.54)	0.42 (0.32–0.55)	0.43 (0.32–0.56)
$B_{proj}\%B_{msy}$	1.51 (1.17–1.95)	1.53 (1.18–1.98)	1.56 (1.19–2.03)	1.58 (1.19–2.07)
$\Pr(>B_{msy})$	1.00	1.00	1.00	1.00
$\Pr(>B_{current})$	0.00	0.84	0.81	0.81
$\Pr(>40\%B_0)$	0.55	0.60	0.64	0.67
$\Pr(<20\%B_0)$	0.00	0.00	0.00	0.00
$\Pr(<10\%B_0)$	0.00	0.00	0.00	0.00
$\%B_0^r$	0.32(0.23–0.43)	0.32 (0.23–0.44)	0.33 (0.24–0.44)	0.33 (0.24–0.45)
$\%B_{msy}^r$	1.83 (1.27–2.70)	1.86 (1.27–2.77)	1.89 (1.28–2.82)	1.92 (1.30–2.85)
$\Pr(>B_{msy}^r)$	1.00	1.00	1.00	1.00
$\Pr(>B_{current}^r)$	0.00	0.72	0.80	0.90
$\Pr(U_{proj}>U_{40\%B0})$	0.14	0.08	0.04	0.02

Northern area

Assuming that the future catch remains at current level the projection suggested that the spawning stock abundance will remain relatively stable over the next three years, and the projected biomass in 2017 was 47% B_0 (Table 8). The probability of the spawning biomass in 2017 being above the target (40% B_0) was greater than 90%, and the stock status is very unlikely to be below the soft (20% B_0) or hard limit (10%B0) in the short term. Assuming a 10% increase in the annual catch, the projected biomass will decrease slightly over the next three years, and the projected biomass in 2017 was 46% B_0. Assuming a 20% increase in annual catch, the projected biomass decreased to 44% in 2017.

Table 8: Summary of key indicators from the projection for the base case (1.5) MCMC of the northern area assessment with future commercial catch assumed to be the same the current catch: projected biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass.

	2014	2015	2016	2017
$B_{proj}\%B_0$	0.47 (0.39–0.56)	0.47 (0.39–0.56)	0.47 (0.39–0.56)	0.47 (0.38–0.57)
$B_{proj}\%B_{msy}$	1.74 (1.46–2.08)	1.74 (1.45–2.08)	1.74 (1.44–2.10)	1.75 (1.41–2.13)
$\Pr(>B_{msy})$	1.00	1.00	1.00	1.00
$\Pr(>B_{current})$	0.00	0.48	0.47	0.50
$\Pr(>40\%B_0)$	0.95	0.95	0.94	0.92
$\Pr(<20\%B_0)$	0.00	0.00	0.00	0.00
$\Pr(<10\%B_0)$	0.00	0.00	0.00	0.00
$\%B_0^r$	0.37 (0.30–0.47)	0.32 (0.25–0.41)	0.32 (0.25–0.41)	0.32 (0.24–0.41)
$\%B_{msy}^r$	2.42 (1.81–3.36)	2.10 (1.54–2.93)	2.10 (1.51–2.95)	2.09 (1.50–2.96)
$\Pr(>B_{msy}^r)$	1.00	1.00	1.00	1.00
$\Pr(>B_{current}^r)$	0.00	0.00	0.00	0.00
$\Pr(U_{proj}>U_{40\%B0})$	0.07	0.08	0.09	0.09

4.5 Other factors

A number of factors affected the overall validity of the assessment.

There were uncertainties in the estimated catch history for PAU 5A and its subareas before 1995. The results from the southern area assessment suggested that estimates of stock status are sensitive to the range of assumptions made for the estimated catch history. Between the lower-bound and upper-bound catch estimates, model estimates of current spawning stock status ranged from 34 to 46% B_0. For the northern area of PAU 5A, the commercial catch history is well determined back to 1984, although uncertainty exists for the pre-1984 catch, which is expected to have minor effects on the overall assessment. There is little information on the historical catches in Fiordland, but anecdotal evidence suggested that the catch between 1981 and 1984 was about 60–70 t annually (Storm Stanley pers. comm.). The lower and upper-bound catch estimates used in the assessment may have encompassed many of the uncertainties in the historical catches. In addition, non-commercial catch estimates are also very uncertain, and large differences may exist between the catches assumed and the catch actually taken. In both assessments, the modelled area is treated as if it were a single stock with homogeneous biology, habitat and fishing pressure. It is assumed that:

- recruitment affects the modelled area in the same way;
- natural mortality does not vary by length or year in the modelled area;
- growth has the same mean and variance in the modelled area, although in reality growth may be stunted in some areas and fast in others.

The models showed some conflicts between length frequencies and CPUE. The early CPUE for the southern area showed a declining trend, indicating that large fish were probably being removed from the stock, which would most likely have resulted in a decline of mean length in the commercial catch over time. But this is not consistent with trend in the observed length distributions. A plausible explanation for this contradiction is that the commercial catch samples in the early years were unrepresentative of the fishery.

Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on increments observed in several different sites. Similarly, the length frequency data are integrated across samples from many places. An open question is whether a model fitted to data aggregated from a large area, within which smaller populations respond differently to fishing, results in credible estimates of the response of the aggregated sub-populations.

This effect is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others are not fished, recruitment failure can result due to the depletion of spawners, because spawners must breed close to each other, and because the dispersal of larvae may be limited. Recruitment failure is a common observation in abalone fisheries internationally. Local processes may decrease recruitment, an effect that cannot be accounted for in the current model.

A significant source of uncertainty is that fishing may cause spatial contraction of populations or that some populations become relatively unproductive after initial fishing due, for example, to reductions in density that may impede successful spawning. If this happens, the model will overestimate productivity in the population as a whole. Historical catches may have been interpreted in the model as good recruitments, whereas they may actually have been the result of serial depletion.

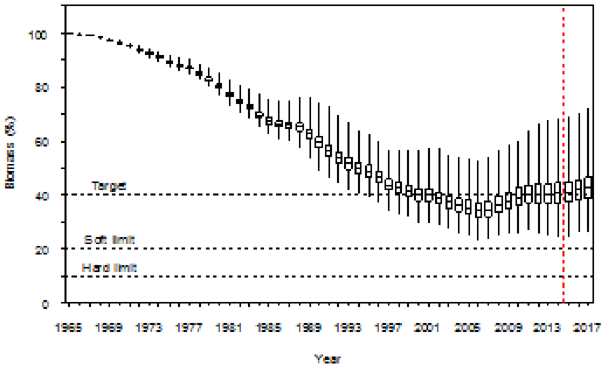
5. STATUS OF THE STOCKS

Stock Structure Assumptions
A genetic discontinuity between North Island and South Island paua populations was found approximately around the area of Cook Strait (Will & Gemmell 2008).

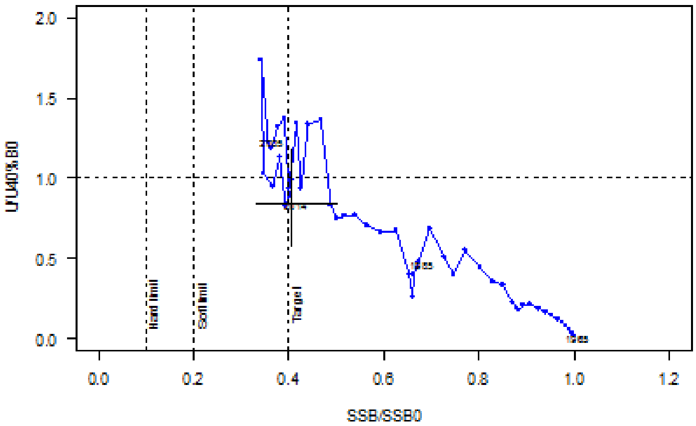
- **PAU 5A - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Southern Area: base case model (run 1.5) Northern Area: base case model (run 1.5)
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS) Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	Southern Area: B_{2014} was estimated at 41% (32–53%) B_0 Northern Area: B_{2014} was estimated at 47% (39–56%) B_0
Status in relation to Limits	Southern Area: B_{2014} is Very Unlikely (< 10%) to be below the soft and hard limits. Northern Area: B_{2014} is Very Unlikely (< 10%) to be below the soft limit and hard limits.
Status in relation to Overfishing	Southern Area: The fishing intensity in 2014 was Unlikely (< 40%) to be above the overfishing threshold Northern Area: The fishing intensity in 2014 was Very Unlikely (< 10%) to be above the overfishing threshold

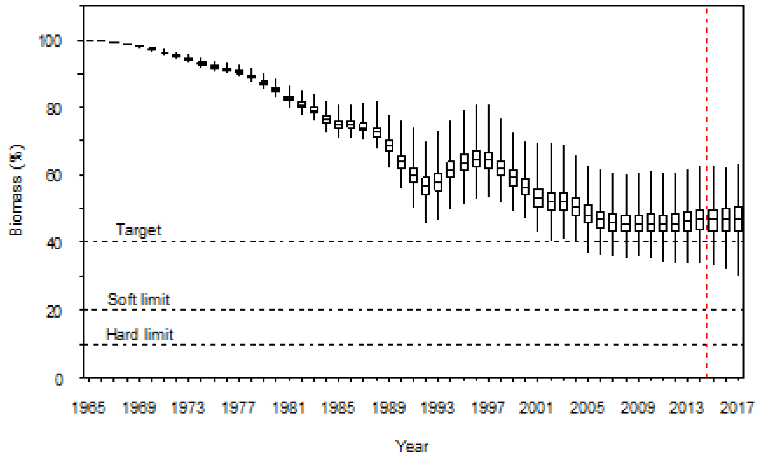
Historical Stock Status Trajectory and Current Status



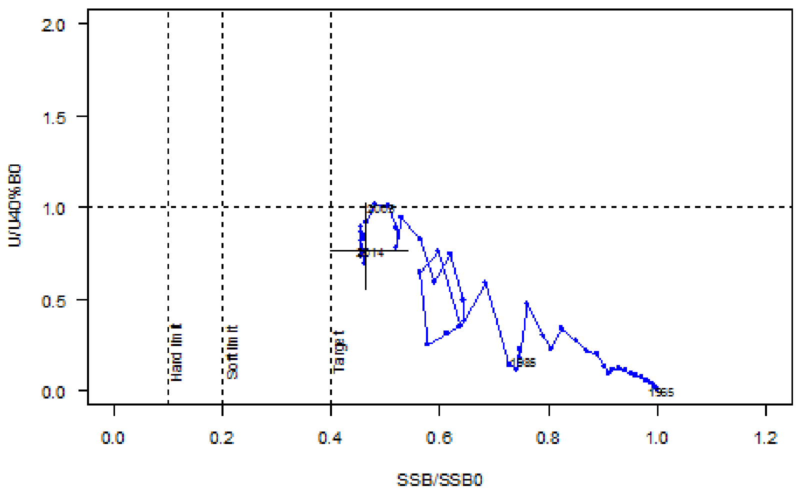
Posterior distributions from the base case model of spawning stock biomass (including projection) as a percentage of B_0 for the southern area assessment. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The boxes to the right of the dashed line indicate the projected spawning biomass to 2017 for each model assuming current catch level.



Trajectory of exploitation rate as a ratio of $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1965 to 2014 for the southern area base case model. The vertical lines at 10%, 20%, and 40% B_0 represent the hard limit, the soft limit, and the target respectively. $U_{\%40B0}$ is the exploitation rate at which the spawning stock biomass would stabilise at 40% B_0 over the long term. Each point on the trajectory represents the estimated annual stock status: the value on the x axis is the mid-season spawning stock biomass (as a ratio of B_0) and the value on the y axis is the corresponding exploitation rate (as a ratio $U_{\%40B0}$) for that year. The estimates are based on MCMC medians and the 2014 90% CI is shown by the cross line.



Posterior distributions from the base case model of spawning stock biomass (including projection) as a percentage of B_0 for the northern area assessment. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The boxes to the right of the dashed line indicate the projected spawning biomass to 2017 for each model assuming current catch level.



Trajectory of exploitation rate as a ratio of $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1965 to 2014 for the northern area base case model. The vertical lines at 10%, 20%, and 40% B_0 represent the hard limit, the soft limit, and the target respectively. $U_{\%40B0}$ is the exploitation rate at which the spawning stock biomass would stabilise at 40% B_0 over the long term. Each point on the trajectory represents the estimated annual stock status: the value on the x axis is the mid-season spawning stock biomass (as a ratio of B_0) and the value on the y axis is the corresponding exploitation rate (as a ratio of $U_{\%40B0}$) for that year. The estimates are based on MCMC medians and the 2014 90% CI is shown by the cross line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Southern Area: Spawning stock biomass has declined from the early years of the fishery up to 2007. Since 2007 biomass has been increasing. Northern Area: Spawning stock biomass has declined from the early years of the fishery up to 2007. Since 2007 the biomass has increased slightly.

Recent Trend in Fishing Intensity or Proxy	Southern Area: Exploitation rates have an overall declining trend since early 2000s, but have increased slightly over the last four years. Northern Area: Exploitation rates have declined since the mid-2000s.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Southern Area: At current levels of catch spawning stock biomass is projected to increase to 43% (32–56%) B_0 by 2017. If shelving is reduced by 20% spawning stock biomass is projected to remain stable at 41% (32–52%) of B_0 for the next 3 years. Northern Area: At current levels of catch spawning stock biomass is projected to remain unchanged at 47% (39–56%) B_0 for the next 3 years. If shelving is reduced by 10% spawning stock biomass is projected to decline to 46% (37–56%) B_0. If shelving is reduced by 20% spawning stock biomass is projected to decline to 44% (35–55%) B_0.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Southern Area: Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%) Northern Area current catch: Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Southern Area: Unlikely (< 40%) at current catch levels Unlikely (< 40%) if shelving reduced by 10% About as Likely as Not (40-60%) if shelving reduced by 20% Northern Area: Very Unlikely (< 10%) at current catch levels Unlikely (< 40%) if shelving reduced by 10% About as Likely as Not (40-60%) if shelving reduced by 20%

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian model	
Assessment Dates	Latest assessment: 2014	Next assessment: 2017
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch history - CPUE indices early series - CPUE indices later series - Commercial sampling	1 – High Quality for commercial catch 2 – Mixed or Medium Quality for customary catch 1. No data for recreational or illegal catch 2 – Medium or Mixed Quality: not believed to be fully representative of the entire QMA 1 – High Quality 2 – Medium or Mixed Quality: not believed to be fully representative of the entire QMA

	length frequencies - Tag recapture data (for growth estimation) - Maturity at length data	1 – High Quality 1 – High Quality
Data not used (rank)	- Research Dive Survey Indices - Research Dive Length Frequencies	3 – Low Quality: not believed to index the stock 3 – Low Quality: not believed to be representative of the entire QMA
Changes to Model Structure and Assumptions	-	
Major sources of Uncertainty	- *M* may not be estimated accurately. There is information in the data that has informed the estimation of *M* and the prior has also strongly influenced the estimate. - CPUE may not be a reliable index of abundance. - Any effect of voluntary increases in MHS may not have been adequately captured by the model, which could therefore be underestimating the spawning biomass in recent years.	

Qualifying Comments
-

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Andrew, N L; Naylor, J R; Gerring, P (1999) A modified timed-swim method for paua stock assessment. *New Zealand Fisheries Assessment Report 2000/4*. 23 p.

Andrew, N L; Naylor, J R; Kim, S W (2002) Fishery independent surveys of the relative abundance and size structure of paua (Haliotis iris) in PAU 5B and 5D. *New Zealand Fisheries Assessment Report 2002/41*. 41 p.

Breen, P.A., Andrew, N.L., & Kendrick, T.H. 2000: The 2000 stock assessment of paua (Haliotis iris) in PAU 5B using an improved Bayesian length-based model. New Zealand Fisheries Assessment Report 2000/48.36 p.

Breen, P A; Kim, S W (2004) The 2004 stock assessment of paua (*Haliotis iris*) in PAU 5A. *New Zealand Fisheries Assessment Report 2004/40*. 86 p.

Breen, P.A.; Kim, S.W.(2 005). The 2005 stock assessment of paua *(Haliotis iris)* in PAU *7*. New *Zealand Fisheries Assessment Report 2005/47. 114* p.

Breen, P A; Kim, S W (2007) The 2006 stock assessment of paua (*Haliotis iris*) stocks PAU 5A (Fiordland) and PAU 5D (Otago). *New Zealand Fisheries Assessment Report 2007/09*. 164 p.

Breen, P A; Kim, S W; Andrew, N L (2003) A length-based Bayesian stock assessment model for abalone. *Marine and Freshwater Research* 54(5): 619–634.

Breen, P A; Smith, A N H (2008) Data used in the 2007 assessment for paua (*Haliotis iris*) stock PAU 5B (Stewart Island). *New Zealand Fisheries Assessment Report 2008/6*. 45 p.

Chen, Y; Breen, P A; Andrew, N L (2000) Impacts of outliers and mis-specification of priors on Bayesian fish stock assessment. *Canadian Journal of Fisheries and Aquatic Science.* 57: 2293–2305.

Cordue, P L (2009) Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 report. 45 p.

Fu, D. (2015a) The 2014 stock assessment of paua (*Haliotis iris*) for Chalky and South Coast in PAU 5A. *New Zealand Fisheries Assessment Report 2015/xx.*

Fu, D. (2015b) The 2014 stock assessment of paua (*Haliotis iris*) for Milford, George, Central, and Dusky in PAU 5A. *New Zealand Fisheries Assessment Report 2015/xx.*

Fu, D. (2014) The 2013 stock assessment of paua (*Haliotis iris*) for PAU 5B. *New Zealand Fisheries Assessment Report 2014/45.*

Fu, D. (2013). The 2012 stock assessment of paua (Haliotis iris) for PAU 5D. *New Zealand Fisheries Assessment Report. 2013/57.*

Fu, D; McKenzie, A (2010a) The 2010 stock assessment of paua (*Haliotis iris*) for Chalky and South Coast in PAU 5A. *New Zealand Fisheries Assessment Report 2010/36*.

Fu, D; McKenzie, A (2010b) The 2010 stock assessment of paua (*Haliotis iris*) for Milford, George, Central, and Dusky in PAU 5A. *New Zealand Fisheries Assessment Report 2010/46*.

Fu, D; McKenzie, A; Naylor, R (2010) Summary of input data for the 2010 PAU 5A stock assessment. *New Zealand Fisheries Assessment Report 2010/35*.

Fu, D.; McKenzie, A; Naylor, R. (2015). Summary of input data for the 2014 PAU 5A stock assessment. *New Zealand Fisheries Assessment Report 2015*/xx.

Gerring, P K; Andrew, N L; Naylor, J R (2003) Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. *New Zealand Fisheries Assessment Report 2003/56*. 13 p.

Haist, V (2010) Paua research diver survey: review of data collected and simulation study of survey method. *New Zealand Fisheries Assessment Report 2010/38*.

Hart, A M (2005) Review of paua research surveys. Final Research Report to the Ministry of Fisheries for project SAP2005-02. 20 p (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Kendrick, T H; Andrew, N L (2000) Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5a, PAU 5B, and PAU 5D. *New Zealand Fisheries Assessment Report 2000/47*. 25 p.

McKenzie, A; Smith, A N H (2009) The 2008 stock assessment of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report 2009/34*. 84 p

Naylor, J R; Andrew, N L (2002) Determination of paua growth in PAU 2, 5A, 5B, and 5D. *New Zealand Fisheries Assessment Report. 2002/34*.

Naylor, J R; Breen, P A (2008) Fine-scale growth in paua populations. Final Research Report for Ministry of Fisheries Project PAU2006/04. 33 p. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Pirker, J G (1992) Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165 p.

Sainsbury, K J (1982) Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. *New Zealand Journal of Marine and Freshwater Research* 16: 147–161.

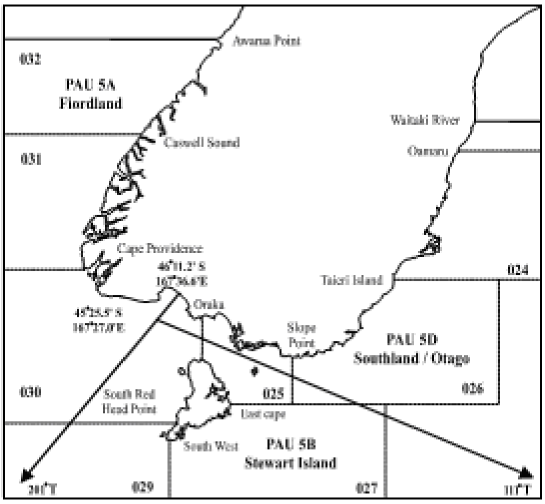
Schiel, D R (1992) The paua (abalone) fishery of New Zealand. *In:* Shepherd, S A; Tegner, M J; Guzman del Proo, S (Eds.) *Abalone of the World: Biology, fisheries, and culture*. Blackwell Scientific, Oxford.

Schiel, D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone (*Haliotis iris*). *Fishery Bulletin* 89: 681–691.

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

PAUA (PAU 5B) - Stewart Island

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

Before 1995, PAU 5B was part of the PAU 5 QMA, which was introduced into the QMS in 1986 with a TACC of 445 t. As a result of appeals to the Quota Appeal Authority, the TACC increased to 492 t in the 1991–92 fishing year; PAU 5 was then the largest QMA by number of quota holders and TACC. Concerns about the status of the PAU 5 stock led to a voluntary 10% reduction in the TACC in 1994–95. On 1 October 1995, PAU 5 was divided into three QMAs (PAU 5A, PAU 5B, and PAU 5D; see the figure above) and the TACC was divided equally among them; the PAU 5B TACC was set at 148.98 t.

On 1 October 1999 a TAC of 155.98 t was set for PAU 5B, comprising a TACC of 143.98 t (a 5 t reduction) and customary and recreational allowances of 6 t each. The TAC and TACC have been reduced twice since then and the current TAC is 105 t with a TACC of 90 t, customary and recreational allowances at 6 t each and an allowance of 3 t for other mortality (Table 1.)

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 5 and PAU 5B since introduction into the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1991*	-	-	-	-	445
1991–1994*	-	-	-	-	492
1994–1995*	-	-	-	-	442.8
1995–1999	-	-	-	-	148.98
1999–2000	155.9	6	6	-	143.98
2000–2002	124.87	6	6	-	112.187
2002–present	105	6	6	3	90

*PAU 5 TACC figures

1.1 Commercial fishery

The fishing year runs from 1 October to 30 September.

Concerns about the status of the stock led to the commercial fishers agreeing to voluntarily reduce their Annual Catch Entitlement (ACE) by 25t for the 1999/00 fishing year. This shelving continued for the 2000/01and 2001/02 fishing years at a level of 22 t but was discontinued at the beginning of the 2002/03 fishing year (Table 2).

On 1 October 2001 it became mandatory to report catch and effort on Paua Catch Effort Landing Returns (PCELRs) using fine-scale reporting areas that had been developed by the New Zealand Paua Management Company for their voluntary logbook programme (Figure 1).

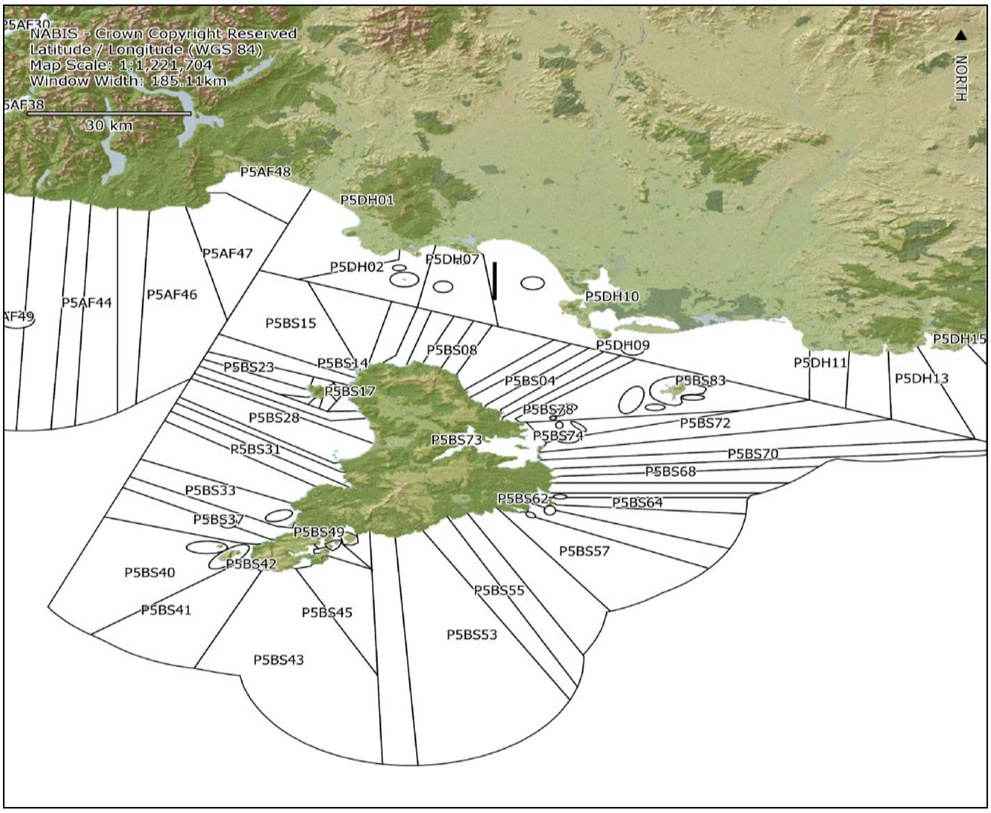


Figure 1: Map of fine scale statistical reporting areas for PAU 5B.

Landings for PAU 5B are shown in Table 2 and Figure 2. Landings for PAU 5 are reported in the introductory PAU Working Group Report.

Table 2: TACC and reported commercial landings (t) of paua in PAU 5B, 1995–96 to present, from QMR and MHR returns.

Year	Landings	TACC
1995–96	144.66	148.98
1996–97	142.36	148.98
1997–98	145.34	148.98
1998–99	148.55	148.98
1999–00	118.07	143.98
2000–01	89.92	112.19
2001–02	89.96	112.19
2002–03	89.86	90.00
2003–04	90.00	90.00
2004–05	89.97	90.00
2005–06	90.47	90.00
2006–07	89.16	90.00
2007–08	90.21	90.00
2008–09	90.00	90.00
2009–10	90.23	90.00
2010–11	89.67	90.00
2011–12	89.59	90.00
2012–13	90.58	90.00
2013-14	88.84	90.00

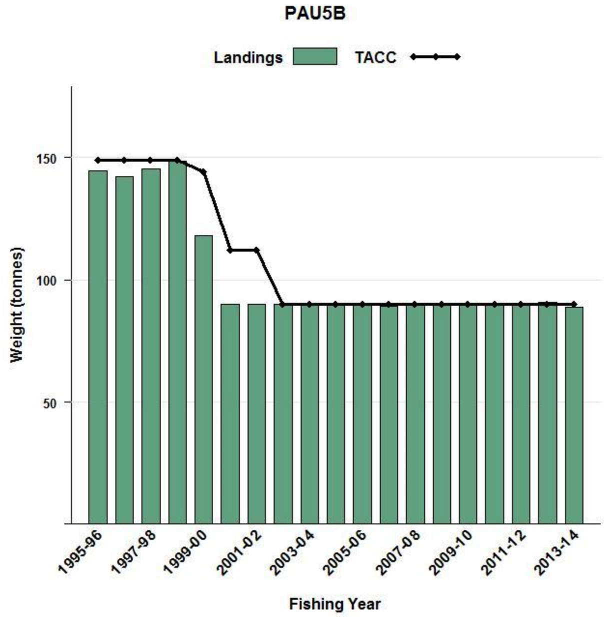


Figure 2: Reported commercial landings and TACC for PAU 5B from 1995–96 to present. For reported commercial landings in PAU 5 before 1995–96 refer to figure 1 and table 1 in the introductory PAU Working Group Report.

1.2 Recreational fisheries

The 'National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates' estimated that the recreational harvest for PAU 5B was 0.82 t with a CV of 50%. For the 2013 assessment, the SFWG agreed to assume that the recreational catch rose linearly from 1t in 1974 to 5 t in 2006, and remained at 5t between 2007 and 2013. For further information on recreational fisheries refer to the introductory PAU Working Group Report.

1.3 Customary fisheries

The SFWG agreed to assume for the 2013 assessment that customary catch has been 1 t for the whole period modelled. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

Illegal catch was estimated by the Ministry of Fisheries to be 15 t, but "Compliance express extreme reservations about the accuracy of this figure." The SFWG agreed to assume for the 2013 assessment that illegal catch was zero before 1986, then rose linearly from 1 t in 1986 to 5 t in 2006, and remained constant at 5 t between 2007 and 2013. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of biological parameters used in the PAU 5B assessment is presented in Table 3.

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report

Table 3: Estimates of biological parameters (*H. iris*).

		Estimate	Source
1. Natural mortality (M)		0.10 (CV 0.10)	Assumed prior probability distribution
2. Weight = a(length)^b (Weight in g, length in mm shell length).			
	All		
	a	b	
	2.99 x 10^{-5}	3.303	Schiel & Breen (1991)
3. Size at maturity (shell length)			
		50% maturity at 91 mm	Naylor (NIWA unpub. data)
		95% maturity at 133mm	Naylor (NIWA unpub. data)
4. Growth parameters (both sexes combined)			
	Growth at 75 mm	Growth at 120 mm	Median (5–95% range) of posterior distributions estimated by the assessment model
	26.1 mm (24.8 to 27.2)	6.9 mm (6.5–7.3)	

4. STOCK ASSESSMENT

The stock assessment was done with a length-based Bayesian estimation model, with parameter point estimates based on the mode of the joint posterior distribution and uncertainty estimated from marginal posterior distributions generated from Markov chain-Monte Carlo simulations. The most recent stock assessment was conducted in 2014 for the fishing year ended 30 September 2013. A base case model (0.1) was chosen from the assessment. The SFWG also suggested a sensitivity run (model 0.4) which assumed a uniform prior on *M* to explore the influence of this prior on the estimates of stock status.

4.1 Estimates of fishery parameters and abundance

Parameters estimated in the assessment model and their Bayesian prior distributions are summarized in Table 4.

Table 4: A summary of estimated model parameters, lower bound, upper bound, type of prior, (U, uniform; N, normal; LN = lognormal), mean and c.v. of the prior.

Parameter	Prior	μ	c.v.	Bounds	
				Lower	Upper
ln(*R0*)	U	–	–	5	50
M (natural mortality)	LN	0.1	0.35	0.01	0.5
g_1(Mean growth at 75 mm)	U	–	–	1	50
g2(Mean growth at 120 mm)	U	–	–	0.01	50
φ (*CV* of mean growth)	U	–	–	0.001	1
Ln(q^I) (catchability coefficient of CPUE)	U	–	–	-30	0
Ln(q^J) (catchability coefficient of PCPUE)	U	–	–	-30	0
L_{50} (Length at 50% maturity)	U	–	–	70	145
L_{95-50}(Length between 50% and 95% maturity)	U	–	–	1	50
D_{50}(Length at 50% selectivity for the commercial catch)	U	–	–	70	145
D_{95-50}(Length between 50% and 95% selectivity for the commercial catch)	U	–	–	0.01	50
ϵ (Recruitment deviations)	N	0	0.4	-2.3	2.3

The observational data were:
1. A 1990–2001 standardised CPUE series based on CELR data.
2. A 2002–2012 standardised CPUE series based on PCELR data.
3. A commercial catch sampling length frequency series for 1998, 2002–04, 07, 2009–2012.
4. Tag-recapture length increment data.
5. Maturity at length data

4.1.1 Relative abundance estimates from standardised CPUE analyses

The 2013 stock assessment used two sets of standardised CPUE indices: one based on CELR data covering 1990–2001, and another based on PCELR data covering 2002–2013. For both series, standardised CPUE analyses were carried out using Generalised Linear Models (GLMs). A stepwise procedure was used to select predictor variables, with variables entering the model in the order that gave the maximum decrease in the residual deviance. Predictor variables were accepted in the model only if they explained at least 1% of the deviance.

For both the CELR and PCELR data, the Fisher Identification Number (FIN) was used in the standardisations instead of vessel, because the FIN is associated with a permit holder who may employ a suite of grouped vessels, which implies that there could be linkage in the catch rates among vessels operated under a single FIN.

For the CELR data there is ambiguity in what is recorded for estimated daily fishing duration, and it has not been used in past standardisations as a measure of effort, instead the number of divers has been used. However, there is evidence that the fishing duration for a diver changes over time, and because of this a subset of the data was selected for which the recorded fishing duration was less ambiguous. The criteria used to subset the data were: (i) just one diver or (ii) fishing duration >= 8 hours and number of divers >=2. This data subset was used for the CELR standardisation using estimated daily catch and effort as either number of divers or estimated fishing duration (both were offered to the standardisation model).

For the PCELR data the unit of catch was diver catch, with effort as diver duration.

FIN codes were used to select a core group of fishers from the CELR data, with the requirement that there be a minimum of 5 records per year for a minimum of 2 years to qualify for the core fisher group. This retained 80% of the catch over 1990-2001. For the PCELR data the FIN was also used to select a core group of fishers, with the requirement that there be a minimum of 20 records per year for a minimum of 3 years. This retained 89% of the catch over 2002-2013.

For the CELR data year was forced into the model and other predictor variables offered to the model were FIN, statistical area (024, 025, 026, 030), month, fishing duration (as a cubic polynomial), number of divers, and a month:area interaction. For the PCELR data fishing year was forced into the model and variables offered to the model were month, diver key, FIN statistical area, diver duration (third degree polynomial), and diving conditions.

The standardised CPUE from the CELR data have a bump in 1991 but is relatively flat for the first four years, then declines to 40–50% of its initial level (Figure 3-top). The standardised CPUE from the PCELR data show a 60% increase from 2002 to 2013 (Figure 3-bottom).

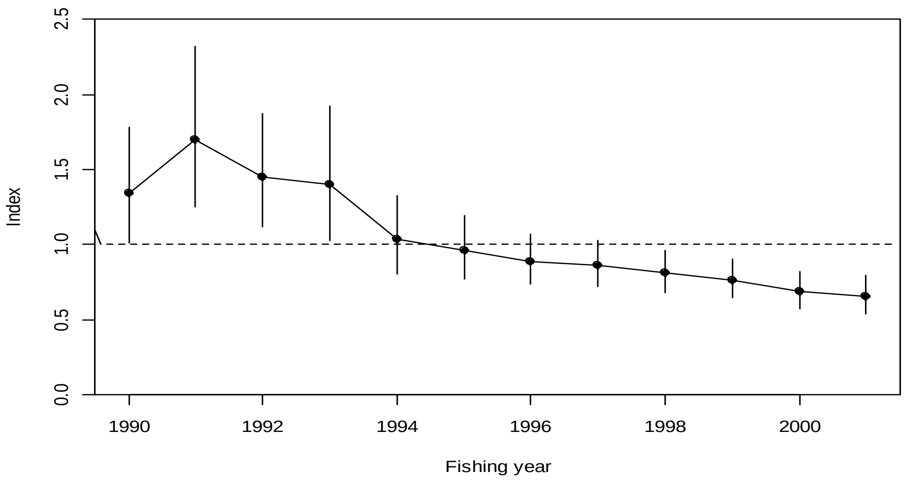


Figure 3: The standardised CPUE indices with 95% confidence intervals for the early CELR/FSU series **[Continued on next page].**

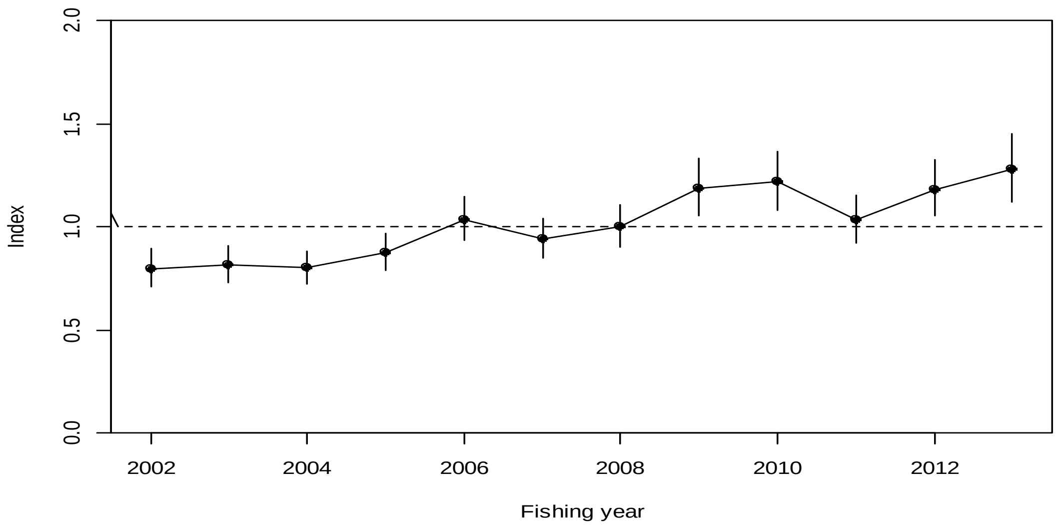


Figure 3 [Continued]: The standardised CPUE indices with 95% confidence intervals for the recent PCELR series

4.1.2 Relative abundance estimates from research diver surveys

The relative abundance of paua in PAU 5B has also been estimated from a number of independent research diver surveys (RDSI) undertaken in various years between 1993 and 2007. The survey strata included Ruggedy, Waituna, Codfish, Pegasus, Lords, and East Cape. These data were not included in the assessment because there is concern that the data are not a reliable index of abundance.

Concerns about the ability of the data collected in the independent Research Dive surveys to reflect relative abundance instigated several reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed the reliability of the research diver survey index as an index of abundance and whether the RDSI, when used in the paua stock assessment models, results in model outputs that adequately reflect the status of the stocks. Both reviews suggested that outputs from paua stock assessments using the RDSI should be treated with caution. For a summary of the conclusions from the reviews refer to the introductory PAU Working Group Report

4.2 Stock assessment methods

The 2013 PAU 5B stock assessment used the same length-based model as the 2012 PAU 5D assessment (Fu 2013). The model was described by Breen *et al.* (2003). PAU 5B was last assessed in 2007 (Breen & Smith 2008) and the most recent assessment is 2013 (Fu 2014 in prep).

The model structure assumed a single sex population residing in a single homogeneous area, with length classes from 70 mm to 170 mm in 2 mm bins. Growth is length-based, without reference to age, mediated through a growth transition matrix that describes the probability of transitions among length class at each time step. Paua enter the model following recruitment and are removed by natural mortality and fishing mortality.

The model simulates the population from 1965 to 2013. Catches were available for 1974-2013 although catches before 1995 must be estimated from the combined PAU 5 catch. Catches were assumed to increase linearly between 1965 and 1973 from 0 to the 1974 catch level. Catches included commercial, recreational, customary, and illegal catch, and all catches occurred within the same time step.

Recruitment was assumed to take place at the beginning of the annual cycle, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. No explicit stock-recruitment relationship was modelled in previous assessments; however, the Shellfish Working Group agreed to use a Beverton-Holt stock-recruitment relationship with steepness (h) of 0.75 for this assessment.

Maturity is not required in the population partition but is necessary for estimating spawning biomass. The model estimated proportions mature from length-at-maturity data. Growth and natural mortalities were also estimated within the model. The model estimated the commercial fishing selectivity, assumed to follow a logistic curve and asymptote at 1. The increase in Minimum Harvest Size between 2006 and 2011 was modelled as an annual shift in fishing selectivity.

The assessment was conducted in several steps. First, the model was fitted to the data with parameters estimated at the mode of their joint posterior distribution (MPD). Next, from the resulting fit, Markov chain-Monte Carlo (MCMC) simulations were made to obtain a large set of samples from the joint posterior distribution. From this set of samples, forward projections were made and an agreed set of biological indicators obtained. Model sensitivity was explored by comparing MPD fits made under alternative model assumptions.

The base case model excluded the RDSI and RDLF data, used the methods recommended by Francis (2011) to determine the relative weights for the proportion-at-length and abundance data, and estimated *M* assuming a lognormal prior with a mean of 0.1. When the RDSI and RDLF data were included in the model, they had almost no influence on model results. This suggested that the RDSI and RDLF were probably not in conflict with other observations, but this could also be related to their small model weights.

The sensitivity trials included an alternative prior on *M*, alternative catch history estimates with lower catches between 1985 and 1995, the use of inverse-logistic growth model, and the exclusion of the early or the recent CPUE indices. The sensitivity trials addressed uncertainties associated with various aspects of the input data and model assumptions. MCMCs were carried out for the base case and model run 0.4, which used a uniform prior on *M*.

The assessment calculates the following quantities from their posterior distributions: the equilibrium spawning stock biomass with recruitment equal to the average recruitment from the period for which recruitment deviation were estimated (B_0,), the mid-season spawning and recruited biomass for 2013 (B_{2013} and B^r_{2013}) and for the projection period (B_{proj} and B^r_{proj}). This assessment also reports the following fishery indictors:

- $B\%B_0$ Current or projected spawning biomass as a percentage of B_0
- $B\%B_{msy}$ Current or projected spawning biomass as a percentage of B_{msy}
- $\Pr(B_{proj} > B_{msy})$ Probability that projected spawning biomass is greater than B_{msy}
- $\Pr(B_{proj} > B_{2012})$ Probability that projected spawning biomass is greater than $B_{current}$
- $B\%B^r_0$ Current or projected recruited biomass as a percentage of B^r_0
- $B\%B^r_{msy}$ Current or projected recruited biomass as a percentage of B^r_{msy}
- $\Pr(B_{proj} > B^r_{msy})$ Probability that projected recruit-sized biomass is greater than B^r_{msy}
- $\Pr(B_{proj} > B^r_{2012})$ Probability that projected recruit-sized biomass is greater than B^r_{2012}
- $\Pr(B_{proj} > 40\%B_0)$ Probability that projected spawning biomass is greater than 40% B_0
- $\Pr(B_{proj} < 20\%B_0)$ Probability that projected spawning biomass is less than 20% B_0
- $\Pr(B_{proj} < 10\%B_0)$ Probability that projected spawning biomass is less than 10% B_0
- $\Pr(U_{proj} > U_{40\%B0})$ Probability that projected exploitation rate is greater than $U_{40\%B0}$

4.3 Stock assessment results

The base case model (0.1) estimated that the unfished spawning stock biomass (B_0) was about 3625 t (3390–3870 t) (Figure 4), and the spawning stock population in 2013 (B_{2013}) was about 44% (36–54%) of B_0 (Table 5). The base case indicated that spawning biomass increased rapidly after 2002 when the stock was at its lowest level. The 3-year model projection, assuming current catch levels and using recruitments re-sampled from the recent model estimates, suggested that the spawning stock abundance will increase to about 48% (0.38–0.61) of B_0 over the next three years (Table 6). The projection also indicated that the probability of the spawning stock biomass being above the target (40% B_0) will increase from about 80% in 2013 to 93% by 2016. The projection assumed the Minimum Harvest Size will remain at 135 mm for the next three years; the projected stock status changed very little if an MHS of 125 mm was assumed

The MCMC simulation started at the MPD parameter values and the traces show good mixing. MCMC chains starting at either higher or lower parameter values also converged after the initial burn-in phase. The base case model estimated an *M* of 0.12 with a 90% credible interval between 0.11 and 0.14. The midpoint of the commercial fishery selectivity (pre-2006), where selectivity is 50% of the maximum, was estimated to be about 125 mm and the selectivity ogive was very steep. The model estimated an annual shift of about 1.9 mm in selectivity, with a total increase of about 10 mm between 2006 and 2011.

The estimated recruitment deviations showed a period of relatively low recruitment through the 1990s to the early 2000s and the recruitment in recent years (after 2002) has been above the long term average. Exploitation rates peaked around 2002, but have decreased since then. The base case estimated exploitation rate in 2013 to be about 0.11 (0.09–0.14).

When a uniform prior on *M* was used (MCMC 0.4), the posterior median of *M* was estimated to be 0.15, and the posterior distribution had a much wider range, with a 90% credible interval between 0.13 and 0.19. This model run produced a more rapid increase in spawning biomass after 2002 with $B_{current}$ estimated to be about 55% (43–73%) of B_0. Model fits to both CPUE and CSLF changed very little from when the uninformative prior on *M* was used.

Deterministic B_{msy} was calculated using posterior samples of estimated parameters assuming constant recruitments and a B-H stock-recruitment relationship with a steepness of 0.75. The median of B_{msy} was estimated to be about 28% B_0 for both MCMC 0.1 and 0.4. The corresponding exploitation rate (U_{msy}) was estimated to be 37% for MCMC 0.1 and 67% for MCMC 0.4. The MHS was fixed at 135 mm in the calculation and U_{msy} was sensitive to this value: U_{msy} was estimated to be 22% for MCMC 0.1 and 31% for MCMC 0.4 when an MHS of 125 mm was used. However both MSY and B_{msy} were less sensitive to the values of MHS. Assuming an MHS of 135 mm, $U_{\%40B_0}$ was estimated to be 19% and 30% for MCMC 0.1 and 0.4 respectively.

For a number of reasons (as outlined below) B_{msy} is not currently used as a reference point for managing paua stocks. However, because determining the most suitable target and limit reference points for managing paua stocks is still work in progress, B_{msy} is among the indicators that are being estimated.

There are several reasons why B_{MSY} is not considered a suitable target for management of the paua fishery. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge including perfect catch and biological information and perfect stock assessments (because current biomass must be known exactly in order to calculate target catch), a constant-exploitation management strategy with annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders), and perfect management implementation of the TACC and catch splits with no under- or overruns. Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy

Standard. Thus, the actual target needs to be above this theoretical optimum, but the extent to which it needs to be above has not been determined.

Table 5: Summary of the marginal posterior distributions from the MCMC chain from the base case (Model 0.1), and sensitivity trial (model 0.4). The columns show the median, the 5th and 95th percentiles values observed in the 1000 samples. Biomass is in tonnes.

	MCMC 0.1	MCMC 0.4
B_0	3635 (3392–3872)	3366 (3063–3691)
B_{msy}	1021 (960–1086)	967 (887–1119)
B_{2013}	1592 (1293–1975)	1855 (1441–2486)
$B_{2013}\,\%B_0$	44 (36–53)	55(43–73)
$B_{2013}\,\%B_{msy}$	156 (128–156)	194 (152–231)
$B_{msy}\,\%B_0$	28 (28–29)	28 (28–34)
rB_0	3194 (2952–3440)	2838 (2490–3185)
rB_{msy}	664 (587–737)	534 (448–648)
rB_{2013}	1210 (953–1534)	1375 (1045–1851)
rB_{2013}/rB_0	0.38 (0.30–0.47)	0.49 (0.37–0.67)
rB_{2013}/rB_{msy}	1.82 (1.40–2.39)	2.64 (1.79–3.48)
rB_{msy}/rB_0	0.21 (0.19–0.22)	0.19 (0.17–0.21)
MSY	166 (156–182)	190 (167–234)
$U_{40\%B0}$	19 (16–24)	30 (20–56)
U_{msy}	37 (29–0.50)	67 (39–98)
U_{2013}	11 (9–14)	10 (7–13)

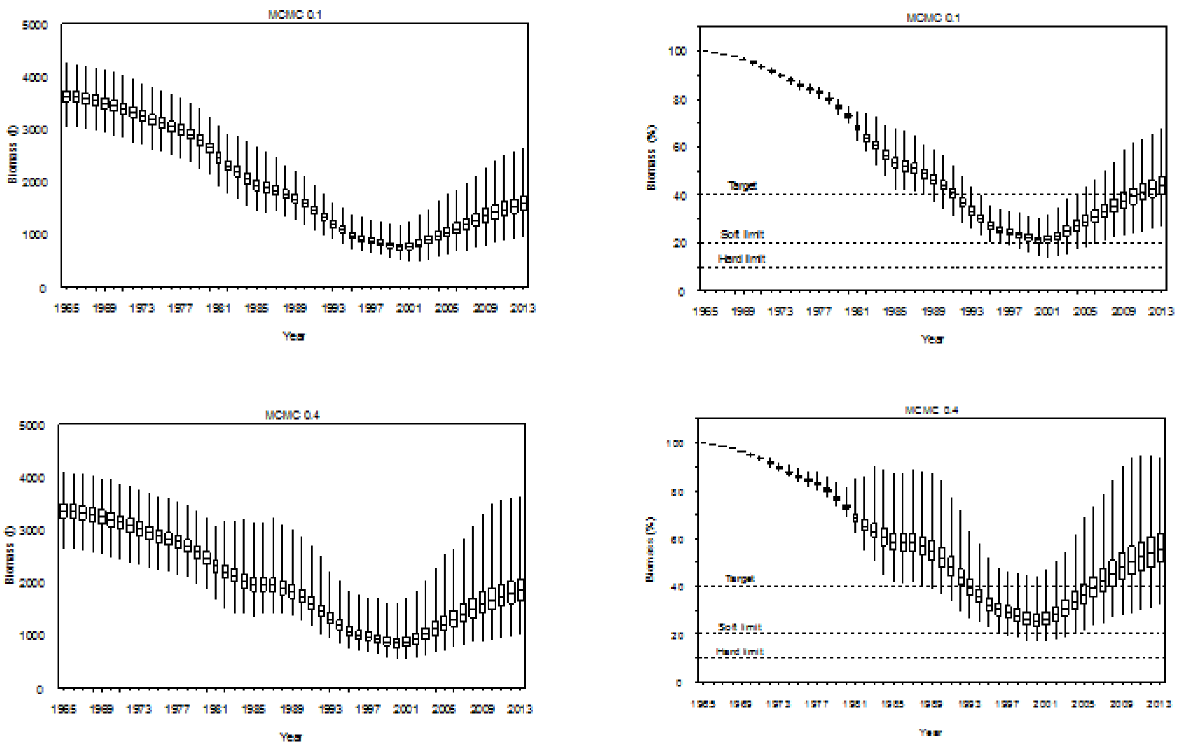


Figure 4: Posterior distributions of spawning stock biomass and spawning stock biomass as a percentage of the virgin level from MCMC 0.1 and 0.4. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

Table 6: Summary of current and projected indicators for the base case with future commercial catch set to current TACC and future minimum harvest size set to 135 mm or 125 mm: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. B() (current or projected biomass), $U(\ )$(current or projected exploitation rate).

	135 mm		125 mm	
	2013	2015	2013	2015
$B_{()}\%B_0$	44 (35–55)	48 (38–61)	44 (35–55)	47 (37–61)
$B_{()}\ \%B_{msy}$	156 (124–197)	169 (132 –218)	159 (126–203)	172 (134–223)
$\Pr(B_{()} > B_{msy})$	1.00	1.00	1.00	1.00
$\Pr(B_{()} > B_{2012})$	–	0.92	–	0.91
$\Pr(B_{()} > 40\%B_0)$	0.80	0.93	0.79	0.92
$\Pr(B_{()} < 20\%B_0)$	0.00	0.00	0.00	0.00
$\Pr(B_{()} < 10\%B_0)$	0.00	0.00	0.00	0.00
$B_{()} / B_0^r$	0.38 (0.29–0.49)	0.42 (0.33–0.53)	0.38 (0.29–0.49)	0.419 (0.33–0.53)
$B_{()} / B_{msy}^r$	1.82 (1.34–2.53)	2.02 (1.51–2.74)	1.87 (1.36–2.62)	2.07 (1.54–2.84)
$\Pr(B_{()} > B_{msy}^r)$	1.00	1.00	1.00	1.00
$\Pr(B_{()} > B_{2012}^r)$	–	1.00	–	1.00
$\Pr(U_{()} > U_{\%40B0})$	0.14	0.02	0.14	0.00

4.4 Other factors

The assessment used CPUE as an index of abundance. The assumption that CPUE indexes abundance is questionable. The literature on abalone fisheries suggests that CPUE is problematic for stock assessments because of serial depletion. This can happen when fishers deplete unfished or lightly fished beds and maintain their catch rates by moving to new areas. Thus CPUE stays high while the biomass is actually decreasing. For PAU 5B, the model estimate of stock status was strongly driven by the trend in the recent CPUE indices. It is unknown to what extent the CPUE series tracks stock abundance. The SFWG believed that the increasing trend in recent CPUE series may be credible, corroborating anecdotal evidence from the commercial divers in PAU 5B that the stock has been in good shape in recent years.

Natural mortality is an important productivity parameter. It is often difficult to estimate *M* reliably within a stock assessment model and the estimate is strongly influenced by the assumed prior. For the paua assessment, the choice of prior has been based on current belief on the plausible range of the natural mortality for paua, and therefore it is reasonable to incorporate available evidence to inform the estimation of *M*. The sensitivity of model results to the assumptions on *M* could be assessed through the use of alternative priors.

Another source of uncertainty is the data. The commercial catch is unknown before 1974 and is estimated with uncertainty before 1995. Major differences may exist between the catches we assume and what was actually taken. In addition, non-commercial catch estimates are poorly determined and could be substantially different from what was assumed, although generally non-commercial catches appear to be relatively small compared with commercial catch. The estimate of illegal catch in particular is uncertain.

The model treats the whole of the assessed area of PAU 5B as if it were a single stock with homogeneous biology, habitat and fishing pressures. The model assumes homogeneity in recruitment and natural mortality, and assumes that growth has the same mean and variance throughout. However, it is known that paua in some areas have stunted growth and others are fast-growing.

Heterogeneity in growth can be a problem for this kind of model (Punt 2003). Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on increments observed in several different places; similarly the length frequency data are integrated across samples from many places.

The effect of these factors is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others not fished, recruitment failure can result because of the localized depletion of spawners. Spawners must be close to each other to breed and the dispersal of larvae is unknown and may be limited. Recruitment failure is a common observation in overseas abalone fisheries, so local processes may decrease recruitment, an effect that the current model cannot account for.

Another source of uncertainty is that fishing may cause spatial contraction of populations (Shepherd & Partington 1995), or that some populations become relatively unproductive after initial fishing (Gorfine & Dixon 2000). If this happens, the model will overestimate productivity in the population as a whole. Past recruitments estimated by the model might instead have been the result of serial depletion.

5. STATUS OF THE STOCK

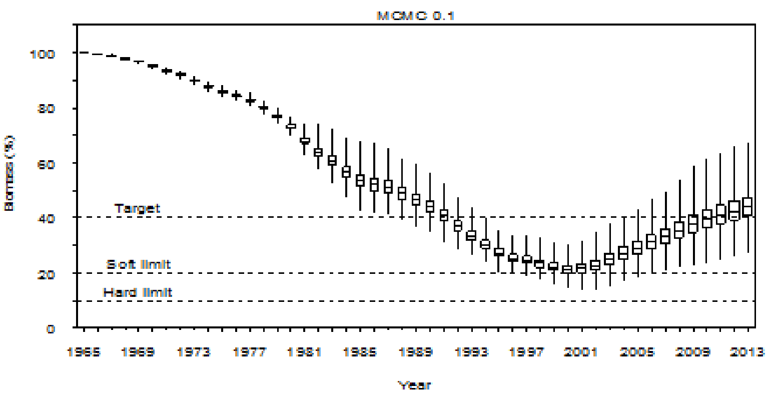
Stock Structure Assumptions

PAU 5B is assumed to be a homogenous stock for purposes of the stock assessment.

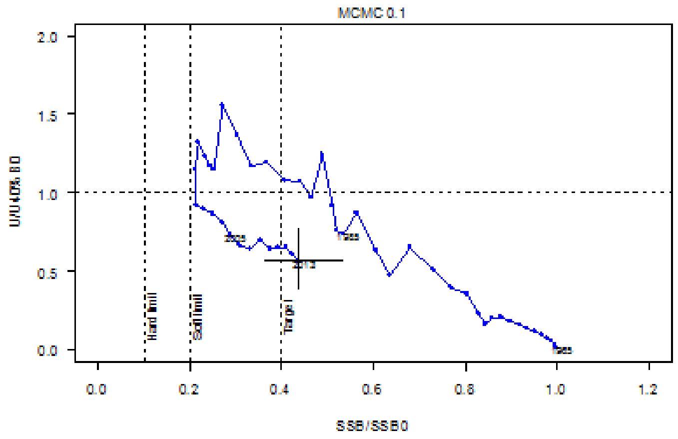
- **PAU 5B - *Haliotis iris***

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MCMC 0.1 (base case)
Reference Points	Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS) Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	B_{2013} was estimated to be 44% B_0 for the base case; About as Likely as Not (40–60%) to be at or above the target
Status in relation to Limits	Very Unlikely (< 10%) to be below the soft and hard limits
Status in Relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Posterior distributions spawning stock biomass as a percentage of the virgin level from MCMC 0.1. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.



Trajectory of exploitation rate as a ratio $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1965 to 2013 for MCMC 0.1 (base case). The vertical lines at 10%, 20%, 40% B_0 represent the hard limit, the soft limit, and the target respectively. $U_{\%40B0}$ is the exploitation rate at which the spawning stock biomass would stabilise at 40% B_0 over the long term. Each point on trajectory represents the estimated annual stock status: the value on x axis is the mid-season spawning stock biomass (as a ratio of B_0) and the value on the y axis is the corresponding exploitation rate (as a ratio $U_{\%40B0}$) for that year. The estimates are based on MCMC medians and the 2012 90% CI is shown by the cross line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass decreased to its lowest level in 2002 but has increased since then.
Recent Trend in Fishing Mortality or Proxy	Exploitation rate peaked in late 1990s and has since declined.
Other Abundance Indices	Standardised CPUE generally declined until the early 2000s, but has shown an increase since then.
Trends in Other Relevant Indicators or Variables	Estimated recruitment was relatively low through the 1990s to the early 2000s and since 2002 has been close to the long term average.

Projections and Prognosis		
Stock Projections or Prognosis	At the current catch level biomass is expected to increase over the next 3 years.	
Probability of Current Catch or TACC causing decline below Limits	Results from all models suggest it is Very Unlikely (< 10%) that current catch or TACC will cause a decline below the limits.	
Assessment Methodology & Evaluation		
Assessment Type	Full quantitative stock assessment	
Assessment Method	Length based Bayesian model	
Assessment Dates	Latest: 2014	Next: 2017
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	-Catch history -CPUE indices early series -CPUE indices later series -Commercial sampling length frequencies -Tag recapture data (for	1 – High Quality for commercial catch 2 – Medium or Mixed Quality for recreational, customary and illegal as catch histories are not believed to be fully representative of the QMA 2 – Medium or Mixed Quality: not believed to be fully representative of the whole QMA 1 – High Quality 2 – Medium or Mixed Quality: not believed to be fully representative of the whole QMA

	growth estimation) -Maturity at length data	1 – High Quality 1 – High Quality
Data not used (rank)	-Research Dive Survey Indices -Research Dive Length Frequencies	3 – Low Quality: not believed to index the stock 3 – Low Quality: not believed to be representative of the entire QMA
Changes to Model Structure and Assumptions	New model	
Major Sources of Uncertainty	-*M* may not be estimated accurately. There is information in the data that has informed the estimation of *M* and the prior has also strongly influenced the estimate. - CPUE may not be a reliable index of abundance. -The model treats the whole of the assessed area of PAU 5B as if it were a single stock with homogeneous biology, habitat and fishing pressure. -Any effect of voluntary increases in MHS from 125mm to 135 mm between 2006 and 2011 may not have been adequately captured by the model, which could therefore be underestimating the spawning biomass in recent years.	
Qualifying Comments:		
-		
Fishery Interactions		
-		

6. FOR FURTHER INFORMATION

Andrew, N L; Naylor, J R; Gerring, P (2000a) A modified timed-swim method for paua stock assessment. *New Zealand Fisheries Assessment Report 2000/4*. 23 p.

Andrew, N L; Naylor, J R; Gerring, P; Notman, P R (2000b) Fishery independent surveys of paua (*Haliotis iris*) in PAU 5B and 5D. *New Zealand Fisheries Assessment Report 2000/3*. 21 p.

Andrew, N L; Naylor, J R; Kim, S W; Doonan, I J (2002) Fishery independent surveys of the relative abundance and size-structure of paua (*Haliotis iris*) in PAU 5B and PAU 5D. *New Zealand Fisheries Assessment Report 2002/41*. 25 p.

Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document. 1998/16. 27 p. (Unpublished document held by NIWA library, Wellington.)

Breen, P A; Andrew, N L; Kendrick, T H (2000a) Stock assessment of paua (*Haliotis iris*) in PAU 5B and PAU 5D using a new length-based model. *New Zealand Fisheries Assessment Report 2000/33*. 37 p.

Breen, P A; Andrew, N L; Kendrick, T H (2000b) The 2000 stock assessment of paua (*Haliotis iris*) in PAU 5B using an improved Bayesian length-based model. *New Zealand Fisheries Assessment Report 2000/48*. 36 p.

Breen, P A; Andrew, N L; Kim, S W (2001) The 2001 stock assessment of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report 2001/55*. 53 p.

Breen, P A; Kim, S W (2005) The 2005 stock assessment of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report 2005/47*. 114 p.

Breen, P A; Kim, S W; Andrew, N L (2003) A length-based Bayesian stock assessment model for abalone. *Marine and Freshwater Research 54(5): 619–634*.

Breen, P A; Smith, A N H (2008) The 2007 assessment for paua (*Haliotis iris)* stock PAU 5B (Stewart Island). *New Zealand Fisheries Assessment Report 2008/05*. 64 p

Cordue, P L (2009) Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 unpublished report held by Paua Industry Council. 45 p.

Gerring, P K (2003) Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. *New Zealand Fisheries Assessment Report 2003/56*.

Gorfine, H K; Dixon, C D (2000) A behavioural rather than resource-focused approach may be needed to ensure sustainability of quota managed abalone fisheries. *Journal of Shellfish Research* 19: 515–516.

Haist, V (2010) Paua research diver surveys: review of data collected and simulation study of survey method. *New Zealand Fisheries Assessment Report 2010/38*. 54 p.

Kendrick, T H; Andrew, N L (2000) Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5A, 5B, and 5D. *New Zealand Fisheries Assessment Report 2000/47*. 25 p.

Punt, A E (2003) The performance of a size-structured stock assessment method in the face of spatial heterogeneity in growth. *Fisheries Research* 65: 391–409.

Schiel, D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris*. *Fishery Bulletin* 89: 681–691.

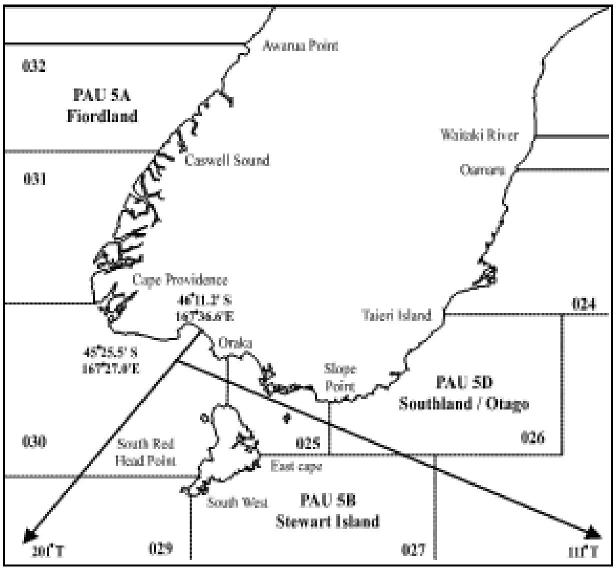
Shepherd, S A; Partington, D (1995) Studies on Southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations. *Marine and Freshwater Research* 46: 669–680.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held by NIWA library, Wellington.)

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

PAUA (PAU 5D) - Southland / Otago

(*Haliotis iris*)
Paua



1. FISHERY SUMMARY

Before 1995, PAU 5D was part of the PAU 5 QMA, which was introduced into the QMS in 1986 with a TACC of 445 t. As a result of appeals to the Quota Appeal Authority, the TACC increased to 492 t for the 1991–92 fishing year; PAU 5 was then the largest QMA by number of quota holders and TACC. Concerns about the status of the PAU 5 stock led to a voluntary 10% reduction in the TACC in 1994–95. On 1 October 1995, PAU 5 was divided into three QMAs (PAU 5A, PAU 5B, and PAU 5D; see figure above) and the TACC was divided equally among them; the PAU 5D quota was set at 148.98 t.

On 1 October 2002 a TAC of 159 t was set for PAU 5D, comprising a TACC of 114 t, customary and recreational allowances of 3 t and 22 t respectively and an allowance of 20 t for other mortality. The TAC and TACC have been changed since then but customary, recreational and other mortality allowances have remained unchanged (Table 1).

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 5 and PAU 5D since introduction to the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–1991*	-	-	-	-	445
1991–1994*	-	-	-	-	492
1994–1995*	-	-	-	-	442.8
1995–2002	-	-	-	-	148.98
2002–2003	159	3	22	20	114
2003–present	134	3	22	20	89

*PAU 5 TACC figures

1.1 Commercial fishery

The fishing year runs from 1 October to 30 September. On 1 October 2001 it became mandatory to report catch and effort on Paua Catch Effort Landing Returns PCELRs using fine-scale reporting areas that had been developed by the New Zealand Paua Management Company for their voluntary logbook programme (Figure 1). Since 2010 the commercial industry has adopted some voluntary management initiatives which include raising the minimum harvest size for commercial fishers over specific statistical reporting areas. The industry has also voluntarily closed, to commercial harvesting, specific areas that are of high importance to recreational paua fishers.

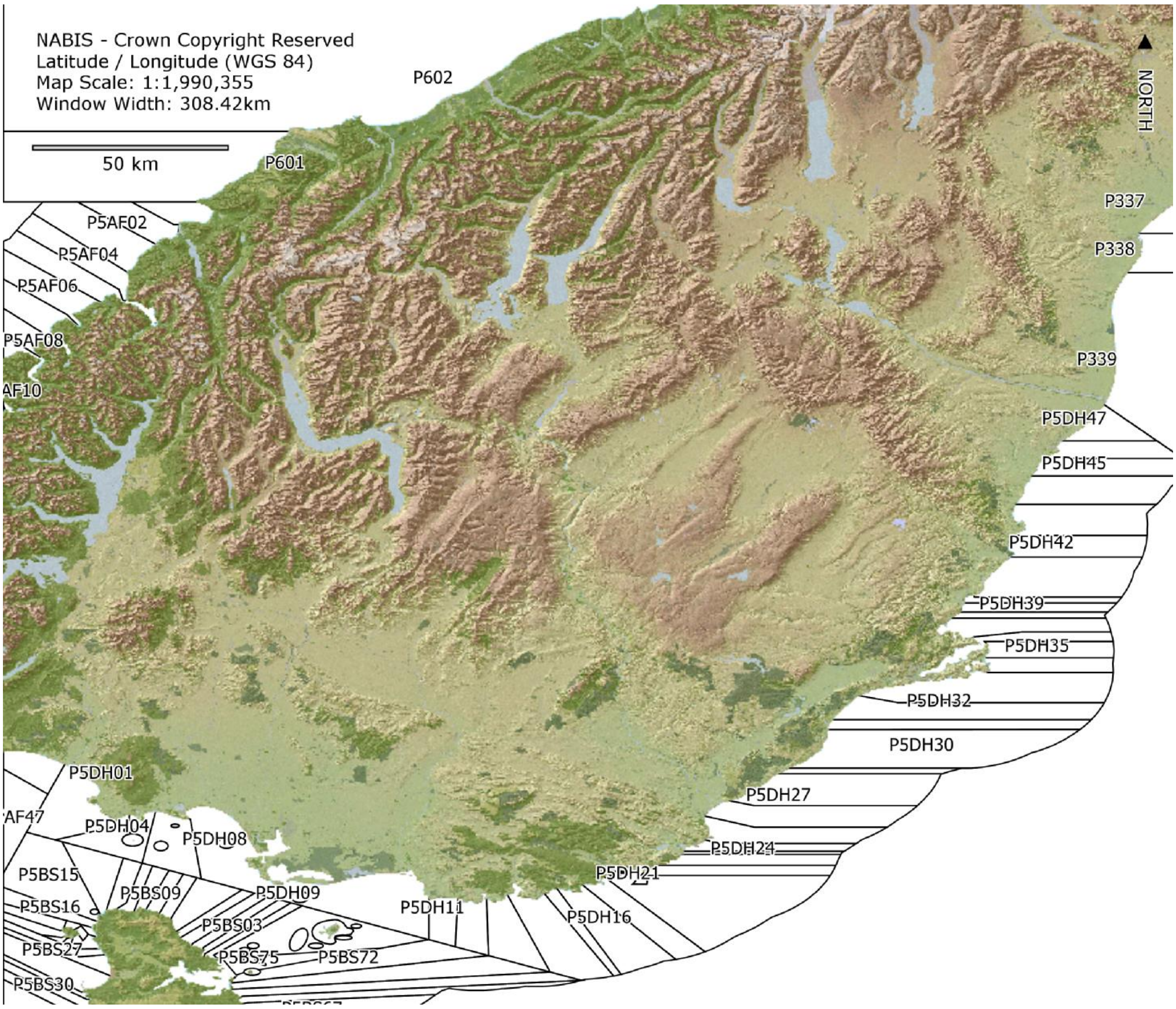


Figure 1: Map of fine scale statistical reporting areas for PAU 5D.

Landings for PAU 5D are shown in Table 2 and Figure 2. Landings for PAU 5 are reported in the introductory PAU Working Group Report.

Table 2: TACC and reported landings (t) of paua in PAU 5D from 1995–96 to the present. Data were estimated from CELR and QMR returns.

Year	Landings	TACC
1995–96	167.42	148.98
1996–97	146.6	148.98
1997–98	146.99	148.98
1998–99	148.78	148.98
1999–00	147.66	148.98
2000–01	149.00	148.98
2001–02	148.74	148.98
2002–03	111.69	114.00
2003–04	88.02	89.00
2004–05	88.82	89.00
2005–06	88.93	89.00
2006–07	88.97	89.00
2007–08	88.98	89.00
2008–09	88.77	89.00
2009–10	89.45	89.00
2010–11	88.70	89.00
2011–12	89.23	89.00
2012-13	87.91	89.00
2013-14	84.59	89.00

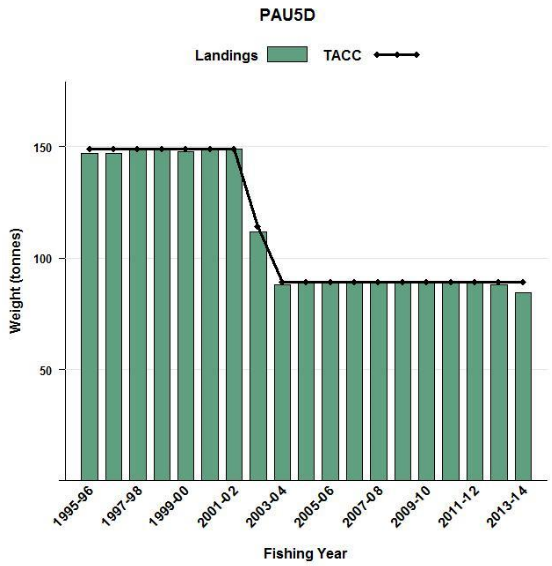


Figure 2: Reported commercial landings and TACC for PAU 5D from 1995–96 to present. For reported commercial landings in PAU 5 prior to 1995–96 refer to figure 1 and table 1 of the introductory PAU Working Group Report.

1.2 Recreational fisheries

For the purpose of the stock assessment model, the SFWG agreed to assume that the 1974 recreational catch was 2 t increasing linearly to 10 t by 2005. For further information on recreational fisheries refer to the introductory PAU Working Group Report.

1.3 Customary fisheries

For the purpose of the stock assessment model, the SFWG agreed to assume that the customary catch has been constant at 2 t for PAU 5D. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

For the purpose of the stock assessment model, the SFWG agreed to assume that illegal catches have been constant at 10 t for PAU 5D. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality

For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of biological parameters used in the PAU 5D assessment is presented in Table 3.

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

Table 3: Estimates of biological parameters (*H. iris*).

	Estimate		Source
1. Natural mortality (*M*)			
	0.149 (0.134–0.167)		Median (5–95% range) of posterior estimated by the base case model
2. Weight = a(length)^b (Weight in g, length in mm shell length)			
All	a	b	
	2.99 x 10 $^{-5}$	3.303	Schiel & Breen (1991)
3. Size at maturity (shell length)			
	50% maturity at 79 mm (78–80)		Median (5–95% range) of posterior estimated by the base case model
	95% maturity at 93mm (89–97)		Median (5–95% range) of posterior estimated by the base case model
4. Estimated annual growth increments (both sexes combined)			
	at 75 mm	at 120 mm	Median (5–95% range) of posteriors estimated by the base case model
	29.3 (26.4–32.5)	7.4 (7.0–7.8)	

4. STOCK ASSESSMENT

The stock assessment was implemented as a length-based Bayesian estimation model, with point estimates of parameters based on the mode of the joint posterior distribution, and uncertainty of model estimates investigated using the marginal posterior distributions generated from Markov chain-Monte Carlo simulations. The most recent stock assessment was conducted for the fishing year ended 30 September 2012. A base case model (5.2 - referred to as the reference model henceforth) was chosen from the assessment. However, most data sets used in the model were from a limited number of locations, and were most likely not representative of the whole QMA therefore; to capture the uncertainty in the stock assessment, three sensitivity runs were conducted: run 5.5 where the early CPUE series was removed, run 6.3 where the growth was fixed high and run 6.5 where the growth was fixed low. All four runs were considered to be equally plausible and showed that it was Very Unlikely the stock will fall below the soft or hard limits over the next three years at current levels of catch and suggested that biomass would increase. However, the four runs differed in their assessment of the status of the stock relative to the target.

4.1 Estimates of fishery parameters and abundance indices

Parameters estimated in the assessment model and their assumed Bayesian priors are summarized in Table 4.

Table 4: A summary of estimated model parameters, lower bound, upper bound, type of prior, (U, uniform; N, normal; LN = lognormal), mean and CV of the prior.

Parameter	Prior	μ	CV	Bounds	
				Lower	Upper
ln(*R0*)	U	–	–	5	50
M (Natural mortality)	LN	0.1	0.35	0.01	0.5
g_1*(Mean growth at 75 mm)*	U	–	–	1	50
g2(Mean growth at 120 mm)	U	–	–	0.01	50
φ (CV of mean growth)	U	–	–	0.001	1
$Ln(q^I)$ (catchability coefficient of CPUE)	U	–	–	-30	0
$Ln(q^J)$ (*catchability coefficient of PCPUE)*	U	–	–	-30	0
L_{50} (Length at 50% maturity)	U	–	–	70	145
$L_{95\text{-}50}$(Length between 50% and 95% maturity)	U	–	–	1	50
D_{50}(Length at 50% selectivity for the commercial catch)	U	–	–	70	145
$D_{95\text{-}50}$(Length between 50% and 95% selectivity the commercial catch)	U	–	–	0.01	50
ϵ (Recruitment deviations)	N	0	0.4	-2.3	2.3

The observational data were:

1. A standardised CPUE series covering 1990–2001 based on CELR data.
2. A standardised CPUE series covering 2002–2012 based on PCELR data.
3. A commercial catch sampling length frequency series for 1998, 2002–04, 07, 2009–2012.
4. Tag-recapture length increment data.
5. Maturity at length data

4.1.1 Relative abundance estimates from standardised CPUE analyses

The 2012 stock assessment used two sets of standardised CPUE indices: one based on CELR data covering 1990–2001, and another based on PCELR data covering 2002–2012. For both series, standardised CPUE analyses were carried out using Generalised Linear Models (GLMs). A stepwise procedure was used to select predictor variables, and they were entered into the model in the order that gave the maximum decrease in the Akaike Information Criterion (AIC). Predictor variables were accepted into the model only if they explained at least 1% of the deviance.

For the CELR data, the unit of catch used was the total estimated daily catch for a vessel. Because the diver-hours field on the CELR forms contains errors and ambiguity, the unit of effort used was the total number of diver days (total number of divers on a vessel for a day). The catch effort records from Statistical Areas 025 and 030 before 30 September 1995 were not included in the standardizations as the stock source of the data was unknown. The standardised index is shown in the upper panel of Figure 3.

For the PCELR data, the Fisher Identification Number (FIN) was used in the standardisation instead of vessel, because the FIN is associated with a permit holder who may employ a suite of grouped vessels, which implies that there could be linkage in the catch rates among vessels operated under a single FIN.

The FIN was used to select a core group of records from the CELR data, with the requirement that there be a minimum of 10 records per year for a FIN, for a minimum of two years. This retained 80% of the catch over the period 1990–2001. For the PCELR data the FIN was also used to select a core group of records, with the requirement that there be a minimum of 20 records per year for a minimum of three years. This retained 82% of the catch over the 2002–2012 time period.

The standardisation was done on the natural log of catch per diver day. Variables offered to the model were diver, diving condition, fishing duration, FIN (Fisher identification number), fishing year, month and statistical area; no interactions were included in the model and fishing year was forced to be in the model as an explanatory variable. The standardised index is shown in the lower panel of Figure 3.

The CELR data showed an overall decline in CPUE from 1990 through to the early 2000s. The CPUE estimated from PCELR data s showed a generally increasing trend from 2002 until 2011, with a slight decrease in 2012.

In some circumstances commercial CPUE may not be proportional to abundance because it is possible to maintain catch rates of paua despite a declining biomass. This occurs because paua tend to aggregate and divers move among areas to maximise their catch rates. Apparent stability in CPUE should therefore be interpreted with caution.

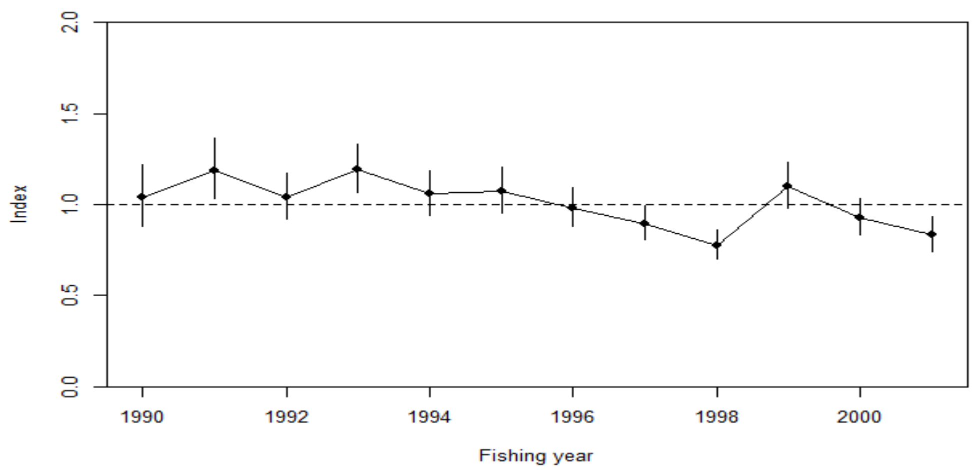


Figure 3: The standardised CPUE indices with 95% confidence intervals for the early CELR series [Continued on next page].

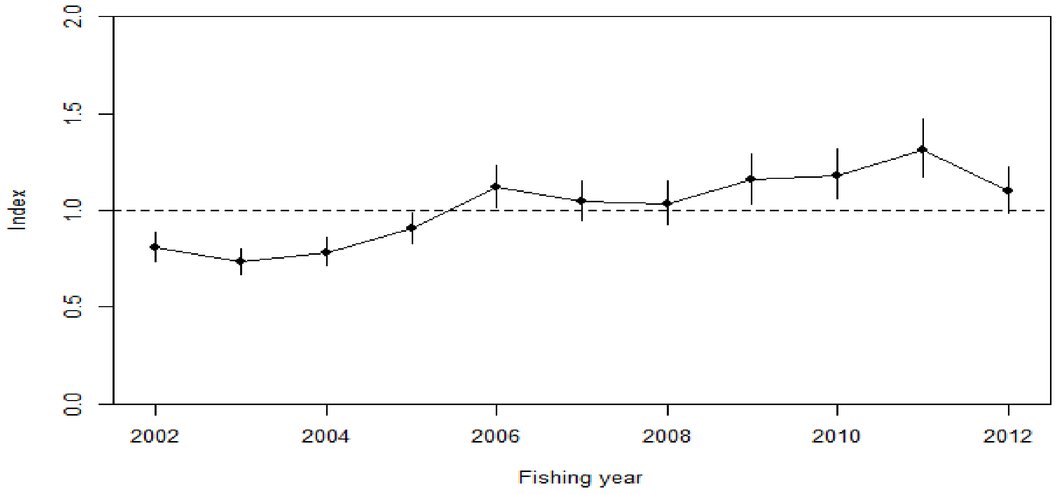


Figure 3 [Continued]: The standardised CPUE indices with 95% confidence intervals for the recent PCELR series (lower panel).

4.1.2 Relative abundance estimates from research diver surveys

The relative abundance of paua in PAU 5D has also been estimated from a number of independent research diver surveys (RDSI) undertaken in various years between 1994 and 2004. The survey strata (Catlins East and Catlins West) cover the areas that produced about 25% of the recent catches in PAU 5D. This data was not included in the assessment because there is concern that the data is not a reliable index of abundance and the data is not representative of the whole PAU 5D QMA.

Concerns about the ability of the data collected in the independent Research Dive surveys to reflect relative abundance instigated reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed the reliability of the research diver survey index as a proxy for abundance and whether the RDSI, when used in the paua stock assessment models, results in model outputs that adequately reflect the status of the stocks. Both reviews suggested that outputs from paua stock assessments using the RDSI should be treated with caution. For a summary of the conclusions from the reviews refer to the introductory PAU Working Group Report

4.2 Stock assessment methods

The 2012 PAU 5D stock assessment used the same length-based model used for the 2011 PAU 7 assessment Fu et al 2012). The model was described by Breen et al (2003). PAU 5D was last assessed in 2006 (Breen & Kim 2007) and the most recent assessment is 2012 (Dan Fu 2013).

The model structure assumed a single sex population residing in a single homogeneous area, with length classes from 70 mm to 170 mm, in groups of 2 mm. Growth is length-based, without reference to age, mediated through a growth transition matrix that describes the probability of each length class changing at each time step. Paua entered the partition following recruitment and were removed by natural mortality and fishing mortality.

The model simulates the population from 1965 to 2012. Catches were available for 1974–2012 although catches before 1995 must be estimated from the combined PAU 5 catch, and were assumed to increase linearly between 1965 and 1973 from 0 to the 1974 catch level. Catches included commercial, recreational, customary, and illegal catch, and all catches occurred within the same time step.

Recruitment was assumed to take place at the beginning of the annual cycle, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. The stock-recruitment relationship is unknown for paua. No explicit stock-recruitment relationship was modelled in previous assessments; however, the Shellfish Working Group agreed to use a Beverton-Holt stock-recruitment relationship with steepness (h) of 0.75 for this assessment.

Maturity is not required in the population partition but is necessary for estimating spawning biomass. The model estimated proportions mature from length-at-maturity data. Growth and natural mortalities were also estimated within the model. The model estimated the commercial fishing selectivity, assumed to follow a logistic curve and to reach an asymptote.

The assessment was conducted in several steps. First, the model was fitted to the data with arbitrary weights on the various data sets. The weights were then iteratively adjusted to produce balanced residuals among the datasets where the standardised deviation of the normalised residuals was close to one for each dataset. The length frequency data were further down-weighted using the method by Francis (2011). The fit obtained is the mode of the joint posterior distribution of parameters (MPD). Next, from the resulting fit, Markov chain-Monte Carlo (MCMC) simulations were made to obtain a large set of samples from the joint posterior distribution. From this set of samples, forward projections were made with a set of agreed indicators obtained. Sensitivity trials were explored by comparing MPD fits made with alternative model assumptions.

The reference model (5.2) excluded the RDSI and RDLF data; fitted the two CPUE series and the CSLF data; estimated growth parameters within the model using an exponential growth curve with the CV fixed at 0.30; estimated M within the model; weighted the CSLF data using the TA1.8 method (Francis 2011). The effects of dropping the tag-recapture data from the model showed that the model is taking a lot of information about growth from the commercial catch length frequency (CSLF) data and it appears that the CSLF data is having the biggest effect on model outcomes.

The sensitivity trials carried out for the MCMC included Run 5.5 where the early CPUE series were dropped, and Run 6.3 and 6.5 where the growth parameters were fixed at values representing either fast growth ($g_1 = 32.5$ and $g_2 = 10$) or slow growth ($g_1 = 24.5$ and $g_2 = 5$) respectively. The sensitivity trials addressed uncertainties in various aspects of the input data.

The assessment calculates the following quantities from their posterior distributions: the equilibrium spawning stock biomass assuming that recruitment is equal to the average recruitment from the period for which recruitment deviation were estimated (B_0,), and the mid-season spawning and recruited biomass for 2012 (B_{2012} and B^r_{2012}) and for the projection period (B_{proj} and B^r_{proj}). This assessment also reports the following fishery indictors:

- $B\%B_0$ — Current or projected spawning biomass as a percentage of B_0
- $B\%B_{msy}$ — Current or projected spawning biomass as a percentage of B_{msy}
- $\Pr(B_{proj} > B_{msy})$ — Probability that projected spawning biomass is greater than B_{msy}
- $\Pr(B_{proj} > B_{2012})$ — Probability that projected spawning biomass is greater than $B_{current}$
- $B\%B^r_0$ — Current or projected recruited biomass as a percentage of B^r_0
- $B\%B^r_{msy}$ — Current or projected recruited biomass as a percentage of B^r_{msy}
- $\Pr(B_{proj} > B^r_{msy})$ — Probability that projected recruit-sized biomass is greater than B^r_{msy}
- $\Pr(B_{proj} > B^r_{2012})$ — Probability that projected recruit-sized biomass is greater than B^r_{2012}
- $\Pr(B_{proj} > 40\%B_0)$ — Probability that projected spawning biomass is greater than 40% B_0
- $\Pr(B_{proj} < 20\%B_0)$ — Probability that projected spawning biomass is less than 20% B_0
- $\Pr(B_{proj} < 10\%B_0)$ — Probability that projected spawning biomass is less than 10% B_0
- $\Pr(U_{proj} > U_{40\%B0})$ — Probability that projected exploitation rate is greater than $U_{40\%B0}$

4.3 Stock assessment results

The reference case model (5.2) estimated that the unfished spawning stock biomass (B_0) was about 2285 t (2099–2487 t) (Figure 4), and the spawning stock population in 2012 (B_{2012}) was about 35% (28–44%) of B_0 (Table 5). The model projection made for three years assuming current catch levels and using recruitments re-sampled from the recent model estimates, suggested that the spawning stock abundance will increase to about 39% (27–54%) of B_0 over the next three years (Table 6). The projection also indicated that the probability of the spawning stock biomass being above the target (40% B_0) will increase from about 15% in 2012 to 43% by 2015.

The reference case model appeared to fit most data well, and there is no obvious indication of lack of fit. Natural mortality was estimated to be about 0.15. Estimated commercial catch selectivity was very steep with the 50% selectivity (D_{50}) being close to125 mm. The estimated recruitment was high in the mid-1990s and early 2000s. The estimated exploitation rate peaked in 2001 and since then has been decreasing, with the U_{2012} estimated at 21% and the exploitation rate required to achieve the target of 40% B_0 ($U_{40\%B0}$) over the long term was 16%.

When the early CPUE series was dropped (Run 5.5), the model estimated the unfished spawning stock biomass (B_0) to be about 2535 t (2335–2742 t) and showed a much steeper decline in biomass between 1990 and 2001(Figure 5). Estimated B_{2012} was about 26% (20–35%) of B_0, current exploitation rate was 26% and $U_{40\%B0}$ was 13% (Table 5). The model projections (Table 7) suggested an increase in biomass over the next three years, with a 3% probability of being above the target of 40% B_0 by 2015.

When the growth parameters were fixed at higher values (Run 6.3), the unfished spawning stock biomass (B_0) was estimated at 1987 t (1821–2158 t) (Figure 4). B_{2012} was 22% (19–27%) of B_0, U_{2012} was 35% and $U_{40\%B0}$ was 16% (Table 5). The model projections (Table 8) suggested an increase in biomass over the next three years, with a 2% probability of being above the target by 2015.

When the growth parameters were fixed at lower values (Run 6.5), the unfished spawning stock biomass (B_0) was estimated at 3375 t (3053–3841) (Figure 4). B_{2012} was estimated to be 60% (50–72%) of B_0, U_{2012} was 8% and $U_{40\%B0}$ was 16% (Table 5). The model projections (Table 9) suggest that the stock biomass is currently above target and will increase over the next three years.

Projections made from all four assessment runs presented suggest that the stock is Very Unlikely (less than 10%) to fall below the soft or hard limits at the current level of catch.

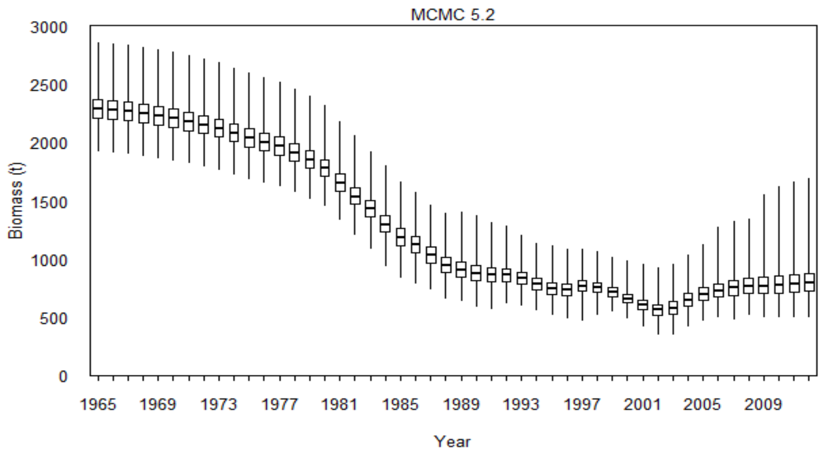
Deterministic B_{msy} was also calculated in the 2012 assessment with B_{msy} estimated at 624 t, 704 t, 556 t and 912 t for the 5.2, 5.5, 6.3 and 6.5 assessment runs respectively (Table 5). The corresponding exploitation rates (U_{msy}) were estimated at 26%, 20%, 25% and 31% (Table 5). Projections from the different assessment runs estimated the probability of the biomass in 2015 being above B_{msy} to be 40–100% (Tables 6, 7, 8 and 9).

For a number of reasons (as outlined below) B_{msy} is not currently used as a reference point for managing paua stocks. However, because determining the most suitable target and limit reference points for managing paua stocks is still work in progress, B_{msy} is among the indicators that are being estimated.

There are several reasons why B_{msy} is not considered a suitable target for management of the paua fishery. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge including perfect catch and biological information and perfect stock assessments (because current biomass must be known exactly in order to calculate target catch), a constant-exploitation management strategy with annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders), and perfect management implementation of the TACC and catch splits with no under- or overruns. Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known. Third, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20% B_0, the default soft limit according to the Harvest Strategy Standard. Thus, the actual target needs to be above this theoretical optimum; but the extent to which it needs to be above has not been determined.

Table 5: Summary of the marginal posterior distributions from the MCMC chain from Run 5.2 (base case), and sensitivity trials Run 5.5 (no early CPUE), 6.3 (fast growth), and 6.5 (slow growth). The columns show the median, the 5th and 95th percentiles values observed in the 1000 samples. Biomass is in tonnes.

	MCMC 5.2	MCMC 5.5	MCMC 6.3	MCMC 6.5
B_0	2285 (2099–2487)	2535 (2335–2742)	1987 (1821–2158)	3375 (3053–3841)
B_{msy}	624 (569–684)	704 (640–771)	556 (506–609)	912 (825–1036)
B_{2012}	795 (640–1028)	647 (524–814)	444 (379–526)	2015 (1576–2702)
B_{2012} %B_0	35 (28–44)	26 20–32)	22 (19–27)	60 (50–72)
B_{2012} %B_{msy}	128 (103–161)	92 (73–118)	80 (66–97)	221 (185–266)
rB_0	1954 (1760–2158)	2241 (2025–2469)	1772 (1596–1951)	2650 (2358–3021)
rB_{msy}	361 (297–427)	467 (390–550)	385 (327–443)	342 (257–434)
rB_{2012}	514 (387–710)	414 (318–548)	279 (225–352)	1339 (1002–1863)
rB_{2012}/rB_0	0.26 (0.2–0.35)	0.19 (0.14–0.25)	0.16 (0.13–0.2)	0.51 (0.41–0.64)
rB_{2012}/rB_{msy}	1.43 (1.05–2.02)	0.89 (0.64–1.26)	0.73 (0.56–0.96)	3.91 (2.81–5.82)
MSY	121 (115–130)	113 (108–120)	119 (116–122)	156 (136–189)
$U_{40\%B0}$	16 (14–18)	13 (11–15)	16 (14–19)	16 (13–20)
U_{msy}	26 (22–32)	20 (17–24)	25 (22–29)	31 (24–41)
U_{2012}	21 (15–27)	26 (20–33)	35 (29–43)	8 (6–11)



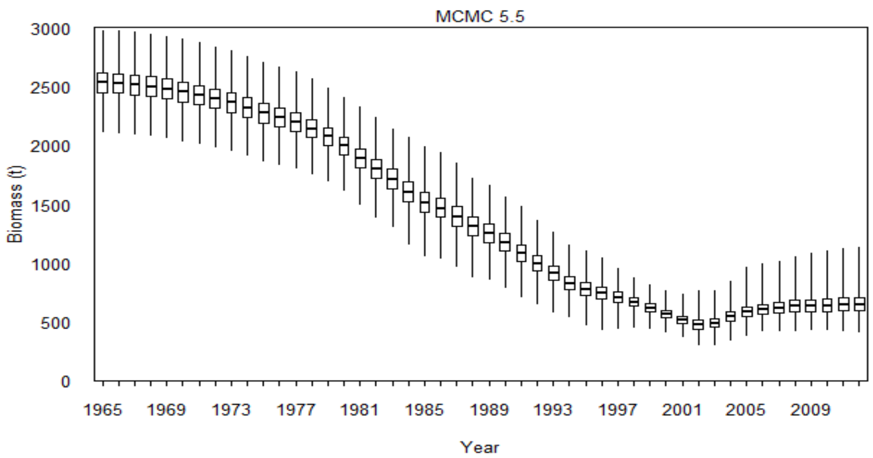


Figure 4: Posterior distributions of spawning stock biomass from MCMC 5.2 (base case), 5.5 (no early CPUE) The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The red horizontal line shows 40% B_0. [Continued on next page].

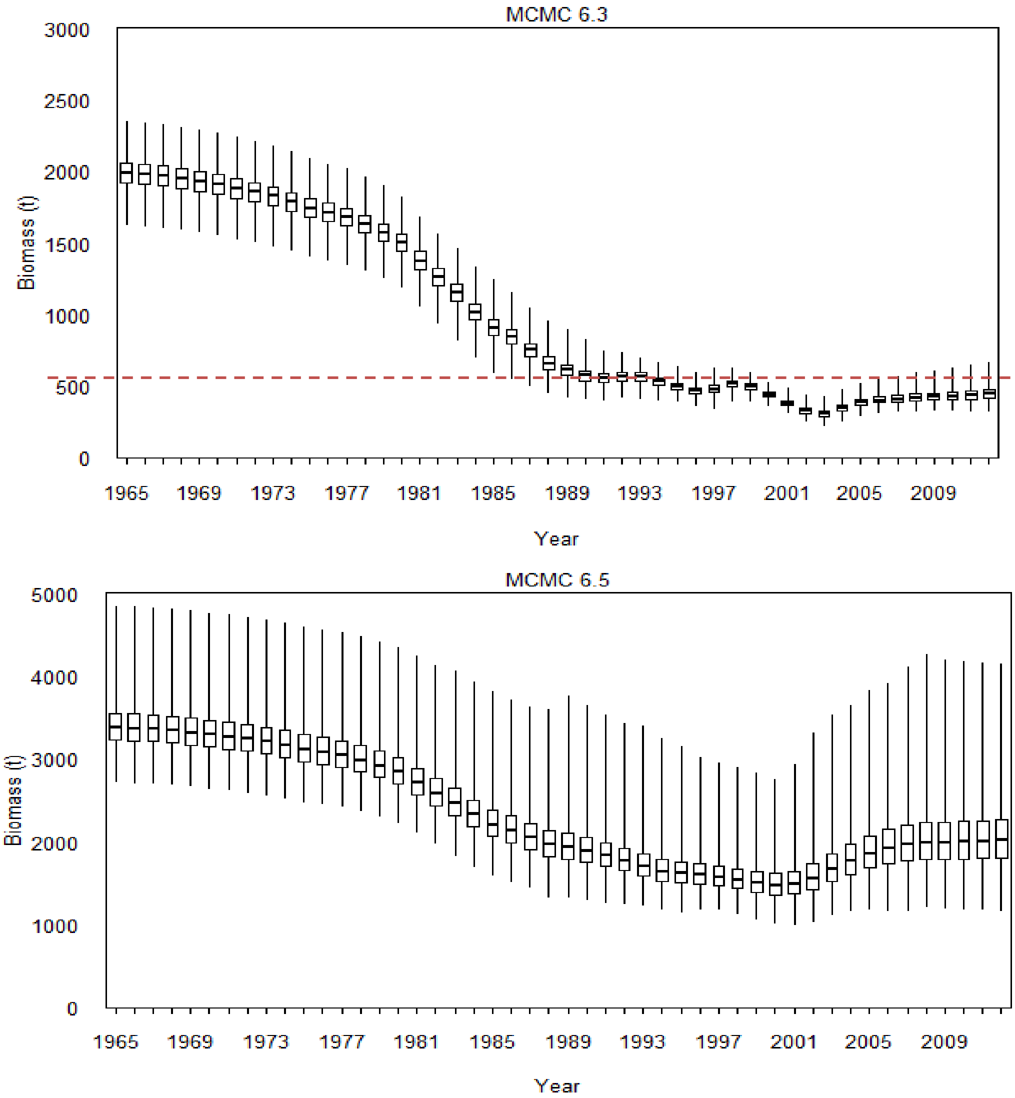


Figure 4: [Continued] Posterior distributions of spawning stock biomass from MCMC 6.3 (fast growth), and 6.5 (slow growth). The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The red horizontal line shows 40% B_0. [Continued on next page].

Table 6: Summary of current and projected indicators from the MCMCs for assessment run 5.2 with future commercial catch set to the current TACC and non-commercial catch set to 20 t: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. $B_{()}$ (current or projected biomass), $U_{()}$ (current or projected exploitation rate).

	2012	2015
$B_{()}\%B_0$	34.9(27.5–45.6)	38.8(27.3–53.8)
$B_{()}\ \%B_{msy}$	127.6(99.9–168.7)	141.9(98.8–198.7)
$\Pr(B_{()} > B_{msy})$	97.4	97.2
$\Pr(B_{()} > B_{2012})$		79.1
$\Pr(B_{()} > 40\%B_0)$	15.2	42.6
$\Pr(B_{()} < 20\%B_0)$	0.0	0.0
$\Pr(B_{()} < 10\%B_0)$	0.0	0.0
$B_{()}\%B_0^r$	26.4(19.2–37.1)	28.7(19.9–40.7)
$B_{()}\%B_{msy}^r$	142.6(99.2–216.4)	155(102–236)
$\Pr(B_{()} > B_{msy}^r)$	97.3	98.1

Table 6 [Continued]

	2012	2015
$\Pr(B_{()} > B^r_{2012})$	0.0	84.6
$\Pr(U_{()} > U_{\%40B0})$	91.7	84.9

Table 7: Summary of current and projected indicators from the MCMCs for assessment run 5.5 with future commercial catch set to current TACC and non-commercial catch set to 20 t: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. $B_{()}$ (current or projected biomass), $U_{()}$ (current or projected exploitation rate).

	2012	2015
$B_{()}\%B_0$	25.6(19.5–34.2)	28.2(18.9–40.3)
$B_{()}\ \%B_{msy}$	92.4(69.9–124.6)	101.7(67.7–147.1)
$\Pr(B_{()} > B_{msy})$	29.1	53.2
$\Pr(B_{()} > B_{2012})$		76.2
$\Pr(B_{()} > 40\%B_0)$	0.2	2.9
$\Pr(B_{()} < 20\%B_0)$	3.7	4.2
$\Pr(B_{()} < 10\%B_0)$	0.0	0.0
$B_{()}\%B^r_0$	18.5(13.3–26.2)	19.8(13.0–29.3)
$B_{()}\%B^r_{msy}$	89(61–136)	94.9(59.2–150.6)
$\Pr(B_{()} > B^r_{msy})$	28.2	41.4
$\Pr(B_{()} > B^r_{2012})$		76.0
$\Pr(U_{()} > U_{\%40B0})$	99.9	99.8

Table 8: Summary of current and projected indicators from the MCMCs for assessment run 6.3 with future commercial catch set to current TACC and non-commercial catch set to 20 t: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. $B_{()}$ (current or projected biomass), $U_{()}$ (current or projected exploitation rate).

	2012	2015
$B_{()}\%B_0$	22.4(17.9–28.2)	26.7(17.2–39.5)
$B_{()}\ \%B_{msy}$	80.0(63.7–101.4)	95.4(61.1–141.8)
$\Pr(B_{()} > B_{msy})$	3.24	40.9
$\Pr(B_{()} > B_{2012})$		83.0
$\Pr(B_{()} > 40\%B_0)$	0	2.3
$\Pr(B_{()} < 20\%B_0)$	16.32	9.9
$\Pr(B_{()} < 10\%B_0)$	0	0.02
$B_{()}\%B^r_0$	15.8(11.9–21.2)	18.7(11.6–28.4)
$B_{()}\%B^r_{msy}$	73.1(53.5–101.4)	86.7(52.5–135.7)
$\Pr(B_{()} > B^r_{msy})$	0.031	27.2
$\Pr(B_{()} > B^r_{2012})$		83.9
$\Pr(U_{()} > U_{\%40B0})$	100	100

Table 9: Summary of current and projected indicators from the MCMCs for assessment run 6.5 with future commercial catch set to current TACC and non-commercial catch set to 20 t: biomass as a percentage of the virgin and current stock status, for spawning stock and recruit-sized biomass. $B_{()}$ (current or projected biomass), $U_{()}$ (current or projected exploitation rate).

	2012	2015
$B_{()}\%B_0$	59.8(48.6–73.6)	63.1(48.9–80.8)
$B_{()}\ \%B_{msy}$	221(179–272)	233(180–299)
$\Pr(B_{()} > B_{msy})$	100.0	100.0
$\Pr(B_{()} > B_{2012})$		74.0
$\Pr(B_{()} > 40\%B_0)$	100.0	100.0
$\Pr(B_{()} < 20\%B_0)$	0.0	0.0
$\Pr(B_{()} < 10\%B_0)$	0.0	0.0
$B_{()}\%B_0^r$	50.6(38.8–66.2)	51.0(38.6–66.2)
$B_{()}\%B_{msy}^r$	391(266–626)	392(264–632)
$\Pr(B_{()} > B_{msy}^r)$	100.0	100.0
$\Pr(B_{()} > B_{2012}^r)$		50.2
$\Pr(U_{()} > U_{\%40B0})$	1.2	1.4

4.4 Other factors

The assessment used the CPUE as an index of abundance. The assumption that CPUE indexes abundance is questionable. The literature on abalone fisheries suggests that CPUE is difficult to use in abalone stock assessments because of serial depletion. This can happen when fishers can deplete unfished or lightly fished beds and maintain their catch rates by moving to new unfished beds, thus CPUE stays high while the biomass is actually decreasing. For PAU 5D, there is some additional uncertainty associated with the early CPUE: the standardisations suggested that there were different trends among statistical areas (the overall indices were unlikely to track abundance as the weights for each area cannot be easily determined); the level of decline in the CPUE indices appeared too small for the early stage of the fishery. The model results were sensitive to the inclusion/exclusion of the early CPUE indices.

Another source of uncertainty is the data. The commercial catch is unknown before 1974 and is estimated with uncertainty before 1995. Major differences may exist between the catches we assume and what was actually taken. In addition, non-commercial catch estimates are poorly determined and could be substantially different from what was assumed, although generally non-commercial catches appear to be relatively small compared with commercial catch. The estimate of illegal catch in particular is uncertain.

Tag-recapture data were mainly from the Catlin areas and therefore may not reflect fully the average growth in the population. Model estimates of stock status were sensitive to the range of possible growth values examined. Maturity data were collected from Catlin West and may not represent the population either. Length frequency data collected from the commercial catch may not represent the commercial catch with high precision. The research diver survey covered only the Catlin Area, the abundance indices and associated length frequencies were unlikely to represent the trend in the whole population.

The model treats the whole of the assessed area of PAU 5D as if it were a single stock with homogeneous biology, habitat and fishing pressures. The model assumes homogeneity in recruitment and natural mortality, and assumes that growth has the same mean and variance throughout. However it is known that paua in some areas have stunted growth, and others are fast-growing.

Heterogeneity in growth can be a problem for this kind of model (Punt 2003). Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on increments observed in several different places; similarly the length frequency data are integrated across samples from many places.

The effect of these factors is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others not fished, recruitment failure can result because of the depletion of spawners, because spawners must breed close to each other and the dispersal of larvae is unknown and may be limited. Recruitment failure is a common observation in overseas abalone fisheries, so local processes may decrease recruitment, an effect that the current model cannot account for.

Another source of uncertainty is that fishing may cause spatial contraction of populations (Shepherd & Partington 1995), or that some populations become relatively unproductive after initial fishing (Gorfine & Dixon 2000). If this happens, the model will overestimate productivity in the population as a whole. Past recruitments estimated by the model might instead have been the result of serial depletion.

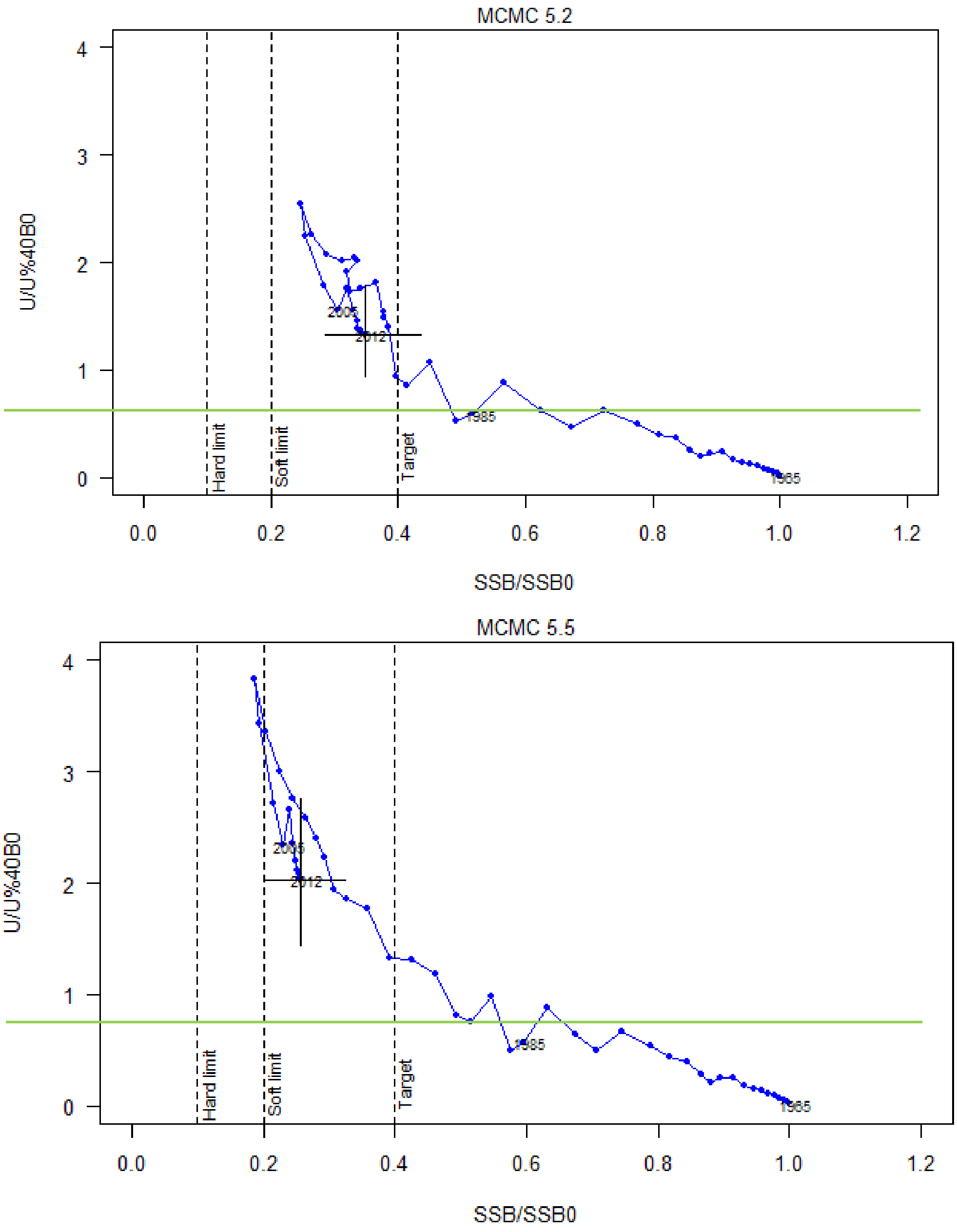
5. STATUS OF THE STOCK

Stock Structure Assumptions
PAU 5D is assumed in the model to be a discrete and homogenous stock

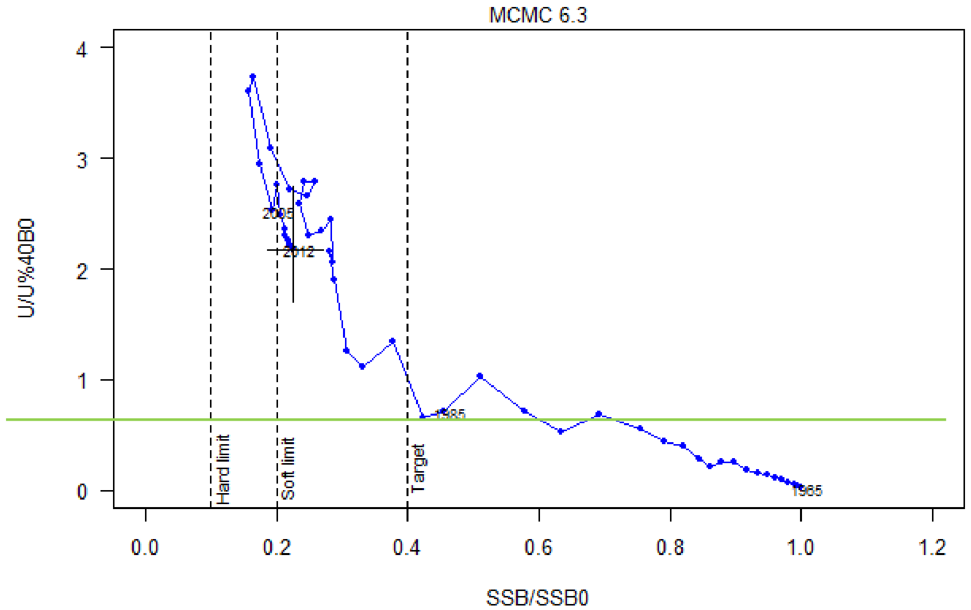
- **PAU 5D - *Haliotis iris***

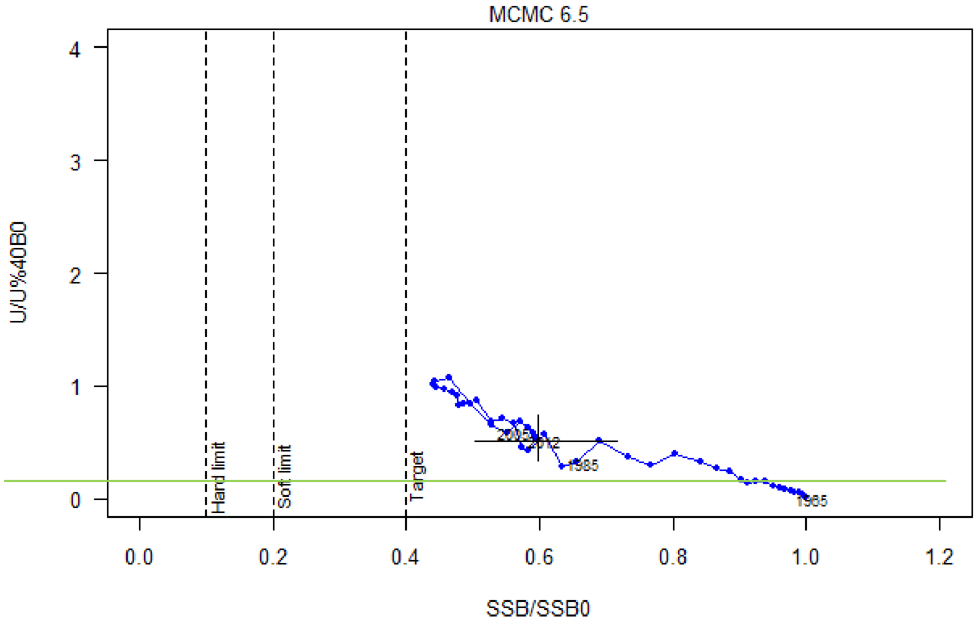
Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	Reference case MCMC (5.2) Early CPUE data excluded MCMC (5.5) Growth fixed high MCMC (6.3) Growth fixed low MCMC (6.5) All assessment runs are considered equally valid
Reference Points	Interim Target: 40% B_0 (Default as per HSS) Soft Limit: 20% B_0 (Default as per HSS) Hard Limit: 10% B_0 (Default as per HSS) Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	B_{2012} is estimated to be at 35%, 26% and 22% B_0 for assessment runs 5.2, 5.5 and 6.3 respectively. Run 6.5 estimates B_{2012} to be 60% $B_{0.}$
Status in relation to Limits	The stock is Very Unlikely (< 10%) to be below the soft and hard limits
Status in Relation to Overfishing	Assessment runs 5.2, 5.5 and 6.3 suggest that a reduction in exploitation rate may achieve the interim target of 40% B_0 more quickly. Run 6.5 suggests that the current exploitation rate meets and exceeds the target.

Historical Stock Status Trajectory and Current Status



Trajectory of exploitation rate as a ratio of $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1965 to 2012 for MCMC 5.2 (base case), 5.5 (no early CPUE), 6.3 (fast growth), and 6.5 (slow growth). The vertical lines at 10%, 20%, 40% B_0 represent the hard limit, the soft limit, and the target respectively. $U_{\%40B0}$ is the exploitation rate at which the spawning stock biomass would stabilise at 40% B_0 over the long term. Each point on trajectory represents the estimated annual stock status: the value on the x axis is the mid-season spawning stock biomass (as a ratio of B_0) and the value on the y axis is the corresponding exploitation rate (as a ratio $U_{\%40B0}$) for that year. For all the models, the trajectory started in year 1965 when the SSB is close to B_0 and the exploitation rate is close to 0. The estimates are based on MCMC median and the 2012 90% CI is shown by the cross line. [Continued on next page].





Trajectory of exploitation rate as a ratio of $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1965 to 2012 for MCMC 5.2 (base case), 5.5 (no early CPUE), 6.3 (fast growth), and 6.5 (slow growth). The vertical lines at 10%, 20%, 40% B_0 represent the hard limit, the soft limit, and the target respectively. $U_{\%40B0}$ is the exploitation rate at which the spawning stock biomass would stabilise at 40% B_0 over the long term. Each point on trajectory represents the estimated annual stock status: the value on the x axis is the mid-season spawning stock biomass (as a ratio of B_0) and the value on the y axis is the corresponding exploitation rate (as a ratio $U_{\%40B0}$) for that year. For all the models, the trajectory started in year 1965 when the SSB is close to B_0 and the exploitation rate is close to 0. The estimates are based on MCMC median and the 2012 90% CI is shown by the cross line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass increased from about 2002 to 2008 and has since been stable.
Recent Trend in Fishing Mortality or Proxy	Exploitation rate peaked in 2002 and has since declined.
Other Abundance Indices	Standardised CPUE generally declined until the early 2000s, but has shown a gradual increase since then.
Trends in Other Relevant Indicators or Variables	Estimated recruitment was relatively low in the late 1990s, and high in the early 2000s, and since 2004 has been close to long term average.

Projections and Prognosis	
Stock Projections or Prognosis	At the current catch level biomass is expected to increase over the next 3 years.
Probability of Current Catch or TACC causing decline below Limits	Results from all models assessment runs presented suggest it is very unlikely (<10%) that current catch or TACC will cause a decline below the limits.

Assessment Methodology and Evaluation		
Assessment Type	1- Full Quantitative Stock Assessment	
Assessment Method	Length based Bayesian model	
Assessment Dates	Latest: 2013	Next: 2016
Overall assessment quality (rank)	1 – High Quality	
Main data inputs (rank)	- Catch History	2 – Medium or Mixed Quality: not believed to be fully representative of catch in the QMA
	- CPUE Indices early series	2 – Medium or Mixed Quality: not believed to be fully representative of CPUE in the QMA
	- CPUE Indices later series	1– High Quality
	- Commercial sampling length frequencies	2 – Medium or Mixed Quality: not believed to be representative of the whole QMA
	- Tag recapture data	2 – Medium or Mixed Quality: not believed to be representative of the whole QMA
	- Maturity at length data	2 – Medium or Mixed Quality: not believed to be representative of the whole QMA
Data not used (rank)	- Research Dive survey indices	3 – Low Quality: not believed to be a reliable indicator of abundance in the whole QMA
	- Research Dive length frequencies	3 – Low Quality: not believed to be a reliable indicator of length frequency in the whole QMA
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- Growth data were limited and may not be representative of growth within the whole QMA. This was explored through models with alternative growth assumptions, which show the high degree of uncertainty about current stock status associated with uncertainty about growth. - Assuming CPUE is a reliable index of abundance. - The model treats the whole of the assessed area of PAU 5D as if it were a single stock with homogeneous biology, habitat and fishing pressures. - Any effect of voluntary increases in MHS from 125mm to 132mm over the last five years may not have been adequately captured by the model, which could therefore be underestimating the spawning	

	biomass in recent years.
Qualifying Comments	
-	

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Andrew, N L; Kim, S W; Naylor, J R; Gerring, P; Notman, P R (2002) Fishery independent surveys of paua (*Haliotis iris*) in PAU 5B and PAU 5D. *New Zealand Fisheries Assessment Report 2002/3*. 21 p.

Andrew, N L; Naylor, J R; Gerring, P (2000a) A modified timed-swim method for paua stock assessment. *New Zealand Fisheries Assessment Report 2000/4*. 23 p.

Andrew, N L; Naylor, J R; Gerring, P; Notman, P R (2000b) Fishery independent surveys of paua (*Haliotis iris*) in PAU 5B and 5D. *New Zealand Fisheries Assessment Report 2000/3*. 21 p.

Breen, P A; Andrew, N L; Kendrick, T H (2000a) Stock assessment of paua (*Haliotis iris*) in PAU 5B and PAU 5D using a new length-based model. *New Zealand Fisheries Assessment Report 2000/33*. 37 p.

Breen, P A; Andrew, N L; Kendrick, T H (2000b) The 2000 stock assessment of paua (*Haliotis iris*) in PAU 5B using an improved Bayesian length-based model. *New Zealand Fisheries Assessment Report 2000/48*. 36 p.

Breen, P A; Kim, S W (2005) The 2005 stock assessment of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report 2005/47*. 114 p.

Breen, P A; Kim, S W (2007) The 2006 stock assessment of paua (*Haliotis iris*) stocks PAU 5A (Fiordland) and PAU 5D (Otago). *New Zealand Fisheries Assessment Report 2007/09*. 164 p.

Breen, P A; Kim, S W; Andrew, N L (2003) A length-based Bayesian stock assessment model for abalone. *Marine and Freshwater Research* 54(5): 619–634.

Cordue, P L (2009) Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 report. 45 p

Elvy, D; Grindley, R; Teirney, L (1997) Management Plan for Paua 5. Otago Southland Paua Management Working Group Report. 57 p. (Unpublished document held by Ministry for Primary Industries, Dunedin).

Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* 68: 15.

Fu, D.; McKenzie, A.; Naylor, J.R. (2012). Summary of input data for the 2011 PAU 7 stock assessment. *New Zealand Fisheries Assessment Report 2012/26*. 46 p.

Fu, D.; McKenzie, A; Naylor, R. (2013). Summary of input data for the 2012 PAU 5D stock assessment. *New Zealand Fisheries Assessment Report 2013/56*. 51 p.

Fu, D. (2013). The 2012 stock assessment of paua (*Haliotis iris*) for PAU 5D . *New Zealand Fisheries Assessment Report 2013/57*. 51 p.

Gerring, P K (2003) Incidental fishing mortality of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report 2003/56*. 13 p.

Gorfine, H K; Dixon, C D (2000) A behavioural rather than resource-focused approach may be needed to ensure sustainability of quota managed abalone fisheries. *Journal of Shellfish Research* 19: 515–516.

Haist, V (2010) Paua research diver surveys: review of data collected and simulation study of survey method. *New Zealand Fisheries Assessment Report 2010/38*. 54 p.

Kendrick, T H; Andrew, N L (2000) Catch and effort statistics and a summary of standardised CPUE indices for paua (*Haliotis iris*) in PAU 5A, 5B, and 5D. *New Zealand Fisheries Assessment Report 2000/47*. 25 p.

McShane, P E; Naylor, J R (1995) Small-scale spatial variation in growth, size at maturity, and yield- and egg-per-recruit relations in the New Zealand abalone (*Haliotis iris*). *New Zealand Journal of Marine and Freshwater Research* 29: 603–612.

Pirker, J G (1992) Growth, shell-ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165 p.

Punt, A E (2003) The performance of a size-structured stock assessment method in the face of spatial heterogeneity in growth. *Fisheries Research* 65: 391–409.

Sainsbury, K J (1982) Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. *New Zealand Journal of Marine and Freshwater Research* 16: 147–161.

Schiel, D R (1989) Paua fishery assessment 1989. New Zealand Fishery Assessment Research Document 1989/9. 20 p. (Unpublished document held by NIWA library, Wellington.)

Schiel, D R (1992) The paua (abalone) fishery of New Zealand. *In:* Shepherd, S A; Tegner, M J; Guzman del Proo, S (Eds.) *Abalone of the World: Biology, fisheries, and culture*. Blackwell Scientific, Oxford.

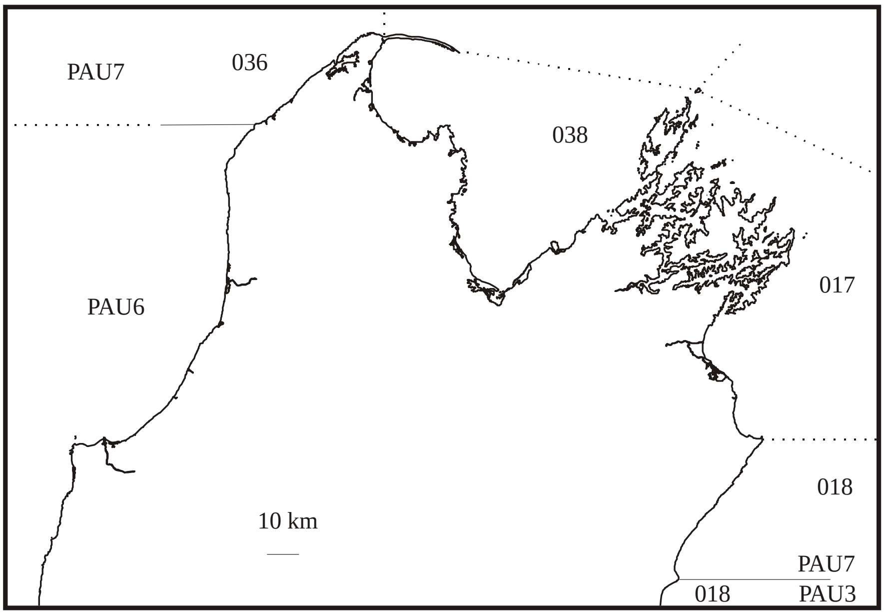
Schiel, D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone (*Haliotis iris*). *Fishery Bulletin* 89: 681–691.

Shepherd, S A; Partington, D (1995) Studies on Southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations. *Marine and Freshwater Research* 46: 669–680.

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

PAUA (PAU 7) – Marlborough

(Haliotis iris)
Paua



1. FISHERY SUMMARY

PAU 7 was introduced into the Quota Management System in 1986–87 with a TACC of 250 t. As a result of appeals to the Quota Appeal Authority the TACC increased to 267.48 t by 1989. On 1st October 2001 a TAC of 273.73 t was set with a TACC of 240.73 t, customary and recreational allowances of 15 t each and an allowance of 3 t for other mortality. On 1 October 2002 the TAC was reduced to 220.24 t and the TACC was set at 187.24 t. No changes were made to the customary, recreational or other mortality allowances (Table 1).

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for PAU 7 since introduction into the QMS.

Year	TAC	Customary	Recreational	Other mortality	TACC
1986–89	-	-	-	-	250.00
1989–2001					267.48
2001–02	273.73	15	15	3	240.73
2002–present	220.24	15	15	3	187.24

1.1 Commercial fisheries

The fishing year runs from 1 October to 30 September. In 2001–02 concerns about the status of the PAU 7 fishery led to a decision by the commercial sector to voluntarily shelve 20% of the TACC for that fishing year. From the 2003–04 to the 2006–07 fishing years the industry proposed to shelve 15% of the TACC. The proposal met with varying success, with less than 15% of the ACE being shelved in three of the four years.

On 1 October 2001 it became mandatory to report catch and effort on PCELRs using fine-scale reporting areas that had been developed by the New Zealand Paua Management Company for their voluntary logbook programme (Figure 1). Reported landings and TACCs for PAU 7 are shown in Table 2 and Figure 2.

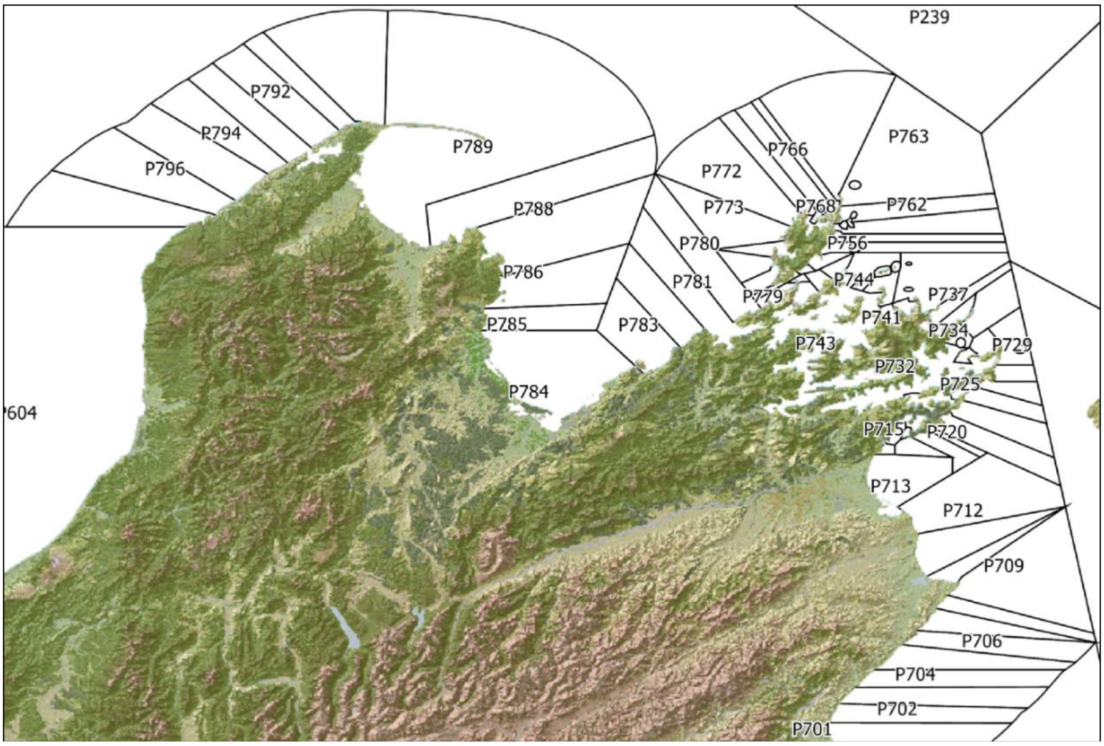


Figure 1: Map of fine scale statistical reporting areas for PAU 7.

Table 2: Reported Landings and TACC in PAU 7 from 1983–84 to the present. The last column shows the TACC after shelving has been accounted for.

Year	Landings (kg)	TACC (t)	After shelving
1973–74	147 440	-	-
1974–75	197 910	-	-
1975–76	141 880	-	-
1976–77	242 730	-	-
1977–78	201 170	-	-
1978–79	304 570	-	-
1979–80	223 430	-	-
1980–81	490 000	-	-
1981–82	370 000	-	-
1982–83	400 000	-	-
1983–84	330 000	-	-
1984–85	230 000	-	-
1985–86	236 090	-	-
1986–87	242 180	250	250
1987–88	255 944	250	250
1988–89	246 029	250	250
1989–90	267 052	263.53	263.53
1990–91	273 253	266.24	266.24
1991–92	268 309	266.17	266.17
1992–93	264 802	266.17	266.17
1993–94	255 472	266.17	266.17
1994–95	247 108	266.17	266.17
1995–96	268 742	267.48	267.48
1996–97	267 594	267.48	267.48
1997–98	266 655	267.48	267.48
1998–99	265 050	267.48	267.48
1999–00	264 642	267.48	267.48
2000–01	215 920	267.48	*213.98
2001–02	187 152	240.73	240.73
2002–03	187 222	187.24	187.24
2003–04	159 551	187.24	*159.15
2004–05	166 940	187.24	*159.15
2005–06	183 363	187.24	*159.15
2006–07	176 052	187.24	*159.15
2007–08	186 845	187.24	187.24
2008–09	186 846	187.24	187.24
2009–10	187 022	187.24	187.24
2010–11	187 240	187.24	187.24
2011–12	186 980	187.24	187.24
2012-13	149 755	187.24	187.24
2013-14	145 523	187.24	187.24

* Voluntary shelving

1.2 Recreational fisheries

For the purpose of the stock assessment, the Shellfish Working Group (SFWG) agreed to assume that recreational catch was 5 t in 1974 and that it increased linearly to 15 t in 2000, and then remained at 15 t. For further information on recreational fisheries refer to the introductory PAU Working Group Report.

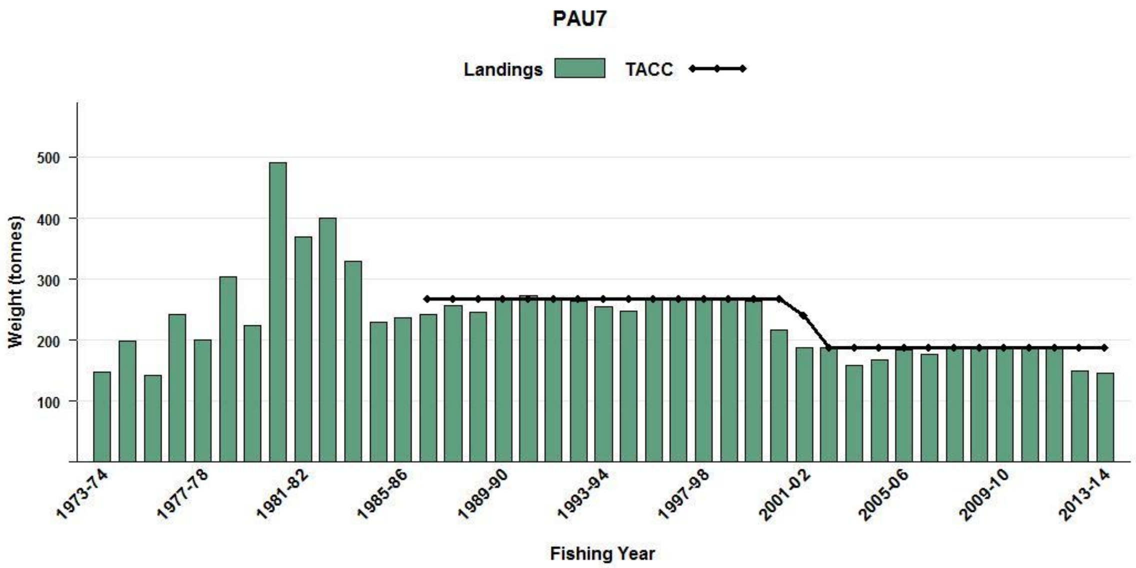


Figure 2: Reported commercial landings and TACC for PAU 7 from 1986–87 to present.

1.3 Customary fisheries

For the purpose of the stock assessment the SFWG agreed to assume that customary catch was 4 t in 1974, increasing linearly to 10 t between 1974 and 2000, and then remaining at 10 t. For further information on customary fisheries refer to the introductory PAU Working Group Report.

1.4 Illegal catch

For the purpose of the stock assessment the SFWG agreed to assume that illegal catch was 1 t in 1974 and that it increased linearly to 15 t between 1974 and 2000, remaining at 15 t from 2000 through to 2005, and then decreasing linearly to 7.5 t in 2008. For projections the Working Group agreed to assume that illegal catch would remain at 7.5 t. For further information on illegal catch refer to the introductory PAU Working Group Report.

1.5 Other sources of mortality

The Working Group agreed that handling mortality would not be factored into the model. For further information on other sources of mortality refer to the introductory PAU Working Group Report.

2. BIOLOGY

For further information on paua biology refer to the introductory PAU Working Group Report. A summary of biological parameters used in the PAU 7 stock assessment is presented in Table 3.

Table 3: Estimates of biological parameters (*H. iris*).

		Estimate	Source
1. Natural mortality (*M*)			
All		0.02–0.25	Sainsbury (1982)
PAU 7	0.14 (0.13–0.15)	Median (5%–95% C.L.)	estimated by the assessment model
2. Weight = a (length)^b (weight in g, shell length in mm)			
	a = 2.59E–08	b = 3.322	Schiel & Breen (1991)
3. Size at maturity (shell length)			
50% mature	90.7(89.9–91.5) mm	Median (5%–95% C.L.)	estimated by the assessment model
length at 95% mature - 50% mature	11.6(9.6–13.4) mm	Median (5%–95% C.L.)	estimated by the assessment model
4. Exponential growth parameters (both sexes combined)			
g_{75}	25.8(23.0–28.7) mm	Median (5%–95% C.L.)	estimated by the assessment model: growth increment of animal with initial length of 75 mm.
g_{120}	5.5 (5.1–5.8) mm	Median (5%–95% C.L.)	estimated by the model: growth increment of animal with initial length of 120 mm.

3. STOCKS AND AREAS

For further information on stocks and areas refer to the introductory PAU Working Group Report.

4. STOCK ASSESSMENT

The stock assessment is implemented as a length-based Bayesian estimation model, with point estimates of parameters based on the mode of the joint posterior distribution, and uncertainty of model estimates investigated using the marginal posterior distributions generated from Markov chain-Monte Carlo simulations. The 2011 assessment was restricted to Statistical Areas 017 and 038 which includes most (over 90%) of the recent catch**.**

4.1 Estimates of fishery parameters and abundance indices

Parameters estimated in the assessment model and their assumed Bayesian priors are summarized in Table 4.

Table 4: A summary of estimated model parameters, lower bound, upper bound, type of prior, (*U*, uniform; *N*, normal; *LN* = lognormal), mean and CV of the prior.

Parameter	Prior	μ	C.V.	Bounds	
				Lower	Upper
ln(*R0*)	*U*	–	–	5	50
M (Natural mortality)	*LN*	0.1	0.35	0.01	0.5
g_1*(Mean growth at 75 mm)*	*U*	–	–	1	50
g2(Mean growth at 75 mm)	*U*	–	–	0.01	50
φ *(cv of mean growth)*	*U*	–	–	0.001	1
$Ln(q^I)$ (catchability cofficient of CPUE)	*U*	–	–	-30	0
$Ln(q^J)$ (*catchability cofficient of PCPUE)*	*U*	–	–	-30	0
$Ln(q^k)$ (catchability cofficient of RDSI)	*U*	–	–	-30	0
L_{50} (Length at 50% maturity)	*U*	–	–	70	145
$L_{95\text{-}50}$(Length beteen 50% and 95% maturity)	*U*	–	–	1	50
T_{50}(Length at 50% selectivty for the divery survey)	*U*	–	–	70	125
$T_{95\text{-}50}$(Length between 50% and 95% selectivty for the divery survey)	*U*	–	–	0.001	50
D_{50}(Length at 50% selectivty for the divery survey)	*U*	–	–	70	145
$D_{95\text{-}50}$(Length between 50% and 95% selectivty for the divery survey)	*U*	–	–	0.01	50
ϵ (Recruiment deviations)	*N*	0	0.4	-2.3	2.3
h (CPUE shape parameter)	*U*	–	–	0.01	2

The observational data were:

1. A standardised CPUE series covering 1983–2001 based on FSU/CELR data.
2. A standardised CPUE series covering 2002–2011 based on PCELR data.
3. A standardised research diver survey index (RDSI).
4. A research diver survey proportions-at-lengths series (RDLF).
5. A commercial catch sampling length frequency series (CSLF).
6. Tag-recapture length increment data.
7. Maturity at length data.

4.1.1 Relative abundance estimates from standardised CPUE analyses

The 2011 stock assessement used two sets of standardised CPUE indices: one based on FSU/CELR data covering 1983–2001, and another based on PCELR data covering 2002–2011. For both series, standardised catch per unit effort (CPUE) analyses were carried out using Generalised Linear Models (GLMs). A stepwise procedure was used to select predictor variables, and they were entered into the model in the order that gave the maximum decrease in the Akaike Information Criterion (AIC). Predictor variables were accepted into the model only if they explained at least 1% of the deviance.

The standardised index of FSU/CELR series from the 2005 assessment is re-presented here, as the SFWG agreed that it was not necessary to update this series. The unit of catch used was the total estimated daily catch for a vessel. As the diver-hours field on the CELR forms contains a high number of errors, the unit of effort used was the total number of diver days (total number of divers on a vessel for a day). Records were restricted to those from vessels that fished the top 75% of catch in any given year, and from areas 017 and 038. The standardised index is shown in the left panel of Figure 3.

PCELR data were extracted in October 2011 for the time frame 1 October 2001 to 30 September 2011.The Shellfish Working Group suggested that the Fisher Identification Number (FIN) be used in the standardisation instead of vessel. The reason for this is that the FIN is associated with a permit holder who may employ a suite of grouped vessels, which implies that there could be linkage in the catch rates among vessels operated under a single FIN. It was decided to use criteria which specified a minimum number of records (PCELRs and CELRs) per year for a minimum number of years for selecting FIN permit holders for the model. The selected criteria were at least 40 records per year for a minimum of four years. This reduced the number of FIN permit holders from 72 to 20, but retained 76% of the original catch over 2002–2011.

To ensure that there were sufficient data to estimate fine scale statistical area and diver effects in the standardisation, only those fine scale statistical areas and divers with at least 10 diver days were retained. This dropped the number of fine scale statistical areas from 54 to 45, and the number of divers from 379 to 82 (51% of divers have just one dive-day).

The standardisation was done on the natural log of catch per diver day. Variables offered to the model were diver, diving condition, fishing duration FIN (Fisher identification number), fishing year, month and statistical area; no interactions were included in the model and fishing year was forced to be in the model as an explanatory variable. The standardised index is shown in the right panel of Figure 3.

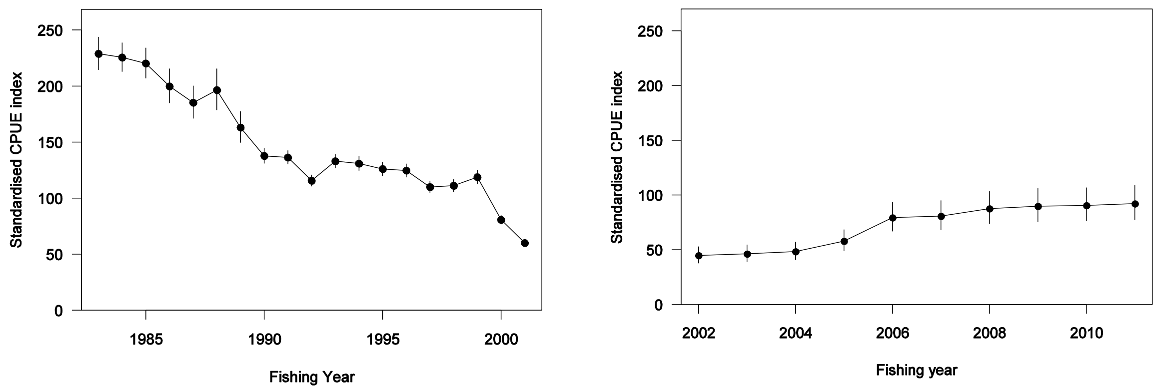


Figure 3: The standardised CPUE indices with 95% confidence intervals for the early CELR/FSU series (left) and the recent PCELR series (right).

4.1.2 Relative abundance estimates from research diver surveys

The relative abundance of paua in PAU 7 was also estimated from a number of independent research diver surveys (RDSI) undertaken in various years between 1992 and 2005. Concerns about the reliability of these data to estimate relative abundance instigated reviews in 2009 (Cordue 2009) and 2010 (Haist 2010). The reviews assessed i) the reliability of the research diver survey index as a proxy for abundance and ii) whether the RDSI, when used in the paua stock assessment models, results in model outputs that adequately reflect the status of the stocks. Both reviews suggested that outputs from paua stock assessments using the RDSI should be treated with caution. For a summary of the conclusions from the reviews refer to the introductory PAU Working Group Report. Relative abundance estimates from research diver surveys are shown in Figure 4.

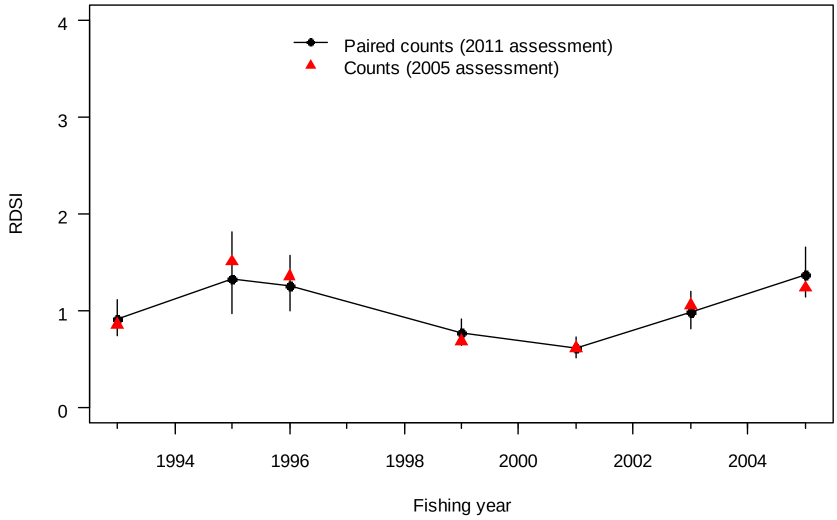


Figure 4: The standardised RDSI from the negative-binomial GLM models fitted to paired diver counts for surveys in Statistical Areas 017 and 038 within PAU 7.

4.2 Stock assessment methods

The 2012 PAU 7 stock assessment (Fu 2012, Fu et al 2012) used the length-based model first implemented in 1999 for PAU 5B (Breen et al 2000 and revised for subsequent assessments in PAU 7 (Andrew et al 2000, Breen & Kim 2003, Breen & Kim 2005 and Fu 2012). The model is described in Breen et al (2003).

The model structure assumes a single sex population residing in a single homgeneous area, with length classes from 70 mm to 170 mm, in groups of 2 mm. Growth is length-based, without reference to age, mediated through a growth transition matrix that describes the probability of each length class changing at each time step. Paua enter the partition following recruitment and are removed by natural mortality and fishing mortality. The assessment addresses only Areas 017 and 038 within PAU 7. These areas have supported most (more than 90%) of the catch until recently, and all of the available data originate from these two areas, but the relationship between this subset of PAU 7 and the remainder of PAU 7 is uncertain.

The model simulates the population dynamics from 1965 to 2011. Catches were available for 1974–2011, and were assumed to increase linearly between 1965 and 1973 from 0 to the 1974 catch level. Catches included commercial, recreational, customary, and illegal catch, and all catches occurred within the same time step.

Recruitment was assumed to take place at the beginning of the annual cycle, and length at recruitment was defined by a uniform distribution with a range between 70 and 80 mm. The stock-recruitment relationship is unknown for paua. A relationship may exist on small scales, but not be apparent when large-scale data are modelled (Breen et al 2003). No explicit stock-recruitment relationship was modelled in previous assessments; however, the SFWG agreed to use a Beverton-Holt stock-recruitment relationship with steepness (h) of 0.75 for this assessment.

Maturity is not required in the population partition. The model estimated proportions mature with the inclusion of length-at-maturity data. Growth and natural mortalities were also estimated within the model.

The models used two selectivities: the commercial fishing selectivity and research diver survey selectivity, both assumed to follow a logistic curve and to reach an asymptote.

The assessment was conducted in several steps. First, the model was fitted to the data with arbitrary weights on the various data sets. The weights were then iteratively adjusted to produce balanced residuals among the datasets where the standardised deviation of the normalised residuals was close to one for each dataset. The fit obtained is the mode of the joint posterior distribution of parameters (MPD). Next, from the resulting fit, Markov chain-Monte Carlo (MCMC) simulations were made to obtain a large set of samples from the joint posterior distribution. From this set of samples, forward projections were made with a set of agreed indicators obtained. Sensitivity trials were explored by comparing MPD fits made with alternative model assumptions.

A base case model (1.0) was chosen by the SFWG for the assessment: the tag-recapture data from all areas (except for D'Urville) were included, growth parameters were estimated within the model using an exponential growth curve, the weighting of the proportion-at-length data was determined using the TA1.8 method (Francis 2011), and maturity data from Northern faces were excluded. The base case model also assumed a steepness of 0.75 for the stock-recruitment relationship and estimated the CPUE shape parameter. The base case and sensitivities are summarised in Table 5.

The assessment reported:

- B_0 (the equilibrium spawning stock biomass assuming that recruitment is equal to the average recruitment from the period for which recruitment deviation were estimated).
- The mid-season spawning and recruited biomass for 2011 ($B_{current}$ and $B^r_{current}$), and for the projected period (B_{proj} and B^r_{proj}), and from a reference period, 1985–87. The latter was a period that had been previously chosen because the biomass was relatively stable. The means of values from the three years were called B_{ref} and B^r_{ref} for spawning and legal biomass respectively. Legal biomass is the biomass of paua above the legal size limit (currently 125 mm).
- % B_0 — Ratio of current and projected spawning biomass to B_0.
- % B_{ref} — Ratio of current and projected spawning biomass to B_{ref}.
- Pr(>B_{ref}) — Probabilities that current and projected spawning biomass greater than B_{ref}.
- Pr(>$B_{current}$) — Probabilities that projected spawning biomass greater than $B_{current}$.
- Pr(<20% B_0) — Probabilities that projected spawning biomass is less than 20% B_0.
- Pr(<10% B_0) — Probabilities that projected spawning biomass is less than 10% B_0.
- %B^r_0 — Ratio of current and projected legal biomass to B^r_0.
- %B^r_{ref} — Ratio of current and projected legal biomass to B^r_{ref}.
- Pr(>B^r_{ref}) — Probabilities that current and projected legal biomass greater than B^r_{ref}.
- Pr(>$B^r_{current}$) — Probabilities that projected legal biomass greater than $B^r_{current}$.

Recruitments for projections were obtained by randomly re-sampling model estimates from 1996 to 2006. Projections were run at four different levels of catch: the current TACC, and reductions of 10%, 15% and 20%.

4.2.1 Stock assessment results

Current estimates from the base case suggested that spawning stock population in 2011 ($B_{current}$) was about 22% (19–26%) of the unfished level (B_0), and vulnerable biomass ($B^r_{current}$) was about 10% (8–12%) of the initial state (B^r_0) (Figure 5, Table 6). Model projections made for three years, assuming current catch levels and using recruitments re-sampled from the recent model estimates, suggested that the spawning stock biomass will slightly increase to about 23.4% (17–32%) B_0 over the next three years (Table 7). Projections made with alternative catch levels showed that the spawning stock biomass will increase to about 24.4%, 25.0%, and 25.5% B_0 respectively, if the current TACC was to be reduced by 10%, 15% and 20% respectively (Table 7).

Table 5: Summary descriptions for base case and sensitivity model runs.

Model runs	Descriptions
0.0 (Initial model)	Iterative reweighting, assumed *h* of 0.75 and U^{max} of 0.8, estimated *h*
1.0 (Base case)	TA1.8 weighting method, assumed *h* of 0.75 and U^{max} of 0.8, estimated *h*
1.1	1.0, but fixed CPUE shape parameter (*??*) at 1
1.2	1.0, but assuming steepness (*h*) of 1
1.3	1.0, but assuming steepness (*h*) of 0.5
1.4	1.0, but assuming maximum exploitation rate (U^{max}) of 0.9
1.5	1.0, but assuming maximum exploitation rate (U^{max}) of 0.65
2.0	1.0, fixed growth parameters at low values
3.0	1.0, fixed growth parameters at high values

The base case model appeared to have represented most observational data well, and there is no obvious indication of lack of fit. The CPUE shape parameter was estimated to be less than 1, suggesting possible hyper-stability in the relationship between CPUE and abundance. However, model results changed very little when a linear relationship between CPUE and abundance was assumed.

Model sensitivity runs which assumed different values for the stock-recruitment steepness (*h*) parameter appeared to compensate for the differences in the stock-recruitment relationship with changes in R_0, recruitment deviations, and natural mortality. Estimates of current stock status were similar between these model runs, although there were some differences in the size of the estimated B_0.

Table 6: Summary of the marginal posterior distributions from the MCMC chain from the base case (1.0). The columns show the 5th and 95th percentiles, and the medians. Biomass is in tonnes.

	5%	Median	95%	MPD estimate
B_0	3905	4242	4541	4156
B_{ref}	1299	1426	1561	1359
$B_{current}$	790	933	1115	877
$B_{current}/B_0$	0.19	0.22	0.26	0.21
$B_{current}/B_{ref}$	0.56	0.66	0.78	0.65
B_0^r	3063	3417	3719	3368
B_{ref}^r	669	816	971	777
$B_{current}^r$	261	334	428	313
$B_{current}^r/B_0^r$	0.08	0.10	0.12	0.09
$B_{current}^r/B_{ref}^r$	0.32	0.41	0.54	0.40
$U_{current}$	0.33	0.41	0.49	0.43

The base case assumed a maximum exploitation rate (U_{max}) of 0.8 and there were two years (2001 and 2003) in which the exploitation rate was estimated to be at this bound. When U_{max} was assumed to be 0.65, the estimated exploitation rates for 2001 and 2003 were also at the bound; when U_{max} was assumed to be 0.9, the estimated exploitation rate for 2003 was at the bound. However, biomass estimates were similar among all these runs.

The base case assessment estimated growth parameters within the model using the tag-recapture data. The fits to the tag-recapture data appear adequate, but are likely to have been influenced by the proportion-at-length data as well. Sensitivity runs, which assumed alternative growth parameters (fixed at values representing either a fast or slow growth rate), led to significant changes to the estimates of abundance, but had poor fits to the proportion-at-length data.

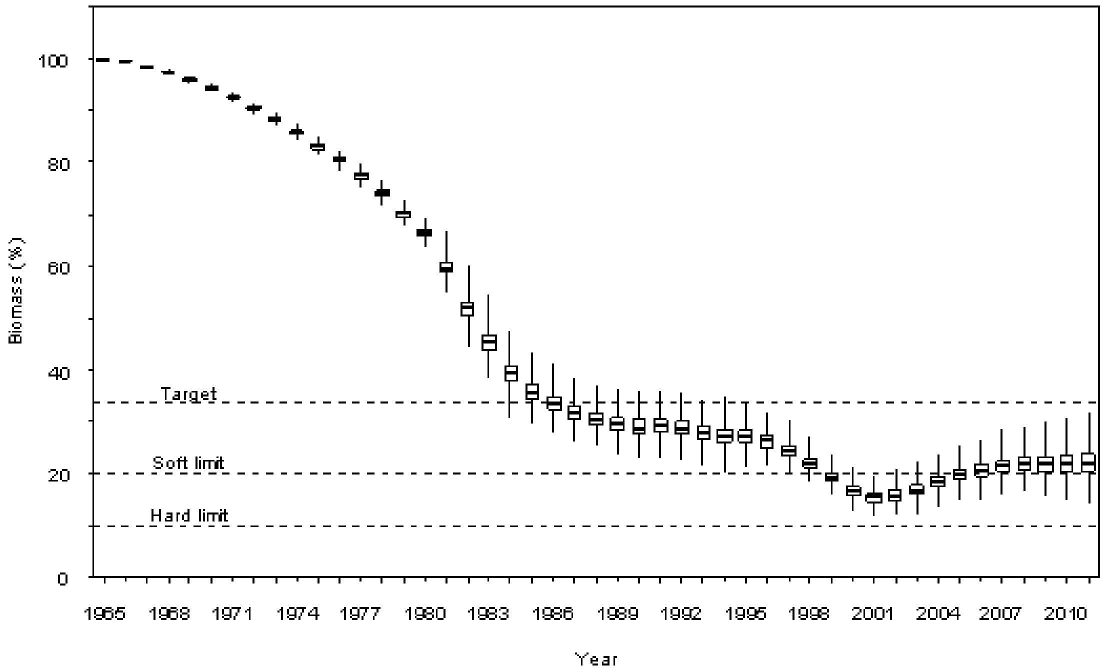


Figure 5: Posterior distributions of spawning stock biomass as a percentage of virgin level from MCMC 1.0. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The target is the median reference biomass (33.6% B_0).

The base case estimated growth parameters within the model incorporating the tag-recapture data. The fits to the tag-recapture data appear adequate, but are likely to have been influenced by the proportion-at-length data. Sensitivity runs assuming alternative growth parameters (fixed at values representing either a fast or slow growth rate) led to significant changes to the estimates of abundance, but had poor fits to the proportion-at-length data.

4.5 Yield estimates and projections

No estimate of *MCY* has been made for PAU 7.

No estimate of *CAY* has been made for PAU 7.

4.6 Other factors

The stock assessment model assumed homogeneity in recruitment, that natural mortality does not vary by size or year, and that growth has the same mean and variance throughout the entire area. However, it is known that paua fisheries are spatially variable and that apparent growth and maturity in paua populations can vary over very short distances. Variation in growth is addressed to some extent by having a stochastic growth transition matrix based on tagging data collected from a range of different locations. Similarly, the length frequency data are integrated across samples from many places. The effect of this integraion across local areas is likely to make model results optimistic. For instance, if some local stocks are fished very hard and others not fished, local recruitment failure can result due to the limited dispersal range of this species. Recruitment failure is a common observation in overseas abalone fisheries. Fishing may also cause spatial contraction of populations (e.g., Shepherd & Partington 1995), and some populations appear to become relatively unproductive after initial fishing (Gorfine & Dixon 2000). If this happens, the assessment will overestimate productivity in the population as a whole. It is also possible that good recruitments estimated by the model might have been the result of serial depletion.

Table 7: Projections to 2014 of the key indicators (from the base case MCMC) with future commercial catch set to 100%, 90%, 85%, and 80% of the TACC. Key indicators are spawning stock biomass (*B*) and recruited biomass (*rB*) and include % of virgin biomass and % biomass from a reference period (B_{ref}) and the probability of being above current biomass or below default limits.

	2011	2014			
Projection		Current TACC	90% TACC	85% TACC	80% TACC
$\%B_0$	22.1 (18.0–27.2)	23.4 (16.5–31.5)	24.4 (17.5–32.6)	25.0(18.0–33.1)	25.5 (18.5–33.6)
$\%B_{ref}$	65.5 (53.7–80.5)	69.3 (49.4–942)	72.4 (52.5–97.4)	74.0(54.1–99.0)	75.6 (55.7–100.6)
$Pr(> B_{ref})$	0.000	0.008	0.015	0.021	0.029
$Pr(>B_{current})$		0.671	0.796	0.854	0.897
$Pr(<20\%B_0)$	0.173	0.176	0.112	0.086	0.063
$Pr(<10\%B_0)$	0.000	0.000	0.000	0	0
$\%rB_0$	9.8 (0.073–0.130)	10.5 (6.2–15.9)	11.7 (7.4–17.1)	12.3(8.0–17.7)	12.9 (8.6–18.4)
$\%rB_{ref}$	41.2 (30.0–56.6)	43.9 (26.3–67.6)	49.0 (30.9–73.2)	51.6(33.3–76.1)	54.2 (35.6–79.0)
$Pr(> rB_{ref})$	0.000	0.000	0.000	0.000	0.000
$Pr(>rB_{current})$		0.679	0.926	0.975	0.995

CPUE provides information in the model on changes in relative abundance. However, CPUE is generally considered to be a poor index of stock abundance for paua, due to divers' ability to maintain catch rates by moving from area to area despite a decreasing biomass (hyperstability). Breen et al (2003) argued that standardised CPUE might monitor changes of abundance in a fully exploited fishery, and that declines in the CPUE most likely reflected a decline in the population. PAU 7 is generally considered to be a fully developed fishery: the exploitation rate in Statistical Areas 017 and 038 is known to have been high and there are unlikely to be many unfished areas within the area.

Commercial catch length frequencies provide information on changes in population structure under fishing pressure. However, if serial depletion has occurred and fishers have moved from area to area, samples from the commercial catch may not correctly represent the population of the entire stock. For PAU 7, there has been a long time-series of commercial catch sampling and the spatial coverage of the available samples is generally considered to be adequate throughout the years.

The utility of research diver survey indices to provide relative abundance information has been an ongoing concern in the SFWG. Cordue (2009) identified issues associated with diver surveys based on the timed swim approach and questioned their adequacy as indices of relative abundance. Haist (2010) suggested that the existing RDSI data were likely to be more useful at a stratum level. The general consensus is that the index-abundance relationship from the research diver survey is likely to be nonlinear, and cannot easily be quantified in a stock assessment.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

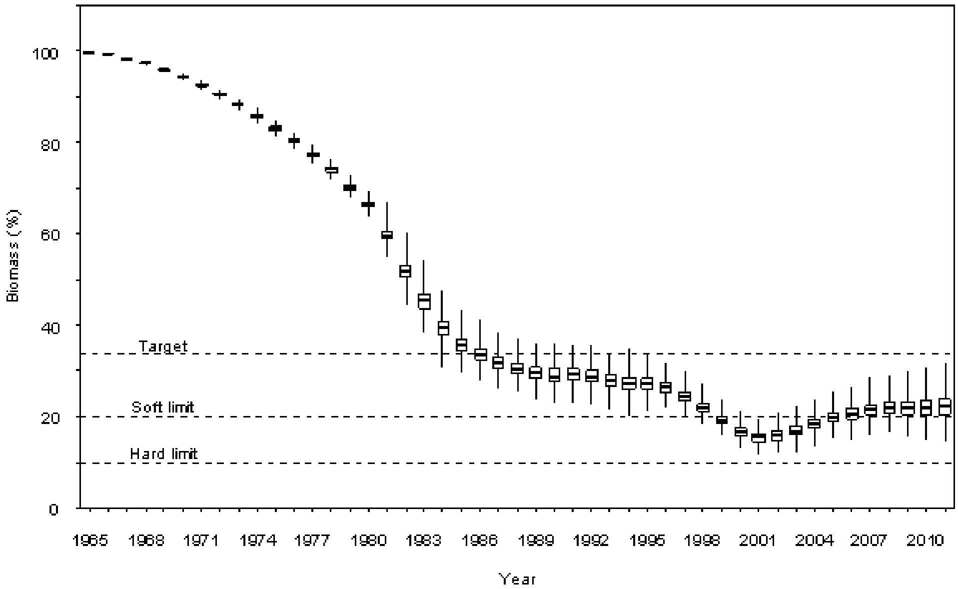
The 2012 assessment was conducted for Statistical Areas 017 and 038 only, but these include most (more than 90%) of the recent catch.

- **PAU 7-** *Haliotis iris*

Stock Status	
Year of Most Recent Assessment	2012
Assessment Runs Presented	Base case MCMC

Reference Points	Interim Target: B_{ref} (average spawning biomass from 1985–1987) = 33.6% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Spawning stock biomass was estimated to be 66% B_{ref} and is Very Unlikely (< 10%) to be at or above the interim target
Status in relation to Limits	Spawning stock biomass was estimated to be 22% B_0, and is About as Likely as Not (40–60%) to be below the soft limit and Unlikely (< 40%) to be below the hard limit

Historical Stock Status Trajectory and Current Status



Posterior distributions of spawning stock biomass as a percentage of virgin level from MCMC 1.0. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. The target is the median reference biomass (33.6% B_0).

Projections and Prognosis	
Stock Projections or Prognosis	Three year projections indicate that spawning and recruited biomass are likely to increase but are Very Unlikely (< 10%) to be at or above the target by this time.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: About as Likely as Not (40–60%) Hard Limit: Unlikely (< 40%)

Assessment Methodology & Evaluation		
Assessment Type	Full quantitative stock assessment	
Assessment Method	Length based Bayesian model	
Assessment Dates	Latest: 2012	Next: 2015
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE	1 – High Quality
	- Research diver survey indices	2 – Medium or Mixed Quality: it is suggested that the RDSI do not provide a reliable index of abundance
	- Commercial catch length frequency	1 – High Quality
	- Research diver length frequency	1 – High Quality

	- Tag-recapture data - Maturity at length data	1 – High Quality 1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	- Data weighting (LF only) and steepness	
Major Sources of Uncertainty	- Spatial heterogeneity not incorporated - Potential hyperstability in CPUE - Potential for localised recruitment failure	

Qualifying Comments
No account has been taken of the voluntary closure of areas affected by “greening”. Stock projections also do not account for reduced production due to potential closed areas in the future, which are likely to slow or reverse projected increases in stock size.

Fishery Interactions
-

6. FOR FURTHER INFORMATION

Andrew, N L; Breen, P A; Kendrick, T H; Naylor, J R (2000) Stock assessment of PAU 7 for 1998–99. *New Zealand Fisheries Assessment Report 2000/48*. 22 p.

Andrew, N L; Naylor, J R; Gerring, P (1999) A modified timed–swim method for paua stock assessment. *New Zealand Fisheries Assessment. Report 2000/4*. 23 p.

Breen, P.A., Andrew, N.L., & Kendrick, T.H. 2000: Stock assessment of paua (*Haliotis iris*) in PAU 5B and PAU 5D using a new length-based model. *New Zealand Fisheries Assessment Report 2000/33*.37 p.

Breen, P A; Kim, S W (2003) The 2003 stock assessment of paua (*Haliotis iris*) in PAU 7. *New Zealand Fishery Assessment Report. 2003/41*. 119 p.

Breen, P A; Kim, S W; Andrew, N L (2003) A length-based Bayesian stock assessment model for abalone. *Marine and Freshwater Research* 54(5): 619–634.

Breen, P A; Kim, S W (2005) The stock assessment of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report. 2005/47*. 114 p.

Cordue, P L (2009) Analysis of PAU 5A diver survey data and PCELR catch and effort data. SeaFic and PAUMac 5 report. 45 p.

Chen, Y; Breen, P A; Andrew, N L (2000) Impacts of outliers and mis-specification of priors on Bayesian fish stock assessment. *Canadian Journal of Fisheries and Aquatic Sciences*. 57: 2293–2305.

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* 68: 15.

Fu, D (2012) The 2011 stock assessment of paua (*Haliotis iris*) for PAU 7. *New Zealand Fisheries Assessment Report 2012/27*. 57 p.

Fu, D; McKenzie, A; Naylor, R (2012) Summary of input data for the PAU 7 stock assessment for the 2010–11. *New Zealand Fisheries Assessment Report 2012/26*.

Gerring, P; Andrew, N L; Naylor, J R (2003) Incidental fishing mortality of paua (*Haliotis iris*) in the PAU 7 commercial fishery. *New Zealand Fisheries Assessment Report. 2003/56*. 13 p.

Gorfine, H K; Dixon, C D (2000) A behavioural rather than resource-focused approach may be needed to ensure sustainability of quota managed abalone fisheries. *Journal of Shellfish Research* 19: 515–516.

Haist, V (2010) Paua research diver surveys: review of data collected and simulation study of survey method. *New Zealand Fisheries Assessment Report. 2010/38*. 54p.

McKenzie, A (2004) Alternative CPUE standardization for PAU 7. NIWA Client Report WLG2004-74. 18 p.

McKenzie, A (2010) CPUE standarisation for PAU 7 in 2010. NIWA Client Report, WLG2010-29. 12 p.

McKenzie, A; Smith, A N H (2009) Data inputs for the PAU 7 stock assessment in 2008. *New Zealand Fisheries Assessment Report. 2009/33*. 34 p.

McKenzie, A; Smith, A N H (2009) The 2008 stock assessment of paua (*Haliotis iris*) in PAU 7. *New Zealand Fisheries Assessment Report. 2009/34*. 86 p.

McShane, P E; Naylor, J R (1995) Small-scale spatial variation in growth, size at maturity, and yield- and egg-per-recruit relations in the New Zealand abalone *Haliotis iris*. *New Zealand Journal of Marine and Freshwater Research* 29: 603–612.

Pirker, J G (1992) Growth, shell–ring deposition and mortality of paua (*Haliotis iris* Martyn) in the Kaikoura region. MSc thesis, University of Canterbury. 165 p.

Punt, A E (2003) The performance of a size-structured stock assessment method in the face of spatial heterogeneity in growth. *Fisheries Research* 65: 391–409.

Sainsbury, K J (1982) Population dynamics and fishery management of the paua, *Haliotis iris*. 1. Population structure, growth, reproduction and mortality. *New Zealand Journal of Marine and Freshwater Research* 16: 147–161.

Schiel, D R (1989) Paua fishery assessment 1989. New Zealand Fishery Assessment Research Document 1989/9: 20 p. (Unpublished document held by NIWA library, Wellington.)

Schiel, D R (1992) The paua (abalone) fishery of New Zealand. *In:* Shepherd, S A; Tegner, M J; Guzman del Proo, S (Eds.), *Abalone of the World: Biology, fisheries, and culture*. Blackwell Scientific, Oxford.

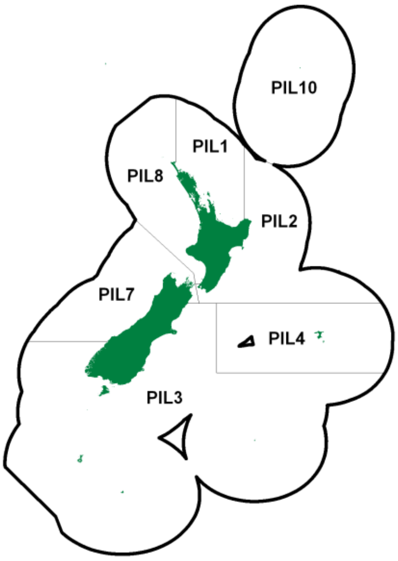
Schiel,D R; Breen, P A (1991) Population structure, ageing and fishing mortality of the New Zealand abalone *Haliotis iris*. *Fishery Bulletin* 89: 681–691.

Shepherd, S A; Partington, D (1995) Studies on Southern Australian abalone (genus *Haliotis*). XVI. Recruitment, habitat and stock relations. *Marine and Freshwater Research* 46: 669–680.

Will, M C; Gemmell, N J (2008) Genetic Population Structure of Black Foot paua. New Zealand Fisheries Research Report. GEN2007A: 37 p. (Unpublished document held by Ministry for Primary Industries, Wellington.)

PILCHARD (PIL)

(*Sardinops sagax*)
Mohimohi



1. FISHERY SUMMARY

Pilchards were introduced into the QMS in October 2002 with allowances, TACCs and TACs as shown in Table 1.

Table 1: Recreational and Customary non-commercial allowances, TACCs and TACs by Fishstock.

Fishstock	Recreational Allowance	Customary Non-commercial Allowance	TACC	TAC
PIL 1	20	10	2 000	2 030
PIL 2	10	5	200	215
PIL 3	5	2	60	67
PIL 4	3	2	10	15
PIL 7	10	5	150	165
PIL 8	10	5	65	80
PIL 10	0	0	0	0

1.1 Commercial fisheries

Pilchards occur around most of New Zealand, however, commercial fisheries have only developed in north-eastern waters (east Northland to Bay of Plenty), and in Tasman Bay and Marlborough Sounds at the north of the South Island.

Historical estimated and recent reported pilchard landings and TACCs are shown in Tables 2 and 4, while Figure 1 shows the historical and recent landings and TACC values for the main pilchard stocks.

The first recorded commercial landings of pilchards were in 1931 (Table 2), but a minor fishery existed before this. Informal sales, mainly as bait, or as food for zoos and public aquariums, were unreported. A fishery for pilchard developed in the Marlborough Sounds in 1939 and operated through the war years providing canned fish for the armed forces. Landings reached over 400 t in 1942, but the fishery was unsuccessful for a variety of reasons and ceased in 1950. Between 1950 and 1990 landings were generally less than 20 t, intermittently reaching 70–80 t.

From 1990–91 the northeastern fishery was developed by vessels using both lampara nets and purse seines (Table 3). Lampara netting was the main method in the first couple of years, and continued at a low level through the 1990s. From 1993–94 onwards, purse seining became the dominant method. A diminishing catch (less than 10 t annually) was caught by beach seine. Almost all the pilchard catch (particularly in the northeastern fishery) is targeted. A small catch (less than 10 t annually), has been recorded as a bycatch of jack mackerel targeting. Total annual landings increased steadily from 1990 as the fishery developed in northeastern waters, reaching over 1200 t in 1999–00, and almost 1500 t in 2000–01. Landings declined consistently after 2003-04, largely influenced by catches from PIL 1, and since 2010-11 have been between 221 and 391t. Landings in PIL 8 have fluctuated between 12 t and 153 t since this stock was introduced to the QMS, and have not exceeded the TACC (65 t) in the last five years. The sudden increase in catches in PIL 8 from 1999–2000 to 2005-6 was thought to be in part the result of previously unreported catches now being reported due to the species being introduced to the QMS.

Table2: Reported landings (t) for the main QMAs from 1931 to 1990.

Year	PIL 1	PIL 2	PIL 3	PIL 4	Year	PIL 1	PIL 2	PIL 3	PIL 4
1931-32	5	0	0	0	1957	2	0	0	0
1932-33	4	0	0	0	1958	8	0	0	0
1933-34	2	0	0	0	1959	3	2	0	0
1934-35	0	0	0	0	1960	3	3	0	0
1935-36	0	0	0	0	1961	0	8	0	0
1936-37	0	0	0	0	1962	0	1	0	0
1937-38	0	0	0	0	1963	0	0	0	0
1938-39	0	0	0	0	1964	0	0	0	0
1939-40	0	5	0	0	1965	2	0	0	0
1940-41	3	41	0	0	1966	3	0	0	0
1941-42	15	73	0	0	1967	8	0	0	0
1942-43	0	69	0	0	1968	8	2	0	0
1943-44	0	9	0	0	1969	3	4	0	0
1944	0	0	0	0	1970	1	0	1	0
1945	0	0	0	0	1971	1	0	0	0
1946	0	0	0	0	1972	0	0	8	0
1947	0	0	0	0	1973	0	67	0	0
1948	0	0	0	0	1974	18	1	0	0
1949	0	0	0	0	1975	2	0	0	0
1950	0	0	0	0	1976	6	0	0	0
1951	0	0	0	0	1977	20	0	0	0
1952	0	0	0	0	1978	5	0	0	0
1953	0	0	0	0	1979	1	0	2	0
1954	0	0	0	0	1980	1	16	0	0
1955	0	0	0	0	1981	0	8	0	0
1956	4	0	0	0	1982	0	16	0	0

Year	PIL 7	PIL8	Year	PIL 7	PIL8
1931-32	0	0	1957	0	0
1932-33	0	0	1958	0	0
1933-34	0	0	1959	2	0
1934-35	0	0	1960	3	0
1935-36	0	0	1961	8	0
1936-37	0	0	1962	1	0
1937-38	0	0	1963	0	0
1938-39	0	0	1964	0	0
1939-40	5	0	1965	1	0
1940-41	49	0	1966	0	0
1941-42	79	0	1967	0	1
1942-43	69	0	1968	0	0
1943-44	9	0	1969	7	0
1944	217	0	1970	81	0
1945	74	0	1971	0	0
1946	61	0	1972	0	0
1947	5	0	1973	3	0
1948	46	0	1974	0	0
1949	11	0	1975	0	0
1950	0	0	1976	0	0
1951	0	0	1977	0	0
1952	9	0	1978	0	0
1953	0	0	1979	0	0
1954	0	0	1980	24	0
1955	0	0	1981	8	0
1956	0	0	1982	16	0

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 3: Reported total New Zealand landings (t) of pilchard from 1931 to 1990.

Year	Landings	Year	Landings	Year	Landings	Year	Landings	Year	Landing	Year	Landing
1931	5	1941	168	1951	0	1961	17	1971	1	1981	17
1932	4	1942	418	1952	9	1962	2	1972	8	1982	32
1933	2	1943	219	1953	0	1963	0	1973	70	1983	-
1934	0	1944	218	1954	0	1964	1	1974	19	1984	-
1935	0	1945	74	1955	0	1965	3	1975	2	1975	49
1936	0	1946	61	1956	4	1966	3	1976	6	1986	29
1937	0	1947	5	1957	2	1967	9	1977	20	1987	70
1938	0	1948	46	1958	8	1968	10	1978	6	1988	6
1939	10	1949	11	1959	7	1969	15	1979	4	1989	1
1940	93	1950	0	1960	8	1970	83	1980	41	1990	2

Source: Annual reports on fisheries and subsequent MAF data.

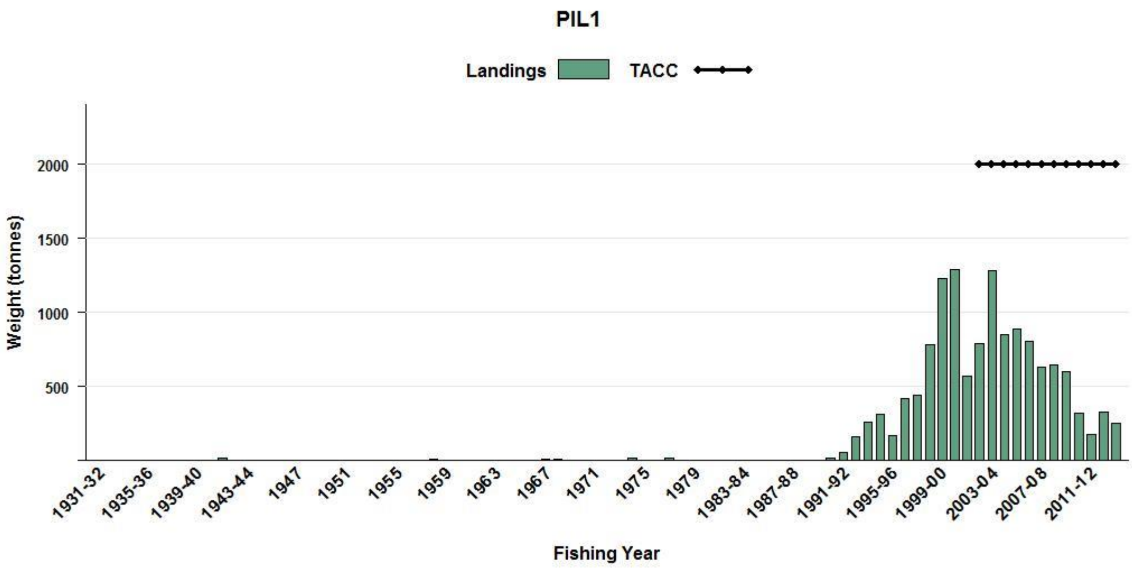
A 2000 t annual Commercial Catch Limit (CCL) was introduced for FMA 1 from 01 October 2000. The CCL was subject to a logbook programme, a catch spreading arrangement and the avoidance of areas of particular importance to non-commercial fishers. The CCL was superseded when the PIL 1 stock was introduced to the QMS with a TACC of 2000 t on 1st October 2002.

Table 4: Reported landings (t) of pilchard by Fishstock from 1990–91 to 2012–13.

QMA	PIL 1		PIL 2		PIL 3		PIL 7		PIL 8		Total
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TAC	Landings	TACC	Landings
1990–91	15	-	0	-	0	-	9	-	< 1	-	25
1991–92	59	-	0	-	0	-	< 1	-	0	-	59
1992–93	163	-	2	-	0	-	0	-	0	-	164
1993–94	258	-	0	-	0	-	0	-	1	-	259
1994–95	317	-	0	-	0	-	< 1	-	< 1	-	317
1995–96	168	-	< 1	-	0	-	2	-	0	-	170
1996–97	419	-	0	-	0	-	2	-	< 1	-	421
1997–98	440	-	0	-	0	-	1	-	0	-	447
1998–99	785	-	0	-	< 1	-	2	-	1	-	788
1999–00	1 227	-	0	-	0	-	4	-	< 1	-	1 231
2000–01	1 290	-	0	-	0	-	12	-	188	-	1 491
2001–02	574	-	0	-	0	-	93	-	129	-	796
2002–03	792	2 000	0	200	0	60	8	150	153	65	953
2003–04	1 284	2 000	0	200	< 1	60	1	150	34	65	1 320
2004–05	853	2 000	0	200	< 1	60	< 1	150	106	65	959
2005–06	892	2 000	< 1	200	< 1	60	2	150	116	65	1 010
2006–07	808	2 000	0	200	0	60	11	150	45	65	864
2007–08	635	2 000	0	200	0	60	10	150	71	65	716
2008–09	644	2 000	< 1	200	0	60	3	150	23	65	670
2009–10	599	2 000	0	200	4	60	10	150	54	65	667
2010–11	319	2 000	< 1	200	<1	60	2	150	12	65	333
2011–12	178	2 000	0	200	< 1	60	< 1	150	42	65	221
2012–13	332	2 000	<1	200	0	60	2	150	58	65	391
2013-14	255	2 000	<1	200	<1	60	13	150	97	65	365

1.2 Recreational fisheries

Recreational fishers seldom target pilchards, except perhaps for bait. However bait is generally bought in commercially frozen packs (the main product of the commercial fishery). Pilchard may be caught accidentally in small mesh nets that are set or dragged to catch mullet, or on small hooks fished from wharves. They are rarely reported as a catch in recreational fishing activities. An estimate of the recreational harvest is not available.



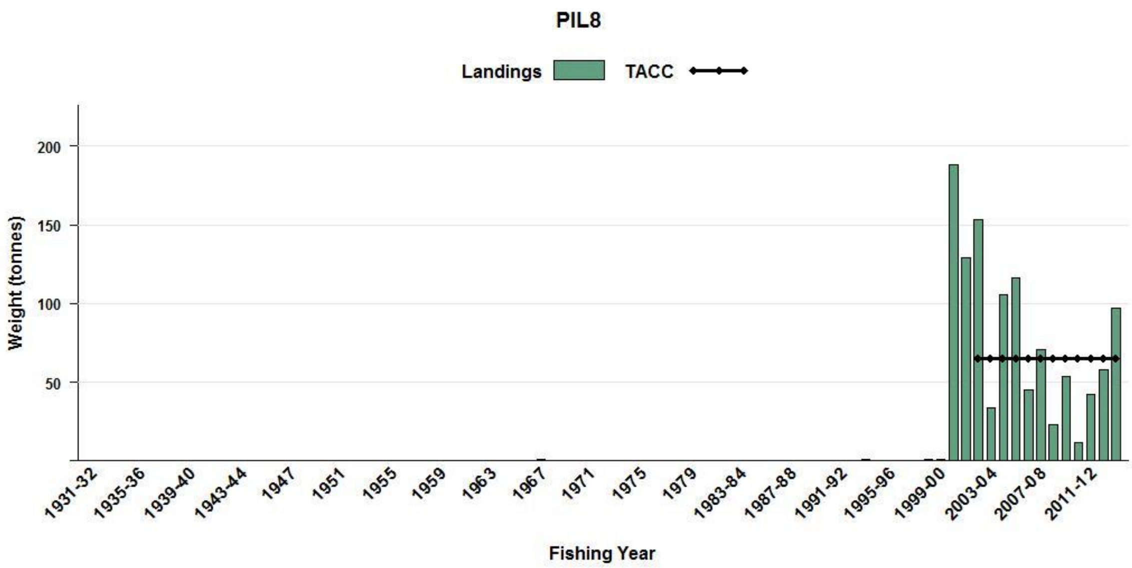


Figure 1: Reported commercial landings and TACC for the two main PIL stocks. PIL 1 (Auckland East), and PIL 8 (Central Egmont, Auckland West).

1.3 Customary non-commercial catch

Pilchards were known by the early Maori as mohimohi, and could have been taken in fine mesh nets, but there are very few accounts of pilchard capture and use. An estimate of the current customary non-commercial catch is not available.

1.4 Illegal catch

There is no known illegal catch of pilchards.

1.5 Other sources of mortality

Some accidental captures by vessels purse seining for jack mackerel or kahawai may be discarded if no market is available. Pilchard mortality is known to be high in some places as a result of scale loss resulting from net contact.

2. BIOLOGY

The taxonomy of *Sardinops* is complex. The New Zealand pilchard was previously identified as *Sardinops neopilchardus*, but there is now considered to be a single species, *S. sagax*, with several regional subspecies or populations.

Pilchard are generally found inshore, particularly in gulfs, bays, and harbours. They display seasonal changes in abundance (e.g. locally abundant in Wellington Harbour during spring), reflecting schooling and dispersal behaviour, localised movement, and actual changes in population size. The geographical extent of their movements in New Zealand is unknown.

Their vertical distribution in the water column varies, but on the inner shelf they move between the surface and the seafloor. Pilchards form compact schools (known as 'meatballs'), particularly during summer, and these are heavily preyed upon by larger fishes, seabirds, and marine mammals and are thought to form an important part of the diet for many species. There have been no biological studies that are directly relevant to the recognition of separate stocks.

Spawning is recorded from many coastal regions over the shelf during spring and summer. The pelagic eggs are at times extremely abundant.

Otolith readings suggest that pilchard are relatively fast growing and short-lived. They reach a maximum length of about 25 cm, and perhaps 9 years, but the main size range is of 10−20 cm fish, 2 to 6 years old. Maturity is probably at age 2.

A study on the feeding of Northland pilchards found that phytoplankton was probably the dominant food, but organic detritus was also important, and small zooplankton - mainly copepods - were taken and at times were the main component. Feeding by females diminished during the spawning season.

Although they generally comprise single-species schools, pilchards associate with other small pelagic fishes, particularly anchovy. In northern waters they also occur with juvenile jack mackerel, and in southern waters with sprats.

During the 1990s pilchard populations were severely impacted by natural mass mortalities, generally attributed to a herpes virus. The first outbreak occurred in Australia and New Zealand in 1995 and Australia experienced another outbreak in 1998.

Biological parameters relevant to stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters.

Fishstock		Estimate	Source
1. Natural mortality (*M*)			
PIL 1		$M = 0.66$	NIWA, unpublished estimate[1]
PIL 1		$M = 0.46$	NIWA, unpublished estimate[2]
2. Weight = a (length)^b			
	Both sexes combined		
PIL 1	a = 2.2	b = 3.3	Paul et al (2001)[3]
PIL 7	a = 3.7	b = 3.3	Baker (1972)[4]

Notes:
1. Hoenig's rule-of-thumb estimate, maximum age = 7 years.
2. Hoenig's rule-of-thumb estimate, maximum age = 10 years.
3. Fork length in mm, weight in g, n = 493.
4. Standard length in mm, weight in g, n = 660.

3. STOCKS AND AREAS

No biological information is available on which to make an assessment on whether separate pilchard biological stocks exist in New Zealand (in Australia there is evidence of small differences between some populations off the southwest coast).

Pilchard and anchovy are often caught together. Pilchard Fishstock boundaries are fully aligned with those for anchovy.

4. STOCK ASSESSMENT

There have been no stock assessments of New Zealand pilchard.

4.1 Estimates of fishery parameters and abundance

No fishery parameters are available.

4.2 Biomass estimates

No estimates of biomass are available.

4.3 Yield estimates and projections

(i) Northeast North Island (PIL 1)

MCY has been estimated using the equation $MCY = cY_{AV}$ (Method 4). The most appropriate Y_{AV} was considered the average of landings for the three years 1998–99 to 2000–01. Although a brief period, three years represents at least half the exploited life span for this species. The mean of these landings is 1101 t. With provisional values of *M* about 0.4 or 0.6, the value of c becomes 0.6 (i.e. high natural variability).

1998–99 to 2000–01 *MCY* = 0.6 * 1101 t = 661 t (rounded to 660 t)

However, the *MCY* approach is considered to be of limited value for pilchards, because this fishery has been developing rapidly, was historically infrequently targeted, and since 2000 has been subject to a CCL and more recently a TACC. The level of risk to the stock by harvesting the northeast North Island population at the estimated *MCY* value cannot be determined.

(ii) Tasman Bay/Marlborough Sounds (PIL 7)

MCY cannot be estimated for this region because the fishery has been largely unexploited since the 1940s, and no appropriate biological parameters exist.

(iii) Other regions

MCY cannot be estimated because of insufficient information, and absence of fisheries.

Current biomass cannot be estimated, so *CAY* cannot be determined.

4.4 Other factors

It is likely that pilchard, although not strongly migratory, will vary considerably in their regional abundance over time. The larger vessels in the fleet that targets them are capable of travelling moderate distances to the best grounds. Thus, while the resource may have a relatively localised distribution, the catching sector of the fishery does not. Should the pilchard fishery develop again after recent declineit is likely to become one component of a set of fisheries for small pelagic species (anchovy, sprats, and small jack mackerels). Mixed catches will be inevitable.

Pilchard is abundant in some New Zealand regions. However, it is unlikely that the biomass is comparable to the very large stocks of pilchard (sardine) in some world oceans where strong upwelling promotes high productivity. It is more likely that the New Zealand pilchard comprises abundant but localised coastal populations, comparable to those of southern Australia. They appear to be adaptable feeders, able to utilise food items from organic detritus through phytoplankton to zooplankton. East Northland is a region where under neutral to El Niño conditions moderately productive upwelling predominates, but in La Niña years downwelling and oceanic water incursion will limit recruitment and may affect adult condition and survival.

In those regions of the world where small pelagic fishes are particularly abundant and have been well studied, there is often a reciprocal relationship between the stock size of pilchard and anchovy, as well as great variability in their overall abundance. Many pilchard/anchovy fisheries have undergone boom-and-bust cycles.

In both Australia and New Zealand, pilchard have been affected by mass mortality events, the two in Australia are estimated to have each killed over 70% of the adult fish. The mortality rate of the 1995 event in New Zealand is not known, but was high. In combination, these features of the pilchard's biology suggest that the yield from the New Zealand stock will be variable, both short-term (annual) and long-term (decadal).

5. STATUS OF THE STOCKS

MCY estimates for PIL are considered unreliable. It is not known if the current catches or TACCs are sustainable.

Yield estimates, TACCs and reported landings by Fishstock are summarised in Table 6.

Table 6: Summary of yield estimates (t), TACCs (t), and reported landings (t) of pilchards for the most recent fishing year.

Fishstock		FMA	*MCY* Estimates	2013–14 Actual TACC	2013–14 Reported landings
PIL 1	Auckland (East)	1	660	2 000	255
PIL 2	Central (East)	2	–	200	<1
PIL 3	South-east (Coast)/Southland & Sub-Antarctic	3, 5 & 6	–	60	<1
PIL 4	South-east (Chatham)	4	–	10	0
PIL 7	Challenger	7	–	150	13
PIL 8	Central (West)/Auckland (West)	8, 9	–	65	97
PIL 10	Kermadec	10	–	0	0

6. FOR FURTHER INFORMATION

Baker, A N (1972) Reproduction, early life history, and age-growth relationships of the New Zealand pilchard, *Sardinops neopilchardus* (Steindachner). *Fisheries Research Bulletin* No. 5. 64 p.

Jacobson, L D; De Oliveira, J A A; Barange, M; Cisneros-Mata, M A; Félix-Uraga, R; Hunter, J R; Kim, J Y; Matsuura, Y; Ñiqueen, M; Porteiro, C; Rothschild, B; Sanchez, R P; Serra, R; Uriarte, A; Wada, T (2001) Surplus production, variability, and climate change in the great sardine and anchovy fisheries. *Canadian Journal of Fisheries and Aquatic Sciences* 58(9): 1891–1903.

Paul, L J; Bradford-Grieve, J M; Tasker, R A; Chang, F H; Manning, M J (2005) Guts, gill rakers, and ENSO oceanography: a pilot study on feeding patterns in the New Zealand pilchard, *Sardinops sagax*, off east Northland. Final Research Report for Ministry of Fisheries Research Project PIL2003/01, Objective 1. 30 p. (Unpublished Report held by the Ministry for Primary Industries, Wellington).

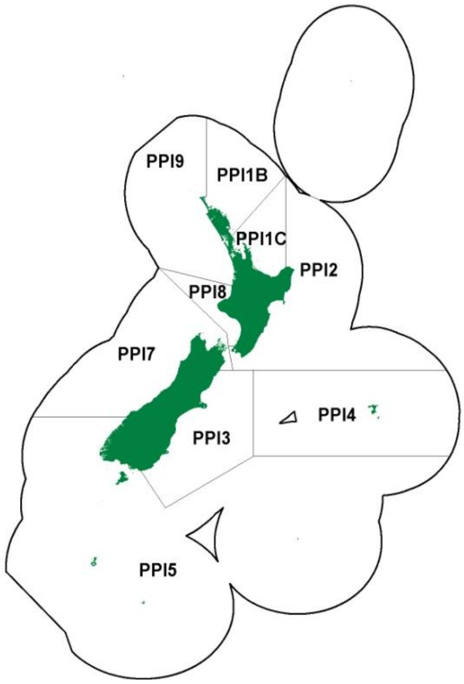
Paul, L J; Taylor, P R; Parkinson, D M (2001) Pilchard (*Sardinops neopilchardus*) biology and fisheries in New Zealand, and a review of pilchard (*Sardinops*, *Sardina*) biology, fisheries, and research in the main world fisheries. *New Zealand Fisheries Assessment Report 2001/37*. 44 p.

Schwartzlose, R A; Ahleit, J; Bakun, A; Baumgartner, T R; Cloete, R; Crawford, R J M; Fletcher, W; Green-Ruiz, Y; Hagen, E; Kawasaki, T; Lluch-Belda, D; Lluch-Cota, S E; MacCall, A D; Matsuura, Y; Nevarez-Martínez, M O; Parrish, R H; Roy, C; Serra, R; Shust, K V; Ward, M N; Zuzunaga, J Z (1999) Worldwide large-scale fluctuations of sardine and anchovy populations. *South African Journal of Marine Science* 21: 289–347.

Ward, T M; Hoedt, F; McLeay, L; Dimmlich, W F; Kinloch, M; Jackson, G; McGarvey, R; Rogers, P J; Jones, K (2001) Effects of the 1995 and 1998 mass mortality events on the spawning biomass of sardine, *Sardinops sagax*, in South Australian waters. *ICES Journal of Marine Science* 58(4): 865–875.

PIPI (PPI)

(*Paphies australis*)
Pipi



1. FISHERY SUMMARY

Pipi are important shellfish both commercially and for non-commercial fishers. PPI 1A (which is located in Whangarei harbour and mapped in the following PPI 1A section) was introduced into the Quota Management System (QMS) on 1 October 2004, the other PPI stocks listed in Table 1 were introduced in October 2005. The total TAC introduced to the QMS was 713 t. This consisted of a 204 t TACC, an allocation of 242 t for both recreational allowance and customary allowance and 25 t allowance for other sources of mortality (Table 1). No changes have occurred to the TAC since. The fishing year is from 1 October to 30 September and commercial catches are measured in greenweight. The largest commercial fishery is in PPI 1A and the largest recreational fishery is in PPI 1C.

Table 1: Recreational, Customary non-commercial allocations, TACs and TACCs (t) for pipi.

Fishstock	Recreational Allowance	Customary non-commercial allowance	Other sources of mortality	TACC	TAC
PPI 1A	25	25	0	200	250
PPI 1B	76	76	8	0	160
PPI 1C	115	115	10	3	243
PPI 2	3	3	1	0	7
PPI 3	9	9	1	0	19
PPI 4	1	1	1	0	3
PPI 5	1	1	1	0	3
PPI 7	1	1	1	1	4
PPI 8	1	1	1	0	3
PPI 9	10	10	1	0	21
Total	242	242	25	204	713

Regulations require that all commercial gathering is to be done by hand. Fishers typically use a mask and snorkel. There is no minimum legal size (MLS) for pipi, although fishers probably favor larger pipi (over 60 mm shell length). There is no apparent seasonality in the pipi fishery, as pipi are available for harvest year-round. Some commercial catch is taken from PPI 1C (Table 2 and Figure 1) but the great majority of commercial catch is reported from PPI 1A and this will be dealt with in a separate section.

New Zealand operates a mandatory shellfish quality assurance programme for all areas of commercially growing or harvesting bivalve shellfish for human consumption. Shellfish caught outside this programme can be sold only for bait. This programme is based on international best practice and is managed by MPI in cooperation with the District Health Board Public Health Units and the shellfish industry[1]. Before any area can be used to grow or harvest bivalve shellfish, public health officials survey both the water catchment area to identify any potential pollution issues and microbiologically sample water and shellfish over at least a 12-month period, so that all seasonal influences are explored. This information is evaluated and, if suitable, the area classified and listed by NZFSA for harvest. There is then a requirement for regular monitoring of the water and shellfish flesh to verify levels of microbiological and chemical contaminants. Management measures stemming from this testing include closure after rainfall, to deal with microbiological contamination from runoff. Natural marine biotoxins can also cause health risks so testing also occurs for this at regular intervals. If toxins are detected above the permissible level the harvest areas are closed until the levels fall below the permissible level. Products are also traceable so the source and time of harvest can always be identified in case of contamination.

Table 2: Reported commercial landings of pipi (t greenweight) from PPI 1C from 2004–05 to present.

Year	Reported landings (t)	Limit (t)
2004–05	0	3
2005–06	0.86	3
2006–07	1.69	3
2007–08	1.80	3
2008–09	0.38	3
2009–10	0.62	3
2010–11	0	3
2011–12	0	3
2012–13	0	3
2013-14	0	3

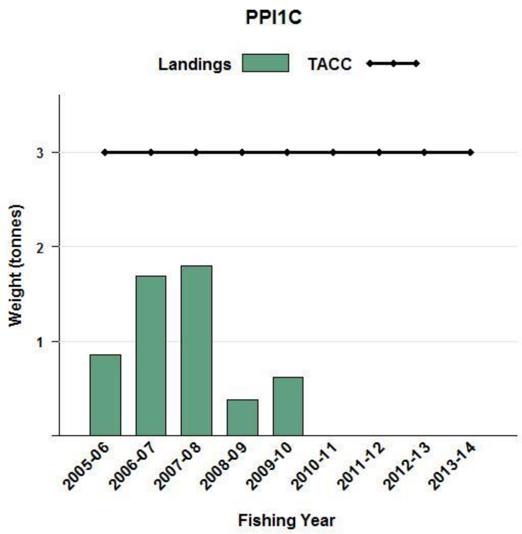


Figure 1: Reported commercial landings and TACC for PPI 1C (Hauraki Gulf and the Bay of Plenty).

---

[1]. For full details of this programme, refer to the Animal Products (Regulated Control Scheme-Bivalve molluscan Shellfish) Regulations 2006 and the Animal Products (Specifications for Bivalve Molluscan Shellfish) Notice 2006 (both referred to as the BMSRCS), at: http://www.foodsafety.govt.nz/industry/sectors/seafood/bms/growers-harvesters.htm

1.2 Recreational fisheries

The recreational fishery is harvested entirely by hand digging. Large pipi 50 mm (maximum shell length) or greater are probably preferred. The 1996, 1999–00, and 2000–01 National Marine Recreational Fishing Surveys recorded recreational harvests for pipi in FMA 1. The estimated numbers of pipi harvested were 2.1, 6.6, and 7.2 million respectively but no mean harvest weight was available to convert these harvest estimates to tonnages. The Recreational Technical Working Group concluded that the harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and, c) the 2000 and 2001 estimates are implausibly high for many important fisheries. No recreational harvest estimates specific to the Mair Bank pipi fishery are available but the recreational harvest of pipi is likely to be small compared with commercial landings there prior to 1 October 2014. After 1 October 2014 all take of pipi from Mair Bank was prohibited due to historically low pipi biomass levels.

1.3 Customary fisheries

In common with many other intertidal shellfish, pipi are very important to Maori as a traditional food. However, no reliable quantitative information on the level of customary take is available. After 1 October 2014 all take of pipi from Mair Bank was prohibited due to historically low pipi biomass levels.

1.4 Illegal catch

No quantitative information on the level of illegal catch is available.

1.5 Other sources of mortality

No quantitative nationwide information on the level of other sources of mortality is available.

2. BIOLOGY

The pipi (*Paphies australis*) is a common burrowing bivalve mollusc of the family Mesodesmatidae. Pipi are distributed around the New Zealand coastline, including the Chatham and Auckland Islands (Powell 1979), and are characteristic of sheltered beaches, bays and estuaries (Morton & Miller 1968). Pipi are tolerant of moderate wave action, and commonly inhabit coarse shell sand substrata in bays and at the mouths of estuaries where silt has been removed by waves and currents (Morton & Miller 1968). They have a broad tidal range, occurring intertidally and subtidally in high-current harbour channels to water depths of at least 7 m (Dickie 1986a, Hooker 1995a), and are locally abundant, with densities greater than 1000 m^{-2} in certain areas (Grace 1972).

Pipi reproduce by free-spawning, and most individuals are sexually mature at about 40 mm shell length (SL) (Hooker & Creese 1995a). Gametogenesis begins in autumn, and by late winter many pipi have mature, ready-to-spawn gonads (Hooker & Creese 1995a). Pipi have an extended breeding period from late winter to late summer, with greatest spawning activity occurring in spring and early summer. Fertilised eggs develop into planktotrophic larvae, and settlement and metamorphosis occur about three weeks after spawning (Hooker 1997). In general, pipi have been considered sedentary when settled, although Hooker (1995b) found that pipi may utilise water currents to disperse actively within a harbour. The trigger for movement is unknown, but this ability to migrate may have important implications to their population dynamics.

Pipi growth dynamics are not well known. Growth appears to be fairly rapid, at least in dynamic, high-current environments such as harbour channels. Hooker (1995a) showed that pipi at Whangateau Harbour (northeastern New Zealand) grew to about 30 mm in just over one year (16–17 months), reached 50 mm after about three years, and grew very slowly after attaining 50 mm. There was a strong seasonal component to growth, with rapid growth occurring in spring and summer, and little growth in autumn and winter. Williams et al (2007) used Hooker’s (1995a) tag-recapture and length frequency time series data to generate formal growth estimates for Whangateau Harbour pipi (Table 3). Estimates are also available from time series of size frequencies on sheltered Auckland beaches (Table 3; Morrison & Browne 1999, Morrison et al 1999), although these were likely to have been poorly estimated due to variability in the length data. Growth on the intertidal section of Mair bank was estimated by (Pawley et al 2013) using the results of a notch-tagging experiment in 2009–10. These estimates are likely to underestimate growth of pipi in the commercial fishery because tagged shells came from the intertidal zone wheras commercial harvesting is conducted primarily in the subtidal (where growth is expected to be quicker).

Little is known about the natural mortality or maximum longevity of pipi. Haddon (1989) suggested that pipi are unlikely to live much more than 10 years, and used assumed maximum ages of 10, 15 and 20 years old to estimate maximum constant yield for Mair Bank pipi in 1989. The estimation of the rate of instantaneous natural mortality (*M*) is difficult for pipi owing to the immigration and emigration of individuals from different areas. As the timing and frequency of these movements are largely unknown, the separation of mortality from movement effects is likely to be problematic. Williams et al (2007) assumed values of M = 0.3, 0.4, and 0.5 to estimate yields for Mair Bank in 2005–06.

Table 3: Estimates of biological parameters for pipi.

Growth		Location	Year	Source
L_∞ (mm SL)	K			
57.3	0.46	Inner Whangateau Harbour site	1992–93	Williams et al (2007)
63.9	0.57	Whangateau Harbour entrance	1992–93	Williams et al (2007)
41.1	0.48	Cheltenham Beach, North Shore	1997–98	Morrison et al (1999)
58.9	0.15	Mill Bay, Manukau Harbour	1997–98	Morrison et al (1999)
84.6	0.09	Mill Bay, Manukau Harbour	1998–99	Morrison & Browne (1999)
Natural mortality				
M = 0.3–0.5 (assumed values)		-	-	Williams et al (2007)
Size at maturity				
40 mm SL		Whangateau Harbour	-	Hooker & Creese (1995a)

3. STOCKS AND AREAS

Little is known of the stock structure of pipi. A study of biological connectivity that is currently underway includes pipi, but no results have been reported at the time of this report.

4. STOCK ASSESSMENT

There is a stock assessment for PPI 1A.

5. STATUS OF THE STOCKS

There were negligible reported landings in 2012–13 for any PPI stocks except PPI 1A (which is reported separately). The status of all PPI stocks other than PPI 1A are unknown, but are assumed to be close to virgin biomass.

6. FOR FURTHER INFORMATION

Cranfield, H J; Michael, K P; Stotter, D (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. *New Zealand Fisheries Assessment Research Document 1993/20*. 47 p.

Dickie, B N (1986a) Physical and biological survey of a subtidal *Paphies australis* population in the lower Whangarei Harbour. Whangarei Water Quality Management Plan. Working Report 4. 45 p. (Unpublished report to the Northland Catchment Commission and Regional Water Board, New Zealand).

Dickie, B N (1986b) Topographic survey of three intertidal *Paphies australis* habitats in the lower Whangarei Harbour. Whangarei Water Quality Management Plan. Working Report 2. 45 p. (Unpublished report to the Northland Catchment Commission and Regional Water Board, New Zealand).

Fournier, D A; Sibert, J R; Majkowski, J; Hampton, J (1990) MULTIFAN: a likelihood-based method for estimating growth parameters and age composition from multiple length frequency data sets illustrated using data for southern bluefin tuna (*Thunnus maccoyi*). *Canadian Journal of Fisheries and Aquatic Sciences 47*: 301–317.

Francis, R I C C (1988) Maximum likelihood estimation of growth and growth variability from tagging data. *New Zealand Journal of Marine and Freshwater Research* 22(1): 43–51.

Grace, R G (1972) The benthic ecology of the entrance to the Whangateau Harbour, Northland, New Zealand. Unpublished PhD thesis. University of Auckland, Auckland, New Zealand.

Haddon, M (1989) Biomass estimate of the pipi *Paphies australis* on Mair Bank, Whangarei Harbour. 23 p. (Unpublished report to MAF Fisheries North, Auckland, New Zealand).

Hooker, S H (1995a) Life history and demography of the pipi *Paphies australis* (Bivalvia: Mesodesmatidae) in northeastern New Zealand. Unpublished PhD thesis. University of Auckland, Auckland, New Zealand. 230 p.

Hooker, S H (1995b) Preliminary evidence for post-settlement movement of juvenile and adult pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). *Marine and Freshwater Behaviour and Physiology* 27(1): 37–47.

Hooker, S H (1997) Larval and postlarval development of the New Zealand pipi, *Paphies australis* (Bivalvia : Mesodesmatidae). *Bulletin of Marine Science* 61(2): 225–240.

Hooker, S H; Creese, R G (1995a) The reproductive biology of pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). I. Temporal patterns of the reproductive cycle. *Journal of Shellfish Research* 14(1): 7–15.

Hooker, S H; Creese, R G (1995b) The reproductive biology of pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). II. Spatial patterns of the reproductive cycle. *Journal of Shellfish Research* 14(1): 17–24.

Morrison, M A; Browne, G N (1999) Intertidal shellfish population surveys in the Auckland region, 1998–99, and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/43. 21 p. (Unpublished report held in NIWA library, Wellington.)

Morrison, M A; Pawley, M D M; Browne, G N (1999) Intertidal surveys of shellfish populations in the Auckland region, 1997–98, and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/25. 25 p. (Unpublished report held in NIWA library, Wellington).

Morton, J E; Miller, M C (1968) *The New Zealand Sea Shore*. Collins, Auckland, New Zealand. 653 p.

OtterResearch (1992) MULTIFAN 32(f). *User's Guide and Reference Manual*. Otter Research Ltd., Nanaimo, Canada. 67 p.

Pawley M.D, Hannaford O., Morgan K. (2013) Biomass survey and stock assessment of pipi (*Paphies australis*) on Mair and Marsden Bank, Whangarei Harbour. *New Zealand Fisheries Assessment Report 2013/42*. 32 p.

Powell, A W B (1979) *New Zealand Mollusca: Marine, Land and Freshwater Shells.* Collins, Auckland, New Zealand. 500 p.

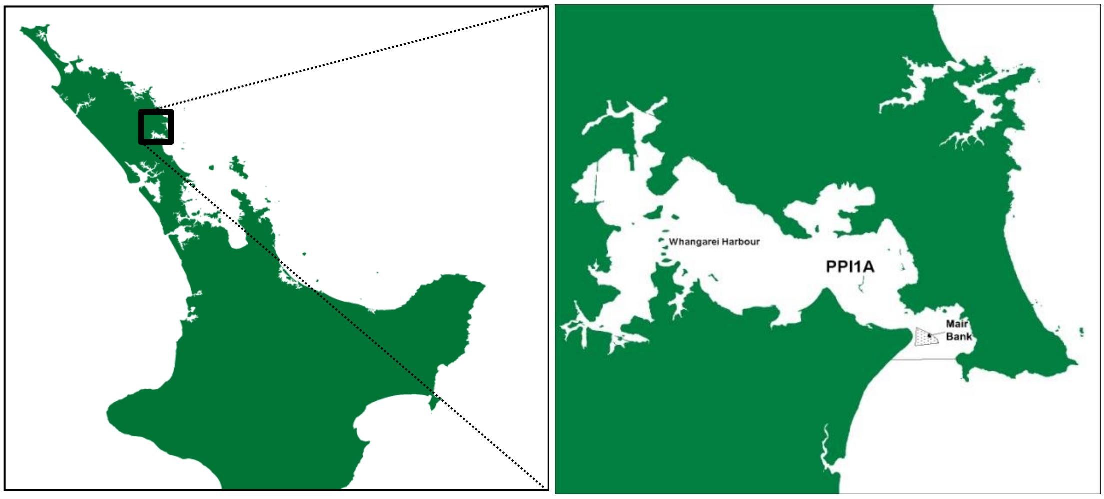
Sullivan, K J; Mace, P M; Smith, N W M; Griffiths, M H; Todd, P R; Livingston, M E; Harley, S J; Key, J M; Connell, A M (Comps.) (2005). Report from the Fishery Assessment Plenary, May 2005: stock assessments and yield estimates. 792 p. (Unpublished report held in NIWA library, Wellington.)

Venus, G C (1984) *Paphies australis* (pipis) in Whangarei Harbour. Whangarei Harbour Study Technical Report No. 6. 60 p. (Unpublished technical report coordinated by the Northland Harbour Board).

Williams, J R; Cryer, M; Hooker, S H; Smith, M D; Watson, T G; MacKay, G; Tasker, R (2007) Biomass survey and stock assessment of pipi (*Paphies australis*) on Mair Bank, Whangarei Harbour, 2005. *New Zealand Fisheries Assessment Report. 2007/03*, 29 p.

PPI (PPI 1A) Mair Bank (Whangarei Harbour)

(*Paphies australis*)
Pipi



1. FISHERY SUMMARY

Pipi 1A was introduced into the Quota Management System (QMS) on 1 October 2004 with a TAC of 250 t, comprising a TACC of 200 t, and customary and recreational allowances of 25 t each. After 1 October 2014 all take of pipi from Mair Bank was prohibited due to historically low pipi biomass levels.

1.1 Commercial fisheries

Prior to the introduction of pipi, in Whangarei Harbour (PPI 1A) and FMA PPI 1, to the QMS in 2004, the commercial fishery area was defined in regulation as that area within 1.5 nautical miles of the coastline from Home Point, at the northern extent of the Whangarei Harbour entrance, to Mangawhai Heads, south of the harbour. Commercial fishers tend to gather pipi from the seaward edge of Mair Bank, particularly the southern end, and avoid the centre of the bank itself where there is a lot of shell debris. Regulations require that all gathering be done by hand, and fishers typically use a mask and snorkel. There is no minimum legal size (MLS) for pipi, although a sample measured from the commercial catch in PPI 1A in 2005 suggested that fishers favour larger pipi (over 60 mm SL, Williams et al 2007). Pipi are available for harvest year-round, so there is no apparent seasonality in the fishery.

Over 99% of the total commercial landings of pipi in New Zealand have been from general statistical area 003 and PPI 1. In the most recent years, where a distinction has been made, virtually all the landings have been from PPI 1A (Whangarei Harbour). Total commercial landings of pipi reported on Licensed Fish Receiver Returns (LFRRs) have remained reasonably stable through time, averaging 187 t annually in New Zealand since 1986–87 (Table 1). The highest recorded landings were in 1991–92 (326 t). There is no evidence of any consistent seasonal pattern in either the level of effort or catch per unit effort (CPUE) in the pipi fishery. CPUE in the pipi targeted fishery increased between 1989–90 and 1992–93, was then relatively stable up to 2002–03 but increased in 2003–04 and 2004–05 (Williams et al 2007). No CPUE information has since been analysed.

Prior to the introduction of PPI 1A to the QMS there were nine permit holders for Whangarei Harbour. No new entrants have entered the fishery since 1992 when commercial access to the fishery was constrained by the general moratorium on granting new fishing permits for non-QMS fisheries. Access to the fishery has, however, been restricted through other regulations since the mid-1980s, and more formally since 1988. Under previous non-QMS management arrangements, there was a daily catch limit of 200 kg per permit holder, meaning that, collectively, the nine permit holders could, theoretically, take 657 t of pipi per year. The permit holders have indicated that annual harvest quantities have been considerably less than the potential maximum, because of the relatively low market demand for commercial product rather than the availability of the resource. On 1 October 2004, pipi in Whangarei Harbour (PPI 1A) were introduced into the QMS, and the nine existing permits were replaced with individual transferable quotas. The 200 kg daily catch limit no longer applies. A total allowable catch (TAC) of 250 t was set, comprised of a total allowable commercial catch (TACC) of 200 t, a customary allowance of 25 t, and a recreational allowance of 25 t. Figure 1 shows the historical landings and TACC values for PPI 1A. After 1 October 2014 all take of pipi from Mair Bank was prohibited due to historically low pipi biomass levels.

Table 1: Reported commercial landings (from Licensed Fish Receiver Returns; LFRR) of pipi (t greenweight) in New Zealand since 1986–87. Prior to the introduction of PPI 1A to the QMS on 1 October 2004, the fishery was limited by daily limits which summed to 657 t greenweight in a 365 day year, but there was no explicit annual restriction. A TACC of 200 t was set for PPI 1A on 1 October 2004.

Year	Reported landings (t)	Limit (t)	Year	Reported landings (t)	Limit (t)
1986–87	131	657	2000–01	184	657
1987–88	133	657	2001–02	191	657
1988–89	134	657	2002–03	191	657
1989–90	222	657	2003–04	266	657
1990–91	285	657	2004–05	206	200
1991–92	326	657	2005–06	137	200
1992–93	184	657	2006–07	135	200
1993–94	258	657	2007–08	142	200
1994–95	172	657	2008–09	131	200
1995–96	135	657	2009–10	136	200
1996–97	146	657	2010–11	87	200
1997–98	122	657	2011–12	55	200
1998–99	130	657	2012–13	0	200
1999–00	143	657	2013-14	0	200

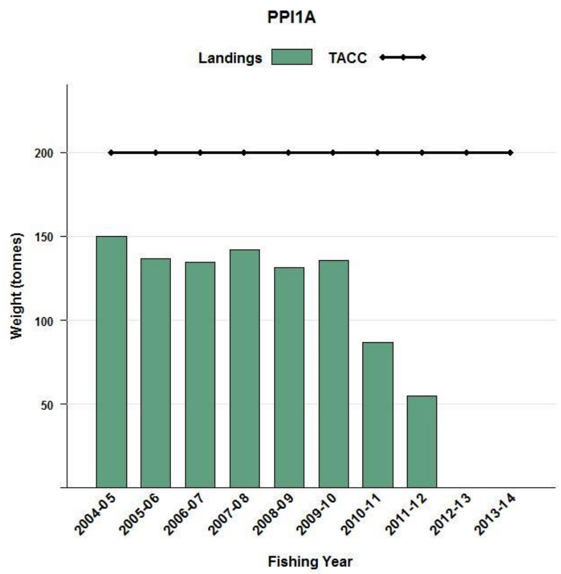


Figure 1: Total commercial landings and TACC for PPI 1A (Whangarei Harbour). QMS data from 2004–05 to present.

1.2 Recreational fisheries
This is covered in the general pipi section.

1.3 Customary non-commercial fisheries
This is covered in the general pipi section.

1.4 Illegal catch
This is covered in the general pipi section.

1.5 Other sources of mortality
There is some concern about the possibility of changes in bank stability that could arise from operations other than fishing in Whangarei Harbour (e.g., harbour dredging, port developments), which could lead to changes in the pipi fishery. Radical changes to the local hydrology could affect the size or substratum of Mair Bank with consequent effects on its pipi population. Also, as suspension feeders, pipi may be adversely affected by increased sediment loads in the water column.

The potential causes of low biomass from the 2014 biomass survey were investigated in the desktop report of Williams and Hume (2014). They concluded that: "*potential causes of the pipi decline were high natural mortality of an ageing pipi population and low recruitment, both of which may be related to observed changes in the morphology of Mair Bank. There was no evidence of disease in the population, and the decline did not appear to be associated with potential anthropogenic sources of mortality (e.g., sedimentation, contaminants, harvesting). It is possible that substances not measured in shellfish, sediment, or water quality monitoring work may have influenced the pipi decline*."

2. BIOLOGY

This is covered in the general pipi section.

3. STOCKS AND AREAS

Little is known of the stock structure of pipi. A study of biological connectivity that is currently underway includes pipi, but no results have not been finalised at the time of this report. The commercial fishery based on Mair Bank in Whangarei Harbour (PPI 1A) forms a geographically discrete area and is assumed for management purposes to be a separate stock.

4. STOCK ASSESSMENT

Stock assessment for Mair Bank pipi was conducted in 2005 and 2010 using absolute biomass surveys, and yield per recruit and spawning stock biomass per recruit modelling. MPI in association with Northland Regional Council and the Harbour board was also commissioned a biomass survey in 2014 in response to local concerns about low biomass.

4.1 Estimates of fishery parameters and abundance
Estimates of the fishing mortality reference point $F_{0.1}$ are available from yield per recruit modeling (Table 2). Parallel spawning stock biomass per recruit modeling was conducted to estimate the SSBPR corresponding with each estimate of $F_{0.1}$. These estimates are sensitive to the assumed value of natural mortality (M) and uncertainty in pipi growth parameters.

Table 2: Estimates of the reference rate of fishing mortality $F_{0.1}$ and corresponding spawning stock biomass per recruit at three different assumed rates of natural mortality (*M*) for two harvest strategies ('no restriction' and 'current'). SL, shell length (at recruitment). Estimates from Williams et al (2007).

'No restriction' strategy (harvest pipi of a size that maximizes YPR)					
Assumed M	Optimal age at recruitment (y)	SL (mm)	$F_{0.1}$	YPR (g)	SSBPR (%)
0.3	3	52	0.437	4.93	44
0.4	2.75	51	0.550	3.50	45
0.5	2.5	49	0.648	2.58	45
'Current' strategy (harvest pipi 60 mm and over)					
Assumed M	Age at recruitment (y)	SL (mm)	$F_{0.1}$	YPR (g)	SSBPR (%)
0.3	5	60	0.564	3.98	62
0.4	5	60	0.755	2.41	70
0.5	5	60	0.949	1.47	76

4.2 Biomass estimates

Virgin biomass (B_0) and the biomass that will support the maximum sustainable yield (B_{MSY}) are unknown for Mair Bank pipi. Only four biomass estimates have been made for the Mair Bank pipi population: in 1989 using a grid survey, in 2005 using stratified random sampling,in 2010 using a systematic random start and in 2014 using a stratified grid sampling design. The 1989 estimate of 2245 t (± 10%) can be considered conservative because only the intertidal area of the bank was surveyed, and pipi are known to exist in the shallow subtidal area of the bank. Estimates of biomass are available for Mair Bank (excluding from the 2014 survey) and are sensitive to the assumed size at recruitment (Table 3). The high CV for the estimates from 2014 were due to the unexpectedly low and patchy biomass at the time.

Table 3: Estimated recruited biomass (*B*) of pipi on Mair Bank in 2005 and 2010 for different assumed sizes at recruitment to the fishery. Source: Williams et al (2007), Pawley et al (2013) and Pawley 2014.

Year	Assumed shell length at recruitment (mm)	Intertidal stratum		Subtidal stratum		Mair Bank Total	
		B (t)	CV (%)	*B* (t)	CV (%)	*B* (t)	CV (%)
2005	1 (total biomass)	3 602	11.4	6 940	19.5	10 542	13.4
2005	40	3 569	11.4	6 922	19.5	10 490	13.4
2005	45	3 434	11.4	6 791	19.6	10 226	13.6
2005	50	2 986	11.3	5 989	20.1	8 975	14.0
2005	55	2 022	11.1	3 855	23.8	5 877	16.0
2005	60	1 004	13.1	2 013	37.5	3 017	25.4
2010	1 (total biomass)	2 233	17.4	2 218	33.0	4 452	15.2
2010	50	2 001	18.1	1 889	36.0	3 890	16.6
2010	60	1 751	18.3	1 393	33.7	3 145	17.4
2014	5 (total biomass)	46	50.8	28	25.9	73.5	30.8

4.3 Yield estimates and projections

Maximum Constant Yield (*MCY*) was estimated using method 2 (see the guide to biological reference points in the introduction chapter of this plenary document):

$$\mathrm{MCY} = 0.5 F_{0.1} B_{av}$$

where $F_{0.1}$ is a reference rate of fishing mortality and B_{av} is the historical average recruited biomass (estimated as the mean recruited biomass from the 2005 and 2010 surveys). *M* is assumed to be 0.3 and the corresponding $F_{0.1}$ is 0.564 (Williams et al 2007 revised version). The size at recruitment is assumed to remain at 60 mm and the corresponding B_{av} is 3081 t.

$$\mathrm{MCY} = 0.5 \times 0.564 \times 3081 = 869 \text{ t}$$

This estimate of *MCY* would have a CV at least as large as those associated with the 2005 and 2010 estimates of recruited biomass (17–25%), and is sensitive to the assumed size at recruitment to the fishery, the assumed natural mortality, and to uncertainty in $F_{0.1}$ (arising from the considerable uncertainty in model input values for growth and *M*) (Table 4).

Table 4: Sensitivity of maximum constant yield (*MCY*, method 2) to estimates of size at recruitment and the assumed natural mortality, *M*. B_{av}, the historical average recruited biomass, was estimated for two sizes at recruitment (50 and 60 mm SL) using the 2005 and 2010 survey data.

SL at recruitment (mm)	B_{av}	*M*	$F_{0.1}$	*MCY* (t)
50	6433	0.3	0.40	1 300
		0.4	0.54	1 729
		0.5	0.68	2 182
60	3081	0.3	0.56	869
		0.4	0.76	1 163
		0.5	0.95	1 462

CAY was not estimated because there is no estimate of current biomass.

4.4 Other factors

None

5. STATUS OF THE STOCKS

Stock Structure Assumptions

For the purpose of this assessment PPI 1A is assumed to be a discrete stock.

Stock Status	
Year of Most Recent Assessment	2015
Reference Points	Target: Default 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F_{MSY}
Status in relation to Target	Very Unlikely (< 10%) to be at or above the target
Status in relation to Limits	Soft Limit: Very Likely (> 90%) to be below Hard Limit: Very Likely (> 90%) to be below
Status in relation to Overfishing	Unknown
Historical Stock Status Trajectory and Current Status	
Biomass has not been measured in consistent units for all surveys, but has declined sharply from a total biomass (> 1 mm) of 10 542 tonnes in 2005 to a total biomass (> 5 mm) of 73.5 tonnes in 2014.	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Surveys were conducted in 2005, 2010 and 2014. These surveys have shown a sharp decline in biomass to very low levels.
Recent Trend in Fishing Mortality or Proxy	No commercial landings have been reported since the 2011-12 fishing year.
Other Abundance Indices	-
Trends in Other Relevant Variables or Indicators	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock has declined below limits (causing the fishery to be closed) due to unknown reasons and the likelihood of recovery is unknown.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	There is no current legal catch as biomass has declined below the TACC and limits.
Probability of Current catch or TACC causing Overfishing to Continue or Commence	There is no current legal catch as biomass has declined below the TACC and limits. However, the amount of illegal take is unknown.

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Reference rate of fishing mortality applied to absolute biomass estimates from quadrat surveys	
Assessment Dates	Latest assessment: 2012	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Two absolute abundance estimates (quadrat surveys) - Biological parameters for YPR/SSBPR models	1 – High Quality 1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	Growth for the subtidal portion of this population is poorly known. The available data come from other areas or the intertidal portion, both of which can be expected to support slower growth than the area where the fishery occurs. This, together with poor information on M and the size at recruitment to the fishery, makes the YPR modeling and reference rate of fishing mortality very uncertain.	

Qualifying Comments
Recruitment appears from the 2005 and 2010 survey length frequency distributions to be variable. This may lead to larger variations in the spawning and recruited biomass than the estimates of biomass suggest. The 2014 survey showed very low biomass levels and the commercial, recreational and customary have been closed since 1 October 2014.

Fishery Interactions
This is a hand-gathering fishery with no substantial bycatch or other interactions.

6. FOR FURTHER INFORMATION

Cranfield, H J; Michael, K P; Stotter, D (1993) Estimates of growth, mortality, and yield per recruit for New Zealand surf clams. New Zealand Fisheries Assessment Research Document 1993/20. 47 p. (Unpublished report held by NIWA library, Wellington.)

Dickie, B N (1986a) Physical and biological survey of a subtidal *Paphies australis* population in the lower Whangarei Harbour. Whangarei Water Quality Management Plan. Working Report 4. 45 p. (Unpublished report to the Northland Catchment Commission and Regional Water Board, New Zealand).

Dickie, B N (1986b) Topographic survey of three intertidal *Paphies australis* habitats in the lower Whangarei Harbour. Whangarei Water Quality Management Plan. Working Report 2. 45 p. (Unpublished report to the Northland Catchment Commission and Regional Water Board, New Zealand).

Fournier, D A; Sibert, J R; Majkowski, J; Hampton, J (1990) MULTIFAN: a likelihood-based method for estimating growth parameters and age composition from multiple length frequency data sets illustrated using data for southern bluefin tuna (*Thunnus maccoyi*). *Canadian Journal of Fisheries and Aquatic Sciences* 47: 301–317.

Francis, R I C C (1988) Maximum likelihood estimation of growth and growth variability from tagging data. *New Zealand Journal of Marine and Freshwater Research* 22(1): 43–51.

Grace, R G (1972) The benthic ecology of the entrance to the Whangateau Harbour, Northland, New Zealand. Unpublished PhD thesis. University of Auckland, Auckland, New Zealand.

Haddon, M (1989) Biomass estimate of the pipi *Paphies australis* on Mair Bank, Whangarei Harbour. 23 p. (Unpublished report to MAF Fisheries North, Auckland, New Zealand).

Hooker, S H (1995a) Life history and demography of the pipi *Paphies australis* (Bivalvia: Mesodesmatidae) in northeastern New Zealand. Unpublished PhD thesis. University of Auckland, Auckland, New Zealand. 230 p.

Hooker, S H (1995b) Preliminary evidence for post-settlement movement of juvenile and adult pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). *Marine and Freshwater Behaviour and Physiology* 27(1): 37–47.

Hooker, S H (1997) Larval and postlarval development of the New Zealand pipi, *Paphies australis* (Bivalvia : Mesodesmatidae). *Bulletin of Marine Science* 61(2): 225–240.

Hooker, S H; Creese, R G (1995a) The reproductive biology of pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). I. Temporal patterns of the reproductive cycle. *Journal of Shellfish Research* 14(1): 7–15.

Hooker, S H; Creese, R G (1995b) The reproductive biology of pipi, *Paphies australis* (Gmelin 1790) (Bivalvia: Mesodesmatidae). II. Spatial patterns of the reproductive cycle. *Journal of Shellfish Research* 14(1): 17–24.

Morrison, M A; Browne, G N (1999) Intertidal shellfish population surveys in the Auckland region, 1998–99, and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/43. 21 p. (Unpublished report held in NIWA library, Wellington.)

Morrison, M A; Pawley, M D M; Browne, G N (1999) Intertidal surveys of shellfish populations in the Auckland region, 1997–98, and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/25. 25 p. (Unpublished report held in NIWA library, Wellington.)

Morton, J E; Miller, M C (1968) *The New Zealand Sea Shore*. Collins, Auckland, New Zealand. 653 p.

OtterResearch (1992). MULTIFAN 32(f). User's Guide and Reference Manual. Otter Research Ltd., Nanaimo, Canada. 67 p.

Pawley, M (2014) Population and biomass survey of pipi (*Paphies australis*) on Mair Bank, Whangarei Harbour, 2014. *Report Prepared for Northland Regional Council. 15 p.*

Pawley, M D; Hannaford, O; Morgan, K (2013) Biomass survey and stock assessment of pipi (*Paphies australis*) on Mair and Marsden Bank, Whangarei Harbour. *New Zealand Fisheries Assessment Report 2013/42*. 32 p.

Powell, A W B (1979) *New Zealand Mollusca: Marine, Land and Freshwater Shells*. Collins, Auckland, New Zealand. 500 p.

Sullivan, K J; Mace, P M; Smith, N W M; Griffiths, M H; Todd, P R; Livingston, M E; Harley, S J; Key, J M; Connell, A M (Comps.) (2005) Report from the Fishery Assessment Plenary, May 2005: stock assessments and yield estimates. 792 p. (Unpublished report held in NIWA library, Wellington).

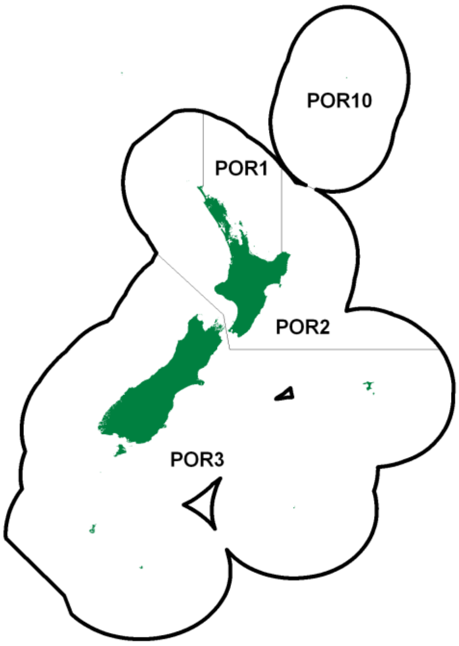
Venus, G C (1984) *Paphies australis* (pipis) in Whangarei Harbour. Whangarei Harbour Study Technical Report No. 6. 60 p. (Unpublished technical report coordinated by the Northland Harbour Board).

Williams, J, Hume, T (2014) Investigation into the decline of pipi at Mair Bank, Whangarei Harbour. Report Prepared for Northland Regional Council. 44 p.

Williams, J R; Cryer, M; Hooker, S H; Smith, M D; Watson, T G; MacKay, G; Tasker, R (2007) Biomass survey and stock assessment of pipi (*Paphies australis*) on Mair Bank, Whangarei Harbour, 2005. *New Zealand Fisheries Assessment Report, 2007/03*. 29 p.

PORAE (POR)

(*Nemadactylus douglasii*)
Porae



1. FISHERY SUMMARY

Porae was introduced into the Quota Management System on 1 October 2004 with the following TACs, TACCs and allowances (Table 1). These have not been changed.

Table 1: TACs (t), TACCs (t) and allowances (t) for porae.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
POR 1	6	3	4	62	75
POR 2	1	1	1	18	9
POR 3	1	1	1	2	5
POR 10	1	1	1	1	4
Total	9	6	7	83	93

1.1 Commercial fisheries

Commercial catches of porae throughout New Zealand are generally small (Table 2, Table 3 and Table 4). Annual catches in FMA 1, where the majority of porae are caught, have approximately halved since the early 1990s. Catches in FMAs 2, 3, 7, and 9 have remained low. No catches have been reported from FMAs 4, 5, or 6.

Porae is principally caught as a bycatch in inshore setnet fisheries in northern New Zealand. It is generally taken in association with snapper and trevally in east Northland and Coromandel, and tarakihi and blue moki around Gisborne. Small quantities are taken by bottom longline and trawl fisheries targeting snapper off east Northland and Ninety Mile Beach.

Landings are typically under 10 t and the proportion of vessels reporting catches declined steadily during the 1990s. Fishers may confuse the codes PAR (parore) and POR (porae) when reporting catches, but given that both species occur in shallow northern waters, misreporting is difficult to discern.\

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	POR 1	POR 2	POR 3	Year	POR 1	POR 2	POR 3
1931-32	0	0	0	1957	0	0	0
1932-33	0	0	0	1958	0	0	0
1933-34	0	0	0	1959	0	0	0
1934-35	0	0	0	1960	0	0	0
1935-36	0	0	0	1961	0	0	0
1936-37	0	0	0	1962	0	0	0
1937-38	0	0	0	1963	0	0	0
1938-39	0	0	0	1964	0	0	0
1939-40	0	0	0	1965	0	0	0
1940-41	0	0	0	1966	0	0	0
1941-42	0	0	0	1967	0	0	0
1942-43	0	0	0	1968	0	0	0
1943-44	0	0	0	1969	0	0	0
1944	0	0	0	1970	0	0	0
1945	0	0	0	1971	0	0	0
1946	0	0	0	1972	0	0	0
1947	0	0	0	1973	0	0	0
1948	0	0	0	1974	0	0	0
1949	0	0	0	1975	0	0	0
1950	0	0	0	1976	0	0	0
1951	0	0	0	1977	0	0	0
1952	0	0	0	1978	191	4	0
1953	0	0	0	1979	107	0	0
1954	0	0	0	1980	83	4	0
1955	0	0	0	1981	82	8	0
1956	0	0	0	1982	92	5	0

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings.

Table 3: Reported landings (t) of porae by FMA, fishing years 1989–90 to 2003–04.

	FMA 1	FMA 2	FMA 3	FMA 7	FMA 8	FMA 9	FMA 10
1989–90	98	4	< 1	< 1	< 1	0	0
1990–91	115	2	0	0	< 1	4	0
1991–92	121	5	< 1	0	0	3	0
1992–93	121	8	0	1	< 1	< 1	0
1993–94	77	12	2	0	< 1	1	< 1
1994–95	109	5	0	0	< 1	1	< 1
1995–96	94	8	< 1	< 1	< 1	4	0
1996–97	80	7	< 1	1	< 1	2	0
1997–98	75	4	< 1	< 1	< 1	3	0
1998–99	58	3	3	< 1	< 1	1	0
1999–00	55	4	< 1	2	< 1	1	0
2000–01	64	2	1	< 1	< 1	2	0
2001–02	55	3	1	< 1	< 1	< 1	0
2002–03	62	2	< 1	0	< 1	2	0
2003–04	32	2	< 1	< 1	< 1	2	0

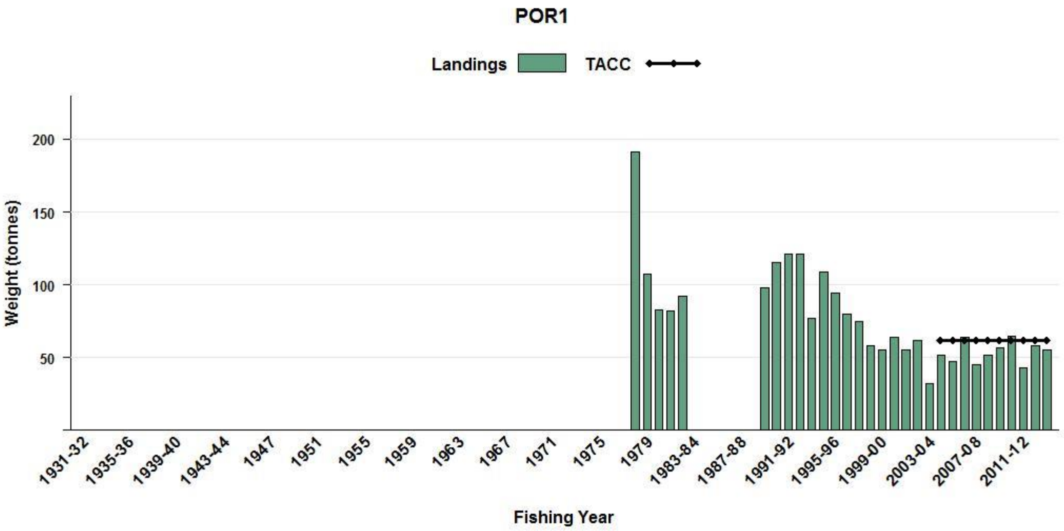


Figure 1: Reported commercial landings and TACC for POR 1 (Auckland East).

Table 4: Reported domestic landings (t) and TACC by Porae Fishstock, fishing years 2004–05 to 2012–13

Fishstock	POR 1		POR 2		POR 3		POR 10			
FMA	1		2, 8&9		3,4,5,6&7		10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2004–05	52	62	5	6	< 1	2	0	1	57	71
2005–06	47	62	2	6	< 1	2	0	1	49	71
2006–07	64	62	9	6	0	2	0	1	73	71
2007–08	45	62	7	6	< 1	2	0	1	53	71
2008–09	52	62	5	6	0	2	0	1	57	71
2009–10	57	62	11	6	< 1	2	0	1	68	71
2010–11	65	62	7	6	< 1	2	0	1	72	71
2011–12	43	62	7	6	< 1	2	0	1	51	71
2012–13	58	62	9	18	0	2	0	1	67	83
2013-14	55	62	10	18	<1	2	0	1	66	83

1.2 Recreational fisheries
Recreational fishers are likely to catch porae whilst targeting species such as snapper, tarakihi and trevally with either hook and line or setnet. Opportunistic targeting of porae is also likely when spearfishing.

1.3 Customary non-commercial fisheries
There is no quantitative information on customary non-commercial harvest levels of porae. Customary non-commercial fishers are likely to catch small quantities of porae when targeting other species such as snapper, tarakihi and trevally.

2. BIOLOGY

Porae (*Nemadactylus douglasii*) is a common inshore species of northern New Zealand (Kermadec Islands, west Auckland and Northland, east Northland, Hauraki Gulf, and the Bay of Plenty). It is also found at some localities as far south as Kapiti Island, Cook Strait and Kaikoura over the summer months, but has not been recorded around the Chatham Islands. Porae also occurs in southeast Australia (New South Wales to Tasmania), where it is known as the grey or rubberlip morwong.

Porae are generally found on reef/sand interfaces in 10–60 m depth, but have been recorded at 100 m. This diurnal species tends to aggregate to form small to large groups over sandy areas. Adults are thought to occupy distinctive home ranges, with individuals residing in the same area for many years. A study along the east coast of Northland recorded an average of 200 porae for each kilometre of rocky coastline.

Very little is known about the biology of this species. They spawn in late summer and autumn, and have an extended planktonic postlarval stage. Juveniles settle to the seafloor at 8–10 cm long. Although they attain a maximum length of at least 70 cm, the average size is 40−60 cm. They live to at least 30 years and growth is believed to slow substantially at maturity (Ayling & Cox 1984, Francis 2001).

3. STOCKS AND AREAS

There is no biological information to suggest separate stocks around New Zealand. However, evidence of residential behaviour and the fact that they are long-lived, suggests that localised depletion is likely to occur.

4. STOCK ASSESSMENT

There is no fishery independent stock assessment information to determine the stock status of porae. Biomass estimates have not been determined for porae.

5. STATUS OF THE STOCK

Estimates of current and reference biomass are not available. It is not known if recent catch levels or TACs are sustainable. The status of POR 1, 2 and 3 relative to B_{MSY} is unknown.

TACCs and reported landings for the 2012–13 fishing year are summarised in Table 5.

Table 5: Summary of TACCs (t) and reported landings (t) of porae for the most recent fishing year.

Fishstock		FMA	2013–14 Actual TACC	2013–14 Reported landings
POR 1	Auckland (East)	1	62	55
POR 2	Central (East)	2	18	10
POR 3	South east, Southland, sub-Antarctic, Challenger	3,4,5,6,7, 8 &9	2	<1
POR 10	Kermedec	10	1	0
Total			83	66

6. FOR FURTHER INFORMATION

Ayling, T; Cox, G J (1984) *Collins guide to the sea fishes of New Zealand*. Collins, Auckland. 343 p.

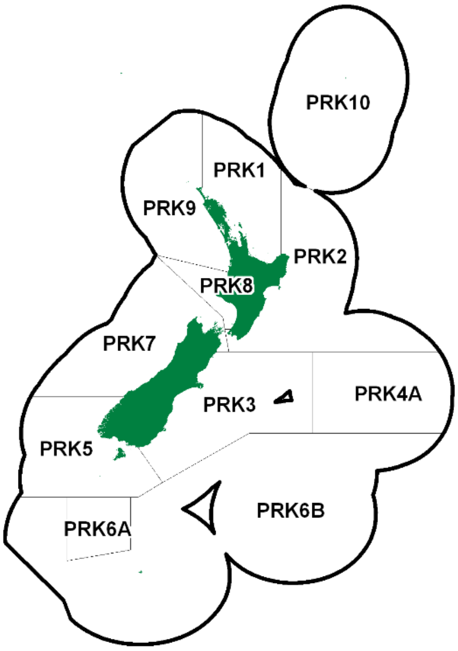
Francis, M (2001) *Coastal fishes of New Zealand. An identification guide*. Reed Books, Auckland. 103 p. + pls.

Stewart, P (1993) Morwong, *Nemadactylus* species. *In* Kailola *et al*. (Eds), Australian fisheries resources. pp. 324–326. Bureau of Resource Sciences, Canberra. 422 p.

Thompson, S (1981) *Fish of the Marine Reserve. A guide to the identification and biology of common coastal fish of north-eastern New Zealand*. Leigh Laboratory, University of Auckland. 364 p.

PRAWN KILLER (PRK)

(*Ibacus alticrenatus*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Prawn killer (*Ibacus alticrenatus*) was introduced into the Quota Management System on 1 October 2007, with a combined TAC of 37.4 t and TACC of 36 t. There are no allowances for customary non-commercial or recreational fisheries, and 1.4 t was allowed for other sources of mortality. Almost all prawn killer are taken as a bycatch in the scampi target bottom trawl fishery in SCI 1 and SCI 2. Reported catches in PRK 1 have a maximum of 42 t in 1992–93. Landings in PRK 2 are minimal with a maximum of 8 t in 2002–03 (Table 1). Landings are minimal to non-existent in other QMAs. Years with higher landings coincide with years in which the scampi fleet fished at shallower depths than usual. They can be legally discarded under Schedule 6 of the Fisheries Act but it is still likely that reported catches are lower than actual catches due to non-reporting.

Table 1: TACCs and reported landings (t) of Prawn killer by Fishstock from 1990–91 until the present from CELR and CLR data. FMAs are shown as defined in 2007–08. [Continued on next page].

	PRK 1		PRK 2		PRK 3		PRK 4A		PRK 5		PRK 6A	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990–91	11.59	-	0	-	0	-	0	-	0	-	0	-
1991–92	3.34	-	0.48	-	0	-	0	-	0	-	0	-
1992–93	42.24	-	6.86	-	0	-	0	-	0	-	0	-
1993–94	10.95	-	0.03	-	0	-	0	-	0	-	0	-
1994–95	0.52	-	0	-	0	-	0	-	0	-	0	-
1995–96	1.78	-	0	-	0	-	0	-	0	-	0	-
1996–97	23.13	-	0	-	0	-	0	-	0	-	0	-
1997–98	0	-	0	-	0	-	0	-	0	-	0	-
1998–99	0	-	0.19	-	0	-	0	-	0	-	0	-
1999–00	0.08	-	0	-	0	-	0	-	0	-	0	-
2000–01	0	-	0	-	0	-	0	-	0	-	0	-
2001–02	6.05	-	0.37	-	0	-	0	-	0	-	0	-
2002–03	20.99	-	8.09	-	0	-	0	-	0	-	0	-
2003–04	24.35	-	0.57	-	0.01	-	0.01	-	0	-	0	-
2004–05	3.25	-	1.15	-	0	-	0	-	0	-	0	-
2005–06	2.25	-	0.20	-	0	-	0	-	0	-	0	-
2006–07	4.6	-	0.10	-	0	-	0	-	0	-	0	-
2007–08	5.36	24.5	0.92	3.5	0.01	1	0.02	1	0	1	0	1
2008–09	0.22	24.5	0.08	3.5	0	1	0	1	0	1	0	1

Table 1 [Continued]

	PRK 1		PKR2		PKR3		PKR4A		PKR5		PKR6A	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2009–10	0.75	24.5	0.03	3.5	0.001	1	0	1	0	1	0	1
2010–11	3.55	24.5	0.08	3.5	0	1	0.002	1	0	1	0	1
2011–12	0.42	24.5	0.17	3.5	0	1	0.001	1	0	1	0	1
2012–13	0.26	24.5	0.02	3.5	0	1	0	1	0	1	0	1
2013-14	0.098	24.5	0.036	3.5	0	1	0	1	0.001	1	0	1

	PRK 6B		PRK 7		PRK 8		PRK 9		TOTAL	
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1990–91	0	-	0	-	0	-	0	-	11.58	-
1991–92	0	-	0	-	0	-	0	-	3.82	-
1992–93	0.02	-	0	-	0	-	0	-	49.12	-
1993–94	0	-	0	-	0	-	0	-	10.98	-
1994–95	0	-	0	-	0	-	0	-	0.52	-
1995–96	0	-	0	-	0	-	0	-	1.78	-
1996–97	0	-	0	-	0	-	0	-	23.13	-
1997–98	0	-	0	-	0	-	0	-	0	-
1998–99	0	-	0	-	0	-	0	-	0.19	-
1999–00	0	-	0	-	0	-	0	-	0.08	-
2000–01	0	-	0	-	0	-	0	-	0	-
2001–02	0	-	0	-	0	-	0	-	6.42	-
2002–03	0	-	0	-	0	-	0	-	29.08	-
2003–04	0	-	0	-	0	-	0	-	24.94	-
2004–05	0	-	0	-	0	-	0	-	4.40	-
2005–06	0	-	0.01	-	0	-	0.01	-	2.47	-
2006–07	0	-	0.03	-	0	-	0	-	4.73	-
2007–08	0	1	1.2	1	0	1	0	1	7.51	36
2008–09	0	1	0.88	1	0	1	0	1	1.18	36
2009–10	0	1	0.48	1	0	1	0	1	1.27	36
2010–11	0	1	0.69	1	0.008	1	0	1	4.33	36
2011–12	0	1	0.73	1	0.004	1	0	1	1.32	36
2012–13	0	1	0.60	1	0.006	1	0.01	1	0.896	36
2013-14	0	1	0.66	1	0.007	1	0.145	1	0.942	36

1.2 Recreational fisheries

Given the depths and locations at which prawn killer are found recreational catch is likely to be negligible or non-existent.

1.3 Customary non-commercial fisheries

Given the depths and locations at which prawn killer are found customary catch is likely to be negligible or non-existent.

1.4 Illegal catch

No quantitative information is available on the level of illegal catch of prawn killer. Given the low value and lack of markets illegal catches are unlikely.

1.5 Other sources of mortality

There is no quantitative information on other sources of mortality, although analysis of benthic invertebrate samples and the distribution of trawl tows in the Bay of Plenty (PRK 1) suggests that this species is negatively affected by trawling.

2. BIOLOGY

Ibacus alticrenatus is widely distributed around the New Zealand coast, principally in depths of 80–300 m. Prawn killers are found on soft sediment seafloors, where they dig into the substrate and cover themselves with sediment.

There is not much information about growth and development of *I. alticrenatus* in New Zealand waters, but females are thought to mature at a carapace length of about 40 mm. Trawl surveys of the Bay of Plenty and Hawke Bay and Wairarapa regions have found maximum carapace length of 46 and 52 mm for males and females respectively. Information from Australia suggests that this species has relatively low fecundity (1 700–14 800 eggs, increasing with size) and spawns annually. Larval development takes 4–6 months, an intermediate duration for a Scyllarid lobster. Females of other *Ibacus* species reach maturity about two years after settlement and longevity is suggested to be five years or more. No ageing work has been carried out on prawn killer in either New Zealand or Australia.

The following species may also be caught as bycatch of the prawn killer catch – *Ibacus brucei, Antipodarctus aoteanus,* and *Scyllarus mawsoni* (which is thought to be rare).

3. STOCKS AND AREAS

For management purposes stock boundaries are based on those used for scampi. There is no biological information on stock structure, recruitment patterns, or other biological characteristics which might indicate stock boundaries, but there are three main fishing areas where they are caught: Bay of Plenty, and to a lesser extent Hawke Bay and Wairarapa and the upper west coast of the South Island. The lack of prawn killer bycatch in the scampi target fisheries on the Mernoo Bank (PRK 3) and around the Auckland Islands (PRK 6A) would suggest the prawn killer numbers are very low to non-existent south of the three main areas described above and they probably prefer warmer waters.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any prawn killer fishstock. Sporadic and varying catches by the scampi fleet mean that development of reliable CPUE indices are not possible.

4.2 Biomass estimates

There are no reliable biomass estimates for any prawn killer fishstock. Combined trawl and photographic surveys for scampi in the Bay of Plenty (PRK 1) and Hawke Bay and Wairarapa (PRK 2) are the only trawl surveys that catch prawn killer regularly. Prawn killer biomass estimates from these surveys are variable from year to year and high coefficents of variation. The focus of these surveys has changed over the years to focus more on photographic work and not all strata have been surveyed in all years.

4.3 Yield estimates and projections

There are no estimates of *MCY* for any prawn killer fishstock.

There are no estimates of *CAY* for any prawn killer fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any prawn killer fishstock. It is not known whether prawn killer stocks are at, above, or below a level that can produce *MSY*.

6. FOR FURTHER INFORMATION

Atkinson, J M; Boustead, N C (1982) The complete larval development of the scyllarid lobster *Ibacus alticrenatus* Bate, 1888 in New Zealand waters. *Crustaceana* 42: 275–287.

Booth, J D; Webber, W R; Sekiguchi, H; Coutures, E (2005) Diverse larval recruitment strategies within the Scyllaridae. *New Zealand Journal of Marine and Freshwater Research* 39: 581–592.

Brown, D E; Holthuis, L B (1998) The Australian species of the genus *Ibacus* (Crustacea: Decapoda: Scyllaridae), with the description of a new species and addition of new records. *Zoologische Mededelingen (Leiden)* 72(10): 113–141.

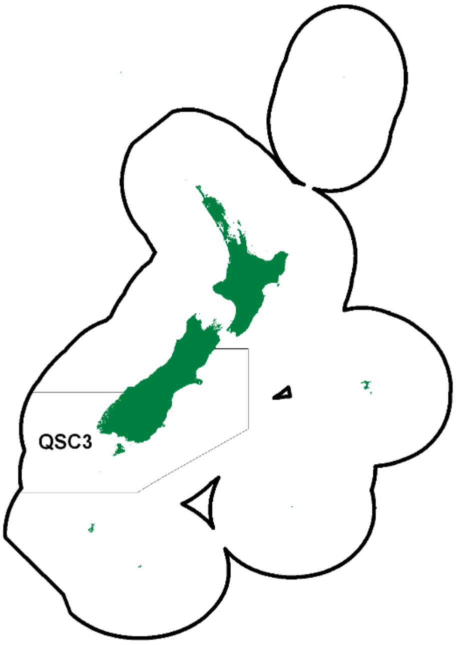
Cryer, M; Hartill, B; O'Shea, S (2002) Modification of marine benthos by trawling: toward a generalization for the deep ocean? *Ecological Applications*, 12(6): 1824–1839.

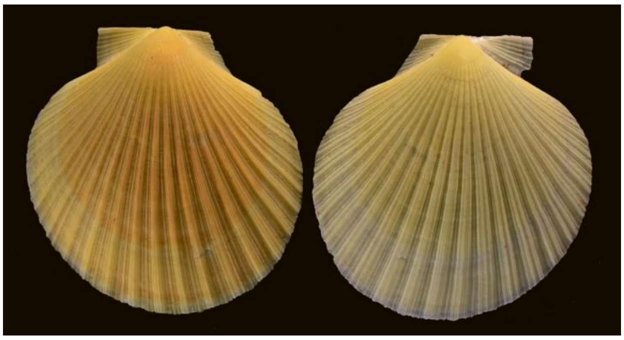
Haddy, J A; Courtney, A J; Roy, D P (2005) Aspects of the reproductive biology and growth of Balmain bugs (*Ibacus* spp.) (Scyllaridae). *Journal of Crustacean Biology*, 25(2): 263–273.

MacGibbon D.J. (2015) Fishery characterization for prawn killer, *Ibacus alticrenatus* (Spence Bate, 1888) (Scyllaridae), 1989-90 to 2012-13. *New Zealand Fisheries Assessment Report* 2015/05 108p.

QUEEN SCALLOPS (QSC)

(*Zygochlamys delicatula*)





1. FISHERY SUMMARY

Queen scallops were introduced into the QMS in October 2002, with a current TACC (unchanged since its introduction) of 380 t and a 20 t allowance for other sources of fishing related mortality. The fishing year runs from the 1 October to the 30 September and the catch is reported in greenweight.

1.1 Commercial fisheries

The QSC 3 fishery initially developed in the 1984–85 fishing year; it is a small-scale fishery with only a few fishing vessels involved (Michael & Cranfield 2001). Queen scallops (*Zygochlamys delicatula*) are predominantly harvested commercially off the Otago coast, in depths of 130–200 m (predominately 150–200m) near the edge of the continental shelf. Reported landings from this fishery peaked at 711 t in the 1985–86 fishing year (not shown in the table below). Annual landings in most recent years have been less than 200 t, although this is more likely to be associated with economic, rather than biological, factors. The TACC was set in 2002 at a slightly higher level than recent landings but lower than the non-QMS competitive catch limit of 750 t which applied to FMA 3 from 1990–91. Reported landings of queen scallops are given in Table 1, and Figure 1 shows historical landings and the TACC for QSC 3. The queen scallop fishery is a trawl fishery using specialised gear (including a relatively light ‘tickler’ chain or wire to induce swimming) and the catch is sorted both mechanically and by hand (Michael & Cranfield 2001, R. Belton pers. comm.).

1.2 Recreational fisheries

There is no known recreational fishery for queen scallops.

1.3 Customary fisheries

There is no known customary harvest of queen scallops.

1.4 Illegal catch

Current levels of illegal harvest are not known.

1.5 Other sources of mortality

No quantitative estimate of other sources of mortality is available. Some grading of catch may occur (queen scallops may be returned to the sea) and an allowance of 20 t for potential mortality has been set within the current TAC.

Table 1: Reported landings (t greenweight) of queen scallops (QSC) by FMA, QMA and fishing year by all methods trawl and dredge) 1989–90 until the present day from Quota Management Reports (QMR), Monthly Harvest Returns (MHR) and Catch Effort Landing Returns (CELR landed and CELR estimated).

	QSC 3			FMA 3	FMA 5
Fishing year	Catch (QMR/MHR)	TACC*	Estimated catch (TCEPR/CELR)	Landings (CELR/CLR)	Landings (CELR/CLR)
1989–90	11.9	_-	288.1	-	-
1990–91	61.8	-	238.3	-	22.9
1991–92	77.4	-	193.7	-	-
1992–93	0.4	-	104.7	-	-
1993–94	1.1	-	133.6	-	-
1994–95	23.6	-	146.9	-	-
1995–96	4.5	-	149.5	-	0.2
1996–97	20.9	-	118.0	-	6.6
1997–98	56.0	-	208.3	-	6.0
1998–99	85.9	-	81.7	-	-
1999–00	180.2	-	176.8	-	-
2000–01	162.2	-	162.1	-	-
2001–02	223.7	-	168.9	-	-
2002–03	139.0	380	-	-	-
2003–04	114.0	380	-	-	-
2004–05	35.1	380	-	-	-
2005–06	18.6	380	-	-	-
2006–07	6.5	380	-	-	-
2007–08	9.5	380	-	-	-
2008–09	48.7	380	-	-	-
2009–10	25.3	380	-	-	-
2010–11	2.8	380	-	-	-
2011–12	1.9	380	-	-	-
2012–13	70.5	380			
2013-14	5.024	380	-	-	-

* QMS introduction 1 October 2002

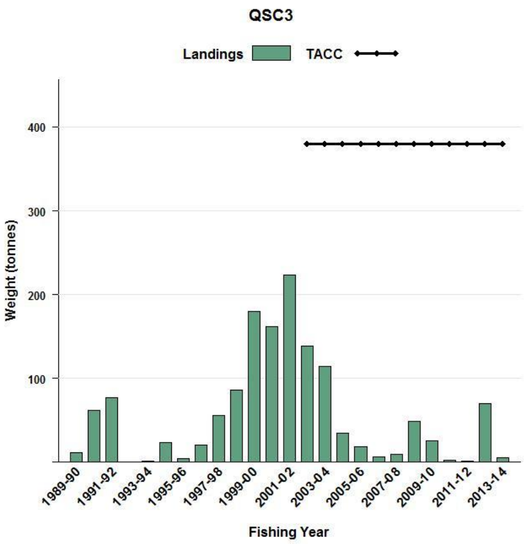


Figure 1: Reported commercial landings and TACC for QSC 3 (South East Coast, Southland).

2. BIOLOGY

The New Zealand queen scallop (*Zygochlamys delicatula*) is also known as the southern queen scallop, southern fan scallop, and gem scallop. This small pectinid species is distributed on the outer continental shelf along the east coast of the South Island, from Kaikoura down to Macquarie Island. There are nine other species in the genus, none of which have attracted commercial interest, probably because of their small size. Similar species such as *Chlamys islandica* and *Chlamys varia* support important fisheries in other countries. New Zealand queen scallops are distributed from Kaikoura to the southern islands including the Snares, Bounty, Antipodes, and Macquarie Islands. There are no records of live queen scallops being caught north of Kaikoura, or on the west coast of the South Island.

A dredge survey off Otago in October 1983 showed that queen scallops were distributed in long patches orientated along the slope of the continental shelf. They were most abundant in depths beyond 130 m, on the plateau between the Taiaroa and Papanui Canyons, and south. North of the Taiaroa Canyon catches diminished steadily towards the Karitane Canyon; few were caught north of the canyon. Only low numbers of queen scallops were caught in depths shallower than 110 m.

Juvenile queen scallops are frequently found attached to fragments of bryozoa and other biogenic debris, including the shells of other scallops and the dredge oyster. Height frequency distributions of samples show that the size composition of the population differs with area, and it is inferred that settlement probably varies spatially and temporally. The estimated 40–50 days larval life may result in queen scallop larvae being well mixed, both vertically and horizontally, in the water column. Predation of newly settled spat may also affect the pattern of recruitment and add to the variability in year class representation.

Estimates of growth for New Zealand queen scallops suggest that they become sexually mature at four years for males and five years for females. As length is slightly less than height, queen scallops are estimated to reach the minimum takeable size of 50 mm at about eight years. However, growth estimates are uncertain, with information from tagging studies suggesting that queen scallops enter the fishery much earlier, at three to five years.

3. STOCKS AND AREAS

Queen scallops are distributed throughout the QSC 3 area. From harvest records the scallops inhabit waters between 130 and 200 m depth. The extent to which various beds or populations are separate reproductively or functionally is not known.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

No estimates of fishery parameters or abundance are available at present.

4.2 Biomass estimates

A trawl survey, (Jiang et al 2005) carried out in February–April 2004, provided estimates of total and recruited biomass (shells at least 50 mm) available from the fished area of QSC 3, from Moeraki to just north of the Nuggets within the depth range 130 to 200 m, which covers 90% of the fished area within QSC 3 (Table 2). These estimates assumed that the efficiency of the survey trawl was 100%. However trawl efficiency is unlikely to be 100% and in other scallop fisheries can vary significantly depending on dredge and substrate type. Consequently estimates of current absolute biomass cannot be estimated. The Shellfish Working Group had concerns over methodology and conduct of the survey, and that the reported survey CVs may not be reliable.

Table 2: Estimated scallop biomass (recruit and pre-recruit) (t) in fished areas of QSC 3 February–April 2004.

Biomass Recruit (CV)	Biomass (CV) Pre-recruit	Total Biomass (CV)
1 950.8 (18.2)	363.6 (21.48)	2 314.4 (18.22)

4.3 Yield estimates and projections

As absolute biomass has not been estimated, *MCY* cannot be estimated

CAY cannot be estimated.

5. STATUS OF THE STOCKS

Stock structure assumptions

QSC 3 is assumed to be a single stock.

- QSC - *Zygochlamys delicatula*

Stock Status	
Year of Most Recent Assessment	2004
Assessment Runs Presented	Recruited biomass (shells ≥ 50 mm)
Reference Points	Target: Undefined Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	-
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status	
-	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Landings are less than a quarter of the TACC and have generally been declining since 2002–03.

Projections and Prognosis		
Stock Projections or Prognosis	Unknown	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	
Assessment Methodology		
Assessment Type	-	
Assessment Method	-	
Main data inputs	-	
Period of Assessment	-	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
Landings are thought to have been declining in recent times due to economic rather than biological factors.

Fishery Interactions
Concerns over interactions between dredge fishing and complex habitats

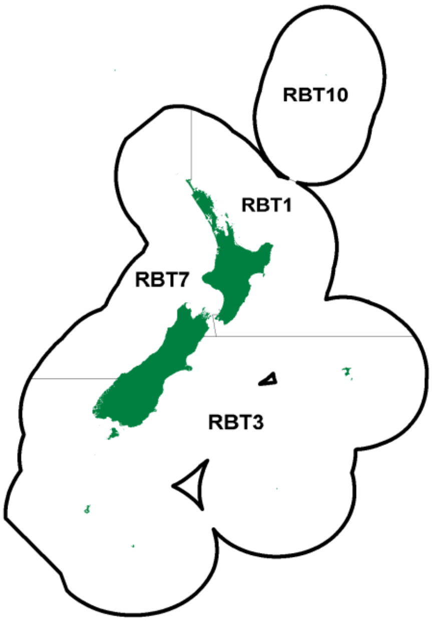
6. FOR FURTHER INFORMATION

Jiang, W; Gibbs, M; Hatton, S (2005) Stock assessment of the queen scallop fishery in QSC3. Final Research Report for Ministry of Fisheries project QSC2002/01. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Michael, K P; Cranfield, H J (2001) A summary of the fishery, commercial landings, and biology of the New Zealand queen scallop, *Zygochlamys delicatula* (Hutton, 1873). *New Zealand Fisheries Assessment Report 2001/68*. 25p.

REDBAIT (RBT)

(*Emmelichthys nitidus*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Redbait (*Emmelichthys nitidus*) was introduced to the Quota Management System on 1 October 2009, with a combined TAC of 5316 t and TACC of 5050 t. There are no allowances for customary non-commercial or recreational fisheries, and 266 t was allowed for other sources of mortality.

RBT is mainly taken as bycatch of the jack mackerel target trawl fishery, but also widely taken as bycatch of barracouta trawl tows, with some taken in the squid and hoki fisheries. A target fishery developed in the mid 2000s taking up to 11% of the catch of redbait in 2007–08. Reported total catches ranged from 2185 to 4308 tonnes during the 2000s, but declined across all QMAs and target fisheries in 2009–10 and 2010–11 to nearer 1000 t.

RBT 3 includes the southern fisheries for squid, and fisheries for Jack Mackerel on the Mernoo Bank and Chatham Rise, and accounted for most of the redbait landed in each year during the 1990s. From 2002–03 to 2009–10 however, the Jack Mackerel fishery on the west coast expanded into north and south Taranaki Bights, and catches from RBT 7 have exceeded those from RBT 3. Landings to RBT 1 have been small (less tha 5 t) in most years, increasing slightly in the late 2000s.

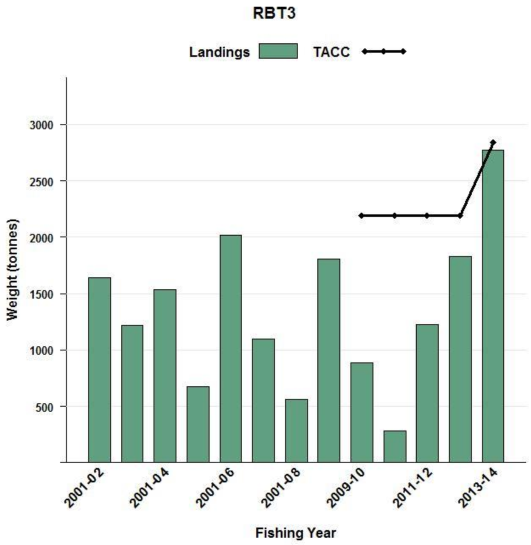
TACs, allowances and TACCs from 1 October 2009 are reported in Table 1. Table 2 and Figure 1 show historical landings from 2001–02 to 2013–14, reported by newly defined QMAs.

Table 1: TACs, allowances and TACCs of redbait.

Fishstock	Other mortality	Customary non–commercial and recreational	TACC	TAC
RBT 1	1	0	19	20
RBT 3	115	0	2 190	2 305
RBT 7	150	0	2 841	2 991
RBT 10	0	0	0	0

Table 2: Reported landings (t) of redbait by Fishstock and TACCs from 2001–02 to 2012–13.

	RBT 1		RBT 3		RBT 7		RBT 10			
FMA		1, 2		3, 4, 5, 6		7, 8, 9		10		Total
Fishstock	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
2001–02	1	-	1 638	-	1 669	-	0	-	3 308	-
2002–03	1	-	1 219	-	2 113	-	0	-	3 333	-
2003–04	1	-	1 535	-	2 771	-	0	-	4 307	-
2004–05	1	-	676	-	1 507	-	0	-	2 184	-
2005–06	3	-	2 016	-	1 936	-	0	-	3 955	-
2006–07	3	-	1 098	-	1 506	-	0	-	2 607	-
2007–08	5	-	560	-	2 376	-	0	-	2 941	-
2008–09	10	-	1 808	-	1 649	-	0	-	3 467	-
2009–10	9	19	886	2 190	170	2 841	0	0	1 066	5 050
2010–11	21	19	284	2 190	713	2 841	0	0	1 017	5 050
2011–12	2	19	1 229	2 190	369	2 841	0	0	1 599	5 050
2012–13	2	19	1 826	2 190	325	2 841	0	0	2 153	5 050
2013-14	4	19	2 774	2190	78	2 841	0	0	2 856	5 050



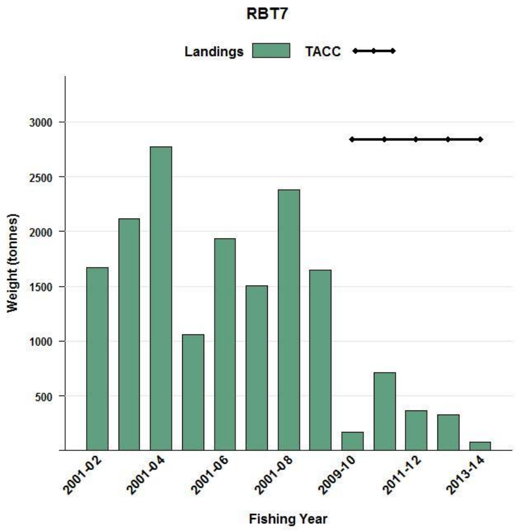


Figure 1: Reported commercial landings and TACC for the two main RBT stocks. From left: RBT3 (South East Coast) and RBT7 (Challenger).

1.2 Recreational fisheries
There is no known non-commercial fishery for redbait.

1.3 Customary non-commercial fisheries
There is no known customary non-commercial fishery for redbait.

1.4 Illegal catch
No quantitative information is available on the level of illegal catch of redbait.

1.5 Other sources of mortality

Taylor (2009) described up to 345 tonnes (but usually less than 200 t annually of redbait reported as discarded between 1988–89 to 2008–09.

2. BIOLOGY

Emmelichthys nitidus is a schooling, bathypelagic species that is closely related to rubyfish. It is widely distributed around New Zealand in depths from 85 to 500m. Juveniles are found at the surface and adults near the bottom in deeper waters, including seamounts.

There is not much information about growth and development of redbait in New Zealand. Offshore studies suggest regional differences in maximum size with a maximum age of 10 years in east Victoria and 7 years in Tasmania, where the maximum reported size of redbait is 316 mm fork length. Spawning in Tasmania is thought to last 2-3 months during spring, with 50% mature at 24 cm FL and 2-3 years. Von Bertalanffy growth parameters of Tasmanian redbait for both sexes combined are given in Table 3.

Research data from New Zealand show that the maximum size of redbait here is about 420 mm FL, which is larger than most other regions where length of this species has been recorded, except South Africa. Recent validation of the ageing of the closely related rubyfish in New Zealand confirms maximum ages of 90+ suggesting that some emmelichthyids may be long-lived, so current estimates of growth and maximum age may not be reliable

Table 3 shows estimated biological parameters for redbait.

Table 3: Estimates of biological parameters for redbait. Growth is based on Australian studies (Welsford & Lyle 2003).

Fishstock	Estimate			Source
1. Weight = a (length)^b (Weight in g, length in cm fork length)				
	Combined sexes			
RBT (All)	**a**	**b**		
	0.004947	3.259168		
				NIWA (unpub. data)
2. von Bertalanffy growth parameters				
	Combined sexes			
RBT (Tasmania)	L_∞	k	t_0	
	28.7	0.56	-0.36	Welsford & Lyle (2003)

3. STOCKS AND AREAS

There is no information about stock structure, recruitment patterns, or other biological characteristics that would indicate stock boundaries. As the catch of redbait has been mainly (66%) from bycatch in the jack mackerel trawl fisheries, management boundaries have been set the same as those used for jack mackerel. Analysis of encounter rates suggests a north-south seasonal movement of redbait may occur at a spatial scale that is greater than QMAs.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any redbait fishstock.

4.2 Biomass estimates

There are no biomass estimates for any redbait fishstock.

4.3 Yield estimates and projections

There are no yield estimates for any redbait fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any redbait fishstock. It is not known whether redbait stocks are at, above, or below a level that can produce *MSY*.

6. FOR FURTHER INFORMATION

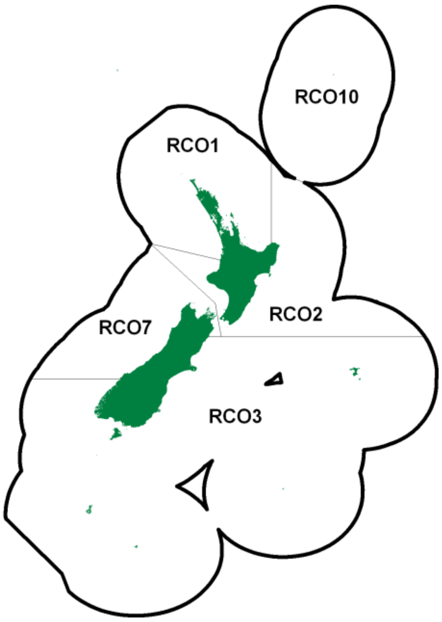
Bentley, N; Kendrick, T H; MacGibbon, D J (in press). Fishery characterisation and catch-per-unit-effort analyses for redbait (*Emmelichthys nitidus*), 1989–90 to 2010–11. (2014 Draft New Zealand Fisheries Assessment Report held by MPI.)

Taylor, P R (2009) A summary of information on redbait *Emmelichthys nitidus*. Final Research Report for Ministry of Fisheries Project SAP2008-18. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Welsford, D C; Lyle, J M (2003) Redbait (*Emmelichthys nitidus*): a synopsis of fishery and biological data. *TAFI Technical Report Series 20*. 32 p.

RED COD (RCO)

(*Pseudophycis bachus*)
Hoka



1. FISHERY SUMMARY

1.1 Commercial fisheries

Red cod are targeted primarily by domestic trawlers in the depth range between 30 and 200 m and are also a bycatch of deepwater fisheries off the southeast and southwest coasts of the South Island. The domestic red cod fishery is seasonal, usually beginning in November and continuing to May or June, with peak catches around January and May. During spring and summer, red cod are caught inshore before the fishery moves into deeper water during winter. RCO entered the QMS in 1986.

Reported annual catches by nation from 1970 to 1986–87 are given in Table 1. Foreign vessel catches declined and were negligible by 1987-88.

Table 1: Reported annual catch (t) of red cod by nation from 1970 to 1986–87.

	New Zealand		Foreign licensed				Combined Total
Fishing year	Domestic	Chartered	Japan	Korea	USSR	Total	
1970*	760	-	995	-	-	995	1 755
1971*	393	-	2 140	-	-	2 140	2 533
1972*	301	-	2 082	-	< 100	2 182	2 483
1973*	736	-	2 747	-	< 100	2 847	3 583
1974*	1 876	-	2 950	-	< 100	3 050	4 926
1975*	721	-	2 131	-	< 100	2 231	2 952
1976*	948	-	4 001	-	600	4 601	5 549
1977*	2 690	-	8 001	1 358	§2 200	11 559	14 249
1978–79*	5 343	124	2 560	151	51	2 762	8 229
1979–80*	5 638	883	537	259	116	912	7 433
1981–82*	3 210	387	474	70	102	646	4 243
1982–83*	4 342	406	764	675	52	1 493	6 241
1983–83†	3 751	390	149	401	3	553	4 694
1983–84†	10 189	1 764	1 364	480	49	1 893	13 846
1984–85†	14 097	2 381	978	829	7	1 814	18 292
1985–86†	9 035	1 014	739	147	5	891	10 940
1986–87‡	2 620	1 089	197	4	59	261	3 969

1970–1977 = calendar years; 1978–79 to 1982–83 = 1 April–31 March; 1980–1981=no fishing returns processed this year; 1983–1983 - 1 April–30 September; 1983–84 to 1986–87 - 1 October–30 September; * MAF data; † FSU data; ‡ QMS data § mainly ribaldo and red cod.

Recent reported landings and TACCs of red cod by Fishstock are shown in Table 2, while Figure 1 depicts historical landings and TACC values for the three main RCO stocks.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	RCO 1	RCO 2	RCO 3	RCO 7	Year	RCO 1	RCO 2	RCO 3	RCO 7
1931-32	0	0	16	6	1957	0	5	189	6
1932-33	0	51	41	67	1958	0	8	84	6
1933-34	0	0	28	21	1959	0	15	95	23
1934-35	0	0	18	0	1960	0	16	165	46
1935-36	0	0	12	0	1961	0	16	184	41
1936-37	0	13	35	14	1962	0	48	193	60
1937-38	0	27	143	32	1963	0	27	248	46
1938-39	0	19	279	27	1964	0	29	377	49
1939-40	5	24	213	19	1965	0	65	339	120
1940-41	0	41	213	50	1966	0	91	500	234
1941-42	0	12	539	61	1967	0	54	1358	243
1942-43	1	4	728	54	1968	0	13	1124	87
1943-44	0	3	362	34	1969	0	35	1645	69
1944	0	2	287	5	1970	0	34	1536	184
1945	0	5	423	5	1971	0	8	2453	72
1946	0	13	434	51	1972	1	10	274	19
1947	3	18	322	74	1973	1	44	475	219
1948	9	8	202	17	1974	1	37	6788	949
1949	0	4	123	19	1975	0	37	4798	233
1950	0	3	199	13	1976	0	20	10960	535
1951	0	13	198	23	1977	0	242	12379	2666
1952	0	11	133	35	1978	4	224	7069	2296
1953	0	19	205	41	1979	5	76	7921	1936
1954	0	59	233	48	1980	2	41	3644	628
1955	0	28	247	37	1981	0	42	2478	705
1956	0	11	297	18	1982	9	125	5088	787

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Reported landings (t) of red cod by Fishstock from 1983–84 to 2013–14, and actual TACCs (t) for 1986–87 to 2012–13. The QMS data is from 1986–present.

Fishstock	RCO 1		RCO 2		RCO 3		RCO 7		RCO 10	
FMA (s)	1 & 9		2 & 8		3, 4, 5 & 6		7		10	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	12	-	197	-	9 357	-	3051	-	0	-
1984–85*	9	-	126	-	14 751	-	1 442	-	0	-
1985–86*	6	-	48	-	9 346	-	408	-	0	-
1986–87	5	30	46	350	3 300	11 960	619	2 940	0	10
1987–88	8	40	81	357	2 878	12 182	1 605	2 982	0	10
1988–89	9	40	85	359	7 732	12 362	1 345	3 057	0	10
1989–90	8	42	105	362	6 589	13 018	800	3 105	0	10
1990–91	12	42	68	364	4 630	12 299	839	3 125	0	10
1991–92	26	42	358	364	6 500	12 299	2 220	3 125	0	10
1992–93	46	42	441	364	9 633	12 389	4 083	3 125	0	10
1993–94	44	42	477	364	7 977	12 389	2 992	3125	0	10
1994–95	63	42	762	364	12 603	12 389	3 569	3 125	0	10
1995–96	28	42	584	500	11 038	12 389	3 728	3 125	0	10
1996–97	42	42	396	500	10 056	12 389	3 710	3 125	0	10
1997–98	22	42	192	500	9 972	12 389	2 700	3 125	0	10
1998–99	10	42	282	500	13 926	12 389	2 055	3 125	0	10
1999–00	3	42	130	500	4 824	12 389	633	3 125	0	10
2000–01	5	42	112	500	2 776	12 389	1 538	3 125	0	10
2001–02	6	42	150	500	2 862	12 389	1 409	3 126	0	10
2002–03	8	42	144	500	5 107	12 389	1 657	3 126	0	10
2003–04	11	42	225	500	7 724	12 389	2 358	3 126	0	10
2004–05	21	42	423	500	4 212	12 389	3 052	3 126	0	10
2005–06	24	42	372	500	3 222	12 389	3 061	3 126	0	10
2006–07	25	42	256	500	1 877	12 389	3 409	3 126	0	10
2007–08	12	42	225	500	3 236	4 600	2 984	3 126	0	10
2008–09	12	42	212	500	2 542	4 600	2 131	3 126	0	10
2009–10	14	42	364	500	2 994	4 600	1 864	3 126	0	10
2010–11	19	42	501	500	4 567	4 600	1 603	3 126	0	10
2011–12	8	42	549	500	5 389	4 600	1 608	3 126	0	10
2012–13	6	42	300	500	5 292	4 600	1 282	3 126	0	10
2013-14	6	42	167	500	4 411	5 391	1 272	3 126	0	10

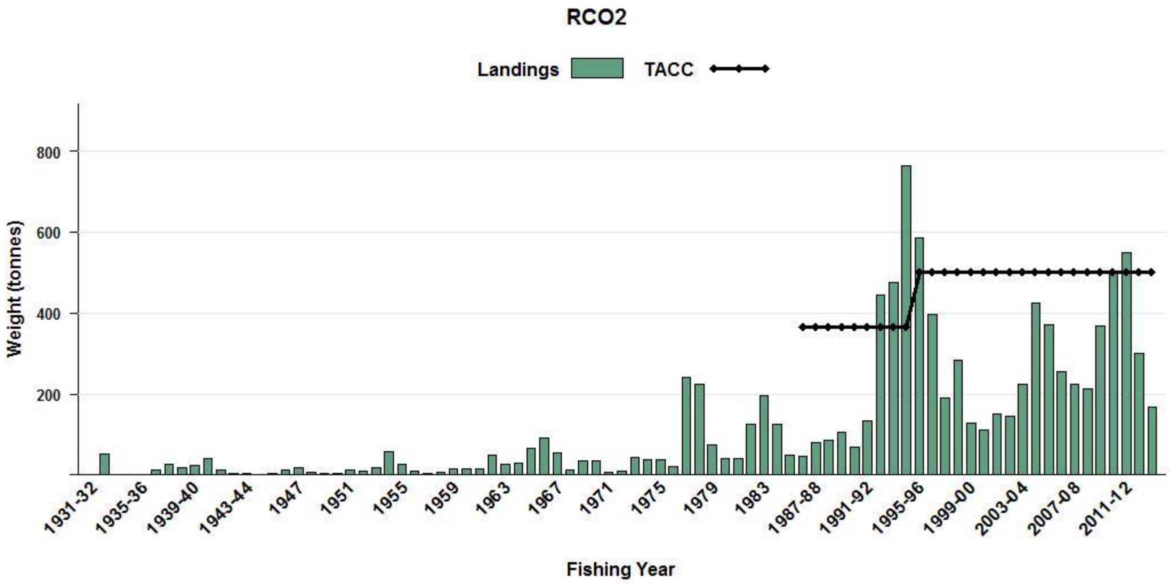
Table 3 [continued]

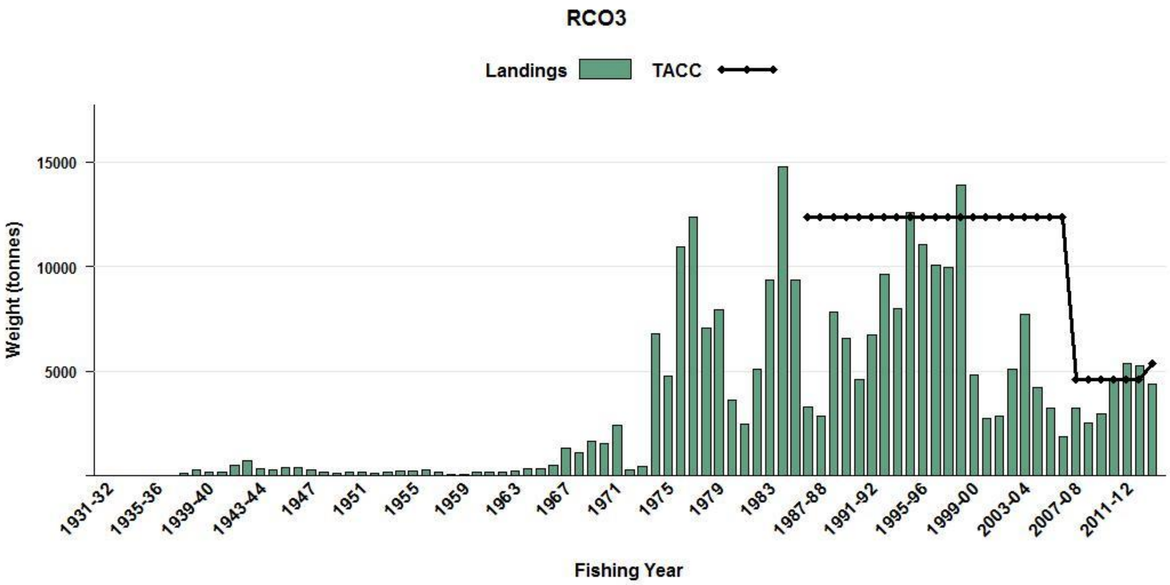
Fishstock FMA (s)	Total	
	Landings§	TACC
1983–84*	13 848	-
1984–85*	18 292	-
1985–86*	10 940	-
1986–87	3 970	15 290
1987–88	4 506	15 571
1988–89	9 171	15 828
1989–90	7 502	16 537
1990–91	5 549	15 840
1991–92	9 104	15 840
1992–93	14 203	15 930
1993–94	11 491	15 930
1994–95	16 997	15 930
1995–96	15 350	16 066
1996–97	14 204	16 066
1997–98	12 886	16 066
1998–99	16 273	16 066
1999–00	5 590	16 066
2000–01	4 432	16 066
2001–02	4 427	16 067
2002–03	6 916	16 067
2003–04	10 318	16 067
2004–05	7 708	16 067
2005–06	6 679	16 067
2006–07	5 567	16 067
2007–08	6 457	8 278
2008–09	4 897	8 278
2009–10	5 236	8 278
2010–11	6 691	8 278
2011–12	7 627	8 278
2012–13	6 881	8 278
2013-14	5 855	9 069

*FSU data.
§ Includes landings from unknown areas before 1986-87.

The bulk of reported landings are taken from RCO 3, in particular the Canterbury Bight and Banks Peninsula areas. The red cod fishery is characterised by large variations in catches between years. Research indicates that this interannual variation in catch is due to varied recruitment causing biomass fluctuations rather than a change in catchability. The RCO 3 TACC was reduced by 63% from the 1 October 2007 to 4600 t, with the TAC being set at 4930 t (customary, recreational and other sources of mortality were allocated 5, 95 and 230 t respectively). All RCO stocks fisheries have been put on to Schedule 2 of the Fisheries Act 1996. Schedule 2 allows that for certain “highly variable” stocks, the Total Annual Catch (TAC) can be increased within a fishing season. The base TAC is not changed by this process and the “in-season” TAC reverts to the original level at the end of each season. No RCO stocks have yet had an in-season increase.

RED COD (RCO)





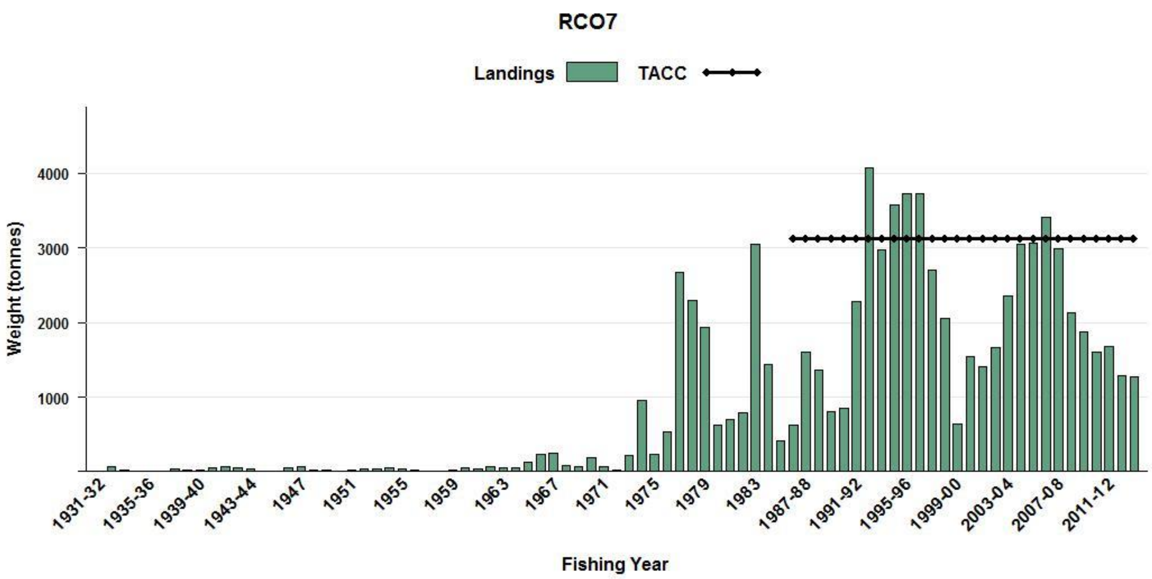


Figure 1: Reported commercial landings and TACC for the three main RCO stocks. Top to bottom: RCO2 (Central East), RCO 3 (South East Coast), RCO7 (Challenger).

1.2 Recreational fisheries

Recreational fishers take red cod, particularly on the east coast of the South Island. Results of five separate recreational fishing surveys are shown in Table 4.

Table 4: Estimated number and weight of red cod harvested by recreational fishers, by Fishstock and survey. Surveys were carried out in different years in the MAF Fisheries regions: South in 1991–92, Central in 1992–93, North in 1993–94 (Teirney *et al*. 1997) and nationally in 1996 (Bradford 1998) and 1999-00 (Boyd & Reilly 2002). Survey harvest is presented as a range to reflect the uncertainty in the estimates.

Fishstock	Survey	Number	CV %	Estimated harvest range (t)	Estimated point estimate (t)
					1991–92
RCO 3	South	104 000	16	90–120	-
RCO 7	South	1 000	-	0-5	-
					1992–93
RCO 2	Central	151 000	19	105–155	-
RCO 7	Central	1 100	34	5–15	-
1993-94					
RCO 1	North	9000	34	5–15	-
					1996
RCO 1	National	11 000	18	515	11
RCO 2	National	88 000	11	80–105	92
RCO 3	National	99 000	10	90–115	103
RCO 7	National	38 000	15	30–50	40
					1999–00
RCO 1	National	21 000	36	5–11	8
RCO 2	National	39 000	25	8–14	11
RCO 3	National	207 000	25	210–349	280
RCO 7	National	23 000	50	5–14	9

A key component of the process of estimating recreational harvest from diary surveys is determining the proportion of the population that fish. The Recreational Technical Working Group concluded that the harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. The 1999–00 harvest estimates for each Fishstock should be evaluated with reference to the coefficient of variation.

1.3 Customary non-commercial fisheries

Quantitative estimates of the current level of customary non-commercial catch are not available.

1.4 Illegal catch

Quantitative estimates of the level of illegal catch are not available.

1.5 Other sources of mortality

Processing limits on red cod are sometimes imposed to discourage fishers from landing red cod when the species cannot be processed or when markets are poor. This practice has encouraged dumping. Processing limits are currently less of a problem than in earlier years.

2. BIOLOGY

Red cod are a fast-growing, short-lived species with few fish in the commercial fishery older than six years. Red cod grow to about 25 cm total length (TL) in the first year, followed by annual growth increments of around 15, 10 and 5 cm. Growth of sexes is similar for the first two years, after which females tend to grow faster than males and reach a larger overall length. Sexual maturity ranges from 45 to 55 cm TL with a mean value of 52 cm TL for both sexes at an age of 2–3 years. *M* has been estimated to equal 0.76 for both sexes. In 1995, ageing of red cod was validated using marginal zone analysis.

In the 1989–90 to 1992–93 fishing years, 80% of the landings in RCO 3 were 2^+ and 3^+ fish (50–57 cm TL). The sex ratio of the commercial catch during this period was skewed towards females during November (F:M ratio of 3.4:1) with the ratio tending to even out by May. Schools are generally comprised of single age cohorts rather than a mix of age classes.

Spawning in red cod varies with latitude, with spawning occurring later at higher latitudes. In the Canterbury Bight, spawning occurs from August to October. No definite spawning grounds have been identified on the southeast coast, but there is some evidence that red cod spawn in deeper water (300–750 m). Running ripe fish were caught on the Puysegur Bank in 600 m during the Southland trawl survey in February 1994. Juvenile red cod are found in offshore waters after the spawning period; however, no nursery grounds are known for this species.

Red cod are seasonally abundant, with schools appearing in the Canterbury Bight and Banks Peninsula area around November. These schools are feeding aggregations and are not found in these waters after about June. Catch data indicates that they move into deeper water after this time. Recruitment is highly variable resulting in large variations in catches between years.

Biological parameters relevant to the stock assessment are shown in Table 5.

Table 5: Estimates of biological parameters for red cod.

Fishstock						**Estimate**	**Source**
1. Natural mortality (*M*)							
RCO 3						0.76	Beentjes (1992)
2. Weight = a(length)^b (Weight in g, length in cm fork length).							
			Females			Males	
		a	b		a	b	
RCO 3		0.0074	3.059		0.0145	2.892	Beentjes (1992)
RCO 3 combined sexes		0.009249	3.001				Beentjes (1992)
3. von Bertalanffy growth parameters							
			Females			Males	
	L_∞	k	t_0	L_∞	k	t_0	
RCO 3	76.5	0.41	-0.03	68.5	0.47	0.06	Horn (1995)
RCO 7	79.6	0.49	0.20	68.2	0.53	0.22	Beentjes (2001)

3. STOCKS AND AREAS

The number of red cod stocks is unknown. There is no information about stock structure, recruitment patterns, or other biological characteristics that would indicate stock boundaries.

4. STOCK ASSESSMENT

No recent stock assessments have been carried out on any red cod stocks. Previous assessments were undertaken, however, these are now outdated.Details appear in previous versions of the Plenary report.

Trawl survey biomass estimates are available from one *Tangaroa* survey, and five summer and ten winter *Kaharoa* surveys (Table 6, Figures 2, 3 and 4). In 2001, the Inshore FAWG recommended that the summer east coast South Island trawl survey be discontinued due to the extreme variability in the catchability of the target species. The winter surveys were reinstated in 2007 and this time included additional 10–30 m strata in an attempt to index elephantfish and red gurnard which were included in the list of target species. Only 2007, 2012, and 2014 surveys provide full coverage of the 10–30 m depth range. The winter surveys are currently conducted on a biennial cycle.

4.1 Biomass estimates

ECSI

Biomass for red cod from 2007 to 2009 ECSI trawl survey core strata (30–400 m) was largely unchanged and remained low relative to the period between 1991 and 1994. In contrast the biomass in 2012 was more than six-fold greater than in 2009, followed by a drop of similar magnitude in 2014 (Table 6, Figure 3). The relatively high biomass in 1994 and the low biomass in 2007–09 are consistent with commercial landings in RCO 3, a fishery in which cyclical fluctuating catches are characteristic. The large biomass in 2012 consisted predominantly of 1+ year fish. The proportion of pre-recruit biomass varied greatly among surveys ranging from 7 to 59% of the total biomass and in 2014 it was 49%, reflecting relatively low numbers of adult fish rather than a strong 1+ cohort. The proportion of juvenile biomass (based on the length-at-50% maturity) also varied greatly among surveys, from 27 to 80%, and in 2014 it was 70% (Figure 4).

The additional red cod biomass captured in the shallow strata (10–30 m) accounted for only 4% and 2% of the biomass in the core plus shallow strata (10–400 m) for 2007 and 2012 respectively, but in 2014 it was 44%, indicating that in terms of biomass, it is important to monitor the shallow strata for red cod (Table 6, Figure 3). The addition of the 10–30 m depth range had little effect on the shape of the length frequency distributions in 2007 and 2012, but in in 2014 the largest fish were in 10–30 m (Beentjes et al. 2015).

The distribution of red cod hot spots within the ECSI survey area varies, but overall this species is consistently well represented over the entire survey area, most commonly from 30 m to about 300 m, but is also found in waters shallower than 30 m.

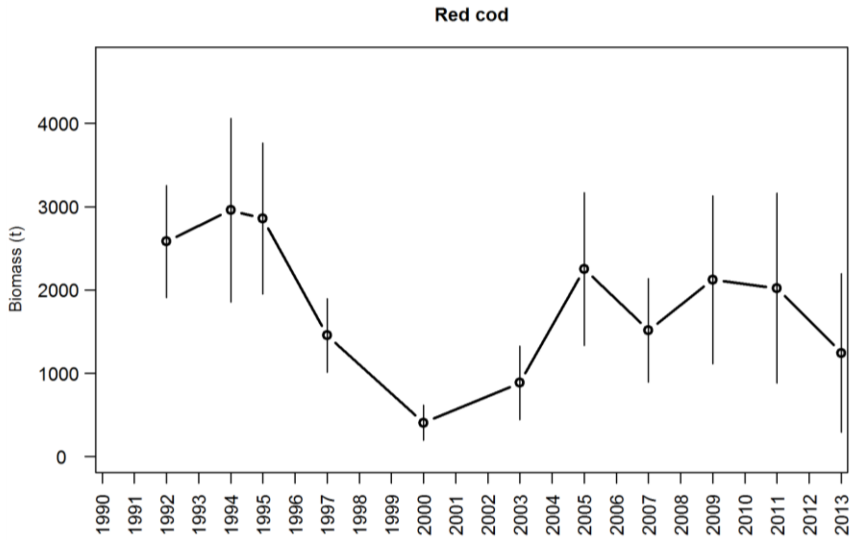


Figure 2: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) and the time series mean (dotted line) from the West Coast South Island trawl survey

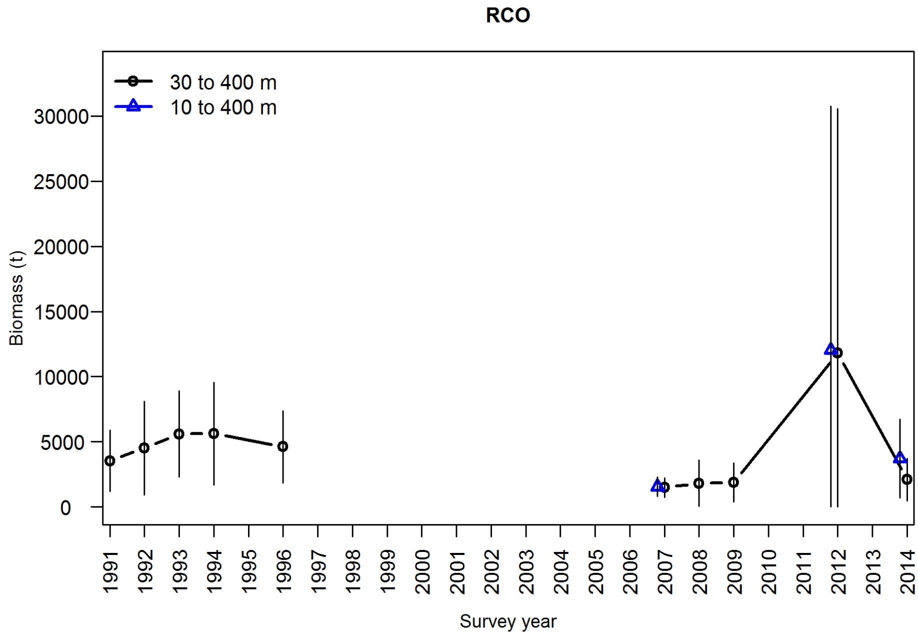


Figure 3: Red cod total biomass and 95% confidence intervals for the all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007, 2012, and 2014.

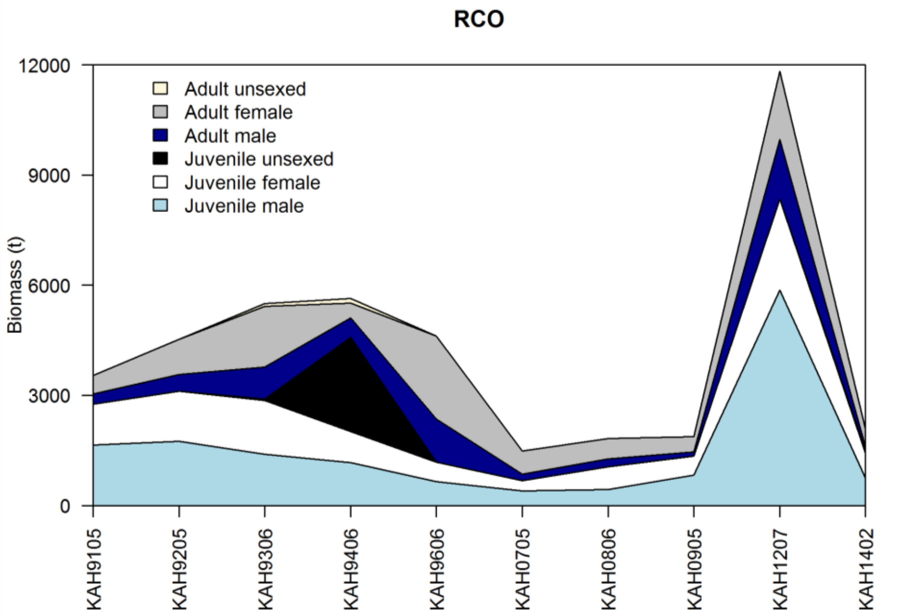


Figure 4: Red cod juvenile and adult biomass for ECSI winter surveys in core strata (30–400 m), where juvenile is below and adult is equal to or above length at which 50% of fish are mature.

4.2 Length frequency distributions

The size distributions of red cod in each of the ten core strata (30–400 m) ECSI surveys were similar and generally characterised by a 0+ mode (10–20 cm), 1+ mode (30–40 cm), and a less defined right hand tail comprised predominantly of 2+ and 3+ fish (Beentjes et al. 2015). The 1996 to 2009 surveys showed poor recruitment of 1+ fish compared to earlier surveys, whereas the 1+ cohort was the largest of all ten surveys in 2012 and only average in 2014. Red cod on the ECSI, sampled during these surveys, were generally smaller than those from Southland, suggesting that this area may be an important nursery ground for juvenile red cod. The addition of the 10–30 m depth range had little effect on the shape of the length frequency distributions in 2007 and 2012, but in in 2014 the largest fish were in 10–30 m (Beentjes et al. 2015).

Table 6: Relative biomass indices (t) and coefficients of variation (CV) for red cod for east coast South Island (ECSI) - summer and winter, west coast South Island (WCSI), and Southland survey areas*. Biomass estimates for ECSI in 1991 have been adjusted to allow for non-sampled strata (7 & 9 equivalent to current strata 13, 16 and 17). The sum of pre-recruit and recruited biomass values do not always match the total biomass for the earlier surveys because at several stations length frequencies were not measured, affecting the biomass calculations for length intervals. – , not measured; NA, not applicable. Recruited is defined as the size-at-recruitment to the fishery (40 cm).

Region	Fishstock	Year	Trip number	Total Biomass estimate	CV (%)	Total Biomass estimate	CV (%)	Pre-recruit	CV (%)	Pre-recruit	CV (%)	Recruited	CV (%)	Recruited	CV (%)
ECSI(winter)	RCO 3			30–400m		10–400m		30–400m		10–400m		30–400m		10–400m	
		1991	KAH 9105	3 760	40	-	-	1 823	45	-	-	2 054	37	-	-
		1992	KAH 9205	4 527	40	-	-	2 089	50	-	-	2 438	33	-	-
		1993	KAH 9306	5 601	30	-	-	1 025	51	-	-	4 469	27	-	-
		1994	KAH 9406	5 637	35	-	-	3 338	40	-	-	2 299	36	-	-
		1996	KAH 9606	4 619	30	-	-	590	31	-	-	4 029	34	-	-
		2007	KAH0705	1 486	25	1 552	24	190	33	-	-	1 295	25	-	-
		2008	KAH0806	1824	49	-	-	129	36	-	-	1 695	50	-	-
		2009	KAH0905	1 871	40	-	-	833	50		-	1 038	41	-	-
		2012	KAH1207	11 821	79	12 032	78	7 015	97	-	-	4 806	55	-	-
		2014	KAH1402	2 096	39	3 714	41	409	45	-	-	1 654	23	-	-
ECSI(summer)	RCO 3	1996-97	KAH 9618	10 634	23	-	-	4 101	23	-	-	-	-	-	-
		1997-98	KAH 9704	7 536	23	-	-	4 426	24	-	-	-	-	-	-
		1998-99	KAH 9809	12 823	17	-	-	3 770	15	-	-	-	-	-	-
		1999-00	KAH 9917	6 690	30	-	-	2 728	41	-	-	-	-	-	-
		2000-01	KAH 0014	1 402	82	-	-	1 283	89	-	-	-	-	-	-
ECNI	RCO 2	1993	KAH 9304	913	52			197	31						
		1994	KAH 9402	1 298	50			547	52						
		1995	KAH 9502	469	36			47	34						
WCSI	RCO 7	1992	KAH 9204	2 719	13	-	-	1 167	17	-	-	-	-	-	-
		1994	KAH 9404	3 169	18	-	-	888	25	-	-	-	-	-	-
		1995	KAH 9504	3 123	15	-	-	1 007	18	-	-	-	-	-	-
		1997	KAH 9701	2 546	23	-	-	1 353	28	-	-	-	-	-	-
		2003	KAH 0304	906	24	-	-	290	31	-	-	-	-	-	-
		2005	KAH0503	2610	18	-	-	501	-	-	-	-	-	-	-
		2007	KAH0704	1638	19	-	-	842	-	-	-	-	-	-	-
		2009	KAH0904	2 782	25	-	-	1 614	27	-	-	-	-	-	-
		2013	KAH1305	1 247	38	-	-								
Southland	RCO 3	1993	TAN 9301	100	68	-	-	-	-	-	-	-	-	-	-
		1994	TAN 9402	707	68	-	-	-	-	-	-	-	-	-	-
		1995	TAN 9502	2 554	49	-	-	182	66	-	-	-	-	-	-
		1996	TAN 9604	33 390	94	-	-	736	99	-	-	-	-	-	-

*Assuming areal availability, vertical availability and vulnerability equal 1.0. Biomass is only estimated outside 10 m depth except for COM9901 and CMP0001. Note: because trawl survey biomass estimates are indices, comparisons between different seasons (e.g., summer and winter ECSI) are not valid

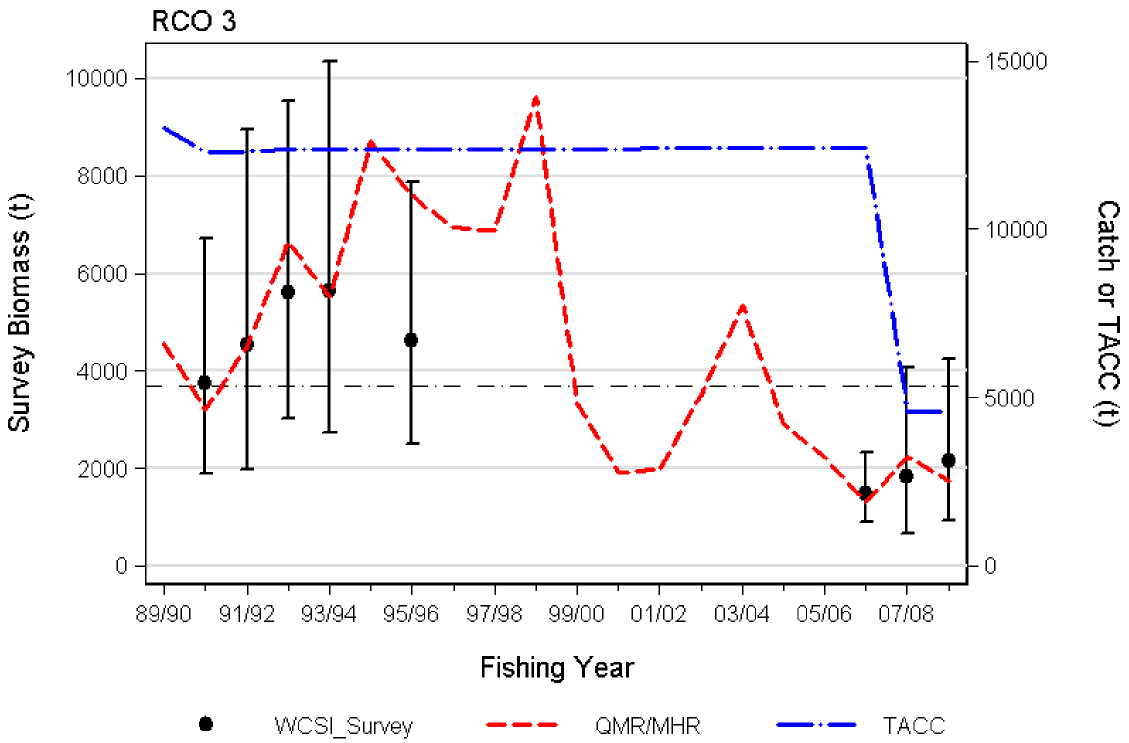
5. STATUS OF THE STOCKS

Yearly fluctuations in red cod catch reflect changes in recruitment. Trawl surveys and catch sampling of red cod have shown that the fishery is based almost exclusively on two and three year old fish and is highly dependent on recruitment success.

RCO 3

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	-
Reference Points	Target: *MSY*-compatible proxy based on the East Coast South Island trawl survey (to be determined) Soft Limit: 50% of target Hard Limit: 25% of target
Status in relation to Target	Unknown
Status in relation to Limits	Soft limit: Unknown Hard Limit: Unknown

Historical Stock Status Trajectory and Current Status



East Coast South Island survey biomass (points) commercial catch (red dashed line) and TACC (blue dashed line) for the period 1990 to 2009. Horizontal line dashed is the mean biomass index, 1992-2009.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Both catch and survey biomass have declined substantially since the mid 1990s.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-

Trends in Other Relevant Indicators or Variables	From 1991 to 1994 large recruitment pulses were seen in the survey catch. The most recent three surveys (2007, 2008 and 2009) have not detected any significant recruitment.	
Projections and Prognosis		
Stock Projections or Prognosis	Biomass estimates from the recently re-instated winter East Coast South Island since 2007 confirm that biomass is low relative to the 1990s.	
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown	

Assessment Methodology and Evaluation		
Assessment Type	Level 2: Trawl survey	
Assessment Method	Accepted biomass index	
Assessment Dates	Latest assessment: 2011	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the East Coast South Island index was a credible measure of red cod biomass.	
Main data inputs (rank)	Trawl survey biomass estimates and length frequency analysis	1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	

Qualifying Comments
-

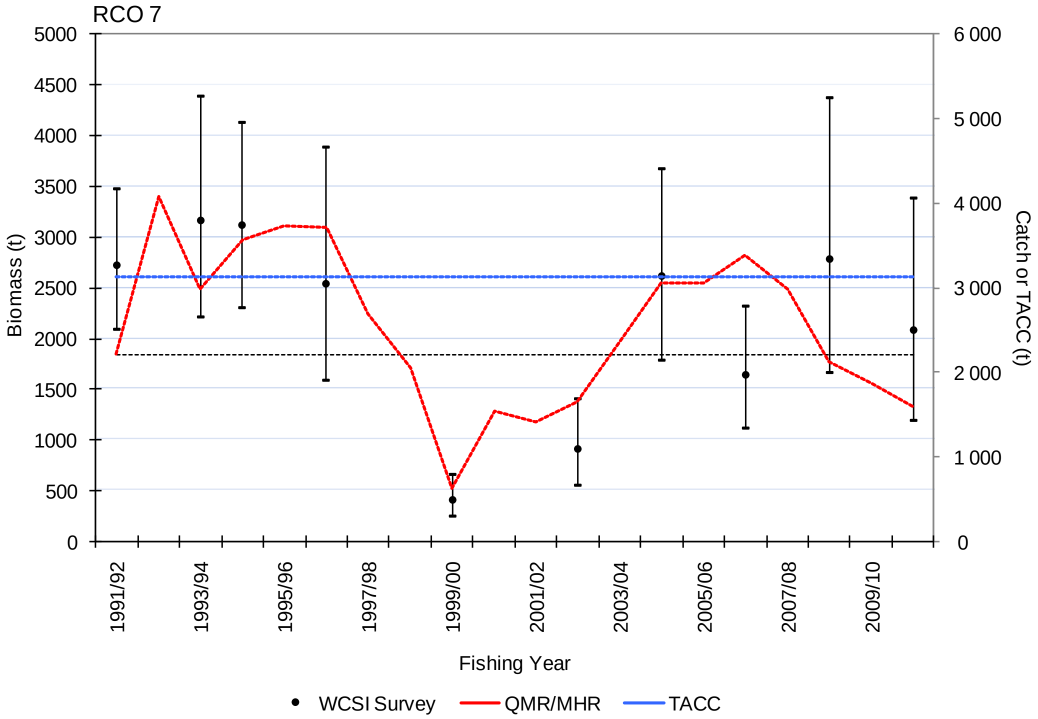
Fishery Interactions
Red cod are landed as bycatch in barracouta, flatfish, squid and tarakihi bottom trawl fisheries and ling, school shark, spiny dogfish, rig, tarakihi and moki setnet fisheries. Incidental captures of seabirds occur.

RCO 7

Stock Structure Assumptions

Stock boundaries are unknown, but for the purpose of this summary RCO 7 is considered to be a single management unit.

Stock Status	
Year of Most Recent Assessment	2009 West Coast South Island trawl survey
Reference Points	Target: *MSY*-compatible proxy based on the West Coast South Island trawl survey (to be determined) Soft Limit: 50% of target Hard Limit: 25% of target
Status in relation to Target	Unknown
Status in relation to Limits	Soft limit: Unknown Hard Limit: Unlikely (< 40%) to be below
Fishery and Stock Trends	
Trend in Biomass or Proxy	Biomass indices have been increasing from a series low in 2000, with the current 2009 index above the long-term mean.
Trend in Fishing Mortality or Proxy	Unknown

Historical survey biomass, Catch and TACC Trajectories	
	
West Coast South Island survey biomass (points) commercial catch (red line) and TACC (blue line) for the period 1990 to 2009. Horizontal line dashed represents the mean biomass index, 1992–2011.	
Other Abundance Indices	-
Trends in Other Relevant Indicator or Variables	Length frequency analysis from the West Coast South Island trawl survey in 2009 show a wide distribution of male fish in 2009.

Projections and Prognosis	
Stock Projections or Prognosis	Based on the broad size composition in the survey, high biomass levels are expected to persist in the short-term.
Probability of Current Catch / TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 2: Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of survey biomass trends and length frequencies.	
Assessment Date	Latest assessment: 2009	Next assessment: 2013
Overall assessment quality rank	1 – High Quality. The Southern Inshore Working Group agreed that the West Coast South Island survey was a credible measure of biomass.	
Main data inputs (rank)	West Coast South Island survey biomass length frequency	1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	-	
Qualifying Comments		
-		

Fishery Interactions
Red cod are primarily taken in conjunction with the following QMS species: stargazer, red gurnard, tarakihi and various other species in the West Coast South Island target bottom trawl fishery. Smooth skates are caught as a bycatch in this fishery, and the biomass index for smooth skates in the west coast trawl survey has declined substantially since 1997. There may be similar concerns for rough skates but the evidence is less conclusive. Incidental captures of seabirds occur.

Yield estimates, TACCs and reported landings for the 2013–14 fishing year are summarised in Table 7.

Table 7: Summary of yield estimates (t), TACCs (t) and reported landings (t) of red cod for the most recent fishing year. *MCY*(1) from cY_{AV} method, *MCY*(2) from MIAEL method (range only given).

Fishstock	FMA		*MCY*(1)	*MCY*(2)	2013–14 Actual TACC	2013–14 Reported landings
RCO 1	Auckland (East) (West)	1 & 9	60		42	6
RCO 2	Central (East) (West)	2 & 8		500	500	167
RCO 3	South-East, Southland and Sub-Antarctic	3, 4, 5, & 6	4 400	2 418–13 330	5 391	4 410
RCO 7	Challenger	7	800	2 568–3 452	3 126	1 272
RCO 10	Kermadec	10	-		10	0
Total			5 260		9 069	5 855

6. FOR FURTHER INFORMATION

Annala, J H; Sullivan, K J; O'Brien, C; Iball, S (Comps.) (1998) Report from the Fishery Assessment Plenary, May 1998: Stock assessments and yield estimates. 409 p. (Unpublished report held in NIWA library, Wellington.)

Beentjes, M P (1992) Assessment of red cod based on recent trawl survey and catch sampling data. New Zealand Fisheries Assessment Research Document 1992/16. 41 p. (Unpublished report held in NIWA library, Wellington.)

Beentjes, M P (1995a) Inshore trawl survey of the Canterbury Bight and Pegasus Bay, May–June 1992 (KAH9205). *New Zealand Fisheries Data Report* No: 55.

Beentjes, M P (1995b) Inshore trawl survey of the Canterbury Bight and Pegasus Bay, May–June 1993 (KAH9306). *New Zealand Fisheries Data Report* No: 56.

Beentjes, M P (2000) Assessment of red stocks (RCO 3 and RCO 7) for 1999. *New Zealand Fisheries Assessment Report 2000/25*. 78 p.

Beentjes, M.P.; MacGibbon, D.; Lyon, W.S. (2015). Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2014 (KAH1402). *New Zealand Fisheries Assessment Report 2015/14*. 136 p.

Beentjes, M. P., & Renwick, J. A. (2001). The relationship between red cod, *Pseudophycis bachus*, recruitment and environmental variables in New Zealand. *Environmental biology of fishes*, *61*(3), 315-328.

Beentjes, M P; Wass, R (1994) Inshore trawl survey of the Canterbury Bight and Pegasus Bay, May–June 1991 (KAH9105). *New Zealand Fisheries Data Report* No: 48.

Boyd, R O; Reilly, J L (2005) 1999/2000 National marine recreational fishing survey: harvest estimates. Final Research Report for Ministry of Fisheries Research Project REC9803. (Unpublished report held by Ministry for Primary Industries, Wellington.)Bradford, E (1998) Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research .Document 1998/16. 27 p. (Unpublished report held in NIWA library, Wellington.)

Cordue, P L (1998a) An evaluation of alternative stock reduction estimators of virgin biomass and the information content of various research survey scenarios. New Zealand Fisheries Assessment Research Document 1998/22. 35 p. (Unpublished report held in NIWA library, Wellington.)

Cordue, P L (1998b) Designing optimal estimators for fish stock assessment. *Canadian Journal of Fisheries and Aquatic Science* 55: 376–386.

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. (Unpublished report held in NIWA library, Wellington.)

Habib, G (1975) Aspects of biology of red cod (*Pseudophycis bachus*). (Unpublished Ph.D thesis, University of Canterbury.) 203 p.

Horn, P (1995) A validated ageing methodology, and growth parameters for red cod (*Pseudophycis bachus*) off the southeast coast of the South Island, New Zealand. New Zealand Fisheries Assessment Research Document 1995/6. 15 p. (Unpublished report held in NIWA library, Wellington.)

Stevenson, M L (2007) Inshore trawl surveys of the west coast of the South Island and Tasman and Golden Bays, March–April 2007 (KAH0704). New Zealand Fisheries Assessment Research Document 2007/41. 64 p. (Unpublished report held in NIWA library, Wellington.)

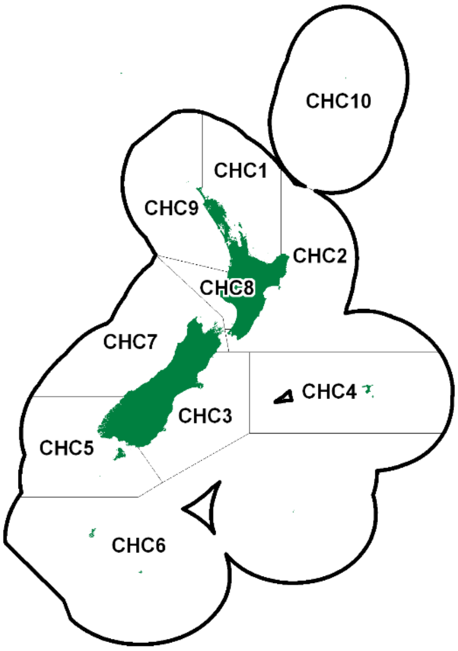
Stevenson, M L (2012) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March–April 2011 (KAH1104). *New Zealand Fisheries Assessment Report 2012/50.* 77 p.

Stevenson, M L; Beentjes, M P (1999) Inshore trawl survey of the Canterbury Bight and Pegasus Bay, December 1998–January 1999 (KAH9809*). NIWA Technical Report* No 63. 66 p.

Teirney, L D; Kilner, A R; Millar, R E; Bradford, E; Bell, J D (1997) Estimation of recreational catch from 1991/92 to 1993/94. New Zealand Fisheries Assessment Research Document 1997/15. 43 p. (Unpublished report held in NIWA library, Wellington.)

RED CRAB (CHC)

(*Chaceon bicolour*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

The red crab (*Chaceon bicolor*) was introduced into the Quota Management System on 1 April 2004 with a combined TAC of 48 t and TACC of 48 t (Table 1). There are no allowances for customary, recreational or other sources of mortality. The fishing year is from 1 April to 31 March and commercial catches are measured in greenweight. There were no commercial catches of this crab until 2001–02, when landings of about 1.5 t were reported. *C. bicolor*, along with several other deepwater crabs, was the focus of an exploratory fishing (potting) permit during 2000–02. Significant quantities have been found in the Bay of Plenty, east of Great Barrier Island, and east of Northland. The other region fished was the east coast of the North Island south of East Cape, where smaller catches were periodically reported (Table 1). Figure 1 shows the historical landings and TACC for CHC 1.

There are two species of *Chaceon* known from New Zealand waters. *C. yaldwyni* is almost indistinguishable from *C. bicolor*, but is a very rarely caught species from the eastern Chatham Rise (fewer than five specimens have ever been caught).

Table 1: TACCs and reported landings (t) of red crab by Fishstock from 2001–02 to present from CELR and CLR data. There have never been any reported landings of red crab from CHC 3–10, so these are not tabulated; although CHC 3–9 have TACCs of 4 t.

Fishstock	CHC 1		CHC 2		Total	
	Landings	TACC	Landings	TACC	Landings	
2001–02	1.132	-	0.065	-	1.27	-
2002–03	0.604	-	0	-	0.604	-
2003–04	0	-	0.009	-	0.009	-
2004–05	0	10	0.215	10	0.215	48
2005–06	0.021	10	0	10	0.021	48
2006–07	0.017	10	0.004	10	0.021	48
2007–08	5.870	10	0.081	10	5.951	48
2008–09	0	10	0.068	10	0.068	48
2009–10	0.985	10	0.071	10	1.056	48
2010–11	5.532	10	0.420	10	5.970	48
2011–12	0	10	0.011	10	0.043	48
2012–13	0	10	0.01	10	0.01	48
2013-14	1.052	10	0.063	10	1.135	48

*In 2001–02 77.5 kg were reportedly landed, but the FMA is not recorded. This amount is included in the total landings for that year.

1.2 Recreational fisheries
There are no known records of recreational use of this crab.

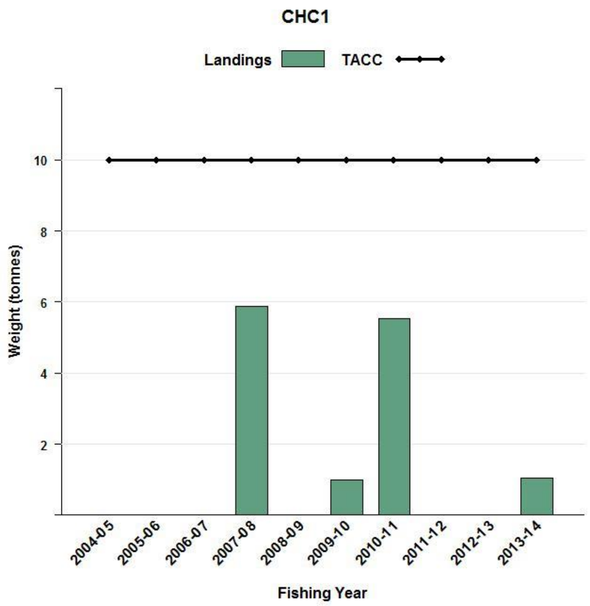


Figure 1: Reported commercial landings and TACC for CHC 1 (Auckland East). QMA data from 2004–05 to present.

1.3 Customary non-commercial fisheries
There are no known records of customary use of this crab.

1.4 Illegal catch
There is no known illegal catch of this crab.

1.5 Other sources of mortality
There is no quantitative information on other sources of mortality, although this crab is often taken as a bycatch in orange roughy fishing.

2. BIOLOGY

C. bicolor is a very large, purple and tan to yellowy tan coloured crab that reaches at least 192 mm carapace width (CW). It is found on and north of the Chatham Rise, and particularly along the east coast north of Hawkes Bay to North Cape. It has been found on both hard and soft substrates, but is considered to be a burrowing crab, living in soft sediments. It has been recorded from depths between 800 and 1100 m around New Zealand, and between 275 and 1620 m elsewhere in the Pacific.

C. bicolor was previously referred to as *C.* (sometimes *Geryon*) *quinquedens* and belongs to the family Geryonidae which has an almost world-wide distribution. There is no information on its reproduction, age, growth, or natural mortality in New Zealand waters—which may or may not be similar to the same or similar *Chaceon* species elsewhere.

Geryonid crabs such as *C. bicolor* tend to show partial sex segregation, females being in shallower water than males. Small crabs are usually found in deeper water than the adults, as a result of juvenile settlement in deep water. There can be both seasonal and ontogenetic movements between depth zones.

Females carry a single clutch of eggs during the winter, which hatch the following summer. Clutch size increases with female size, and egg numbers are of the order of 100 000 to 400 000. The eggs are small (0.5–0.6 mm diameter), suggesting a relatively long larval life, probably resulting in widespread dispersal. Off Western Australia, however, *C. bicolor* females may be ovigerous at any time of the year. One study off Western Australia found that the lengths at 50% maturity were 90.5 mm and 94 mm carapace length (CL) for females and males respectively.

Pot catches usually yield a very biased sex ratio favouring males, which may be due to the fact that ovigerous females remain buried in the substrate during incubation.

3. STOCKS AND AREAS

For management purposes stock boundaries are based on QMAs, however, there is currently no biological or fishery information which could be used to identify biological stock boundaries.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

There are no estimates of fishery parameters or abundance for any red crab fishstock.

4.2 Biomass estimates

There are no biomass estimates for any red crab fishstock.

4.3 Yield estimates and projections

There are no estimates of *MCY* for any red crab fishstock.

There are no estimates of *CAY* for any red crab fishstock.

5. STATUS OF THE STOCKS

There are no estimates of reference or current biomass for any red crab fishstock.

6. FOR FURTHER INFORMATION

Dawson, E W; Webber, W R (1991) The deep-sea red crab *Chaceon* ("*Geryon*"): a guide to information and a reference list of the family Geryonidae. *National Museum of New Zealand Miscellaneous Series* No. 24.

McLay, C L (1988) Brachyura and crab-like Anomura of New Zealand. *Leigh Laboratory Bulletin* No. 22. 463 p.

Manning, R B; Dawson, E W; Webber, W R (1990) A new species of *Chaceon* from New Zealand (Crustacea: Decapoda: Geryonidae). *Proceedings of the Biological Society of Washington* 103: 602–607.

Manning, R B; Holthuis, L B (1989) Two new genera and nine new species of geryonid crabs (Crustacea, Decapoda, Geryonidae). *Proceedings of the Biological Society of Washington* 102: 50–77.

Melville-Smith, R (1982) A brief exploitation of the stone crab Lithodes murrayi (Henderson) off South West Africa, 1979/80. *Fisheries Bulletin of South Africa* 16: 45–55.

Naylor, J R; Webber, W R; Booth, J D (2005) A guide to common offshore crabs in New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 2.*

Smith, K D; Potter, I C; Hall, N G (2004) Biological and fisheries data for managing the deep-sea crabs *Hypothalassia acerba* and *Chaceon bicolor* in Western Australia. Projects No. 1999/154 and 2001/055. FRDC Australia.

Webber, R; Dawson, E; Stephenson, B (1989) The deep-sea red crab - a new resource? *Professional Fisherman* 3(6):10–11.