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Estimation of release survival of pelagic sharks and fish in New Zealand commercial fisheries

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Plain language summary

This project estimated survival of six pelagic species (southern bluefin tuna, Pacific bluefin tuna, swordfish, blue shark, mako shark, and porbeagle shark) following release from commercial fishing gear to inform a government review of their landing exceptions.

Fishery characterisations revealed that the main fishing gears responsible for discarded fish were surface longline (all species) and trawl (swordfish, mako, and porbeagle).

Literature reviews were conducted to document current knowledge on the status of an individual when brought to the vessel and 'post-release' survival (i.e., survival in the weeks to months following release) from these fishing gears, as well as the factors that affect survival of each species. The key results were:

- Bluefin tunas (including southern bluefin tuna and Pacific bluefin tuna) and swordfish typically have high post-release survival following capture by surface longline, with most studies reporting survival rates of 88% or greater for bluefin tunas and 50–88% for swordfish.
- Blue shark have high at-vessel and post-release survival following capture by surface longline, with most studies reporting at-vessel and post-release survival rates of > 80%.
- Mako have moderate to high at-vessel and post-release survival following capture by surface longline, with most studies reporting at-vessel and post-release survival rates ranging from about 50–87% and 56–94%, respectively.
- Porbeagle have moderate to high at-vessel survival and variable post-release survival following capture by surface longline, with estimates of 56–79% and 25–90% for at-vessel and post-release survival, respectively.
- There have been no comparable studies documenting at-vessel or post-release survival of swordfish, mako, or porbeagle from trawl.

A questionnaire was developed and circulated to fishers, fishery observers, and scientists with knowledge of each species to obtain their estimates of at-release survival (i.e., the probability the fish/shark was alive when put back into water), post-release survival, and combined survival (the probability an individual was both alive at release and survived following release) of the three shark species, and post-release survival of the thee fish species (in accordance with their current landing exceptions).

Questionnaire responses were used to derive survival probability range estimates for each species, with separate analyses conducted that included and excluded information from the literature.

For individuals released after capture by surface longline, the results of this analysis indicated post-release survival for southern bluefin tuna, Pacific bluefin tuna, and swordfish is likely to be high; blue shark are likely to have high at-release and post-release survival, and a medium-high combined survival; mako are likely to have medium at-release and medium-high post-release survival (reduced to medium if excluding information from the literature in the analysis), and low-medium combined survival; and porbeagle are likely to have low at-release survival, low-medium post-release survival, and low combined survival.

Post-release survival of swordfish released from trawl gear was likely to be low, and mako and porbeagle caught by trawl were likely to have low at-release, post-release, and combined survival.

These results, however, resulted from a small number of survey responses (only one respondent for trawl gear) and often without any comparable supporting published studies.

Survival probability estimates presented here should thus be interpreted with caution.

EXECUTIVE SUMMARY

Moore, B.R.[1]; Finucci, B.[1] (2024). Estimation of release survival of pelagic sharks and fish in New Zealand commercial fisheries.

***New Zealand Fisheries Assessment Report 2024/07.* 129 p.**

Under the New Zealand Fisheries Act 1996, commercial fishers are prohibited from returning or abandoning to the sea, or other waters, any fish or other animal that is aquatic life that are subject to the Quota Management System (QMS). However, there are exceptions to this rule. Under Section 72A of the Fisheries Act 1996, the Minister for Oceans and Fisheries may permit or require a stock or species managed under the QMS to be returned or abandoned to the sea if they are satisfied the return meets one of the provisions under section 72A(2) (termed 'landing exceptions' herein). Currently, landing exceptions are permitted for several pelagic fish and shark species, namely southern bluefin tuna (*Thunnus maccoyii*), swordfish (*Xiphias gladius*), blue shark (*Prionace glauca*), mako shark (*Isurus oxyrinchus*), and porbeagle shark (*Lamna nasus*). The landing exceptions vary among species; for example, southern bluefin tuna and swordfish can only be released if likely to survive and releases are made as soon as practical[2], while blue, mako, and porbeagle sharks can be released alive or dead. The objective of this study was to estimate the proportion that survive release for the species listed above, to inform a review of their current landing exceptions. An additional objective was to estimate post-release survival of Pacific bluefin tuna (*Thunnus orientalis*), which does not currently have landing exceptions.

Fishery characterisations were undertaken to understand the fishing methods and operational characteristics responsible for disposals of the six species. These analyses indicated that most disposals of southern bluefin tuna, Pacific bluefin tuna, and blue shark derive from surface longline fisheries. For swordfish, mako, and porbeagle, a substantial proportion of disposals derive from trawl fisheries, in addition to surface longline. A literature review was then undertaken to document current knowledge on at-vessel (i.e., the probability that a fish/shark is alive when released) and post-release (i.e., the probability of a fish/shark surviving after release) survival of each species from these fishing methods. Results from this review indicated survival varied by species, with reported post-release survival estimates typically higher than 80% for bluefin tunas and between 50% and 88% for swordfish, and at-vessel and post-release survival rates of > 80% for blue shark, 50–87% and 56–94% for mako, and 56–79% and 25–90% for porbeagle. No comparable studies documenting at-vessel or post-release survival of swordfish, mako, or porbeagle from trawl were identified.

An online questionnaire was developed and sent to fishers and fishery observers experienced with these species in New Zealand's fisheries as well as domestic and international scientists experienced with the six species. The questionnaire was based on key findings from the fishery characterisations and literature reviews and was structured into 'at-release' and 'post-release' survival components. Respondents were invited to provide a survival probability range for each species-method-factor-category (e.g., swordfish-surface longline-soak time->18 hours) that they had knowledge of.

Questionnaire responses were then used to derive expected survival probability ranges (90% confidence intervals) for each species-method-factor-category using a Monte Carlo parametric bootstrap approach. For the three shark species, separate analyses were conducted to derive estimates of at-release survival only, post-release survival only, and at-release and post-release survival combined. For the three pelagic fish species, it was assumed that all released individuals were alive at the time of release, in accordance with current landing exceptions. Survival estimates from the literature, where suitable, were used to bound the expected survival probability estimates. An overall 90% survival probability range estimate

[1] National Institute of Water and Atmospheric Research Ltd (NIWA), New Zealand.
[2] For swordfish, there is an additional provision that a released individual has a lower jaw to fork length of less than 1.25 m.

for each species-method-factor combination was computed, with each factor-category weighted proportionally to its occurrence in the fishery in the last three years.

Results from this analysis estimated that post-release survival probabilities for southern bluefin tuna, Pacific bluefin tuna, and swordfish following release after capture by surface longline are likely to be high. Post-release survival of swordfish from trawl was estimated to be low. Blue shark caught by surface longline were estimated to have high at-release and post-release survival probabilities, and medium-high combined survival probability. Mako caught by surface longline were estimated to have medium at-release and medium-high post-release survival probabilities (the latter being estimated as medium if not using information derived from the literature) and a low-medium combined survival probability, while porbeagle were estimated to have low at-release survival probability, medium-low post-release survival probability, and low combined survival probability. Both mako and porbeagle caught by trawl were estimated to have low at-release, post-release, and combined survival probabilities. These results, however, were derived from a small number of survey responses (e.g., for post-release survival, there were no more than five respondents for any question, and typically only one respondent for trawl gear), and often without any supporting published studies. As such, survival estimates presented here should be interpreted with caution.

The holistic approach taken here highlighted several areas of further research needed to better quantify at-vessel condition and post-release survival of the six focal species, including *inter alia*: increased data collection for pelagic sharks caught in surface longline and trawl fisheries; improved quantification of soak time; increased electronic tagging to better quantify post-release survival; continued research to improve handling and release practices; and continued research to minimise pelagic shark bycatch.

1. INTRODUCTION

Post-release survival, or the long-term survival after capture and release from fishing gear, is an important component of fisheries management. Mortality that occurs after the release of a live fish is often unaccounted for and can be a significant source of cryptic fishing mortality, especially for species subject to high discard or low post-release survival rates (Davis 2002, Carruthers et al. 2009, Muir et al. 2022). Quantifying post-release survival is therefore critical to estimating overall fishing mortality. Understanding rates of post-release survival for a given species, and how these vary by fishing method, fishing operation (e.g., depth), and other factors (e.g., environmental conditions) is a particularly important consideration when developing fisheries management initiatives that allow for discarding (Molina & Cooke 2012, Hutchinson et al. 2021).

Under the New Zealand Fisheries Act 1996, commercial fishers are prohibited from returning or abandoning to the sea, or other waters, any fish or other animal that is aquatic life that are subject to the Quota Management System (QMS). However, there are exceptions to this rule (hereafter termed 'landing exceptions'). Under the Fisheries (landing and discard exception) notice, issued under Section 72A of the New Zealand Fisheries Act 1996, the Minister for Oceans and Fisheries may:

a) Permit a stock or species to be returned or abandoned if they are satisfied the stock or species has an acceptable likelihood of survival if returned or abandoned in the manner specified, or
b) Permit the stock or species to be returned or abandoned if they are satisfied that the stock or species:
    i) would damage other stocks or species taken by the commercial fisher if retained (for example, an ammoniating species); or
    ii) is damaged as a result of unavoidable circumstances (for example, diseased or predated fish); or
c) Require a stock or species be returned or abandoned if they are satisfied that the return or abandonment is for a biological, a fisheries management, or an ecosystem purpose and there is an acceptable likelihood of survival if returned or abandoned in the manner specified.

Pelagic fish and shark species currently managed under the QMS that may be returned to the sea include southern bluefin tuna (*Thunnus maccoyii*), swordfish (*Xiphias gladius*), blue shark (*Prionace glauca*), mako shark (*Isurus oxyrinchus*), and porbeagle shark (*Lamna nasus*). The landing exceptions vary for each species (Table 1). These landing exceptions need to be assessed against the new exception provisions by September 2026 to determine whether they should continue, be amended, or be revoked.

This report is an output from the Fisheries New Zealand project SEA2022-09 "Estimation of release mortality for pelagic sharks and fish". The overall objective of this project was to estimate the proportion that survive release for those species listed above as well as Patagonian toothfish (*Dissostichus eleginoides*), to inform a governmental review of the current legislation concerning releases of these species. An additional objective was to estimate the post-release survival of Pacific bluefin tuna (*Thunnus orientalis*), which does not currently have landing exceptions. This work was conducted in parallel with a similar study of release survival of inshore fish and shark species (see McKenzie et al. in press).

The Specific Research Objectives were:

1. To undertake fishery characterisations to understand the main methods and operational characteristics responsible for disposals of southern bluefin tuna (*Thunnus maccoyii*), Pacific bluefin tuna (*Thunnus orientalis*), swordfish (*Xiphias gladius*), blue shark (*Prionace glauca*), mako shark (*Isurus oxyrinchus*), porbeagle shark (*Lamna nasus*), and Patagonian toothfish (*Dissostichus eleginoides*).
2. To collate available scientific literature on the release survival of southern bluefin tuna, Pacific bluefin tuna, swordfish, blue shark, mako shark, porbeagle shark, and Patagonian toothfish.
3. To convene a workshop of relevant experts to derive survival estimates for each species, according to gear type, handling behaviour, and environmental conditions, for the species listed in Objective One.

This report covers the six pelagic species (southern bluefin tuna, Pacific bluefin tuna, swordfish, blue shark, mako shark, and porbeagle shark). Patagonian toothfish are covered in a separate report (Devine & Underwood in review).

Table 1: Landing exceptions for the six species considered in this report.

Species	Scientific name	Species code	Landing exception
Southern bluefin tuna	*Thunnus maccoyii*	STN	A person who is a New Zealand national fishing against New Zealand's national allocation of southern bluefin tuna may return any southern bluefin tuna to the waters from which it was taken if— (a) that southern bluefin tuna is likely to survive on return; and (b) the return takes place as soon as practicable after the southern bluefin tuna is taken.
Pacific bluefin tuna	*Thunnus orientalis*	TOR	None
Swordfish	*Xiphias gladius*	SWO	A commercial fisher may return any swordfish to the waters from which it was taken if— (a) that swordfish is likely to survive on return; and (b) the return takes place as soon as practicable after the swordfish is taken; and (c) that swordfish has a lower jaw to fork length (LJFL) of less than 1.25 m. For the purposes of this requirement, lower jaw to fork length means the projected straight line distance from the foremost point of the lower jaw to the rear centre edge of the tail (caudal fin).
Blue shark	*Prionace glauca*	BWS	A commercial fisher may return any blue shark to the waters from which it was taken— (a) live, if the blue shark is likely to survive on return and the return takes place as soon as practicable after the blue shark was taken; or (b) dead or near-dead, if paragraph (a) does not apply. For the purposes of paragraph (b) of this requirement, near-dead means unlikely to survive on return.
Mako shark	*Isurus oxyrinchus*	MAK	A commercial fisher may return any mako shark to the waters from which it was taken— (a) live, if the mako shark is likely to survive on return and the return takes place as soon as practicable after the mako shark was taken; or (b) dead or near-dead, if paragraph (a) does not apply. For the purposes of paragraph (b) of this requirement, near-dead means unlikely to survive on return.
Porbeagle shark	*Lamna nasus*	POS	A commercial fisher may return any porbeagle shark to the waters from which it was taken— (a) live, if the porbeagle shark is likely to survive on return and the return takes place as soon as practicable after the porbeagle shark was taken; or (b) dead or near-dead, if paragraph (a) does not apply. For the purposes of paragraph (b) of this requirement, near-dead means unlikely to survive on return.

2. METHODS

2.1 Fishery characterisations

To inform the analysis, fishery characterisations were carried out for each of the six pelagic species using data from fishing years 2004–05 to 2021–22. Data extracts (landings, effort, and estimated catch files) were obtained from the Fisheries New Zealand Enterprise Data Warehouse on 4 May 2023 (replog 15040). Records containing the species codes STN (southern bluefin tuna), TOR (Pacific bluefin tuna), SWO (swordfish), BWS (blue shark), MAK (mako shark), and POS (porbeagle shark) were extracted from all landing form types.

The fishery characterisations presented here are based on three datasets. The first included all commercial catch and associated fishing effort data between 2004–05 and 2021–22, including landing and disposal (i.e., discarded or released) components (Table 2). The second dataset included only disposals and their associated fishing effort. Since the introduction of the Electronic Reporting System (ERS), it is now possible to link disposal records in the landings file to the individual fishing effort event from which the disposal resulted via the 'FishingEventID' field in the landings dataset and the 'LogbookEventId' in the effort dataset. This link was made for landings between the 2019–20 and 2021–22 fishing years. Records that could not be linked in this way (e.g., those resulting from factory trawlers that report disposal weights at the daily processing level) were linked to the average of all effort events for the day the disposal was reported.

To avoid double-counting of landings, records with temporary landing or disposal codes (i.e., P, Q, R, and T) were removed, as were records with secondary landed states and where the fate was unclear. For the species of interest, records were aggregated as follows:

- Landings: Landing codes EOY, L, LF, LFL, LR, and QL, as well as codes indicating that a dead individual was used in some way (e.g., codes B, E, O, S, U, and W) (see Appendix 1).
- Disposals: Disposals included components considered as:
    - Discarded: Disposal codes A, J, and Z (Table 2).
    - Released: Disposal code X (Table 2).

Unless otherwise specified, references to disposals in this report refer to any disposals under codes A, J, X, and Z (i.e., discarded/released components outlined above.).

Table 2: Description of the disposal codes referred to in this report (Fisheries New Zealand 2021).

Disposal code	Disposal type
A	Fish or fish product of a stock managed under the QMS that are abandoned in the sea, or accidentally lost at sea, except for fish or fish product to which another disposal code applies.
J	Fish or fish product of a stock subject to the QMS that are returned to, or abandoned in, the sea in accordance with the requirements set out in section 72(5)(c)(i) to (iii) of the Act.
X	Fish of stocks subject to the QMS that are— (a) Listed in Schedule 6 of the Act; and (b) Not spiny dogfish; and (c) Not blue shark, mako shark or porbeagle shark that are returned to the water dead or near-dead; and (d) Not rock lobster that must be returned to the sea; and (e) Returned to the water in accordance with the requirements set out for the relevant species or class of fish in Schedule 6 of the Act.
Z	Blue shark (*Prionace glauca*), mako shark (*Isurus oxyrinchus*) or porbeagle shark (*Lamna nasus*) that are returned to the water dead or near-dead in accordance with the requirements set out for those species in Schedule 6 of the Act.

For the surface longline fishery, we also examined available data collected by fishery observers. Observer data were extracted from the Centralised Observer Database (*cod*). Examination of the observer data focused on the fate (i.e., landed or disposed), size, life status (i.e., alive – uninjured, alive – minor injury, alive – severe injury, alive – moribund, or dead), and hooking location (i.e., mouth/jaw, gills, gullet/gut, foul-hooked) of all observed captures and those individuals that were discarded or released, as recorded by observers. Foul-hooked refers to individuals hooked anywhere on the body or fins other than the mouth/jaw, gills, gullet/gut. Soak time was calculated as the time difference (in hours) between the start of the set and the landing time for each observed individual. Soak times were then categorised into cumulative bins: 0–12 hours, 0–18 hours, 0–24 hours, and 0–48 hours for the characterisation analyses.

Fishing years for the characterisations were denoted in two ways: (i) 2019–20 fishing year referring to 1 October 2019 to 30 September 2020; and (ii) the abbreviated form 2020 signifying the 2019–20 fishing year.

2.2 Literature reviews

Literature reviews were undertaken to document current knowledge on the at-vessel (i.e., the status of an individual when brought to the vessel) and post-release survival (i.e., the long-term survival following release) of each species, and key influencing factors.

The most common approach to assess post-release survival of large pelagic fish and sharks is via the application of electronic tags such as pop-up satellite archival transmitters (PSATs) (e.g., Block et al. 2005, Dewar et al. 2011, Marcek & Graves 2014, Tracey et al. 2016). The data returned from the tags provide a timeline of depth and temperature experienced after release over a span of days to months, from which fate of the tagged individual, along with its behaviour, can be inferred.

The Web of Science, Google Scholar, and Google were searched using all permutations of the species name, common name, family, and genus, and for the keywords at-vessel survival/mortality, at-haul-back survival/mortality, post-release survival/mortality, capture, catch-and-release, as well as tagging terms including capture-mark-recapture, tagging, pop-up satellite tags, PSATs, acoustic tag, archival tag. At-retrieval and/or at-release survival estimates and factors influencing survival from the literature reviews were documented and compiled specific to the relevant species-method combinations for review by a workshop panel of experts (see Section 2.3).

2.3 Expert elicitation and workshop review

The process of deriving a species survival probability estimates for a given method capture-release event typically needs to combine (multiply) two separate survival probabilities:

1. the probability of surviving the capture process, i.e., the expected probability that a fish/shark will be alive when put back in the water, i.e., 'at-release' or 'immediate' survival; and
2. the probability of the fish/shark surviving after release given it was released alive, i.e., 'post-release' survival.

We elicited input from a range of experts who had observation knowledge of fish survival in respect to one, or both, of the components. This included domestic and international scientists, commercial vessel skippers and fishers, fishery observers, industry representatives, and fishery managers. Most of the participating experts with observational knowledge as to the state of a fish or shark being put back in the water after capture (i.e., its condition at-release) were commercial fishers and fisheries observers, while post-release survival expertise was constrained to fisheries scientists who had either conducted post-release survival studies or had knowledge of the release survival literature.

Following initial consultations with fishers, fishery observers, and scientists, an online Google Forms questionnaire was developed to capture information on at-release survival and post-release survival components of the study species. The questionnaire was structured by species and fishing gear method (as informed by the fishery characterisations) and split into questions pertaining to at-release and post-release survival. Questions in each category were based on key findings from the literature review, as well as to provide additional context regarding the reasons for individuals being released and to fill in knowledge gaps. In general, three types of questions were posed:

1. Likert categorical questions, whereby respondents had the option of selecting check boxes.
2. Multi-level Likert categorical questions, whereby respondents had the option of selecting multiple check boxes.
3. Open-ended questions, where the respondents had the option of providing brief answers.

The questionnaire required categorising continuous factors (e.g., tow duration) into range categories (e.g., tow durations 0–2 hours, 2–5 hours, 5–10 hours, greater than 10 hours). Each questionnaire respondent was requested to provide a survival probability range for each species-method-factor-category for which they had observational or research knowledge. Respondents did this by selecting up to six numerical response boxes: < 10%, 10–25%, 26–50%, 51–75%, 76–90%, > 90%. Respondents could select multiple boxes. For example, checking all six denoted that the respondent thought survival probability could be anywhere between 0 and 100%. Checking only box 3, for example, denoted that the respondent believed survival to be within the 26–50% range. Respondents were also given the option of selecting a box labelled ‘unsure’ or not answering a question if they were not comfortable to do so.

It was not feasible, within the limits of the questionnaire approach used, to explicitly account for species-method-factor crossed effects for continuous factors, e.g., all levels of ‘tow depth’ crossed with all levels of ‘tow duration’ for trawl fisheries. Survey respondents were therefore required to provide survival estimates for each factor-category assuming other factors were at their most benign category level (e.g., expected survival relative to various ‘tow depth’ categories assuming ‘tow duration’ to be at the highest survival category level).

A summary of background information on each species and links to relevant publicly available reports and papers were also incorporated into the questionnaire.

Prior to being sent to respondents, the questionnaire was sent to small number of fishers and non-New Zealand based experts to ensure questions were clear, unambiguous, and not influenced by local parlance or assumed knowledge.

Once finalised and released to willing participants, respondents were asked to provide their perceived survival estimates via this online survey for species methods and relevant treatment effects or factors (e.g., soak time) for which they had knowledge or expertise. Questionnaire results and resulting preliminary survival probability estimates (see Section 2.4) were then reviewed and discussed at a workshop held on 6 September 2023 and attended by respondents, fishery managers, fishing industry representatives, and other scientists and stakeholders. After the workshop, respondents were given the opportunity to revise their survival estimates. The final respondent estimates were then analysed and aggregated to derive expected survival probability ranges for each species-method-factor-category in accordance with the methods described in Section 2.4 below.

2.4 Fishery survival probability estimation

A Monte Carlo simulation approach was employed to derive 90% confidence ranges on the expected survival (mean survival) from the questionnaire responses (n = 31, including 16 fishers, 7 fishery observers, and 8 scientists) for each species-gear-factor (e.g., soak time, fishing depth) level combination, as well as for overall (i.e., combined) survival estimates for each species-gear-factor following the approach of McKenzie et al. (in press) that was reviewed and ratified by the Fisheries New Zealand Inshore Working Group under project INS2021–01. Individual survival values were assumed to follow a parametric Beta distribution (a continuous probability distribution often used to represent probability values as it is defined from 0 to 1) (see Appendix 2).

At the request of Fisheries New Zealand, three separate analyses were conducted for the three pelagic shark species:

1. Analyses based on at-release (immediate) survival (*p*[IS]) only.
2. Analyses based on post-release survival (*p*[PRS]) only, assuming all individuals released to the water were alive.
3. A combined at-release and post-release survival analysis, whereby overall survival (*p*[OS]) was the probability of an individual surviving the entire capture and release process. This was calculated as the probability of being alive at-release (*p*[IS]) multiplied by the probability of surviving after being released (*p*[PRS]):

$$(p[\mathrm{OS}]) = (p[\mathrm{IS}]) \times (p[\mathrm{PRS}]).$$

In each instance, four parameter values were required to specify each Beta probability distribution:

lb	lower 90% probability density bound.
ub	upper 90% probability density bound.
μ	expected survival (mean).
α	shape parameter alpha.

For each of the 'at-release' and 'post-release' survival components, the upper bound (*ub*) and lower bound (*lb*) parameters specific to each species-method-factor-category component probability were derived from the range values of the questionnaire responses. In the absence of information on survival, i.e., from the literature, μ was set at the midpoint of *lb* and *ub*, and α was set at 1. This parametrisation resulted a Beta bootstrap density that was approximately uniform between *lb* and *ub* (Appendix 2). Where suitable survival estimates from the literature were available, these were used as a 'prior'[3], with the Beta distribution *u* set to this value and the alpha parameter changed to 4 commensurate with greater confidence in this estimate (Appendix 2, Appendix 3). Data collected by fishery observers were initially examined for use as priors, but they were ultimately not used due to small numbers of observations of released individuals in the last few years, particularly for the three pelagic shark species (Table 3).

Table 3: Numbers of observed disposals with life status information (e.g., dead, alive – uninjured, alive – minor injury, etc.) available for the six species covered in this report by fishery observers, 2017–18 to 2021–22. STN = southern bluefin tuna, TOR = Pacific bluefin tuna, SWO = swordfish, BWS = blue shark, MAK = mako, POS = porbeagle, SLL = surface longline, MW = mid-water trawl, BT = bottom trawl.

Species	Method	Fishing year				
		2018	2019	2020	2021	2022
STN	SLL	28	36	35	57	12
TOR	SLL	1	0	0	0	0
SWO	SLL	13	0	2	0	0
	MW	0	0	0	0	0
BWS	SLL	437	169	35	138	1
MAK	SLL	40	10	8	7	3
	MW	0	0	0	0	0
POS	SLL	59	9	6	10	0
	MW & BT	0	0	0	0	0

Overall survival by factor-level (i.e., incorporating both at-release and post-release survival estimates) were computed in the same manner as the product of the random draws from the Beta distributions for each factor-level of interest. Finally, an overall release survival estimate for each species-method-factor

[3] Note: the use of the term 'prior' in this report should not be confused with Bayesian priors. The 'prior' as used here parametrises the Beta distribution such that 50% of Beta density is below this value. The parametric bootstrap approach used in this report is strictly frequentist, not Bayesian.

combination was computed as the weighted mean of each category within the factor, with category weight set to be proportional to its occurrence in the fishery disposal profile (proportional occurrence averaged over the most recent three fishing years; see Appendix 4). A similar process was conducted for the three pelagic fish species, although for these species it was assumed that all individuals released were alive at the time of release as per their current landing exceptions; thus only post-release survival was estimated for these species. For Pacific bluefin tuna, survival estimates were weighted to the fishery catch profile over the last three years as opposed to the fishery disposal profile, as there are no landing exceptions for this species.

Final survival determinations for each species were based on the lowest estimated survival probability for each factor, using the decisions rules outlined in Table 4 and presented in Figure 1.

Table 4: Description of the 90% confidence interval categories on mean survival used in this report.

Survival probability	Description
High	Lower 90% CI greater than 0.50
Medium-high	Lower 90% CI greater than 0.25 but lower than 0.50, upper 90% CI exceeds 0.75
Medium	Lower 90% CI greater than 0.25, upper 90% CI less than 0.75
Low-medium 1	Lower 90% CI less than 0.25, upper 90% CI greater than 0.25 but less than 0.75
Low-medium 2	Lower 90% CI greater than 0.25, upper 90% CI less than 0.50
Low	Upper 90% CI does not exceed 0.25
Uncertain	Survival probability range crosses all four probability quartiles

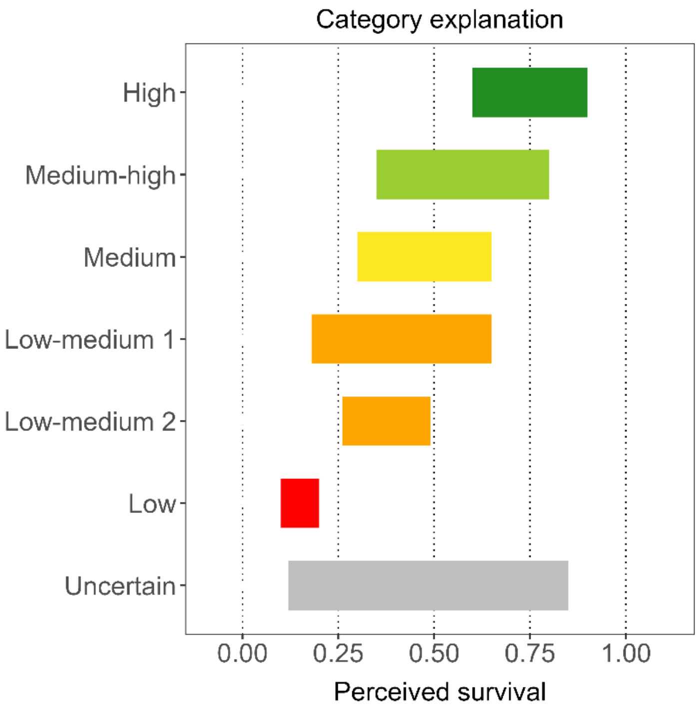


Figure 1: Graphical representation of the 90% survival probability confidence range definitions used in this report.

Project results were presented in-person at a meeting of surface longline fishers in Nelson on 14 September 2023 and in Tauranga (via MS Teams) on 19 September 2023 to further ratify project findings and obtain additional information from those persons not involved in the workshop. Project results were presented to the Fisheries New Zealand Highly Migratory Species Working Group (HMSWG) on 3 and 11 October 2023.

3. RESULTS

3.1 Southern bluefin tuna (*Thunnus maccoyii*) and Pacific bluefin tuna (*T. orientalis*)

3.1.1. Fishery characterisations

Southern bluefin tuna

The annual mean total catch (i.e., including landings and disposals) of southern bluefin tuna in the three-year period from 2019–20 to 2021–22 was 897.4 t (Table 5 and Figure 2). Annual average disposals (including live releases) were 27 t, representing ~3% of the annual commercial catch by weight (Table 5 and Figure 2).

Between 2019–20 and 2021–22, surface longline accounted for 97.7% of commercial captures by weight and 87.9% of disposals (Figure 3 and Figure 4). Troll accounted for just 1.2% of the total southern bluefin catch but 8.4% of disposals, due to a relatively high amount of live disposals from the troll fishery targeting albacore tuna (*Thunnus alalunga*) in 2021–22 compared with previous years (6.7 t in 2021–22 vs. 0.2 t in 2019–20 and 0 t in 2020–21; Figure 5, Figure 6, and Figure 7). The other methods that accounted for the remaining disposals between 2019–20 and 2021–22 were mid-water trawl (2.7 t of disposals, representing 3.3% of total disposals by weight), bottom trawl (0.1 t of disposals, 0.1% of total disposals by weight), and set net (0.02 t of disposals, 0.02% of total disposals by weight). A further 0.2 t (0.2 % of total disposals by weight) could not be attributed to a particular fishing method.

Most disposals of southern bluefin tuna from surface longlining in the last three fishing years have been attributed to disposal code X (i.e., alive and likely to survive), with a small proportion attributed to disposal codes A (i.e., abandoned in or accidentally lost at sea), and J (i.e., observer-authorised disposals) (1.3% and 2.8%, respectively) (Figure 5).

The majority of the southern bluefin tuna catch by surface longline in the last three fishing years was taken off the east coast of the North Island, in particular around Bay of Plenty, as well as from the west coast of the South Island (Figure 8). A larger proportion of disposals resulted from catches from the west coast of the South Island (Figure 8).

Table 5: Estimated catches of southern bluefin tuna in New Zealand by weight and proportion by destination and fishing year, 2004–05 to 2021–22.

	Total catch (t)			Proportion		
Fishing year	Landed	Discarded	Released	Landed	Discarded	Released
2005	265.36	2.02	–	0.992	0.008	–
2006	237.24	0.58	–	0.998	0.002	–
2007	377.61	0.45	0.37	0.998	0.001	0.001
2008	315.58	0.33	1.60	0.994	0.001	0.005
2009	417.51	–	1.26	0.997	–	0.003
2010	493.20	0.20	0.94	0.998	–	0.002
2011	556.10	0.16	0.22	0.999	–	–
2012	775.39	0.16	0.91	0.999	–	0.001
2013	744.36	0.19	9.86	0.987	–	0.013
2014	815.49	2.43	9.09	0.986	0.003	0.011
2015	902.09	10.1	6.22	0.982	0.011	0.007
2016	949.02	5.47	14.87	0.979	0.006	0.015
2017	911.64	1.15	6.64	0.992	0.001	0.007
2018	1002.3	2.19	3.11	0.995	0.002	0.003
2019	912.28	1.19	2.62	0.996	0.001	0.003
2020	961.90	0.84	10.12	0.989	0.001	0.010
2021	776.57	1.70	18.80	0.974	0.002	0.024
2022	871.86	2.37	47.97	0.945	0.003	0.052

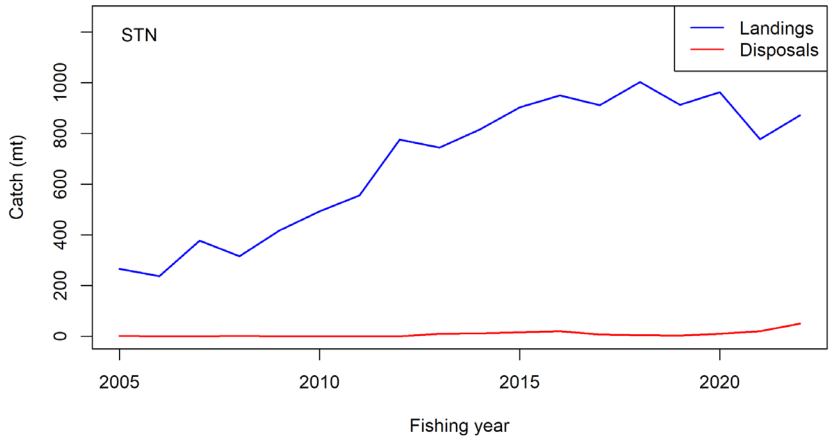


Figure 2: Annual commercial landings and disposals of southern bluefin tuna (STN) in New Zealand's Exclusive Economic Zone from 2004–05 (2005) to 2021–22 (2022).

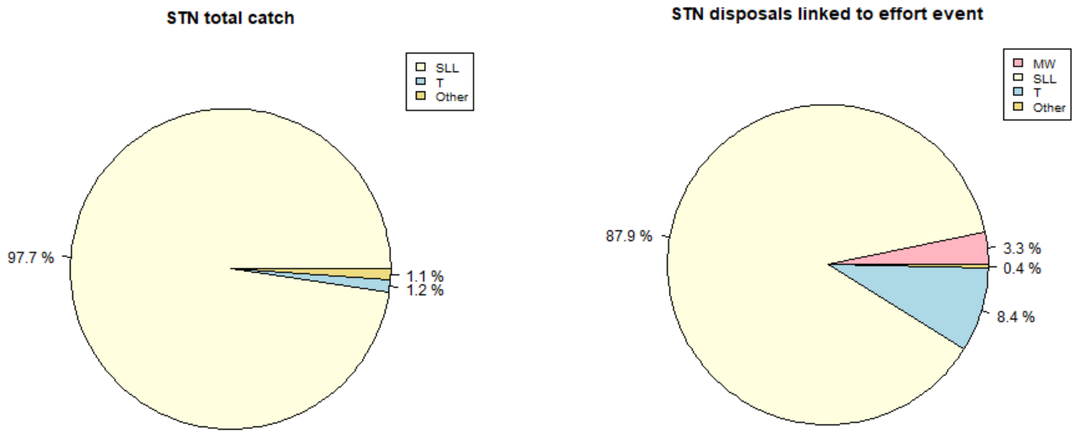


Figure 3: Southern bluefin tuna (STN) total catches (left) and disposals (right) in New Zealand's Exclusive Economic Zone by fishing method, 2019–20 to 2021–22. MW = mid-water trawl; SLL = surface longline; T = troll.

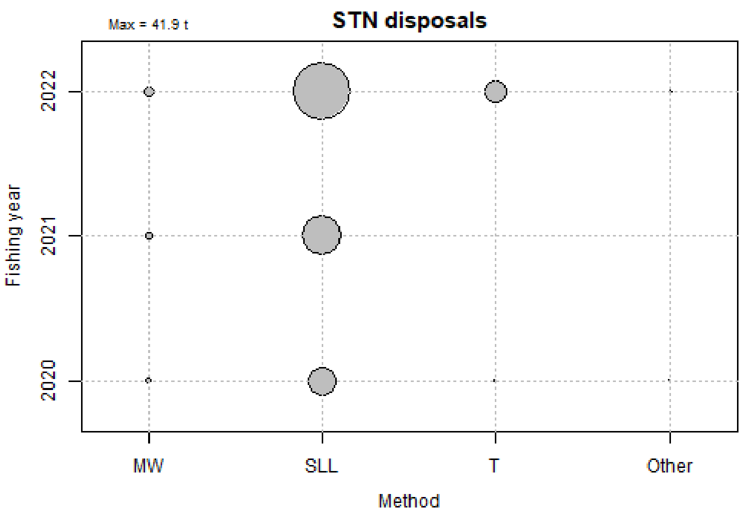


Figure 4: Disposals of southern bluefin tuna (STN) by fishing method in New Zealand's Exclusive Economic Zone from 2019–20 to 2021–22. MW = mid-water trawl; SLL = surface longline; T = troll.

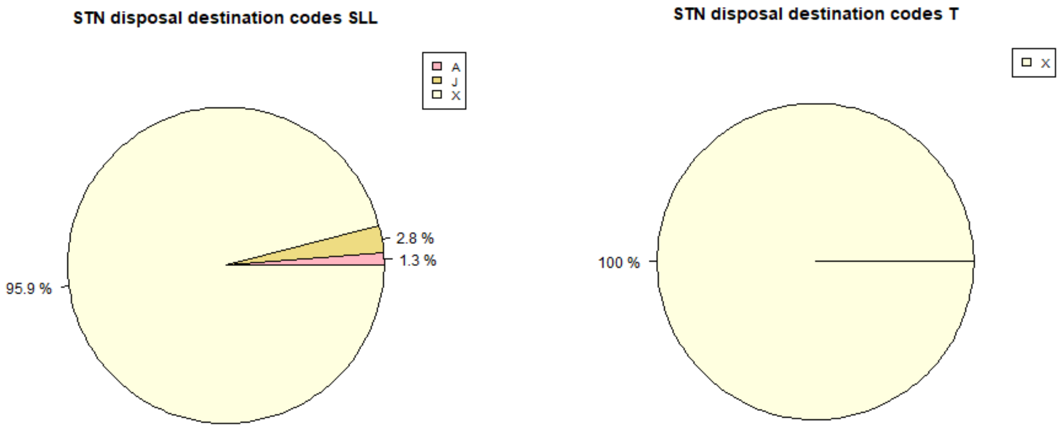


Figure 5: **Codes attributed to disposals of southern bluefin tuna (STN) from the surface longline (SLL; left) and troll (T; right) fisheries in New Zealand's Exclusive Economic Zone between 2019–20 and 2021–22.**

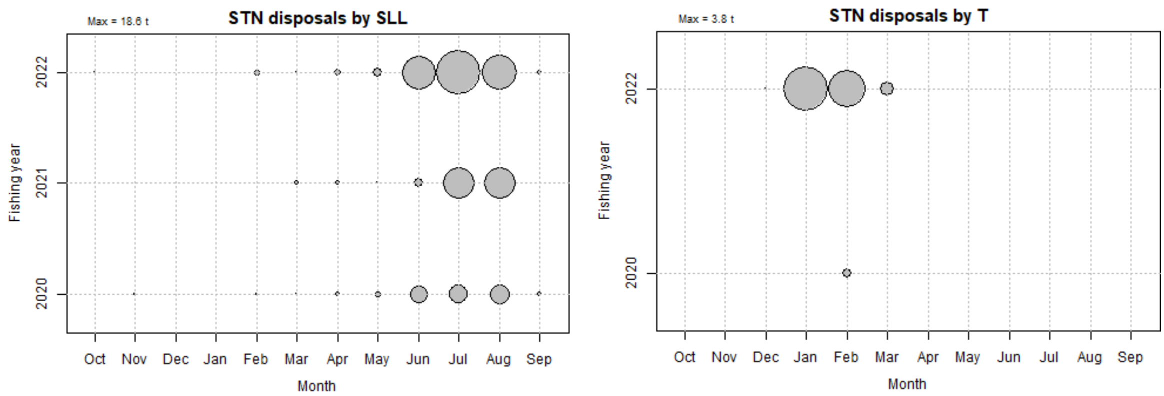


Figure 6: **Disposals of southern bluefin tuna (STN) by month in New Zealand's Exclusive Economic Zone for 2019–20 to 2021–22 for surface longline (SLL; left) and troll (T; right).**

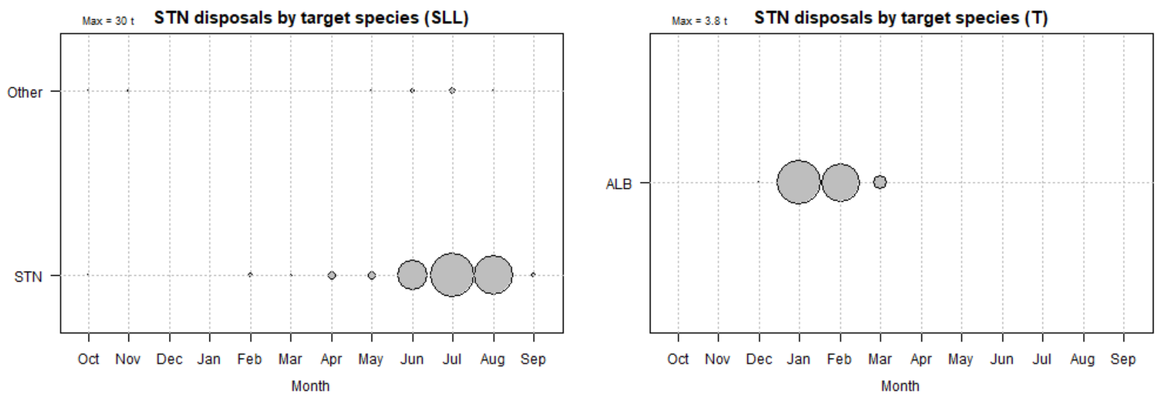


Figure 7: **Disposals of southern bluefin tuna (STN) by month and target species in New Zealand's Exclusive Economic Zone for 2019–20 to 2021–22 for surface longline (SLL; left) and troll (T; right). ALB = albacore tuna.**

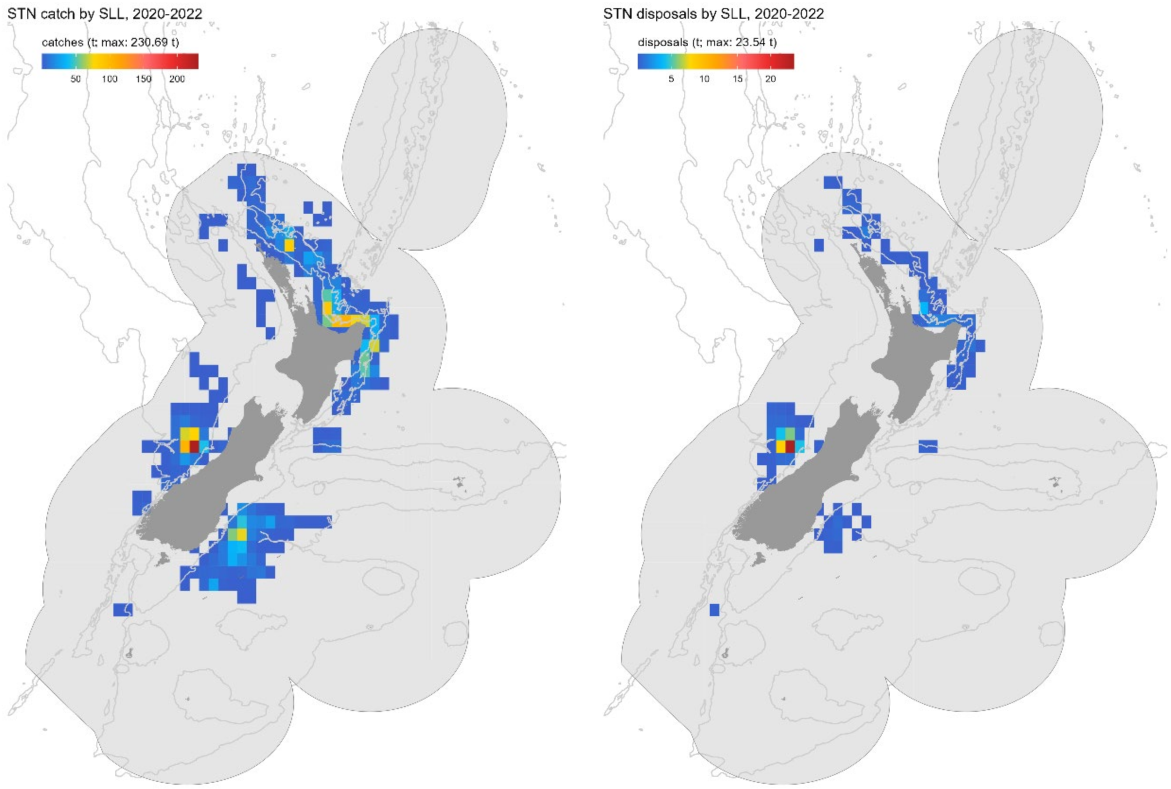


Figure 8: Total catches (including disposals; left) and disposals (right) of southern bluefin tuna (STN) by surface longline (SLL) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

Since 2005, over 48 000 southern bluefin tuna captures have been observed by fisheries observers on surface longline vessels. The vast majority of observed southern bluefin tuna have been landed, with disposals limited to mainly smaller fish (Figure 9 and Figure 10). At-vessel survival rates of southern bluefin tuna have been around 80% (i.e., 20% mortality), with at-vessel survival being highest for fish between 90 and 140 cm fork length (Figure 11). Targeting behaviour appeared to have little influence on southern bluefin tuna at-vessel survival, with approximately equal survival rates when bigeye tuna (*Thunnus obesus*) or southern bluefin tuna were targeted (Figure 12). Southern bluefin tuna were more likely to be reported dead for fishing events with longer soak times and when foul-hooked, although hooking anywhere other than the mouth/jaw was rare—99.1% of observed southern blue tuna with hooking location information available were recorded as being hooked in the mouth/jaw (Figure 13).

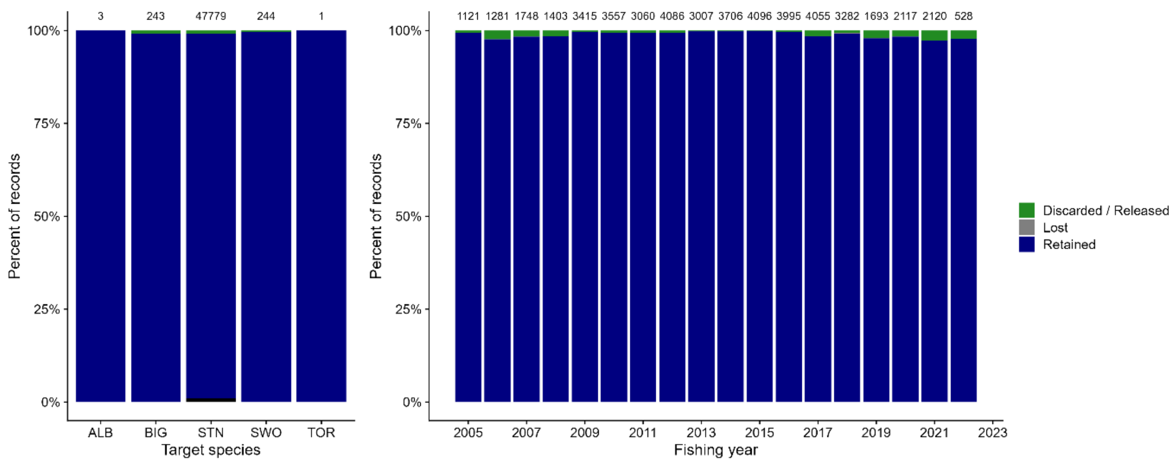


Figure 9: Fate of southern bluefin tuna (STN) from observer records from the surface longline fishery by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. ALB = albacore tuna, BIG = bigeye tuna, SWO = swordfish, TOR = Pacific bluefin tuna.

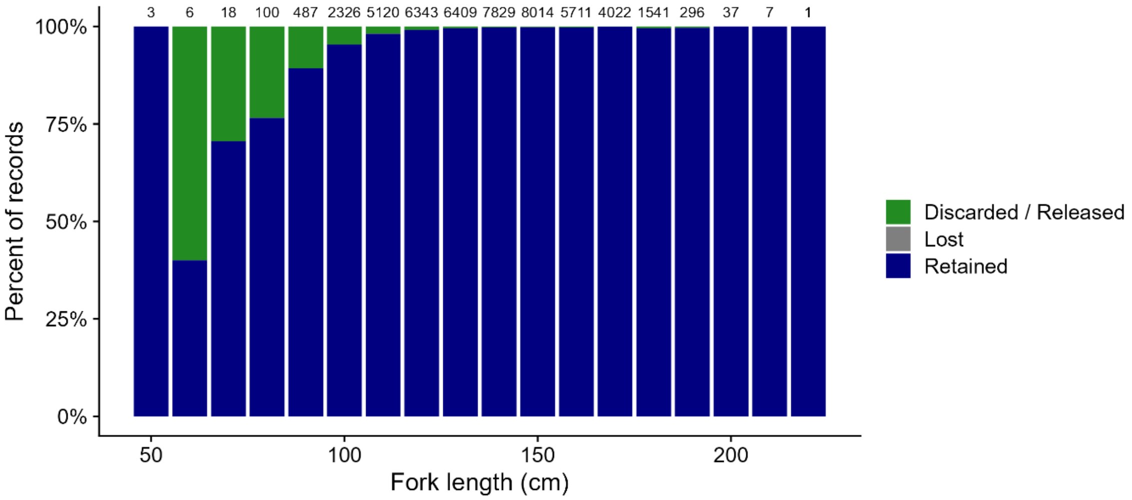


Figure 10: Fate of southern bluefin tuna by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

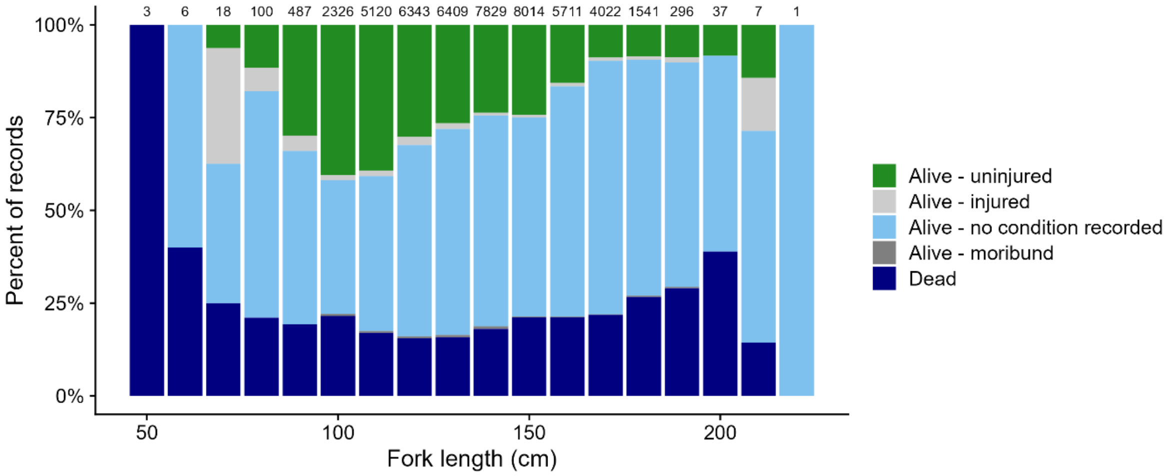


Figure 11: Life status at haul of southern bluefin tuna by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

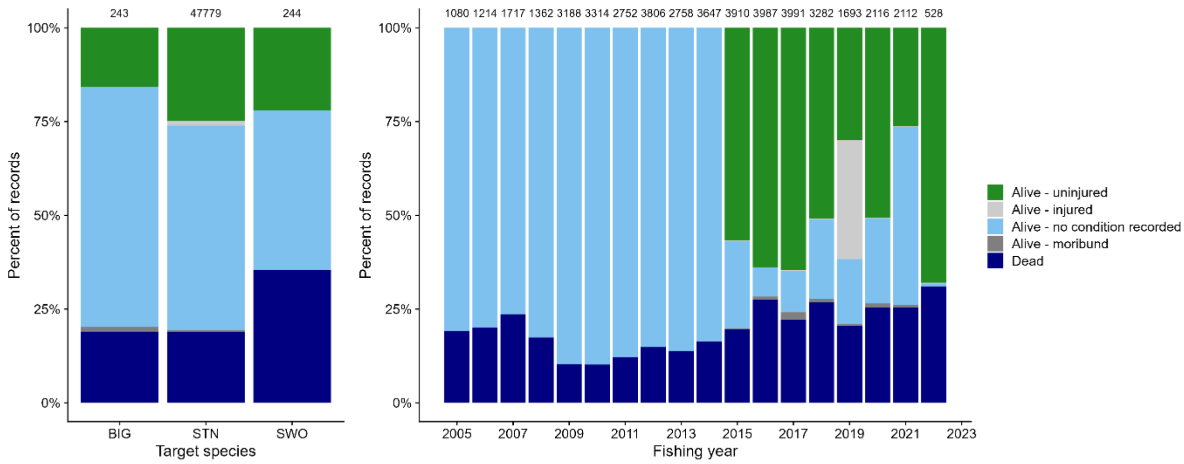


Figure 12: Life status of southern bluefin tuna (STN) from observer records from the surface longline fishery at-vessel by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. BIG = bigeye tuna, SWO = swordfish.

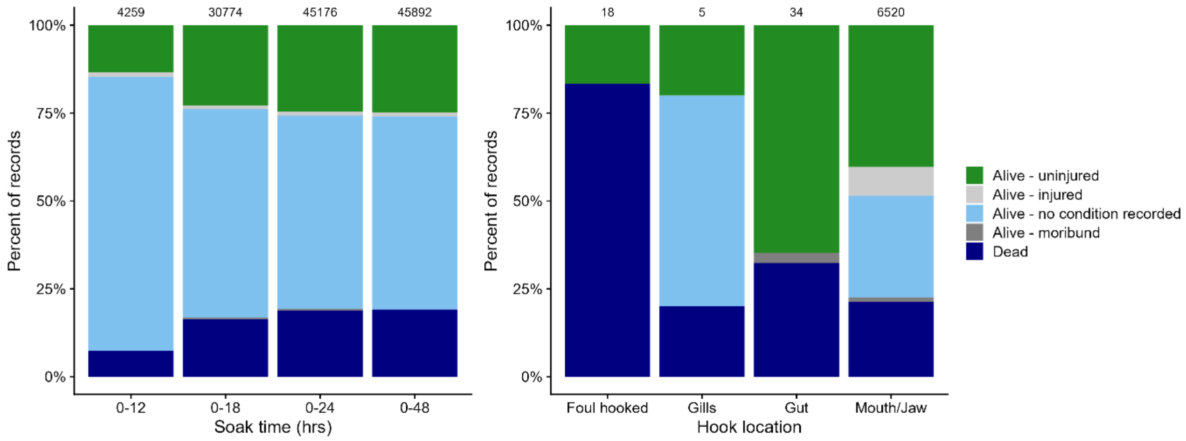


Figure 13: Life status of southern bluefin tuna from observer records from the surface longline fishery at-vessel by soak time (left) and hooking location (right). Numbers above the columns indicate sample sizes.

Pacific bluefin tuna

The annual mean total catch (i.e., including landings and disposals) of Pacific bluefin tuna in the three-year period from 2019–02 to 2021–22 was 39.8 t. Consistent with this species not currently having landing exceptions, there have been few disposals of Pacific bluefin since 2005, with only a single 350 kg individual being discarded in the last three fishing years (with this individual being reported as abandoned/accidentally lost at sea) (Table 6 and Figure 14). Surface longline accounted for 99.1% of total Pacific bluefin tuna commercial captures over the period 2019–20 to 2021–22 (Figure 15).

The majority of the Pacific bluefin catch in the last three fishing years was taken off the east coast of the North Island, in particular around East Cape, as well as from the west coast of the South Island (Figure 16).

Table 6: Estimated catches of Pacific bluefin tuna in New Zealand by weight and proportion by destination and fishing year, 2004–05 to 2021–2022.

	Total catch (t)			Proportion		
Fishing year	Landed	Discarded	Released	Landed	Discarded	Released
2005	20.09	1.25	–	0.941	0.059	–
2006	20.21	0.29	–	0.986	0.014	–
2007	12.80	0.15	–	0.988	0.012	–
2008	11.13	0.20	–	0.982	0.018	–
2009	14.74	–	–	1.000	–	–
2010	12.07	–	–	1.000	–	–
2011	27.03	–	–	1.000	–	–
2012	13.24	–	–	1.000	–	–
2013	23.68	–	–	1.000	–	–
2014	11.93	0.19	–	0.984	0.016	–
2015	15.44	0.32	–	0.980	0.020	–
2016	16.92	0.25	–	0.985	0.015	–
2017	13.39	0.25	–	0.982	0.018	–
2018	19.86	0.27	–	0.986	0.014	–
2019	21.16	–	–	1.000	–	–
2020	46.61	–	–	1.000	–	–
2021	40.46	0.35	–	0.991	0.009	–
2022	32.03	–	–	1.000	–	–

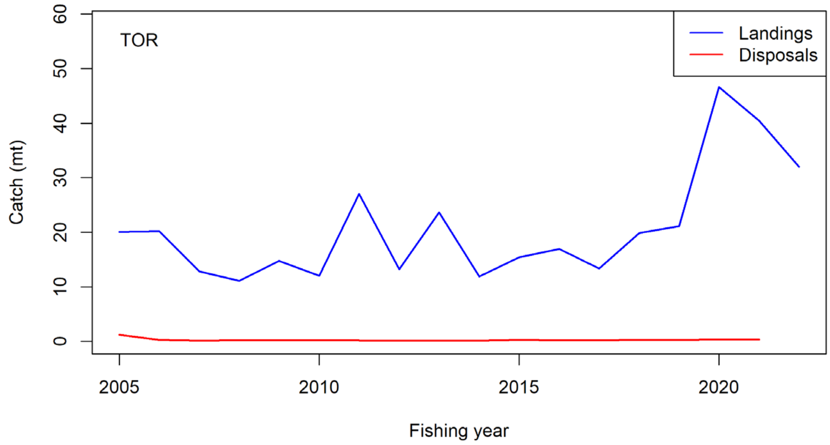


Figure 14: Annual commercial landings and disposals of Pacific bluefin tuna (TOR) in New Zealand's Exclusive Economic Zone from 2004–05 (2005) to 2021–22 (2022).

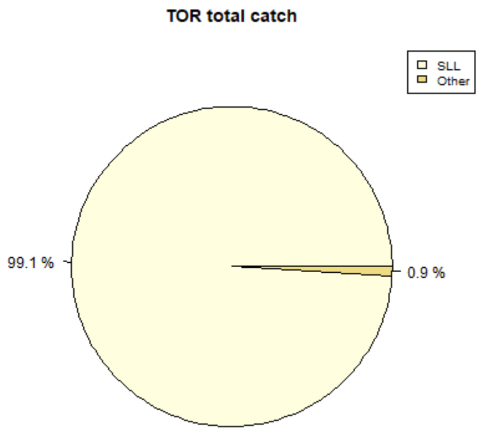


Figure 15: Pacific bluefin tuna (TOR) total catches in New Zealand's Exclusive Economic Zone by fishing method, 2019–20 to 2021–22. SLL = surface longline.

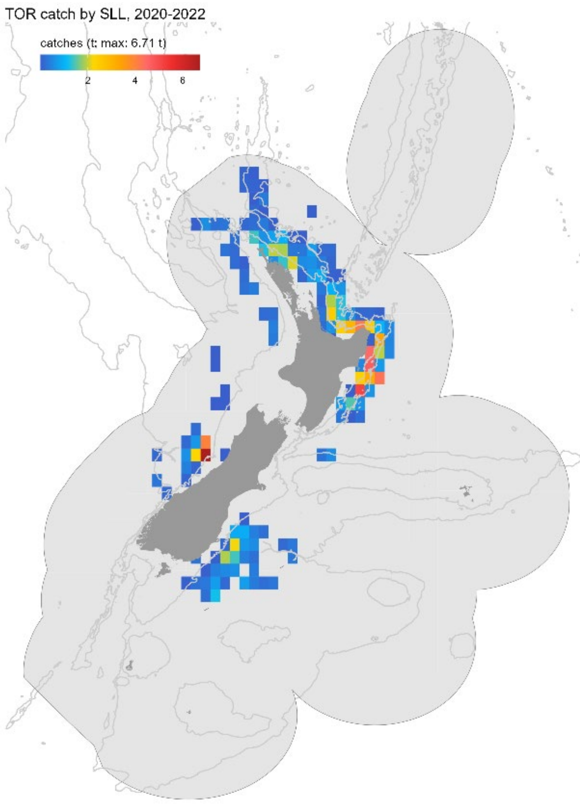


Figure 16: Total catches (including disposals) of Pacific bluefin tuna (TOR) by surface longline (SLL) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

There have been relatively few observations of Pacific bluefin tuna by fishery observers, with information on fate recorded for just 217 individuals since 2005. The vast majority of these individuals were landed (Figure 17 and Figure 18). At-vessel survival rates of Pacific bluefin tuna have typically been around 65% (i.e., 35% mortality), with at-vessel survival being higher for smaller fish (Figure 19 and Figure 20). Pacific bluefin tuna were more likely to be reported dead when brought to the vessel for fishing events encompassing longer soak times (Figure 21). For those individuals for which hooking location was recorded, all were hooked in the mouth/jaw (Figure 21).

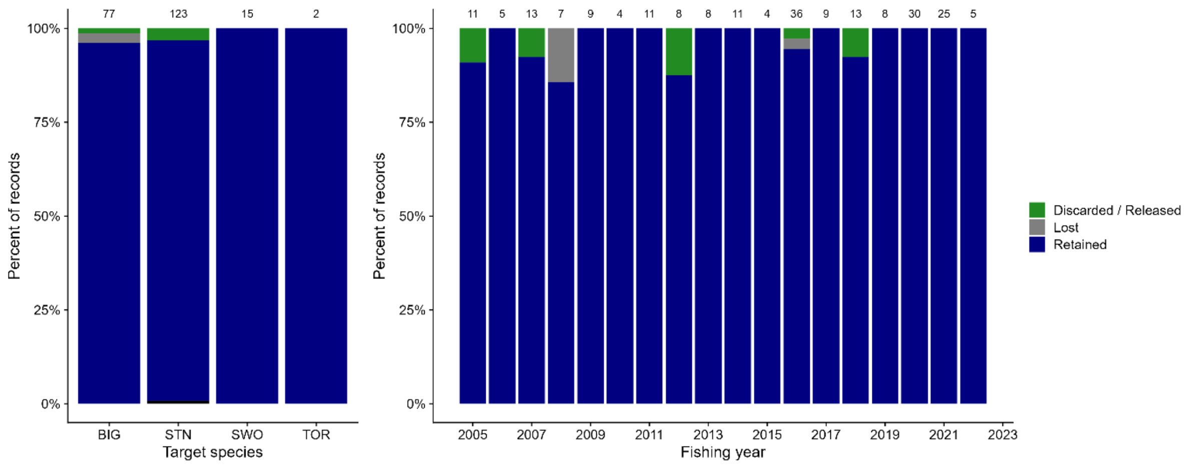


Figure 17: Fate of Pacific bluefin tuna (TOR) from observer records from the surface longline fishery by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish.

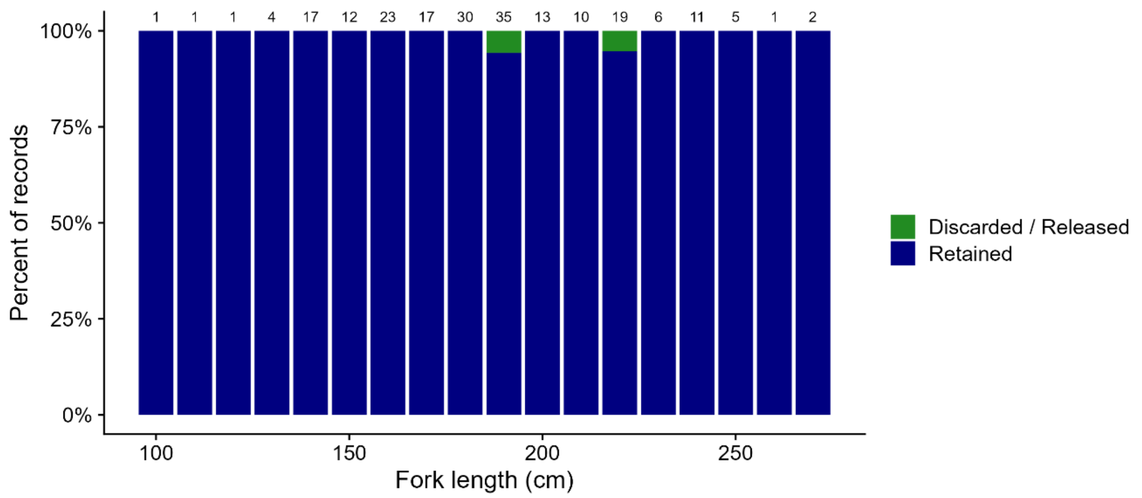


Figure 18: Fate of Pacific bluefin tuna by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

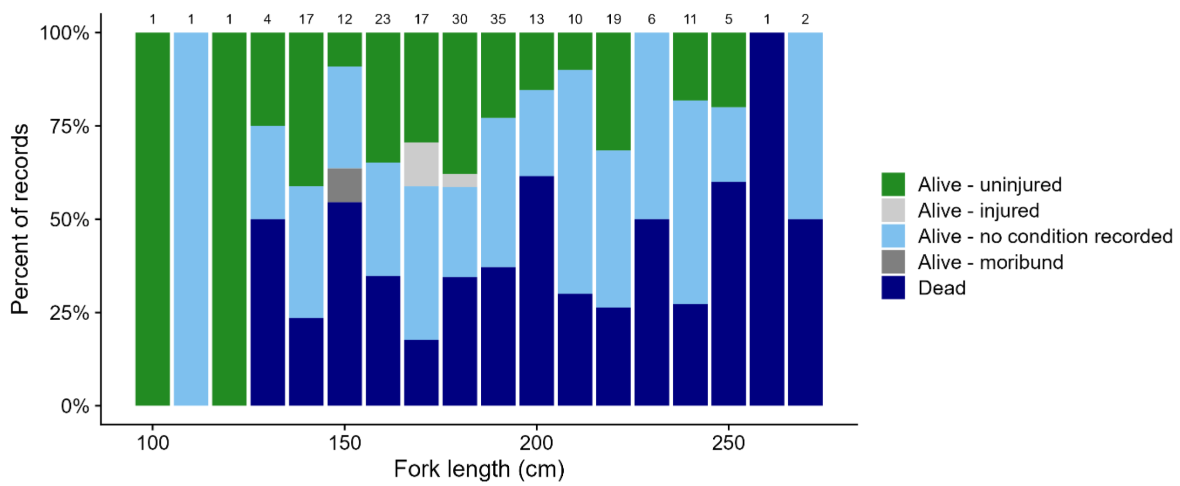


Figure 19: Life status at haul of Pacific bluefin tuna by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

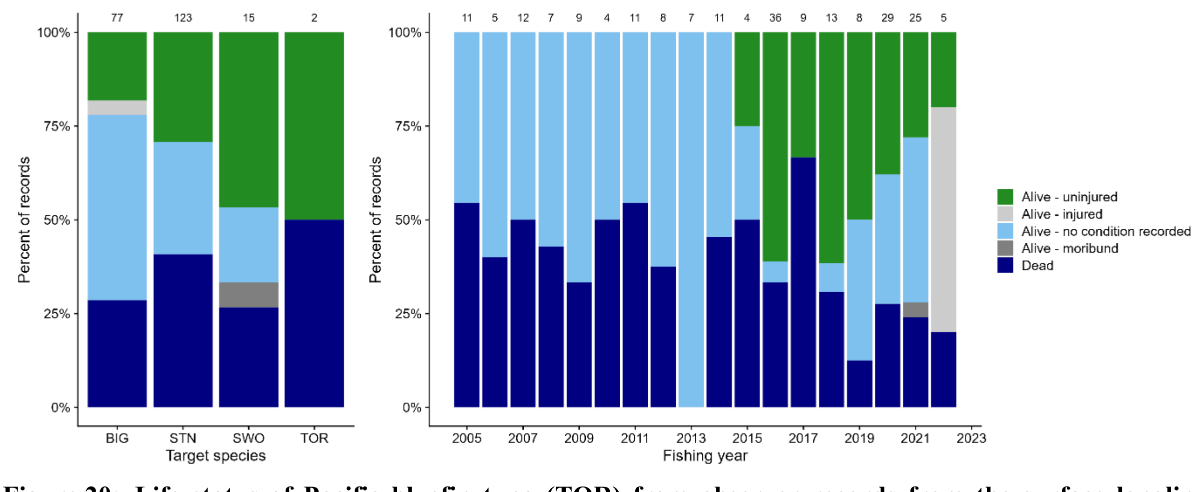


Figure 20: Life status of Pacific bluefin tuna (TOR) from observer records from the surface longline fishery at-vessel by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish.

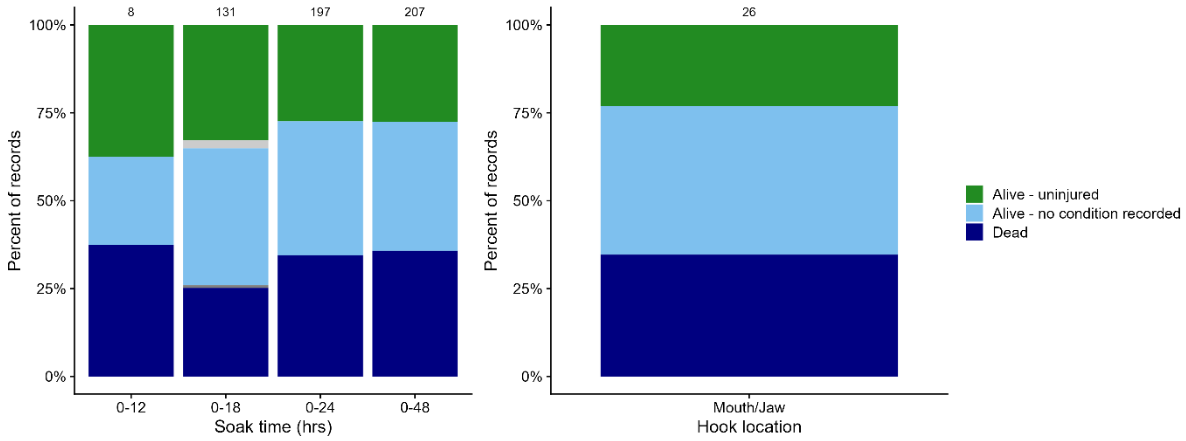


Figure 21: Life status of Pacific bluefin tuna from observer records from the surface longline fishery at-vessel by soak time (left) and hooking location (right). Numbers above the columns indicate sample sizes.

3.1.2. Review of at-vessel and post-release survival studies

Species biology

Southern bluefin tuna are found in eastern Atlantic, Indian, and south-west Pacific ocean waters between 30° S and 50° S. They can reach up to 2.5 m in length and up to 260 kg. Southern bluefin tuna comprise a single stock, with mature fish migrating to a single spawning ground located in the north-east Indian Ocean between Indonesia and Australia (Hobday et al. 2016). They occupy a broad thermal niche, occurring in waters from ~6 °C to 30 °C, and in surface waters to depths greater than 600 m (although typically show a preference for surface waters to around 250 m in depth) (Patterson et al. 2008).

Pacific bluefin tuna are found throughout the Pacific Ocean between approximately 60° N and 50° S. Spawning is centred in two geographic regions of the western North Pacific Ocean (WNPO): (1) East China Sea between the Philippines, Taiwan, and Ryukyu Archipelago (Nansei Islands); and (2) Sea of Japan. Pacific bluefin tuna can reach up to 3 m in length and at least 450 kg in weight. Like southern bluefin tuna, Pacific bluefin tuna occupy a broad thermal niche, occurring in waters from < 10 °C to 30 °C, and in surface waters to depths greater than 600 m (although typically show a preference for surface waters to around 150 m in depth) (Fujioka et al. 2021).

Like all *Thunnus* species, southern bluefin tuna and Pacific bluefin tuna are obligate ram ventilators, requiring a constant supply of water over their gills to breath. Both species have a complex system of heat exchangers (retia mirabilia) in their muscle, eyes, brain, and viscera, that, coupled with their elevated metabolic rates, enable bluefins to conserve heat (Shiels et al. 2011).

Studies assessing capture (at-vessel) survival relevant to southern and Pacific bluefin tunas

There have been a small number of studies that have directly assessed at-vessel survival of bluefin tunas (Table 7). In the Gulf of Mexico, at approximately 27° N, Block et al. (2005) observed at-vessel survival rates of 69% for Atlantic bluefin tuna (*Thunnus thynnus*) caught by research longlining (commercial longline gear deployed with soak times typically less than 2 hours). At the same location, Orbesen et al. (2019) estimated at-vessel survival rates as being 32% for individual Atlantic bluefin tuna caught with J-hooks, 35% for individuals caught with standard circle hooks, and 46% for individuals caught with weak circle hooks (circle hooks with a reduced wire diameter that are designed to allow bluefin tuna to straighten the hook). Block et al. (2005) postulated that the overall relatively high mortality rates of Atlantic bluefin tuna in the Gulf of Mexico surface longline fishery could be a result of asphyxiation due to inability to ram ventilate, thermal stress from confinement in warm surface waters, or other capture related trauma that could be exacerbated by longer soak times. Orbesen et al. (2019) postulated that the overall relatively high mortality rates observed for Atlantic bluefin tuna in their study relative to the results of Block et al. (2005) likely resulted from the longer soak times of the commercial fishery (the average soak duration in the study of Orbesen et al. (2019) was 7.5 hours). On the Grand Banks, Epperly et al. (2012) estimated at-vessel survival of Atlantic bluefin tuna to be between 46.2 and 60.2% depending on the type and size of hook, with individuals caught on 18/0 circle hooks with a 10° offset having a higher at-vessel survival (60.2%) compared with individuals caught on the same hook without an offset (58.5% survival) and individuals caught with 9/0 J-hooks with a 10–30° offset (46.2% survival) (Table 7).

Studies assessing post-release survival relevant to southern and Pacific bluefin tunas

Despite the species significance to commercial longline fisheries throughout their distributions, there have been few dedicated studies assessing post-release survival of southern bluefin tuna or Pacific bluefin tuna following capture by surface longline (Table 8). Harley et al. (2008) report on the post-release survival of 10 southern bluefin tuna tagged with PSATs following capture by surface longline off the north-east coast of North Island, New Zealand. All fish survived the initial post-capture period. A single tagged fish was predated just over two weeks after being released. If this event was included as a post-release mortality, their survival estimate was therefore 90%. A similarly high survival rate (91%) was derived by Sakai & Itoh (2013) for southern bluefin tuna tagged with PSATs following capture by the Japanese surface longline fishery in the Southern Ocean, suggesting post-release survival rates may be comparable between the two species. However, as noted by Patterson & Hansen (2016), it was unclear how fish were selected for tagging in the study of Sakai & Itoh (2013), as the primary objective of the study appeared to be to assess movement patterns. Moreover, in addition to pulling fish on board using the branch line, the study of Sakai & Itoh (2013) used two methods for retrieving fish not currently employed by commercial surface longline vessels (including "scooping by the spoon net" and "lifting electro-hydraulic basket"). Therefore, these results may not be applicable to commercial vessels undertaking normal fishing operations.

There have been a small number of studies assessing post-release survival of other large-bodied tunas following capture by surface longline (Table 8). In the Gulf of Mexico, Orbesen et al. (2019) assessed the survival of 33 Atlantic bluefin tuna released with PSATs after capture by commercial surface longline gear. They found that hook type was a significant factor affecting post-release survival, with a higher survival rate (88%) for fish caught using weak circle hooks than those caught with J-hooks (71%). In contrast, Muir et al. (2022) estimated an overall survival rate of just 10% for bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) released after capture by surface longline in the tropical western and central Pacific Ocean (Table 8).

Several studies have examined post-release survival of bluefin tunas in recreational fisheries (Table 9). While the fishing methods and handling practices are different to those employed in the New Zealand commercial surface longline fishery, the results of these studies do provide information on the relative hardiness of these species, and as such they are worth mentioning here. Tracey et al. (2016) report high survival of southern bluefin tuna following capture by recreational anglers off southeastern Australia. In their analysis, 83% of fish caught on lures configured with J-hooks or those fish caught on circle hooks survived following release, with fish caught on lures with treble hooks having a lower rate of survival (60%). Damage related to hooking location, angling duration, biochemical indicators of physiological stress, and handling duration were not identified as significant factors leading to post-release mortality. Harley et al. (2008) reported 100% survival of 15 Pacific bluefin tuna tagged with PSATs and released after capture by recreational handline and hook and line off the South Island, New Zealand in 2007. High survival rates were also observed for Pacific bluefin tuna tagged in the southern California Bight in the eastern Pacific, with 95% of the 40 fish tagged with PSATs surviving beyond one week following release (Sepulveda et al. 2020).

Table 7: Summary of studies examining at-vessel survival of large-bodied tunas in research and commercial fisheries. SLL = surface longline; FL = fork length; ABT = Atlantic bluefin tuna; ALB = albacore tuna; BIG = bigeye tuna; YFT = yellowfin tuna. Factors in bold font had a significant influence on survival.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Species; Reference
Research SLL	Gulf of Mexico	59	69%	–	Study examined survival at-vessel	ABT; Block et al. (2005)
Commercial SLL	Indian Ocean	79 ALB 86 BIG 66 YFT	4% ALB 49 % BIG 35% YFT	–	Study examined survival at-vessel	ALB, BIG, YFT; Poisson (2009), Poisson et al. (2010)
Commercial SLL	Pacific Ocean (Hawaii)	207 ALB 4 630 BIG 1 097 YFT	28%–43% ALB 78%–82% BIG 53%–59% YFT	Hook type (circle & J-hooks > tuna hooks) Hook type (circle & J-hooks > tuna hooks) Hook type (tuna hook > circle hook > J hook)	Study examined survival at-vessel	ALB, BIG, YFT; Curran & Bigelow (2011)
Commercial SLL	Atlantic Ocean	74 ALB 916 BIG 233 YFT	9%–12% ALB 50%–67% BIG 36%–56% YFT	Hook type (circle > J-hooks) Hook type (circle > J-hooks) Hook type (circle > J-hooks)	Study examined survival at-vessel	ALB, BIG, YFT; Pacheco et al. (2011)
Commercial SLL	Atlantic Ocean	246	46.2–60.2%	**Hook type** (18/0 circle with 10° offset > 18/0 circle no offset > 9/0 J-hooks 10°–30° offset), bait, SST, **soak time**, FL, hooking location	Study examined survival at-vessel	ABT; Epperly et al. (2012)
Commercial SLL	Atlantic Ocean	67 ALB 1 155 BIG 65 YFT	22%–31% ALB 42%–46% BIG 27%–29% YFT	Hook type (circle > tuna hook) Hook type (circle > tuna hook) Hook type (circle > tuna hook)	Study examined survival at-vessel	ALB, BIG, YFT; Huang et al. (2016)
Commercial SLL	Gulf of Mexico	1 498	32%–46%	Hook type (weak circle > circle > J-hooks), set depth, target species, SST, soak time, FL	Study examined survival at-vessel	ABT; Orbesen et al. (2019)
Commercial SLL	Atlantic Ocean	24 ALB 472 BIG 169 YFT	0%–11% ALB 52%–61% BIG 29%–54% YFT	Hook type (small circle > J > large circle) Hook type (large circle > J > small circle) Hook type (large circle > J > small circle)	Study examined survival at-vessel	ALB, BIG, YFT; Nunes et al. (2019)

Table 8: Summary of studies examining post-release survival of large-bodied tunas in commercial fisheries. SLL = surface longline; PS = purse seine; FL = fork length; SST = sea surface temperature; STN = Southern bluefin tuna; ABT = Atlantic bluefin tuna; BIG = bigeye tuna; YFT = yellowfin tuna.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Species; Reference
Commercial SLL	New Zealand	10	100%	–	All tagged fish survived two weeks after capture	STN: Harley et al. (2008)
Commercial SLL	Southern Ocean (including Tasman Sea)	45	91%	Vessel, **FL (small (<105 cm FL) > larger fish)**, SST, tag size**, landing method** (fish 'scooper'- and scoop net-retrieved fish had higher survival than when branch line was pulled up)	Unclear if retrieving practices are representative of commercial SLL	STN; Sakai & Itoh (2013)
Commercial SLL	Gulf of Mexico	33	71% for J-hooks, 88% for weak circle hooks	**Hook type (weak circle > circle > J-hooks)**, set depth, target species, SST, soak time, FL		ABT; Orbesen et al. (2019)
Commercial PS (then caught by hook and line)	Mediterranean	3	100%	–	All 3 tagged fish were hooked in jaw and in good condition (no bleeding or visible injury)	ABT; Rouyer et al. (2020)
Commercial SLL	New Zealand / Fiji / New Caledonia	26	10%	FL, condition at release, **float position on line** (indicative of haul time)		BIG, YFT; Muir et al. (2022)

Table 9: Summary of studies examining post-release survival of bluefin tunas in recreational fisheries. FL = fork length; ABT = Atlantic bluefin tuna; STN = Southern bluefin tuna; TOR = Pacific bluefin tuna.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Species; Reference
Recreational (handline and rod and reel)	New Zealand	15 (in 2007)	100%	–	All tagged fish survived	TOR: Harley et al. (2008)
Recreational angling	Canada	59	97%	Hook type, hooking location, and fight time were similar across all releases	Only two mortalities of tagged fish, did not identify anything particularly unique these events	ABT; Stokesbury et al. (2011)
Recreational (trolling)	US Atlantic Coast	19	100%	–	All releases were of juveniles (69–119 cm FL)	ABT; Marcek (2013); Marcek & Graves (2014)
Recreational angling	Australia	54 J- and circle hooks 5 treble hooks	83% for circle and J-hooks 60% for treble hooks	Angling duration, **hook type**, FL, SST, bleeding index	Six fish retrieved dead / non-responsive, five were deep hooked, leading to gill damage, one was tail wrapped	STN; Tracey et al. (2016)
Recreational angling (on light tackle)		15 (juveniles; 119–185 cm)	100%	–	Tagged fish subjected to a broad range of handling methods and hooking locations with variable levels of bleeding	ABT; Goldsmith et al. (2017)
Recreational	Eastern Pacific (Southern California, Baja)	40	95%	Direct correlation between fight time and blood stress indicators	Two mortalities, one was largest tagged fish (148 cm) that was gut-hooked, other was 87 cm fish that was predated	TOR; Sepulveda et al. (2020)
Recreational (drifting)	Norway	18	83%	–	Three tags popped approx. 3 days after tagging which were considered as mortalities	ABT; Aarestrup et al. (2022)

3.1.3. Expert elicitation

Reasons for release

Stakeholders advised that the most common reason for releasing southern bluefin tuna was reduced profitability of smaller individuals, which attract a lower market price (that typically doesn't cover operational costs) due to poor muscle quality. Additionally, several stakeholders indicated crew safety and fatigue was a factor; often large numbers of small (i.e., less than 90 cm in length) southern bluefin can be caught on a given set, and processing these would take significant time, with limited economic return. Stakeholders advised that it was better to release these fish, which can be done safely and quickly by bringing them on-board first so gear can be retrieved (see below), and leaving crew available to process larger, more profitable, individuals and to attend to their other duties (setting and hauling).

As no landing exceptions exist for Pacific bluefin tuna, there are no releases, and thus no reasons for release. However, stakeholders advised that the main reasons they wished to release Pacific bluefin tuna were the same reasons as for southern bluefin tuna, as well as a lack of quota, particularly with increasing catches observed since the 2019–20 fishing season.

At-release survival

Sixteen respondents answered questions on southern bluefin tuna at-release survival (Figure 22). Survey respondents indicated that most southern bluefin tuna that are returned to the sea are alive and uninjured (> 75%), with respondents indicating that only a small percentage (< 10%) of fish are released with minor injuries, severe injuries, or dead (Figure 22). Survey respondents indicated that most southern bluefin tuna are brought on board prior to release (Figure 22). Workshop participants indicated that this was so fishing gear could be retrieved, minimising time and costs associated with replacing gear, and that this was a relatively quick and easy process, particularly for smaller fish. Survey respondents suggested that targeting behaviour had little influence on life status of southern bluefin tuna, and soak time only had a minimal influence (Figure 22). Most survey respondents suggested the number of released southern bluefin tuna that were foul-hooked, hooked in the gut, or taken by predators following release was low (< 10%) (Figure 22).

Post-release survival

Four respondents answered questions relating to survival of southern bluefin tuna following capture and release from surface longline gear (Figure 22), and three respondents answered questions relating to survival of Pacific bluefin tuna following capture and release from surface longline gear (Figure 23). Overall, survey respondents considered survival of both tuna species to be high, particularly when released uninjured or with minor injuries (Figure 22) (as is the requirement under the current landing exceptions for southern bluefin tuna). Survey respondents indicated that survival of both southern bluefin tuna and Pacific bluefin tuna decreased slightly with longer soak times, or when fish were released after having been foul-hooked, gut-hooked, or hooked in the gills (Figure 22 and Figure 23).

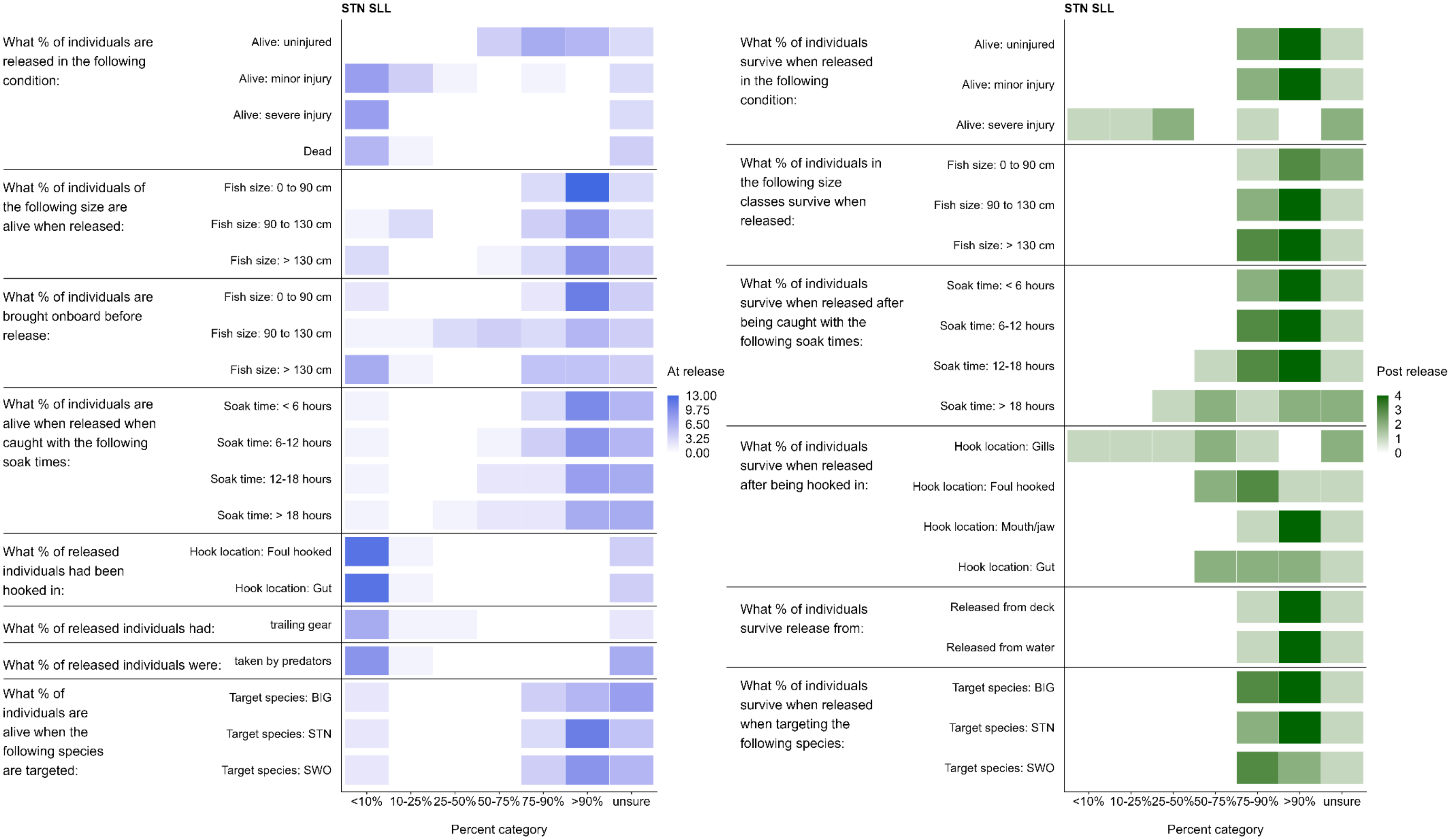


Figure 22: Results from the expert elicitation questionnaire for southern bluefin tuna (STN) caught by surface longline (SLL). Left: responses to questions on at-release survival. Right: responses to questions on post-release survival. Darker colours indicate a greater number of responses. BIG = bigeye tuna, SWO = swordfish.

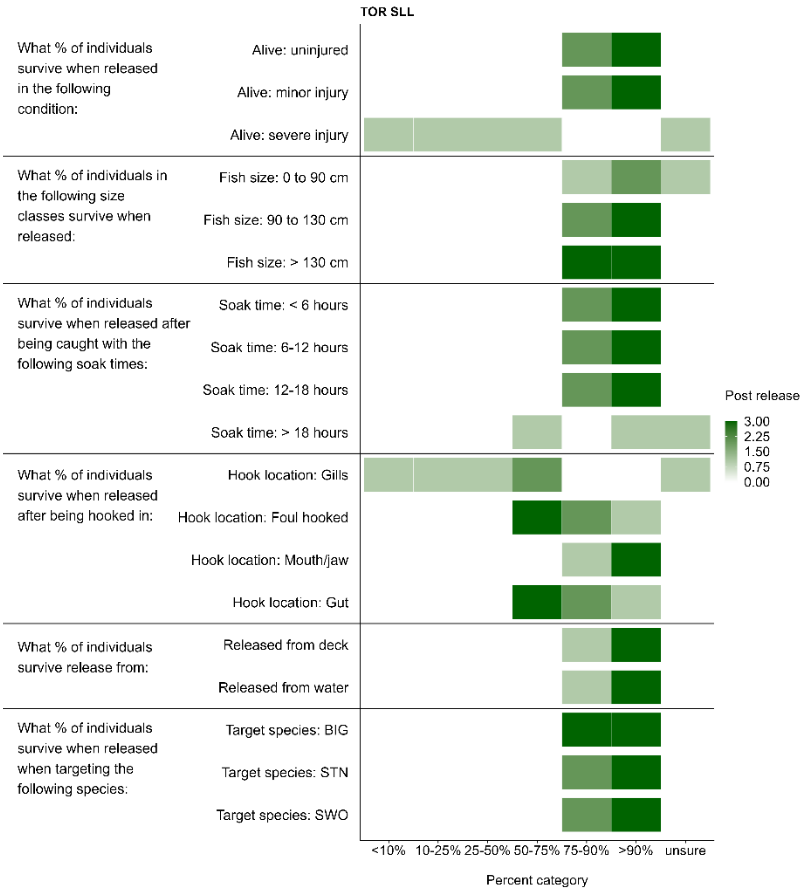


Figure 23: Results from the expert elicitation questionnaire for Pacific bluefin tuna (TOR) following release from surface longline (SLL) in New Zealand waters. Note this survey covered post-release survival; at-release survival questions were not asked for this species as releases of Pacific bluefin tuna are not currently permitted under the New Zealand Fisheries Act 1996. BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish.

3.1.4. Fishery survival probability estimates

Perceived survival probability estimates for each factor-category for southern bluefin tuna following release from surface longline, with and without priors from the literature applied, are provided in Figure 24. Perceived survival of southern bluefin tuna was estimated to be high for each category, although was reduced when fish were released with a severe injury (Figure 24). As the landing exceptions for this species stipulate that individuals must be alive and likely to survive (Table 1), severe injury was not included in the generation of survival estimates by factor (as individuals with severe injuries are unlikely to be released). When scaled to the proportional occurrence of each factor in the fishery, overall perceived survival estimates for southern bluefin tuna, with and without priors applied, were high (Figure 25).

Perceived survival probability estimates for each factor-category and factor for Pacific bluefin tuna following release from surface longline, with and without priors from the literature applied, are provided in Figure 26 and Figure 27. Perceived survival of Pacific bluefin tuna was estimated to be high for most categories, although it was reduced when fish were released with a severe injury or when gill-hooked (Figure 26). The slight difference in survival probability estimates between gill-hooked southern bluefin tuna and Pacific bluefin tuna resulted from a single survey respondent who considered post-release survival was high for the former species when gill-hooked but did not answer this question for the latter species (cf. Figures 22 and 23). As with southern bluefin tuna, when scaled to the proportional occurrence of each factor in the fishery, overall perceived survival probability estimates for Pacific bluefin tuna were high and were little influenced by the application of priors (Figure 27).

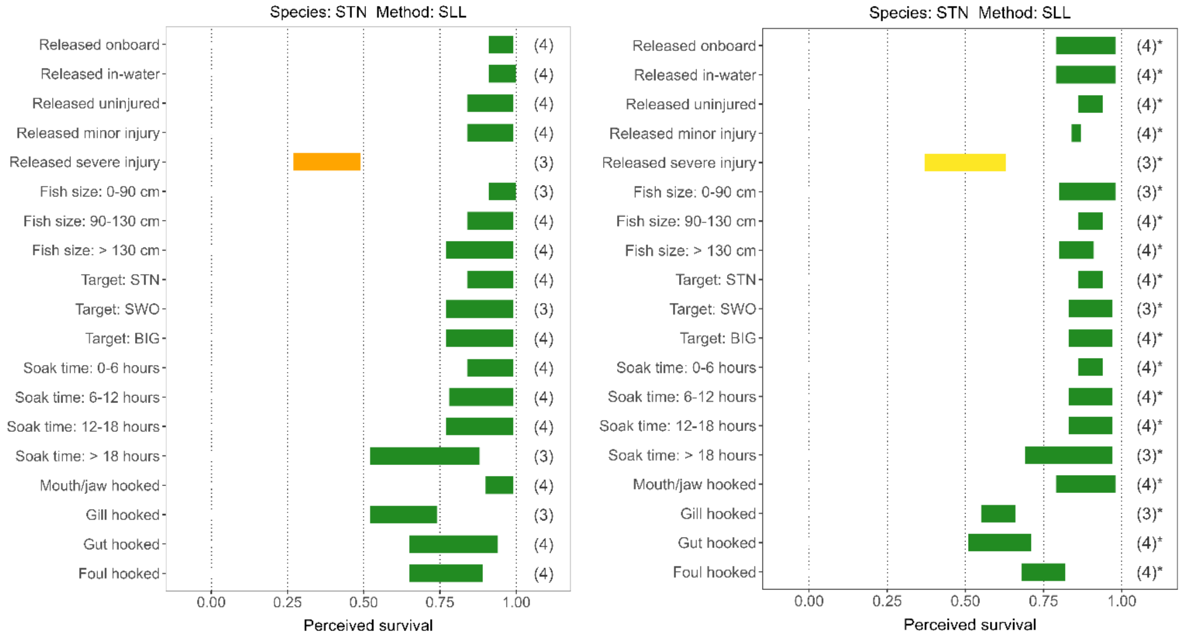


Figure 24: 90% confidence intervals on perceived post-release mean survival estimates for southern bluefin tuna (STN) following release from surface longline (SLL) in New Zealand waters by factor-category. Note this plot assumes all individuals released are alive at the time of release, consistent with current landing exceptions. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. The number in parentheses indicates the number of survey respondents. BIG = bigeye tuna, SWO = swordfish. See Table 4 and Figure 1 for an explanation of colours and survival categories.

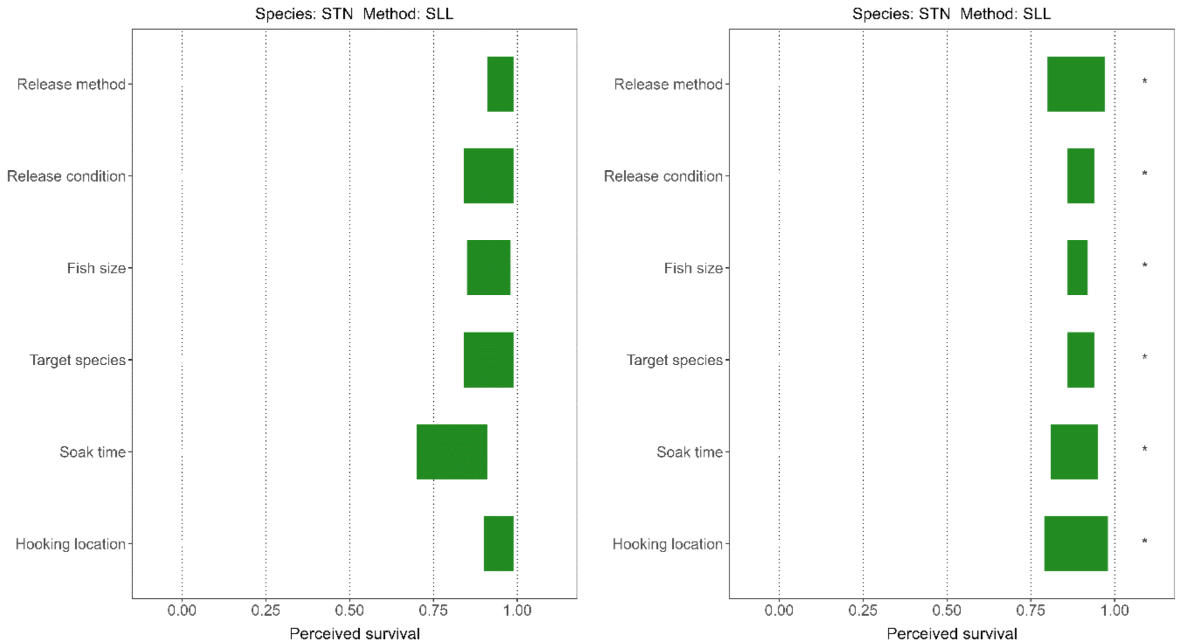


Figure 25: 90% confidence intervals on perceived post-release mean survival estimates for southern bluefin tuna (STN) following release from surface longline (SLL) in New Zealand waters by factor. Note this plot assumes all individuals released are alive at the time of release, consistent with current landing exceptions. Left: without priors applied; right: with priors applied. * denotes those factors informed by priors. See Table 4 and Figure 1 for an explanation of colours and survival categories.

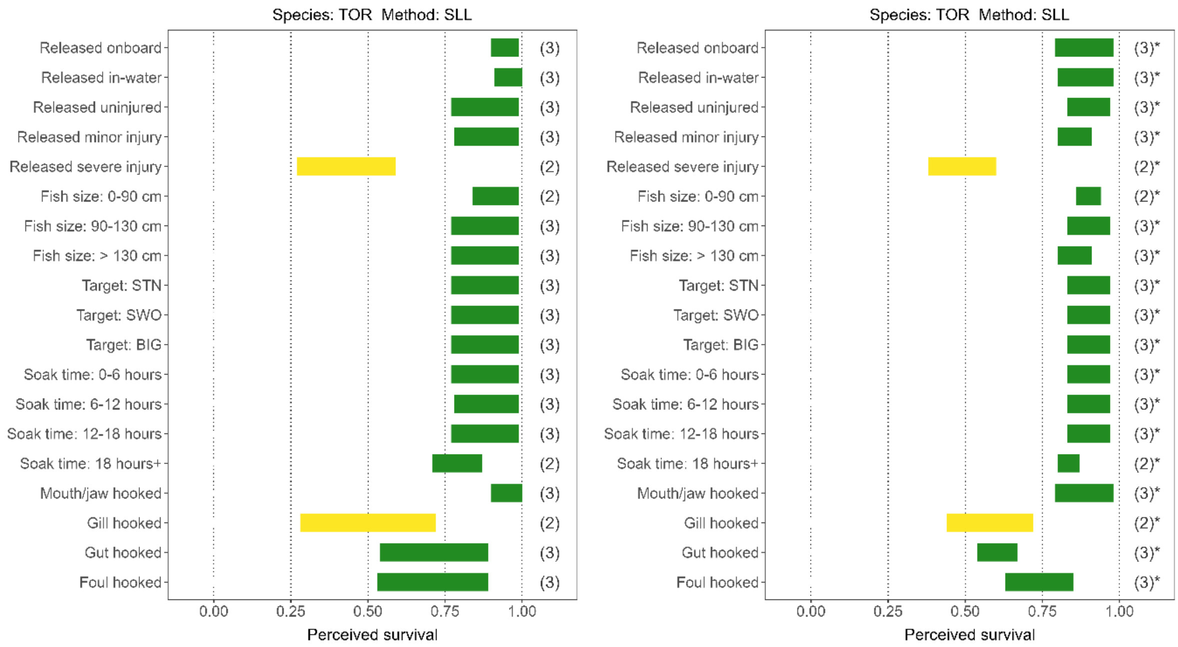


Figure 26: 90% confidence intervals on perceived post-release mean survival estimates for Pacific bluefin tuna (TOR) following release from surface longline (SLL) in New Zealand waters by factor-category. Note this plot assumes all individuals released are alive at the time of release, consistent with current landing exceptions. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. The number in parentheses indicates the number of survey respondents. BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish. See Table 4 and Figure 1 for an explanation of colours and survival categories.

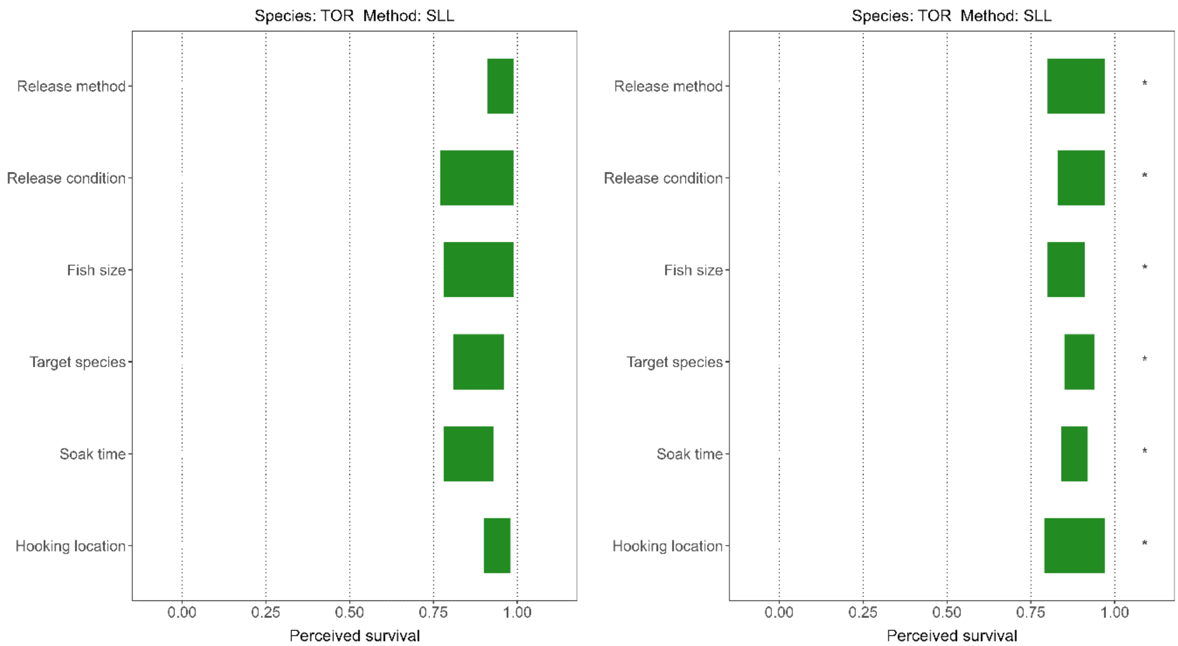


Figure 27: 90% confidence intervals on perceived post-release mean survival estimates for Pacific bluefin tuna (TOR) following release from surface longline (SLL) in New Zealand waters by factor. Note this plot assumes all individuals released are alive at the time of release, . Left: without priors applied; right: with priors applied. * denotes those factors informed by priors. See Table 4 and Figure 1 for an explanation of colours and survival categories.

3.2 Swordfish (*Xiphias gladius*)

3.2.1. Fishery characterisation

The annual mean total catch (i.e., including landings and disposals) of swordfish in the three-year period from 2019–02 to 2021–22 was 224.0 t (Table 10 and Figure 28). Annual average disposals were 1.4 t, representing 0.6% of the annual commercial catch by weight.

Surface longline and mid-water trawl were the main fishing methods resulting in swordfish disposals (Figure 29 and Figure 30). Between 2019–20 and 2021–22, surface longline accounted for 93.2% of total swordfish commercial captures but only 43.2% of disposals (Figure 29). Mid-water trawl accounted for 5.2% of captures but 54.3% of all swordfish disposals between 2019–02 and 2021–22 (Figure 29), with an estimated 0.8 t disposed per year. The other methods that accounted for disposals between 2019–2020 and 2021–22 were bottom trawl (0.07 t disposed, 1.6% of total disposals by weight), precision bottom trawl (0.03 t disposed, 0.6% of total disposals by weight), and bottom longline (0.01 t disposed, 0.2% of total disposals by weight).

In the last three fishing years, most (77.8%) disposals of swordfish from surface longline, and all disposals from trawl, have been attributed to disposal code X (i.e., alive and likely to survive) (Figure 31).

Most of the swordfish catch and disposals by surface longline in the last three fishing years was taken off the east coast of the North Island in fishing events targeting bigeye tuna (*Thunnus obesus*) (Figure 32, Figure 33, Figure 34). Most of the swordfish catch and disposals by trawl in the last three fishing years was taken off the west coast of the South Island (Figure 35), when jack mackerel (*Trachurus* spp.; JMA) and hoki (*Macruronus novaezelandiae*) were targeted (Figure 33).

Table 10: Catches of swordfish in New Zealand by weight and proportion by destination and fishing year, 2004–05 to 2021–2022.

	Total catch (t)			Proportion		
Fishing year	Landed	Discarded	Released	Landed	Discarded	Released
2005	343.93	0.71	–	0.998	0.002	–
2006	558.27	0.61	–	0.999	0.001	–
2007	791.69	0.23	0.22	0.999	0.000	0.000
2008	350.81	0.81	–	0.998	0.002	–
2009	393.45	0.03	–	1.000	0.000	–
2010	537.60	0.01	0.25	1.000	0.000	0.000
2011	731.14	0.17	0.20	0.999	0.000	0.000
2012	682.63	–	0.83	0.999	–	0.001
2013	795.15	0.20	0.95	0.999	0.000	0.001
2014	572.56	0.63	2.24	0.995	0.001	0.004
2015	726.97	0.44	3.12	0.995	0.001	0.004
2016	730.85	0.78	1.72	0.997	0.001	0.002
2017	497.32	0.29	1.32	0.997	0.001	0.003
2018	476.72	0.54	1.98	0.995	0.001	0.004
2019	257.36	0.01	0.69	0.997	0.000	0.003
2020	217.30	0.17	0.60	0.996	0.001	0.003
2021	308.75	0.21	0.94	0.996	0.001	0.003
2022	141.85	0.03	2.21	0.984	0.000	0.015

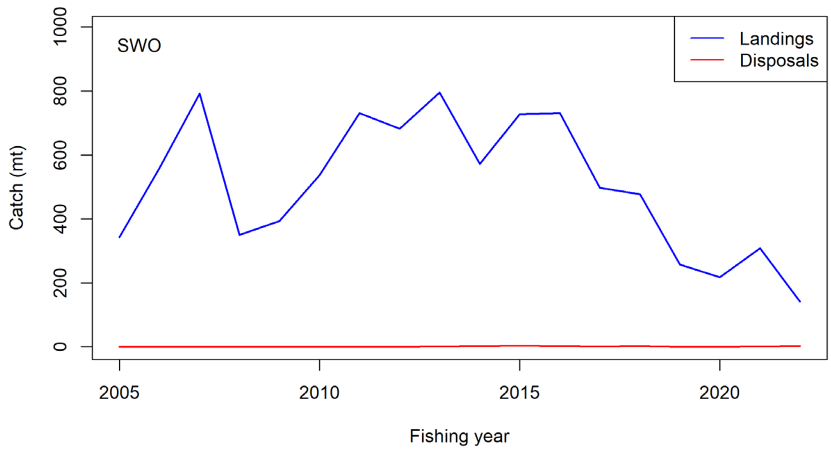


Figure 28: Annual commercial landings and disposals of swordfish (SWO) in New Zealand's Exclusive Economic Zone from 2004–05 (2005) to 2021–22 (2022).

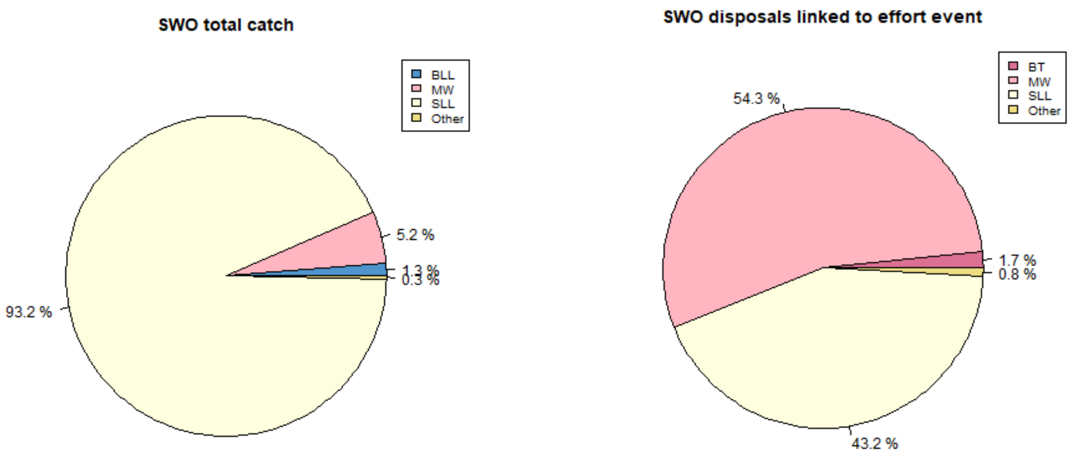


Figure 29: Swordfish (SWO) total catches (left) and disposals (right) in New Zealand's Exclusive Economic Zone by fishing method, 2019–20 to 2021–22. BLL = bottom longline; BT = bottom trawl; MW = mid-water trawl; SLL = surface longline.

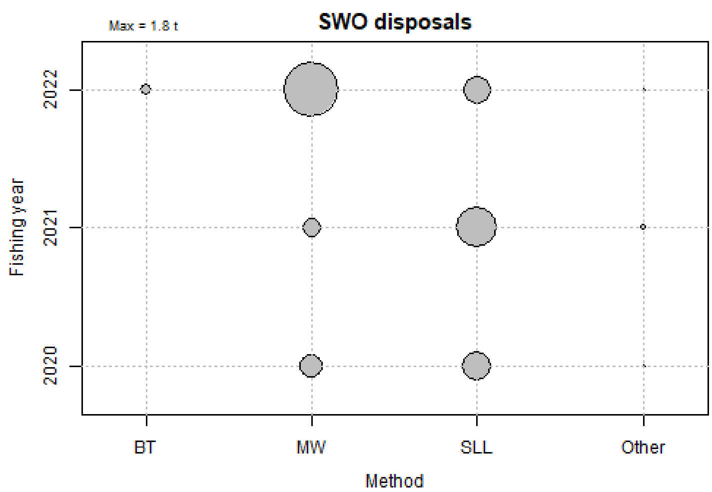


Figure 30: Disposals of swordfish (SWO) by fishing method in New Zealand's Exclusive Economic Zone from 2019–20 to 2021–22. BT = bottom trawl; MW = mid-water trawl; SLL = surface longline.

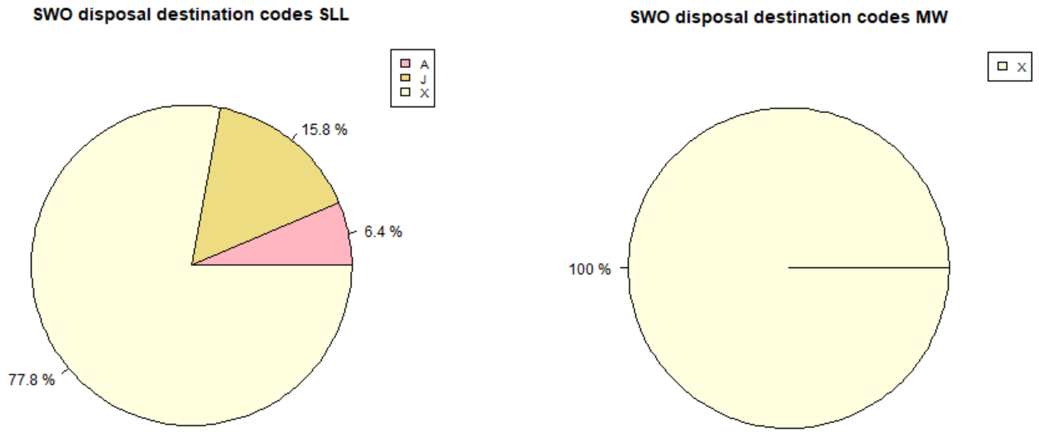


Figure 31: Codes attributed to disposals of swordfish (SWO) from the surface longline (SLL; left) and mid-water trawl (MW; right) fisheries in New Zealand's Exclusive Economic Zone between 2019–20 and 2021–22.

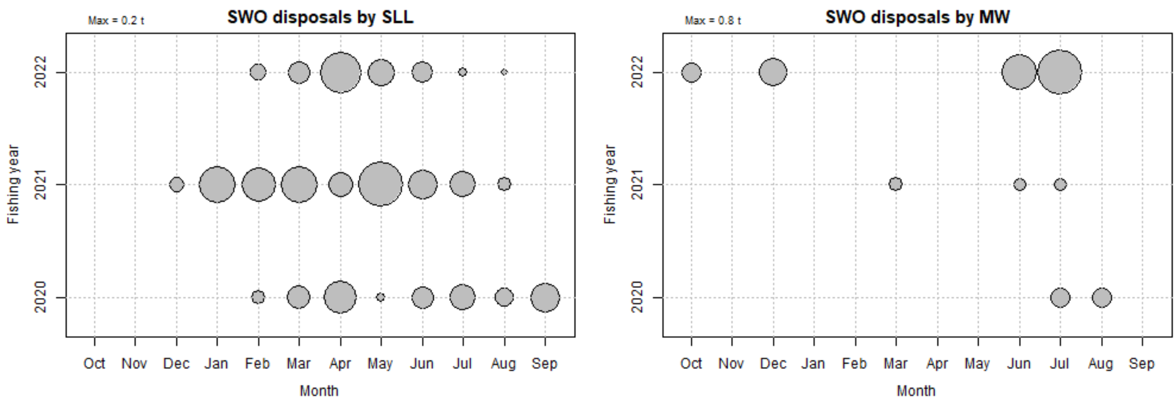


Figure 32: Disposals of swordfish (SWO) by month in New Zealand's Exclusive Economic Zone from 2019–20 to 2021–22 for surface longline (SLL: left) and mid-water trawl (MW; right).

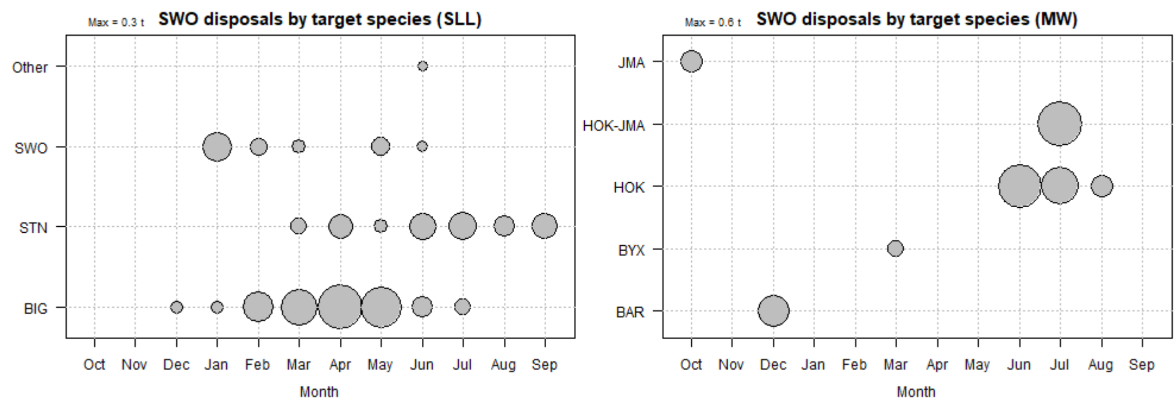


Figure 33: Disposals of swordfish (SWO) by month and target species in New Zealand's Exclusive Economic Zone for 2019–20 to 2021–22 for surface longline (SLL; left) and mid-water trawl (MW; right). STN = southern bluefin tuna, BIG = bigeye tuna; JMA = jack mackerel; HOK – hoki, BYX = *Beryx* spp.; BAR = barracouta.

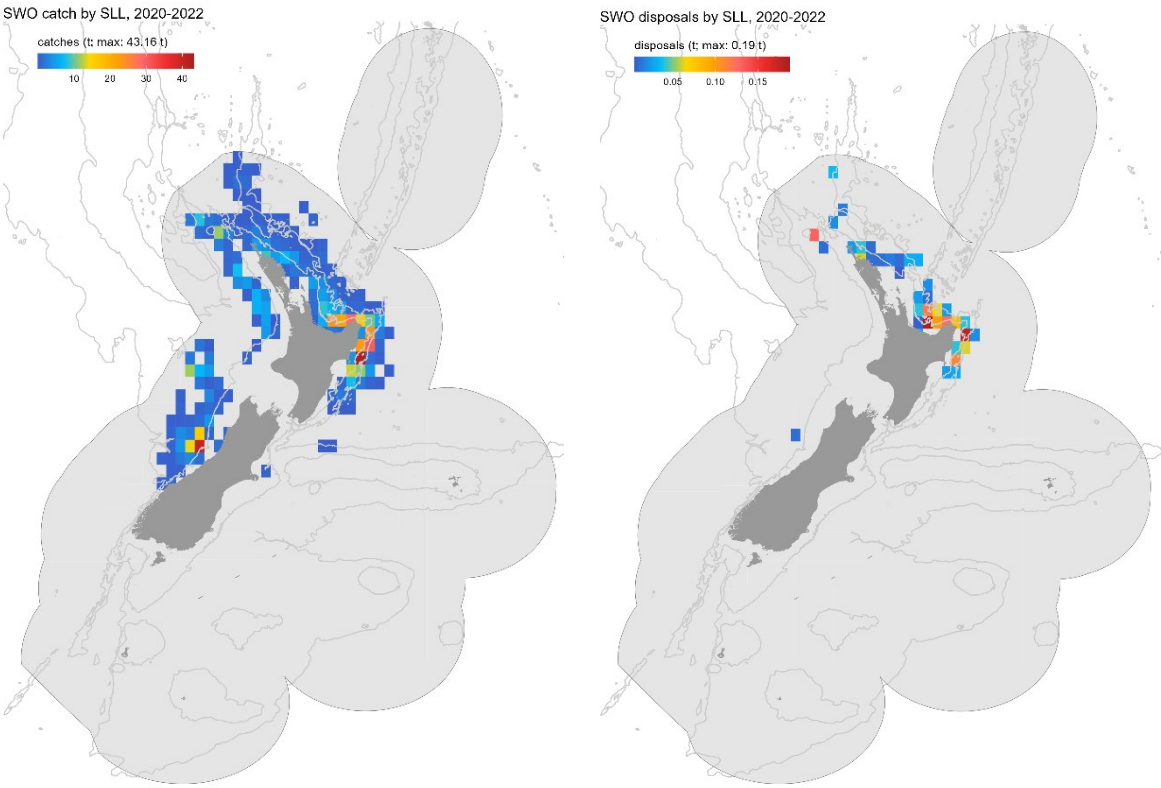


Figure 34: Total catches (including disposals; left) and disposals (right) of swordfish (SWO) by surface longline (SLL) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

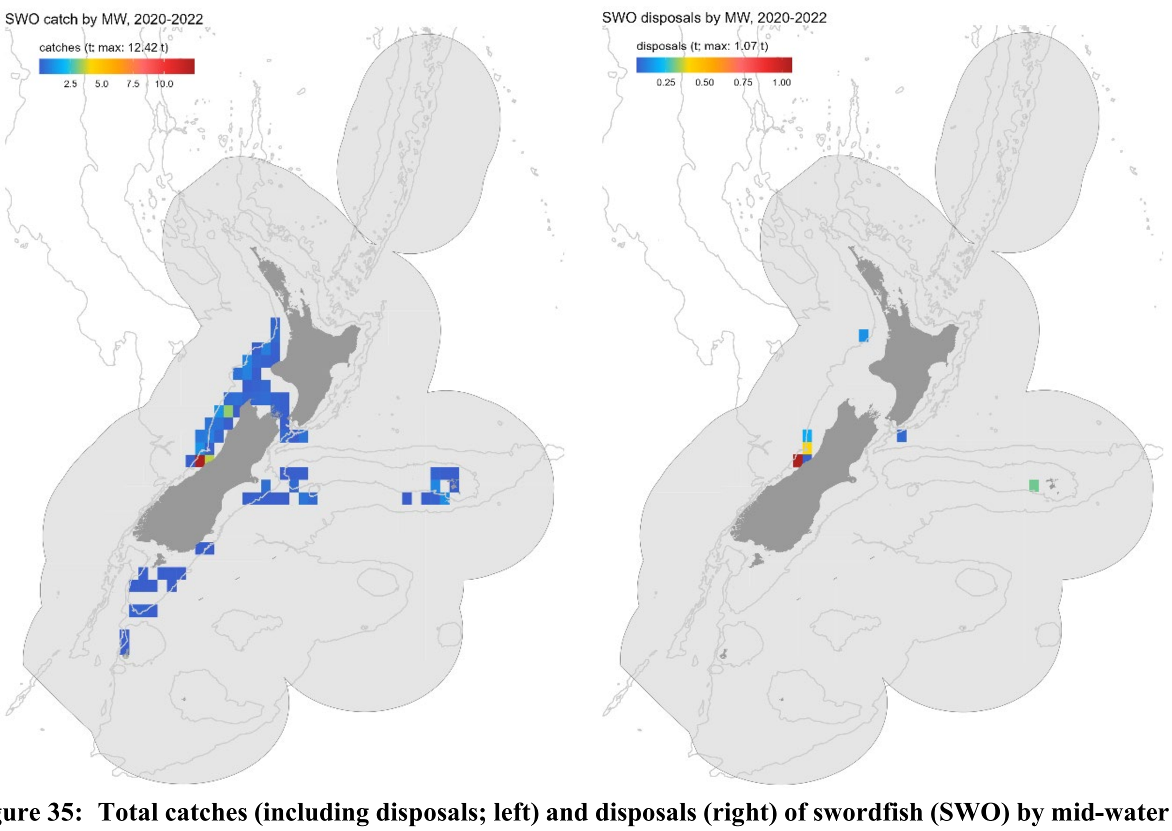


Figure 35: Total catches (including disposals; left) and disposals (right) of swordfish (SWO) by mid-water trawl (MW) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

Since 2005, almost 9000 swordfish captures have been observed by fisheries observers on surface longline vessels. The vast majority of swordfish observed has been landed, with only small swordfish being disposed (Figure 36 and Figure 37). At-vessel survival rates of swordfish have typically been around 25–30% (i.e., 70–75% mortality), with survival generally increasing with fish size (Figure 38 and Figure 39). Targeting behaviour appeared to have little influence on swordfish at-vessel survival, with approximately equal survival rates when bigeye tuna, southern bluefin tuna, swordfish, or Pacific bluefin tuna were targeted (Figure 39). Swordfish were more likely to be reported dead for fishing events with longer soak times and when foul-hooked (89% of foul-hooked swordfish were reported as being dead at retrieval) (Figure 40).

Life status of swordfish caught in trawl fisheries is not currently recorded. Based on observer data collected since 2005, the mean size of swordfish caught in trawl fisheries was 254 LJFL cm (range = 195–371 cm, n = 12).

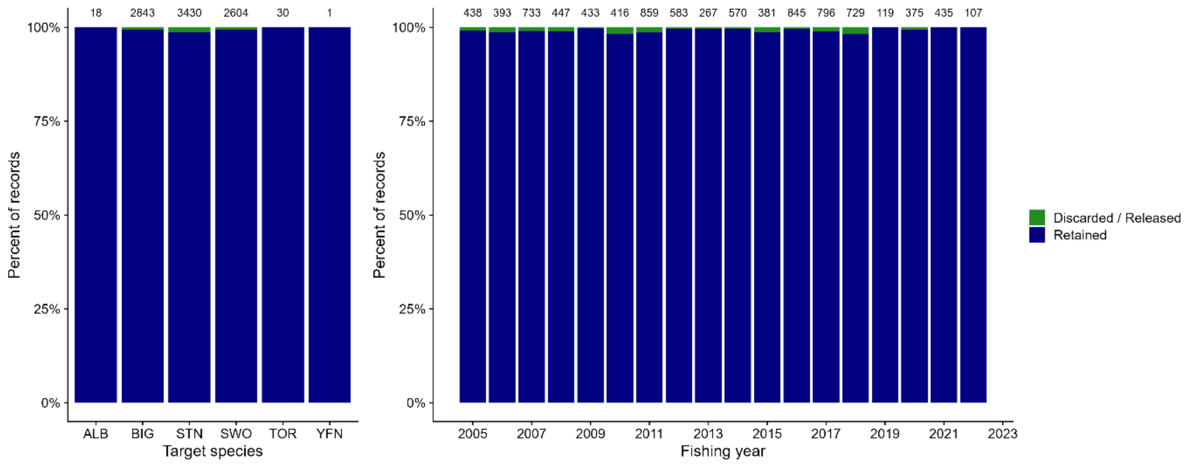


Figure 36: Fate of swordfish (SWO) from observer records from the surface longline fishery by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. ALB = albacore tuna, BIG = bigeye tuna, STN = southern bluefin tuna, TOR = Pacific bluefin tuna, YFN = yellowfin tuna.

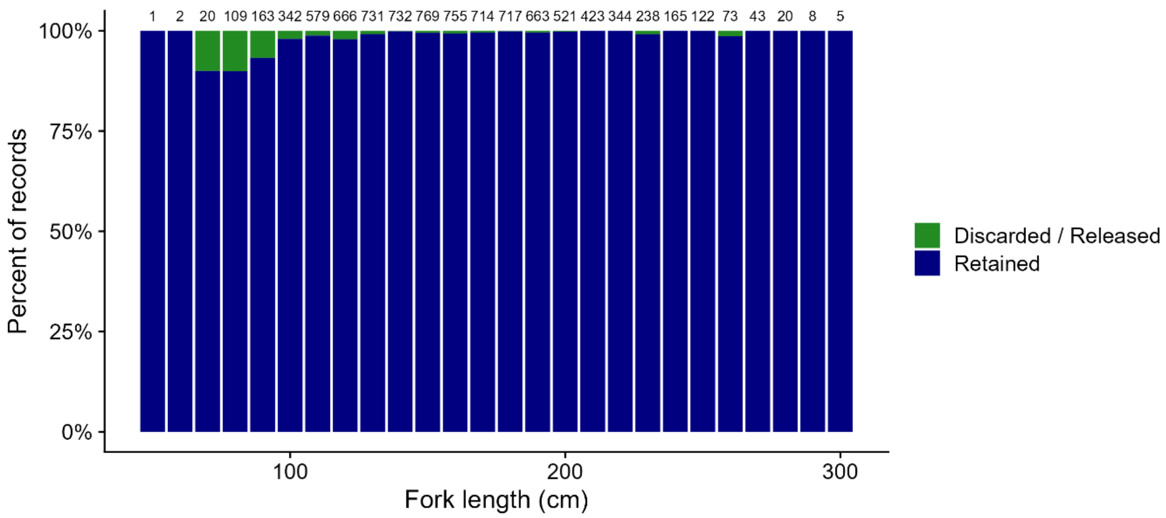


Figure 37: Fate of swordfish by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

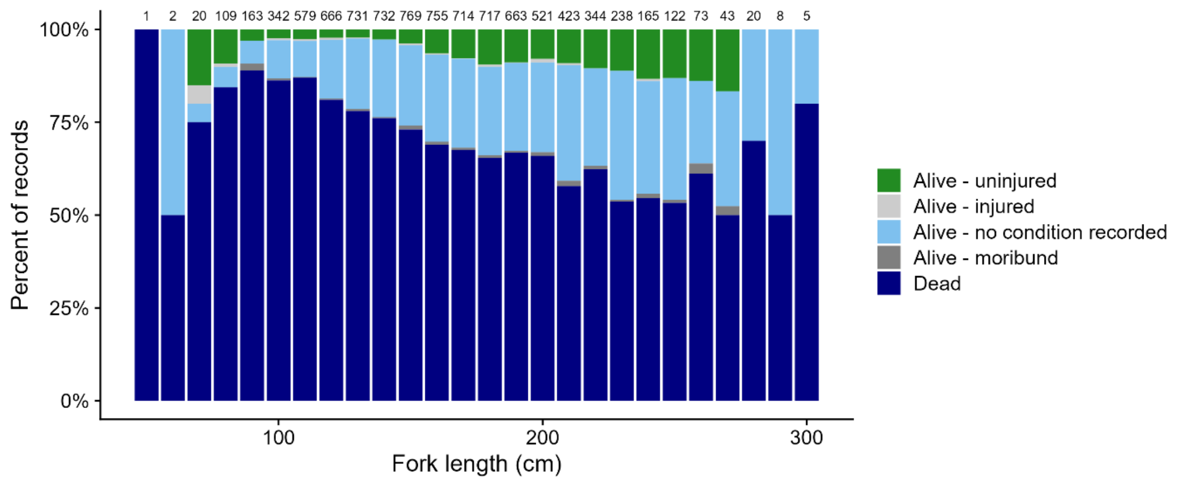


Figure 38: Life status at haul of swordfish by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

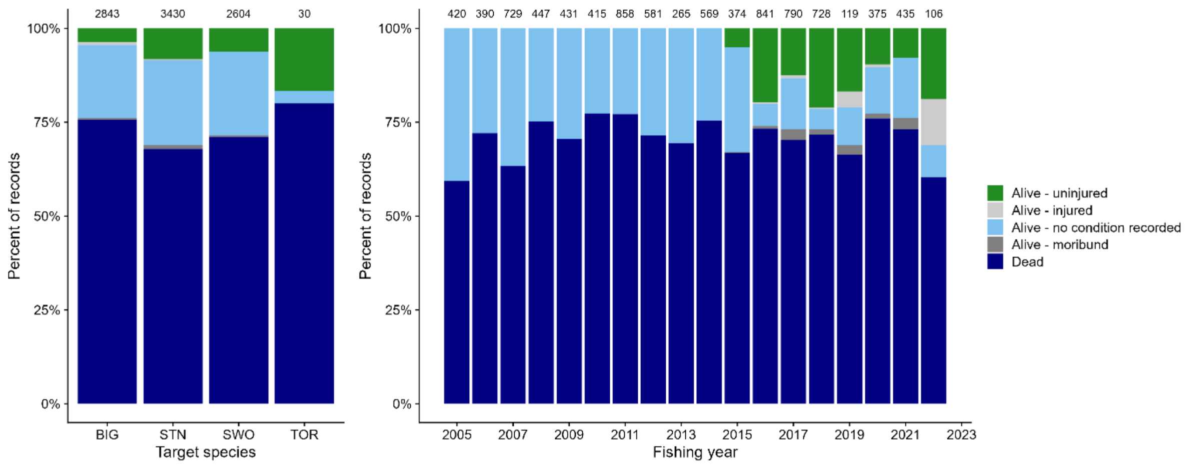


Figure 39: Life status of swordfish (SWO) from observer records from the surface longline fishery at-vessel by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. BIG = bigeye tuna, STN = southern bluefin tuna, TOR = Pacific bluefin tuna.

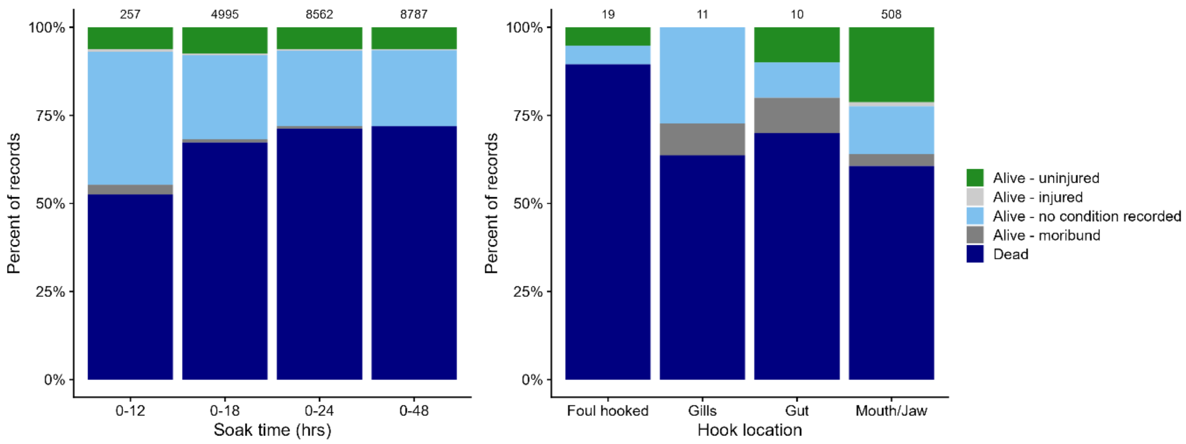


Figure 40: Life status of swordfish from observer records from the surface longline fishery at-vessel by soak time (left) and hooking location (right). Numbers above the columns indicate sample sizes.

3.2.2. Review of at-vessel and post-release survival studies

Swordfish are a highly mobile species, found in all tropical and temperate oceans and large seas from approximately 50° N to 50° S. They reach a maximum size of 445 cm total length and around 540 kg in weight. They occupy a broad thermal niche, occurring in waters from as cool as 3 °C to over 30 °C and from surface waters to depths greater than 700 m. They undertake diurnal migrations, occurring in deeper waters during the day and surface waters at night, and are capable to experiencing large and rapid temperature changes (> 20 °C) (Dewar et al. 2011).

Several studies have assessed at-vessel survival of swordfish following capture by surface longline. Estimates from these studies are comparable with those presented in Section 3.2.1, with typically less than 40% of individuals alive at hauling (Table 11). Hook type is routinely observed to have a significant influence on at-vessel survival of swordfish, with higher survival rates when swordfish are caught using circle hooks than J-hooks or tuna hooks, while smaller fish typically have higher at-vessel survival rates than larger fish (Table 11).

Fewer studies have assessed post-release survival of swordfish following capture in commercial surface longline fisheries (Table 12). Holdsworth et al. (2010) tagged 19 swordfish caught by surface longline in New Zealand. Of these, 17 tags transmitted data, with five of these detaching prematurely, and two fish considered mortalities soon after release (i.e., an 88% post-release survival rate). Abascal et al. (2010) report post-release survival rates of 60% for swordfish tagged opportunistically from commercial longline vessels in the southeast Pacific Ocean. Dewar et al. (2011) report survival rates of 78% and 62% for swordfish caught in the North Atlantic Ocean and eastern Pacific Ocean, respectively, using a combination of recreational fishing, commercial longline, research longline, and harpooning. However, the primary objective of both studies was to assess movements, with Abascal et al. (2010) reporting that only fish in 'prime condition' were tagged. Studies conducted in the tropical and sub-tropical regions of the Indian Ocean (e.g., Evgeny et al. 2023, Nieblas et al. 2023) have generally observed low post-release survival of swordfish caught by surface longlines (Table 12). In contrast, studies on other billfish species, including blue marlin (*Makaira nigricans*), striped marlin (*Tetrapturus audax*), white marlin (*Kajikia albida*), and sailfish (*Istiophorus platypterus*), have generally reported relatively high survival rates following capture and release from surface longlines (> 60%) (Table 13).

To our knowledge there have been no studies assessing at-vessel or post-release survival of swordfish in commercial trawl fisheries.

Table 11: Summary of studies examining at-vessel survival swordfish in commercial fisheries. SLL = surface longline; FL = fork length; SST = sea surface temperature. Factors in bold font had a significant influence on survival.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	North Atlantic Ocean	1 271	~20%	**Hook type** (circle > J-hooks), soak time (short > long), **FL** (small > large)	Study examined survival at-vessel	Carruthers et al. (2009)
Commercial SLL	Indian Ocean	389	20%	FL	Study examined survival at-vessel	Poisson et al. (2010)
Commercial SLL	Pacific Ocean (Hawaii)	1 498	45%–67%	**Hook type** (circle and J-hooks > tuna hooks)	Study examined survival at-vessel	Curran & Bigelow (2011)
Commercial SLL	Atlantic Ocean	608	10–14%	**Hook type**	Study examined survival at-vessel	Pacheco et al. (2011)
Commercial SLL	North Atlantic Ocean	16 372	28–36%	**Hook type** (18/0 circle with 10° offset > 18/0 circle no offset > 9/0 J-hooks 10°–30° offset), **bait, SST**, **soak time**, FL, **hooking location**	Study examined survival at-vessel	Epperly et al. (2012)
Commercial SLL	Atlantic Ocean	561	15%	Hook type	Study examined survival at-vessel	Huang et al. (2016)
Commercial SLL	Atlantic Ocean	26 490	15%	**FL**, **sex**, longitude, **latitude**, **SST**, **fleet type**, leader material, bait, soak time	Study examined survival at-vessel	Coelho & Muñoz-Lechuga (2019)
Commercial SLL	Atlantic Ocean (Brazil)	571	10%–20%	**Hook type** (small circle > J > large circle)	Study examined survival at-vessel	Nunes et al. (2019)
Commercial SLL	Indian Ocean	1 144	36%	Sex, **FL**, SST, dissolved oxygen, **quarter**, **longitude**, latitude, **hook type**, target species	Study examined survival at-vessel	Guo et al. (2022)

Table 12: Summary of studies examining post-release survival of swordfish in commercial fisheries. SLL = surface longline; FL = fork length; SST = sea surface temperature.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	Southeast Pacific Ocean	21	60%	–	Primary purpose of study was to track fish movements – only fish in "prime condition" were tagged	Abascal et al. (2010)
Commercial SLL	New Zealand	17	88%	–	Primary purpose of study was to track fish movements. 19 fish were tagged but two tags failed to submit.	Holdsworth et al. (2010)
Recreational \ LL	Atlantic Ocean, Caribbean	9	78%	–	Primary purpose of study was to track fish movements	Dewar et al. (2011)
Commercial SLL \ harpoon	Eastern Pacific Ocean	13	62%			
Commercial SLL	Southwest Indian Ocean (South Africa)	11	36%	Duration after being hooked, behaviour, fish size	Only 11 of the 59 individuals captured were considered appropriate for tagging. No effect of duration after being hooked, behaviour, or fish size on release success. Four of eleven fish survived beyond one week from tagging event.	West et al. (2012)
Mixed but mainly commercial SLL	Atlantic and Mediterranean	16	50%	–		Rosa et al. (2022)
Commercial SLL	Indian Ocean	7	14%	–	All seven tags failed to report, 6 of these were considered to represent mortalities.	Nieblas et al. (2023)
Commercial SLL or buoy gear	Indian Ocean	7	57%	–	Three mortalities from seven tags; one within 2 days, one predated immediately, and one at 67 days.	Evgeny et al. (2023)

Table 13: Summary of studies examining post-release survival of other billfish species in commercial fisheries. SLL = surface longline; FL = fork length; SST = sea surface temperature; BEM = blue marlin (*Makaira nigricans*); STM = striped marlin (*Tetrapturus audax*); WHM = white marlin (*Kajikia albida*); SAI = sailfish (*Istiophorus platypterus*). Factors in bold font had a significant influence on survival.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	North Atlantic Ocean	9	78%	Soak time, fish weight	Maximum soak times of tagged fish between 6 and 35 hours (mean = 15 hours); tracking period = 5–30 days	BEM; Kerstetter et al. (2003)
Commercial SLL	Atlantic Ocean	-	90%	-	Primary purpose of study was to track fish movements	BEM; Matsumoto et al. (2002, 2003, 2004)
Commercial SLL	Pacific Ocean (Hawaii)	6	83%	FL, fish weight	Primary purpose of study was to track fish movements	STM; Brill et al. (1993)
Commercial SLL	Pacific Ocean (Hawaii)	22	86%	-	Primary purpose of study was to track fish movements	STM; Lam et al. (2022)
Commercial SLL	North Atlantic Ocean	20	63%–90%	Hook type, **hooking location**, FL, fish weight, time of day, SST, location	Fish not brought on board; Tracking to 43 days; Soak time not reported	WHM; Kerstetter & Graves (2006)
Commercial SLL	Gulf of Mexico	17	88%	Hook type, hooking location, FL	Fish not brought on board; Tracking to 10 days; Soak time ~same for all individuals	SAI; Kerstetter & Graves (2008)

3.2.3. Expert elicitation

Reasons for release

Stakeholders indicated that most of the swordfish released as disposals are small (typically less than 100 cm), as these individuals fetch low prices per kilogram.

At-release survival – surface longline

Survey respondents indicated that most swordfish that are returned to the sea after capture by surface longline are alive and uninjured (> 90%), with respondents indicating that only a small percentage (< 10%) of fish are released with minor injuries, severe injuries, or dead (Figure 41). Survey respondents indicated that most swordfish are brought on board prior to release, particularly for smaller individuals, with a slightly greater proportion of larger swordfish being released in the water (when released) (Figure 41). As with southern bluefin tuna, workshop participants indicated that this was so fishing gear could be retrieved, minimising time and costs associated with replacing gear, and that this was a relatively quick and easy process, particularly for smaller fish. Survey respondents suggested that targeting behaviour had little influence on life status of swordfish, while longer soak times were generally associated with reduced survival and greater uncertainty (Figure 41). Most survey respondents suggested the only a small percentage released swordfish are foul-hooked, hooked in the gut, or taken by predators following release (< 10%) (Figure 41).

Post-release survival – surface longline

Two respondents answered questions relating to post-release survival of swordfish following capture by surface longline gear (Figure 41). There was a large degree of uncertainty in the responses, with one respondent suggesting survival was generally between 25 and 75% and the other suggesting survival was high (> 75%) (Figure 41). When released uninjured, both survey respondents considered survival to be high (> 75%). Survey respondents considered that survival was not influenced by targeting behaviour, or whether swordfish were released from on board the vessel or in water. Survey respondents considered survival to be reduced when swordfish were foul-hooked, gut-hooked, or hooked in the gills relative to being hooked in the mouth/jaw, and when soak times exceeded 12 hours (Figure 41).

At-release survival and post-release survival – trawl

Four respondents answered questions relating to at-release survival of swordfish following capture by trawl gear (Figure 42). Respondents indicated that most often swordfish are released uninjured or with only minor injuries, and the percentage of swordfish released alive does not vary with fishing depth, tow duration, or catch weight (as would be expected under the current release requirements for this species) (Figure 42).

Only a single respondent answered questions regarding post-release survival of swordfish following capture by trawl gear (Figure 42), with several scientific experts advising they were not comfortable answering these questions due to a lack of documented information (e.g., published studies on post-release survival). The respondent considered survival to be uncertain, with responses typically ranging from < 10% to 50% survivability, although post-release survival was considered to be reduced (< 25%) when swordfish were returned to the water with severe injuries (Figure 42).

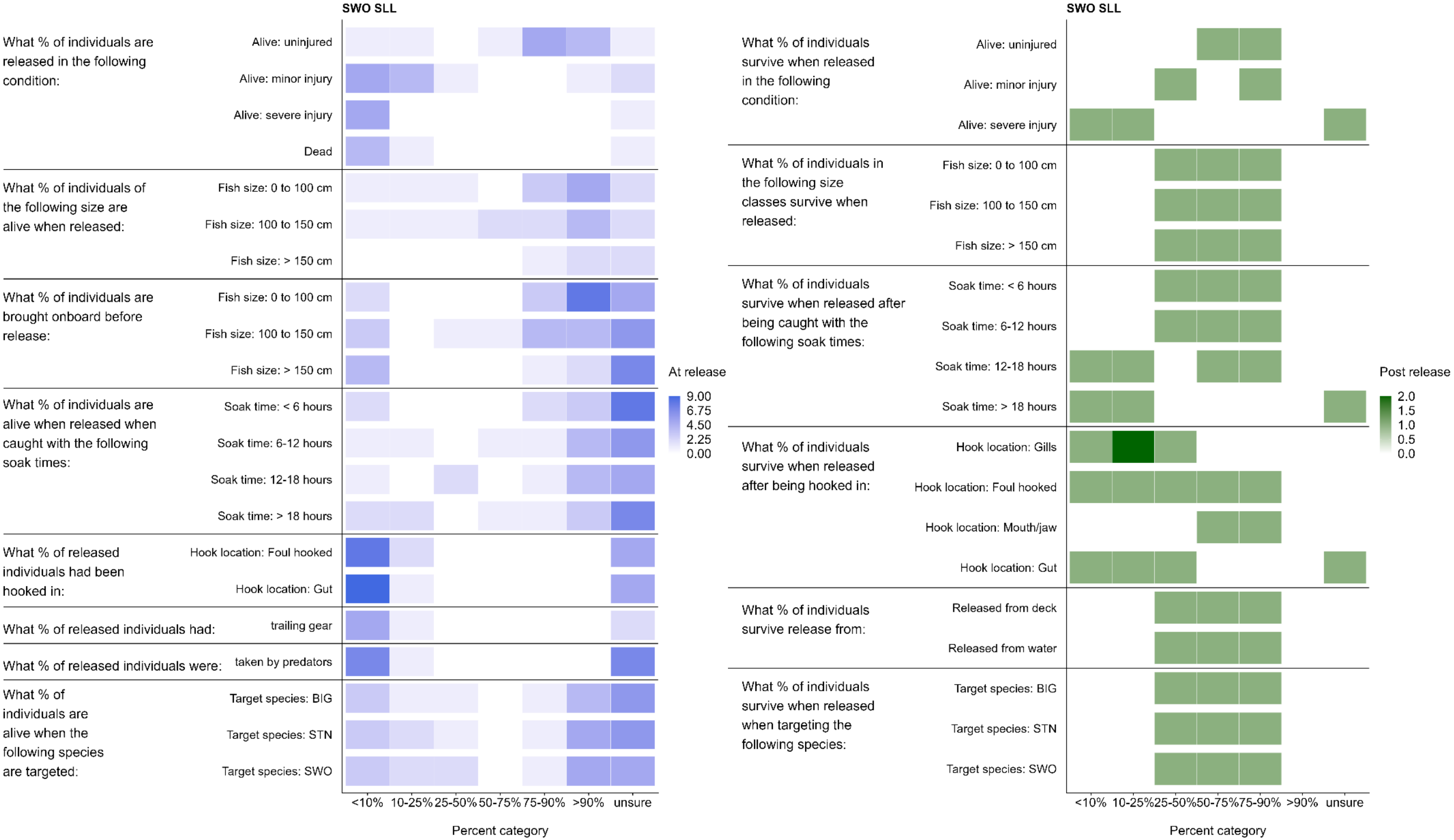


Figure 41: Results from the expert elicitation questionnaire for swordfish (SWO) caught by surface longline (SLL). Left: responses to questions on at-release survival. Right: responses to questions on post-release survival. Darker colours indicate a greater number of responses. BIG = bigeye tuna; STN = southern bluefin tuna.

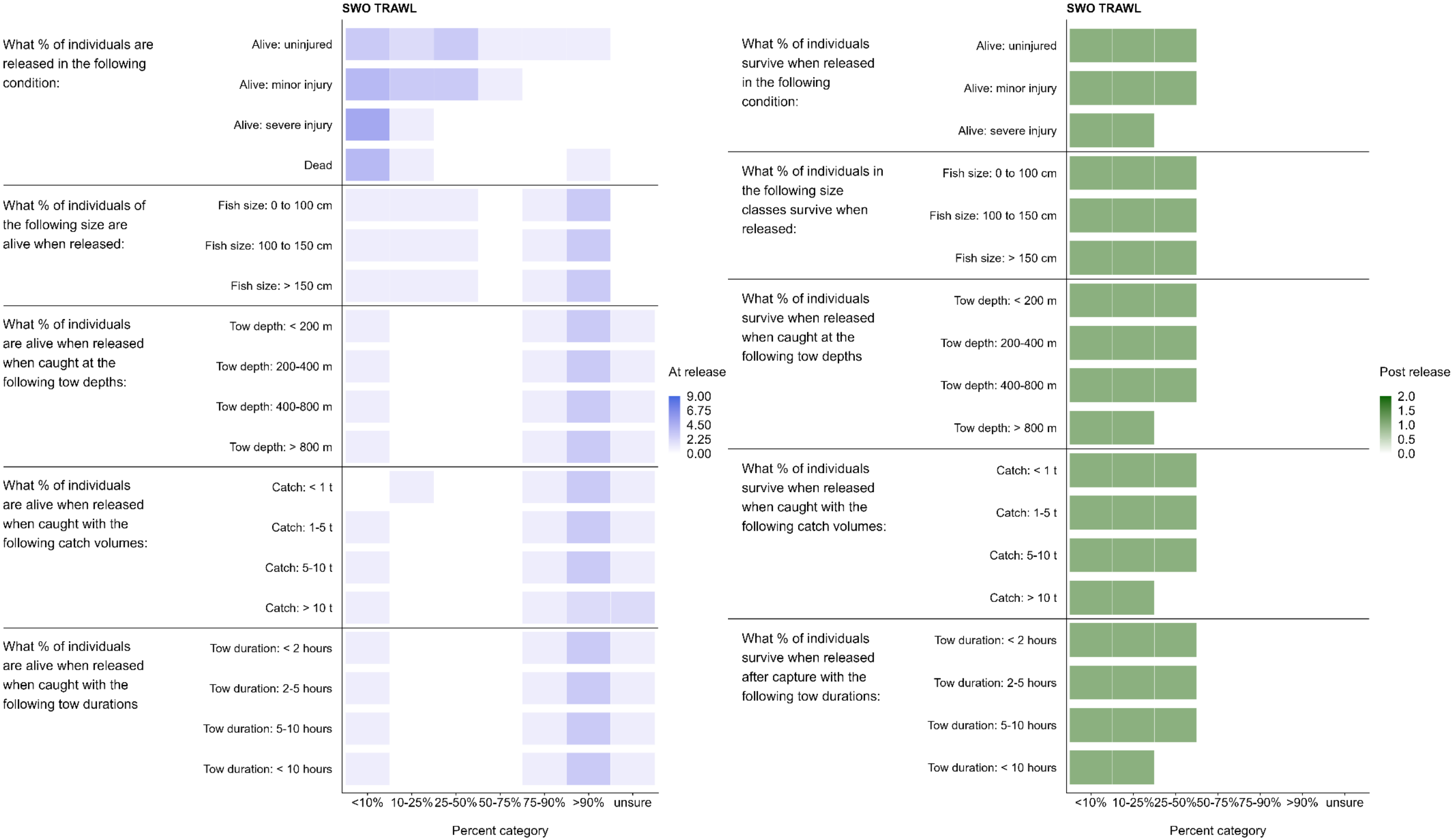


Figure 42: Results from the expert elicitation questionnaire for swordfish (SWO) caught by trawl. Left: responses to questions on at-release survival. Right: responses to questions on post-release survival. Darker colours indicate a greater number of responses.

3.2.4. Fishery survival probability estimates

Surface longline

Perceived survival estimates for swordfish following release after capture by surface longline for each fishery factor-category and factor are presented in Figure 43 and Figure 44, respectively. Swordfish were estimated to have high (greater than 50%) survival following release, although survival was estimated to be greatly reduced in individuals released with a severe injury, with longer soak times, and when gill-hooked, gut-hooked, or foul-hooked (Figure 43). When aggregated across the fishery profile, survival probabilities across all factors were estimated as being high (> 50%), with the exception of soak time (Figure 44). As soak time was considered to significantly affect at-vessel survival, it is likely that released swordfish would have been on the line for short durations only. Accordingly, on recommendation of the HMSWG, soak time was not considered in the final survival determination for this species. As a consequence, post-release survival of swordfish from surface longline was estimated to be high.

Trawl

Perceived survival estimates for swordfish following release after capture by mid-water trawl for each fishery factor-category and by factor are presented in Figure 45 and Figure 46, respectively. Swordfish were estimated to have low-medium survival following release across the assessed factor categories, although survival was estimated to be low for individuals released with a severe injury, when catches exceeded 10 t, or when tows exceeded 10 hours in duration or 800 m in depth (Figure 45). When aggregated across the fishery profile, survival probabilities across all factors were estimated as being low-medium (Figure 46). As such, post-release survival of swordfish from mid-water trawl was estimated to be low-medium. It should be stressed however, that these estimates were based on the responses of a single survey respondent, and were not informed by priors, given a lack of published research on post-release survival of swordfish from trawl fisheries anywhere in the world.

Figure 43: 90% confidence intervals on perceived post-release mean survival estimates for swordfish (SWO) following release from surface longline (SLL) in New Zealand waters by factor-category. Note this plot assumes all individuals released are alive at the time of release, and no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents. BIG = bigeye tuna, STN = southern bluefin tuna. See Table 4 and Figure 1 for an explanation of colours and survival categories.

Figure 44: 90% confidence intervals on perceived post-release mean survival estimates for swordfish (SWO) following release from surface longline (SLL) in New Zealand waters by factor. Note this plot assumes all individuals released are alive at the time of release, and no priors were applied to these particular factors. See Table 4 and Figure 1 for an explanation of colours and survival categories.

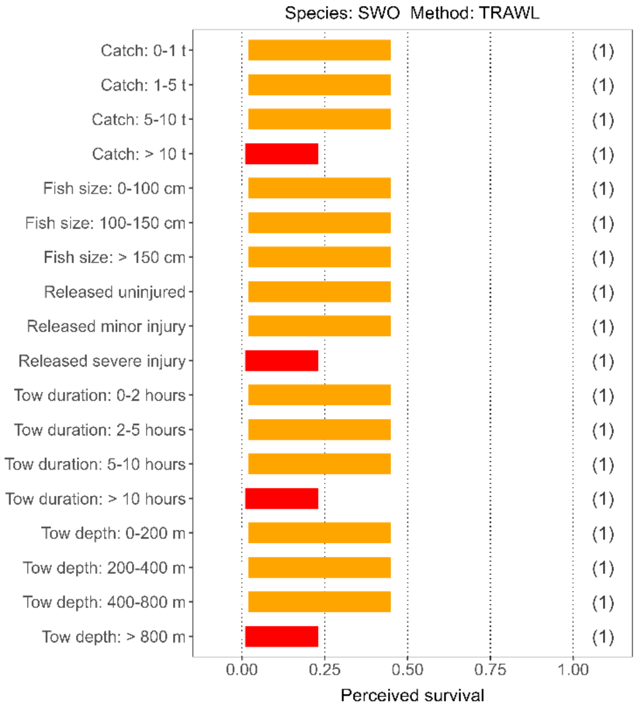


Figure 45: 90% confidence intervals on perceived post-release mean survival estimates for swordfish (SWO) following release from mid-water trawl in New Zealand waters by factor-category. Note this plot assumes all individuals released are alive at the time of release, and no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents. See Table 4 and Figure 1 for an explanation of colours and survival categories.

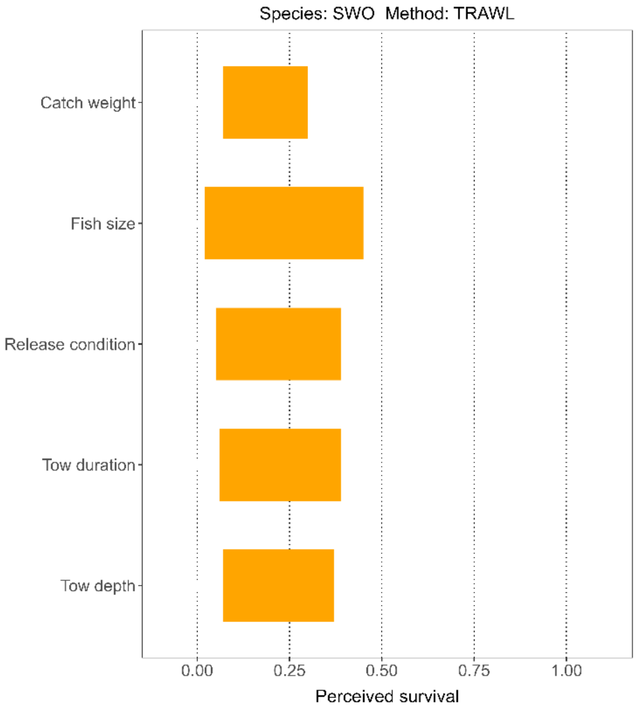


Figure 46: 90% confidence intervals on perceived post-release mean survival estimates for swordfish (SWO) following release from mid-water trawl in New Zealand waters by factor. Note this plot assumes all individuals released are alive at the time of release, and no priors were applied to these particular factors. See Table 4 and Figure 1 for an explanation of colours and survival categories.

3.3 Blue shark (*Prionace glauca*)

3.3.1. Fishery characterisation

Since the ban on shark finning in 2015, almost all blue shark catches are now discarded or actively released (Table 14). The annual mean total catch (i.e., including landings and disposals) of blue shark in the three-year period from 2019–02 to 2021–22 was 588.0 t (Table 14 and Figure 47). Annual average disposals were 587.6 t, representing 99.9% of the total annual commercial catch by weight.

Surface longline accounted for ca. 96% of total blue shark commercial captures and 98.3% of all blue shark disposals between 2019–20 and 2021–22 (Figure 48 and Figure 49). Small numbers of disposals of blue shark were reported from several other fishing methods between 2019–20 and 2021–22, the most significant being mid-water trawl (10.2 t of disposals, representing 0.6% of total disposals by weight), bottom longline (9.6 t of disposals, 0.5% of total disposals by weight), bottom trawl (2.9 t of disposals, 0.2% of total disposals by weight), and set net (1.2 t of disposals, 0.1% of total disposals by weight)

In the last three fishing years, 84.5% of disposals of blue shark from surface longline have been attributed to disposal code X (i.e., alive and likely to survive), with the remaining 15.5% of disposals reported to disposal code Z (i.e., returned to the water dead or near-dead) (Figure 50).

Most blue shark catches and disposals by surface longline in the last three fishing years were taken when targeting southern bluefin tuna in autumn and winter off the east coast of the North Island and the east and west coasts of the South Island (Figure 51, Figure 52, Figure 53).

Table 14: Catches of blue shark in New Zealand by weight and proportion by destination and fishing year, 2004–05 to 2021–2022.

	Total catch (t)			Proportion		
Fishing year	Landed	Discarded	Released	Landed	Discarded	Released
2005	246.49	9.75	–	0.962	0.038	–
2006	213.18	7.78	–	0.965	0.035	–
2007	234.11	5.99	34.15	0.854	0.022	0.125
2008	197.67	5.61	9.72	0.928	0.026	0.046
2009	257.04	17.61	17.08	0.881	0.060	0.059
2010	229.51	4.72	9.53	0.942	0.019	0.039
2011	237.85	13.02	3.16	0.936	0.051	0.012
2012	284.24	0.25	24.02	0.921	0.001	0.078
2013	156.44	4.52	51.37	0.737	0.021	0.242
2014	37.81	14.66	110.41	0.232	0.090	0.678
2015	18.90	76.16	323.60	0.045	0.182	0.773
2016	4.00	63.39	628.01	0.006	0.091	0.903
2017	5.77	60.63	500.11	0.010	0.107	0.883
2018	2.10	93.06	653.43	0.003	0.124	0.873
2019	2.93	124.88	623.77	0.004	0.166	0.830
2020	0.84	130.83	545.31	0.001	0.193	0.806
2021	0.31	99.76	518.81	0.000	0.161	0.838
2022	0.27	55.92	412.06	0.001	0.119	0.880

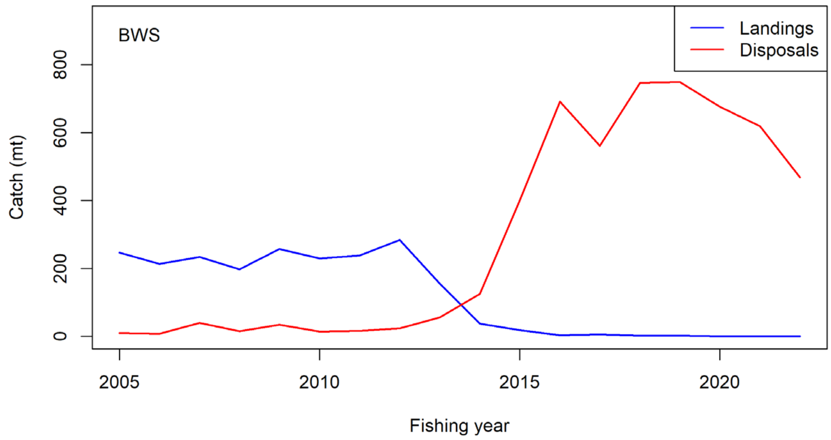


Figure 47: Annual commercial landings and disposals of blue shark (BWS) in New Zealand's Exclusive Economic Zone from 2004–05 (2005) to 2021–22 (2022).

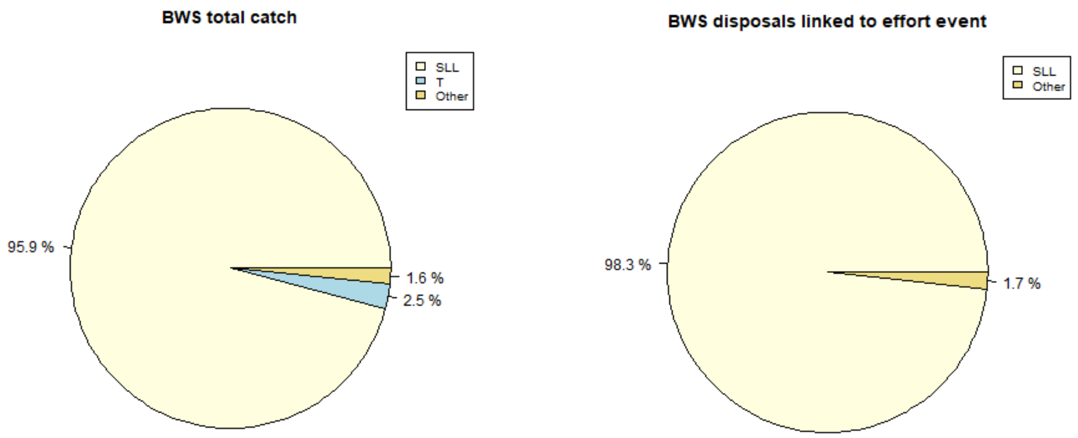


Figure 48: Blue shark (BWS) total catches (left) and disposals (right) in New Zealand's Exclusive Economic Zone by fishing method, 2019–20 to 2021–22. SLL = surface longline, T = troll.

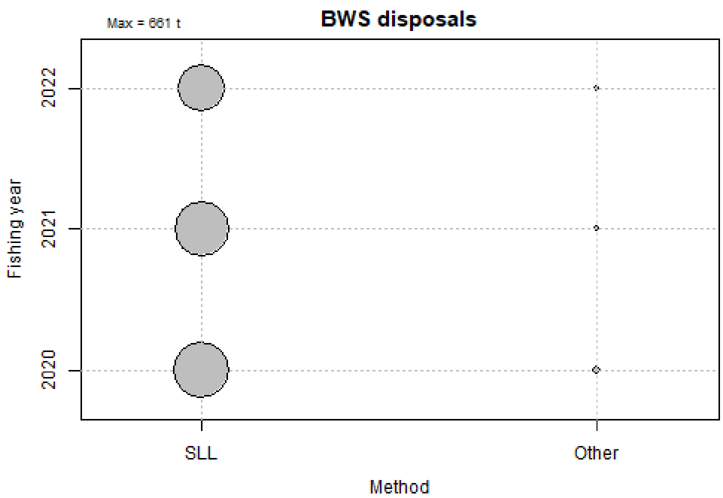


Figure 49: Disposals of blue shark (BWS) by fishing method in New Zealand's Exclusive Economic Zone from 2019–20 to 2021–22. SLL = surface longline.

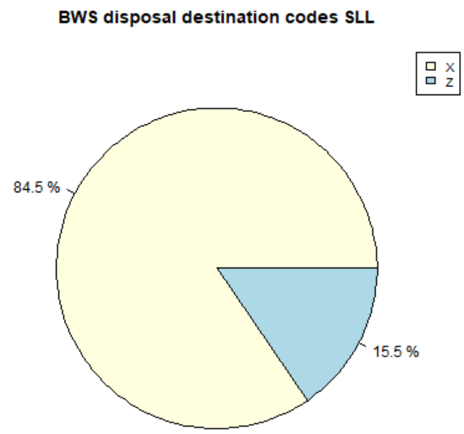


Figure 50: Codes attributed to disposals of blue shark (BWS) from the surface longline (SLL) fishery in New Zealand's Exclusive Economic Zone between 2019–20 and 2021–22.

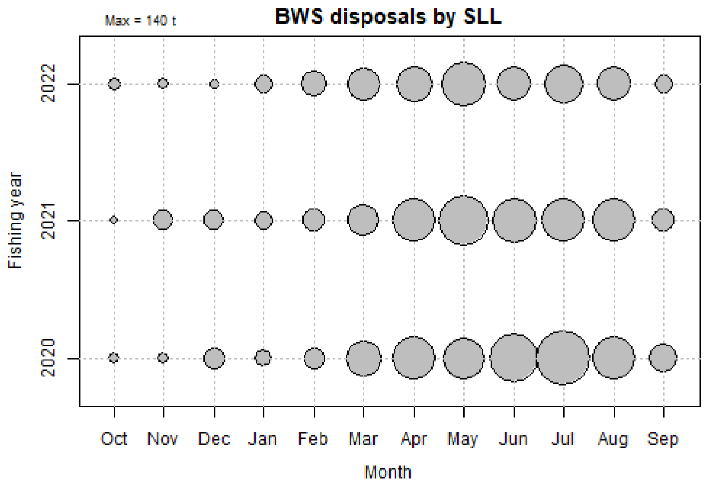


Figure 51: Disposals of blue shark (BWS) by month in New Zealand's Exclusive Economic Zone from 2019–20 to 2021–22 for surface longline (SLL).

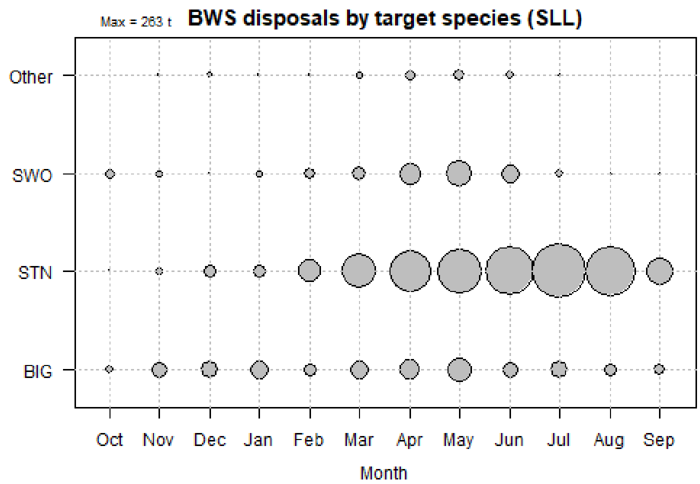


Figure 52: Disposals of blue shark (BWS) by month and target species in New Zealand's Exclusive Economic Zone for 2019–20 to 2021–22 for surface longline (SLL). SWO = swordfish, STN = southern bluefin tuna, BIG = bigeye tuna.

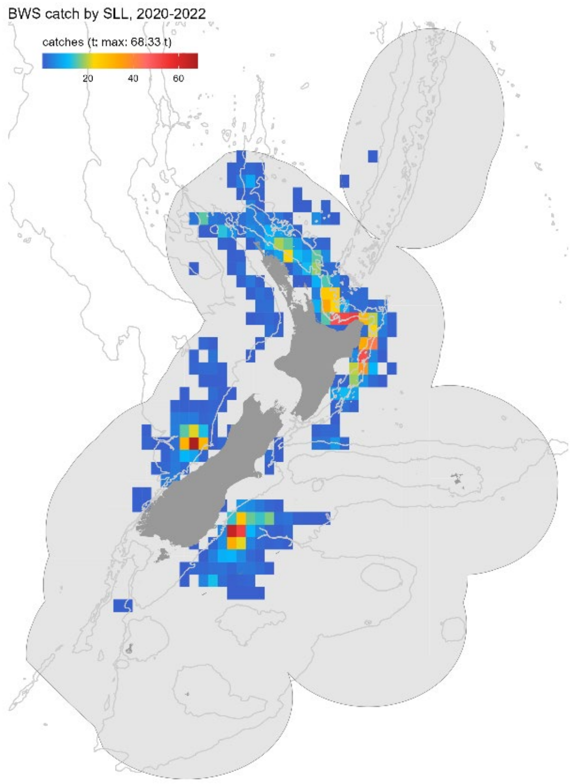


Figure 53: Total catches (including disposals; left) and disposals (right) of blue shark (BWS) by surface longline (SLL) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

Since 2005, over 37 000 blue shark captures have been observed by fisheries observers on surface longline vessels. Up to 2015, the vast majority of observed blue shark were landed, with disposals limited to mainly smaller individuals (Figure 54 and Figure 55). Most observed blue sharks caught in surface longline fisheries have been recorded as being alive at hauling (Figure 56 and Figure 57). For a given 10 cm length class, at-vessel survival rates are typically greater than 75% (i.e., 25% mortality), reaching over 90% survival for individuals between 140 cm and 220 cm in length (Figure 56). There were few data available for large (> 250 cm FL) blue sharks. The life status of blue sharks from observer records was similar across target fisheries, with most blue sharks recorded as alive with no condition recorded, and with overall at-vessel survival of 89.5%, 86.8%, and 81.3% for fishing events targeting bigeye tuna, southern bluefin tuna, and swordfish, respectively (Figure 57). In most years since 2015, blue sharks have been recorded as alive and uninjured at hauling (up to ~85%), although the overall number of blue shark records with life status recorded has declined considerably, from several thousand individuals per year in the mid-2000s, to less than 200 individuals annually since 2019 (Figure 57). Blue shark life status was consistent across soak times, with a lower proportion of blue sharks recorded as dead (~10%) when soak times were under 12 hours (Figure 58). Blue sharks were more likely to be recorded as dead when foul-hooked (40%); however, the sample sizes of sharks with information on hooking location are relatively small (Figure 58). Approximately 75% and 80% of blue sharks were recorded as alive and uninjured when hooked in the mouth/jaw or gut, respectively (Figure 58).

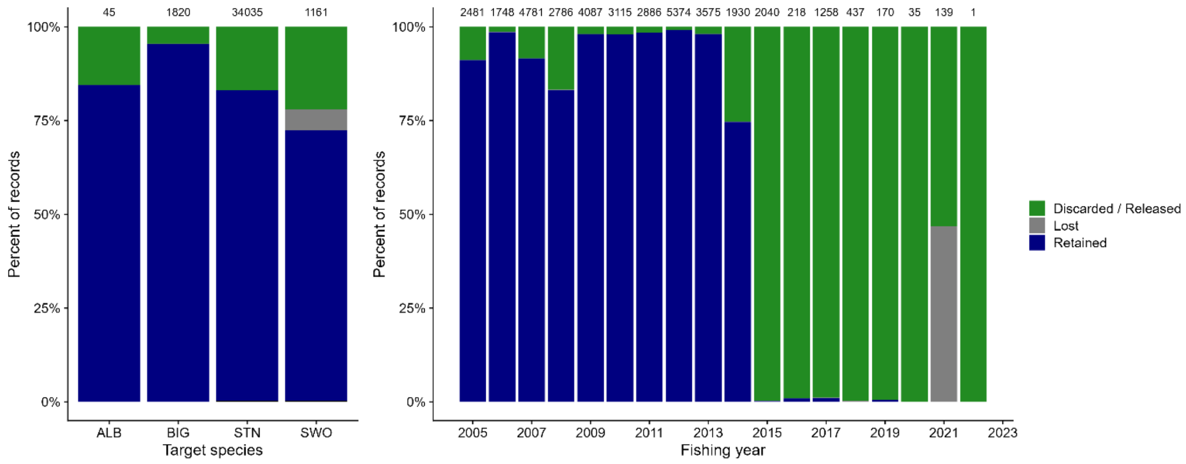


Figure 54: Fate of blue shark from observer records from the surface longline fishery by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. ALB = albacore tuna, BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish.

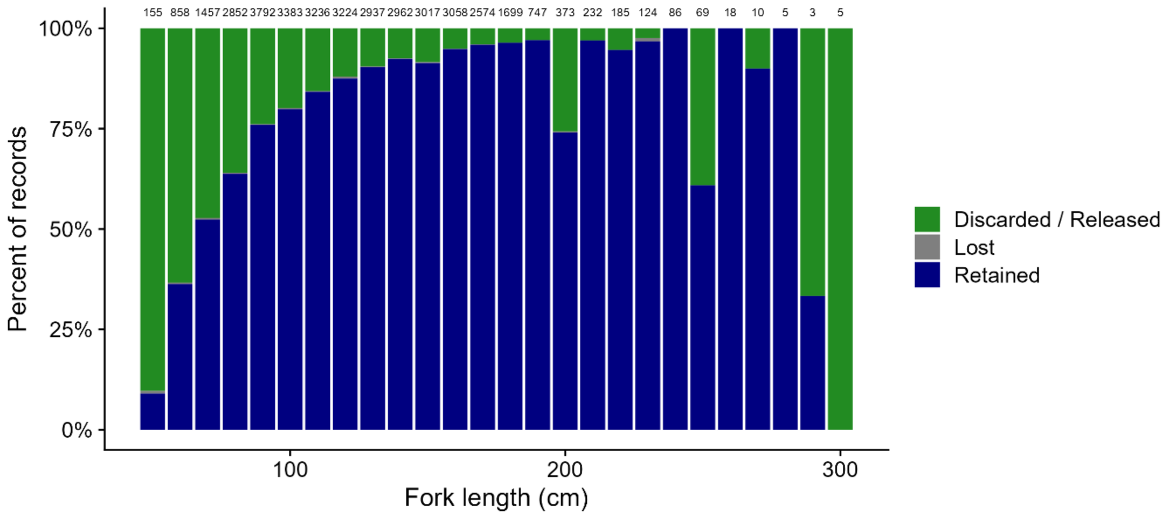


Figure 55: Fate of blue shark by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

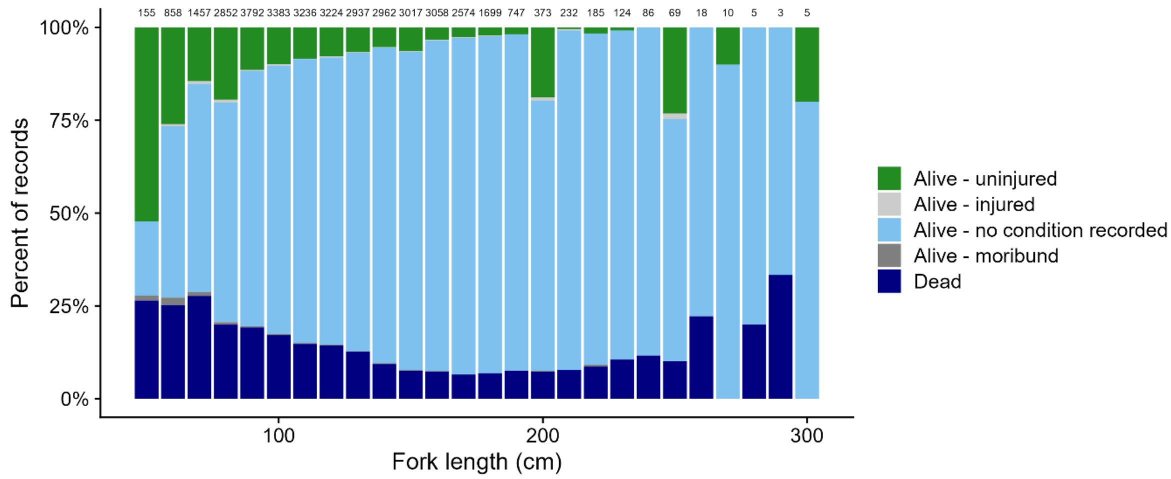


Figure 56: Life status at haul of blue shark by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

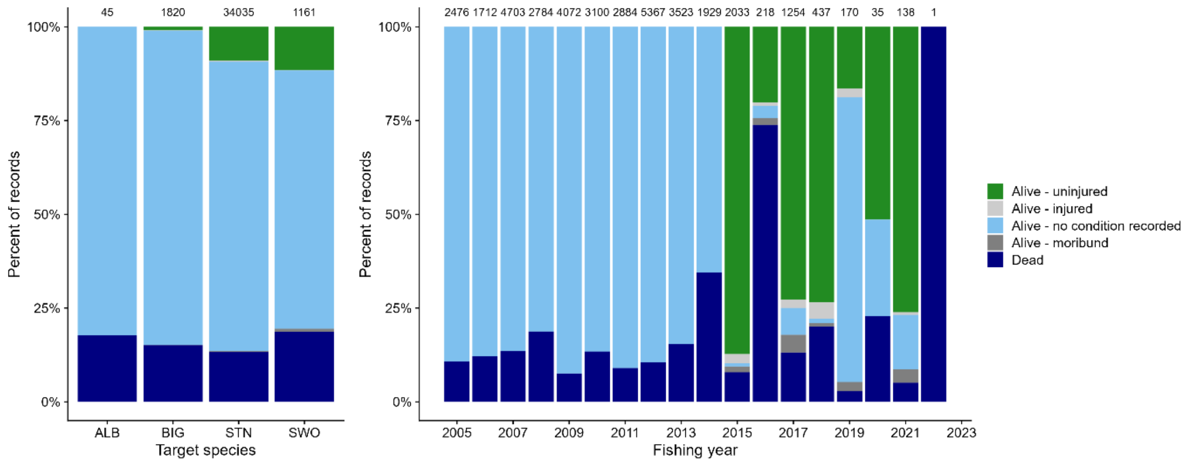


Figure 57: Life status of blue shark from observer records from the surface longline fishery at-vessel by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. ALB = albacore tuna, BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish.

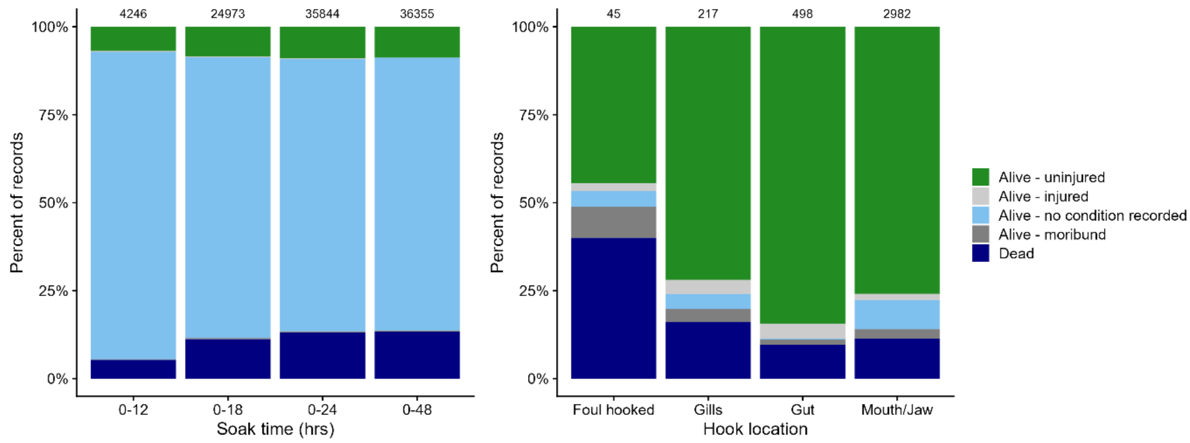


Figure 58: Life status of blue shark from observer records from the surface longline fishery at-vessel by soak time (left) and hooking location (right). Numbers above the columns indicate sample sizes.

3.3.2. Review of at-vessel and post-release survival studies

Blue shark is one of the most wide-ranging of all sharks. They are highly migratory and found throughout all oceans in tropical and temperate waters. They reach lengths of up to 3.8 metres total length (TL). Blue shark likely comprise a single global stock, with little or no structure within and between ocean basins. Blue shark segregate by size and sex. They occupy a broad thermal niche, occurring in waters from ~12 °C to 29 °C, and in surface waters to depths ~1000 m. Like other requiem sharks, blue sharks are obligate ram ventilators.

Globally, at-vessel survival for blue shark caught in surface longline fisheries is generally estimated to be high (~90%, e.g., Gilman et al. 2022) (Table 15). Blue shark at-vessel mortality has been assessed in New Zealand fisheries once before; based on observed captures of pelagic sharks during the 1997–98 fishing year, 7838 blue sharks were recorded as alive at recovery, accounting for 86.5% of observed sharks for that year (Francis et al. 2001). Blue sharks were reported to be more likely alive from fisheries operating around the South Island (91.3%) than those operating around the North Island (73.3–91.7%) and survival was found to be higher for domestic vessels (91.7%) than foreign charter vessels (86.1%) (Francis et al. 2001).

Other studies examining at-vessel survival and the factors that influence it have commonly reported shark size), set duration/soak time, hook type, and sea surface temperature (SST) as significant factors determining survival outputs (Table 15). However, the effects of these factors are variable, and conclusions for some factors (e.g., soak time, sea surface temperature) can be conflicting and are suspected to be confounded by other factors (e.g., shark size, Epperly et al. 2012). Declines in abundance of many shark populations around the world has led to the implementation of management measures over the past two decades. Off the east coast of the US in the Northwest and Central Atlantic Ocean, regulatory period was also found to be an important factor for blue shark at-vessel survival (Dapp et al. 2016). Management actions, such as gear restrictions or modifications and improved handling, implemented over time, were attributed to improved shark survival. At-vessel mortality has also been reported from research surface longline trips, largely to measure the effect of gear modifications (e.g., hook type) on catch and fishing mortality (see Table 15). Although survival estimates from these studies have been largely high (upwards of 95%, Moyes et al. 2006), these estimates may not be reflective of fishing practices in New Zealand's commercial fisheries.

There have been no studies of post-release survival of blue shark in New Zealand waters. From PSATs applied to sharks caught in the Pacific Ocean, blue sharks caught in commercial surface longline fisheries were generally estimated to have relatively high post-release survival (80–90%) and mortality is generally acute (occurring within days of tagging) (e.g., Musyl & Gilman 2018) (Table 16). However, a recent study from Hawaii reported that although blue shark had the lowest at-vessel mortality of the five species of sharks assessed (4.9%), blue shark also had the lowest post-release survival (62%), and high delayed mortality (82%) was projected up to 360 days (Hutchinson et al. 2021). In the Atlantic Ocean, blue shark post-release survival varied between 66–100%, depending on shark condition at release (Campana et al. 2016). Shark condition at release was a consistent factor across studies in determining post-release survival (Musyl & Gilman, 2018; Campana et al. 2009, 2016; Hutchinson et al. 2021). Trailing fishing gear left on the shark was reported to be an important negative factor for post-release survival from the Hawaiian study (Hutchinson et al. 2021) (Table 16).

Table 15: Summary of studies examining at-vessel survival of blue shark in commercial fisheries and research studies. SLL = surface longline; FL = fork length; SST = sea surface temperature; SI = South Island; NI = North Island. Factors in bold font had a significant influence on survival. This list is not exhaustive and only more recent and relevant studies are reported here. FCV = foreign charter surface longline vessels. (Continued on next page)

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	New Zealand	7 838	86%	–	Study examined at-vessel survival (1997/98) and those retained/finned; more sharks alive around SI than NI; survival higher for domestic vessels than FCV	Francis et al. (2001)
Commercial SLL	Pacific (Hawaii)	8 895	~97%	Hook type	Study examined at-vessel survival	Curran & Bigelow (2011)
Commercial SLL	Pacific (American Samoa, Cook Islands, New Caledonia)	144	67–80%	**Hook size (16°C vs <16°C)**	Study examined at-vessel survival; higher survival with large hook	Curran & Beverly (2012)
Commercial SLL	Pacific (Marshall Islands)	3 452	~80%	–	Study examined at-vessel survival; factors influencing shark catch rates	Bromhead et al. (2012)
Commercial SLL	Pacific (Palau)	215	85%	**SST**; Bait; Hook; Month; Location	Study examined at-vessel survival	Gilman et al. (2016)
Commercial SLL	Pacific (Hawaii)	269 112	95%		Study examined at-vessel and post-release survival	Hutchinson et al. (2021)
Commercial SLL	Atlantic (USA)	4 290	69%	**FL**; **Set duration**; SST; Season; Area	Study examined at-vessel survival; survival increased with increasing FL and decreased with increased soak time	Diaz & Serafy (2005)
Commercial SLL	Atlantic (Canada)	21 684	78–81%	**Hook type*Hooking location**; **SST**; **Soak time**; **FL**	Study examined at-vessel survival; mortality increased with increasing SST	Epperly et al. (2012)
Commercial SLL	Atlantic/Gulf of Mexico	17 780	85%	**Target**; **Hook depth**; **SST**; **Soak time**; **FL**	Study examined at-vessel survival	Gallagher et al. (2014)

Commercial SLL	Atlantic (Canada)	19 770	85%	**Condition**	Study examined at-vessel and post-release survival; 25% of sharks reported with injury at hauling; total survival estimate of 77%	Campana et al. (2016)
Commercial SLL	Atlantic (NW, Central)	806 598	82%	**SST**; **Regulatory period**; **Geographic zone**	Study examined at-vessel survival; expected immediate mortality ranged 5–34% based on literature; SST effect was virtually the same at 10°C and 30°C	Dapp et al. (2016)
Commercial SLL	Atlantic (Equatorial)	272	79–88%	**FL**	Study examined fishing mortality using hook timers and hook type (circle and J-hook); blue shark survived on lines up to 14 hours	Nunes et al. (2019)
Commercial SLL	Atlantic/Indian (South Africa)	5 148	66%	–	Study characterised pelagic shark bycatch	Petersen et al. (2009)
Commercial SLL	Indian (Réunion Island)	92	49%		Study examined effect of lunar cycle on fishing performance survival; study employed hook timers with ~30% blue sharks alive after 8-hour soak time	Poisson et al. (2010)
Research SLL	Pacific (Hawaii)	172	95%	–	Study examined at-vessel and post-release survival; long-term survival thought to be likely if released in healthy condition	Moyes et al. (2006)
Research SLL	Pacific (Japan)	3 650	92%	–	Study examined effect of hook type on catch (circle and tuna)	Yokota et al. (2006)
Research SLL	Pacific (Japan)	8 755	92%	–	Study examined effect of circle hook on mortality	Ochi et al. (2021)
Research SLL	Pacific (French Polynesia)	110	87%	–	Study examined at-vessel survival; blue shark and mako were combined in a "mesopelagic shark" category	Massey et al. (2022)
Research SLL	Atlantic (Brazil)	32	30–73%	–	Study examined fishing gear modifications (hook type) to reduce mortality	Afonso et al. (2011)

Table 16: Summary of studies examining post-release survival (PRS) of blue shark in commercial fisheries and research studies. SLL = surface longline; FL = fork length; SST = sea surface temperature; TL = total length. Factors in bold font had a significant influence on survival.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	Pacific (eastern Australia)	5	80%	–	Mortality occurred shortly after tagging; hooks/trailing gear left in	Stevens et al. (2010)
Commercial SLL	Pacific (Palau, Marshall Islands)	48	69–89% (mean=83%)	TL; **Condition**; Hooking location; Hook type; Location; SST; Soak time; Time-in-air; Trailing gear	Mortality acute – 75% within 2 days	Musyl & Gilman (2018)
Commercial SLL	Pacific (Hawaii, American Samoa)	61	62%	Fishery; Handling Method; **Condition** at capture and **release**; **Trailing fishing gear**; Branch line material	At-vessel mortality lowest of 5 sharks assessed (4.9%) but had lowest PRS; high delayed mortality projected (82% at 360 days); susceptible to predation	Hutchinson et al. (2021)
Commercial SLL	Atlantic (Canada)	37	67–100%	**Condition**; Hook type; Hook size; Soak time; Vessel; FL; SST	Mortality acute; 95% within 11 days	Campana et al. (2009, 2016)
Research SLL	Pacific (California)	17	88%	–	Primary focus of study was habitat use; mortalities immediately after tagging	Weng et al. (2005)
Research SLL	Pacific (Hawaii)	16	94%	–	Total of 203 sharks assessed; overall survival estimated at 85%	Musyl et al. (2011)

3.3.3. Expert elicitation

Reasons for release

Stakeholders advised that blue sharks are disposed because they are not commercially viable and that by retaining these species, there is less room in holds for more valuable target species. Fishers were also concerned that storing blue sharks with fish products can cause spoilage due to ammonia contamination. This is especially relevant to the surface longline fleet, the majority of which are single fish-hold vessels that lack on-board freezer facilities. It was also highlighted that blue shark was introduced to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II in November 2023. This introduction has implications for international trade, and thus, further discourages fishers to retain catch (mako and porbeagle were added to CITES Appendix II in 2019 and 2013, respectively).

At-release survival

Survey respondents indicated that most blue sharks were alive at hauling when caught in surface longline fisheries, and only a small percentage (< 25%) of individuals were released as alive (with a severe injury) or dead (Figure 59). Survey respondents considered that shark size/life stage, sea surface temperature, and soak time had little influence on the percentage of sharks released alive. Survey respondents indicated a small percentage of released sharks (< 25%) were foul-hooked or hooked in the gut. There was less certainty with the percentage of sharks released with trailing gear, with some survey respondents suggesting up to 75% of blue sharks have some trailing gear attached when released (Figure 59).

Post-release survival

Survey results indicated blue shark post-release survival was highest (> 75%) when sharks were released alive and uninjured and low when sharks were alive but severely injured (< 10% survival) (Figure 59). Survey respondents considered that shark size/life stage and sea surface temperature did not influence post-release survival and suggested that overall post-release survival of blue shark was high (> 75%). Soak time was considered to have some influence on post-release survival, with higher survival rates when soak time was low (< 12 hours). Survey respondents considered blue shark post-release survival to be highest when sharks were hooked in the jaw, and lowest when hooked in the gut or fouled hooked. Post-release survival was considered to be high (> 90%) when sharks were released from the water and when sharks were released with no or limited (< 1 body length) trailing gear (> 75% survival) (Figure 59).

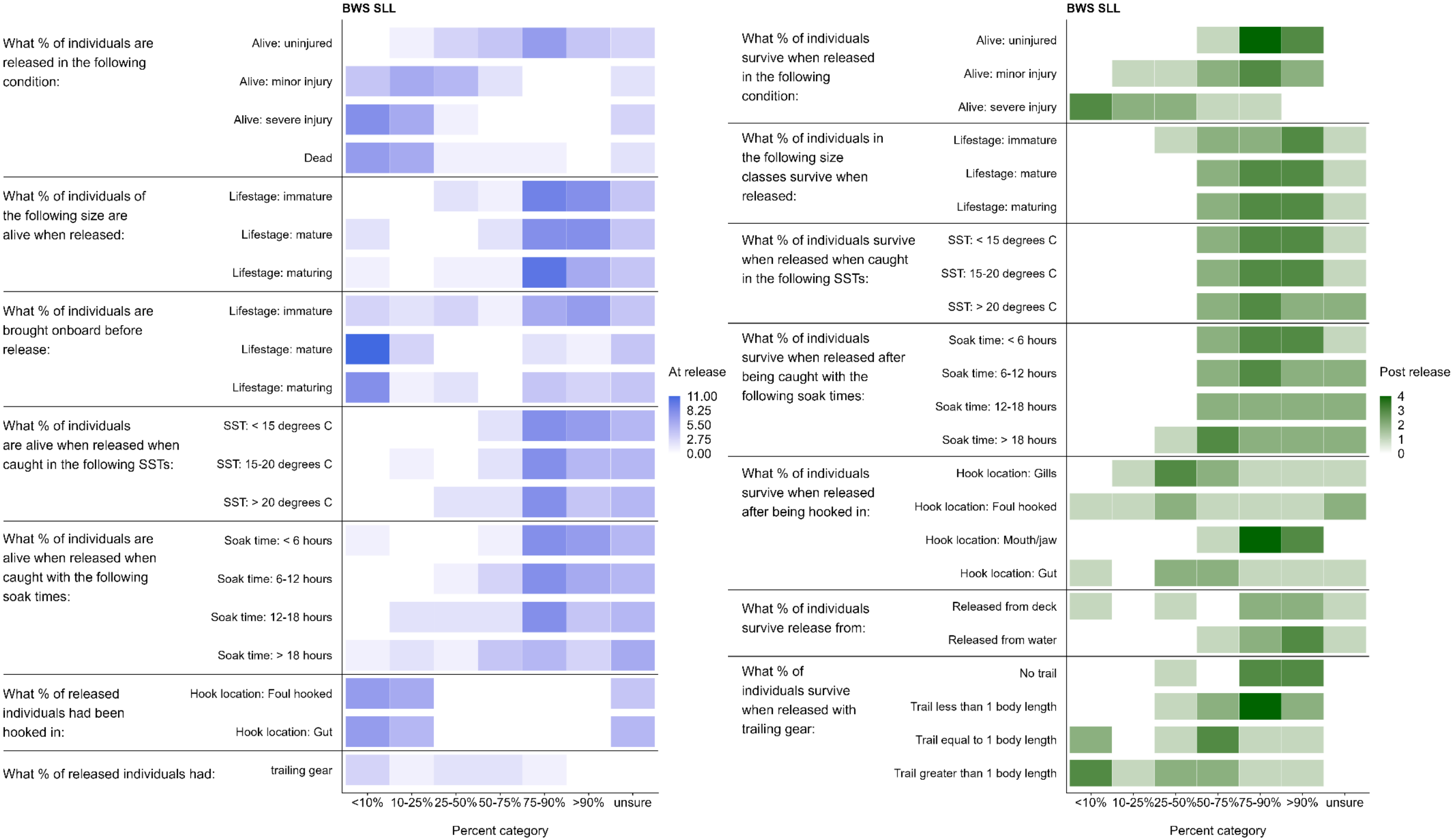


Figure 59: Results from the expert elicitation questionnaire for blue shark (BWS) caught by surface longline (SLL). Left: responses to questions on at-release survival. Right: responses to questions on post-release survival. Darker colours indicate a greater number of responses. SST = sea surface temperature.

3.3.4. Fishery survival probability estimates

Appropriate and comparable priors for blue shark were applied to release condition and trailing gear (Appendix 3). While blue shark is amongst the most widely studied sharks, most studies on blue shark survival are not directly comparable with current New Zealand fisheries or the environment, e.g., studies were completed in tropical waters (equatorial Atlantic, Pacific Islands) or examined the effect of hook type and/or size. For release condition, priors were derived from a North Atlantic Ocean study (Campana et al. 2016). No mortalities were observed for satellite tagged blue sharks that were healthy at release; however, sample sizes in the Campana et al. (2016) study were small (n = 10), so a prior of 0.90 was applied to sharks released uninjured here based on the overall post-release mortality rate of live (healthy and injured) blue sharks from a North Atlantic Ocean study (Campana et al. 2016). A prior of 0.67 was applied to blue sharks released injured (regardless of injury), derived from post-release mortality rates from satellite tagged sharks from the North Atlantic Ocean (Campana et al. 2016) and off Hawaii (Hutchinson et al. 2021). For trailing gear, the following priors were applied: 0.84 for no trailing gear, and 0.83 when trailing gear was less than or equal to shark length. These estimates were derived from satellite tagged sharks off Hawaii at 60 days post-release (Hutchinson et al. 2021) so that the estimates were consistent with those used for mako (see Appendix 3). Priors were not provided when trailing gear length was greater than shark length because estimates varied anywhere from 0.54 to 0.80 depending on the length of trailing gear (Hutchinson et al. 2021).

At-release survival only

Perceived survival probability estimates for blue shark caught in surface longline fisheries when considering at-release survival only were high for all examined factors (SST, shark size, soak time) (Figure 60, Figure 61).

Post-release survival only

When blue sharks were assumed to be released alive, perceived post-release survival was generally estimated to be high across most factors. The exceptions were that survival was considered to be medium if sharks were hooked in the gills or when trailing gear the length of the shark was left, low-medium if sharks were gut-hooked or foul-hooked or with trailing gear longer than the length of the shark was left, and low if released with a severe injury (Figure 62). The inclusion of priors improved perceived survival estimates regarding trailing gear or when individuals were released with a severe injury, although also increased the uncertainty regarding the latter (Figure 63). When the factors for post release survival were combined and weighted proportionally to the fishery profile, all categories indicated that perceived overall post-release survival was high for blue shark when released alive (Figure 64 and Figure 65).

At-release and post-release survival combined

Blue shark perceived survival had greater uncertainty when survey responses for at-release survival and post-release survival were combined, particularly with respect to high SST (> 20 °C) and longer soak times. Final perceived estimates of survival for blue shark caught on surface longline when factors were aggregated and weighted to the fishery profile were high for all categories except for soak time, which was considered to be medium-high (Figure 64 and Figure 65). Based on this latter estimate, the overall combined (i.e., at-release and post-release) perceived survival for blue shark caught in New Zealand's surface longline fisheries was considered to be medium-high.

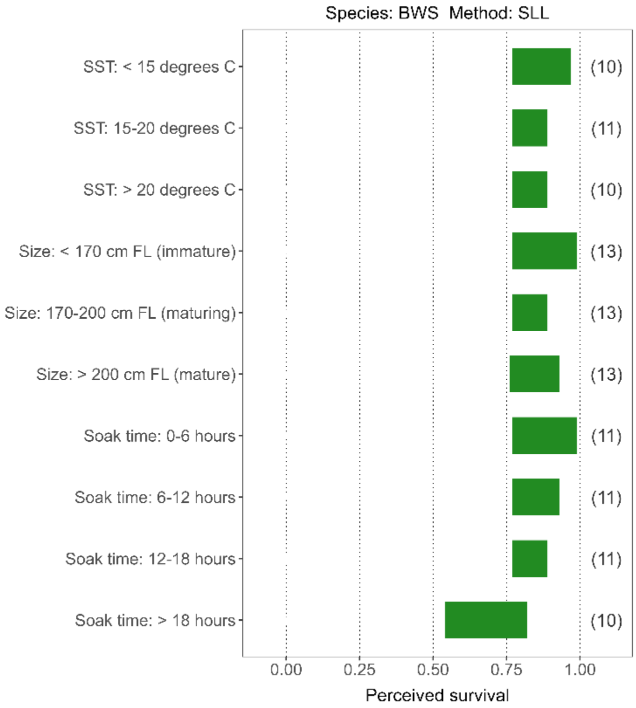


Figure 60: 90% confidence intervals on perceived at-release mean survival estimates for blue shark (BWS) following release from surface longline (SLL) in New Zealand waters by factor-category. Note this plot assesses at-release survival only, and no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

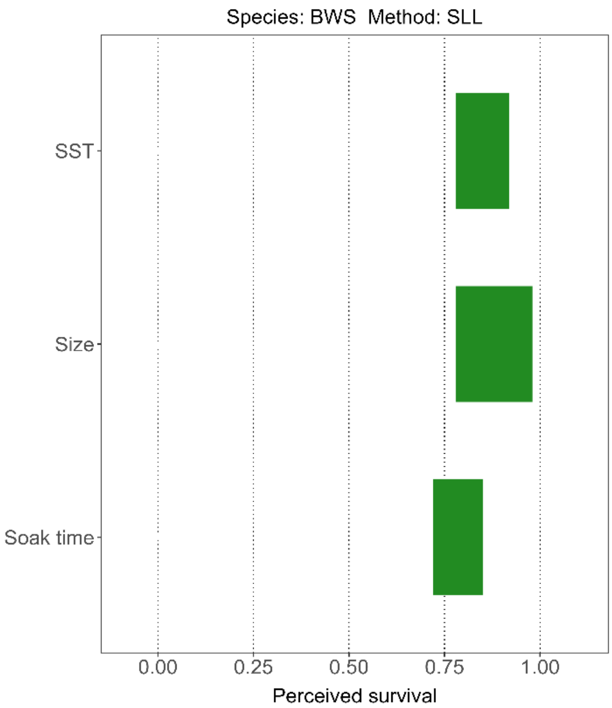


Figure 61: 90% confidence intervals on perceived at-release mean survival estimates for blue shark (BWS) following release from surface longline (SLL) in New Zealand waters by factor. Note this plot assesses at-release survival only, and no priors were applied to these particular categories. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

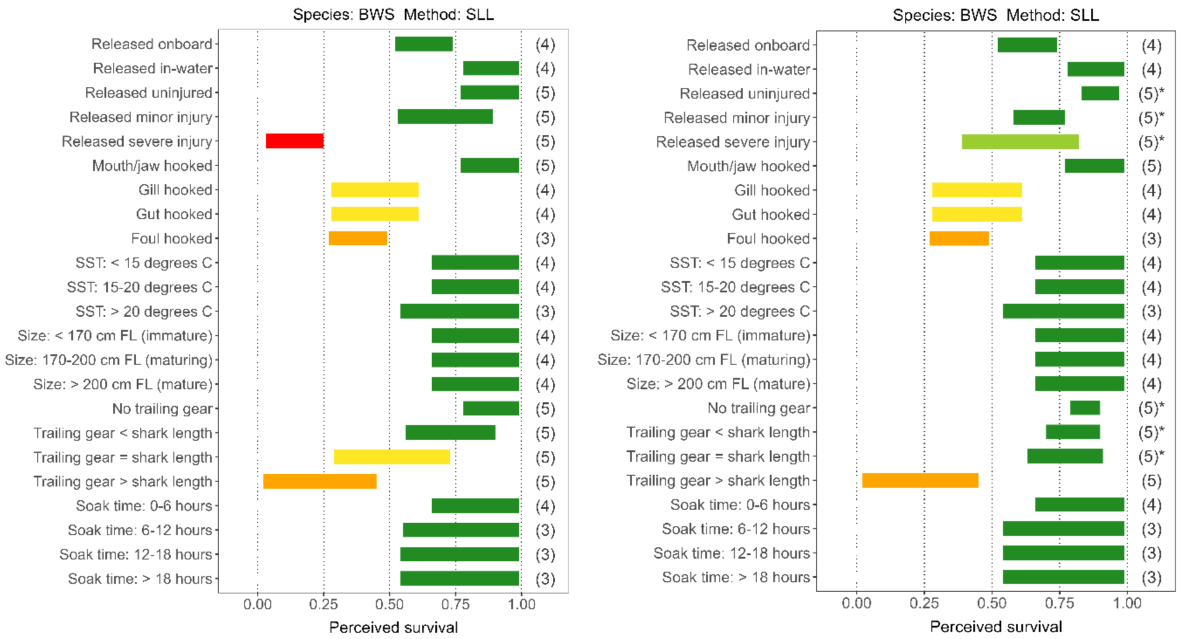


Figure 62: 90% confidence intervals on perceived post-release mean survival estimates for blue shark (BWS) following release from surface longline (SLL) in New Zealand waters by factor-category. Note this plot assumes all individuals released are alive at the time of release, and does not account for condition at release. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. The number in parentheses indicates the number of survey respondents. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

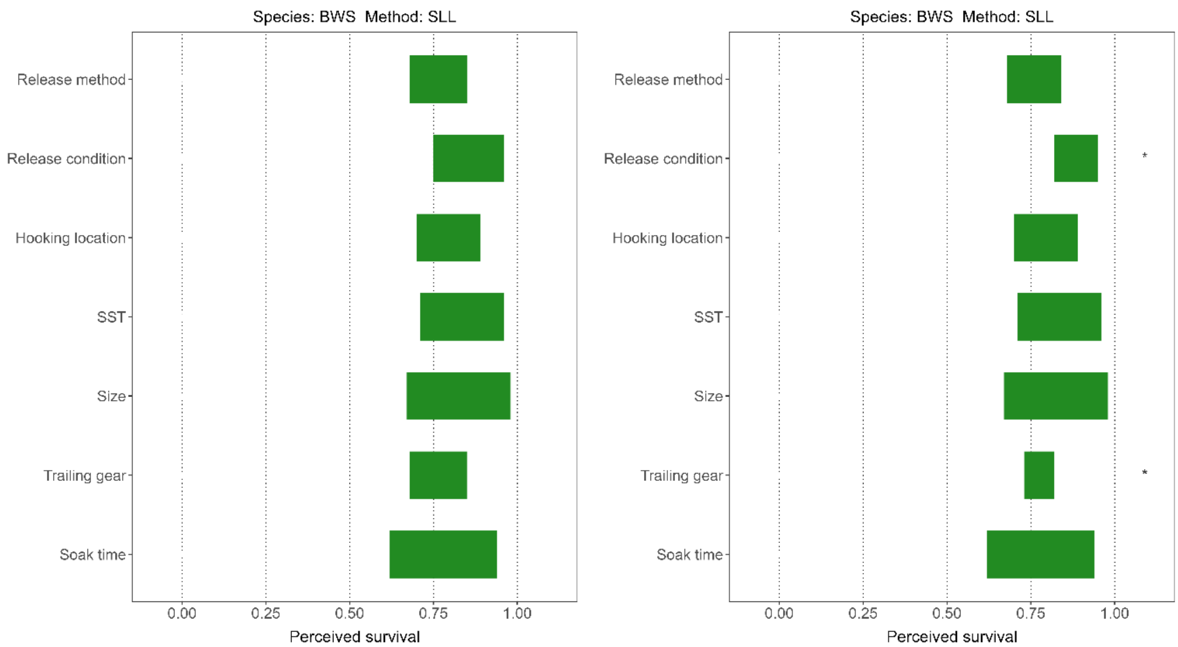


Figure 63: 90% confidence intervals on perceived post-release mean survival estimates for blue shark (BWS) following release from surface longline (SLL) in New Zealand waters by factor. Note this plot assumes all individuals released are alive at the time of release, and does not account for condition at release. Left: without priors applied; right: with priors applied. * denotes those factors informed by priors. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

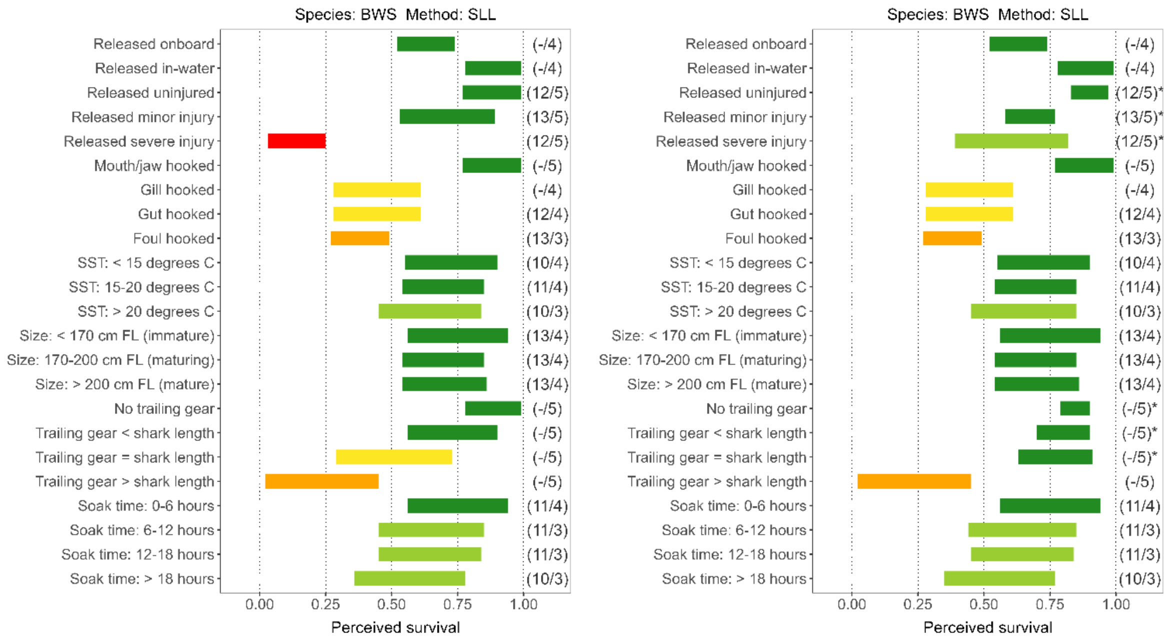


Figure 64: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for blue shark (BWS) following release from surface longline (SLL) in New Zealand waters by factor-category. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. The number in parentheses indicates the number of survey respondents (at-release / post-release). SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

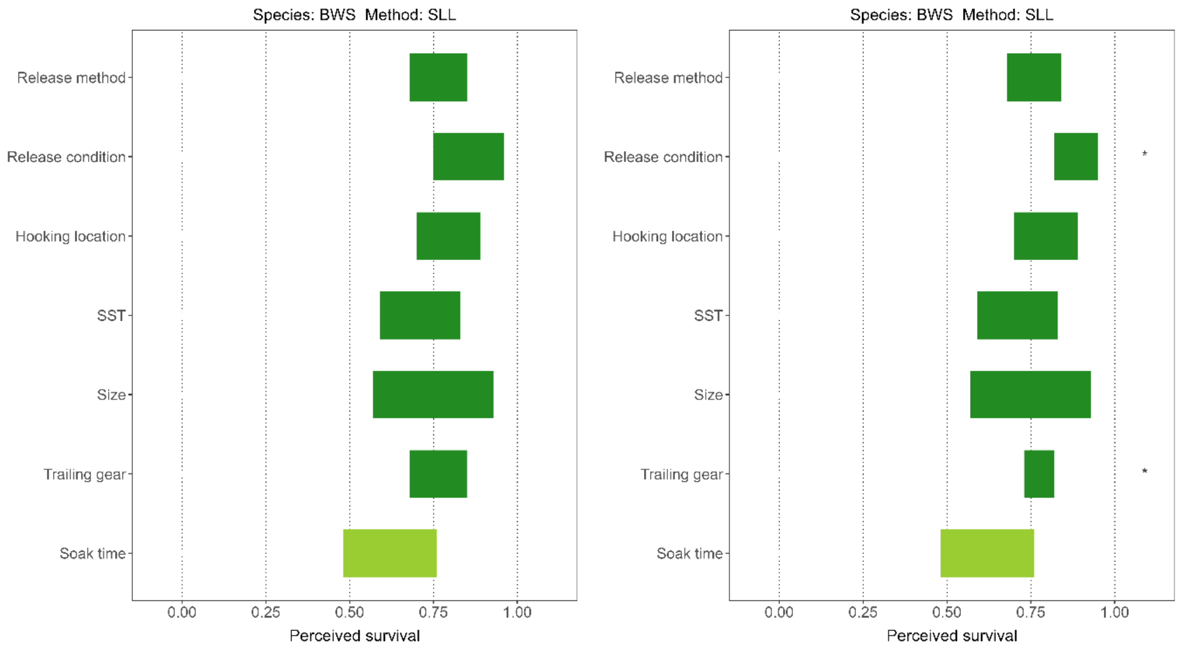


Figure 65: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for blue shark (BWS) following release from surface longline (SLL) in New Zealand waters by factor. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

3.4 Shortfin mako (*Isurus oxyrinchus*)

3.4.1. Fishery characterisation

Since the ban on shark finning in 2015, most mako catches are now discarded or actively released alive (Table 17). The annual mean total catch (i.e., including landings and disposals) of mako in the three-year period from 2019–02 to 2021–22 was 52.5 t (Table 17 and Figure 66). Annual average disposals were 49.1 t, representing 93.5% of the annual commercial catch by weight.

Between 2019–20 and 2021–22, surface longline accounted for 62.7% of total mako commercial captures and 67.4 % of disposals (Figure 67). Mid-water trawl accounted for 19.0% of commercial captures and 20.4% of disposals (Figure 67). Smaller amounts of commercial catch and disposals (9.5% and 5.6%, respectively) were reported from bottom longline over this same period (Figure 67 and Figure 68). Small numbers of disposals of mako were reported from several other fishing methods between 2019–2020 and 2021–22, the most significant being set net (4.4 t of disposals, representing 3.0% of total mako disposals by weight), bottom trawl (2.7 t of disposals, 1.8% of total disposals by weight), and purse seine (0.7 t of disposals, 0.5% of total disposals by weight) (Figure 67).

In the last three fishing years, 66.7% of disposals of mako from surface longline have been attributed to code X (i.e., alive and likely to survive), with the remainder attributed to disposal code Z (i.e., dead or near-dead) (Figure 69). For trawl, most (77.8%) disposals in the last three fishing years have been attributed to disposal code Z (i.e., dead or near-dead), with the remaining 22.2% attributed to disposal code X (Figure 69).

Most of the mako catch and disposals by surface longline in the last three fishing years was taken off the east coast of the North Island in sets targeting southern bluefin tuna, swordfish, and bigeye tuna (Figure 70, Figure 71, Figure 72). Most of the mako catch and disposals by trawl in the last three fishing years was taken off the west coast of the South Island (Figure 73), in tows targeting jack mackerel and hoki (Figure 71).

Table 17: Catches of mako in New Zealand by weight and proportion by destination and fishing year, 2004–05 to 2021–2022.

	Total catch (t)			Proportion		
Fishing year	Landed	Discarded	Released	Landed	Discarded	Released
2005	100.99	3.15	–	0.970	0.030	–
2006	78.21	1.72	–	0.979	0.021	–
2007	78.72	0.79	1.46	0.972	0.010	0.018
2008	69.89	0.61	0.86	0.979	0.009	0.012
2009	74.89	2.49	1.04	0.955	0.032	0.013
2010	68.37	0.29	1.19	0.979	0.004	0.017
2011	88.22	0.41	0.66	0.988	0.005	0.007
2012	106.25	0.21	1.62	0.983	0.002	0.015
2013	81.42	1.46	3.38	0.944	0.017	0.039
2014	42.29	0.61	10.67	0.789	0.011	0.199
2015	21.50	22.17	45.14	0.242	0.250	0.508
2016	16.96	31.27	99.38	0.115	0.212	0.673
2017	12.65	21.59	45.42	0.159	0.271	0.570
2018	7.58	25.13	51.46	0.090	0.299	0.611
2019	5.17	27.78	40.83	0.070	0.376	0.553
2020	5.32	29.40	29.31	0.083	0.459	0.458
2021	3.33	28.07	31.83	0.053	0.444	0.503
2022	1.66	11.13	17.43	0.055	0.368	0.577

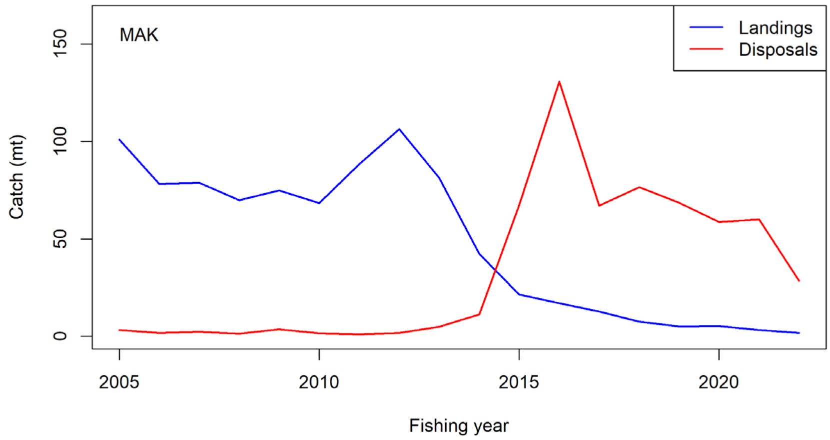


Figure 66: Annual commercial landings and disposals of mako (MAK) in New Zealand's Exclusive Economic Zone from 2004–05 (2005) to 2021–22 (2022).

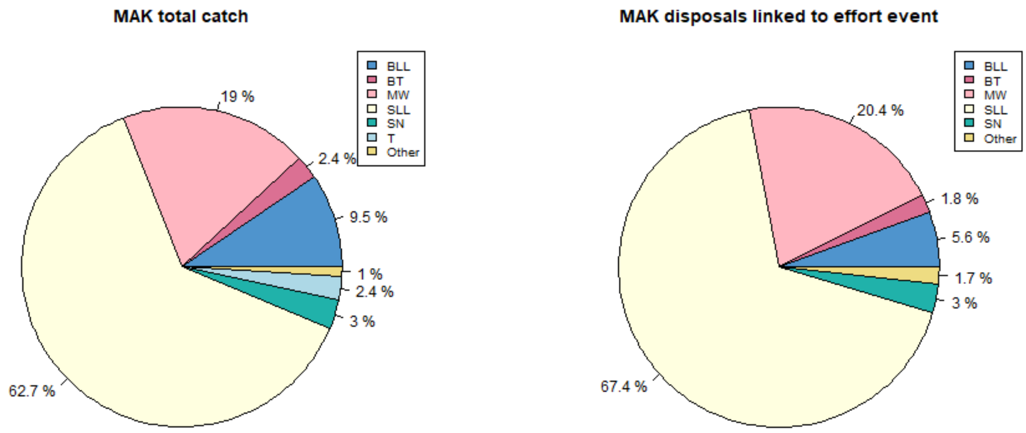


Figure 67: Mako (MAK) total catches (left) and disposals (right) in New Zealand's Exclusive Economic Zone by fishing method, 2019–20 to 2021–22. BLL = bottom longline, BT = bottom trawl, MW = mid-water trawl, SLL = surface longline, SN = set net, T = troll.

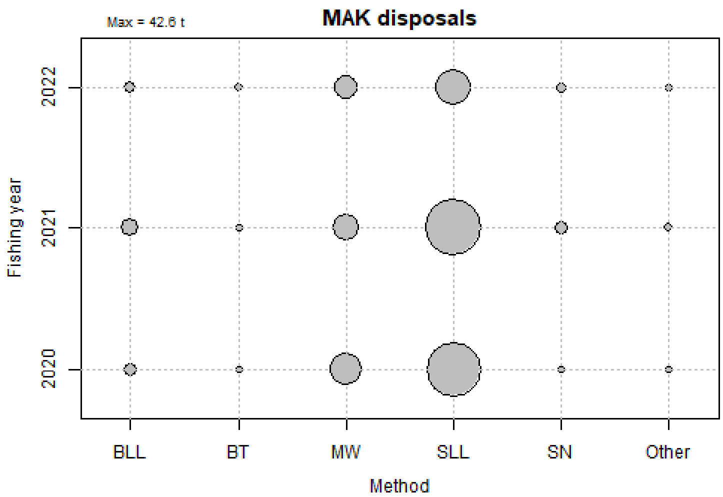
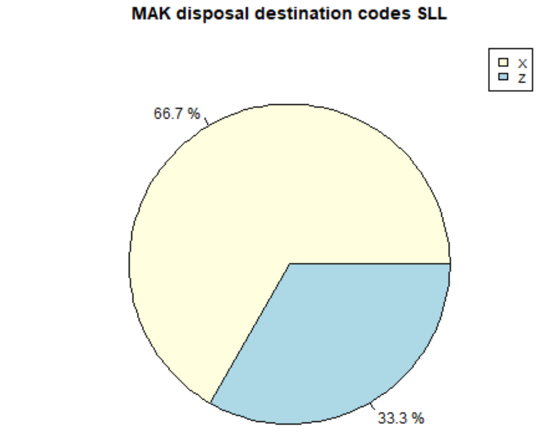


Figure 68: Disposals of mako (MAK) by fishing method in New Zealand's Exclusive Economic Zone from 2019–20 to 2021–22. BLL = bottom longline, BT = bottom trawl, MW = mid-water trawl, SLL = surface longline, SN = set net.



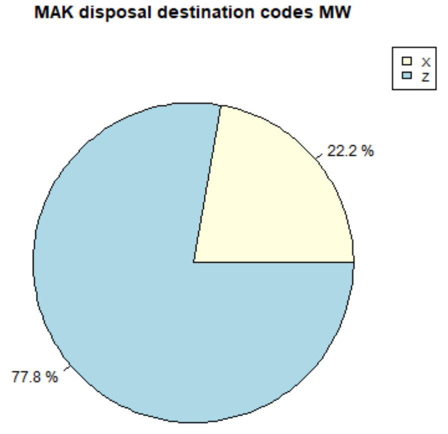
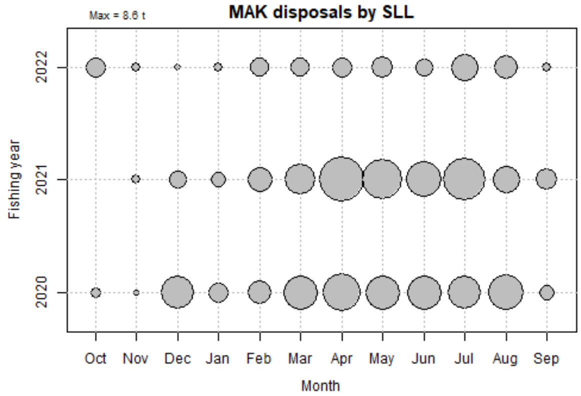


Figure 69: Codes attributed to disposals of mako (MAK) from the surface longline (SLL; left) and mid-water trawl (MW; right) fisheries in New Zealand's Exclusive Economic Zone between 2019–20 and 2021–22.



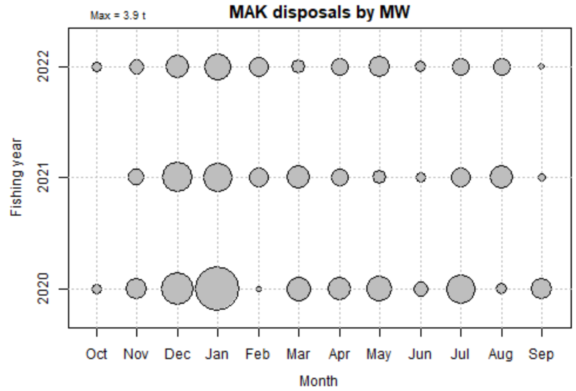
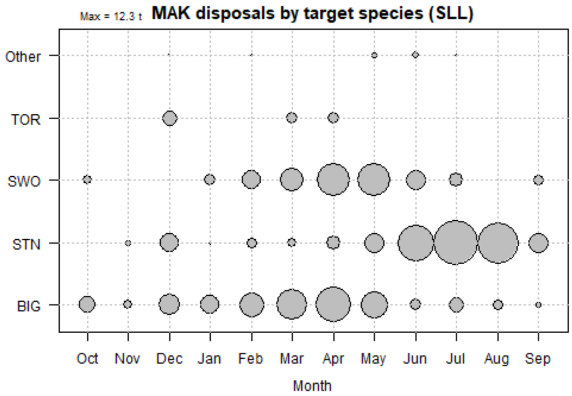


Figure 70: Disposals of mako (MAK) by month in New Zealand's Exclusive Economic Zone from 2019–20 to 2021–22 for surface longline (SLL; left) and mid-water trawl (MW; right).



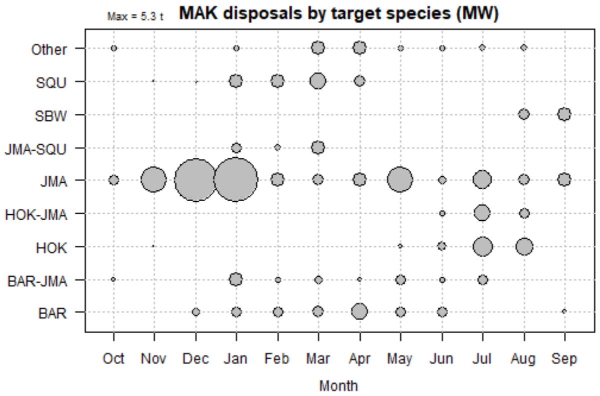


Figure 71: Disposals of mako (MAK) by month and target species in New Zealand's Exclusive Economic Zone for 2019–20 to 2021–22 for surface longline (left) and mid-water trawl (right). TOR = Pacific bluefin tuna, SWO = swordfish, STN = southern bluefin tuna, BIG = bigeye tuna, SQU = squid, SBW = southern blue whiting, JMA = jack mackerel, HOK = hoki, BAR = barracouta.

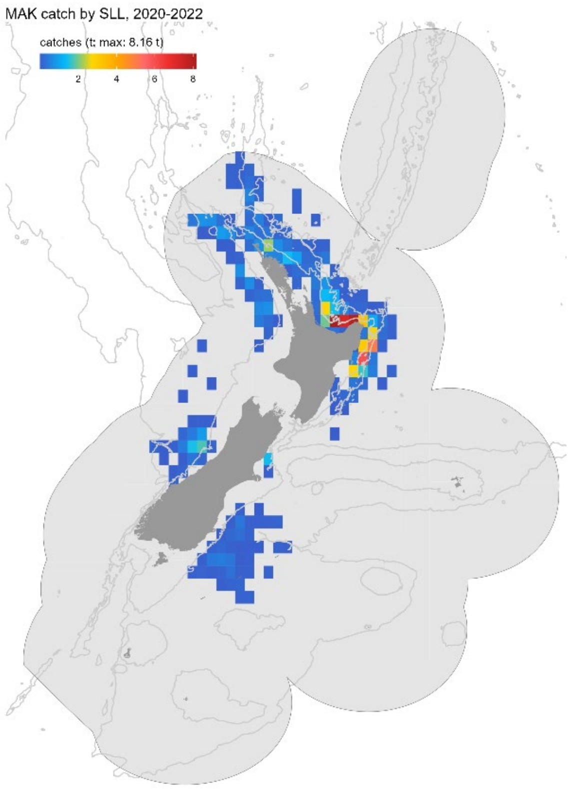


Figure 72: Total catches (including disposals; left) and disposals (right) of mako (MAK) by surface longline (SLL) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

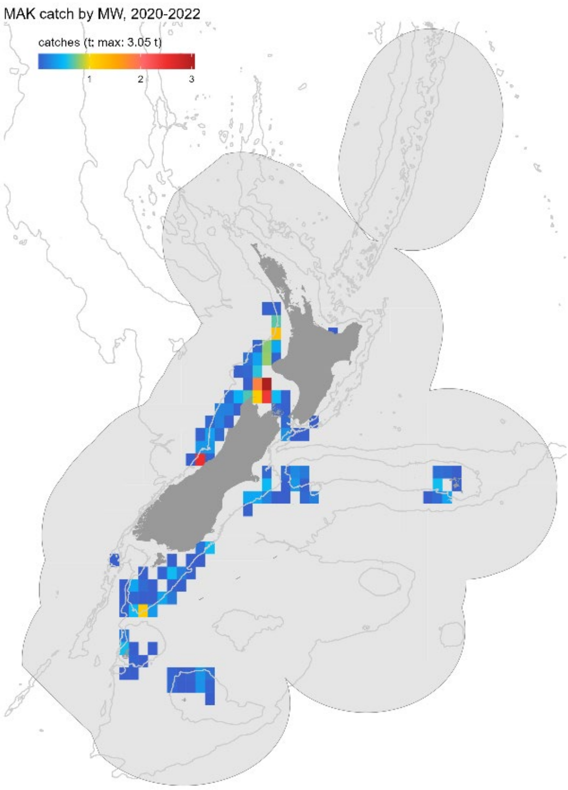


Figure 73: Total catches (including disposals; left) and disposals (right) of mako (MAK) by mid-water trawl (MW) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

Since 2005, destination information has been collected for over 1800 mako captures (Figure 74 and Figure 75). Observed mako caught in surface longline fisheries have mostly been recorded as either alive at hauling (with condition unknown, ~40%) or dead (~40%) (Figure 76 and Figure 77). There was no obvious trend in life status at hauling across shark size, although smaller individuals (< 80 cm FL) were proportionally recorded more often as alive and uninjured (Figure 76). There were few data available for large (> 200 cm FL) mako. The life status of mako from observer records was relatively similar across target fisheries, with proportionally more mako reported dead at hauling in sets targeting bigeye tuna (Figure 77). More detailed information about mako life status has been recorded since the 2015 fishing year (Figure 76 and Figure 77). Recorded life status has varied by fishing year, with up to ~70% of mako recorded as alive and uninjured in 2017 and up to ~85% of mako recorded as dead in 2021. However, data on life status were limited, with no more than 80 individuals recorded annually with life status since 2015, and only 3 individuals in 2022. Mako life status showed an association with soak time, with fewer sharks reported alive and uninjured and the largest proportion of mako recorded dead at hauling with the longest soak times (Figure 78). Mako were more likely to be recorded as alive and uninjured when hooked in the mouth/jaw (~50%), and more likely to be recorded as dead when foul-hooked (~65%) or hooked in the gills (~65%) (Figure 78).

Life status of mako caught in trawl fisheries is not currently recorded. Based on observer data collected since 2005, the mean size of mako caught in trawl fisheries was 171 cm TL (range = 103–249 cm, n = 36).

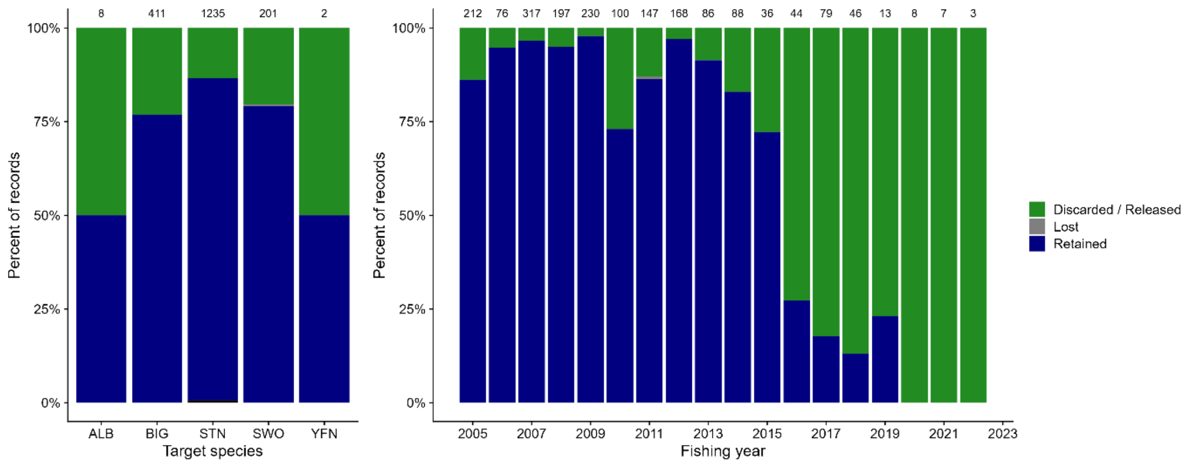


Figure 74: Fate of mako from observer records from the surface longline fishery by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. ALB = albacore tuna, BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish, YFN = yellowfin tuna.

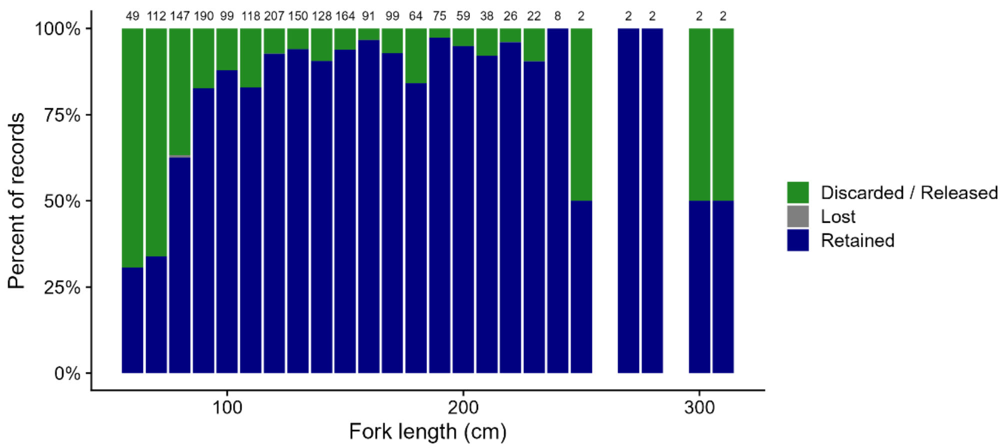


Figure 75: Fate of mako by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

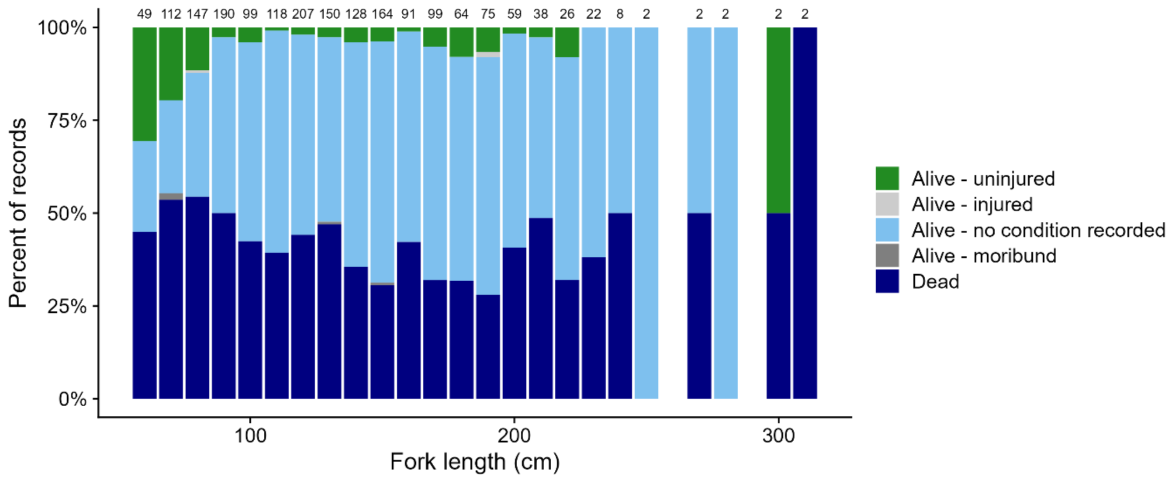


Figure 76: Life status at haul of mako by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

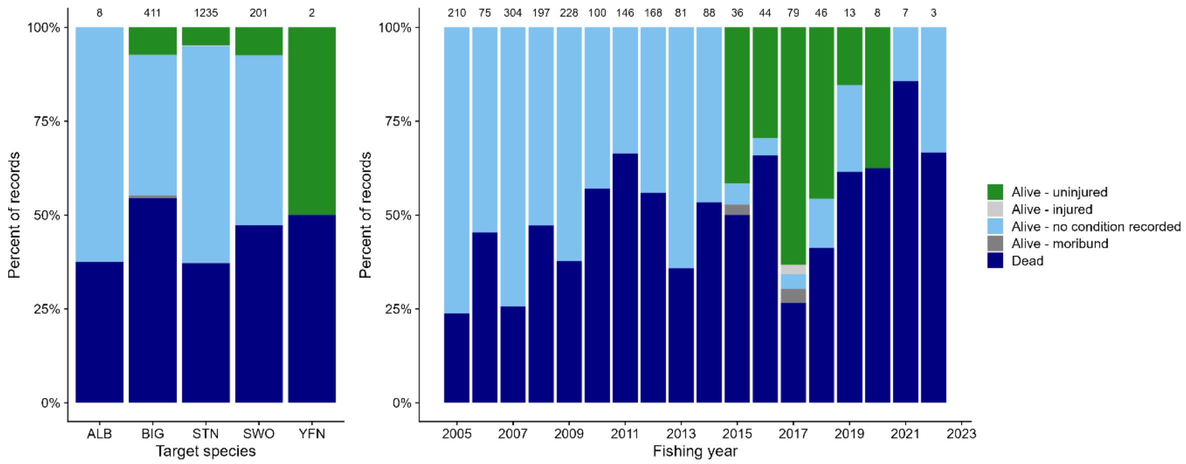


Figure 77: Life status of mako from observer records from the surface longline fishery at-vessel by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. ALB= albacore tuna, BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish, YFN = yellowfin tuna.

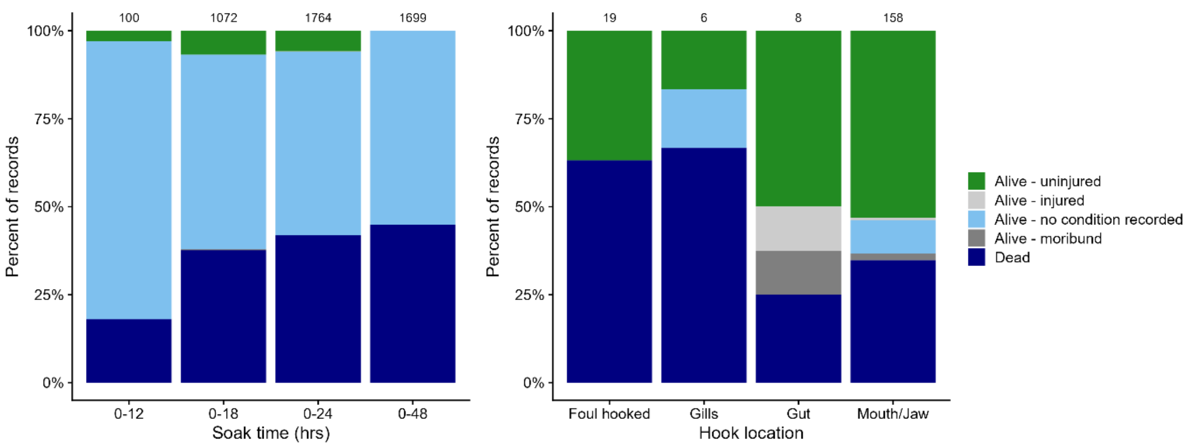


Figure 78: Life status of mako from observer records from the surface longline fishery at-vessel by soak time (left) and hooking location (right). Numbers above the columns indicate sample sizes.

3.4.2. Review of at-vessel and post-release survival studies

Mako is wide-ranging and highly migratory, found throughout all oceans in tropical and temperate waters. They reach lengths of up to 4.3 metres TL. Mako likely comprise one global stock, with some genetic structuring between ocean basins. Mako segregate by size and sex. The species occupies a broad thermal niche, occurring in waters from ~3 °C to 26 °C, and in surface waters to depths ~900 m, with occasional dives recorded as deep as 1400 m. Like other lamnid sharks, mako are obligate ram ventilators and are one of several shark species capable of thermoregulation.

Globally, at-vessel survival for mako is estimated to be moderate (~65%, e.g., Gilman et al. 2022) (Table 18). Mako at-vessel mortality has been assessed in New Zealand fisheries once before; based on observed captures of pelagic sharks during the 1997–98 fishing year, 299 mako were recorded as alive at recovery, accounting for 71.6% of observed sharks for that year (Francis et al. 2001). Sharks were reported to be more likely alive from fisheries operating around the South Island (80.0%) than those operating around the North Island (66.9–73.3%) and survival was found to be higher for domestic vessels (73.3%) than foreign charter vessels (71.0%) (Table 18). At-vessel mortality outside New Zealand has ranged from no survival to up to 100% survival, although studies often rely on much smaller sample sizes than those reported for blue sharks. The largest study assessing mako at-vessel survival (n = 15 726) reported a survival rate of 78% from Hawaiian longline fisheries (Hutchinson et al. 2021). Other studies examining at-vessel survival and the factors that influence it have reported shark size (fork length), soak time/hooking time, and hooking location as significant factors determining survival outputs (Table 18). Like blue sharks, the effect of these factors can vary across studies and effects are not always clear. For example, Miller et al. (2020) reported all mortalities occurred for satellite tagged sharks that had been on the line (i.e., soak time) for more than 16 hours; however, sharks that were hooked for up to 23 hours were also reported to survive fishing events. In the North Atlantic Ocean off Canada, the fishery (target species and an undefined vessel effect) was found to play a factor in shark survival (Campana et al. 2016). Release method (on board vs. in water) and where a shark was hooked have also been shown to be significant factors in determining survival for mako (Bowlby et al. 2021). At-vessel mortality has also been reported from research surface longline trips, largely to measure the effect of gear modifications (e.g., hook type) on catch and fishing mortality (Table 18). While survival estimates from these studies have been high (80–87%, Ochi et al. 2021), these estimates may not be reflective of fishing practices.

There has been one study of post-release survival of mako in New Zealand waters, which was part of a wider South Pacific study (Francis et al. 2023). Here, initial post-release survival based on satellite tagging was considered high (89%), but when factoring in a complete fishing interaction (hauling, handling, release), survival was reduced to 49% (Francis et al. 2023) (Table 19). Shark size, condition, and trailing fishing gear left on the shark were significant factors in determining post-release survival. Elsewhere in the Pacific, post-release survival estimates are variable (83–94%) and are based on small sample sizes (e.g., Musyl et al. 2011, Hutchinson et al. 2021). In the Atlantic Ocean, mako post-release survival has been estimated at ~70% (Campana et al. 2016, Miller et al. 2020) (Table 19).

There are no known studies that have assessed at-vessel and post-release survival from capture in trawl fisheries for mako.

Table 18: Summary of studies examining at-vessel survival of mako in commercial fisheries and research studies. SLL = surface longline; FL = fork length; SST = sea surface temperature; SI = South Island; NI = North Island; FCV = foreign charter vessels. Factors in bold font had a significant influence on survival. (Continued on next page)

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	New Zealand	299	72%	–	Study examined at-vessel survival (1997/98) and those retained/finned; survival SI > NI, domestic > FCV	Francis et al. (2001)
Commercial SLL	Pacific (Marshall Islands)	171	~50%	–	Study examined at-vessel survival; factors influencing shark catch rates	Bromhead et al. (2012)
Commercial SLL	Pacific (Palau)	19	95%	–	Study examined at-vessel survival	Gilman et al. (2016)
Commercial SLL	Pacific (Hawaii)	8	100%	–	No at-vessel mortality observed but 20.5% reported dead by commercial fishery targeting swordfish	Musyl et al. (2011)
Commercial SLL	Pacific (Hawaii)	15 726	78%	–	Study examined at-vessel and post-release survival	Hutchinson et al. (2021)
Commercial SLL	Pacific Community holdings	3 581	55%	–	Total fishing interaction (hauling, handling, release) survival estimated at 49%	Francis et al. (2023)
Commercial SLL	Atlantic (Brazil)	69	0–67%	–	Study examined effect of hook type of catch (circle and J-hook); at-vessel mortality 100% on J-hook	Pacheco et al. (2011)
Commercial SLL	Atlantic	1 414	64%	**FL**	Study examined at-vessel survival; increased survival with increased size	Coelho et al. (2012)
Commercial SLL	Atlantic (Canada)	543	~68–80%	Hook type; **Hook location**; Bait type; SST; **Soak time**; FL	Study examined at-vessel survival; foul-hooking increased mortality but not significantly	Epperly et al. (2012)
Commercial SLL	Atlantic/Gulf of Mexico	2 126	71%	Target; Hook depth; SST; Soak time; FL	Study examined at-vessel survival; no factors considered significant	Gallagher et al. (2014)

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	Atlantic (Canada)	528	74%	**Fishery (target species and/or vessel effect)**	Study examined at-vessel survival; total survival estimated at 49%	Campana et al. (2016)
Commercial SLL	Atlantic/Indian (South Africa)	2041	47%	–	Study characterised pelagic shark bycatch	Petersen et al. (2009)
Research SLL	Pacific (French Polynesia)	8	25%	**Hooking time**; FL; Depth; SST; Dissolved O_2; Hook location; Time of capture	Study examined at-vessel survival; blue shark and mako were combined in a "mesopelagic shark" category	Massey et al. (2022)
Research SLL (chartered commercial vessel)	Atlantic (Brazil)	6	0–20%	–	Study examined fishing gear modifications (hook type) to reduce mortality	Afonso et al. (2011)
Research SLL	Pacific (Japan)	31	87%	–	Study examined effect of hook type on catch (circle and tuna)	Yokota et al. (2006)
Research SLL	Pacific (Japan)	260	80%	–	Study examined effect of circle hook on mortality	Ochi et al. (2021)

Table 19: Summary of studies examining post-release survival of mako in commercial fisheries and research studies. SLL = surface longline; FL = fork length; SST = sea surface temperature. Factors in bold font had a significant influence on survival.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	New Zealand, Fiji, New Caledonia	57	89%	**FL**; **Condition**; **Branch line ratio**; Tag location; Tag country	Total fishing interaction (hauling, handling, release) survival estimated at 49%	Francis et al. (2023)
Commercial SLL	Pacific (Chile)	9	56%	–	Primary focus of study was movement; mortalities observed between 3 and 133 days	Abascal et al. (2011)
Commercial SLL	Pacific (Hawaii, American Samoa)	18	94%	Fishery; Handling Method; Condition at capture and release; Trailing fishing gear; Branch line material	Only 1 mortality of 18 tags reporting; work ongoing	Hutchinson et al. (2021)
Commercial SLL	Atlantic (Canada)	26	~70%	**Condition**; Hook type; Hook size; Soak time; Vessel; FL; SST	Survival of healthy sharks was independent of where shark tagged (in water/on board)	Campana et al. (2016)
Commercial SLL	Atlantic (Canada)	104	64%	**Hooking location**; **Tagging location**; FL; Condition; Sex; Gear type; Hook type	Survivorship was lower when sharks were hooked in the gut and when brought on board	Bowlby et al. (2021)
Research SLL	Pacific (Hawaii)	2	83%	–	Three non-reporting tags (at-vessel mortality estimated as well)	Musyl et al. (2011)

3.4.3. Expert elicitation

Reasons for release

Stakeholders advised that mako are disposed because they are not commercially viable and that by retaining these species, there is less room in fish holds for more valuable target species. There is a small local market for mako, but only for the smallest individuals (the single Licensed Fish Receiver (LFR) currently taking mako will only accept fish less than 75 kg trunked weight); larger individuals are not marketable due to concerns over mercury levels. Mako were also viewed as a health and safety issue, and fishers and observers advised that it was generally safer to cut large sharks off in the water than to bring them on deck for de-hooking.

At-release survival – surface longline

Based on expert elicitation, mako condition at release when caught in surface longline fisheries was uncertain, with responses suggesting that approximately half of mako were alive and uninjured at hauling, a small percentage of mako were released with an injury (minor or severe), and up to half of mako were released dead (Figure 79). Shark size/life stage and sea surface temperature appeared to have little influence on the percentage of sharks released alive. Survey participants indicated that more mako were released alive with shorter soak times (< 12 hours) and that a small percentage of released sharks (generally less than 25%) were foul-hooked or hooked in the gut. There was less certainty with the percentage of sharks released with trailing gear, with some survey respondents suggesting 50–75% of mako have some trailing gear attached when released (Figure 79).

Post-release survival – surface longline

Survey results indicated mako post-release survival when caught in surface longline fisheries was highest (>50%) when sharks were released alive and uninjured and low when sharks were alive and severely injured (<25% survival) (Figure 79). Shark size/life stage and sea surface temperature were not considered to influence post-release survival and survey respondents suggested post-release survival was moderate (50–75%). Soak time was considered to have some influence on post-release survival, with survival rates considered to be higher when soak time was low (<12 hours). Survey respondents considered mako post-release survival to be highest when sharks were hooked in the jaw, and lower when hooked in the gills, gut, or foul-hooked. Post-release survival was considered to be high (> 90%) when sharks were released from the water and moderate (50–75%) when sharks were released with no or limited (< 1 body length) trailing gear. Post-release survival was considered to be reduced (25–50%) with increased length of trailing gear (Figure 79).

At-release and post-release survival – trawl

Survey respondents indicated a small percentage (< 25%) of mako are released alive after capture in mid-water trawl fisheries, regardless of the factors considered (e.g., shark size/life stage, depth of capture, catch volume, tow duration) (Figure 80). Only two respondents answered the questions regarding post-release survival of mako after being caught by trawl. Mako post-release survival estimates when caught in trawl were largely uncertain but were considered to be low (< 50%) across all categories (Figure 80).

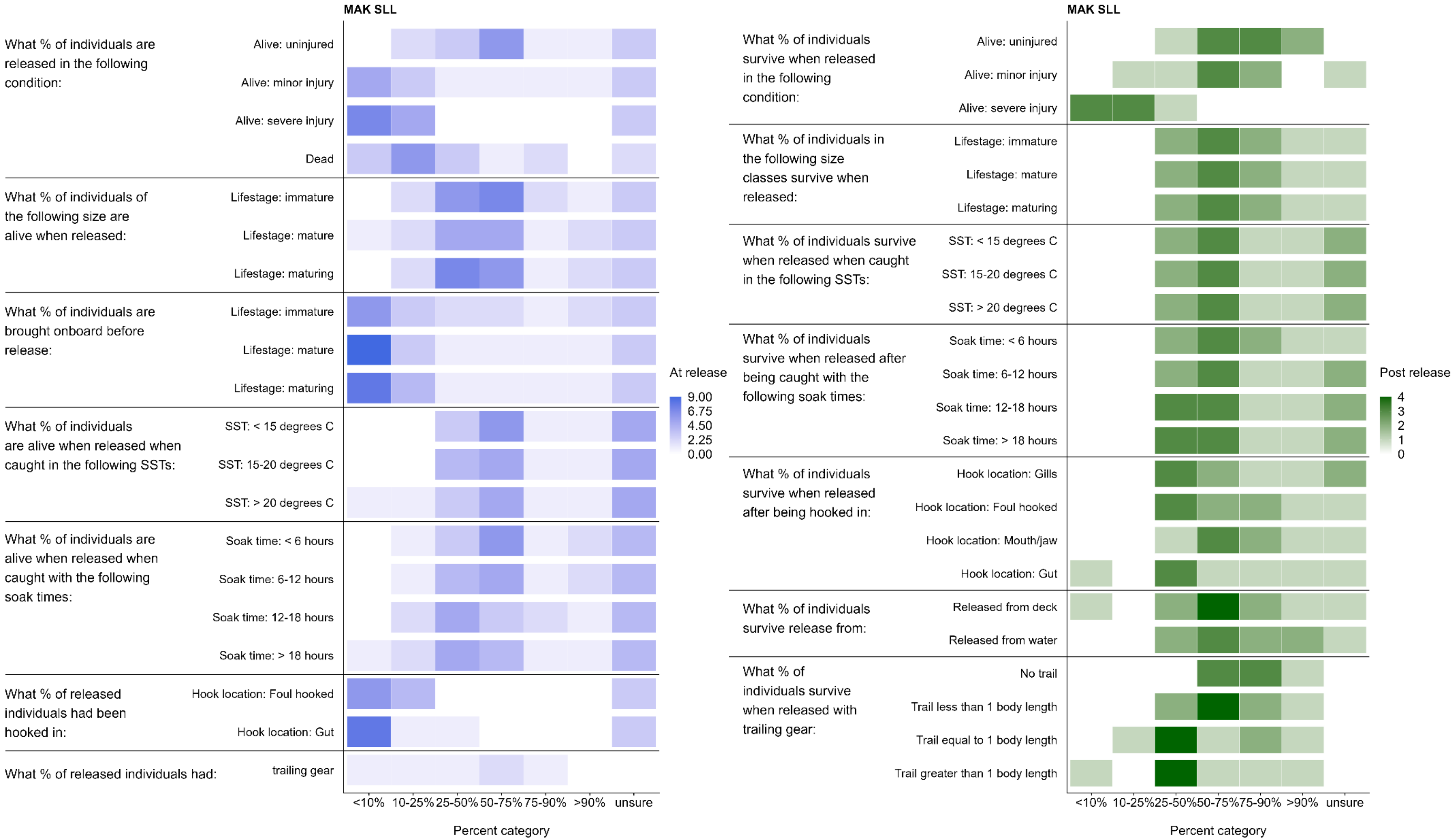


Figure 79: Results from the expert elicitation questionnaire for mako (MAK) caught by surface longline (SLL). Left: responses to questions on at-release survival. Right: responses to questions on post-release survival. Darker colours indicate a greater number of responses. SST = sea surface temperature.

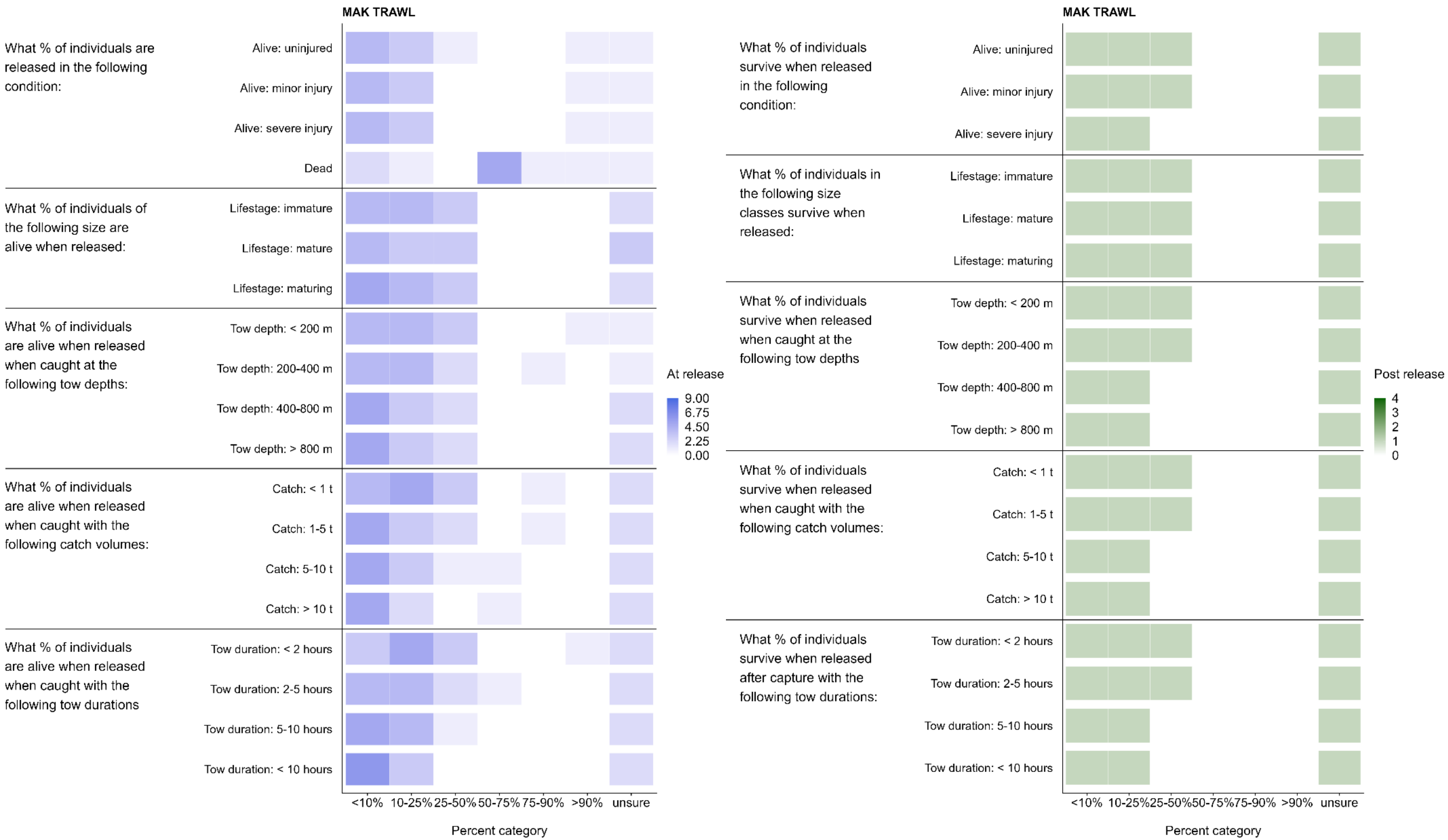


Figure 80: Results from the expert elicitation questionnaire for mako (MAK) caught by trawl. Left: responses to questions on at-release survival. Right: responses to questions on post-release survival. Darker colours indicate a greater number of responses.

3.4.4. Fishery survival probability estimates

Appropriate and comparable priors for mako were applied to most factors for surface longline estimates and were based on the South Pacific study by Francis et al. (2023), which included mako caught in New Zealand waters (see Appendix 3). Additional priors for release method (on board) and hooking location (jaw) were included based on a post-release survival study from the North Atlantic Ocean where these two factors were found to be significant factors in determining survival (Bowlby et al. 2021). No priors could be found for SST, or when mako were caught in the gills, gut, or foul-hooked. No priors were applied for mako caught in trawl fisheries.

Surface longline

At-release survival only

Perceived at-release survival probability estimates for mako caught in surface longline fisheries across the assessed factors were medium (shark size and soak times > 12 hours), medium-high (SST >15 °C and soak time < 12 hours), or high (SST < 15 °C) (Figure 81). When factors were aggregated and weighted to the fishery profile, at-release survival probability estimates were medium (shark size and soak time) to medium-high (SST) (Figure 82). Application of prior values improved at-release survival probability estimates for shark size to high (Figure 81 & Figure 82).

Post-release survival only

When only post-release survival was considered for mako (i.e., on the assumption that individuals were released alive), perceived survival was estimated as medium (e.g., for individuals released following long soak times or when foul- or gill-hooked), medium-high (e.g., for all categories of SST and shark size), or high (e.g., if individuals were jaw-hooked, released uninjured, or released with little to no trailing gear) (Figure 83). Survival probability estimates were low if individuals were released with a severe injury and low-medium if individuals were gut-hooked or released with trailing gear equal to or greater than the shark's body length (Figure 83). Perceived survival estimates improved when priors were applied, and post-release perceived survival was high for mako when sharks were released in water, released uninjured or with minor injury, or released when soak time was < 18 hours (Figure 83). Perceived survival was also high regardless of shark size and the amount of trailing gear left on the shark. When factors were aggregated and weighted across the fishery profile and priors were applied, perceived survival probability estimates improved and were high except for SST, which remained medium-high (Figure 84).

At-release and post-release survival combined

Perceived combined survival probability estimates for mako released from surface longline fisheries were low-medium for most factor categories without the inclusion of priors (Figure 85). Perceived survival was low only when individuals were released with a severe injury. Perceived overall survival was high when sharks were released in the water, released uninjured or with a minor injury, released with little to no trailing gear, and when initially hooked in the mouth/jaw. When priors were applied to the factor categories, mako perceived survival improved to high for trailing gear factors, improved to medium-high for individuals released with a severe injury, but remained low-medium for all levels of SST and most soak times (Figure 85).

When applied to the fishery profile, perceived survival of mako caught in New Zealand's surface longline fisheries was variable across the combined categories. Survival was low-medium for SST, shark size, and soak time, medium-high for release method, and high for release condition, hooking location, and trailing gear (Figure 86). When priors were applied, perceived survival for mako remained high for release condition, hooking location, and trailing gear, improved to high for release method, improved to medium for shark size, and remained low-medium for SST and soak time (Figure 86). Based on these estimates, the overall perceived survival for mako caught in surface longline fisheries was considered to be low-medium.

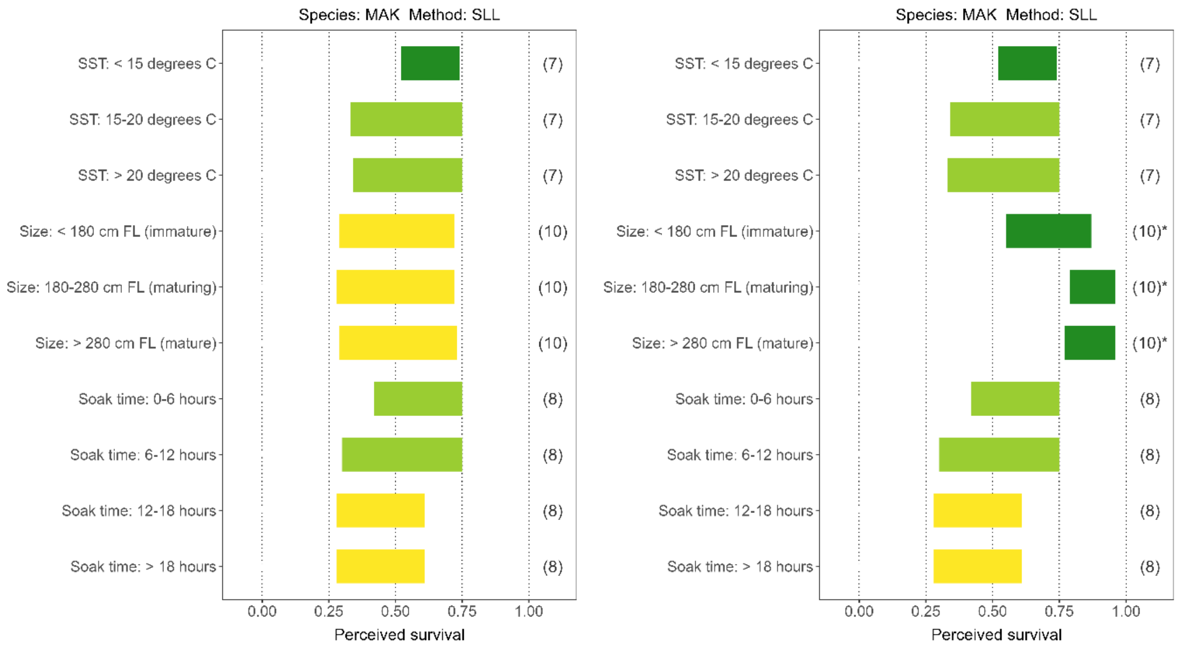


Figure 81: 90% confidence intervals on perceived at-release mean survival estimates for mako (MAK) following release from surface longline (SLL) in New Zealand waters by factor-category. Note this plot assesses at-release survival only. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. The number in parentheses indicates the number of survey respondents. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

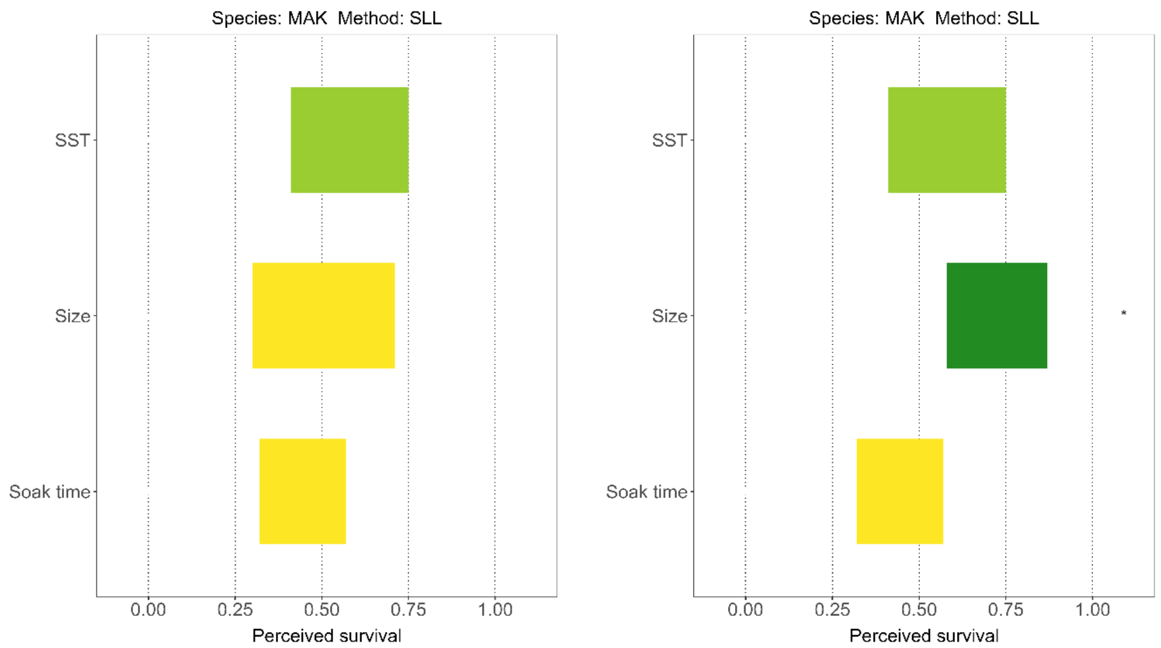


Figure 82: 90% confidence intervals on perceived at-release mean survival estimates for mako (MAK) following release from surface longline (SLL) in New Zealand waters by factor. Note this plot assesses at-release survival only. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

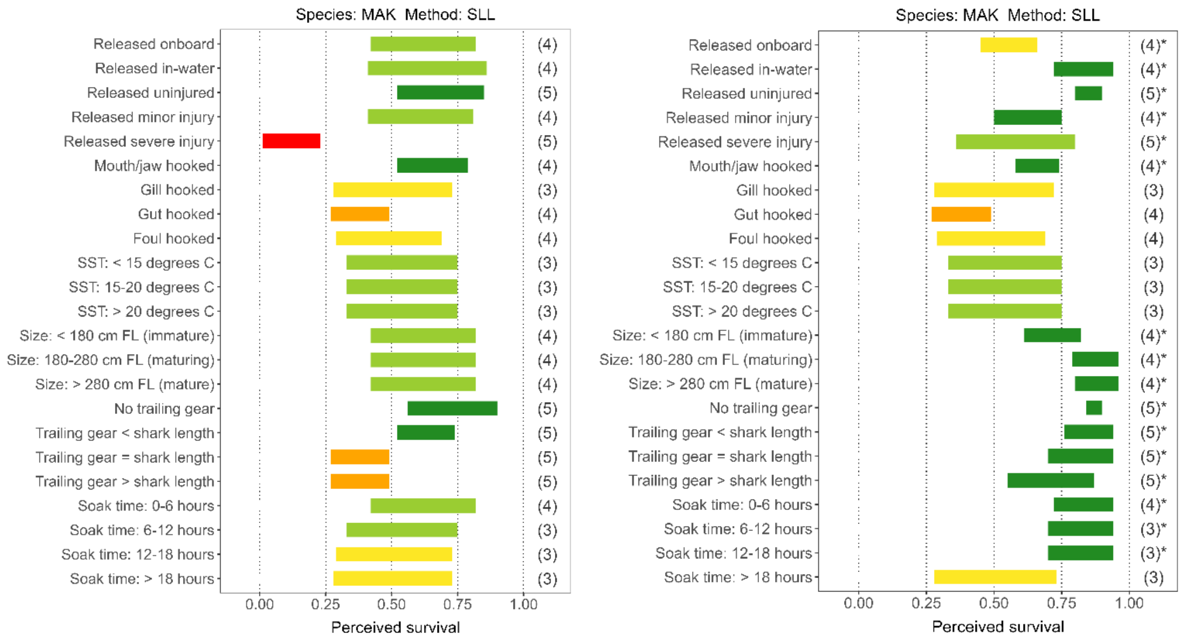


Figure 83: 90% confidence intervals on perceived post-release mean survival estimates for mako (MAK) following release from surface longline (SLL) in New Zealand waters by factor-category. Note this plot assumes all individuals released are alive at the time of release, and does not account for condition at release. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. The number in parentheses indicates the number of survey respondents. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

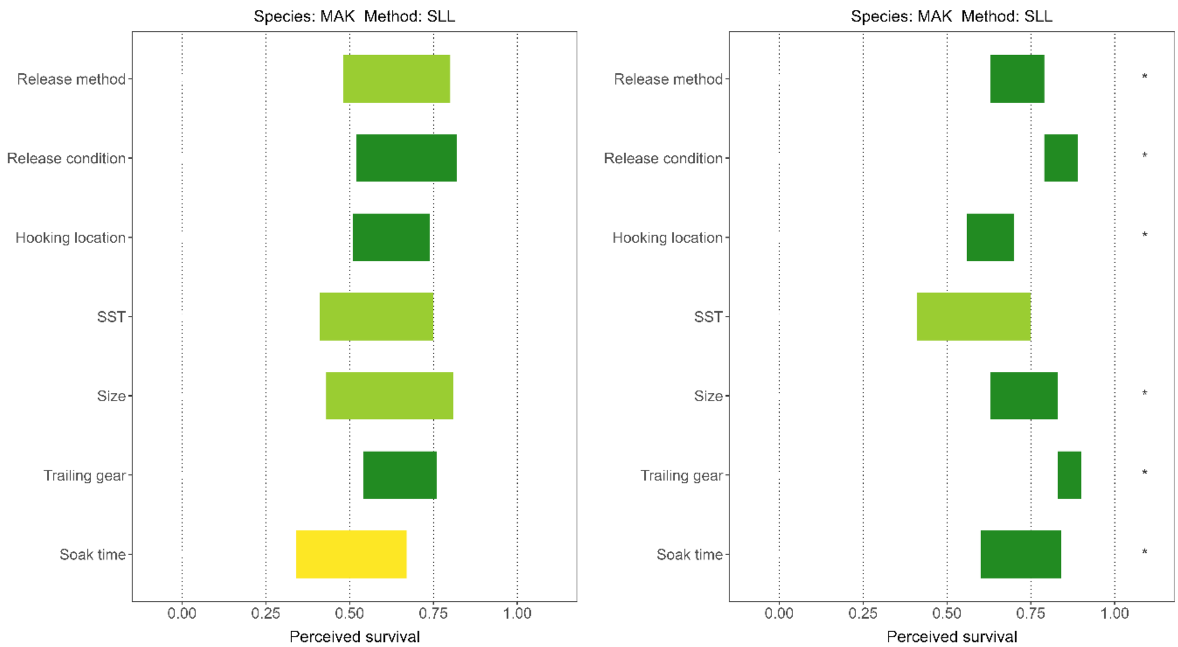
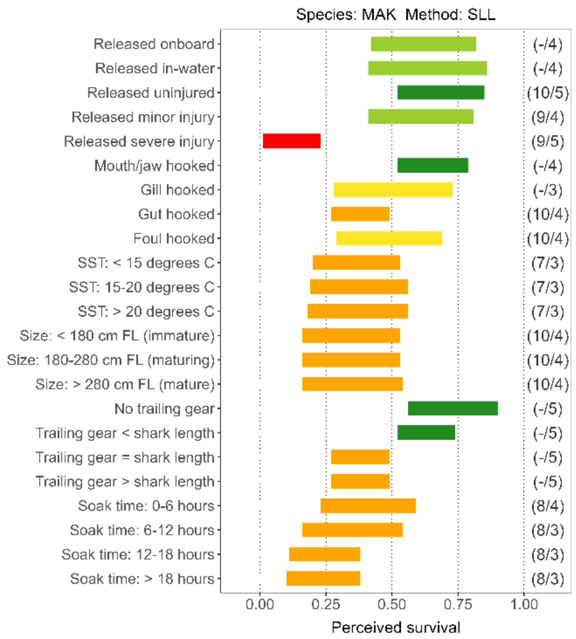


Figure 84: 90% confidence intervals on perceived post-release mean survival estimates for mako (MAK) following release from surface longline (SLL) in New Zealand waters by factor. Note this plot assumes all individuals released are alive at the time of release, and does not account for condition at release. Left: without priors applied; right: with priors applied. * denotes those factors informed by priors. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.



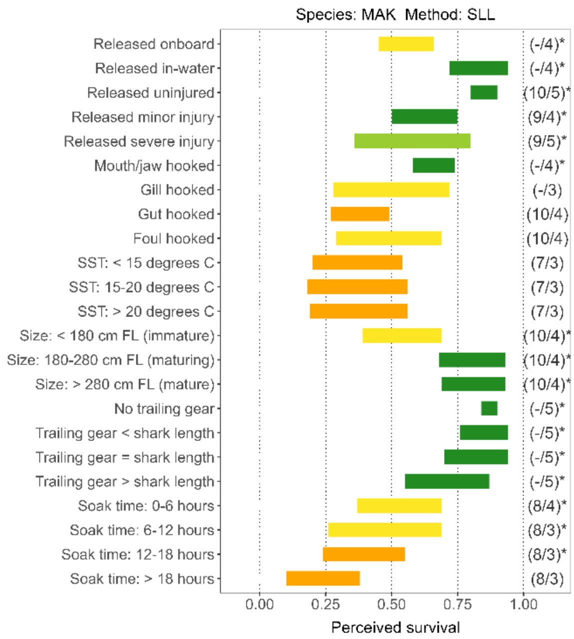


Figure 85: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for mako (MAK) following release from surface longline (SLL) in New Zealand waters by factor-category. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. The number in parentheses indicates the number of survey respondents (at-release / post-release). SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

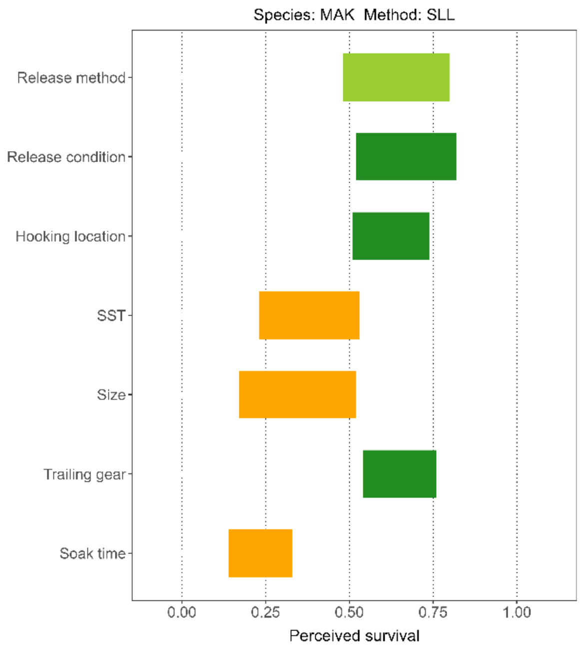


Figure 86: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for mako (MAK) following release from surface longline (SLL) in New Zealand waters by factor. Left: without priors applied; right: with priors applied. * denotes those factors informed by priors. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

Trawl

At-release survival only

Perceived at-release (i.e., immediate) survival probability estimates for mako released after capture in trawl fisheries was considered to be low-medium when catches were < 5 t, tow durations were < 5 hours, tow depths were < 400 m, and across all life stages, and low when catches were > 5 t, tow durations were > 5 hours, and tow depths were > 400 m (Figure 87). When weighted to the fishery profile, mako at-release survival probability estimates were low-medium for fish size, tow depth, and tow duration, and low for catch weight (Figure 88).

Post-release survival only

Perceived post-release survival probability estimates for mako released after capture in trawl fisheries was considered to be low-medium when catches were < 5 t, tow durations were < 5 hours, tow depths were < 400 m, when individuals were released uninjured or with a minor injury, and for all life stages (Figure 89). In contrast, post-release survival probabilities were low when catches were > 5 t, tow durations were > 5 hours, tow depths were > 400 m, and when individuals were released with a severe injury (Figure 89). When weighted to the fishery profile, mako post-release survival probability estimates were low-medium for life stage, release condition, tow duration, and tow depth, and low for catch weight (Figure 90). It should be noted, however, that these estimates were derived from a single survey response and are not informed by priors (due to a lack of published information of post-release survival of mako in comparable trawl fisheries). Accordingly, these estimates should be treated with caution.

At-release and post-release survival combined

Combined survival probability estimates (i.e., accounting for at-release and post-release survival) for mako released after capture in trawl fisheries was low across most factor levels (Figure 91). There was some improvement in perceived survival (to low-medium) when individuals were released uninjured or with a minor injury; however, these estimates were still < 50% (Figure 91). When weighted to the fishery profile, survival probability estimates were low for catch weight, shark size, tow duration, and tow depth, and low-medium for release condition (Figure 92). Based on these estimates, overall combined (i.e., at-release and post-release) perceived survival for mako caught in mid-water trawl fisheries was considered to be low.

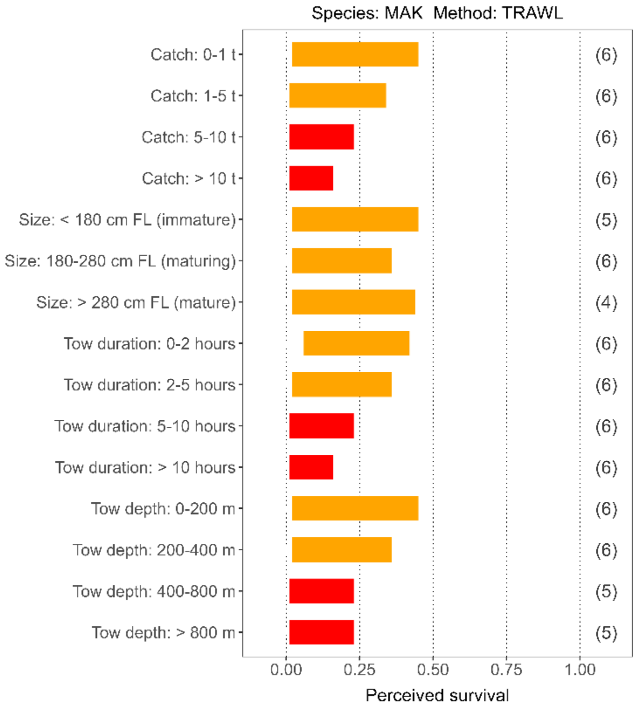


Figure 87: 90% confidence intervals on perceived at-release mean survival estimates for mako (MAK) following release from trawl in New Zealand waters by factor-category. Note this plot assesses at-release survival only, and no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents. See Table 4 and Figure 1 for an explanation of colours and survival categories.

Figure 88: 90% confidence intervals on perceived at-release mean survival estimates for mako (MAK) following release from trawl in New Zealand waters by factor. Note this plot assesses at-release survival only, and no priors were applied to these particular categories. See Table 4 and Figure 1 for an explanation of colours and survival categories.

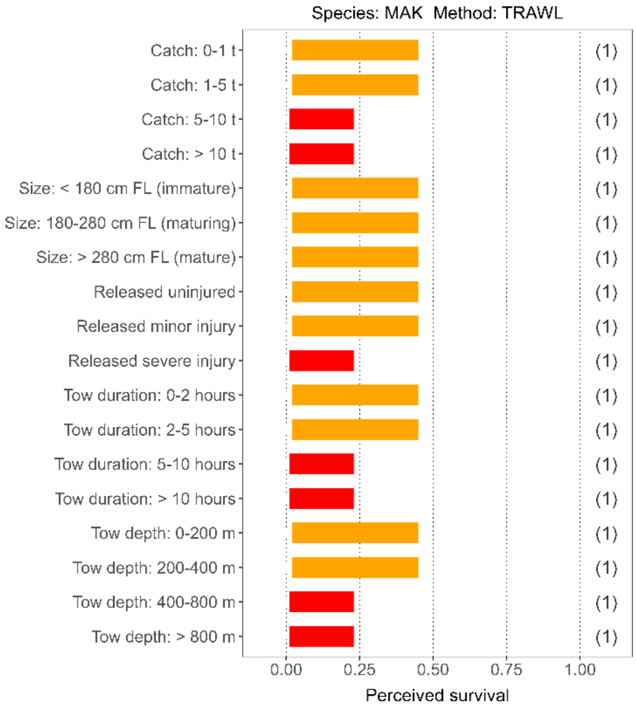


Figure 89: 90% confidence intervals on perceived post-release mean survival estimates for mako (MAK) following release from trawl in New Zealand waters by factor-category. Note this plot assumes all individuals released are alive at the time of release, and no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents. See Table 4 and Figure 1 for an explanation of colours and survival categories.

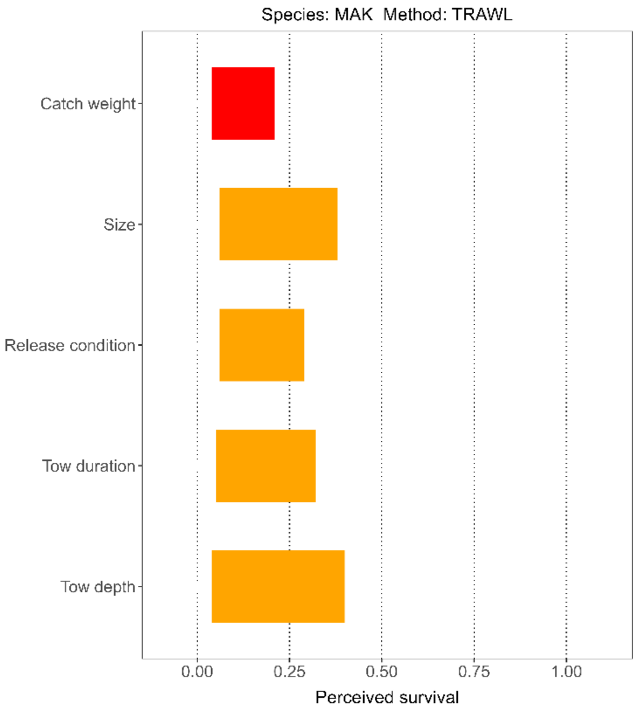


Figure 90: 90% confidence intervals on perceived post-release mean survival estimates for mako (MAK) following release from trawl gear in New Zealand waters by factor. Note this plot assumes all individuals released are alive at the time of release, and no priors were applied to these particular categories. See Table 4 and Figure 1 for an explanation of colours and survival categories.

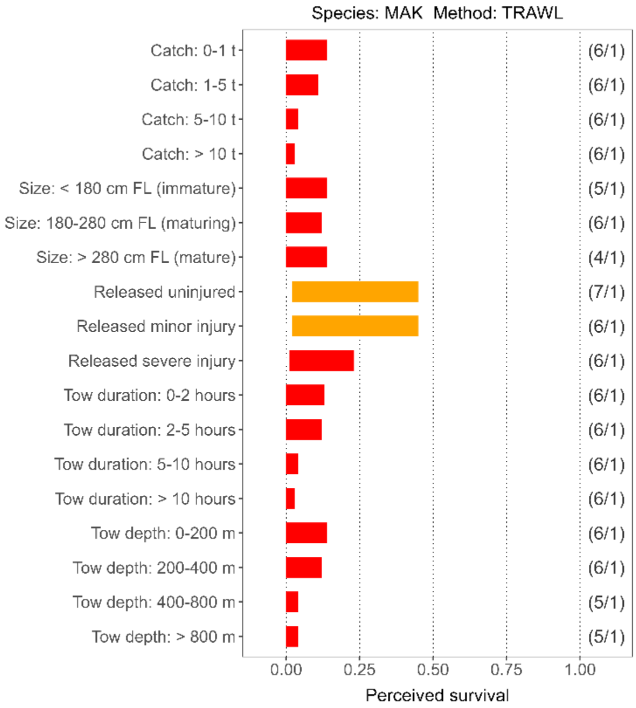


Figure 91: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for mako (MAK) following release from trawl gear in New Zealand waters by factor-category. Note no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents (at-release / post-release). See Table 4 and Figure 1 for an explanation of colours and survival categories.

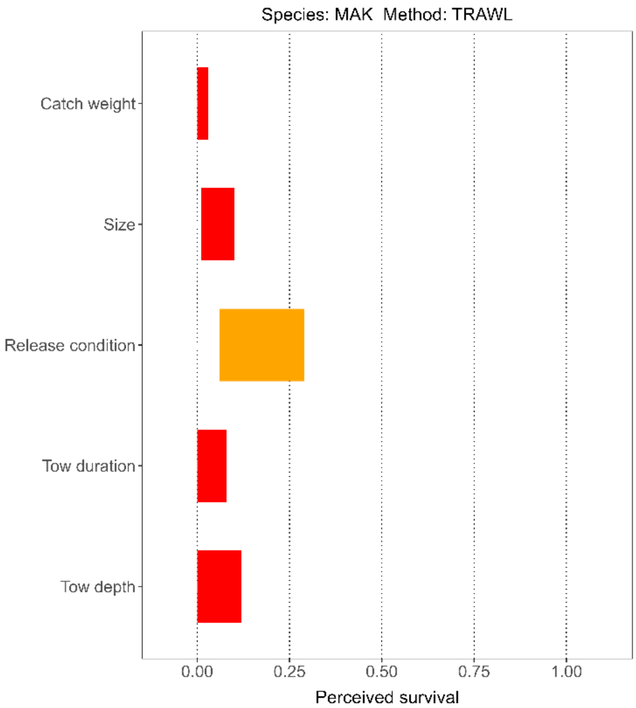


Figure 92: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for mako (MAK) following release from trawl gear in New Zealand waters by factor. Note no priors were applied to these particular categories. See Table 4 and Figure 1 for an explanation of colours and survival categories.

3.5 Porbeagle shark (*Lamna nasus*)

3.5.1. Fishery characterisation

Since the ban on shark finning in 2015, almost all porbeagle catches are now discarded or actively released (Table 20). The annual mean total catch (i.e., including landings and disposals) of porbeagle in the three-year period from 2019–02 to 2021–22 was 47.3 t (Table 20 and Figure 93). Annual average disposals were 47.1 t, representing 99.5% of the annual commercial catch by weight.

Between 2019–20 and 2021–22, surface longline accounted for 49.9% of total porbeagle commercial captures and 50.4% of disposals (Figure 94 and Figure 95). Mid-water and bottom trawl accounted for 33.7% and 10.8% of commercial captures, respectively, and 33.6% and 9.3% of disposals, respectively (Figure 94 and Figure 95). All other fishing methods combined accounted for 6.7% of total porbeagle disposals (Figure 94 and Figure 95). The most significant of these were bottom longline (3.3 t of disposals, representing 2.3% of total disposals by weight) and set net (3.2 t of disposals, 2.3% of total disposals by weight) (Figure 94).

In the last three fishing years, 51.8% of disposals of porbeagle from surface longline have been attributed to disposal code X (i.e., alive and likely to survive), with the remaining 48.2% attributed to disposal code Z (i.e., dead or near-dead) (Figure 96). For trawl, most (82.3%) disposals in the last three fishing years have been attributed to disposal code Z, with the remaining 17.7% attributed to disposal code X (Figure 96).

Most of the porbeagle catch and disposals by surface longline in the last three fishing years was taken by sets targeting southern bluefin tuna off the west coast of the South Island (Figure 97, Figure 98, Figure 99). Most of the porbeagle catch and disposals by mid-water trawl in the last three fishing years has occurred around the Campbell Plateau in trawls targeting southern blue whiting (*Micromesistius australis*) (Figure 98 and Figure 100), as well as off the west coast of the South Island (Figure 100). Most of the porbeagle catch and disposals by bottom trawl in the last three fishing years has occurred around the Auckland Islands (Figure 101), from tows targeting arrow squid (*Nototodarus sloanii*) and hoki (Figure 98).

Table 20: Catches of porbeagle in New Zealand by weight and proportion by destination and fishing year, 2004–05 to 2021–2022.

	Total catch (t)			Proportion		
Fishing	Landed	Discarded	Released	Landed	Discarded	Released
2005	46.53	6.24	–	0.882	0.118	–
2006	44.11	4.01	–	0.917	0.083	–
2007	43.80	2.35	3.32	0.885	0.047	0.067
2008	40.78	0.95	1.68	0.939	0.022	0.039
2009	47.36	0.99	3.29	0.917	0.019	0.064
2010	62.16	1.20	2.71	0.941	0.018	0.041
2011	67.56	0.43	3.69	0.943	0.006	0.051
2012	54.02	0.23	2.28	0.956	0.004	0.040
2013	65.69	2.27	13.04	0.811	0.028	0.161
2014	56.09	6.36	20.31	0.678	0.077	0.245
2015	19.30	49.74	42.24	0.173	0.447	0.380
2016	7.33	32.78	48.54	0.083	0.370	0.548
2017	2.02	19.23	40.80	0.033	0.310	0.658
2018	1.60	58.12	40.19	0.016	0.582	0.402
2019	0.93	41.78	26.96	0.013	0.600	0.387
2020	0.17	28.90	16.07	0.004	0.640	0.356
2021	0.44	33.01	21.12	0.008	0.605	0.387
2022	0.13	26.69	15.41	0.003	0.632	0.365

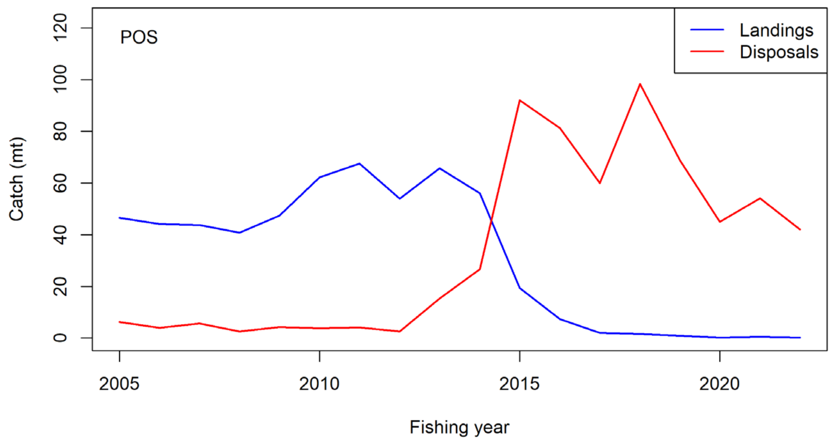


Figure 93: Annual commercial landings and disposals of porbeagle (POS) in New Zealand's Exclusive Economic Zone from 2004–05 (2005) to 2021–22 (2022).

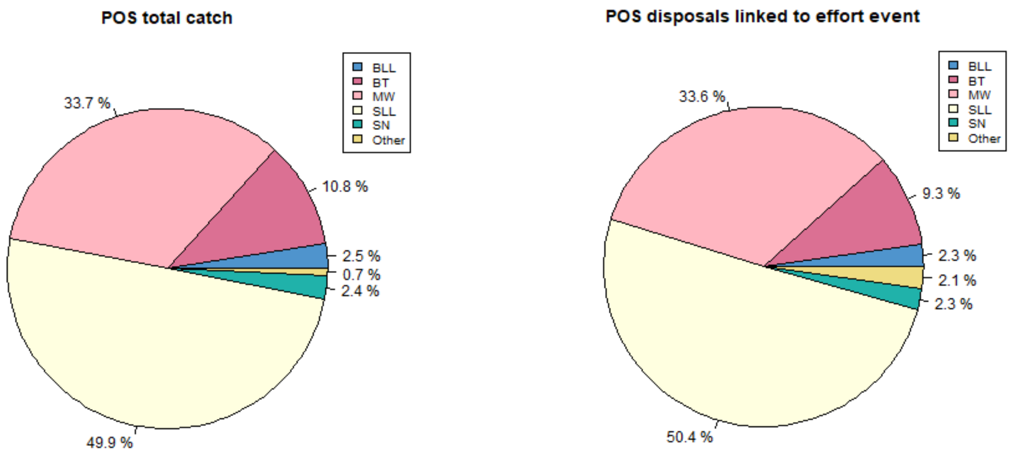


Figure 94: Porbeagle (POS) total catches (left) and disposals (right) in New Zealand's Exclusive Economic Zone by fishing method, 2019–20 to 2021–22. BLL = bottom longline, BT = bottom trawl, MW = mid-water trawl, SLL = surface longline, SN = set net.

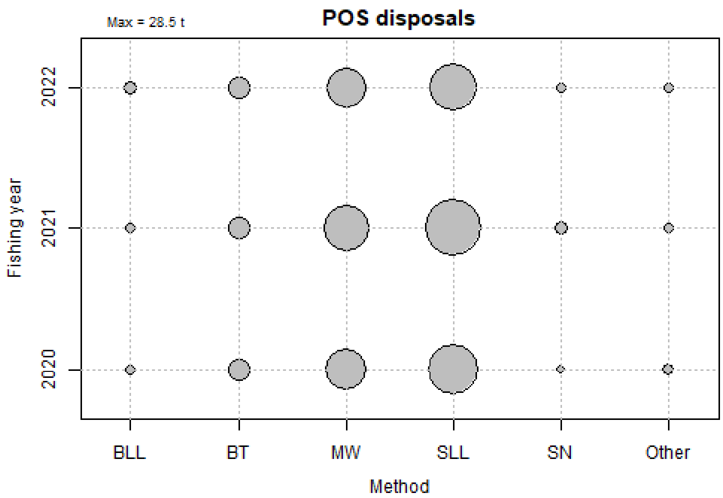


Figure 95: Disposals of porbeagle (POS) by fishing method in New Zealand's Exclusive Economic Zone from 2019–20 to 2021–22. BLL = bottom longline, BT = bottom trawl, MW = mid-water trawl, SLL = surface longline, SN = set net.

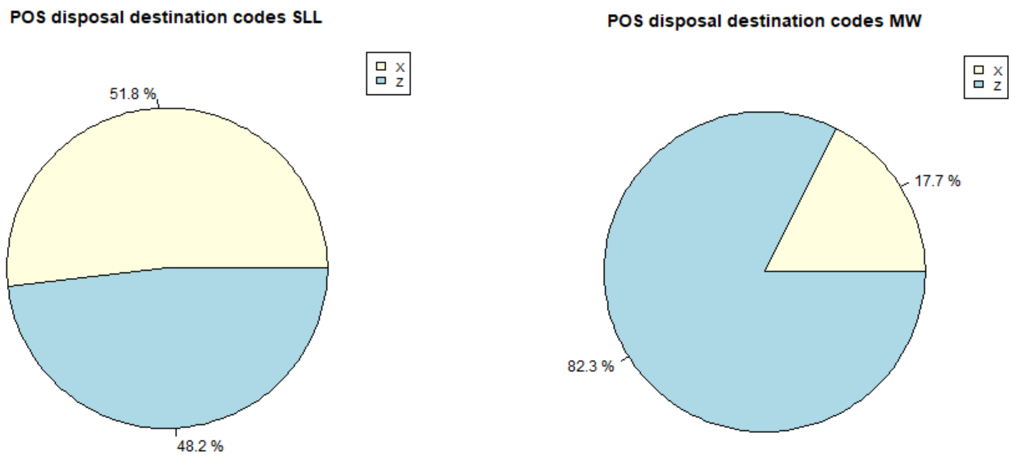


Figure 96: Codes attributed to disposals of porbeagle (POS) from the surface longline (SLL; left) and mid-water trawl (MW; right) fisheries in New Zealand's Exclusive Economic Zone between 2019–20 and 2021–22.

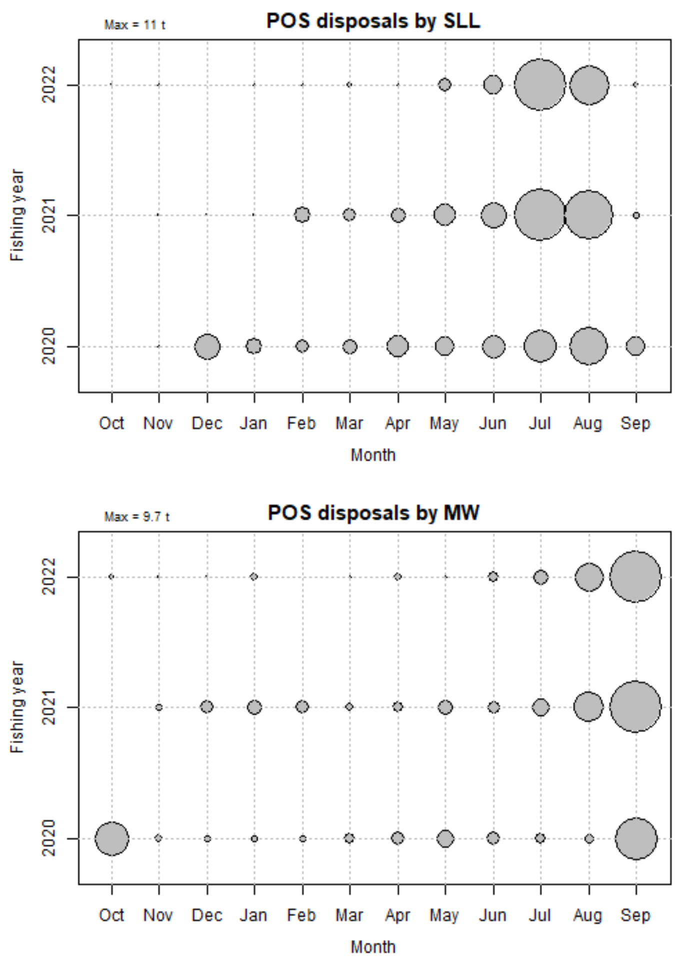


Figure 97: Disposals of porbeagle (POS) by month in New Zealand's Exclusive Economic Zone from 2019–20 to 2021–22 for surface longline (SLL; top) and mid-water trawl (MW; bottom).

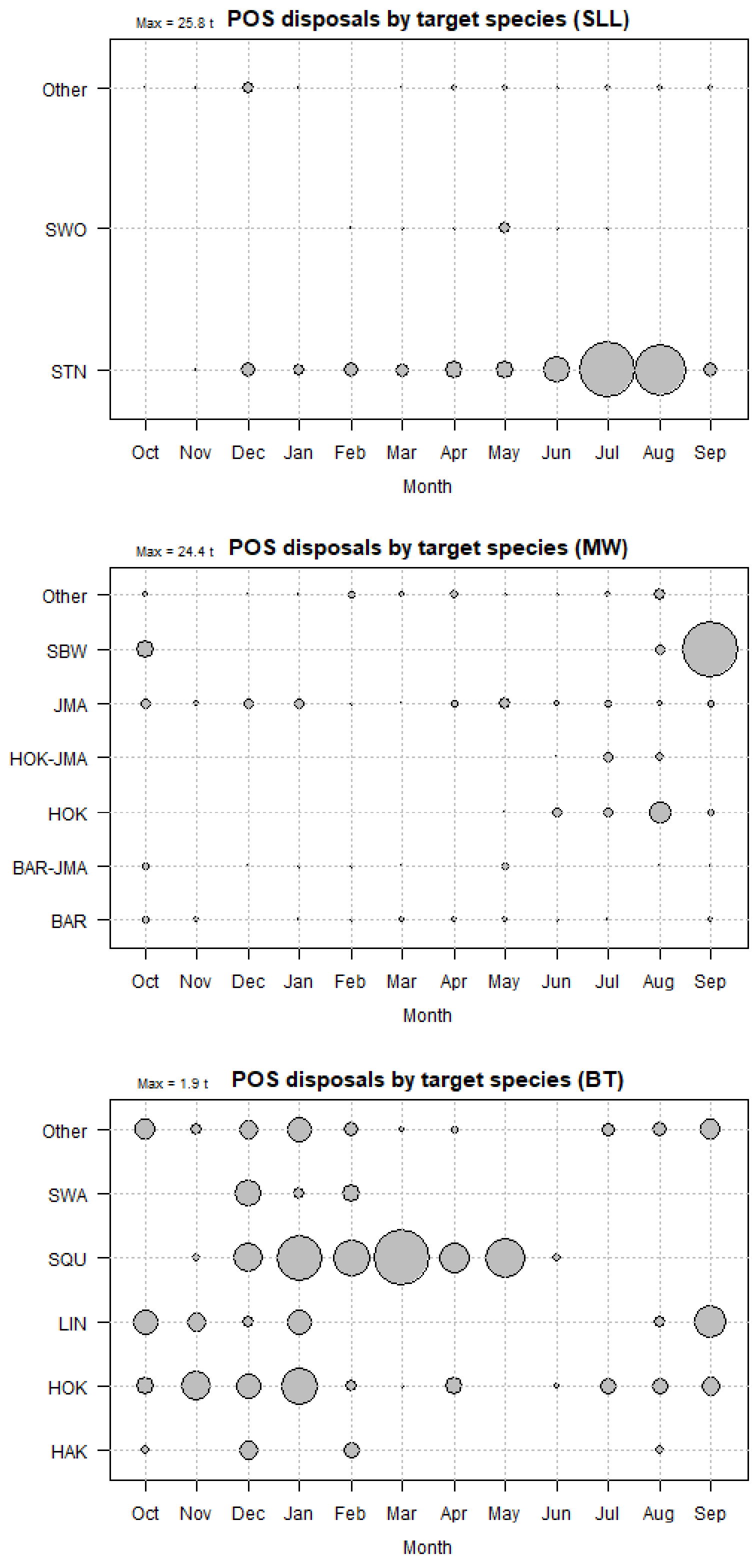


Figure 98: Disposals of porbeagle (POS) by month and target species in New Zealand's Exclusive Economic Zone for 2019–20 to 2021–22 for surface longline (SLL; top), mid-water trawl (MW; middle) and bottom trawl (BT; bottom). SWO = swordfish, STN = southern bluefin tuna, SBW = southern blue whiting, JMA = jack mackerel, HOK = hoki, BAR = barracouta, SWA = silver warehou, SQU = squid, LIN = ling, HAK = hake.

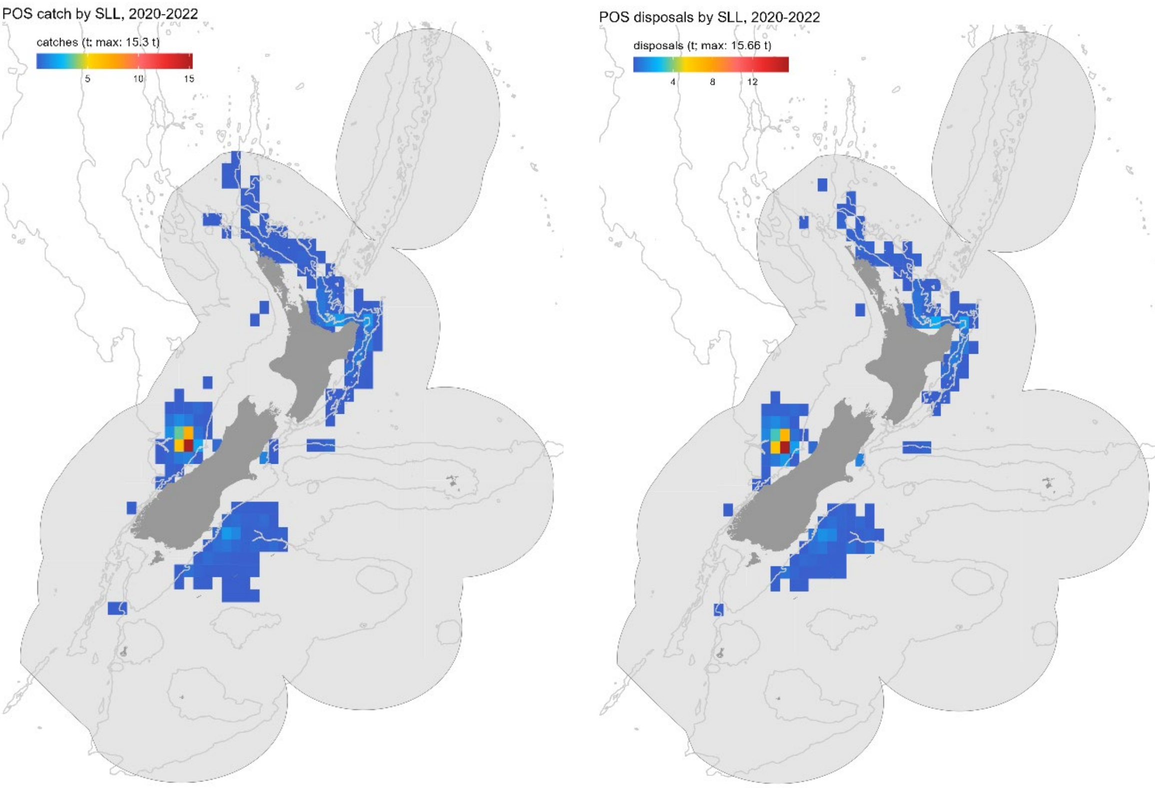


Figure 99: Total catches (including disposals; left) and disposals (right) of porbeagle (POS) by surface longline (SLL) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

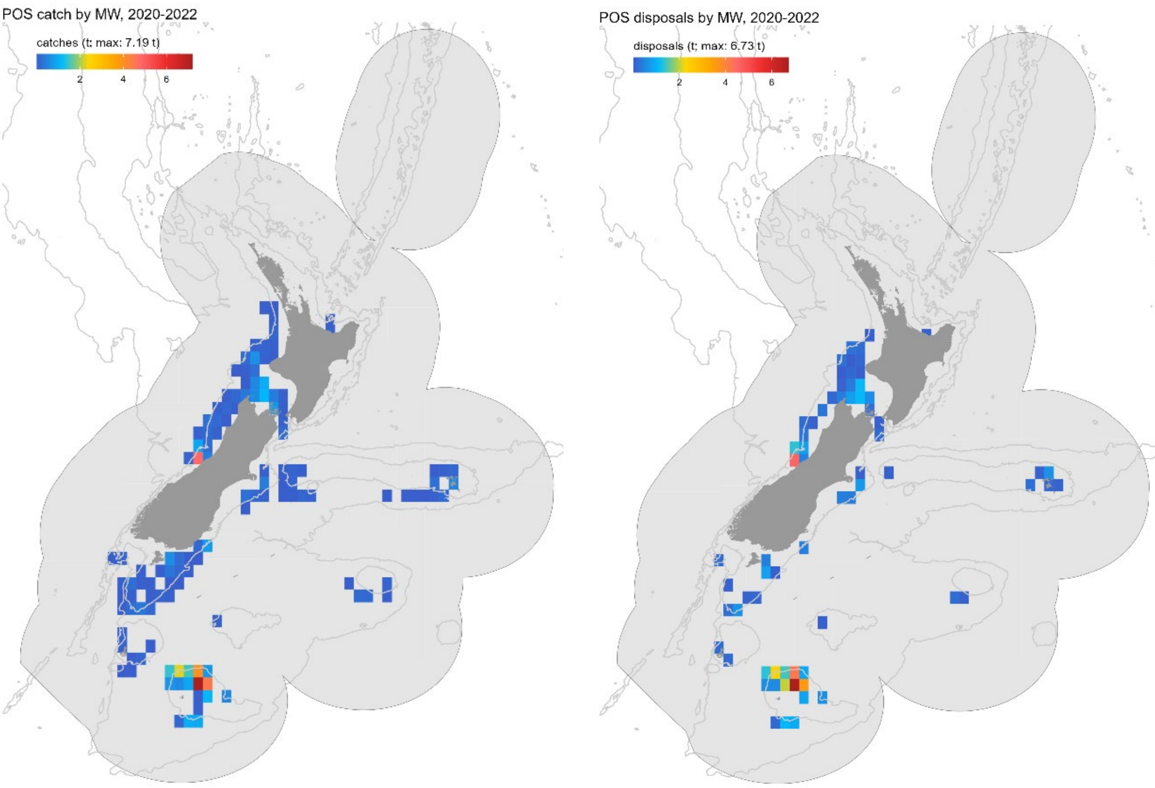


Figure 100: Total catches (including disposals; left) and disposals (right) of porbeagle (POS) by mid-water trawl (MW) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

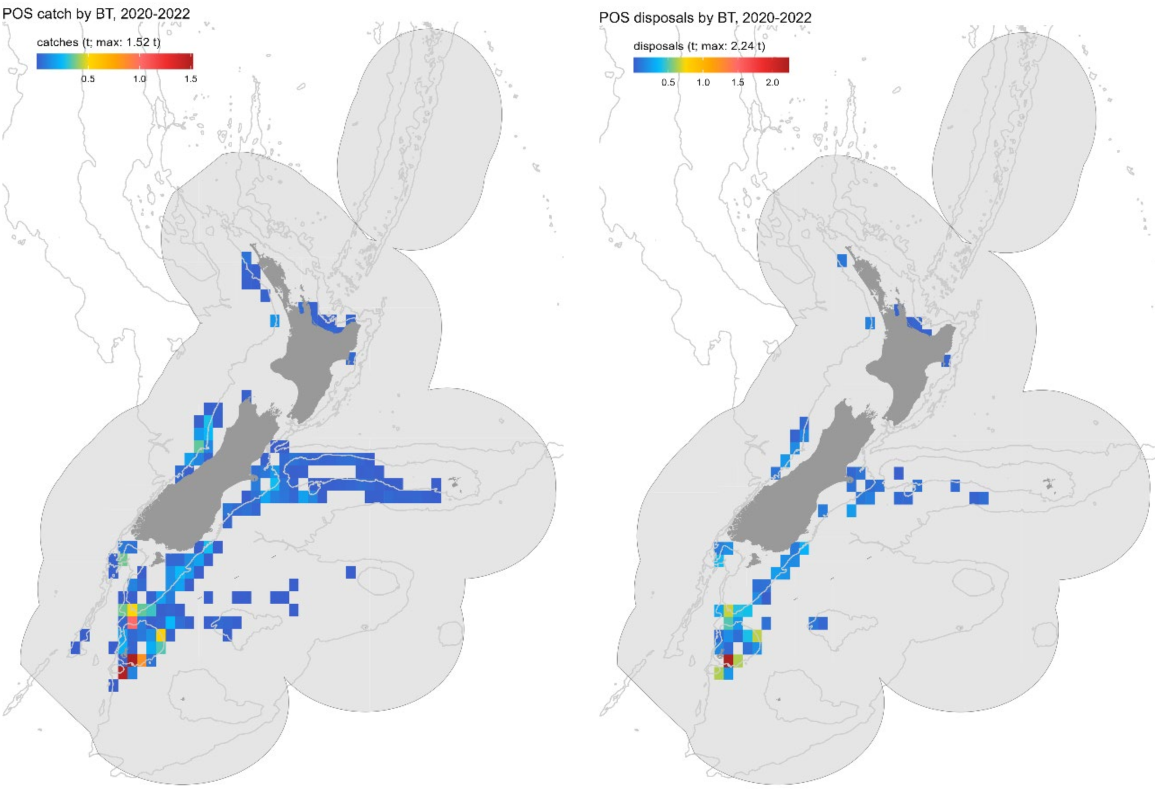


Figure 101: Total catches (including disposals; left) and disposals (right) of porbeagle (POS) by bottom trawl (BT) in New Zealand's Exclusive Economic Zone, aggregated at the 0.5° resolution for 2019–20 to 2021–22.

Since 2005, destination information has been collected for over 2800 porbeagle captures, most of which were derived from surface longline sets targeting southern bluefin tuna (Figure 102 and Figure 103). Observed porbeagle caught in surface longline fisheries have mostly been recorded as dead at hauling (53% of all observed porbeagle with condition recorded have been recorded as dead at-vessel since 2005), with the proportion of individuals recorded as dead at-vessel increasing with shark size (Figure 104). There were few data available for large (> 190 cm FL) porbeagle. The life status of porbeagle from observer records was similar between bigeye tuna and swordfish targeted fisheries, with ~75% of porbeagle recorded dead at hauling (Figure 105). About half of the porbeagle caught in southern bluefin tuna targeted fisheries, from where most porbeagle were recorded, were dead at hauling, with most (~40%) of the remainder reported as alive but with no condition data (Figure 105). More detailed information about porbeagle life status was recorded from the 2015 fishing year onwards (Figure 105). Recorded life status has varied by fishing year, with up to ~45% of porbeagle recorded as alive and uninjured in some years, and 80–100% of porbeagle recorded as dead in other years. However, data on life status were limited, with only six individuals recorded with life status in 2020, 10 in 2021, and none in 2022 (Figure 105). Porbeagle were more likely to be reported dead at-vessel with longer soak times (Figure 106). At-vessel survival rates were similar if a shark was gill-hooked, gut-hooked, or hooked in the jaw, with between 47%–50% of sharks recorded as dead at-vessel when hooked in these locations (Figure 106). A smaller proportion (38%) of porbeagle were recorded dead at hauling when foul-hooked, although only eight sharks were recorded in this category (Figure 106).

Life status of porbeagle caught in trawl fisheries is not currently recorded. Based on observer data collected since 2005, the mean size of porbeagle caught in trawl fisheries was 161 cm TL (range = 93–230 cm, n = 71).

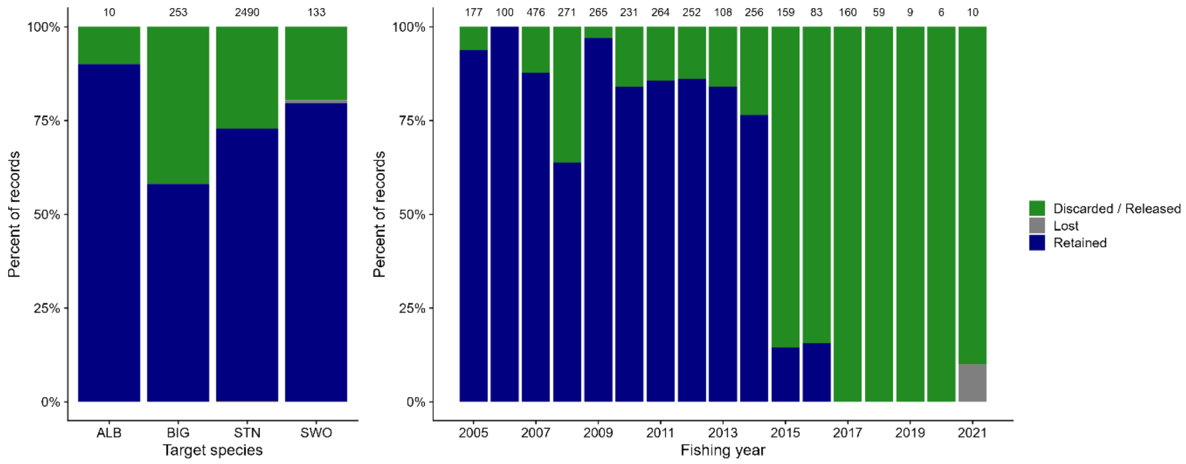


Figure 102: Fate of porbeagle from observer records from the surface longline fishery by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. ALB = albacore tuna, BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish.

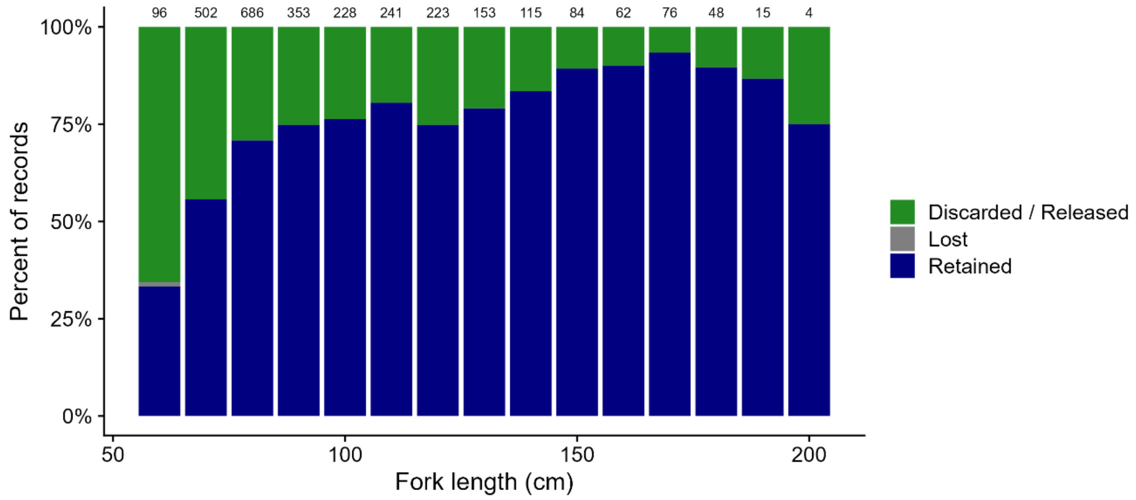


Figure 103: Fate of porbeagle by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

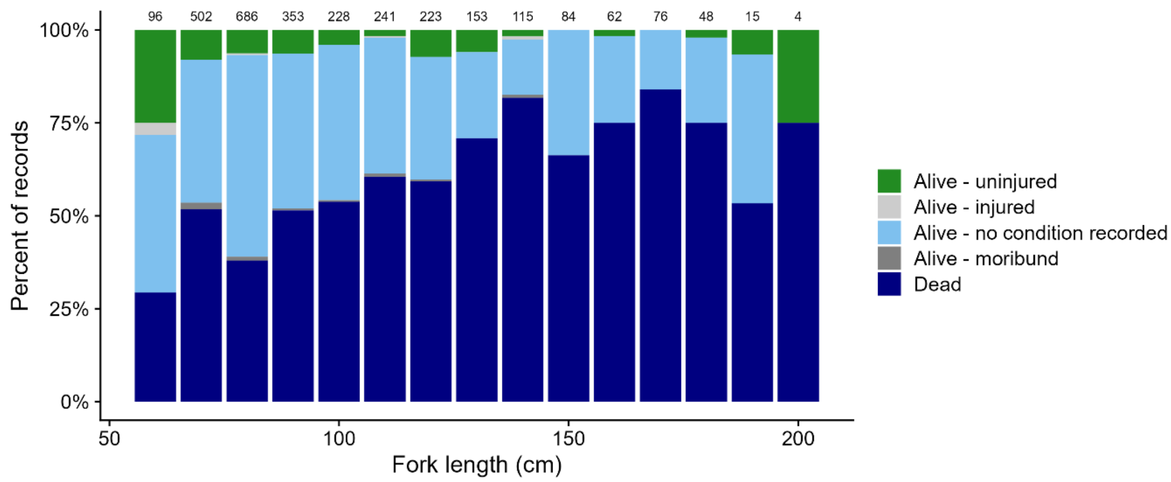


Figure 104: Life status at haul of porbeagle by 10-cm length class from observer records from the surface longline fishery. Numbers above the columns indicate sample sizes.

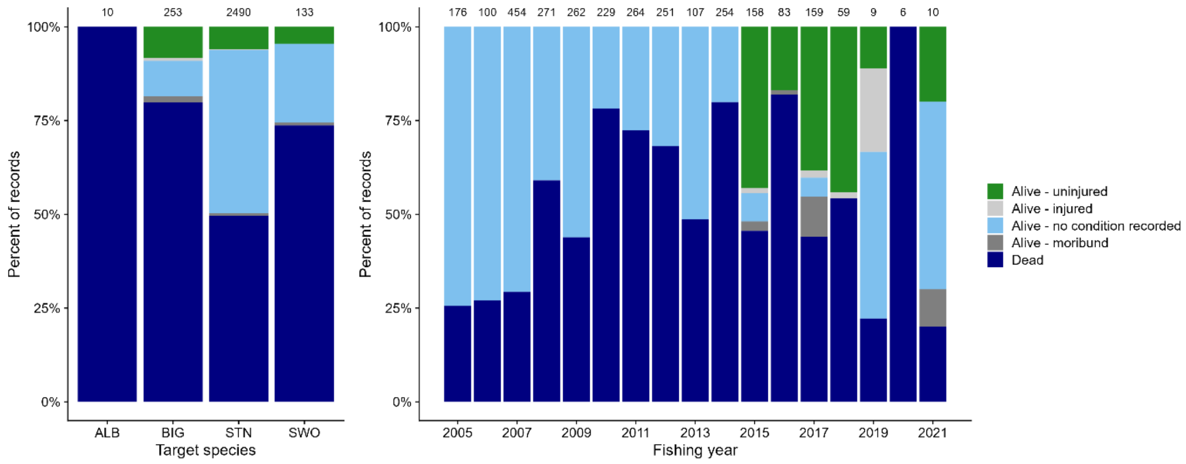


Figure 105: Life status of porbeagle from observer records from the surface longline fishery at-vessel by target species (left) and fishing year (right). Numbers above the columns indicate sample sizes. ALB = albacore tuna, BIG = bigeye tuna, STN = southern bluefin tuna, SWO = swordfish.

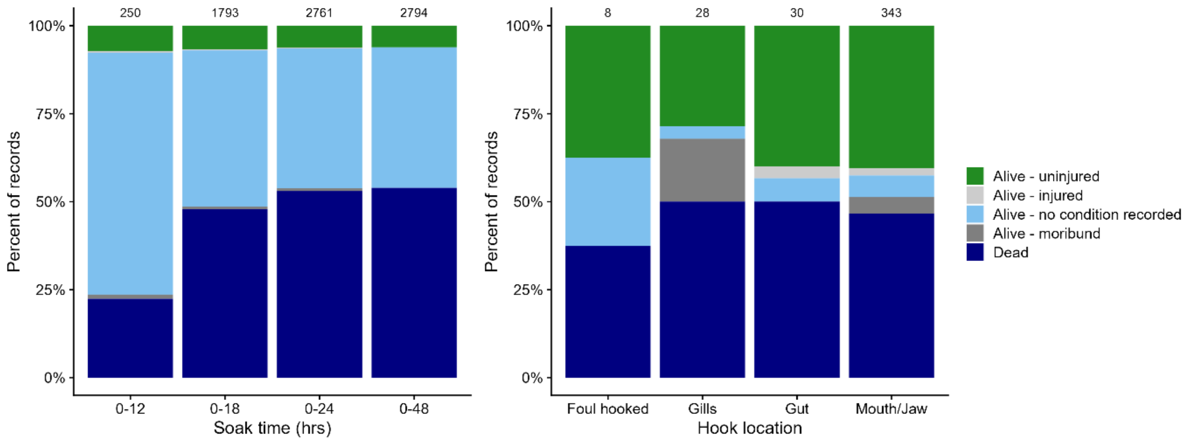


Figure 106: Life status of porbeagle from observer records from the surface longline fishery at-vessel by soak time (left) and hooking location (right). Numbers above the columns indicate sample sizes.

3.5.2. Review of at-vessel and post-release survival studies

Porbeagle are found in temperate and cold-temperate waters in the North Atlantic and Southern Hemisphere. They reach lengths of up to 3.6 metres TL. There are two subpopulations of porbeagle: the North Atlantic and the Southern Hemisphere. Porbeagle segregate by size and sex. This species prefers cooler waters with temperatures below 18 °C, and occur depths from the surface to ~1800 m. Like other lamnid sharks, porbeagle are obligate ram ventilators and are one of several shark species capable of thermoregulation.

Globally, at-vessel survival for porbeagle is estimated to be low to moderate (~50–55%, e.g., Gilman et al. 2022). Porbeagle at-vessel mortality has been assessed in New Zealand fisheries once before; based on observed captures of pelagic sharks during the 1997–98 fishing year, 2370 porbeagle were recorded as alive at recovery, accounting for 60.8% of observed sharks for that year (Francis et al. 2001). Sharks were reported more likely to be alive from fisheries operating around the South Island (68.3%) than those operating around the North Island (25.3%). At-vessel survival outside New Zealand has ranged from 56 to 79% (Table 21). Other studies examining at-vessel survival and the factors that influence it have reported hooking location and depth, soak time, and sea surface temperature as significant factors determining survival outputs (Table 21). In the North Atlantic Ocean off Canada, the fishery (target species and an undefined vessel effect) was found to play a factor in shark survival (Campana et al. 2016).

There have been no studies of post-release survival of porbeagle in New Zealand waters or the wider Pacific Ocean region. From pop-up satellite tags applied to sharks caught in the Atlantic Ocean, porbeagle caught in commercial surface longline fisheries had variable post-release survival rates, ranging from 25 to 90%, depending on shark condition at release, as well as hooking location, with foul hooking reducing survival (Campana et al. 2016, Bowlby et al. 2020, 2021) (Table 22). It was suspected that tagging sharks in the water (rather than on board) improved survival rates (Bowlby et al. 2020, 2021).

Porbeagle at-vessel and post-release survival from trawl fisheries has not been quantified in any substantial detail; four satellite tagged porbeagle caught by commercial otter trawlers in the North Atlantic Ocean were reported to survive post-release (Campana et al. 2015, 2016).

Table 21: Summary of studies examining at-vessel survival of porbeagle in commercial fisheries. SLL = surface longline; FL = fork length; SST = sea surface temperature; SI = South Island; NI = North Island. Factors in bold font had a significant influence on survival.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	New Zealand	2 370	61%	-	Study examined at-vessel survival (1997/98) and those retained/finned; more sharks alive around SI than NI; survival higher for domestic vessels than foreign charter vessels	Francis et al. (2001)
Commercial SLL	Atlantic (Canada)	866	~70%	Hook type; **Hook location**; Bait type; **SST**; **Soak time**; FL	Study examined at-vessel survival	Epperly et al. (2012)
Commercial SLL	Atlantic	10	70%	-	Study examined at-vessel survival	Coelho et al. (2012)
Commercial SLL	Atlantic/Gulf of Mexico	255	79%	Target; **Hook depth**; SST; **Soak time**; FL	Study examined at-vessel survival; decreased survival with increased soak time, hook depth	Gallagher et al. (2014)
Commercial SLL	Atlantic (Canada)	931	56%	**Fishery (target species and/or vessel effect)**	Study examined at-vessel survival; 26% sharks with ‘unknown’ status; total survival estimated at 59%	Campana et al. (2016)

Table 22: Summary of studies examining post-release survival of porbeagle in commercial fisheries. SLL = surface longline; FL = fork length; SST = sea surface temperature. Factors in bold font had a significant influence on survival.

Fishing method	Region	Sample size	Survival estimate	Factors examined / affecting survival	Comments / caveats	Reference
Commercial SLL	Atlantic (Canada)	33	25–90%	Condition; Hook type; Hook size; Soak time; Vessel; FL; SST	75% of injured porbeagle (n=4) died; high metabolic rates and O_2 requirements suggested as factors for increased mortality	Campana et al. (2016)
Commercial SLL	Atlantic (Canada)	73	83%	FL; Stage; Sex; Gear type; Hook type; **Hooking location**; Handling location	Combined results with above; Tagging in water (rather than on board) suspected to improve survival rates; foul-hooked reduced survival; recovery periods available for 53 sharks (mean=9 days); all mortalities within 45 days	Bowlby et al. (2020, 2021)

3.5.3. Expert elicitation results

Reasons for release

Stakeholders advised that porbeagle are disposed of because they are not commercially viable and that by retaining these species, there is less room in fish holds for more valuable target species. There is also resistance from LFRs to purchase porbeagle due to concerns over high mercury levels, particularly for larger individuals. Fishers were also concerned that sharks stored with fish products can cause spoilage due to ammonia contamination. Larger porbeagle were also considered a health and safety issue, and fishers advised that it was generally safer to cut large porbeagle off in the water than to bring them on deck.

At-release survival – surface longline

Based on expert elicitation, porbeagle condition at-release when caught in surface longline fisheries was uncertain, with survey responses suggesting a small percentage (< 25%) of individuals were released alive and injured, and most (25–90%) were released dead (Figure 107). Shark size/life stage and sea surface temperature were considered to have little influence on the percentage of porbeagle that were released alive, with about half of sharks released alive under these conditions. Survey participants indicated that more porbeagle were released alive with shorter soak times (< 6 hours) and that a small percentage of released sharks were foul-hooked (< 25%) or hooked in the gut (< 10%). There was less certainty with the percentage of sharks released with trailing gear, with survey responses suggesting anywhere from < 10% to up to 90% of porbeagle were likely to have some trailing gear attached when released (Figure 107).

Post-release survival – surface longline

Survey results indicated porbeagle post-release survival when caught in surface longline fisheries was low to medium-high (typically 25–75%), although only two responses were received (Figure 107). Survey respondents contended that shark size/life stage did not influence post-release survival and suggested post-release survival was higher in cooler waters, with shorter (< 12 hours) soak times, when sharks were hooked in the jaw, and when sharks were released in the water (as opposed to being brought on board the vessel). Survey respondents considered that porbeagle post-release survival was lowest when sharks were hooked in the gut or foul-hooked. Respondents considered that post-release survival was reduced (< 50%) with increased length of trailing gear (Figure 107).

At-release and post-release survival - trawl

Survey responses indicated a small percentage (< 25%) of porbeagle are released alive after capture in trawl fisheries, regardless of the factors considered (e.g., shark condition and size, depth of capture, catch volume, tow duration) (Figure 108). The percentage of porbeagle released alive was lowest (< 10%) with deep tows (> 800 m), large catch volumes (> 5 t), and long tow durations (> 5 hours). Porbeagle post-release survival estimates when caught in trawl were largely uncertain but were suggested to be low (< 50%) across all categories, although only two respondents answered the questions regarding porbeagle post-release survival in trawl fisheries (Figure 108).

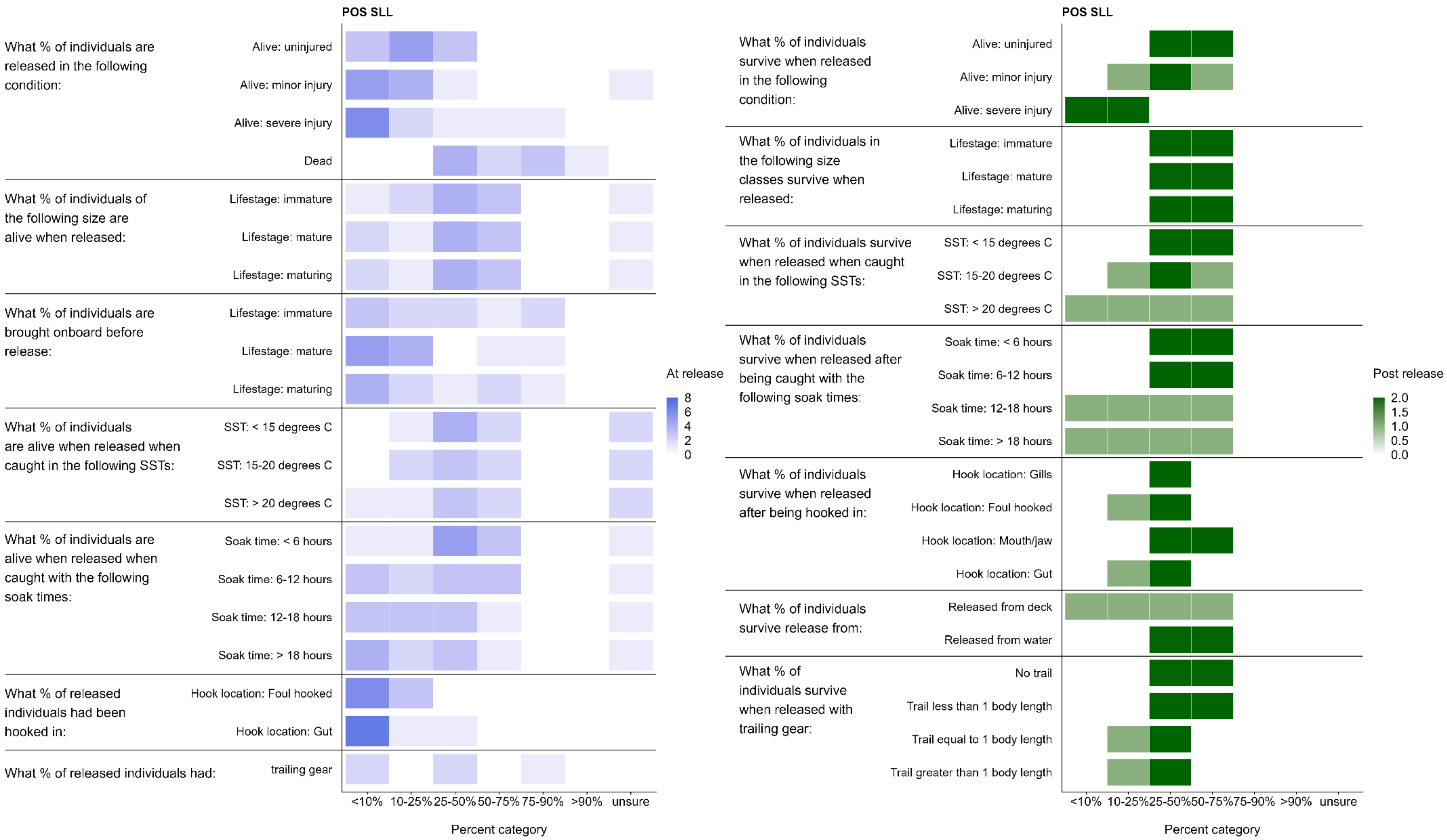


Figure 107: Results from the expert elicitation questionnaire for porbeagle (POS) caught by surface longline (SLL). Left: responses to questions on at-release survival. Right: responses to questions on post-release survival. Darker colours indicate a greater number of responses.

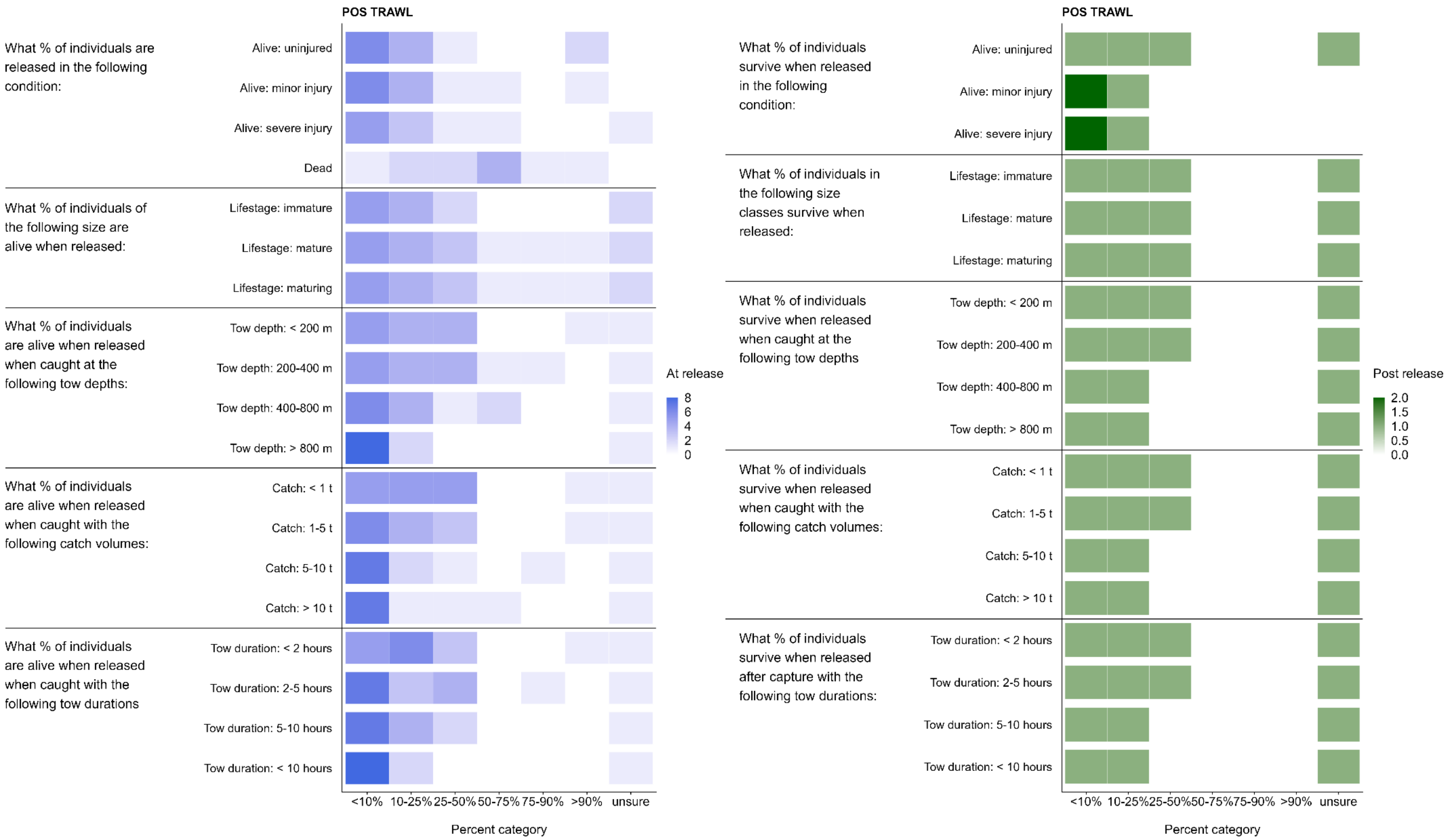


Figure 108: Results from the expert elicitation questionnaire for porbeagle (POS) caught by trawl. Left: responses to questions on at-release survival. Right: responses to questions on post-release survival. Darker colours indicate a greater number of responses.

3.5.4. Fishery survival probability estimates

Appropriate and comparable priors for porbeagle were applied to release condition and hooking location (jaw, gut, and foul-hooked) (see Appendix 3). For release condition, a prior of 0.90 was applied to porbeagle released alive and uninjured and 0.25 was applied to injured sharks (regardless of injury). These estimates were derived from post-release mortality rates from satellite tagged sharks from the North Atlantic Ocean from the study of Campana et al. (2016). For hooking location, priors were derived from estimates reported by Bowlby et al. (2021): for jaw-hooked sharks, 0.92; for gut-hooked sharks, 0.40; and for foul-hooked sharks, 0.67. Survival estimates from studies on the closely related salmon shark (*Lamna ditropis*) were not used here as the salmon shark appears to have considerably lower survival rates than porbeagle, with a global meta-analysis determining mean at-vessel mortality of salmon shark and porbeagle estimated at 0.761 and 0.485, respectively (Gilman et al. 2022). No priors were applied for porbeagle caught in trawl fisheries.

Surface longline

At-release survival only

Perceived at-release survival probability estimates for porbeagle caught in surface longline fisheries were low (soak time > 6 hours) to low-medium (SST, shark size, and soak time < 6 hours) (Figure 109). When factors were weighted to the fishery profile, at-release survival estimates remained low (soak time) to low-medium (SST, shark size) (Figure 110).

Post-release survival only

When only post-release survival was considered for porbeagle (i.e., on the assumption that individuals were released alive), perceived survival across most factor categories was typically low-medium to medium (Figure 111). When priors were applied, survival probability estimates improved to high (from medium) when sharks were released uninjured and when hooked in the jaw, improved to medium-high (from low-medium) for individuals that were foul-hooked, and improved to low-medium (from low) for individuals released with a severe injury (Figure 111). When factors were weighted to the fishery profile, post-release perceived survival was low-medium (soak time) to medium (release method and condition, hooking location, SST, shark size, and trailing gear) (Figure 112). Post-release survival estimates relating to release condition and hooking location improved with the application of priors to high perceived survival (Figure 112).

At-release and post release survival combined

Combined survival probability estimates for porbeagle caught in surface longline fisheries were low to low-medium for most factor categories without the inclusion of priors (Figure 113). Perceived survival was considered to be low when individuals were released with a severe injury, in warm waters (> 15 °C), and when soak times exceeded 6 hours. Perceived survival was considered to be medium when individuals were initially hooked in the mouth/jaw and released uninjured in water, without trailing gear. Porbeagle perceived survival estimates were moderately improved when priors were applied, increasing to high for sharks released uninjured or when hooked in the jaw (Figure 113).

When aggregated and weighted across the fishery profile, combined survival (i.e., at-release and post-release components) was variable; survival was low for SST and soak time, low-medium for shark size, and medium for release method, release condition, hooking location, and trailing gear (Figure 114). When priors were applied, perceived survival for porbeagle was improved to high for release condition and hooking location, but remained low for SST and soak time, for which no priors were available (Figure 114). Based on the final estimates, the overall perceived survival for porbeagle caught in surface longline fisheries is low.

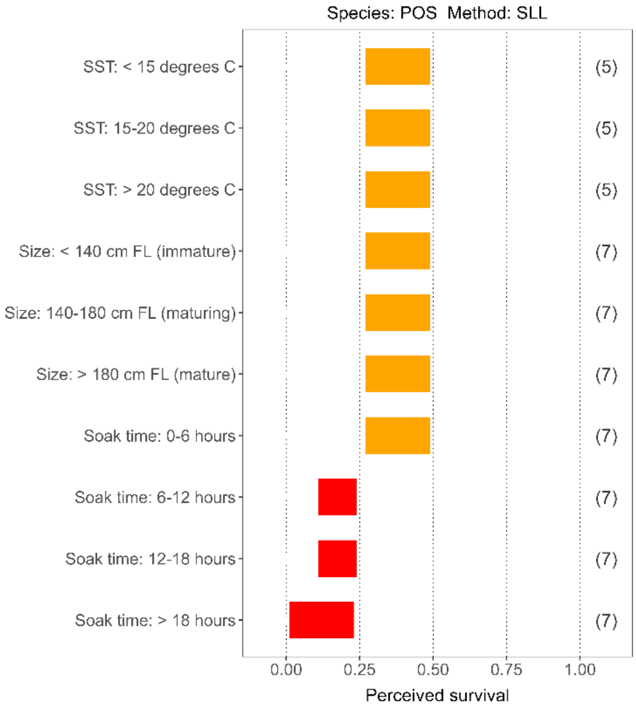


Figure 109: 90% confidence intervals on perceived at-release mean survival estimates for porbeagle (POS) following release from surface longline (SLL) in New Zealand waters by factor-category. Note this plot assesses at-release survival only, and no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

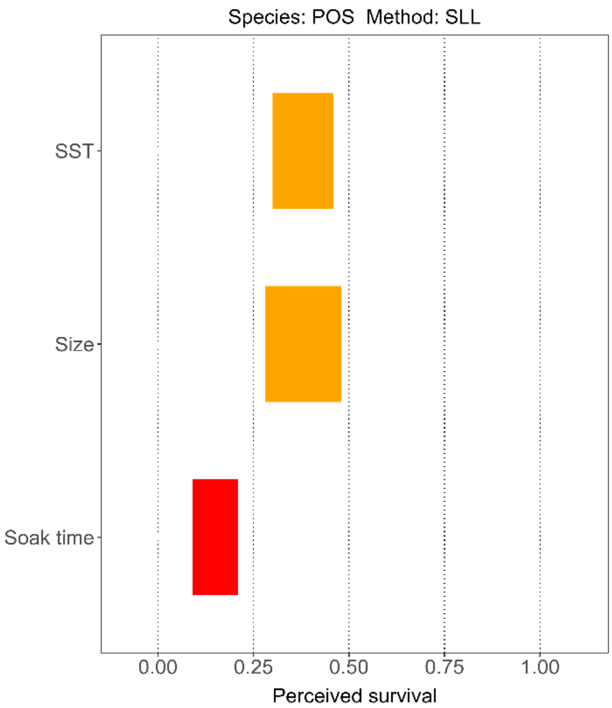


Figure 110: 90% confidence intervals on perceived at-release mean survival estimates for porbeagle (POS) following release from surface longline (SLL) in New Zealand waters by factor. Note this plot assesses at-release survival only, and no priors were applied to these particular categories. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

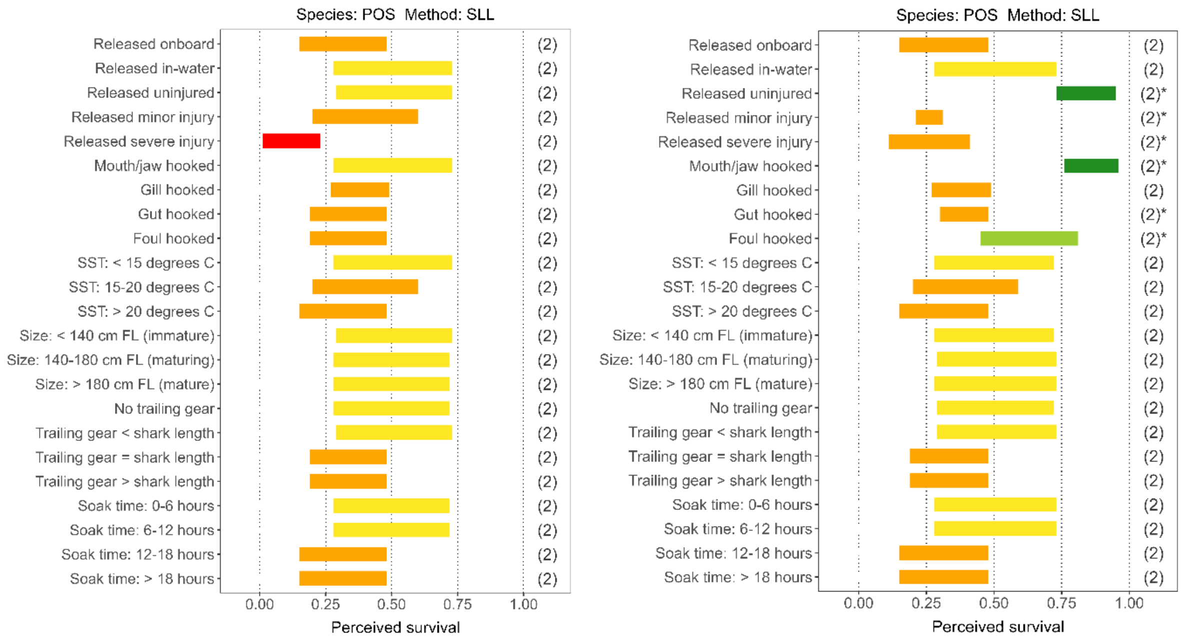


Figure 111: 90% confidence intervals on perceived post-release mean survival estimates for porbeagle (POS) following release from surface longline (SLL) in New Zealand waters by factor-category. Note this plot assumes all individuals released are alive at the time of release, and does not account for condition at release. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. The number in parentheses indicates the number of survey respondents. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

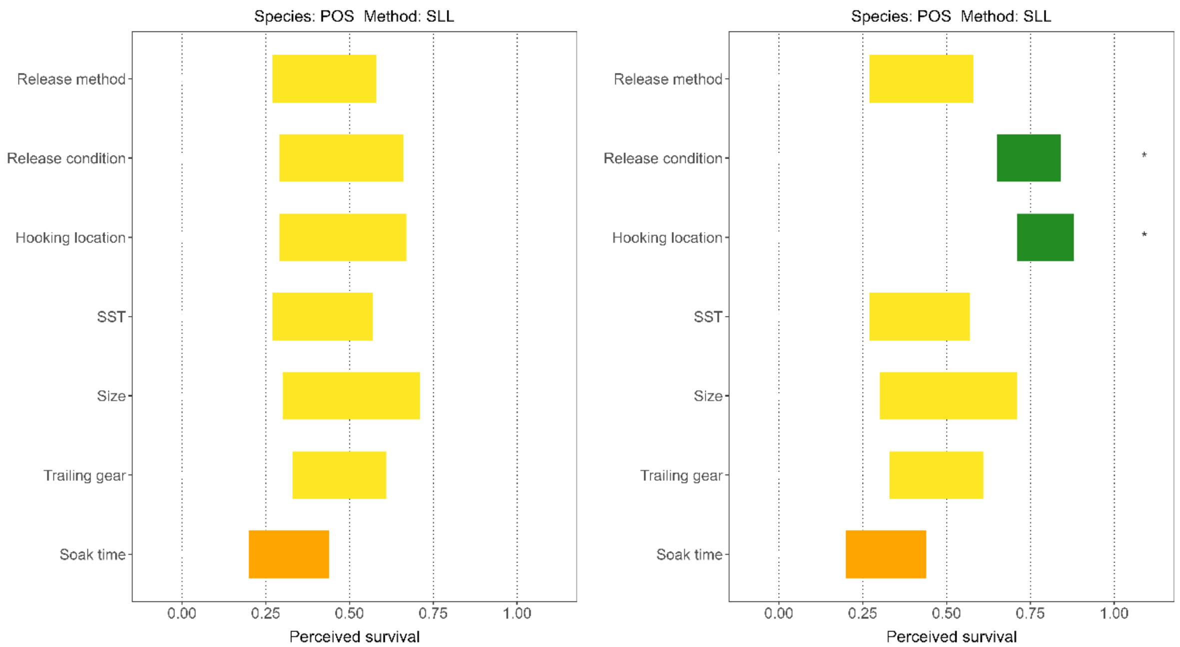


Figure 112: 90% confidence intervals on perceived post-release mean survival estimates for porbeagle (POS) following release from surface longline (SLL) in New Zealand waters by factor. Note this plot assumes all individuals released are alive at the time of release, and does not account for condition at release. Left: without priors applied; right: with priors applied. * denotes those factors informed by priors. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

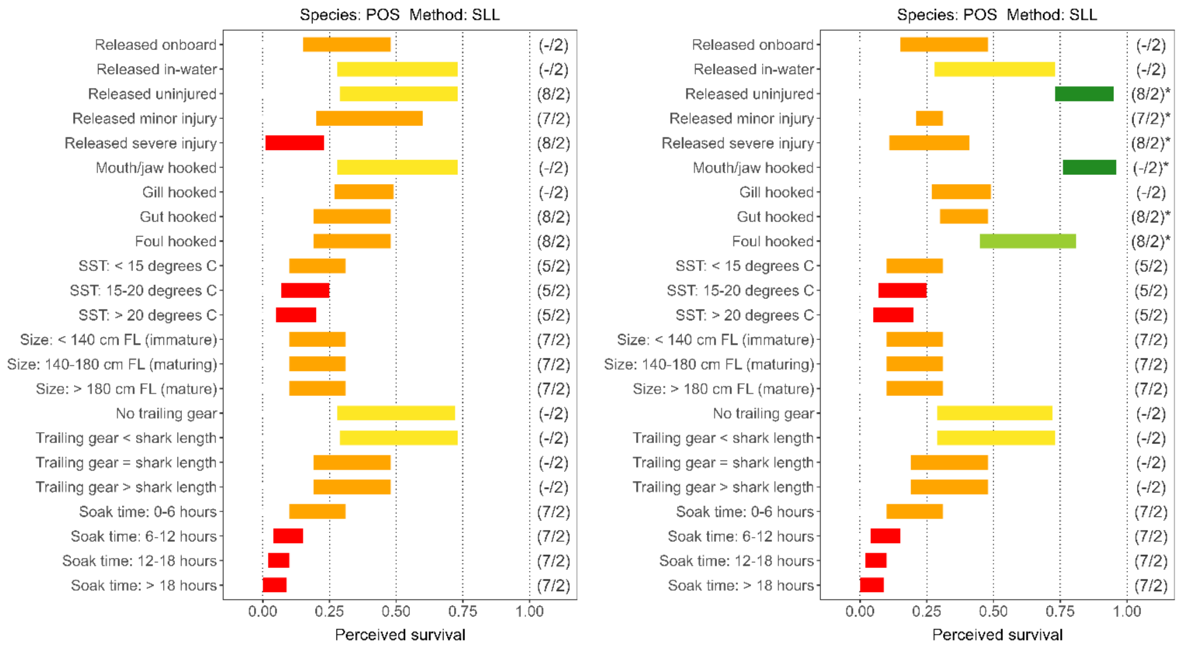


Figure 113: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for porbeagle (POS) following release from surface longline (SLL) in New Zealand waters by factor-category. Left: without priors applied; right: with priors applied. * denotes those factor categories informed by priors. The number in parentheses indicates the number of survey respondents (at-release / post-release). SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

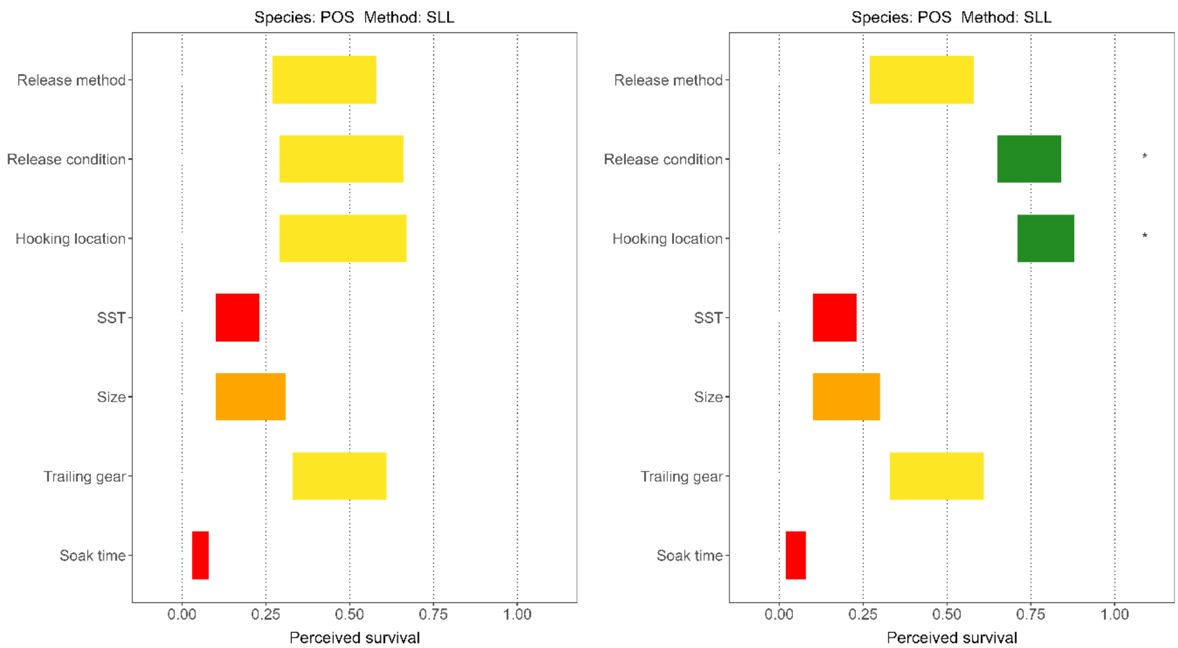


Figure 114: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for porbeagle (POS) following release from surface longline (SLL) in New Zealand waters by factor. Left: without priors applied; right: with priors applied. * denotes those factors informed by priors. SST = sea surface temperature. See Table 4 and Figure 1 for an explanation of colours and survival categories.

Trawl

At-release survival only

Perceived at-release (i.e., immediate) survival probability estimates for porbeagle released after capture in trawl fisheries was considered to be low-medium when catches were < 1 t, tow durations were < 5 hours, and tow depths were < 400 m and low when catches were > 1 t, tow durations were > 5 hours, tow depths were > 400 m, and across all life stages (Figure 115). When aggregated and weighted to the fishery profile, mako survival probability estimates were low-medium for tow depth and low for catch weight, fish size, and tow duration (Figure 116).

Post-release survival only

Perceived post-release survival probability estimates for porbeagle released following capture in trawl fisheries was considered to be low-medium when catches were < 5 t, tow durations were < 5 hours, tow depths were < 400 m, when individuals were released uninjured, and for all life stages and low when catches were > 5 t, tow durations were > 5 hours, tow depths were > 400 m, and when individuals were released with either a minor or severe (Figure 117). When aggregated and weighted to the fishery profile, mako post-release survival probability estimates were low-medium for life stage, tow duration, and tow depth and low for catch weight and release condition (Figure 118). It should be noted, however, that these estimates were derived largely from a single survey response and are not informed by priors (due to a lack of published information of post-release survival of porbeagle in comparable trawl fisheries). Accordingly, these estimates should be treated with caution.

At-release and post-release survival combined

Combined survival probability estimates (i.e., accounting for at-release and post-release survival) for porbeagle released after capture in trawl fisheries were low across most factor levels (Figure 119). There was some improvement in perceived survival (to low-medium) when individuals were released uninjured; however, few individuals were considered to be released in this state (Appendix 4). Accordingly, when aggregated across the fishery profile, survival probability estimates were low for all assessed factors (Figure 120). Based on these estimates, overall combined (i.e., at-release and post-release) perceived survival for porbeagle caught in mid-water trawl fisheries was considered to be low.

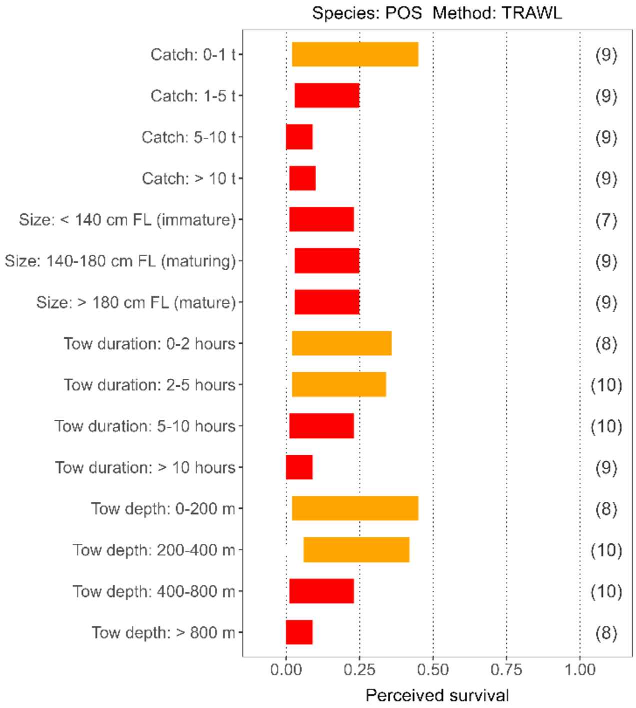


Figure 115: 90% confidence intervals on perceived at-release mean survival estimates for porbeagle (POS) following release from trawl in New Zealand waters by factor-category. Note this plot assesses at-release survival only, and no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents. See Table 4 and Figure 1 for an explanation of colours and survival categories.

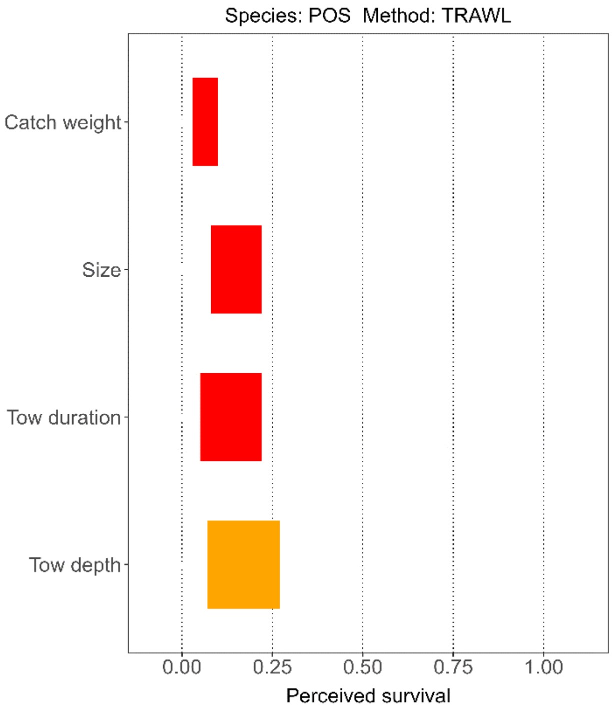


Figure 116: 90% confidence intervals on perceived at-release mean survival estimates for porbeagle (POS) following release from trawl in New Zealand waters by factor. Note this plot assesses at-release survival only, and no priors were applied to these particular categories. See Table 4 and Figure 1 for an explanation of colours and survival categories.

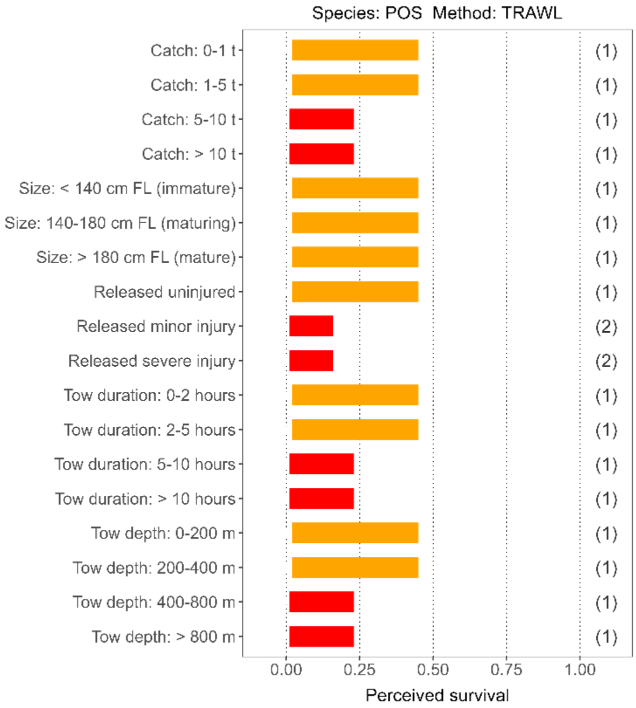


Figure 117: 90% confidence intervals on perceived post-release mean survival estimates for porbeagle (POS) following release from trawl in New Zealand waters by factor-category. Note this plot assumes all individuals released are alive at the time of release, and no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents. See Table 4 and Figure 1 for an explanation of colours and survival categories.

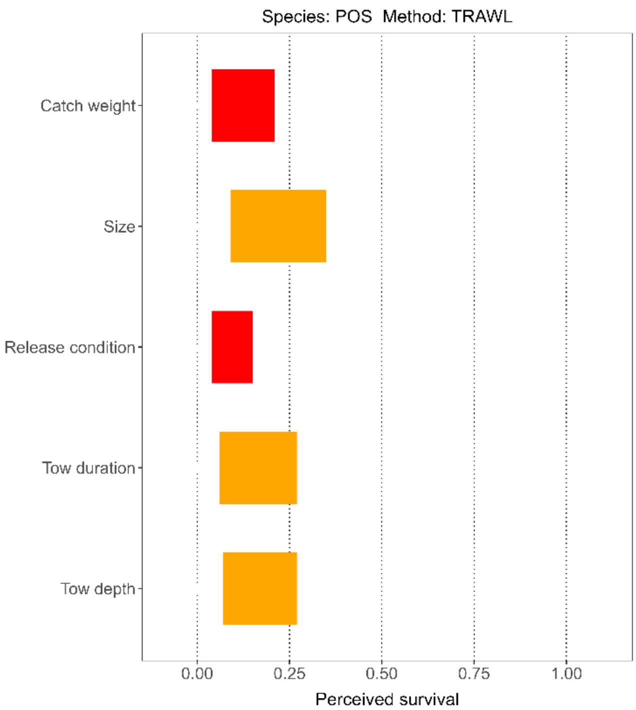


Figure 118: 90% confidence intervals on perceived post-release mean survival estimates for porbeagle (POS) following release from trawl gear in New Zealand waters by factor. Note this plot assumes all individuals released are alive at the time of release, and no priors were applied to these particular categories. See Table 4 and Figure 1 for an explanation of colours and survival categories.

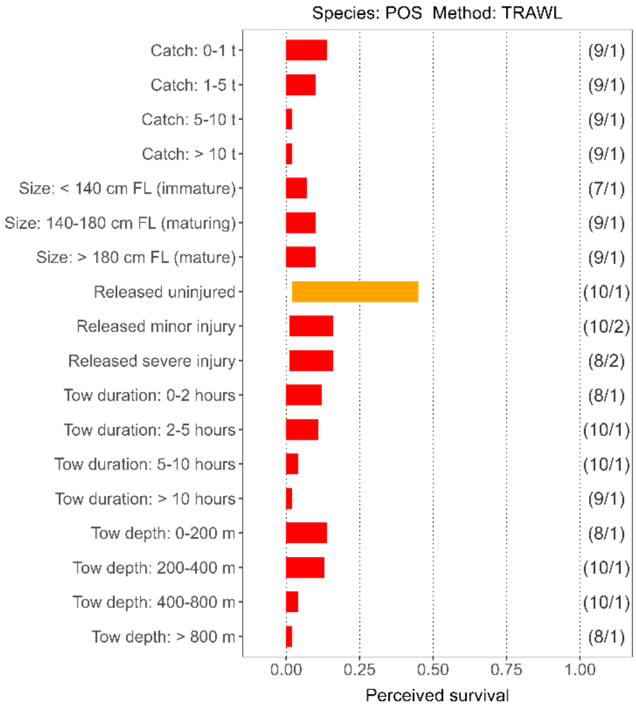


Figure 119: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for porbeagle (POS) following release from trawl gear in New Zealand waters by factor-category. Note no priors were applied to these particular categories. The number in parentheses indicates the number of survey respondents (at-release / post-release). See Table 4 and Figure 1 for an explanation of colours and survival categories.

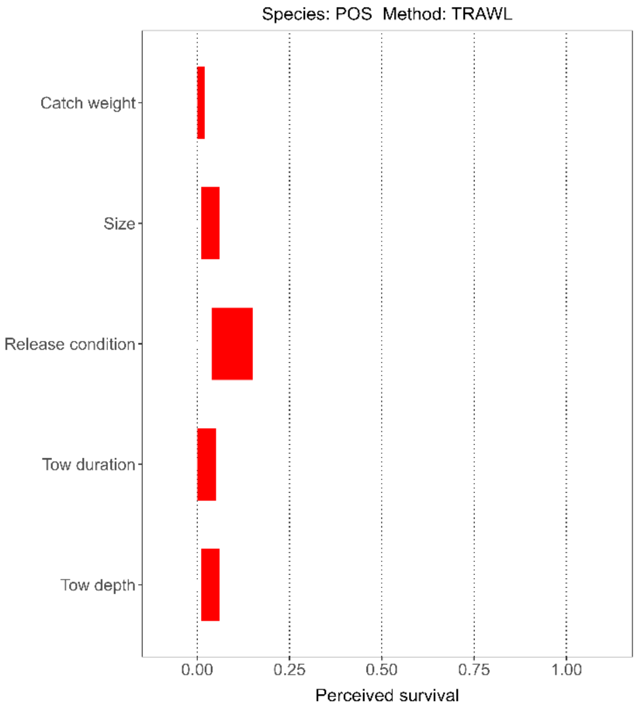


Figure 120: 90% confidence intervals on perceived combined at-release and post-release mean survival estimates for porbeagle (POS) following release from trawl gear in New Zealand waters by factor. Note no priors were applied to these particular categories. See Table 4 and Figure 1 for an explanation of colours and survival categories.

4. DISCUSSION AND POTENTIAL RESEARCH

At-release, post-release, and overall (i.e., combined) survival probability determinations from the survival probability estimation procedure for each species are summarised in Table 23.

Table 23: Overall survival estimates from the survival probability estimation procedure for each species-fishing method combination presented in this report with priors applied (where relevant). STN = southern bluefin tuna, TOR = Pacific bluefin tuna, SWO = swordfish, BWS = blue shark, MAK = mako shark, POS = porbeagle shark. SLL = surface longline.

Species	Fishing method	Survival component		
		At-release survival only[1]	Post-release survival only	Overall (At-release x post-release survival)[1]
STN	SLL	–	High	–
TOR	SLL	–	High	–
SWO	SLL	–	High	–
	Trawl	–	Low–medium	–
BWS	SLL	High	High	Medium–high
MAK	SLL	Medium	Medium-high	Low-medium
	Trawl	Low	Low	Low
POS	SLL	Low	Low-medium	Low
	Trawl	Low	Low	Low

[1] At-release survival was not assessed for STN, TOR, or SWO; landing exceptions for STN and SWO stipulate individuals of these species must be alive and likely to survive if they are released, and there are currently no landing exceptions for TOR.

Where priors were applied in the survival probability estimations, these typically improved the resulting survival probability estimates, particularly for the pelagic shark species. This suggests that in these instances survey respondents had a more pessimistic view of survival compared with the data-informed estimates. This may be due in part to the small numbers of survey responses (in the case of porbeagle, only two), particularly regarding the post-release survival questions. This may also be due, at least in part, to a possible pessimistic bias, with respondents being overly cautious in their individual survey responses relative to experimentally derived data.

It should be noted that the bootstrapped 90% confidence ranges provided in this report represent how precisely mean release survival for a given species-method-factor is known. Wide confidence ranges represent poor knowledge/high uncertainty and narrow bars represent more precise knowledge. This report deliberately provides no indication as to where within each given 90% confidence interval range mean survival is likely to be and it therefore should be assumed that mean survival could be anywhere within the derived range. High survival uncertainty for many of the species in this report mostly reflects a paucity of empirical evidence. The species-method survival confidence ranges presented in this report are based on the best currently available expert knowledge, and thorough reviews of the survival literature, as such, these ranges are unlikely to be improved upon without further investment in release survival research (see Section 4.2).

Hook type has often been demonstrated to have a significant effect on at-vessel and post-release survival of pelagic sharks and fish, including the six species covered in this report (e.g., Curran & Bigelow 2011, Epperly et al. 2012, Orbesen et al. 2019), with J-hooks typically associated with higher gut-hooking rates and lower survival rates than circle hooks (e.g., Curran & Bigelow 2011, Epperly et al. 2012, Orbesen et al. 2019). We purposefully did not include hook type as a factor when considering survival of the pelagic sharks and fish assessed here as, while J-hooks have been used in the fishery historically, their use has been prohibited in New Zealand's commercial surface longline fisheries since August 2023, as a means to reduce the capture rate of sea turtles (Fisheries New Zealand 2022).

A relatively large amount (6.7 t) of southern bluefin tuna were caught and disposed from the troll fishery targeting albacore in 2021–22. This contrasts with previous years, with only 0.2 t of southern bluefin tuna disposals from troll operations in 2019–20 and 0 t in 2020–21, and was considered to be anomalous by fishers, who indicated southern bluefin tuna had turned up exceptionally early in that year. Accordingly, post-release revival of southern bluefin tuna from trolling was not investigated in detail in this study, because this study focused on the main fishing methods that resulted in disposals. Discussions with fishers and fisheries observers during the workshop and subsequent meetings suggested that the vast majority of southern bluefin tuna caught and released from the troll fishery are small individuals, which are quickly released and are in a lively state when released, and thus are likely to have high post-release survival. To our knowledge, there have been no studies of post-release survival of southern bluefin tuna or any *Thunnus* species following release from commercial troll fisheries. However, bluefin tuna caught and released from recreational trolling have been shown to have high post-release survival (Marcek 2013, Marcek & Graves 2014), and a similar result is likely from commercial trolling, particularly given the short fight times associated with commercial troll operations.

There were differences in post-release survival rates amongst the three shark species, with blue shark having medium-high combined survival and mako and porbeagle having low-medium and low combined survival following capture by surface longline. Differences in post-release survival rates amongst shark species is not well understood, although evolutionary history (i.e., phylogeny) plays a significant role in determining species-specific at-vessel mortality rates, particularly for Carcharhiniform (blue shark) and Lamniform (mako, porbeagle) sharks (Gilman et al. 2022). Sharks that are evolutionarily similar are likely to share comparable morphological, physiological, and behavioural traits, and may occur in similar habitats (Campana et al. 2016, Gilman et al. 2022). As mako and porbeagle are both lamnid sharks and are amongst the only sharks capable of endothermy, it is not surprising that these species have similar survival estimates. The ability to thermoregulate allows these species to occur in deeper and colder environments (Campana et al. 2016, Bowlby et al. 2021), and their environmental preferences/requirements may attribute to why their survival rates are lower/different to those for blue shark.

Questionnaire respondents and workshop participants reported conflicting information regarding the influence of sea lion exclusion devices (SLEDs, used in southern squid and southern blue whiting fisheries) on shark survival, with one response suggesting SLEDs may improve the percentage of sharks released alive, and another suggesting that SLEDs may cause injury and death to half of the observed sharks. Observer logbooks have also suggested SLEDs may influence survival of white sharks (*Carcharodon carcharias*) (Finucci et al. 2022). Again, targeted research is required to better quantify the influence of SLEDs on the condition at hauling/release and post-release survival of swordfish, mako, and porbeagle caught in New Zealand's trawl fisheries (see Section 4.1).

There were several general themes for the release of these species reported by the questionnaire respondents and workshop participants. Economic costs were a driving factor for fishers; for the tunas and swordfish, individuals were generally released when they were small and unlikely to attract a good market price. Sharks were also released because of their limited commercial value. There were also strong concerns that retaining shark catch reduces space in fish holds for more profitable target species and can also spoil valuable fish products due to ammonia contamination, particularly given that the majority of the surface longline fleet comprises single-hold vessels without freezer facilities. Health and safety concerns were also identified, with participants indicating in some instances that large numbers of small fish can take significant crew time and effort to process, while large sharks were considered dangerous and, in both cases, it was better to release these individuals. The ecosystem role of these large predatory species should also be considered when reviewing management considerations for release; it has been suggested that the decline of pelagic sharks, tunas, and billfish has led to mesopredator releases in the pelagic ecosystem, with smaller species (e.g., lancetfishes, mahi mahi) flourishing because of a reduction in predators and competitors (Kitchell et al. 2002, Ferretti et al. 2010).

4.1 Key data limitations, assumptions, and caveats to this study

A key limiting factor to deriving the survival estimates presented here for non-surface longline fisheries (i.e., trawl) is that there is virtually no information available on post-release survival. While disposals from fishing methods other than surface longline were found to be minimal for southern bluefin tuna and blue shark, disposals from trawl fisheries formed a substantial proportion of total disposals for swordfish, mako, and porbeagle. The lack of research on post-release survival of these species following capture and release from trawl fisheries constrained the analyses in at least two ways: 1) it resulted in several scientific experts advising they were not comfortable answering these questions due to a lack of prior understanding of survival; and 2) it prevented the generation of priors to apply in the survival probability estimation procedure. Dedicated tagging studies are required to better quantify the post-release survival of swordfish, mako, and porbeagle caught in New Zealand's trawl fisheries.

A second key data limitation is that, unlike for the surface longline fishery, observers on board commercial trawl vessels are not currently required to document condition at-capture of pelagic fish and sharks caught in trawl gear, be they intended for release or otherwise. There were few observer records of sharks caught in trawl gear with biological data recorded, but, where length was recorded, these records indicated that trawl fisheries tend to capture larger sharks than the surface longline fishery. Targeted research is required to better quantify the condition at capture/release of swordfish, mako, and porbeagle caught in New Zealand's trawl fisheries. More generally, research is needed to determine how trawl methods can be optimised to minimise mortality of large fish and sharks intended for release in a manner that optimises crew health and safety and animal welfare.

In addition to the above, another key data limitation is the decline in observer coverage on surface longline vessels evident since around 2015, with coverage decreasing from 25.0% of hooks set in 2014–15 to 5.6% of hooks set in 2021–22 (Fisheries New Zealand 2023). Associated with this decline are reduced numbers of observations. For example, in the 2022 fishing year, life status information was only available for a single disposed blue shark, and no disposals of swordfish or porbeagle were observed (see Table 3). The lack of data makes it difficult to validate questionnaire findings regarding release condition of disposal and subsequently prevented the use of observer data to generate priors relating to release condition to use in the 'at-release' component of the survival probability estimation procedure.

For surface longline, soak time was considered a key factor by survey respondents determining the overall release-condition and post-release survival estimates of all species examined here (albeit to varying degrees), with longer soak times typically associated with low survival. It should be noted, however, that while the soak time metric used here was based on best-available data (start of set to landed time as recorded by fisheries observers), it did not provide an accurate measure of how long an individual spent on the line, as an individual may have been hooked for the entire duration of the set, immediately before landing, or some time in between. For this reason, soak times for surface longline were categorised into cumulative bins in the characterisation analyses (i.e., 0–12, 0–18, 0–24 and 0–48-hour bins). Hook timers are required to accurately define soak times and subsequently assess the influence of soak time on condition at-vessel and post-release survival (Ellis et al. 2017, Whitney et al. 2021).

There are several caveats to interpreting the perceived survival probability estimates presented here. First, as discussed above, in most instances the survival estimates have been derived from informed opinions of a small number of experts and, in some instances, with no empirical data to inform these. For example, only a single respondent answered the question regarding post-release survival of swordfish, mako, and porbeagle following capture by trawl gear.

A second caveat to the results presented here is that it was not feasible, within the limits of the survey approach used, to explicitly account for species-method-factor crossed effects (e.g., all levels of 'fishing depth' crossed with all levels of 'tow-duration') in the generation of survival estimates. Survey respondents were therefore required to provide survival estimates for each factor-category assuming other factors were at their most benign category level (e.g., expected survival relative to various fishing depth categories assuming ‘tow duration’ to be at the highest survival / most benign category level). In reality, however, factors affecting at-release or post-release rarely work in isolation but in synergy with other biological, environmental, and fishing operational variables. Moreover, there was some evidence to suggest that survey respondents did not follow this approach. For example, survey respondents considered mako post-release survival to be high when released alive and uninjured, when hooked in the mouth /jaw, or when released with no trailing gear, then gave reduced estimates of survival for all category levels of the factors SST, shark size, and soak time. As being released uninjured is the most benign category for the ‘location of release’ factor (for example), survival estimates for the most benign levels of these other factors should have been comparable with that when an individual was released in this state.

Third, several of the priors used in the current study were derived from studies on the species outside New Zealand waters, or proxy species (e.g., Atlantic bluefin tuna). The utilisation of proxy species or results from fisheries outside New Zealand requires cautious consideration, as survival estimates may not be directly transferrable to New Zealand fisheries. Dedicated research is required to accurately define survival rates for the species in the context of New Zealand’s fisheries.

Only post-release survival was estimated for southern bluefin tuna and swordfish, as opposed to the three shark species, where at-release survival was also estimated. Discussions with stakeholders during the development of the questionnaire indicated that all actively released individuals of these species are alive at the time of release and considered likely to survive, consistent with their landing exceptions. Stakeholders consequently advised against asking questions regarding at-release survival of these species, to reduce confusion in the questionnaire (in that it was not appropriate to ask “*What proportion of released individuals were alive when released after being caught under scenario X*” as posed for the three pelagic shark species when the landing exceptions for the pelagic fish species stipulate that all released individuals must be alive and likely to survive). A similar approach was taken for Pacific bluefin tuna, which does not have landing exceptions. However, a small number of disposals in each year were coded to disposal codes A (abandoned in or accidentally lost at sea) or J (observer authorised disposal), an unknown proportion of which may be dead or moribund. Accordingly, the survival probability estimates for the three pelagic fish species presented here may be a slight overestimation in that they may exclude a small number of dead or moribund individuals. However, this is unlikely to alter the final survival probability determinations.

4.2 Potential future research

The holistic approach taken here to derive survival probabilities for the six pelagic species across New Zealand’s fisheries has highlighted several areas of further research required to better quantify at-vessel and post-release survival of the pelagic species considered here. These include, but are not limited to:

1. Increased data collection (e.g., species, size, life status) for pelagic sharks caught in both surface longline and trawl fisheries. As noted above, the lack of data due to recent declines in observer coverage makes it difficult to characterise trends in catch and the effects of fishing on these species. Electronic monitoring may provide an alternative means of assessing life status of captured individuals (provided individuals are in view of the camera).

2. Improved quantification of soak time, and understanding of the influence of soak time on at-vessel condition and post-release survival in surface longline fisheries. As noted above, while soak time was a key factor determining the overall release-condition and post-release survival estimates of all species examined here, the soak time metric used here did not provide an accurate measure of how long an individual spent on the line. Hook timers are required to accurately define soak times and subsequently assess the influence of soak time on condition at-vessel and post-release survival (Ellis et al. 2017, Whitney et al. 2021).

3. Quantification of the amount of trailing branch line gear left on pelagic sharks and fish following their release after capture by surface longline. Current evidence (e.g., Hutchinson et al. 2021) indicates that the length of trailing gear left on sharks following release is influential in post-release survival rates. Accordingly, the feasibility of recording the length of trailing gear on cut-free pelagic sharks and fish should be investigated. This should be done in such a way as to optimise crew and observer safety, as well as the health of captured animals.

4. Improving understanding of the cumulative effects of at-vessel condition of each of the species considered here from the surface longline fishery. Existing observer data could be used in a higher analysis of the interactive effects of the various factors on at-vessel condition, such as via a generalised additive mixed model (GAMM) framework.

5. Improved quantification of the condition (e.g., alive uninjured, alive with minor injury, alive with severe injury, dead) of pelagic sharks and fish captured in non-surface longline fisheries, in particularly trawl fisheries, and how this varies by biological, environmental, and fishing operation factors including the influence of SLEDs. Trawl fisheries where these species have been recorded from have relatively high observer coverage (e.g., Finucci et al. 2022), providing opportunity to record data and improve knowledge of interactions in these fisheries.

6. Increased electronic tagging to better quantify post-release survival of the pelagic species assessed here following release from New Zealand's commercial fisheries. Tagging programs should be specifically designed to include crossed effects to better quantify the cumulative impacts of multiple factors on post-release survival. While improved quantification of post-release survival should be the main focus for this work (and studies should be designed with this specific objective), this work would also provide greater understanding of movement patterns of individuals that survive post-release.

7. Continued research to improve handling and release practices, particularly for pelagic sharks, in both surface longline and trawl fisheries, and in ways that optimise crew health and safety and animal welfare.

8. Continued research to reduce capture of pelagic sharks. The vast majority of fishers interviewed during this project stated that their preference is to not catch sharks. Accordingly, continued exploration of approaches to avoid or minimise pelagic shark bycatch in New Zealand's surface longline fisheries are warranted. Such approaches could include, for example:
   (i) reducing spatial and temporal overlap through static and dynamic area-based management tools such as move-on rules;
   (ii) reducing vertical overlap by managing fishing depth;
   (iii) modifying fishing gear for quicker retrieval;
   (iv) reducing / eliminating fish waste discards on fishing grounds, and
   (v) reducing selectivity such as by adjusting leader material, hook and bait type and restricting the use of light attractors (Gilman et al. 2022, Mitchell et al. 2023).

5. FULFILLMENT OF BROADER OUTCOMES

The broader outcomes specific to this project involved building capacity, collaborations, capability, and diversity in the research sector. The project fostered collaboration between NIWA, the fishing industry, other New Zealand research providers, national and overseas universities, and international research organisations. The Workshop successfully provided opportunities for fishing industry stakeholders (including Māori) to contribute their unique observations and knowledge to the research process. Approximately half of workshop participants were female. Through estimation of the post-release survival probabilities and associated uncertainty, and documentation of the associated knowledge gaps, this research contributes to the long-term sustainability of the six pelagic species for the good of the wider community (including stakeholders and the public) and the marine ecosystems they inhabit.

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APPENDIX 1: CODES IN THE LANDING AND DISPOSAL DATA FOR PELAGIC SHARKS AND FISH

The table below presents the codes in the landing and disposal data for the six pelagic species considered in this report. The 'How used' column indicates how the codes were considered in the analyses.

Code	Description	How used
A	Accidental loss	Disposal
B	Bait stored for later use	Landing
D	Discarded	Disposal
E	Eaten	Landing
EOY	Landed under regulation 4(2)(b)	Landing
F	Section 111 Recreational Catch	Landing
H / HW	Loss from holding pot (H) or holding container in water (HW)	Removed from analysis
J	Returned to sea	Disposal
L	Landed in NZ (to LFR)	Landing
LFL	Conveyed or sold to an LFR previously recorded on a landing report under LF	Landing
LR	Landed to a LFR but previously recorded as retained on board	Landing
NP	Not provided	Landing
O	Conveyed outside NZ	Landing
P	Holding receptacle in water	Removed from analysis
Q	Holding receptacle on land	Removed from analysis
QL	Transferred from holding receptacle to LFR	Landing
R	Retained on board	Removed from analysis
S	Seized by Crown	Landed
T	Transferred to another vessel	Removed from analysis
U	Bait used on board	Landing
W	Sold at wharf	Landing
X	QMS returned to sea (except 6A)	Disposal
Z	Discarded blue, mako, and porbeagle sharks	Disposal

APPENDIX 2: THE BETA PARAMETRIC PROBABILITY DENSITY FUNCTION

The beta probability density function for the random deviate *x* is parameterised by two shape parameters alpha (α) and beta (β) such that:

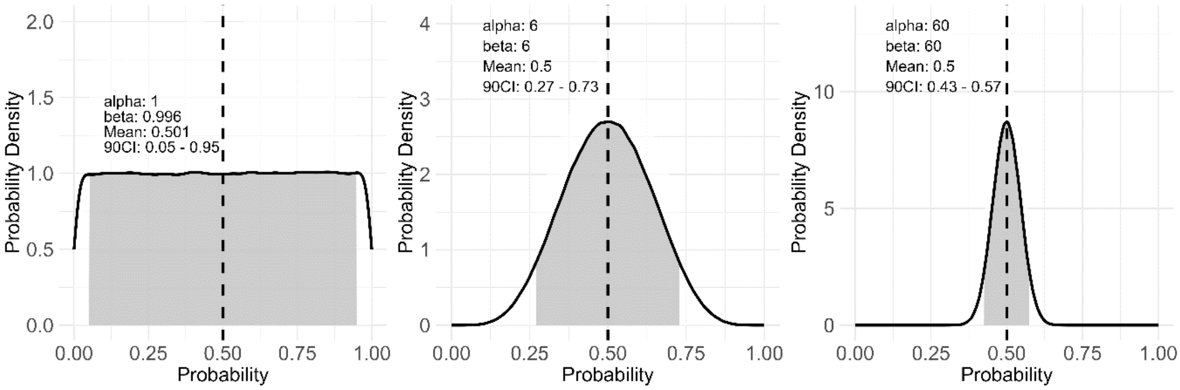
$$f(x;\alpha,\beta) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} x^{\alpha-1}(1-x)^{\beta-1}$$

where $\Gamma(z)$ is a gamma function.

The beta function **B** is a normalisation constant to ensure the total probability density of *x* is 1.

$$f(x;\alpha,\beta) = \frac{1}{\mathrm{B}(\alpha,\beta)} x^{\alpha-1}(1-x)^{\beta-1}$$

When $\alpha = \beta$ then the mean Beta probability will equal the centre of the distribution range (e.g., 0.5 if the range is 0 – 1.0). If $\alpha = \beta = 1$ then the generated Beta probability distribution will be approximately uniform across the distribution range (Appendix Figure 1). The Beta probability distribution becomes progressively narrower as α and β increase (i.e.: $\alpha = \beta \geq 1$; Appendix Figure 1).



Appendix Figure 1: Beta probability distributions where $\alpha = \beta = \{1, 6, 60\}$. Shaded areas show the 90% percentile range.

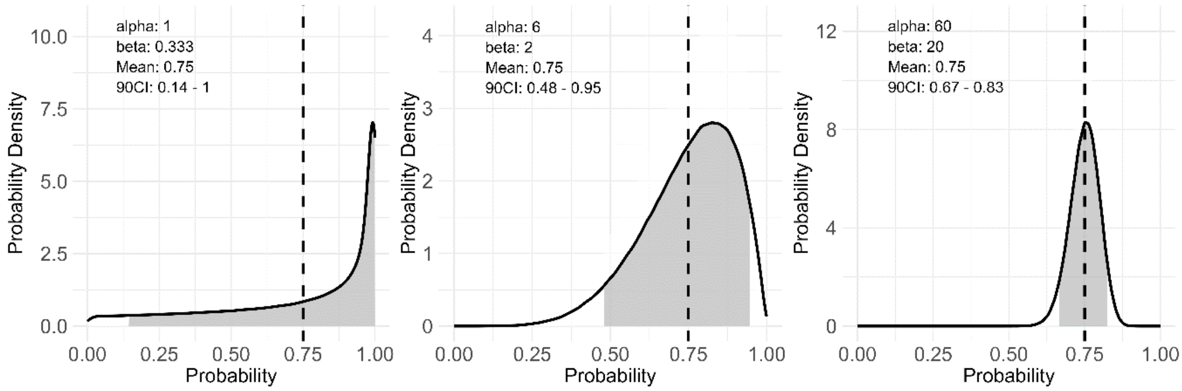
If $\alpha \neq \beta$ the mean μ of the Beta distributional range will shift above or below the mid-point depending on the ratio of the two parameters:

$$\mu = \frac{\alpha}{(\alpha+\beta)}$$

It is possible to approximate the probability density for any random variate *x* with mean μ using a Beta parametric distribution be specifying an appropriate α shape parameter. Note: given μ and α:

$$\beta = \frac{(\alpha - \alpha\mu)}{\mu}$$

As above, increasing α decreases the probability density spread across the 0 – 1.0 probability range about the mean μ, larger α have the effect of making the density distribution about μ more symmetric (Appendix Figure 2).



Appendix Figure 2: **Beta probability distributions for μ = 0.75 and α = {1,6,60}. Shaded areas show the 90% percentile range.**

APPENDIX 3: VALUES USED AS PRIORS IN THE CURRENT STUDY

Species	Method	Mortality component	Factor-category	Prior value used	Source (see footnote)
STN	SLL	RELEASE	RELEASE METHOD: 0–90 cm	-	
STN	SLL	RELEASE	RELEASE METHOD: 90–130 cm	-	
STN	SLL	RELEASE	RELEASE METHOD: 130 cm+	-	
STN	SLL	RELEASE	RELEASE CONDITION: Alive - uninjured	-	
STN	SLL	RELEASE	RELEASE CONDITION: Alive - minor	-	
STN	SLL	RELEASE	RELEASE CONDITION: Alive - severe	-	
STN	SLL	RELEASE	RELEASE CONDITION: Dead	-	
STN	SLL	RELEASE	SIZE: 0–90 cm	-	
STN	SLL	RELEASE	SIZE: 90–130 cm	-	
STN	SLL	RELEASE	SIZE: 130 cm+	-	
STN	SLL	RELEASE	TARGET: STN	-	
STN	SLL	RELEASE	TARGET: SWO	-	
STN	SLL	RELEASE	TARGET: BIG	-	
STN	SLL	RELEASE	SOAK: < 6 hours	-	
STN	SLL	RELEASE	SOAK: 6–12 hours	-	
STN	SLL	RELEASE	SOAK: 12–18 hours	-	
STN	SLL	RELEASE	SOAK: > 18 hours	-	
STN	SLL	RELEASE	HOOK_LOCATION: Gut	-	
STN	SLL	RELEASE	HOOK_LOCATION: Foul hooked	-	
STN	SLL	RELEASE	DEPREDATED	-	
STN	SLL	POST	RELEASE METHOD: Onboard	0.90	1,2,3
STN	SLL	POST	RELEASE METHOD: In-water	0.90	1,2,3
STN	SLL	POST	RELEASE CONDITION: Alive - uninjured	0.90	1,2,3
STN	SLL	POST	RELEASE CONDITION: Alive - minor	0.85	1,2,3
STN	SLL	POST	RELEASE CONDITION: Alive - severe	0.50	1,2,3
STN	SLL	POST	SIZE: 0–90 cm	0.90	1,2,3
STN	SLL	POST	SIZE: 90–130 cm	0.90	1,2,3
STN	SLL	POST	SIZE: 130 cm+	0.85	1,2,3
STN	SLL	POST	TARGET: STN	0.90	1,2,3
STN	SLL	POST	TARGET: SWO	0.90	1,2,3
STN	SLL	POST	TARGET: BIG	0.90	1,2,3
STN	SLL	POST	SOAK: < 6 hours	0.90	1,2,3
STN	SLL	POST	SOAK: 6–12 hours	0.90	1,2,3
STN	SLL	POST	SOAK: 12–18 hours	0.90	1,2,3
STN	SLL	POST	SOAK: > 18 hours	0.85	1,2,3
STN	SLL	POST	HOOK LOCATION: Jaw	0.90	1,2,3
STN	SLL	POST	HOOK LOCATION: Gills	0.60	1,2,3
STN	SLL	POST	HOOK LOCATION: Gut	0.60	1,2,3
STN	SLL	POST	HOOK LOCATION: Foul hooked	0.75	1,2,3
TOR	SLL	RELEASE	RELEASE METHOD: 0–90 cm	-	
TOR	SLL	RELEASE	RELEASE METHOD: 90–130 cm	-	
TOR	SLL	RELEASE	RELEASE METHOD: 130 cm+	-	
TOR	SLL	RELEASE	RELEASE CONDITION: Alive - uninjured	-	
TOR	SLL	RELEASE	RELEASE CONDITION: Alive - minor	-	
TOR	SLL	RELEASE	RELEASE CONDITION: Alive - severe	-	
TOR	SLL	RELEASE	RELEASE CONDITION: Dead	-	
TOR	SLL	RELEASE	SIZE: 0–90 cm	-	
TOR	SLL	RELEASE	SIZE: 90–130 cm	-	

TOR	SLL	RELEASE	SIZE: 130 cm+	-	
TOR	SLL	RELEASE	TARGET: STN	-	
TOR	SLL	RELEASE	TARGET: SWO	-	
TOR	SLL	RELEASE	TARGET: BIG	-	
TOR	SLL	RELEASE	SOAK: < 6 hours	-	
TOR	SLL	RELEASE	SOAK: 6–12 hours	-	
TOR	SLL	RELEASE	SOAK: 12–18 hours	-	
TOR	SLL	RELEASE	SOAK: > 18 hours	-	
TOR	SLL	RELEASE	HOOK LOCATION: Gut	-	
TOR	SLL	RELEASE	HOOK LOCATION: Foul hooked	-	
TOR	SLL	RELEASE	DEPREDATED	-	
TOR	SLL	POST	RELEASE METHOD: Onboard	0.90	1,2,3
TOR	SLL	POST	RELEASE METHOD: In-water	0.90	1,2,3
TOR	SLL	POST	RELEASE CONDITION: Alive - uninjured	0.90	1,2,3
TOR	SLL	POST	RELEASE CONDITION: Alive - minor	0.85	1,2,3
TOR	SLL	POST	RELEASE CONDITION: Alive - severe	0.50	1,2,3
TOR	SLL	POST	SIZE: 0–90 cm	0.90	1,2,3
TOR	SLL	POST	SIZE: 90–130 cm	0.90	1,2,3
TOR	SLL	POST	SIZE: 130 cm+	0.85	1,2,3
TOR	SLL	POST	TARGET: STN	0.90	1,2,3
TOR	SLL	POST	TARGET: SWO	0.90	1,2,3
TOR	SLL	POST	TARGET: BIG	0.90	1,2,3
TOR	SLL	POST	SOAK: < 6 hours	0.90	1,2,3
TOR	SLL	POST	SOAK: 6–12 hours	0.90	1,2,3
TOR	SLL	POST	SOAK: 12–18 hours	0.90	1,2,3
TOR	SLL	POST	SOAK: > 18 hours	0.85	1,2,3
TOR	SLL	POST	HOOK LOCATION: Jaw	0.90	1,2,3
TOR	SLL	POST	HOOK LOCATION: Gills	0.60	1,2,3
TOR	SLL	POST	HOOK LOCATION: Gut	0.60	1,2,3
TOR	SLL	POST	HOOK LOCATION: Foul hooked	0.75	1,2,3
SWO	SLL	RELEASE	RELEASE METHOD: 0–100 cm	-	
SWO	SLL	RELEASE	RELEASE METHOD: 100–150 cm	-	
SWO	SLL	RELEASE	RELEASE METHOD: 150 cm+	-	
SWO	SLL	RELEASE	RELEASE CONDITION: Alive - uninjured	-	
SWO	SLL	RELEASE	RELEASE CONDITION: Alive - minor	-	
SWO	SLL	RELEASE	RELEASE CONDITION: Alive - severe	-	
SWO	SLL	RELEASE	RELEASE CONDITION: Dead	-	
SWO	SLL	RELEASE	SIZE: 0–100 cm	-	
SWO	SLL	RELEASE	SIZE: 100–150 cm	-	
SWO	SLL	RELEASE	SIZE: 150 cm+	-	
SWO	SLL	RELEASE	TARGET: STN	-	
SWO	SLL	RELEASE	TARGET: SWO	-	
SWO	SLL	RELEASE	TARGET: BIG	-	
SWO	SLL	RELEASE	SOAK: < 6 hours	-	
SWO	SLL	RELEASE	SOAK: 6–12 hours	-	
SWO	SLL	RELEASE	SOAK: 12–18 hours	-	
SWO	SLL	RELEASE	SOAK: > 18 hours	-	
SWO	SLL	RELEASE	HOOK LOCATION: Gut	-	
SWO	SLL	RELEASE	HOOK LOCATION: Foul hooked	-	
SWO	SLL	RELEASE	DEPREDATED	-	
SWO	SLL	POST	RELEASE METHOD: Onboard	-	
SWO	SLL	POST	RELEASE METHOD: In-water	-	

SWO	SLL	POST	RELEASE CONDITION: Alive - uninjured	-
SWO	SLL	POST	RELEASE CONDITION: Alive - minor	-
SWO	SLL	POST	RELEASE CONDITION: Alive - severe	-
SWO	SLL	POST	SIZE: 0–100 cm	-
SWO	SLL	POST	SIZE: 100–150 cm	-
SWO	SLL	POST	SIZE: 150 cm+	-
SWO	SLL	POST	TARGET: STN	-
SWO	SLL	POST	TARGET: SWO	-
SWO	SLL	POST	TARGET: BIG	-
SWO	SLL	POST	SOAK: < 6 hours	-
SWO	SLL	POST	SOAK: 6–12 hours	-
SWO	SLL	POST	SOAK: 12–18 hours	-
SWO	SLL	POST	SOAK: > 18 hours	-
SWO	SLL	POST	HOOK LOCATION: Jaw	-
SWO	SLL	POST	HOOK LOCATION: Gills	-
SWO	SLL	POST	HOOK LOCATION: Gut	-
SWO	SLL	POST	HOOK LOCATION: Foul hooked	-
SWO	TRAWL	RELEASE	RELEASE CONDITION: Alive - uninjured	-
SWO	TRAWL	RELEASE	RELEASE CONDITION: Alive - minor	-
SWO	TRAWL	RELEASE	RELEASE CONDITION: Alive - severe	-
SWO	TRAWL	RELEASE	RELEASE CONDITION: Dead	-
SWO	TRAWL	RELEASE	SIZE: 0–100 cm	-
SWO	TRAWL	RELEASE	SIZE: 100–150 cm	-
SWO	TRAWL	RELEASE	SIZE: 150 cm+	-
SWO	TRAWL	RELEASE	DEPTH: < 200 m	-
SWO	TRAWL	RELEASE	DEPTH: 200–400 m	-
SWO	TRAWL	RELEASE	DEPTH: 400–800 m	-
SWO	TRAWL	RELEASE	DEPTH: > 800 m	-
SWO	TRAWL	RELEASE	DURATION: < 2 hours	-
SWO	TRAWL	RELEASE	DURATION: 2–5 hours	-
SWO	TRAWL	RELEASE	DURATION: 5–10 hours	-
SWO	TRAWL	RELEASE	DURATION: > 10 hours	-
SWO	TRAWL	RELEASE	CATCH: < 1 tonne	-
SWO	TRAWL	RELEASE	CATCH: 1–5 tonnes	-
SWO	TRAWL	RELEASE	CATCH: 5–10 tonnes	-
SWO	TRAWL	RELEASE	CATCH: > 10 tonnes	-
SWO	TRAWL	POST	RELEASE CONDITION: Alive - uninjured	-
SWO	TRAWL	POST	RELEASE CONDITION: Alive - minor	-
SWO	TRAWL	POST	RELEASE CONDITION: Alive - severe	-
SWO	TRAWL	POST	SIZE: 0–100 cm	-
SWO	TRAWL	POST	SIZE: 100–150 cm	-
SWO	TRAWL	POST	SIZE: 150 cm+	-
SWO	TRAWL	POST	DEPTH: < 200 m	-
SWO	TRAWL	POST	DEPTH: 200–400 m	-
SWO	TRAWL	POST	DEPTH: 400–800 m	-
SWO	TRAWL	POST	DEPTH: > 800 m	-
SWO	TRAWL	POST	DURATION: < 2 hours	-
SWO	TRAWL	POST	DURATION: 2–5 hours	-
SWO	TRAWL	POST	DURATION: 5–10 hours	-
SWO	TRAWL	POST	DURATION: > 10 hours	-
SWO	TRAWL	POST	CATCH: < 1 tonne	-
SWO	TRAWL	POST	CATCH: 1–5 tonnes	-

SWO	TRAWL	POST	CATCH: 5–10 tonnes	-	
SWO	TRAWL	POST	CATCH: > 10 tonnes	-	
BWS	SLL	RELEASE	RELEASE METHOD: immature	-	
BWS	SLL	RELEASE	RELEASE METHOD: maturing	-	
BWS	SLL	RELEASE	RELEASE METHOD: mature	-	
BWS	SLL	RELEASE	RELEASE CONDITION: Alive - uninjured	0.85	4
BWS	SLL	RELEASE	RELEASE CONDITION: Alive - minor	0.85	4
BWS	SLL	RELEASE	RELEASE CONDITION: Alive - severe	0.85	4
BWS	SLL	RELEASE	RELEASE CONDITION: Dead		
BWS	SLL	RELEASE	SIZE: > 170 cm FL (immature)	-	
BWS	SLL	RELEASE	SIZE: 170-200 cm FL (maturing)	-	
BWS	SLL	RELEASE	SIZE: > 200 cm FL (mature)	-	
BWS	SLL	RELEASE	SOAK: < 6 hours	-	
BWS	SLL	RELEASE	SOAK: 6–12 hours	-	
BWS	SLL	RELEASE	SOAK: 12–18 hours	-	
BWS	SLL	RELEASE	SOAK: > 18 hours	-	
BWS	SLL	RELEASE	HOOK LOCATION: Gut	-	
BWS	SLL	RELEASE	HOOK LOCATION: Foul hooked	-	
BWS	SLL	RELEASE	SST: < 15 degrees C	-	
BWS	SLL	RELEASE	SST: 15–20 degrees C	-	
BWS	SLL	RELEASE	SST: > 20 degrees C	-	
BWS	SLL	POST	RELEASE METHOD: Onboard	-	
BWS	SLL	POST	RELEASE METHOD: In-water	-	
BWS	SLL	POST	RELEASE CONDITION: Alive - uninjured	0.90	4
BWS	SLL	POST	RELEASE CONDITION: Alive - minor	0.67	4,5
BWS	SLL	POST	RELEASE CONDITION: Alive - severe	0.67	4,5
BWS	SLL	POST	SIZE: > 170 cm FL (immature)	-	
BWS	SLL	POST	SIZE: 170-200 cm FL (maturing)	-	
BWS	SLL	POST	SIZE: > 200 cm FL (mature)	-	
BWS	SLL	POST	SOAK < 6 hours	-	
BWS	SLL	POST	SOAK: 6–12 hours	-	
BWS	SLL	POST	SOAK: 12–18 hours	-	
BWS	SLL	POST	SOAK: > 18 hours	-	
BWS	SLL	POST	SST: < 15 degrees C	-	
BWS	SLL	POST	SST: 15–20 degrees C	-	
BWS	SLL	POST	SST: > 20 degrees C	-	
BWS	SLL	POST	HOOK LOCATION: Jaw	-	
BWS	SLL	POST	HOOK LOCATION: Gills	-	
BWS	SLL	POST	HOOK LOCATION: Gut	-	
BWS	SLL	POST	HOOK LOCATION: Foul hooked	-	
BWS	SLL	POST	TRAILING GEAR: None	0.84	5
BWS	SLL	POST	TRAILING GEAR: Less	0.83	5
BWS	SLL	POST	TRAILING GEAR: Equal	0.83	5
BWS	SLL	POST	TRAILING GEAR: Greater	-	
MAK	SLL	RELEASE	RELEASE METHOD: immature	-	
MAK	SLL	RELEASE	RELEASE METHOD: maturing	-	
MAK	SLL	RELEASE	RELEASE METHOD: mature	-	
MAK	SLL	RELEASE	RELEASE CONDITION: Alive - uninjured	0.55	6
MAK	SLL	RELEASE	RELEASE CONDITION: Alive - minor	0.55	6
MAK	SLL	RELEASE	RELEASE CONDITION: Alive - severe	0.55	6
MAK	SLL	RELEASE	RELEASE CONDITION: Dead	0.00	
MAK	SLL	RELEASE	SIZE: > 180 cm FL (immature)	0.75	6

MAK	SLL	RELEASE	SIZE: 180–280 cm FL (maturing)	0.93	6
MAK	SLL	RELEASE	SIZE: > 280 cm FL (mature)	0.93	6
MAK	SLL	RELEASE	SOAK: < 6 hours	-	
MAK	SLL	RELEASE	SOAK: 6–12 hours	-	
MAK	SLL	RELEASE	SOAK: 12–18 hours	-	
MAK	SLL	RELEASE	SOAK: > 18 hours	-	
MAK	SLL	RELEASE	HOOK LOCATION: Gut	-	
MAK	SLL	RELEASE	HOOK LOCATION: Foul hooked	-	
MAK	SLL	RELEASE	SST: < 15 degrees C	-	
MAK	SLL	RELEASE	SST: 15–20 degrees C	-	
MAK	SLL	RELEASE	SST: > 20 degrees C	-	
MAK	SLL	POST	RELEASE METHOD: Onboard	0.55	7
MAK	SLL	POST	RELEASE METHOD: In-water	0.88	6
MAK	SLL	POST	RELEASE CONDITION: Alive - uninjured	0.88	6
MAK	SLL	POST	RELEASE CONDITION: Alive - minor	0.63	6
MAK	SLL	POST	RELEASE CONDITION: Alive - severe	0.63	6
MAK	SLL	POST	SIZE: > 180 cm FL (immature)	0.75	6
MAK	SLL	POST	SIZE: 180–280 cm FL (maturing)	0.93	6
MAK	SLL	POST	SIZE: > 280 cm FL (mature)	0.93	6
MAK	SLL	POST	SOAK < 6 hours	0.88	8
MAK	SLL	POST	SOAK: 6–12 hours	0.88	8
MAK	SLL	POST	SOAK: 12–18 hours	0.88	8
MAK	SLL	POST	SOAK: > 18 hours	-	
MAK	SLL	POST	SST: < 15 degrees C	-	
MAK	SLL	POST	SST: 15–20 degrees C	-	
MAK	SLL	POST	SST: > 20 degrees C	-	
MAK	SLL	POST	HOOK LOCATION: Jaw	0.66	6,7
MAK	SLL	POST	HOOK LOCATION: Gills	-	
MAK	SLL	POST	HOOK LOCATION: Gut	-	
MAK	SLL	POST	HOOK LOCATION: Foul hooked	-	
MAK	SLL	POST	TRAILING GEAR: None	0.89	6
MAK	SLL	POST	TRAILING GEAR: Less	0.89	6
MAK	SLL	POST	TRAILING GEAR: Equal	0.88	6
MAK	SLL	POST	TRAILING GEAR: Greater	0.76	6
MAK	TRAWL	RELEASE	RELEASE CONDITION: Alive - uninjured	-	
MAK	TRAWL	RELEASE	RELEASE CONDITION: Alive - minor	-	
MAK	TRAWL	RELEASE	RELEASE CONDITION: Alive - severe	-	
MAK	TRAWL	RELEASE	RELEASE CONDITION: Dead	-	
MAK	TRAWL	RELEASE	SIZE: > 180 cm FL (immature)	-	
MAK	TRAWL	RELEASE	SIZE: 180–280 cm FL (maturing)	-	
MAK	TRAWL	RELEASE	SIZE: > 280 cm FL (mature)	-	
MAK	TRAWL	RELEASE	DEPTH: < 200 m	-	
MAK	TRAWL	RELEASE	DEPTH: 200–400 m	-	
MAK	TRAWL	RELEASE	DEPTH: 400–800 m	-	
MAK	TRAWL	RELEASE	DEPTH: > 800 m	-	
MAK	TRAWL	RELEASE	DURATION: < 2 hours	-	
MAK	TRAWL	RELEASE	DURATION: 2–5 hours	-	
MAK	TRAWL	RELEASE	DURATION: 5–10 hours	-	
MAK	TRAWL	RELEASE	DURATION: > 10 hours	-	
MAK	TRAWL	RELEASE	CATCH: < 1 tonne	-	
MAK	TRAWL	RELEASE	CATCH: 1–5 tonnes	-	
MAK	TRAWL	RELEASE	CATCH: 5–10 tonnes	-	

MAK	TRAWL	RELEASE	CATCH: > 10 tonnes	-	
MAK	TRAWL	POST	RELEASE CONDITION: Alive - uninjured	-	
MAK	TRAWL	POST	RELEASE CONDITION: Alive - minor	-	
MAK	TRAWL	POST	RELEASE CONDITION: Alive - severe	-	
MAK	TRAWL	POST	SIZE: > 180 cm FL (immature)	-	
MAK	TRAWL	POST	SIZE: 180–280 cm FL (maturing)	-	
MAK	TRAWL	POST	SIZE: > 280 cm FL (mature)	-	
MAK	TRAWL	POST	DEPTH: < 200 m	-	
MAK	TRAWL	POST	DEPTH: 200–400 m	-	
MAK	TRAWL	POST	DEPTH: 400–800 m	-	
MAK	TRAWL	POST	DEPTH: > 800 m	-	
MAK	TRAWL	POST	DURATION: < 2 hours	-	
MAK	TRAWL	POST	DURATION: 2–5 hours	-	
MAK	TRAWL	POST	DURATION: 5–10 hours	-	
MAK	TRAWL	POST	DURATION: > 10 hours	-	
MAK	TRAWL	POST	CATCH: < 1 tonne	-	
MAK	TRAWL	POST	CATCH: 1–5 tonnes	-	
MAK	TRAWL	POST	CATCH: 5–10 tonnes	-	
MAK	TRAWL	POST	CATCH: > 10 tonnes	-	
POS	SLL	RELEASE	RELEASE METHOD: immature	-	
POS	SLL	RELEASE	RELEASE METHOD: maturing	-	
POS	SLL	RELEASE	RELEASE METHOD: mature	-	
POS	SLL	RELEASE	RELEASE CONDITION: Alive - uninjured	0.56	4
POS	SLL	RELEASE	RELEASE CONDITION: Alive - minor	0.56	4
POS	SLL	RELEASE	RELEASE CONDITION: Alive - severe	0.56	4
POS	SLL	RELEASE	RELEASE CONDITION: Dead	0.00	
POS	SLL	RELEASE	SIZE: > 140 cm FL (immature)	-	
POS	SLL	RELEASE	SIZE: 140–180 cm FL (maturing)	-	
POS	SLL	RELEASE	SIZE: > 180 cm FL (mature)	-	
POS	SLL	RELEASE	SOAK: < 6 hours	-	
POS	SLL	RELEASE	SOAK: 6–12 hours	-	
POS	SLL	RELEASE	SOAK: 12–18 hours	-	
POS	SLL	RELEASE	SOAK: > 18 hours	-	
POS	SLL	RELEASE	HOOK LOCATION: Gut	0.40	7
POS	SLL	RELEASE	HOOK LOCATION: Foul hooked	0.67	7
POS	SLL	RELEASE	SST: < 15 degrees C	-	
POS	SLL	RELEASE	SST: 15–20 degrees C	-	
POS	SLL	RELEASE	SST: > 20 degrees C	-	
POS	SLL	POST	RELEASE METHOD: Onboard	-	
POS	SLL	POST	RELEASE METHOD: In-water	-	
POS	SLL	POST	RELEASE CONDITION: Alive - uninjured	0.90	4
POS	SLL	POST	RELEASE CONDITION: Alive - minor	0.25	4
POS	SLL	POST	RELEASE CONDITION: Alive - severe	0.25	4
POS	SLL	POST	SIZE: > 140 cm FL (immature)	-	
POS	SLL	POST	SIZE: 140–180 cm FL (maturing)	-	
POS	SLL	POST	SIZE: > 180 cm FL (mature)	-	
POS	SLL	POST	SOAK.: < 6 hours	-	
POS	SLL	POST	SOAK: 6–12 hours	-	
POS	SLL	POST	SOAK: 12–18 hours	-	
POS	SLL	POST	SOAK: > 18 hours	-	
POS	SLL	POST	HOOK LOCATION: Jaw	0.92	7
POS	SLL	POST	HOOK LOCATION: Gills	-	

POS	SLL	POST	HOOK LOCATION: Gut	0.40	7
POS	SLL	POST	HOOK LOCATION: Foul hooked	0.67	7
POS	SLL	POST	SST: < 15 degrees C	-	
POS	SLL	POST	SST: 15–20 degrees C	-	
POS	SLL	POST	SST: > 20 degrees C	-	
POS	SLL	POST	TRAILING GEAR: None	-	
POS	SLL	POST	TRAILING GEAR: Less	-	
POS	SLL	POST	TRAILING GEAR: Equal	-	
POS	SLL	POST	TRAILING GEAR: Greater	-	
POS	TRAWL	RELEASE	RELEASE CONDITION: Alive - uninjured	-	
POS	TRAWL	RELEASE	RELEASE CONDITION: Alive - minor	-	
POS	TRAWL	RELEASE	RELEASE CONDITION: Alive - severe	-	
POS	TRAWL	RELEASE	RELEASE CONDITION: Dead	-	
POS	TRAWL	RELEASE	SIZE: > 140 cm FL (immature)	-	
POS	TRAWL	RELEASE	SIZE: 140–180 cm FL (maturing)	-	
POS	TRAWL	RELEASE	SIZE: > 180 cm FL (mature)	-	
POS	TRAWL	RELEASE	DEPTH: < 200 m	-	
POS	TRAWL	RELEASE	DEPTH: 200–400 m	-	
POS	TRAWL	RELEASE	DEPTH: 400–800 m	-	
POS	TRAWL	RELEASE	DEPTH: > 800 m	-	
POS	TRAWL	RELEASE	DURATION: < 2 hours	-	
POS	TRAWL	RELEASE	DURATION: 2–5 hours	-	
POS	TRAWL	RELEASE	DURATION: 5–10 hours	-	
POS	TRAWL	RELEASE	DURATION: > 10 hours	-	
POS	TRAWL	RELEASE	CATCH: < 1 tonne	-	
POS	TRAWL	RELEASE	CATCH: 1–5 tonnes	-	
POS	TRAWL	RELEASE	CATCH: 5–10 tonnes	-	
POS	TRAWL	RELEASE	CATCH: > 10 tonnes	-	
POS	TRAWL	POST	RELEASE CONDITION: Alive - uninjured	-	
POS	TRAWL	POST	RELEASE CONDITION: Alive - minor	-	
POS	TRAWL	POST	RELEASE CONDITION: Alive - severe	-	
POS	TRAWL	POST	SIZE: > 140 cm FL (immature)	-	
POS	TRAWL	POST	SIZE: 140–180 cm FL (maturing)	-	
POS	TRAWL	POST	SIZE: > 180 cm FL (mature)	-	
POS	TRAWL	POST	DEPTH: < 200 m	-	
POS	TRAWL	POST	DEPTH: 200–400 m	-	
POS	TRAWL	POST	DEPTH: 400–800 m	-	
POS	TRAWL	POST	DEPTH: > 800 m	-	
POS	TRAWL	POST	DURATION: < 2 hours	-	
POS	TRAWL	POST	DURATION: 2–5 hours	-	
POS	TRAWL	POST	DURATION: 5–10 hours	-	
POS	TRAWL	POST	DURATION: > 10 hours	-	
POS	TRAWL	POST	CATCH: < 1 tonne	-	
POS	TRAWL	POST	CATCH: 1–5 tonnes	-	
POS	TRAWL	POST	CATCH: 5–10 tonnes	-	
POS	TRAWL	POST	CATCH: > 10 tonnes	-	

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APPENDIX 4: PROPORTIONS USED TO WEIGHT SURVIVAL ESTIMATES TO THE FISHERY PROFILE

Species	Method	Factor-category	Proportional weighting	Data source
STN	SLL	TARGET: SWO	0.011	Catch and effort
STN	SLL	TARGET: STN	0.968	Catch and effort
STN	SLL	TARGET: BIG	0.021	Catch and effort
STN	SLL	SOAK: 6–12 hours	0.030	Observer
STN	SLL	SOAK: 12–18 hours	0.564	Observer
STN	SLL	SOAK: > 18 hours	0.397	Observer
STN	SLL	SOAK: < 6 hours	0.000	Observer
STN	SLL	SIZE: 90–130 cm	0.724	Observer
STN	SLL	SIZE: 130 cm+	0.188	Observer
STN	SLL	SIZE: 0–90 cm	0.088	Observer
STN	SLL	RELEASE METHOD: Onboard	0.900	Questionnaire
STN	SLL	RELEASE METHOD: In-water	0.100	Questionnaire
STN	SLL	RELEASE CONDITION: Alive - uninjured	0.943	Observer
STN	SLL	RELEASE CONDITION: Alive - severe	0.000	Observer
STN	SLL	RELEASE CONDITION: Alive - minor	0.057	Observer
STN	SLL	HOOK LOCATION: Jaw	0.991	Observer
STN	SLL	HOOK LOCATION: Gut	0.005	Observer
STN	SLL	HOOK LOCATION: Gills	0.001	Observer
STN	SLL	HOOK LOCATION: Foul hooked	0.003	Observer
TOR	SLL	TARGET: SWO	0.100	Catch and effort
TOR	SLL	TARGET: STN	0.488	Catch and effort
TOR	SLL	TARGET: BIG	0.411	Catch and effort
TOR	SLL	SOAK: 6–12 hours	0.038	Observer
TOR	SLL	SOAK: 12–18 hours	0.596	Observer
TOR	SLL	SOAK: > 18 hours	0.366	Observer
TOR	SLL	SOAK: < 6 hours	0.000	Observer
TOR	SLL	SIZE: 90–130 cm	0.020	Observer
TOR	SLL	SIZE: 130 cm+	0.980	Observer
TOR	SLL	SIZE: 0–90 cm	0.000	Observer
TOR	SLL	RELEASE METHOD: Onboard	0.900	Questionnaire
TOR	SLL	RELEASE METHOD: In-water	0.100	Questionnaire
TOR	SLL	RELEASE CONDITION: Alive - uninjured	1.000	Observer
TOR	SLL	RELEASE CONDITION: Alive - severe	0.000	Observer
TOR	SLL	RELEASE CONDITION: Alive - minor	0.000	Observer
TOR	SLL	HOOK LOCATION: Jaw	0.970	Observer
TOR	SLL	HOOK LOCATION: Gut	0.010	Observer
TOR	SLL	HOOK LOCATION: Gills	0.010	Observer
TOR	SLL	HOOK LOCATION: Foul hooked	0.010	Observer
SWO	SLL	TARGET: SWO	0.148	Catch and effort
SWO	SLL	TARGET: STN	0.287	Catch and effort
SWO	SLL	TARGET: BIG	0.557	Catch and effort
SWO	SLL	SOAK: 6–12 hours	0.000	Observer
SWO	SLL	SOAK: 12–18 hours	0.557	Observer
SWO	SLL	SOAK: > 18 hours	0.418	Observer
SWO	SLL	SOAK: < 6 hours	0.000	Observer
SWO	SLL	SIZE: 100–150 cm	0.443	Observer
SWO	SLL	SIZE: 150 cm+	0.253	Observer

SWO	SLL	SIZE: 0–100 cm	0.304	Observer
SWO	SLL	RELEASE METHOD: Onboard	0.900	Questionnaire
SWO	SLL	RELEASE METHOD: In-water	0.100	Questionnaire
SWO	SLL	RELEASE CONDITION: Alive - uninjured	0.950	Observer
SWO	SLL	RELEASE CONDITION: Alive - severe	0.000	Observer
SWO	SLL	RELEASE CONDITION: Alive - minor	0.050	Observer
SWO	SLL	HOOK LOCATION: Jaw	1.000	Observer
SWO	SLL	HOOK LOCATION: Gut	0.000	Observer
SWO	SLL	HOOK LOCATION: Gills	0.000	Observer
SWO	SLL	HOOK LOCATION: Foul hooked	0.000	Observer
SWO	TRAWL	SIZE: 0–100 cm	0.000	Observer
SWO	TRAWL	SIZE: 100–150 cm	0.000	Observer
SWO	TRAWL	SIZE: 150 cm+	1.000	Observer
SWO	TRAWL	RELEASE CONDITION: Alive - uninjured	0.800	Questionnaire
SWO	TRAWL	RELEASE CONDITION: Alive - severe	0.100	Questionnaire
SWO	TRAWL	RELEASE CONDITION: Alive - minor	0.100	Questionnaire
SWO	TRAWL	DURATION: < 2 hours	0.167	Catch and effort
SWO	TRAWL	DURATION: 2–5 hours	0.750	Catch and effort
SWO	TRAWL	DURATION: 5–10 hours	0.083	Catch and effort
SWO	TRAWL	DURATION: > 10 hours	0.000	Catch and effort
SWO	TRAWL	DEPTH: < 200 m	0.083	Catch and effort
SWO	TRAWL	DEPTH: 200–400 m	0.333	Catch and effort
SWO	TRAWL	DEPTH: 400–800 m	0.583	Catch and effort
SWO	TRAWL	DEPTH: > 800 m	0.000	Catch and effort
SWO	TRAWL	CATCH: < 1 tonne	0.000	Catch and effort
SWO	TRAWL	CATCH: 1–5 tonnes	0.417	Catch and effort
SWO	TRAWL	CATCH: 5–10 tonnes	0.250	Catch and effort
SWO	TRAWL	CATCH: > 10 tonnes	0.333	Catch and effort
BWS	SLL	SIZE: maturing	0.042	Observer
BWS	SLL	SIZE: mature	0.010	Observer
BWS	SLL	SIZE: immature	0.948	Observer
BWS	SLL	TRAILING GEAR: None	0.600	Stakeholder advice
BWS	SLL	TRAILING GEAR: Less	0.200	Stakeholder advice
BWS	SLL	TRAILING GEAR: Greater	0.100	Stakeholder advice
BWS	SLL	TRAILING GEAR: Equal	0.100	Stakeholder advice
BWS	SLL	SOAK: 6–12 hours	0.080	Observer
BWS	SLL	SOAK: 12–18 hours	0.564	Observer
BWS	SLL	SOAK: > 18 hours	0.352	Observer
BWS	SLL	SOAK: < 6 hours	0.000	Observer
BWS	SLL	SST: < 15 degrees C	0.586	Observer
BWS	SLL	SST: 15–20 degrees C	0.401	Observer
BWS	SLL	SST: > 20 degrees C	0.013	Observer
BWS	SLL	RELEASE METHOD: Onboard	0.500	Observer
BWS	SLL	RELEASE METHOD: In-water	0.500	Observer
BWS	SLL	RELEASE CONDITION: Alive - uninjured	0.938	Observer
BWS	SLL	RELEASE CONDITION: Alive - severe	0.032	Observer
BWS	SLL	RELEASE CONDITION: Alive - minor	0.031	Observer
BWS	SLL	HOOK LOCATION: Jaw	0.797	Observer
BWS	SLL	HOOK LOCATION: Gut	0.133	Observer
BWS	SLL	HOOK LOCATION: Gills	0.058	Observer
BWS	SLL	HOOK LOCATION: Foul hooked	0.012	Observer
MAK	SLL	SIZE: maturing	0.056	Observer

MAK	SLL	SIZE: mature	0.007	Observer
MAK	SLL	SIZE: immature	0.937	Observer
MAK	SLL	TRAILING GEAR: None	0.600	Stakeholder advice
MAK	SLL	TRAILING GEAR: Less	0.200	Stakeholder advice
MAK	SLL	TRAILING GEAR: Greater	0.100	Stakeholder advice
MAK	SLL	TRAILING GEAR: Equal	0.100	Stakeholder advice
MAK	SLL	SOAK: 6–12 hours	0.017	Observer
MAK	SLL	SOAK: 12–18 hours	0.597	Observer
MAK	SLL	SOAK: > 18 hours	0.383	Observer
MAK	SLL	SOAK: < 6 hours	0.000	Observer
MAK	SLL	SST: < 15 degrees C	0.017	Observer
MAK	SLL	SST: 15–20 degrees C	0.734	Observer
MAK	SLL	SST: > 20 degrees C	0.249	Observer
MAK	SLL	RELEASE METHOD: Onboard	0.500	Observer
MAK	SLL	RELEASE METHOD: In-water	0.500	Observer
MAK	SLL	RELEASE CONDITION: Alive - uninjured	0.954	Observer
MAK	SLL	RELEASE CONDITION: Alive - severe	0.023	Observer
MAK	SLL	RELEASE CONDITION: Alive - minor	0.023	Observer
MAK	SLL	HOOK LOCATION: Jaw	0.831	Observer
MAK	SLL	HOOK LOCATION: Gut	0.047	Observer
MAK	SLL	HOOK LOCATION: Gills	0.041	Observer
MAK	SLL	HOOK LOCATION: Foul hooked	0.081	Observer
MAK	TRAWL	SIZE: maturing	0.472	Observer
MAK	TRAWL	SIZE: mature	0.000	Observer
MAK	TRAWL	SIZE: immature	0.528	Observer
MAK	TRAWL	RELEASE CONDITION: Alive - uninjured	0.100	Stakeholder advice
MAK	TRAWL	RELEASE CONDITION: Alive - severe	0.450	Stakeholder advice
MAK	TRAWL	RELEASE CONDITION: Alive - minor	0.450	Stakeholder advice
MAK	TRAWL	DURATION: < 2 hours	0.028	Catch and effort
MAK	TRAWL	DURATION: 2–5 hours	0.595	Catch and effort
MAK	TRAWL	DURATION: 5–10 hours	0.350	Catch and effort
MAK	TRAWL	DURATION: > 10 hours	0.028	Catch and effort
MAK	TRAWL	DEPTH: < 200 m	0.845	Catch and effort
MAK	TRAWL	DEPTH: 200–400 m	0.058	Catch and effort
MAK	TRAWL	DEPTH: 400–800 m	0.097	Catch and effort
MAK	TRAWL	DEPTH: > 800 m	0.002	Catch and effort
MAK	TRAWL	CATCH: < 1 tonne	0.009	Catch and effort
MAK	TRAWL	CATCH: 1–5 tonnes	0.058	Catch and effort
MAK	TRAWL	CATCH: 5–10 tonnes	0.146	Catch and effort
MAK	TRAWL	CATCH: > 10 tonnes	0.787	Catch and effort
POS	SLL	SIZE: maturing	0.009	Observer
POS	SLL	SIZE: mature	0.044	Observer
POS	SLL	SIZE: immature	0.947	Observer
POS	SLL	TRAILING GEAR: None	0.600	Stakeholder advice
POS	SLL	TRAILING GEAR: Less	0.200	Stakeholder advice
POS	SLL	TRAILING GEAR: Greater	0.100	Stakeholder advice
POS	SLL	TRAILING GEAR: Equal	0.100	Stakeholder advice
POS	SLL	SOAK: 6–12 hours	0.060	Observer
POS	SLL	SOAK: 12–18 hours	0.570	Observer
POS	SLL	SOAK: > 18 hours	0.369	Observer
POS	SLL	SOAK: < 6 hours	0.001	Observer
POS	SLL	SST: < 15 degrees C	0.294	Observer

POS	SLL	SST: 15–20 degrees C	0.631	Observer
POS	SLL	SST: > 20 degrees C	0.076	Observer
POS	SLL	RELEASE METHOD: Onboard	0.400	Observer
POS	SLL	RELEASE METHOD: In-water	0.600	Observer
POS	SLL	RELEASE CONDITION: Alive - uninjured	0.840	Observer
POS	SLL	RELEASE CONDITION: Alive - severe	0.041	Observer
POS	SLL	RELEASE CONDITION: Alive - minor	0.119	Observer
POS	SLL	HOOK LOCATION: Jaw	0.848	Observer
POS	SLL	HOOK LOCATION: Gut	0.064	Observer
POS	SLL	HOOK LOCATION: Gills	0.075	Observer
POS	SLL	HOOK LOCATION: Foul hooked	0.013	Observer
POS	TRAWL	SIZE: maturing	0.380	Observer
POS	TRAWL	SIZE: mature	0.338	Observer
POS	TRAWL	SIZE: immature	0.282	Observer
POS	TRAWL	RELEASE CONDITION: Alive - uninjured	0.100	Stakeholder advice
POS	TRAWL	RELEASE CONDITION: Alive - severe	0.450	Stakeholder advice
POS	TRAWL	RELEASE CONDITION: Alive - minor	0.450	Stakeholder advice
POS	TRAWL	DURATION: < 2 hours	0.051	Catch and effort
POS	TRAWL	DURATION: 2–5 hours	0.382	Catch and effort
POS	TRAWL	DURATION: 5–10 hours	0.509	Catch and effort
POS	TRAWL	DURATION: > 10 hours	0.058	Catch and effort
POS	TRAWL	DEPTH: < 200 m	0.311	Catch and effort
POS	TRAWL	DEPTH: 200–400 m	0.218	Catch and effort
POS	TRAWL	DEPTH: 400–800 m	0.471	Catch and effort
POS	TRAWL	DEPTH: > 800 m	0.000	Catch and effort
POS	TRAWL	CATCH: < 1 tonne	0.016	Catch and effort
POS	TRAWL	CATCH: 1–5 tonnes	0.077	Catch and effort
POS	TRAWL	CATCH: 5–10 tonnes	0.152	Catch and effort
POS	TRAWL	CATCH: > 10 tonnes	0.756	Catch and effort