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Catch at age of tarakihi from trawl surveys of east coast South Island and Bay of Plenty

New Zealand Fisheries Assessment Report 2017/03

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EXECUTIVE SUMMARY

Beentjes, M.P.; Walsh, C.; Buckthought, D. (2017). Catch at age of tarakihi from east coast South Island and Bay of Plenty trawl surveys.

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Tarakihi population length and age compositions were estimated from inshore bottom trawl surveys on the east coast South Island (ECSI) and Bay of Plenty (BOP). The aim was to investigate temporal trends in age composition, and to determine whether there were spatial differences in length and age between shallow and deep water.

All collected otoliths from six ECSI surveys (kah0014, kah0705, kah0806, kah0905, kah1207 and kah1402) and one BOP survey (kah9902) were prepared and read in accordance with the age determination protocols for tarakihi. Length data were analysed separately for tows less than 80 m (shallow) and tows 80 m and over (deep) for ECSI, and tows less than 150 m (shallow) and tows 150 m and over (deep) for BOP. The indirect ageing method was used, in which age length keys for each survey were used in conjunction with length frequencies to construct the age structure of the population occurring in each of the two depth categories.

Tarakihi from more than 80 m depth off the ECSI were consistently larger by about 4–8 cm and older by about 1 to 2 years, with the exception of 2014 where the differences were less marked. The difference was mainly a result of the largest and oldest fish being caught in deeper water and this was not related to the sex ratio which tended to be balanced in both shallow and deep water. Bay of Plenty tarakihi length and age data were comparatively sparse and hence population estimates were less robust. However, BOP fish tended to be larger and older on average than from the ECSI for both shallow and deep tows, and the same pattern of larger and older fish residing in deeper water was observed.

Because commercial catch sampling in 2009–10, 2010–11, 2013–14 and 2014–15 did not adequately sample the full depth distribution of tarakihi, the generated population age compositions were unlikely to be fully representative of the ECSI population. In the most recent stock assessment for tarakihi in 2012, selectivity was confounded with mortality and emigration, and it was not clear whether the lack of older fish in TAR 3 commercial catches was the result of offshore movement to deeper water. Information on population age structure of TAR 3 by depth presented in this report will make for greater certainty in the estimates of stock status for east coast tarakihi from the next stock tarakihi assessment.

1. INTRODUCTION

1.1 Background

Tarakihi otoliths, collected during east coast South Island (ECSI) trawl surveys from six surveys (2000, 2007, 2008, 2009, 2012 and 2014)) as well as from a single survey of the Bay of Plenty (BOP) in 1999 (Morrison & Parkinson 2000, Beentjes et al. 2015), were prepared and aged. The rationale for this initiative was that tarakihi aged from the 2010 and 2011 catch sampling programme in the TAR 3 trawl fishery were characterised by single and narrow modes for both length and age, with most fish between 5 and 6 years of age (Beentjes et al. 2012). Although the catch sampling design was found to be representative of the commercial fishery, a significant proportion of the catch is taken from depths shallower than 80 m (Beentjes et al. 2012). This resulted in considerable uncertainty in the 2012 stock assessment, as older fish were either in deeper water, or they did not exist (Langley & Starr 2012). The purpose of this study was to establish population age structure across the tarakihi depth distribution so that selectivity of commercial bottom trawl fisheries in TAR 3 and possibly TAR 2, could be better determined in the next east coast tarakihi stock assessment. The ECSI trawl surveys extended from 10 to 400 m and the BOP survey from 10 to 250 m, and tarakihi were sampled across the full depth range where they occurred. We investigated temporal trends in age composition among the surveys, and whether there were spatial differences in length and age of trawl caught tarakihi between shallow and deep water within surveys.

1.2 Objectives

Specific objective:

1. To age tarakihi otoliths collected during previous trawl surveys conducted off the east coasts of both North and South Islands.

2. METHODS

2.1 Survey ageing data

The Southern Inshore Working Group (SINSWG) recommended that the age composition be estimated for six ECSI and one BOP inshore *Kaharoa* trawl surveys where sagittal otoliths had been collected, but not previously aged (Table 1). The 2000 ECSI and 1999 BOP surveys were carried out in summer, whereas the others were winter surveys.

All otoliths collected from the seven surveys were selected, and preparation and reading was carried out in accordance with the age determination protocol for tarakihi (Walsh et al. 2016) summarised below:

1. Tarakihi otoliths were rendered into thin-section preparations as follows: otoliths were individually marked on their distal faces with a fine sectioning line guide, under a stereomicroscope. The sectioning line followed the straightest dorso-ventral axis, orientated through the primordium. Otoliths were then embedded in an epoxy resin mould with standard curing at 50 ºC. Thin sections were taken using a Struers Secotom-10 digital sectioning machine, with a section thickness of approximately 350 μm. Resulting thin section wafers were cleaned and embedded on microscope slides under a few drops of epoxy resin with a coverslip. Finally, these slides were oven cured at 50ºC.
2. Otoliths were read using transmitted light under a binocular microscope at a magnification of 100 times. Under transmitted light the wide opaque zone appears dark and the narrow translucent zone (hyaline) appears light.

3. Two elected core tarakihi “expert” readers (Cameron Walsh and Dane Buckthought) read all otoliths without reference to fish length.
4. Readers conformed to the documented protocols (above) when interpreting zone counts.
5. The forced margin method was used (see ADP report).
6. A subsequent rereading of otoliths with discrepant age estimates was carried out by the two readers and a third adjudicating reader jointly with conferring to arrive at an agreed age.

Between-reader ageing precision was assessed by the application of the methods and graphical techniques documented in Campana et al. (1995) and Campana (2001); including APE (average percent error) and coefficient of variation (CV). All age data from the seven surveys were combined for these analyses.

2.2 Survey length data

The lengths of all measured male, female and unsexed tarakihi from the seven trawl surveys were extracted from the MPI *Trawl* database for tows with gear performance of 1 or 2 (satisfactory), using the NIWA program SurvCalc (Francis & Fu 2012). For ECSI surveys, length data were extracted separately for tows less than 80 m (shallow) and tows 80 m and over (deep). This depth cut-off was recommended by the SINSWG and is consistent with a peak of commercial fishing in depths less than about 80 m. For the BOP survey, however, a cut off of shallower and deeper than 150 m was used because there were few tarakihi caught in water shallower than 140 m. Catch rates (kg/km^2) of tarakihi for each tow were also extracted for scaling the length data.

2.3 Catch-at-age analyses

Length and age compositions of tarakihi from the seven trawl surveys were estimated with ‘Indirect ageing’ using the NIWA program Catch-at-age (Bull & Dunn 2002). The program firstly scales the length frequency and then the length-at-age data are converted into an age-length-key (ALK) comprised of the proportion at age across each length. The ALK is then applied to the scaled length frequency data to provide an estimate of relative proportions or numbers at age. Tarakihi otoliths from each survey were collected from a representative size range for both sexes for the express purpose of building ALKs. To generate scaled numbers at length (NAL) in the catch-at-age program the raw length frequency data were scaled by the area of the stratum, and the catch rate (kg/km^2). Length weight coefficients used in the scaling procedure were survey-specific. For ECSI strata in 30 to 100 m that include the 80 m depth contour (strata 1 to 7), the areas were prorated according to the estimated proportion of the strata less than 80 m, and 80 m and over (Appendix 1). The 80 m depth contour was generated from the NIWA GIS bathymetry database and is not continuous in all strata because of paucity of data (Figure 1). For BOP the 150 m contour corresponds closely to strata depth boundaries so the actual strata areas were used for scaling (Figure 2).

Bootstrap resampling (300 bootstraps) was used to calculate the coefficient of variation (CV) for proportions- and numbers-at-length and age. That is, simulated data sets were created by resampling (with replacement) tows from each stratum, and fish from each tow; and also for fish from the ALK.

For each of the seven surveys, catch-at-age was estimated using the length and age data collected from that survey depth range (i.e., deep or shallow), e.g., using the ALK generated from the ECSI survey kah0014 shallow tows applied to the length data from the same tows. For each survey, scaled length frequency and age frequency proportions are graphically presented, together with CV for each length and age class, and the mean weighted coefficients of variation (MWCV).

Sex ratios (expressed as percentage male), mean lengths and mean ages, for survey depth ranges were calculated from scaled length and age frequencies.

3. RESULTS

3.1 Ageing

3.1.1 Between reader agreement

The age readings were very consistent between the two readers, with an APE of 1.7% and a CV of 2.4% (Figure 3). Percent agreement was 85% and the bulk of discrepant readings were only out by plus or minus one year. There was no age estimation bias across the age range. The range of final agreed age estimates was 1 to 34 years for the ECSI with 92% of the ages 10 years and younger, and 3 to 24 years for BOP with 80% of ages 10 years or younger.

3.1.2 Raw length and age

The raw length versus age plots of the six ECSI surveys had from 185 to 284 individuals (Table 1) and were remarkably consistent among surveys with ages from 1 to 34 years. (Figure 4). When ages were apportioned by depth, 54% of ages were from fish caught in deep tows (80 m and over), and 46% from fish caught in shallow tows (less than 80 m) (Table 1). Similarly, 44% of measured fish were from deep and 56% from shallow tows, with just over half (53%) of all tows in shallow (Table 1).

The raw length versus age plot of the 1999 BOP survey had only 114 individuals (Table 1), ranging from 3 to 24 years. (Figure 5). When ages were apportioned by depth, 80% of ages were from fish caught in deep tows (150 m and over), and 20% from fish caught in shallow tows (less than 150 m) (Table 1). Similarly, 69% of measured fish were from deep and 31% from shallow tows, with 27% of all tows in shallow (Table 1).

Age versus length by depth (deep and shallow) for all seven surveys are clearly different with the bulk of the fish over 6 years of age caught in deeper water (Figure 6).

3.2 Population length and age composition

The scaled length frequency and age distributions for each of the seven surveys by depth (shallow and deep), and between depths, are described for each survey below (Figures 7 to 13).

3.2.1 Individual surveys

ECSI 2000 summer survey (kah0014)

Shallow – scaled length and age frequency distributions for both males and females were similar with ages ranging from 1 to 7 years (Figure 7). The cumulative distribution plots of length and age show little difference between the sexes.

Deep –scaled length frequency distributions for both males and females were similar, but there were too few ages for each sex to comment on age differences. Ages ranged from 1 to 26 years, although most fish were less than 10 years old. (Figure 7).

Between depths – length distributions between shallow and deep tows are similar in shape but modal peaks of fish from deep tows are slightly larger and the distribution has a longer right-hand tail comprising more large fish (Figure 7). Mean length was 23 cm for shallow tows compared to 27 cm for deep tows (Table 2). The differences in length are reflected in the age distributions with all fish older than seven years in the deep water (Table 2). Mean ages were 3.8 years for tarakihi from shallow tows and 4.6 years from deep tows.

ECSI 2007 winter survey (kah0705)

Shallow – scaled length and age frequency distributions for both males and females were similar with ages ranging from 1 to 6 years (Figure 8). The cumulative distribution plots of length and age show very little difference between the sexes.

Deep –scaled length frequency and age distributions for both males and females were similar with ages ranging from 1 to 31 years, although most fish were less than seven years old. (Figure 8).

Between depths – length distributions between shallow and deep tows were broadly similar in shape but fish from the deep tows had virtually no juvenile mode and the distribution has a longer right-hand tail comprising more large fish (Figure 8). Mean length was 19 cm for shallow tows compared to 25 cm for deep tows (Table 2). The differences in length are reflected in the age distributions with all fish older than 6 years in the deeper water (Table 2). Mean ages were 2.3 years for tarakihi from shallow tows and 3.5 years from deep tows.

ECSI 2008 winter survey (kah0806)

Shallow – scaled length and age frequency distributions for both males and females were similar with ages ranging from 1 to 10 years, although nearly all fish were less than 6 years of age (Figure 9). The cumulative distribution plots of length and age show little difference between the sexes.

Deep –scaled length and age frequency distributions for both males and females were similar, with ages ranging from 1 to 27 years, although most were less than 8 years of age (Figure 9).

Between depths – length distributions between shallow and deep tows differ in shape with a more pronounced larger mode in deep tows with a longer right-hand tail comprising more large fish (Figure 9). Mean length was 20 cm for shallow tows compared to 26 cm for deep tows (Table 2). These differences in length are reflected in the age distributions with virtually all fish older than 7 years in deep water, and with the dominant age class in shallow water being 2 years compared to 4 years for deep water (Table 2). Mean ages were 2.4 years for tarakihi from shallow tows and 3.8 years from deep tows.

ECSI 2009 winter survey (kah0905)

Shallow – scaled length and age frequency distributions for both males and females were similar with ages ranging from 1 to 6 years (Figure 10). The cumulative distribution plots of length and age show little difference between the sexes.

Deep –scaled length and age frequency distributions for both males and females were similar, with ages ranging from 1 to 16 years, although more of the older fish were males (Figure 10).

Between depths – length distributions between shallow and deep tows differ in shape with a more pronounced larger mode and less pronounced juvenile mode in deep tows; the distribution also has a longer right-hand tail comprising more large fish (Figure 10). Mean length was 19 cm for shallow tows compared to 27 cm for deep tows (Table 2). The differences in length are reflected in the age distributions with all fish older than 5 years in deep water, and with the dominant age class in shallow water 2 years compared to 4 years for deep water (Table 2). Mean ages were 2.2 years for tarakihi from shallow tows and 4.2 years from deep tows.

ECSI 2012 winter survey (kah1207)

Shallow – scaled length and age frequency distributions for both males and females were similar with ages ranging from 1 to 6 years (Figure 11). The cumulative distribution plots of length and age show little difference between the sexes.

Deep –scaled length and age frequency distributions for both males and females were similar, with ages ranging from 1 to 25 years, although slightly more of the older fish were males (Figure 11).

Between depths – length distributions between shallow and deep tows differ in shape with more pronounced larger modes and a less pronounced juvenile mode in deep tows; the distribution also has a longer right-hand tail comprising more large fish than in the shallow tows (Figure 11). Mean length was 20 cm for shallow tows compared to 28 cm for deep tows (Table 2). The differences in length are reflected in the age distributions with all fish older than 6 years in deep water, and with the dominant age classes in shallow water 2 and 3 years compared to 5 years for deep water (Table 2). Mean ages were 2.9 years for tarakihi from shallow tows and 4.5 years from deep tows.

ECSI 2014 winter survey (kah1402)

Shallow – scaled length and age frequency distributions for both males and females were similar with ages ranging from 1 to 13 years, but virtually all fish were less than 6 years old (Figure 12). The cumulative distribution plots of length and age show little difference between the sexes.

Deep –scaled length and age frequency distributions for both males and females were similar, with ages ranging from 1 to 35 years (Figure 12).

Between depths – length distributions between shallow and deep tows differ in shape with a less pronounced juvenile mode in deep tows and with the distribution also having a longer right-hand tail comprising more large fish than in the shallow tows (Figure 12). Mean length was 22 cm for shallow tows compared to 24 cm for deep tows (Table 2). The differences in length are reflected in the age distributions with nearly all fish older than 5 years in deep water, and with the dominant age classes in shallow water 2 years compared to 3 years for deep water (Table 2). Mean ages were 3 years for tarakihi from shallow tows and 3.6 years from deep tows.

BOP 1999 summer survey (kah9902)

Shallow – the small sample size of 54 fish precludes any comment on scaled length and age frequency distributions between sexes. Age ranged from 3 to 14 years (Figure 13).

Deep –despite small sample sizes, scaled length and age frequency distributions for both males and females appear to be similar with age ranging from 4 to 24 years (Figure 13).

Between depths – length distributions between shallow and deep tows differ in shape with a less pronounced juvenile mode in deep tows (Figure 13). Mean length was 33 cm for shallow tows compared to 35 cm for deep tows (Table 2). The differences in length are reflected in the age distributions with nearly all fish older than 14 years in deep water (Table 2). Mean ages were 6.8 years for tarakihi from shallow tows and 9 years from deep tows.

3.2.2 All surveys summary

There was a consistent pattern of younger smaller fish in shallow water strata and older large fish in the deeper water strata across all BOP and ECSI surveys. Tarakihi from the ECSI in deep compared to shallow water were consistently larger by about 4–8 cm and older by about 1 to 2 years, with the exception of 2014 where the differences were less marked (Figure 14, Table 2). Although there was always considerable overlap in size and age between deep and shallow, the difference was mainly a result of the largest and oldest fish being caught in deeper water; and this was not related to the sex ratio which tended to be balanced in both shallow and deep water (Figure 15).

Bay of Plenty tarakihi length and age data from the 1999 survey were sparse and hence population estimates were less robust. BOP fish tended to be larger and older on average than from the ECSI for both shallow and deep tows and the same pattern of larger and older fish residing in deeper water was observed, despite the 150 depth cut off. There were no fish less than 19 cm and 3 years old in shallow strata from the 1999 BOP summer survey, whereas lengths down to 10 cm and ages down to 1 year were common in shallow strata from most ECSI surveys. The BOP survey also had a broader range of older age classes both deep and shallow than the ECSI survey series. Although the trawl survey results show that older tarakihi are more prevalent deeper than 80 m on the ECSI, fish younger than 6 years predominated in both deep and shallow strata.

4. DISCUSSION

The finding that tarakihi were on average older and larger in deeper water is not surprising given that it is a reasonably common characteristic of inshore fish species for juveniles to be found closer to shore in shallow water inside 100 m. Examples on the ECSI include barracouta, blue cod, warehou, school shark, silver warehou, smooth skate, giant stargazer, red gurnard, and spiny dogfish (Beentjes & MacGibbon 2013, Beentjes et al. 2015). The trawl survey ageing analyses show that the ECSI tarakihi are younger overall than in BOP in deep or shallow water, suggesting that ECSI is largely a nursery or recruitment area for tarakihi.

The catch sampling programme in TAR 3 bottom trawl fishery carried out in 2009–10 and 2010–11 showed that the age composition of the fishery was dominated by a single narrow mode with most fish between three and five years of age, with few older fish (Figure 16). The sampling was representative of the fishery and tended to be in depths shallower than about 100 m (Beentjes 2011, Beentjes et al. 2012). The age compositions for each of six ECSI trawl surveys in shallow are similar to those for the 2009–10 and 2010–11 catch sampling with few fish older than 5 years observed. For example, compare the 2009 survey age composition with that from the 2009–10 catch sampling (Figures 10 and 16). Although most of the commercial ECSI tarakihi catch comes from waters less than 80 m, a significant proportion is still taken deeper than 80 m. Hence the age and length composition of the commercial trawl fishery is at worst only marginally biased toward younger fish, i.e., under representative of the available age and size composition.

Unlike the bottom trawl TAR 3 catch sampling programme, where sampling occurred in processing sheds, the Bay of Plenty catches were sampled at sea by the fishing industry. Half the 2010–11 landed catch was from tows shallower than 150 m, but only a third of the sampled catch was from shallower than 150 m, indicating a bias towards sampling deeper tows, as well as a bias towards sampling at midday (McKenzie et al. 2015). Nevertheless, McKenzie et al. (2015) considered that overall spatial and temporal sampling coverage of Bay of Plenty was 'reasonably' representative of the fishery (Figure 17). The age distribution from the 2010–11 sampling is shown in Figure 17 and reveals an age composition with a broad range of ages, the bulk of which are from 3 to 7 years old, but with virtually all ages represented up to 20 plus. This age composition is more similar to that from the 1999 trawl survey deep tows (150 m and over) than from those in shallow tows under 150 m (see Figures 13 and 17). This finding is perhaps not surprising given that two thirds of sampled landings were from deeper than 150 m.

In conclusion, in both the east coast South Island and the Bay of Plenty there is a tendency for the largest and oldest fish to live in deeper water. Because Bay of Plenty tarakihi tend to be deeper than in the ECSI, this partition occurs in deeper water for BOP than the ECSI. Because commercial catch sampling in 2009–10, 2010–11, 2013–14 and 2014–15 did not adequately sample the full depth distribution of tarakihi, the generated population age compositions were unlikely to be fully representative of the ECSI population. In the most recent stock assessment for tarakihi in 2012, selectivity was confounded with mortality and emigration, and it was not clear whether the lack of older fish in TAR 3 commercial catches was the result of offshore movement to deeper water (Langley & Starr 2012). Information on fisheries independent population age structure of TAR 3 by depth presented in this report will enable greater certainty in the estimates of stock status for east coast tarakihi from the next tarakihi stock assessment.

5. ACKNOWLEDGMENTS

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Table 1: Number of otoliths with agreed ages, numbers of tarakihi measured for length, and tows on the trawl surveys of Bay of Plenty (BOP) and east coast South Island (ECSI). For ECSI, shallow tows were less than 80 m and deep tows 80 m and over. For BOP shallow tows were less than 150 m and deep tows 150 m and over.

Survey	Area	Aged otoliths			Fish measured			Tows		
		Shallow	Deep	Total	Shallow	Deep	Total	Shallow	Deep	Total
kah9902	BOP	22	92	114	54	118	172	57	21	78
kah0014	ECSI	114	71	185	2 040	1 683	3 723	61	62	123
kah0705	ECSI	64	171	235	1 656	1 700	3 356	50	55	105
kah0806	ECSI	108	116	224	1 591	981	2 572	41	58	99
kah0905	ECSI	156	120	276	1 408	575	1 983	37	56	93
kah1207	ECSI	120	133	253	2 335	825	3 160	55	48	103
kah1402	ECSI	103	181	284	1 539	2 655	4 194	58	59	117
Totals		694	893	1587	10 623	8 537	19 160	359	359	718

Table 2: Summary statistics for tarakihi catch at age analyses for the seven trawl surveys. For ECSI, shallow tows were less than 80 m and deep tows 80 m and over. For BOP shallow tows were less than 150 m and deep tows 150 m and over. BOP, Bay of Plenty; ECSI, east coast South Island; MWCV, mean weighted coefficient of variation.

			Age		Length		
Survey	Area	Depth range	Mean (y)	MWCV	Mean (cm)	MWCV	% male
kah9902	BOP	Shallow	6.8	73.7	32.9	76.3	34.5
		Deep	9.0	50.2	34.9	46.6	63.3
kah0014	ECSI	Shallow	3.8	18.0	22.9	22.0	48.7
		Deep	4.6	37.8	27.1	25.7	51.8
kah0705	ECSI	Shallow	2.3	29.8	18.8	34.2	52.2
		Deep	3.5	24.4	24.7	27.2	50.5
kah0806	ECSI	Shallow	2.4	28.0	20.1	35.0	48.1
		Deep	3.8	24.4	26.1	26.6	43.3
kah0905	ECSI	Shallow	2.2	13.7	19.4	30.5	43.4
		Deep	4.2	40.2	27.4	48.4	57.3
kah1207	ECSI	Shallow	2.9	23.8	20.1	32.3	48.3
		Deep	4.5	27.6	28.3	27.9	53.0
kah1402	ECSI	Shallow	3.0	26.1	22.5	33.2	51.0
		Deep	3.6	20.5	24.1	23.4	51.5

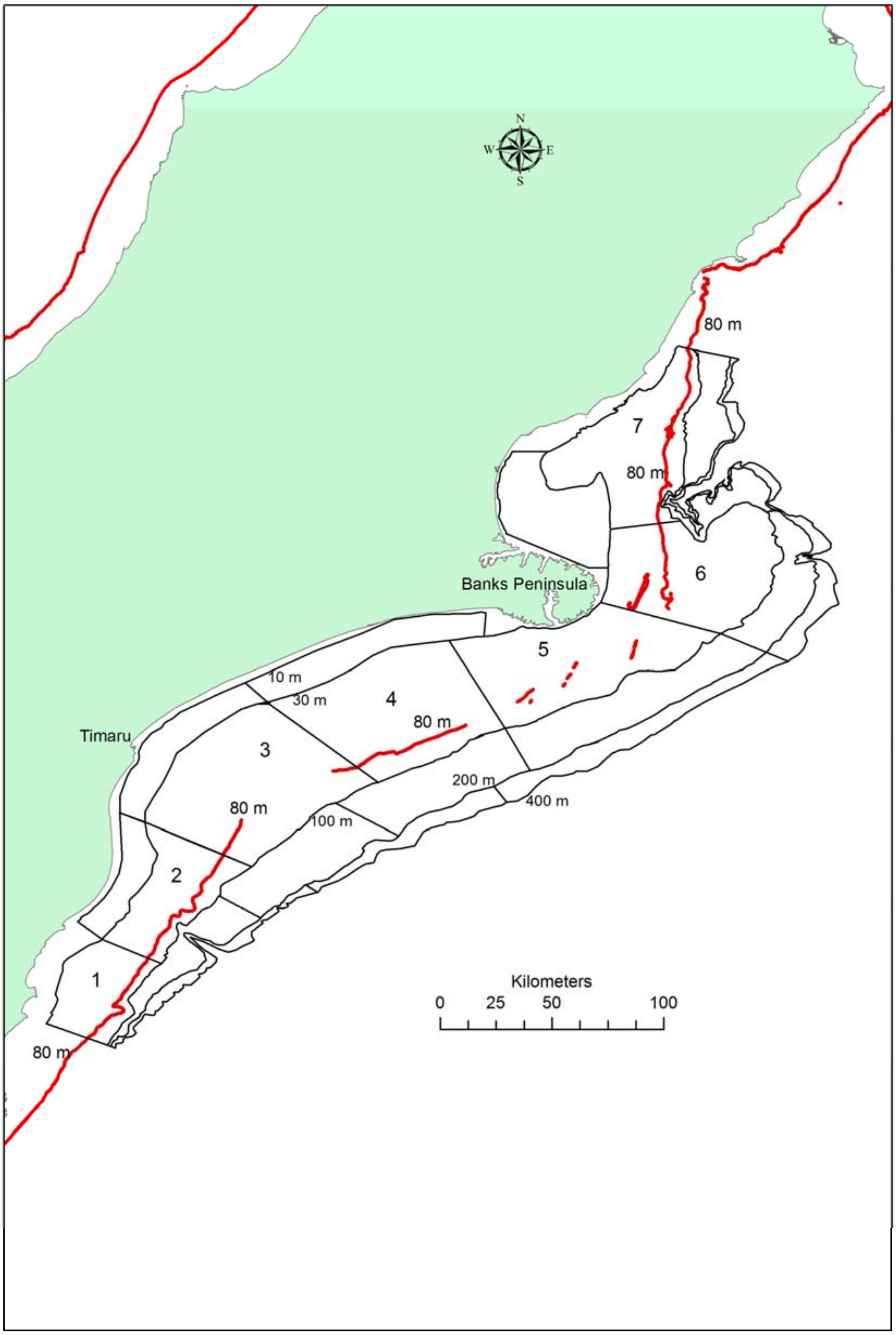

Figure 1: Map of ECSI trawl survey strata with the 80 m depth contour plotted. The areas of strata which the 80 m depth contour bisects (strata 1 to 7) were prorated according to the estimated proportion of area less than and greater than 80 m. The 80 m depth contour is generated from the NIWA bathymetry database.

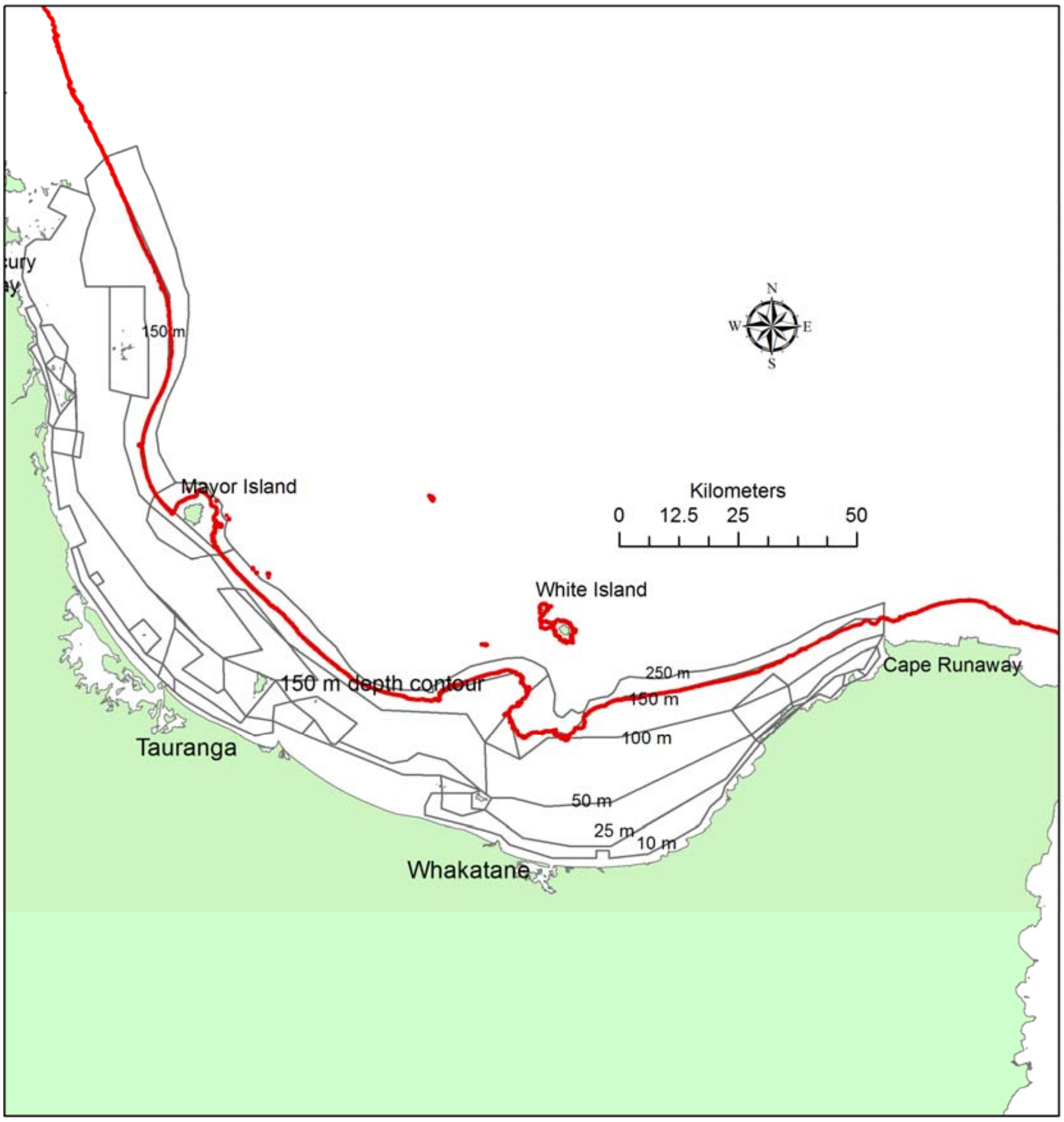

Figure 2: Map of Bay of Plenty trawl survey strata with the 150 m depth contour plotted. The 150 m depth contour is generated from the NIWA bathymetry database.

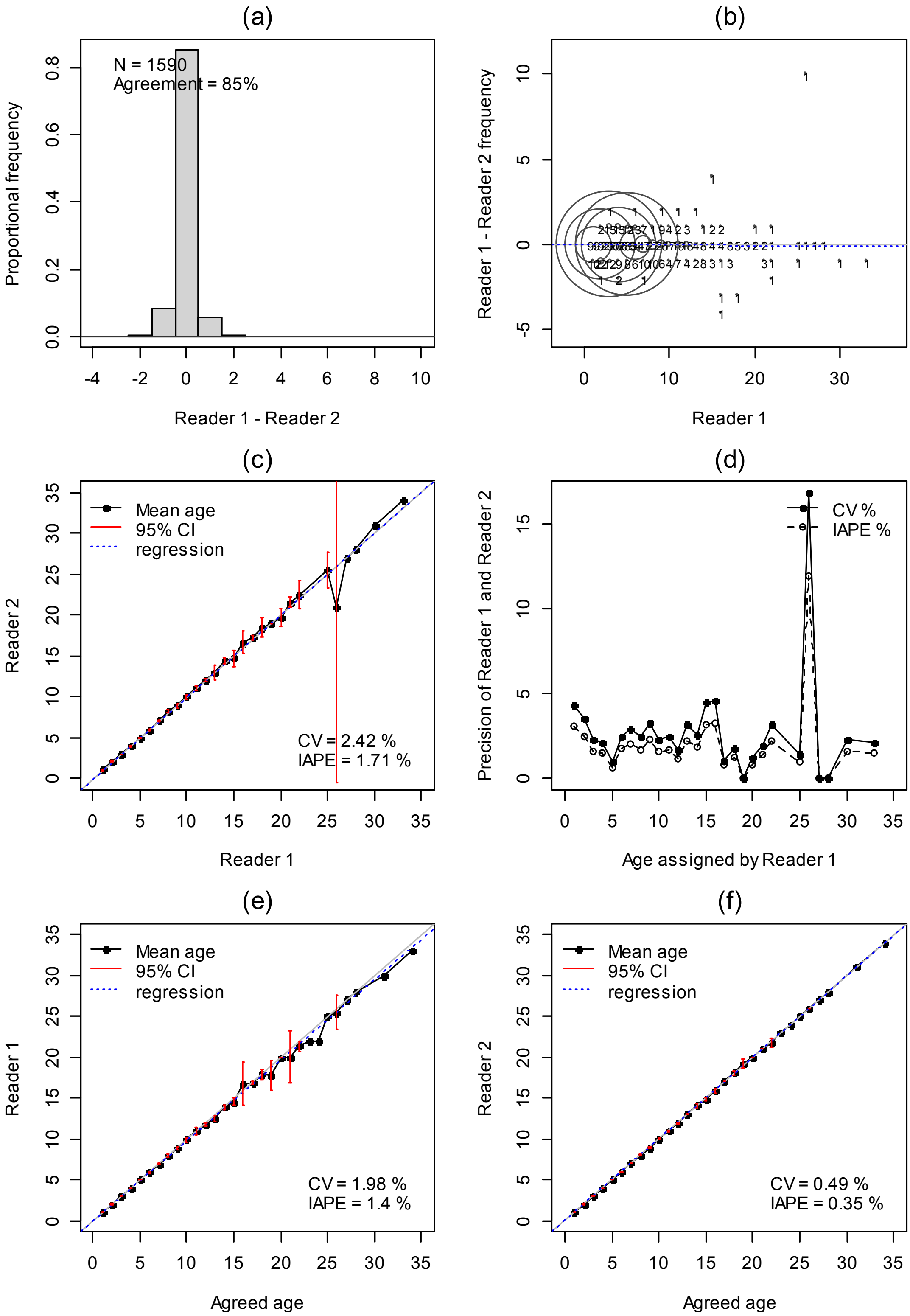

Figure 3: Age reader comparison plots for tarakihi collected from *Kaharoa* inshore trawl surveys of east coast South Island Bay of Plenty. (a) Histogram of age differences between two readers; (b) Difference between reader 1 and reader 2 as a function of the age assigned by reader 1. The number of fish in each bin is plotted as the plot symbol; (c) Age bias plot, showing the correspondence of ages between reader 1 and reader 2 for all ages. (d) Plot of the CV and the average percent error (APE) for each age as assigned by the first reader; (e and f) reader versus agreed age. In panels b, c, e and f solid lines show perfect agreement, dashed lines show the trend of a linear regression of the data. Error bars indicate the coefficient of variation (CV) of the ages for each age by reader 1.

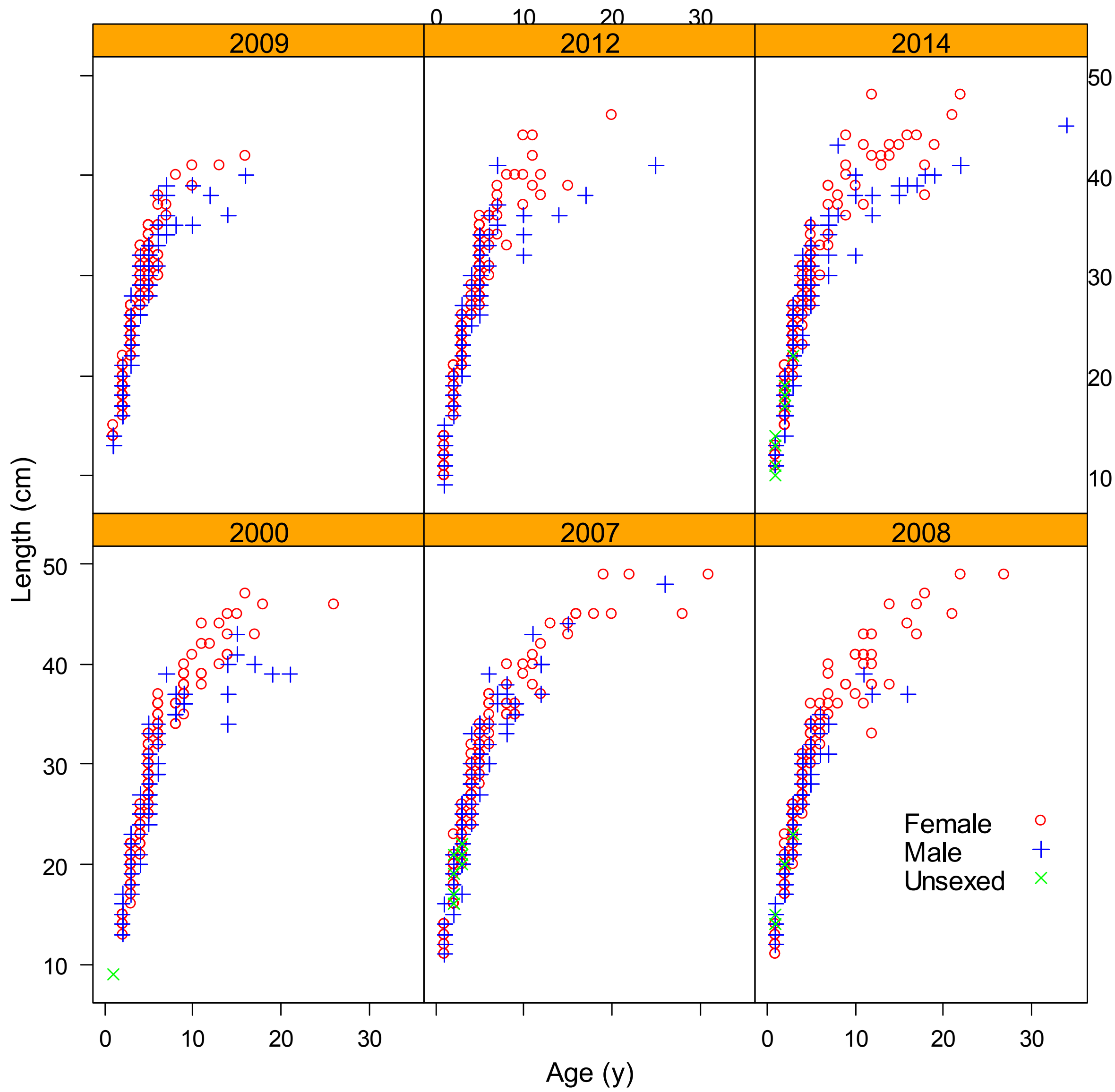

Figure 4: Tarakihi fork length versus age for six ECSI trawl surveys from 2000 to 2014 (kah0014, kah0705, kah0806, kah0905, kah1202, and kah1402).

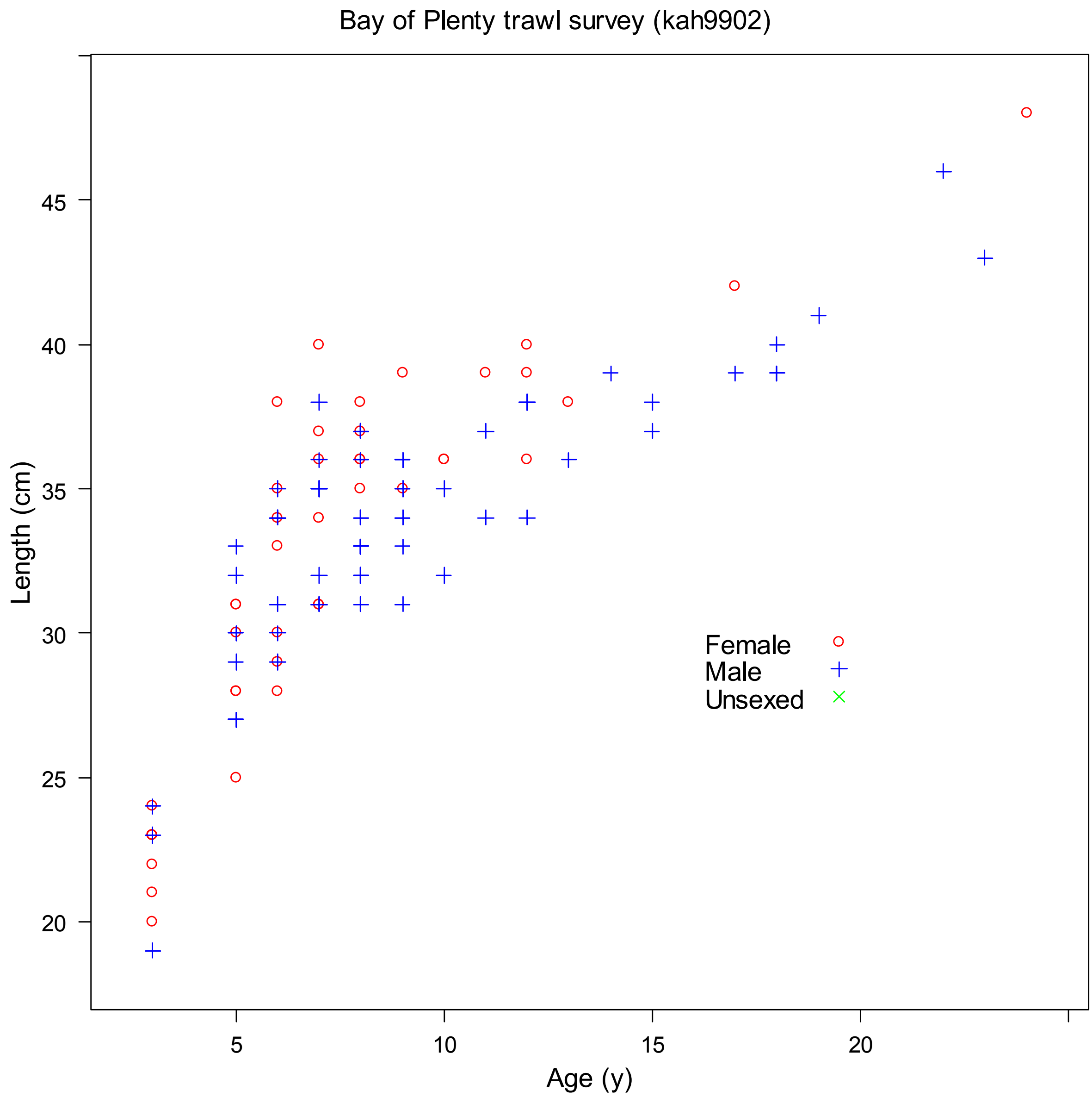

Figure 5: Tarakihi fork length versus age for 1999 BOP trawl survey (kah9902).

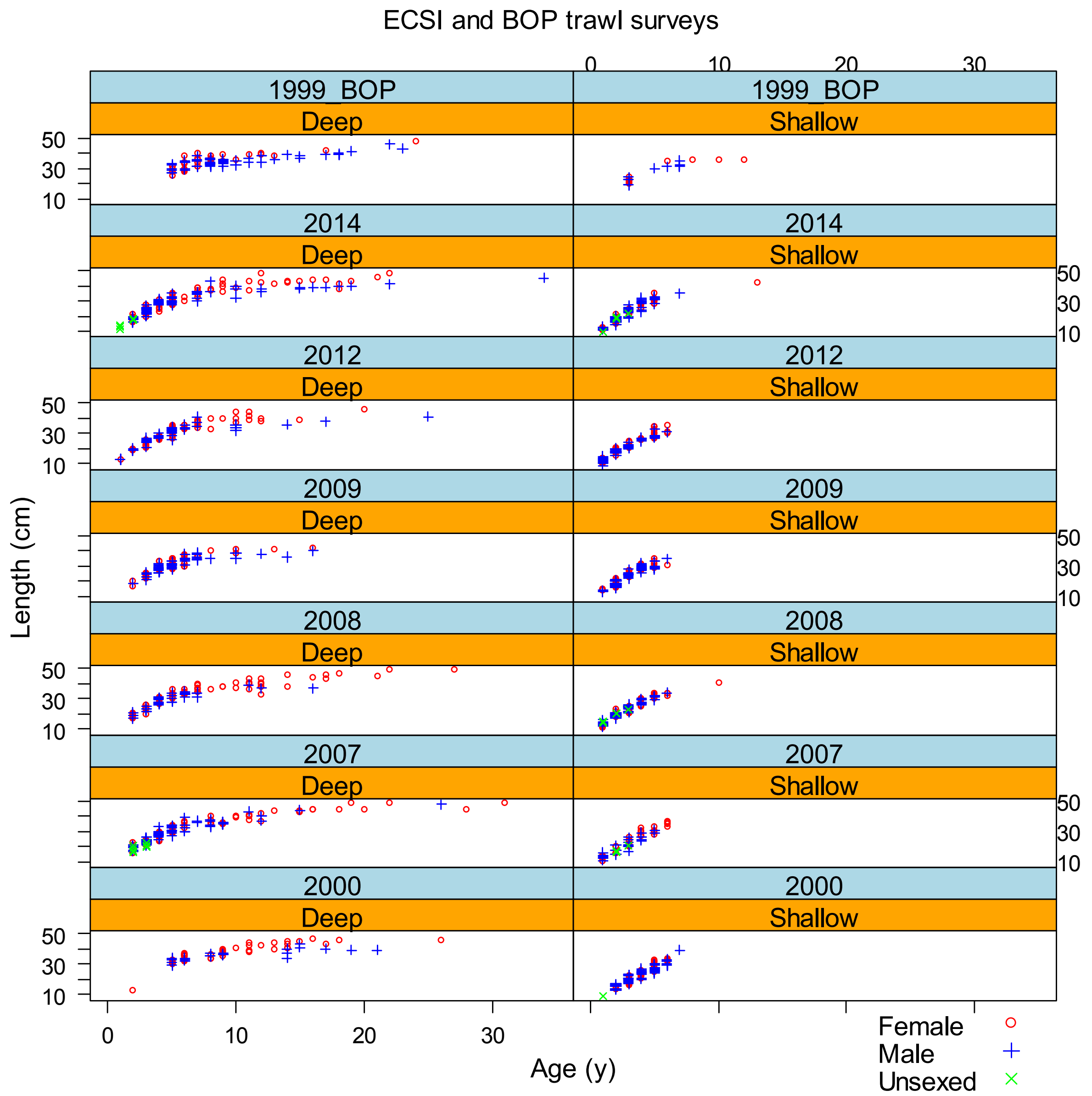

Figure 6: Tarakihi fork length versus age for six ECSI trawl surveys from 2000 to 2014 (kah0014, kah0705, kah0806, kah0905, kah1202, and kah1402) from deep (80 m and over) and shallow (less than 80 m) tows. Length versus age is also shown for the 1999 BOP survey (kah9902) from deep (150 m and over) and shallow (less than 150 m) tows.

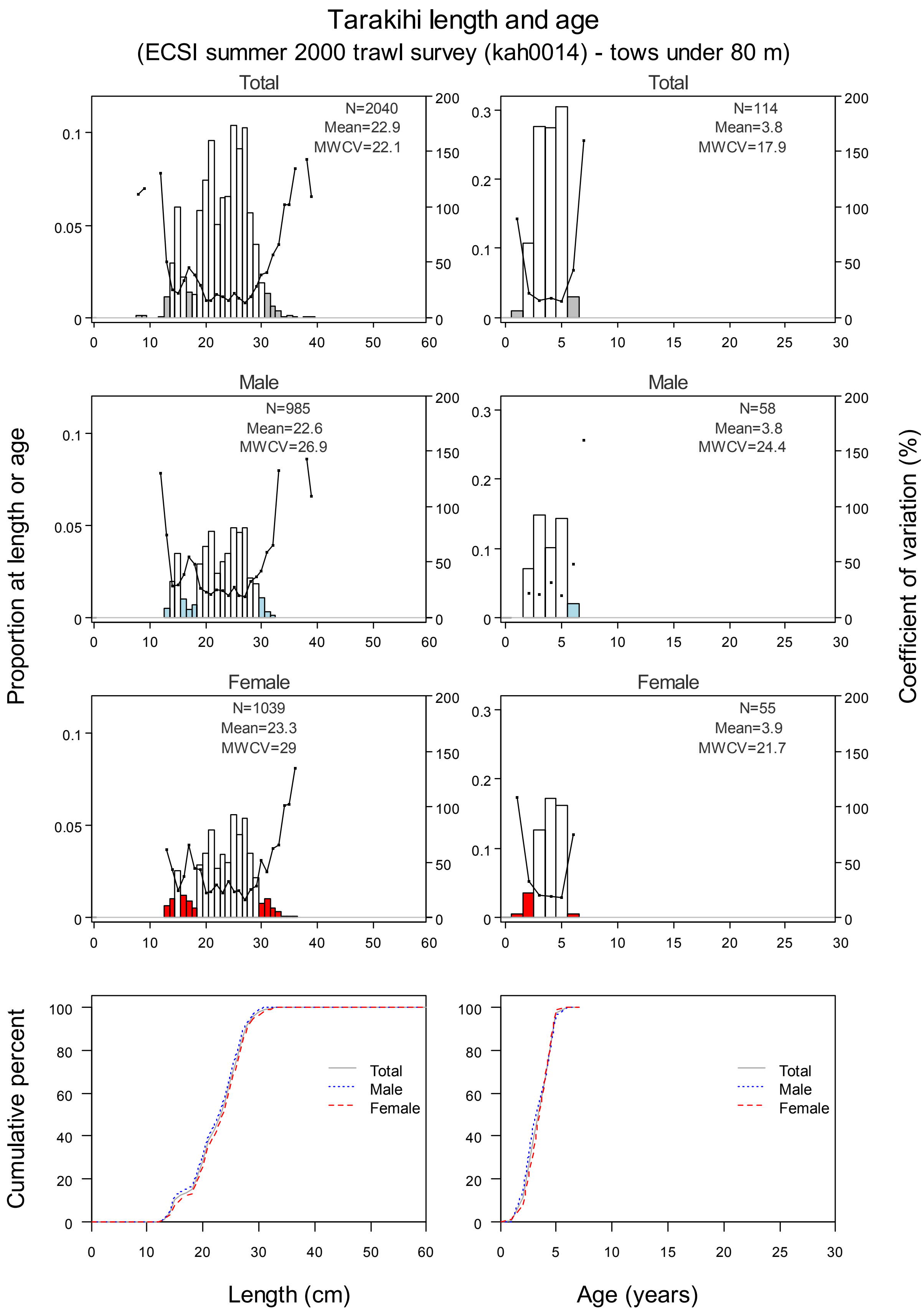

Figure 7: East coast South Island 2000 summer survey scaled length frequency, age frequency, and cumulative distributions for tarakihi from shallow tows (less than 80 m), deep tows (80 m and over), and a comparison between deep and shallow tows. ECSI, east coast South Island; N, sample size; MWCV, mean weighted coefficient of variation.

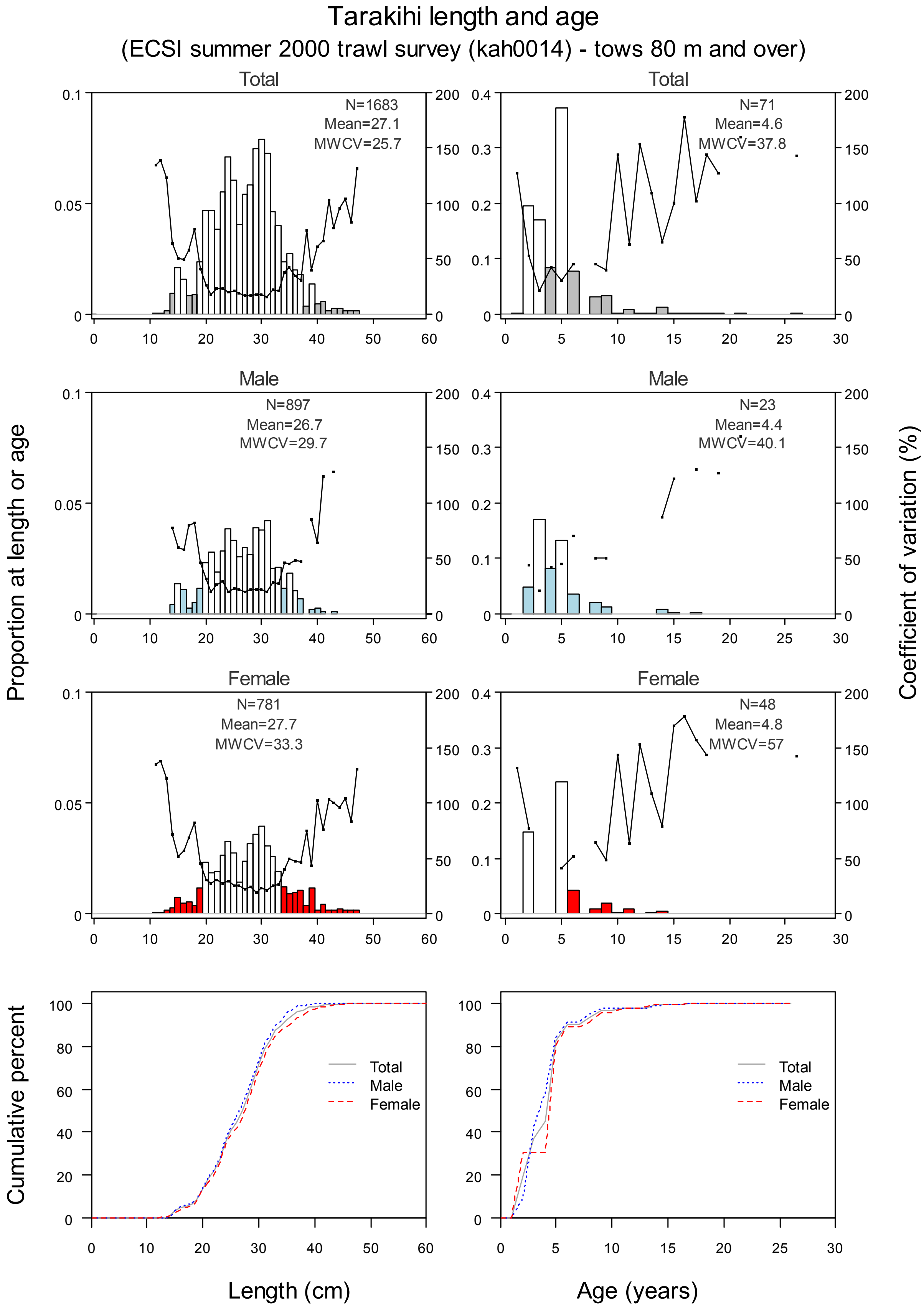

Figure 7 – ***continued***

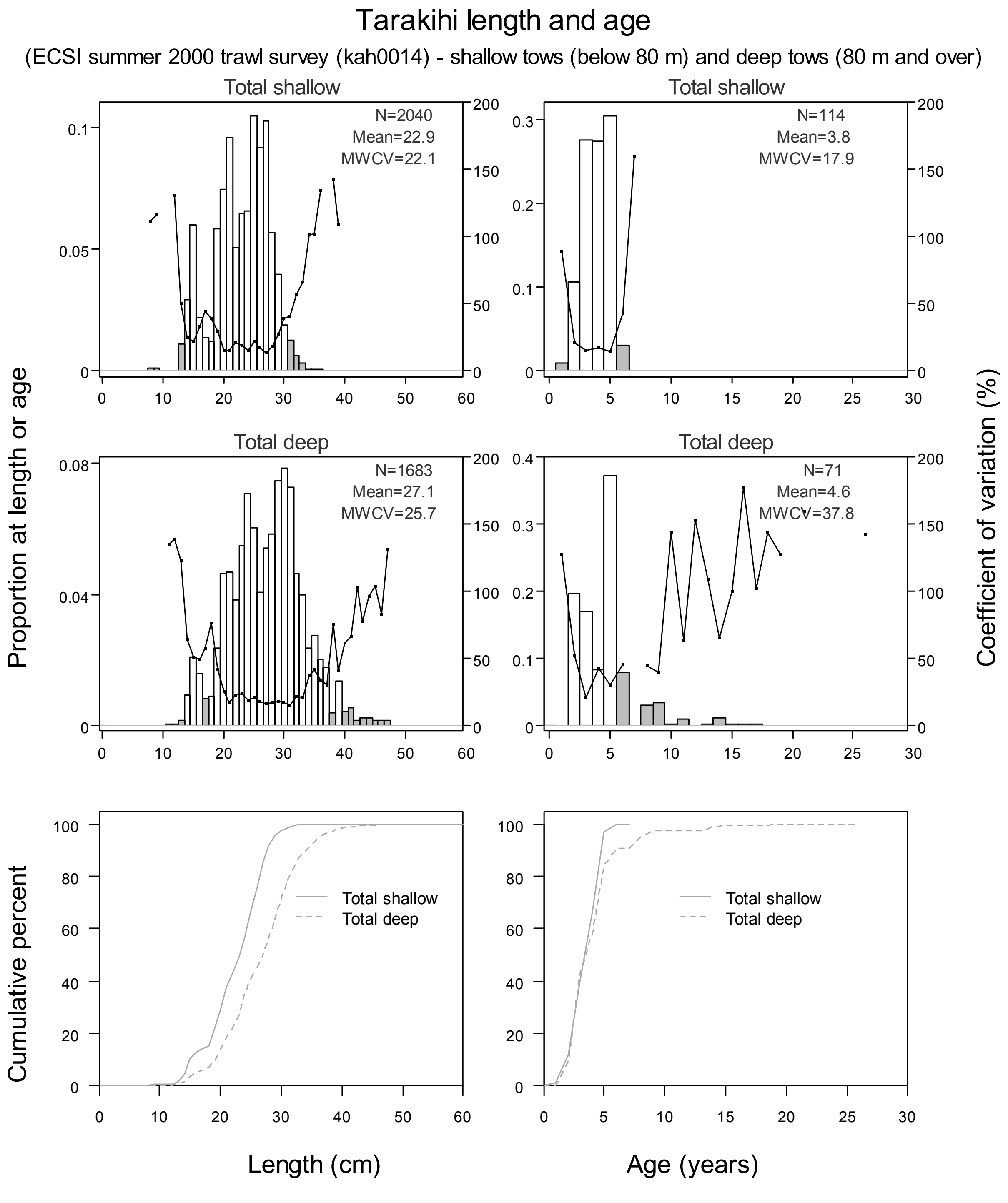

Figure 7 – ***continued***

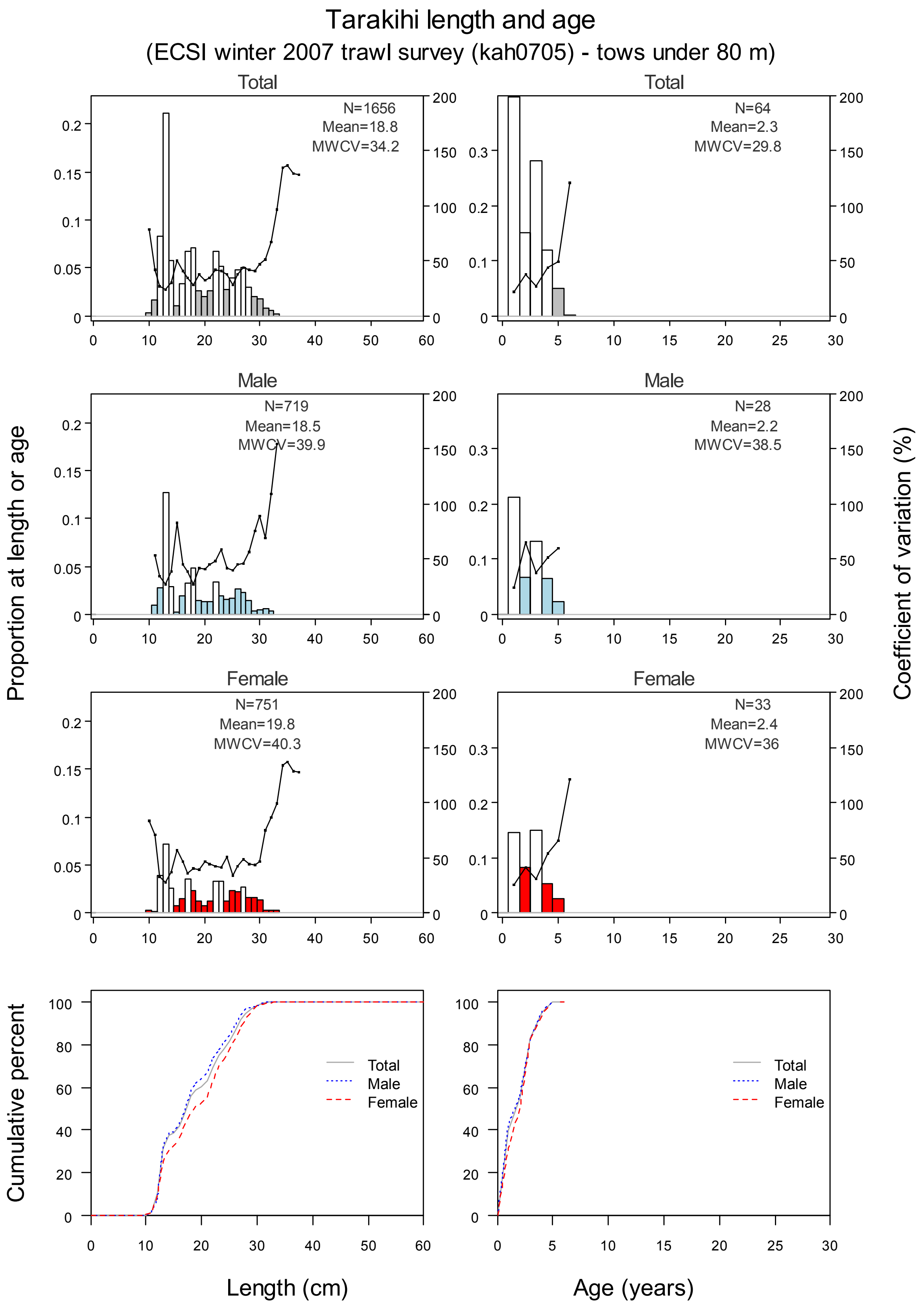

Figure 8: East coast South Island 2007 winter survey scaled length frequency, age frequency, and cumulative distributions for tarakihi from shallow tows (less than 80 m), deep tows (80 m and over), and a comparison between deep and shallow tows. ECSI, east coast South Island; N, sample size; MWCV, mean weighted coefficient of variation.

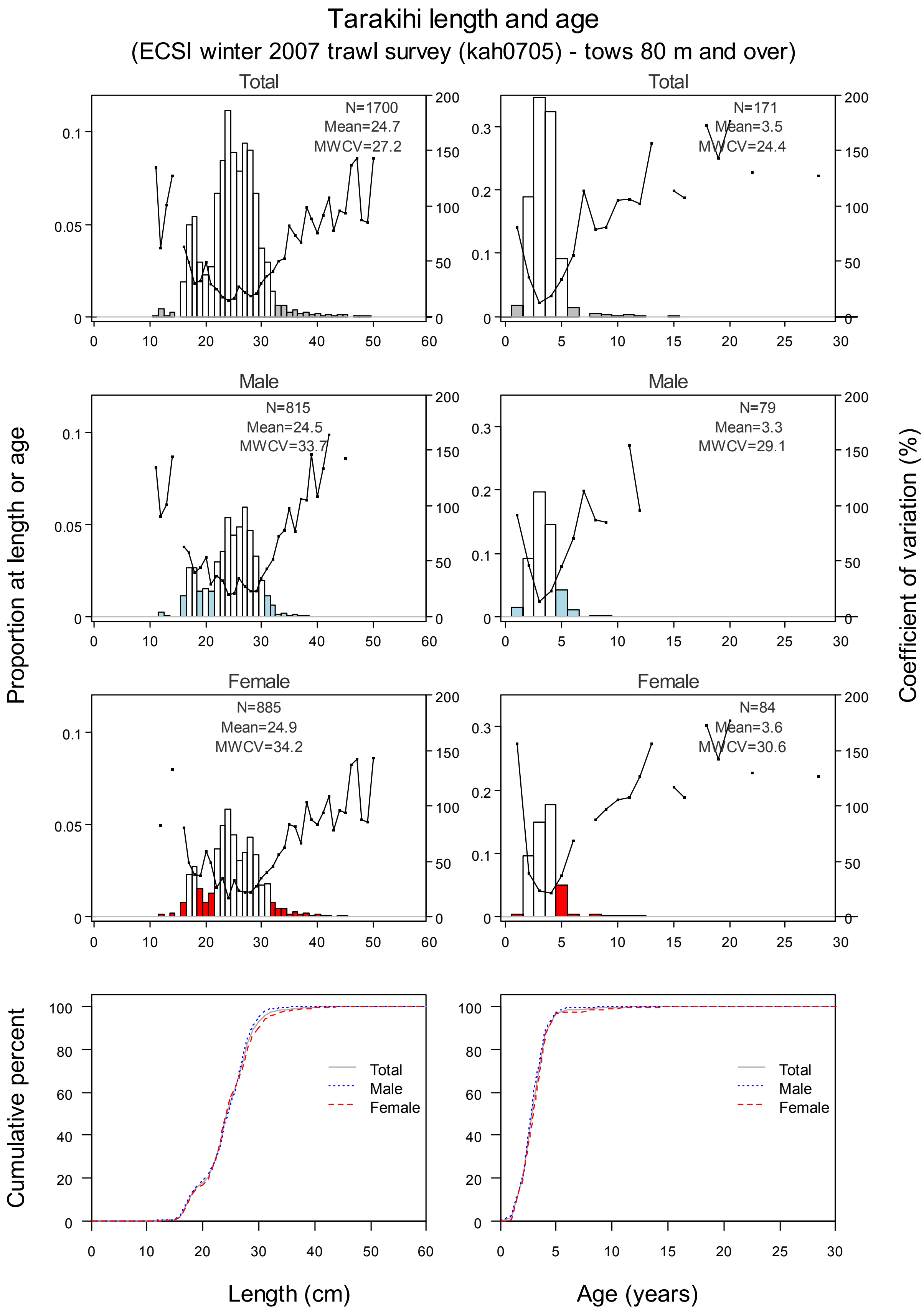

Figure 8 – ***continued***

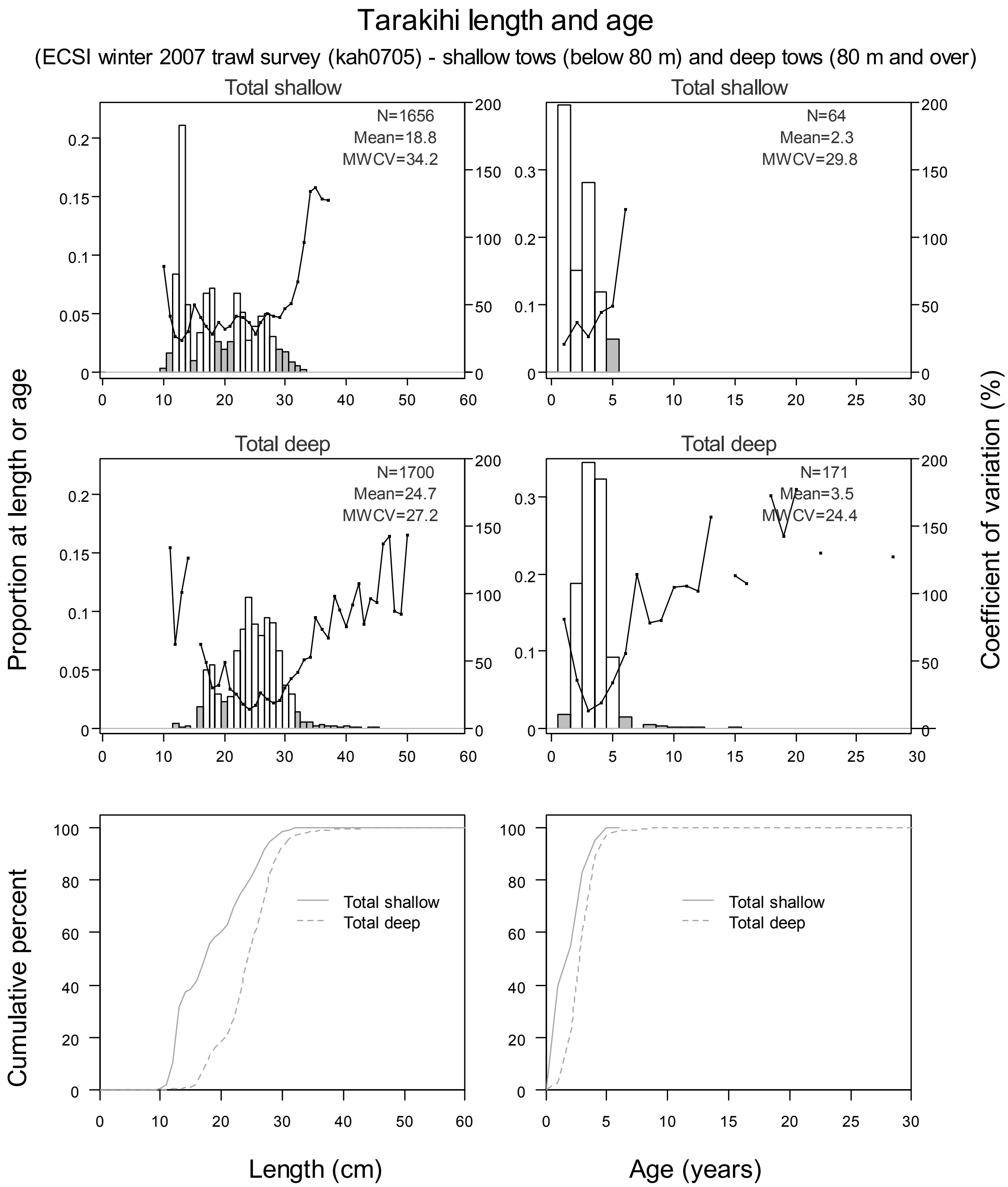

Figure 8 – *continued*

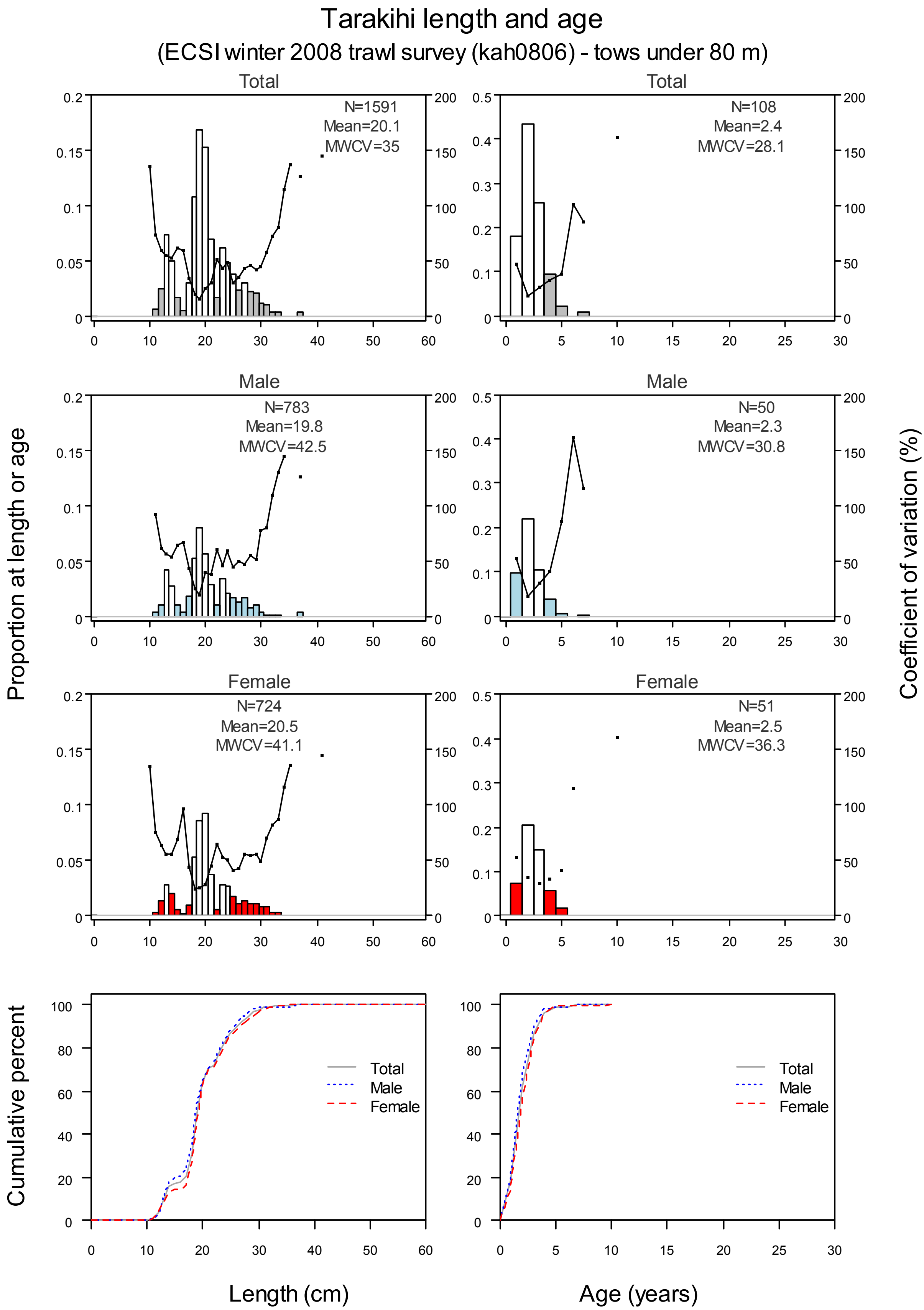

Figure 9: East coast South Island 2008 winter survey scaled length frequency, age frequency, and cumulative distributions for tarakihi from shallow tows (less than 80 m), deep tows (80 m and over), and a comparison between deep and shallow tows. ECSI, east coast South Island; N, sample size; MWCV, mean weighted coefficient of variation.

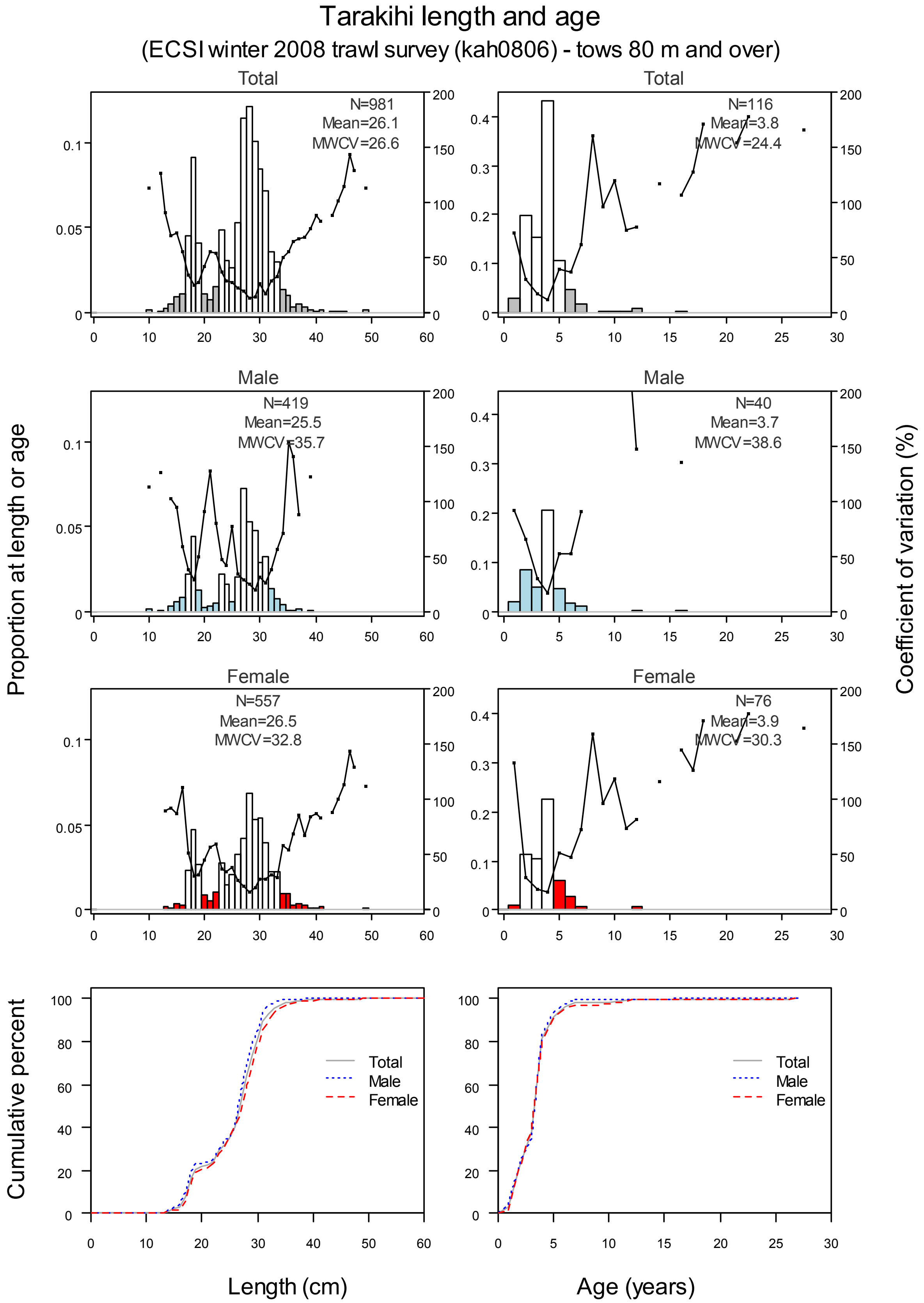

Figure 9 – *continued*

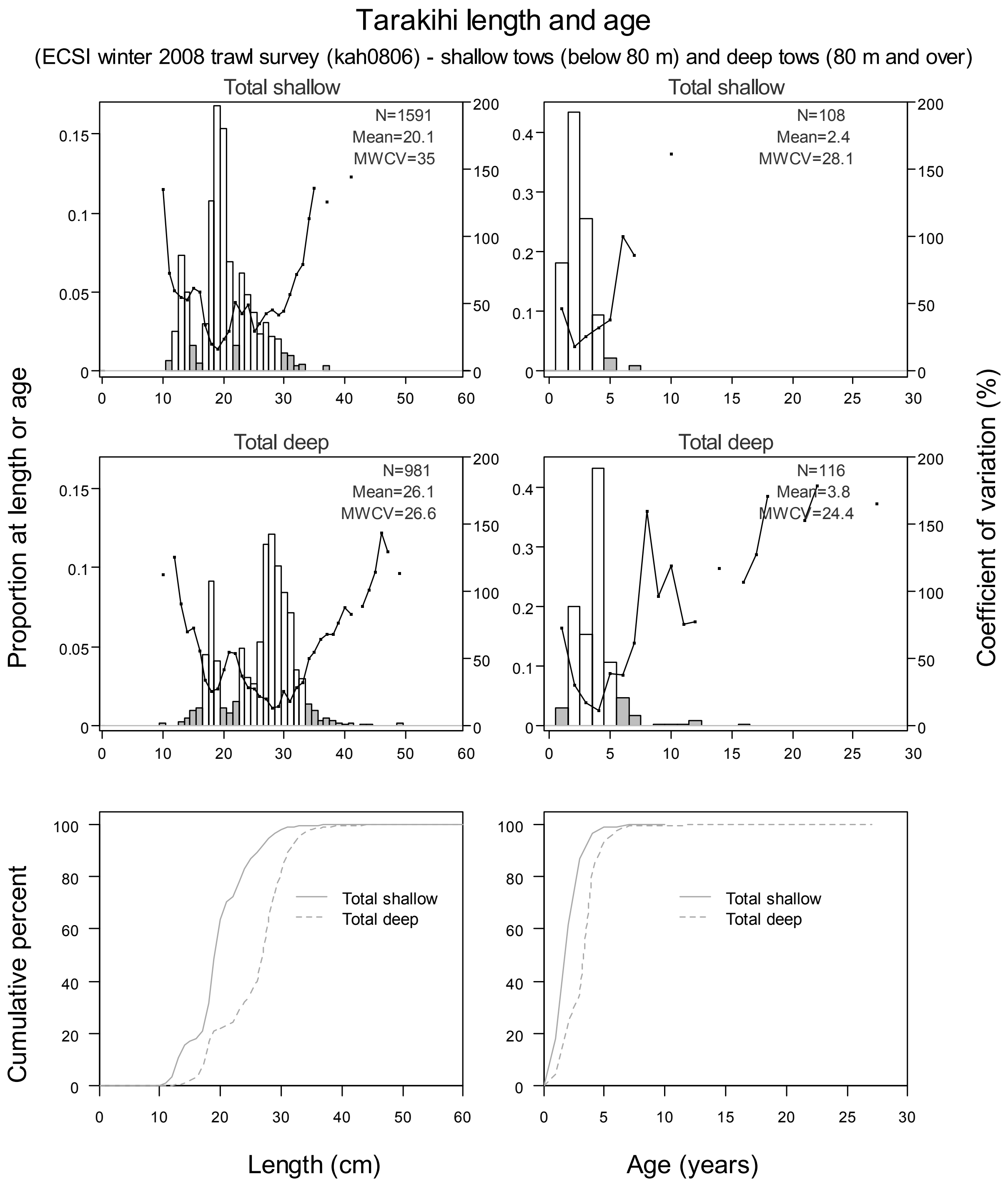

Figure 9 – ***continued***

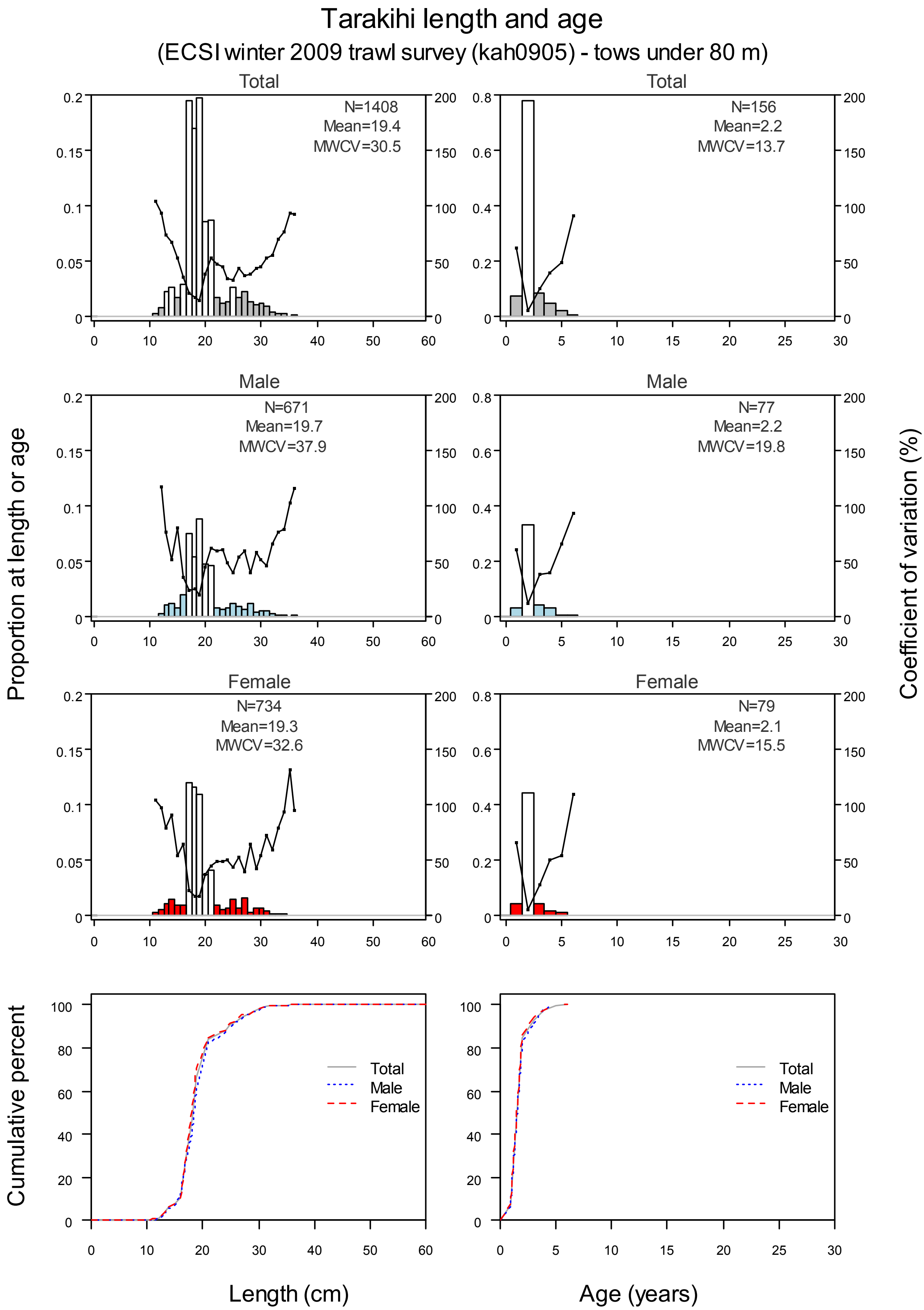

Figure 10: East coast South Island 2009 winter survey scaled length frequency, age frequency, and cumulative distributions for tarakihi from shallow tows (less than 80 m), deep tows (80 m and over), and a comparison between deep and shallow tows. ECSI, east coast South Island; N, sample size; MWCV, mean weighted coefficient of variation.

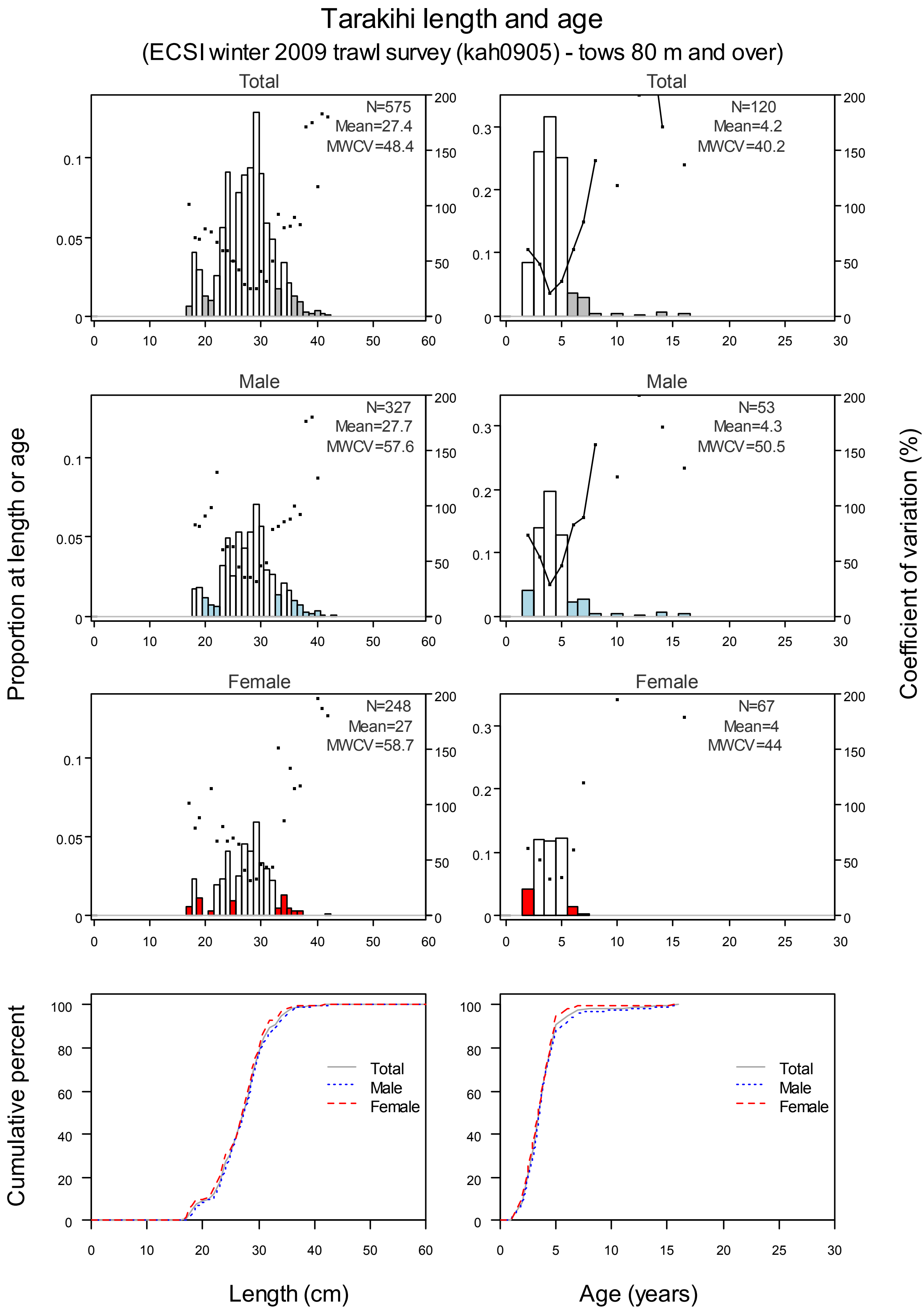

Figure 10 – *continued*

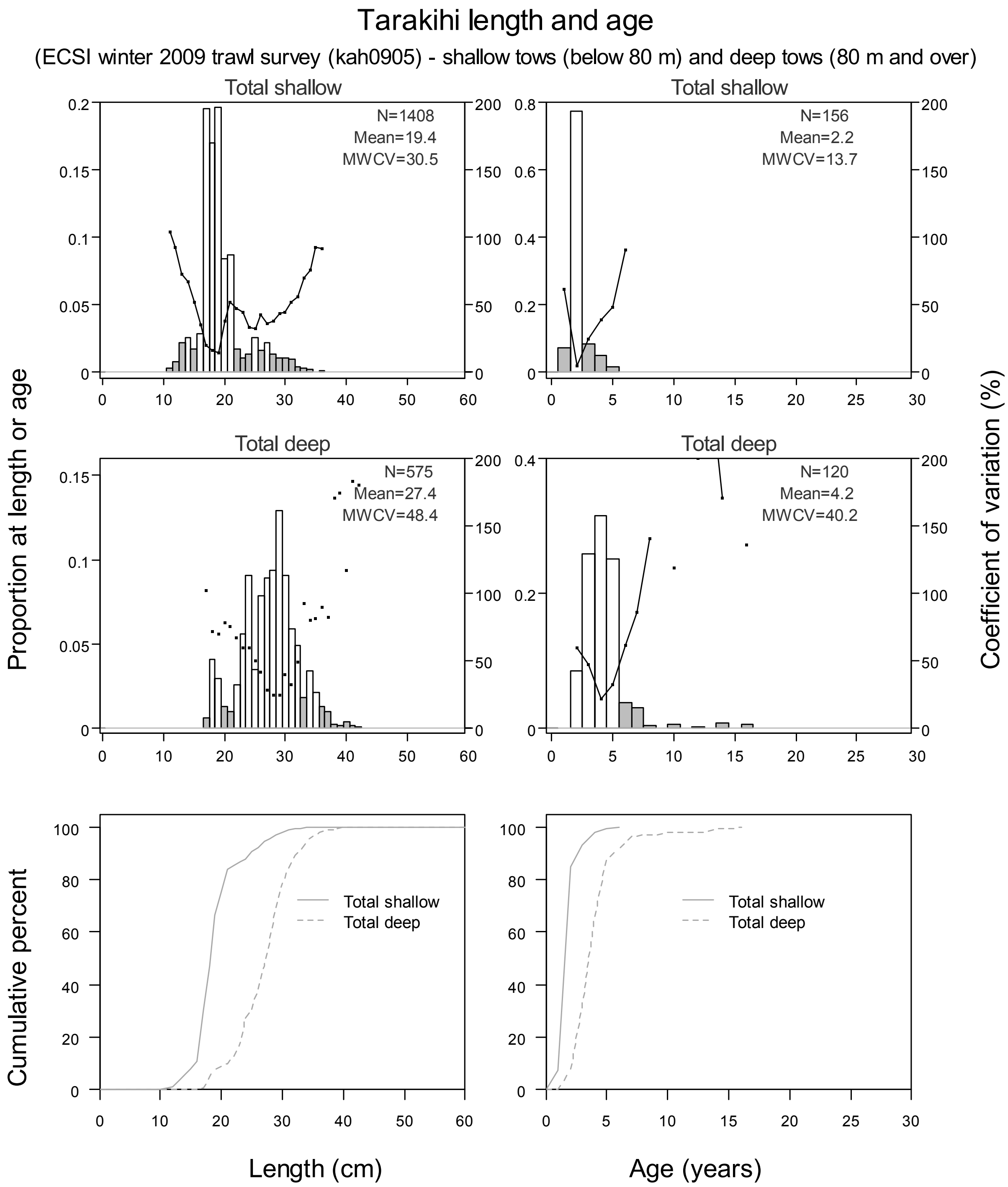

Figure 10 – *continued*

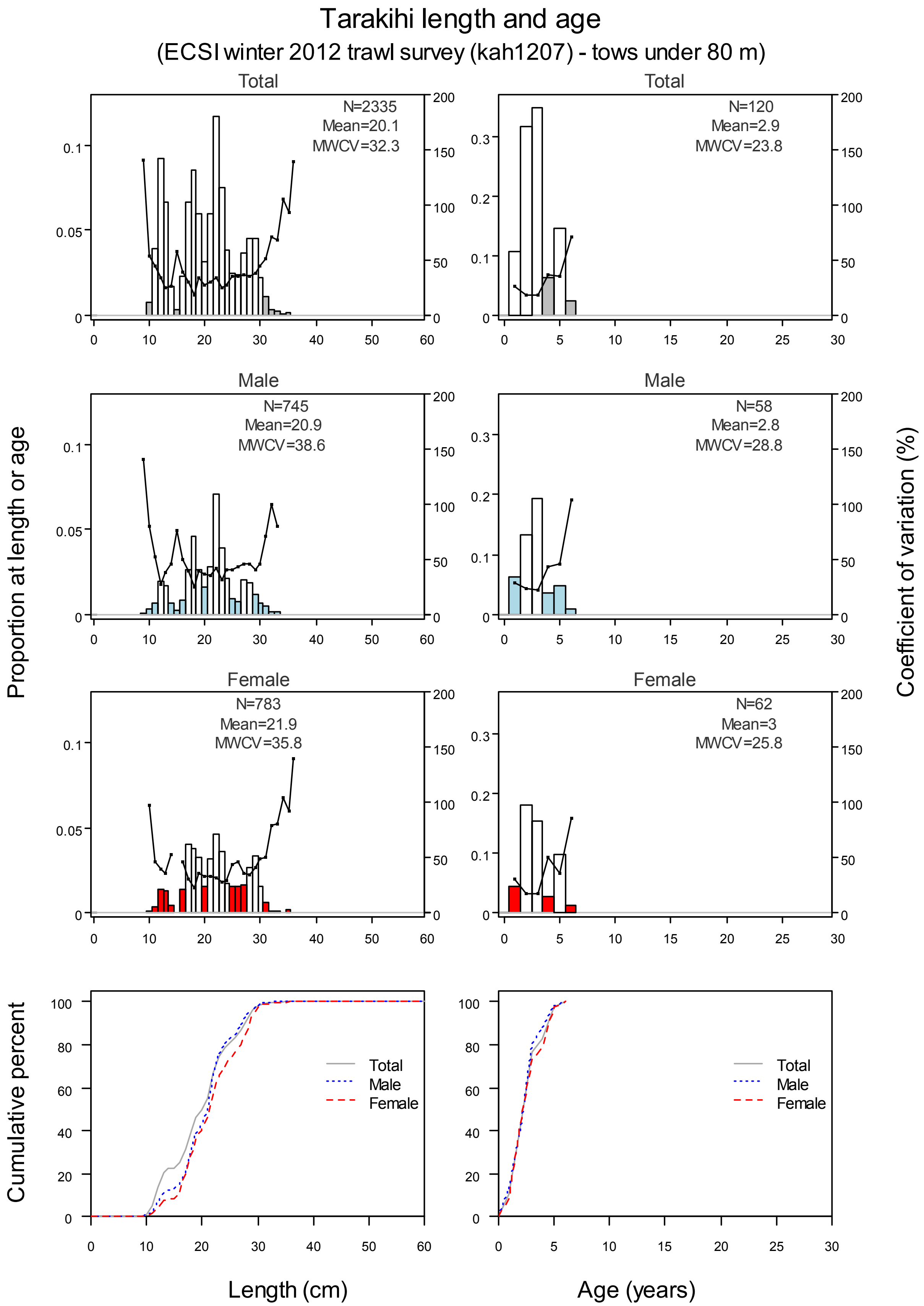

Figure 11: East coast South Island 2012 winter survey scaled length frequency, age frequency, and cumulative distributions for tarakihi from shallow tows (less than 80 m), deep tows (80 m and over), and a comparison between deep and shallow tows. ECSI, east coast South Island; N, sample size; MWCV, mean weighted coefficient of variation.

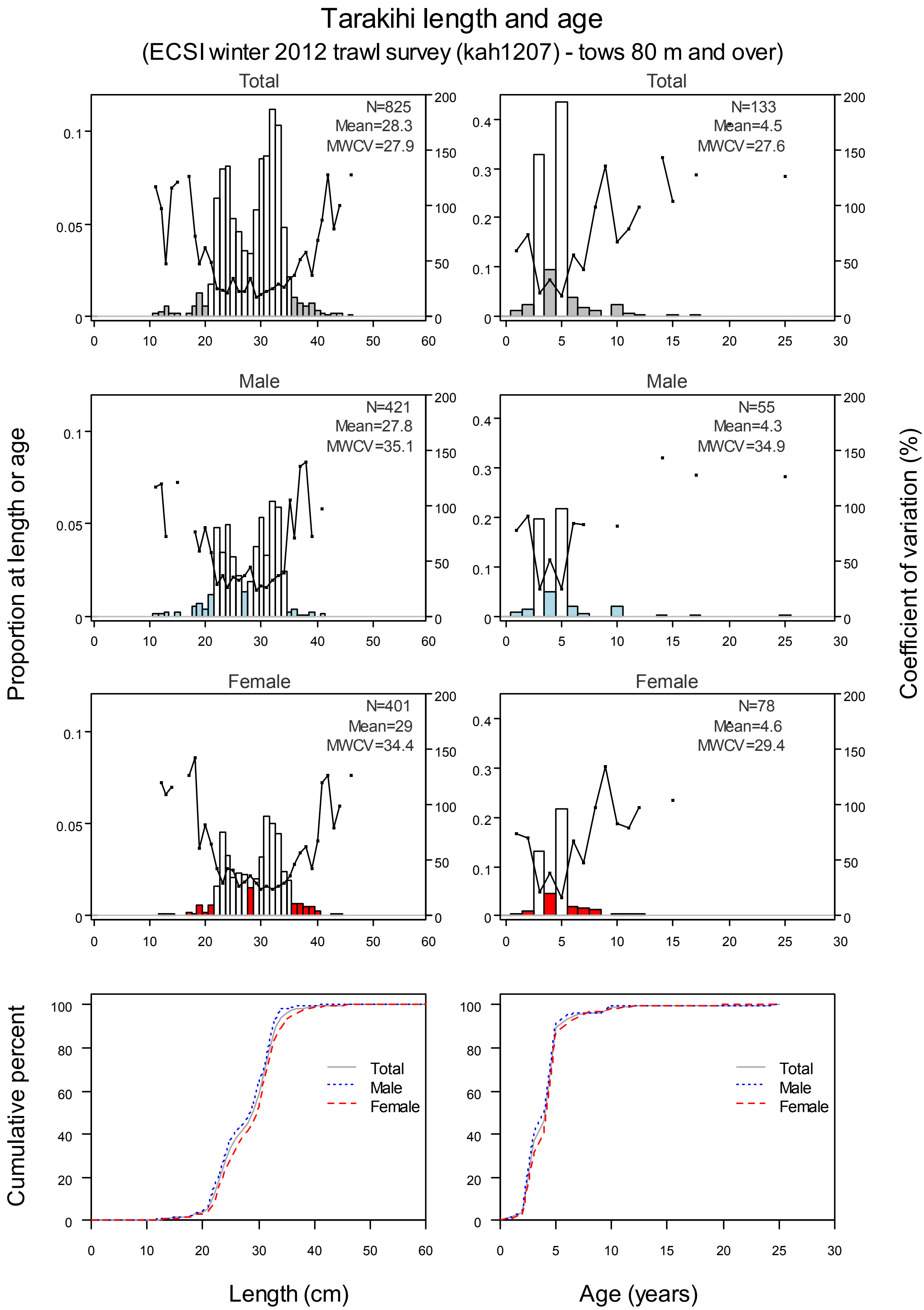

Figure 11 – ***continued***

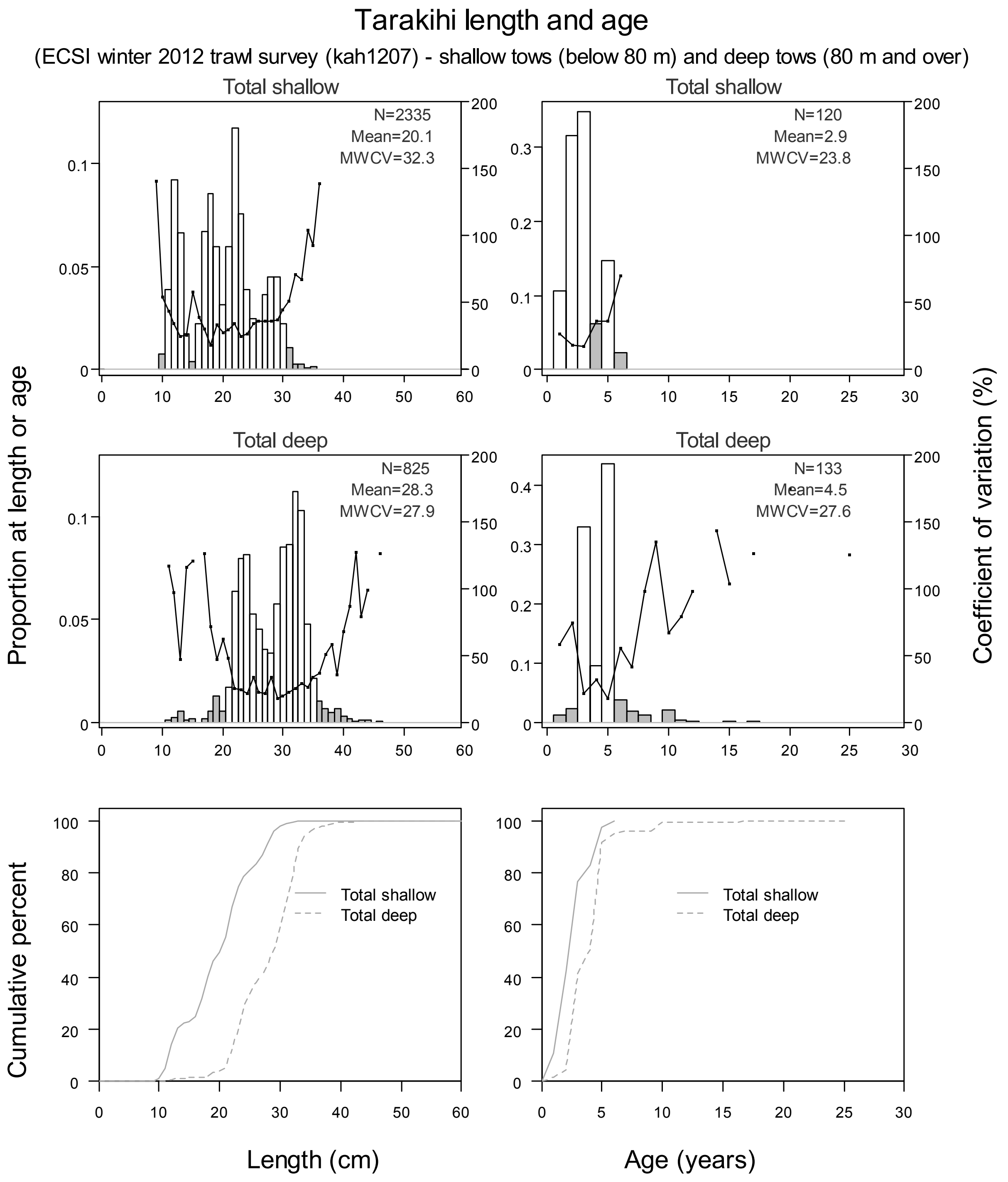

Figure 11 – *continued*

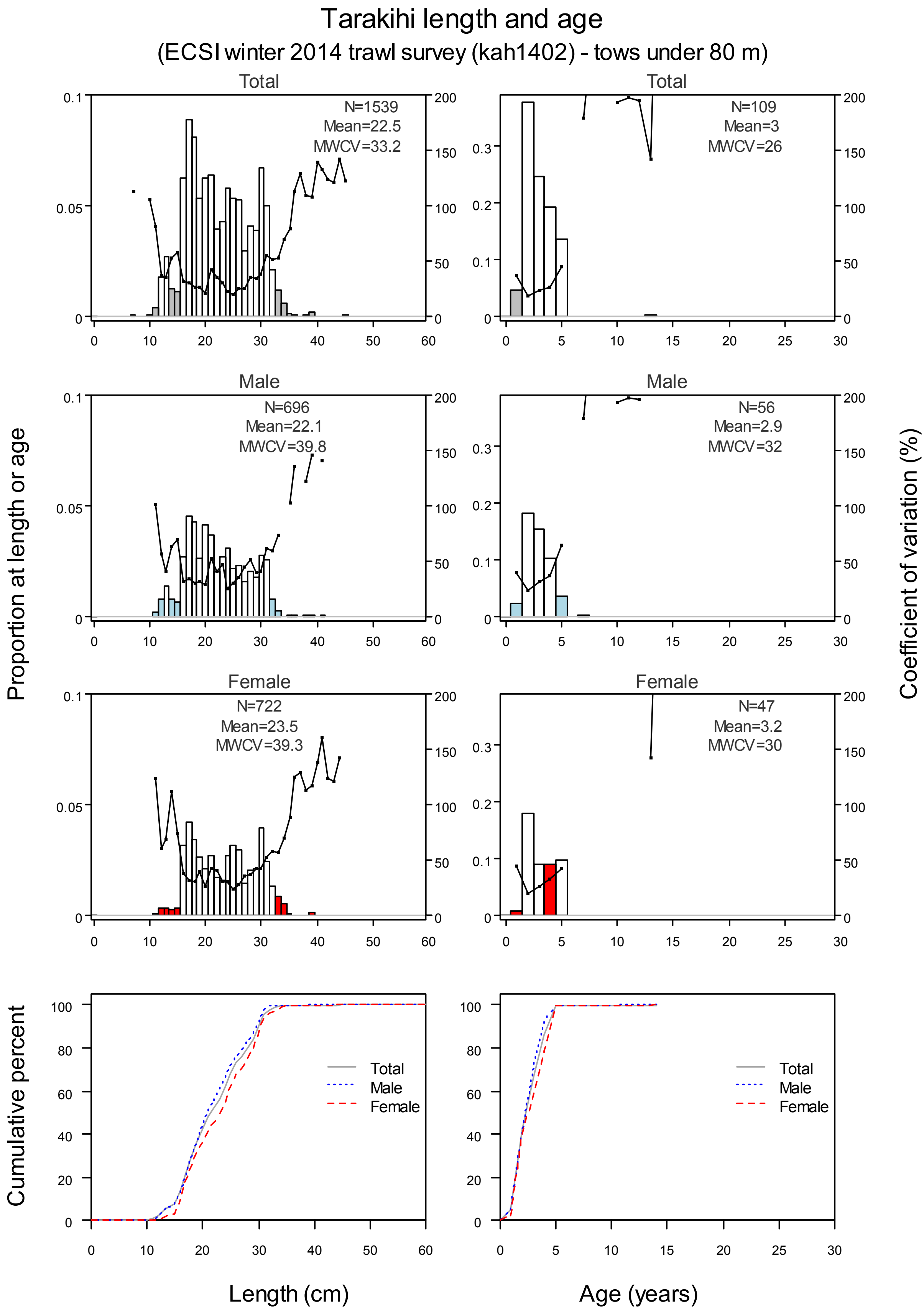

Figure 12: East coast South Island 2014 winter survey scaled length frequency, age frequency, and cumulative distributions for tarakihi from shallow tows (less than 80 m), deep tows (80 m and over), and a comparison between deep and shallow tows. ECSI, east coast South Island; N, sample size; MWCV, mean weighted coefficient of variation.

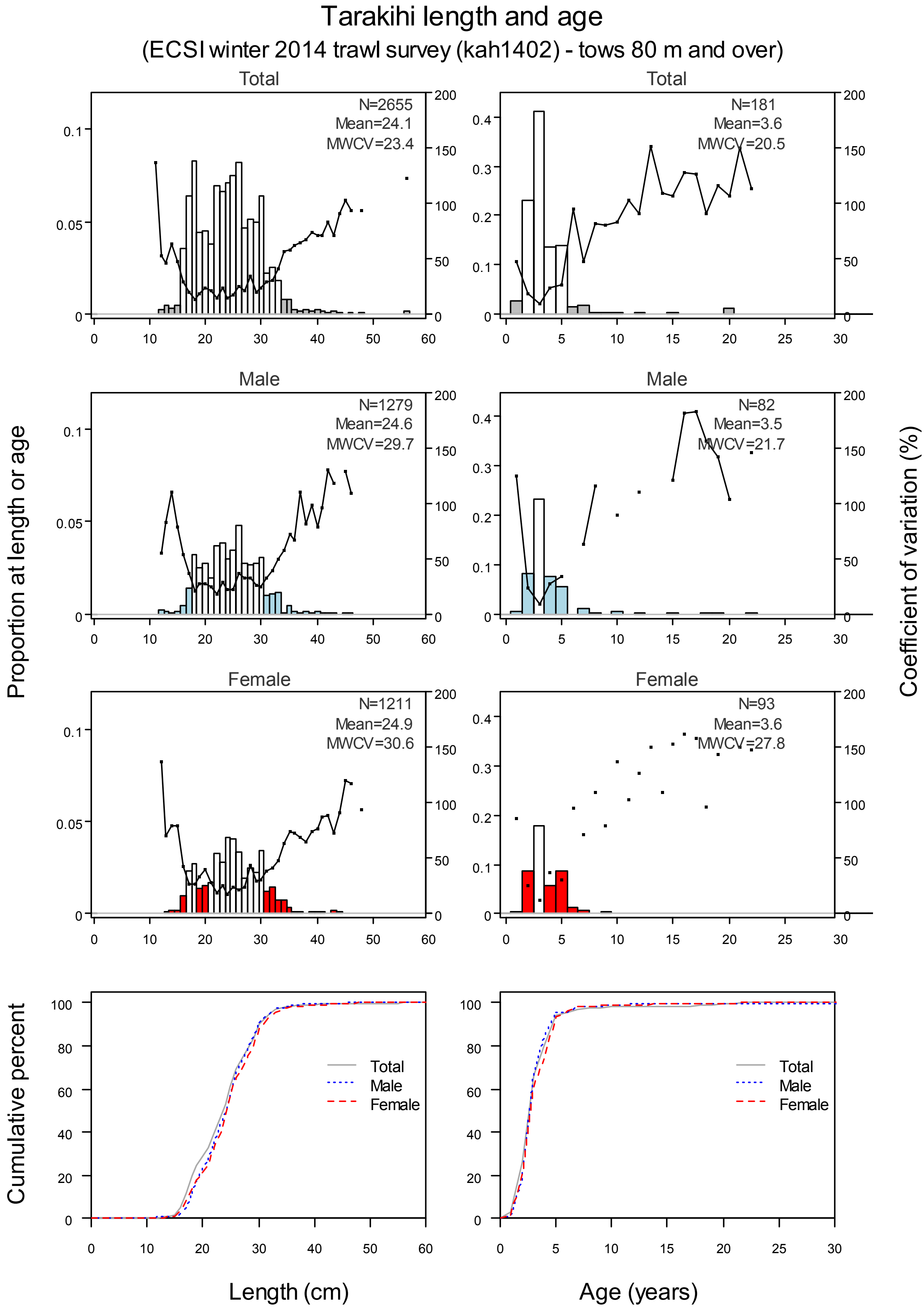

Figure 12 – *continued*

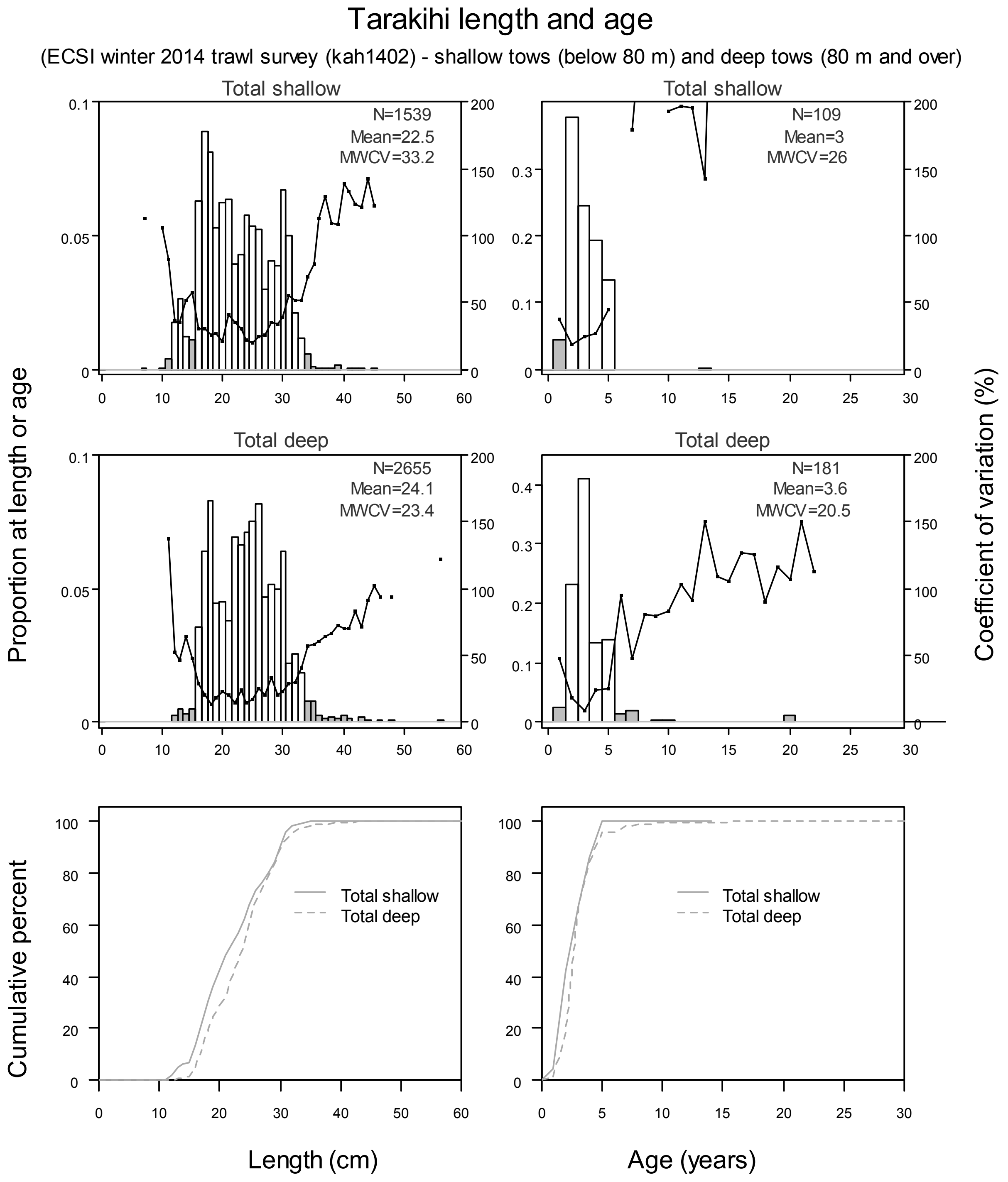

Figure 12 – ***continued***

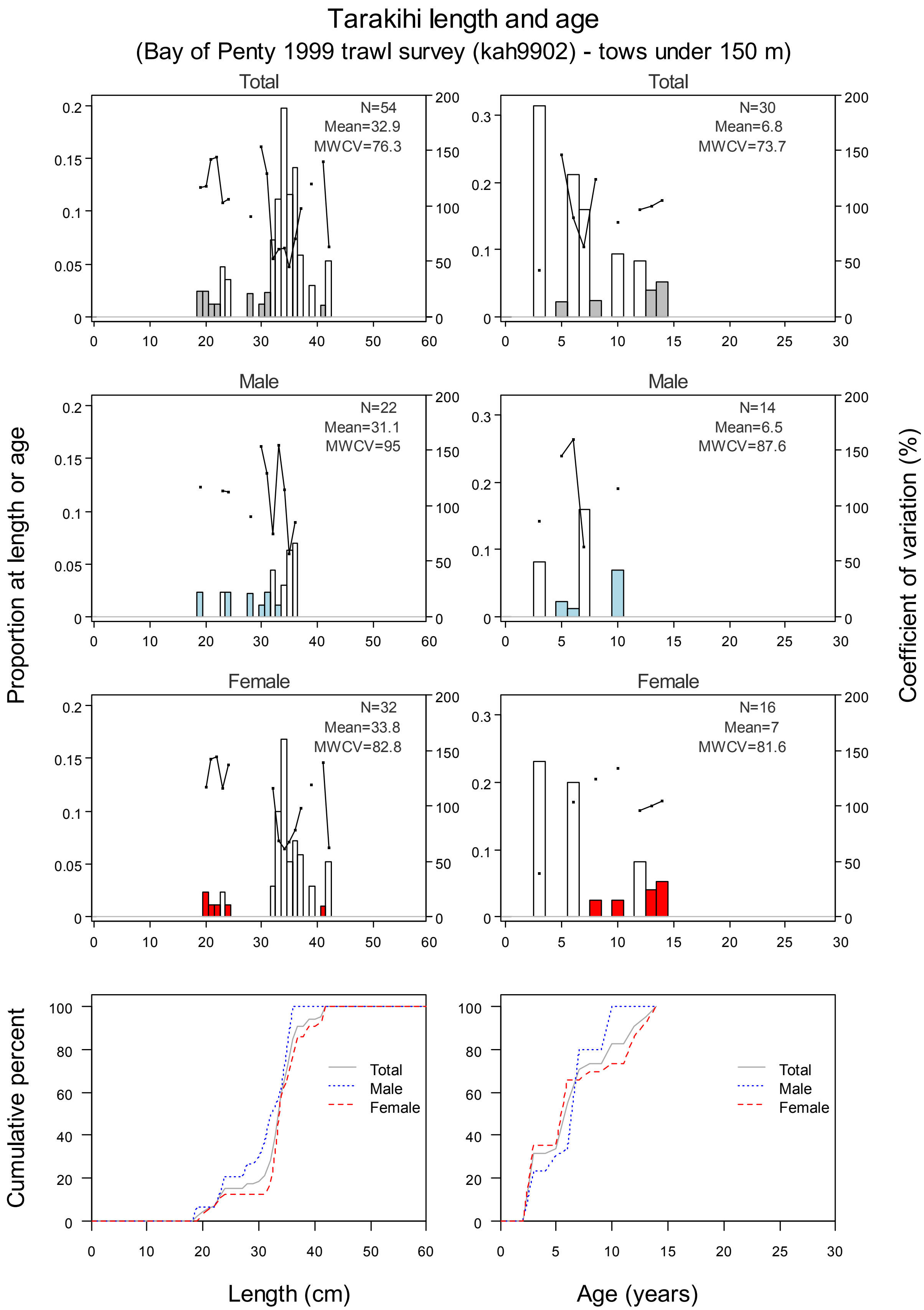

Figure 13: Bay of Plenty 1999 summer survey scaled length frequency, age frequency, and cumulative distributions for tarakihi from shallow tows (less than 150 m), deep tows (150 m and over), and a comparison between deep and shallow tows. N, sample size; MWCV, mean weighted coefficient of variation.

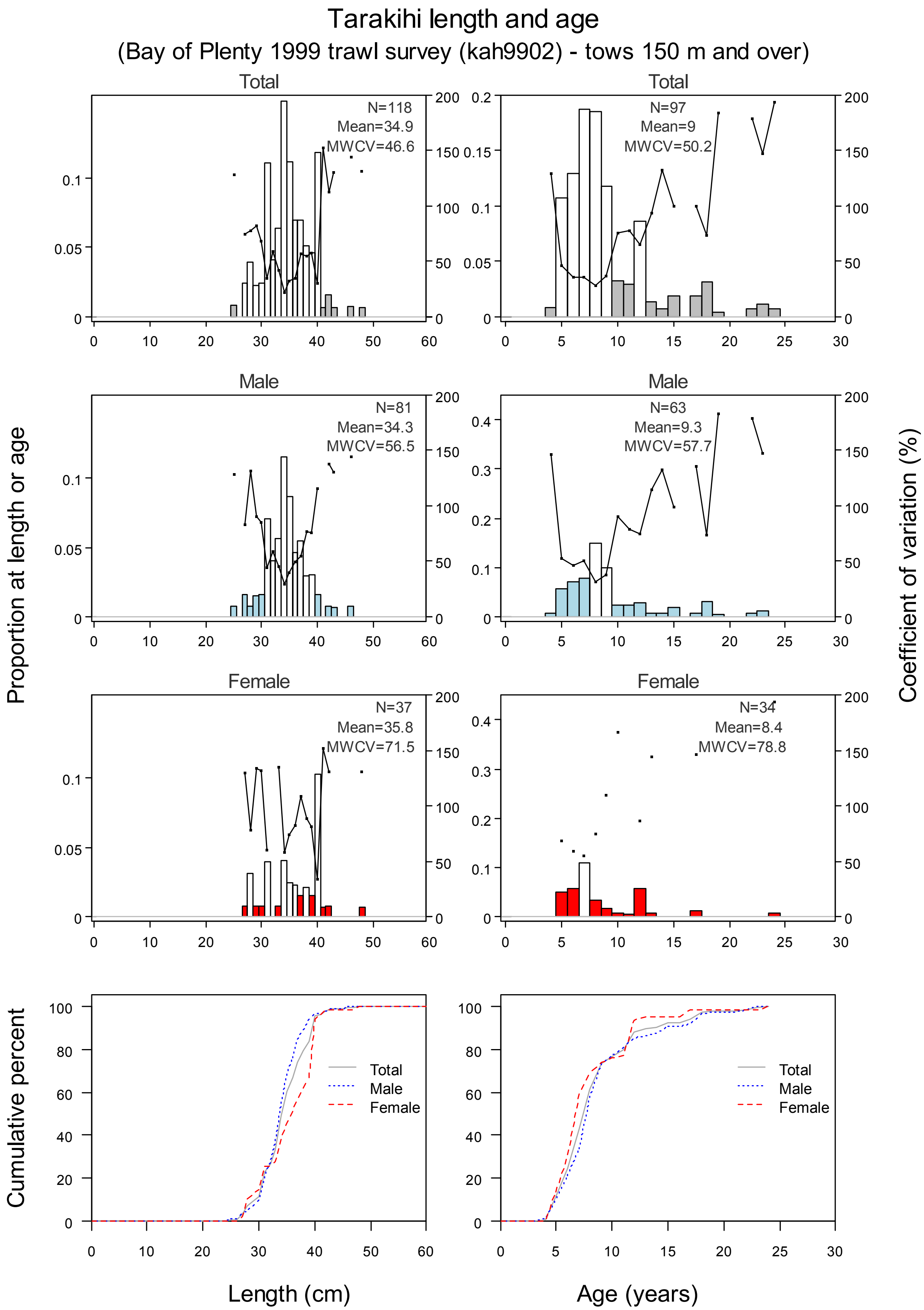

Figure 13 – ***continued***

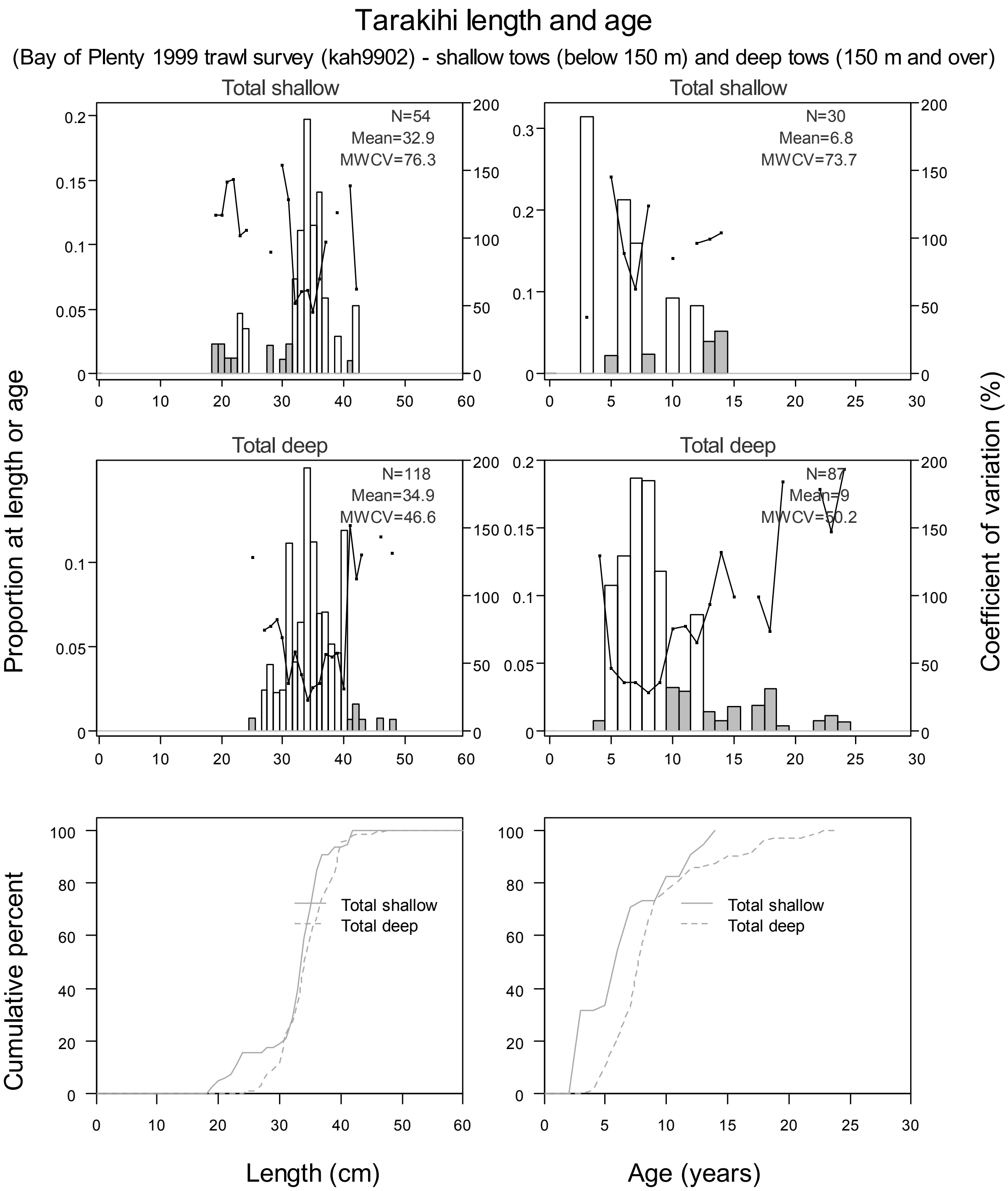

Figure 13 – ***continued***

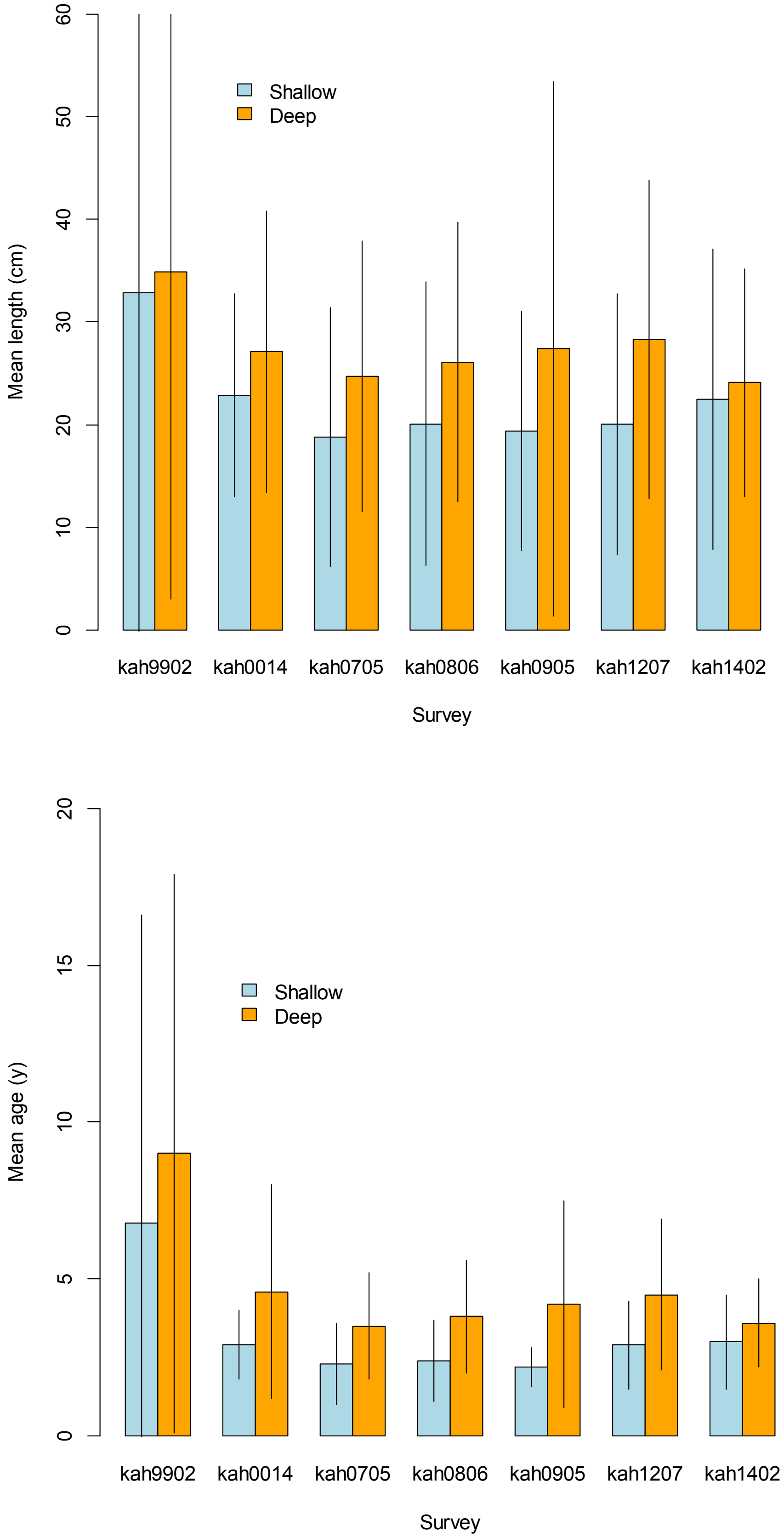

Figure 14: Mean length (top) and age (bottom) of tarakihi from deep and shallow tows for seven trawl surveys. For ECSI surveys (2000 to 2014), shallow is less than 80 m and deep is 80 m and over, whereas for the Bay of Plenty survey (1999) shallow is less than 150 m and deep is 150 m and over. Error bars are 95% confidence intervals.

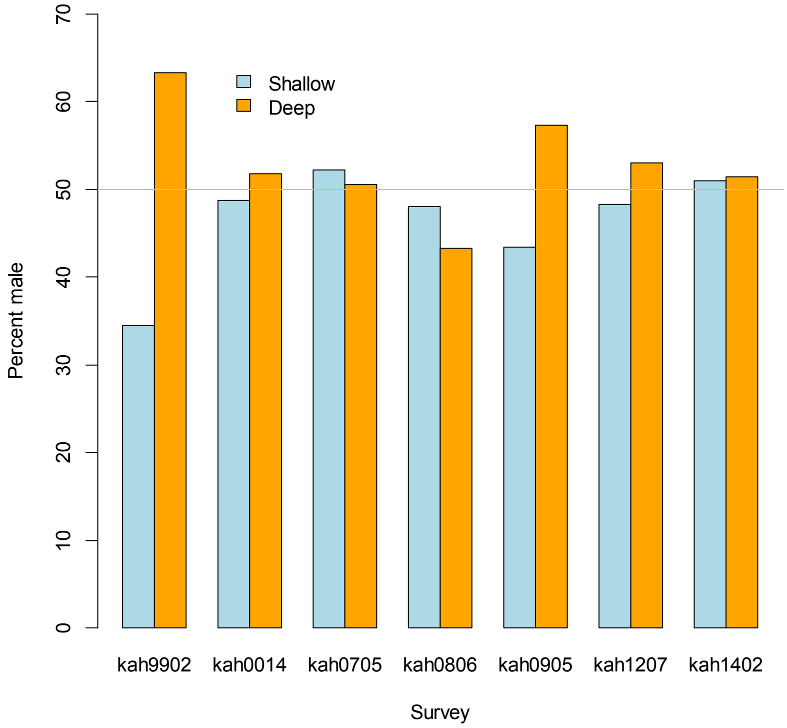

Figure 15: Sex ratio (percent male) tarakihi from deep and shallow tows for seven trawl surveys. For ECSI surveys (2000 to 2014), shallow is less than 80 m and deep is 80 m and over, whereas for the Bay of Plenty survey (1999) shallow is less than 150 m and deep is 150 m and over. The horizontal lines indicates a 1:1 ratio. Error bars are 95% confidence intervals.

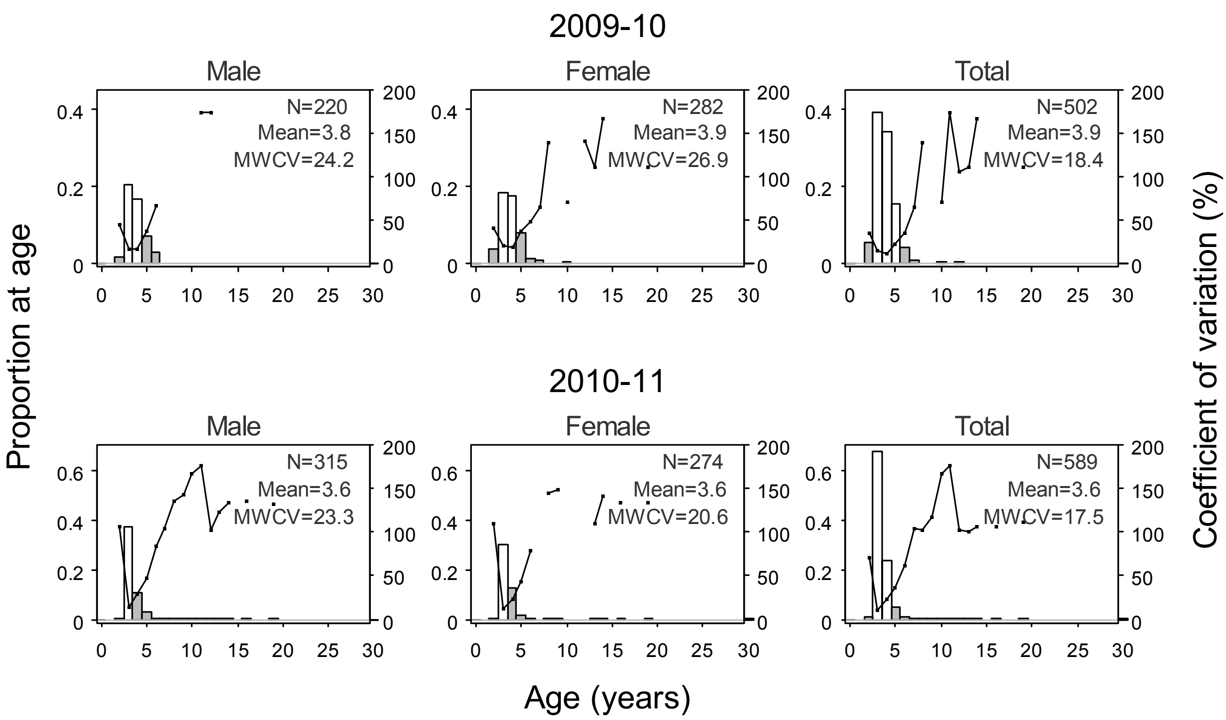

Figure 16: Tarakihi scaled age composition from the 2009–10 and 2010–11 commercial catch sampling of TAR 3 bottom trawl fishery (from Beentjes et al. 2012). n, sample size; CV, mean weighted coefficient of variation.

Figure 17: Tarakihi scaled age composition from the 2010–11 commercial catch sampling of TAR 1 Bay of Plenty bottom trawl fishery (from Beentjes et al. 2012). n, sample size; mwcv, mean weighted coefficient of variation.

Appendix 1: Prorated areas of ECSI trawl survey strata 1 to 7 (30 to 100 m) used for scaling length data in catch at age analyses. (see Figure 1).

			Area (km^2)
Strata	Total	less than 80 m	80 m and over
1	984	836	148
2	1 243	932	311
3	3 005	2 254	751
4	2 709	2 167	542
5	2 488	1 493	995
6	2 372	1 898	474
7	2 084	625	1 459