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# Estimation of release survival of Patagonian toothfish *Dissostichus eleginoides*

New Zealand Fisheries Assessment Report 2025/07

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## PLAIN LANGUAGE SUMMARY

This study estimated the proportion of Patagonian toothfish caught within the New Zealand EEZ that would survive if they were released alive.

These survival estimates were based on the available New Zealand and overseas studies and on information from experts, such as fishers, fishery observers, and research scientists.

## EXECUTIVE SUMMARY

**Devine, J.[1], Underwood, M.J. (2025). Estimation of release survival of Patagonian toothfish *Dissostichus eleginoides*.**

***New Zealand Fisheries Assessment Report 2025/07.* 40 p.**

Under New Zealand's Fisheries Act 1996, commercial fishers are prohibited from returning or abandoning to the sea, or other waters, any fish or other animals that are subject to the Quota Management System. 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 Quota Management System to be returned or abandoned to the sea if they are satisfied that the return meets one of the new provisions under Section 72A(2). Currently, several fish species including Patagonian toothfish (*Dissostichus eleginoides*) are either required (when below a certain size) or permitted to be returned to the sea, but this exception must be reviewed against the relevant new provisions to determine whether it should be should be retained, amended, or revoked. The objective of this report is to quantify release survival for Patagonian toothfish in New Zealand fisheries. Survival estimates were based on the available New Zealand and overseas survival literature on this species and on "expert elicitation" involving fishers, fishery observers, and research scientists.

A fishery characterisation indicated that most discards of Patagonian toothfish in New Zealand's exclusive economic zone (EEZ) were from bottom longline fisheries. A literature review was then undertaken to document current knowledge on the at-vessel and post-release survival of Patagonian toothfish from this fishing method, which was used to develop an online questionnaire. The questionnaire was structured into sections on 'at-release' survival (i.e., the probability that a fish is alive when put back in the water) and 'post-release' survival (i.e., the probability of the fish surviving after release). The questionnaire was sent to those experienced in fishing Patagonian toothfish (i.e., fishers and fishery observers) as well as domestic and international scientists experienced in conducting research on at-release and post-release survival.

After removing respondents with only one year of experience with *Dissostichus* species, questionnaire responses (n = 18, 3 fishers, 8 fishery observers, 1 compliance officer, and 6 scientists, ranging from 3 to over 15 years of experience) were then used to inform a Monte Carlo simulation approach based on a parametric Beta distribution to derive expected survival probability ranges (95% confidence intervals) for each factor and within factor category. Separate analyses were conducted to understand at-release survival only, post-release survival only, and combined at- and post-release survival. All individuals were assumed to be alive at the time of release, in accordance with current release exceptions. Survival estimates obtained from the literature were used as the 'expected mean survival' to bound the expected survival probability estimates within the Beta distribution. An overall 95% survival probability range estimate for each factor category was computed, with each factor proportional to its occurrence in the fishery in the last three years. If information on a factor was not available from the within NZ EEZ data, information of Patagonian toothfish catch and releases from other regional fisheries management organisations were used.

This research highlighted some key areas where data are lacking, or further research is needed to quantify at- and post-release survival of Patagonian toothfish. These include: 1) better quantification of the influence of soak time on at-vessel condition and post-release survival; 2) collection of data that are thought to influence at- and post-release survival for future analyses, e.g., height of release, air temperature, noting wounds (including healed wounds), behaviour of the fish post-release or if it was attacked by birds or other predators; 3) further research with pop-up satellite archival transmitter tags (PSATs) to better quantify post-release survival directly, including studies designed specifically for this aspect.

[1] National Institute of Water and Atmospheric Research Ltd (NIWA).

# 1. INTRODUCTION

This project is directed at quantifying the post-release survival for Patagonian toothfish (*Dissostichus eleginoides*) caught in the New Zealand EEZ. The impetus for this work comes from recent changes to the Fisheries Act 1996 that strengthens rules and polices around fisheries landings and discards. Under the 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, and these were listed in Schedule 6 of the Fisheries Act which was revoked in November 2022.

Patagonian toothfish was listed in Schedule 6 of the Fisheries Act 1996 with the following provisions. A commercial fisher may return any Patagonian toothfish, irrespective of capture method, to the waters from which it was taken if:

(a) The Patagonian toothfish is likely to survive on return; and
(b) The return takes place as soon as practicable after the Patagonian toothfish is taken; and
(c) In the case of a trawl-caught Patagonian toothfish, it is released only in the presence of an observer.

This landing exception needs to be assessed against the new exception provisions by September 2026 to determine whether it should continue, be amended, or be revoked.

Under the new provisions in Section 72A of New Zealand's 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, provided they are satisfied that that any landing exception meets at least one of the new provisions that have been set in the Fisheries Act. Under the new provisions, 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; 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, fisheries management, or ecosystem purpose and there is an acceptable likelihood of survival if returned or abandoned in the specified manner.

To facilitate this review, Fisheries New Zealand commissioned project SEA2022-09 'Estimation of release mortality for pelagic sharks and fish'. The overall objective of this project was to estimate the proportion surviving release for 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*), to inform a governmental review of the current legislation concerning releases of these species. This report covers Patagonian toothfish; survival probability estimates for the pelagic species are covered in Moore & Finucci (2024).

The Specific Research Objectives of SEA2022-09 addressed in this report were:

1. To undertake a fishery characterisation to understand the main methods and operational characteristics responsible for discards of Patagonian toothfish (*Dissostichus eleginoides*).
2. To collate available scientific literature on the release survival of Patagonian toothfish.
3. To convene a workshop of relevant experts to derive survival estimates for Patagonian toothfish, according to gear type, handling behaviour, and environmental conditions.

# 2. METHODS

## 2.1 Fishery characterisation

### 2.1.1 National data

A data extract (commercial landings, effort, and estimated catch files) was obtained from the Fisheries New Zealand Enterprise Data Warehouse on 4 May 2023 (report log 15040). Records containing the species code PTO (Patagonian toothfish) were extracted from all landing form types for the years 2004–05 to 2021–22.

Datasets for the characterisations included: (1) all commercial catches, including landed and discard/release components; and (2) only the discard/release components. Discard records in the disposal reports were linked to the individual fishing effort event for data reported via the Electronic Reporting System (ERS) (fishing years 2019–20 to 2021–22) by using the 'Fishing Event ID' field in the landings dataset and the 'Logbook Event Id' in the effort dataset.

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

- Landed: codes EOY, L, LF, LFL, LR, and QL, as well as disposal codes indicating that a dead individual was used in some way (e.g., codes B, E, O, S, U, and W) (see Appendix 1).
- Released: codes A, D, J, and X (Table 1). With the exception of code X, these codes do not allow for discerning between lost (alive) or returned/abandoned (likely dead) (see Section 3.1).

**Table 1: Description of the discard disposal codes referenced in this report.**

| Disposal code | Description |
|---|---|
| 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. |
| D | Fish or fish product of a stock not managed under the QMS that are returned to the sea, abandoned in the sea, or accidentally lost at sea |
| J | Fish or fish product of a stock managed under the QMS that are returned to, or abandoned in, the sea as authorised by a fishery officer or observer regardless of being either alive or dead |
| X | Fish of stocks subject to the QMS that are listed in the Fisheries (Landing and Discard Exceptions) Notice under provision of being alive and likely to survive |

Observer data were extracted from the Centralised Observer Database (*cod*). Data were examined to determine if additional information for the reason for discarding could be determined.

Fishing years for the characterisations were denoted in two ways: (i) 2021–22 fishing year referring to October 2021 to September 2022; and (ii) the abbreviated form 2022 signifying the 2021–22 fishing year.

### 2.1.2 International data

Data were also requested for Patagonian toothfish from the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and the South Pacific Regional Fisheries Management Organisation (SPRFMO) (Figure 1). Patagonian toothfish are part of a structured mark-recapture research programme and have had dedicated research programmes focused on determining movement and behaviour through the use of archival tags and on factors that might influence release mortality within these two areas. The data request included an extract of all vessels and fishing methods catching

Patagonian toothfish and an extract of all fishing activity data for those vessels and methods, gear specific information, tag release and recapture data, and observer data. These data were used to generate proportions used to weight survival estimates to the fishery profile (Appendix 5) for Patagonian toothfish for factor categories not recorded in the national data.

A request was made to the SPRFMO Secretariat on 5 May 2023, and with subsequent follow-ups; data were released 19 July 2023 with the stipulation that data would be destroyed after the research has been conducted, no sensitive data would be divulged, and contributing Members are acknowledged and allowed to review and comment before the results are made public. Only one Member (European Union) allowed the release of their data (for Spain).

A request to the CCAMLR Secretariat was made 7 May 2023, and with subsequent follow-ups; data were released 6 July 2023 with the stipulation that data access rules were followed, including that Members must be acknowledged and allowed to review and comment before the results are made public. France refused access to their data, while Australia refused access to data from Division 58.5.2 (but allowed access to data from other areas), which meant that information was only available for part of the CCAMLR region. Only data from vessels fishing with bottom longlines had been requested.

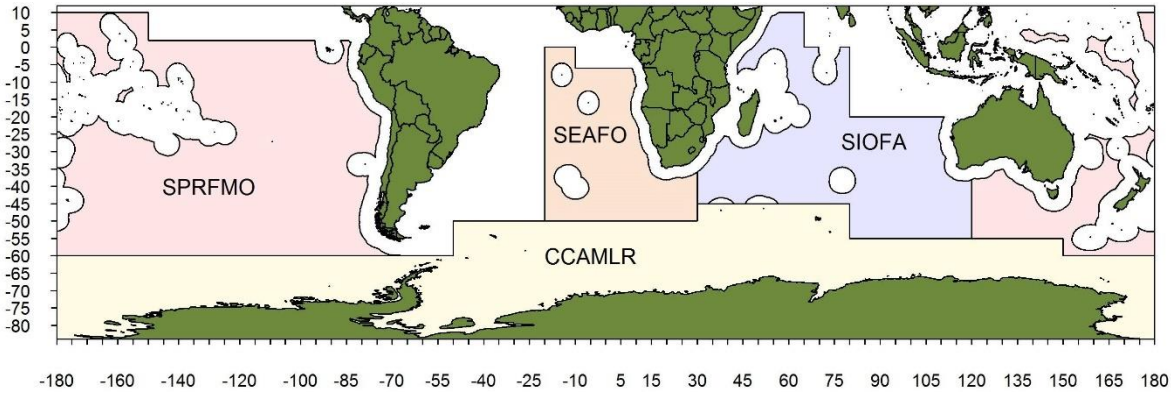


**Figure 1: Map of the boundaries of CCAMLR and the non-tuna regional fishery management organisation (RFMO) convention areas in the Southern hemisphere. The CCAMLR convention area includes national EEZs contained within its boundaries, but the illustrated RFMOs do not. SEAFO, South-East Atlantic Fisheries Organization; SIOFA, Southern Indian Ocean Fisheries Agreement; CCAMLR, Commission for the Conservation of Antarctic Marine Living Resources; SPRFMO, South Pacific Regional Fisheries Management Organisation.**

## 2.2 Literature reviews

Literature reviews were undertaken to document current knowledge on the at-vessel and post-release survival and key factors influencing survival of Patagonian toothfish.

The most common data collected to assess post-release survival of Patagonian toothfish came from conventional T-bar tags and electronic tags such as pop-up satellite archival transmitters (PSATs) (e.g., Brown et al. 2013, Kim & Lam 2023). The data returned from PSAT tags provides a timeline over a span of days to months, some of which are programmed to release if the fish does not move (i.e., dies), from which the fate of the tagged individual can be inferred. However, all of the PSAT studies were for determining movement and stock connectivity, not for determining post-release survival.

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 (i.e., the status of an individual when brought to the vessel), post-release survival/mortality, catch-and-release, tagging terms including capture-mark-recapture, tagging, pop-up satellite tags, PSATs, acoustic tag, and archival tag. At-retrieval and/or at-release survival estimates and factors influencing survival from

the literature review were documented and compiled specific to relevant fishing methods (as determined by the fishery characterisation) for review by a workshop panel of experts and subsequently the CCAMLR working group on Fish Stock Assessment (WG-FSA) (see Section 2.3).

## 2.3 Expert elicitation and workshop review

Two separate survival probabilities were combined to derive a survival probability estimate for a given method of capture-release event:

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

Input was solicited from a range of experts who had 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 representative, and fishery managers. The at-release and post-release survival experts were largely the same individuals. This was because most of those who were commercial fishers, company representatives, and fisheries observers had routinely fished in the CCAMLR area for many years, where toothfish tagging is a requirement of participation in the fishery. Tagging performance, e.g., post-release mortality and tag detection of individual vessels, as well as tagging protocols are routinely assessed (Fenaughty & Brown 2011, Mormede & Dunn 2013, Parker & Fenaughty 2013, CCAMLR 2023), monitored by fishery observers, vessel science officers, and vessel companies. Moreover, training in proper fish handling techniques through various workshops has been provided (Parker et al. 2012, CCAMLR 2023). Fisheries scientists with knowledge of the release survival literature and expertise in post-release survival were also consulted; many also had direct experience in tagging (i.e., at-release survival).

Following initial consultations with fishers and scientists, an online Google Forms questionnaire was developed to capture information on at- and post-release survival components of Patagonian toothfish. The questionnaire was informed by the fishery characterisation and by a recent CCAMLR tagging workshop (CCAMLR 2023), including, in particular, a tagging procedures survey the CCAMLR Secretariat circulated to seventeen vessels and international observers who had participated in exploratory fisheries from 2019 to 2020 (CCAMLR Secretariat 2023a). The questionnaire was split into questions pertaining to at- and post-release survival. Questions in each category were based on key findings from the literature review, to provide additional context regarding the reasons for individuals being released and to fill in knowledge gaps (Appendix 2). Following McKenzie et al. (2024), 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., fishing depth) into range categories (e.g., 0–1000 m, 1000–2000 m, greater than 2000 m). Each questionnaire respondent was requested to provide a survival probability range for each 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; checking all six denoted that the respondent thought survival probability could be anywhere between 0 and 100%. Respondents were also given the option of selecting a box labelled 'unsure' or not answering a question if they felt they did not have enough expertise with that factor. Explicitly accounting for crossed effects for continuous factors, e.g., all levels of 'fishing depth' crossed with all levels of 'time out of water', was not feasible due to the limitations of using a questionnaire approach. Survey respondents were therefore required to provide survival estimates for each factor-category assuming other factors were at

the least harmful level (e.g., expected survival relative to various 'fishing depth' categories assumed 'time out of water' to be at the highest survival category level).

Prior to being sent to respondents, the questionnaire was sent to small number of fishers and New Zealand scientists to ensure that questions were clear, unambiguous, and not influenced by assumed knowledge.

Prior to the workshop, questionnaire results were presented in-person at a meeting of the Fisheries New Zealand Antarctic Working Group (online) on 26 September 2023.

Questionnaire results and resulting preliminary survival probability estimates (see Section 2.4) were then reviewed and discussed at a workshop held on 28 September 2023, which was attended by respondents, fishery managers, fishing industry representatives, and other scientists and stakeholders. After the workshop, the questionnaire was revised to include a question about the number of years of experience handling Patagonian toothfish respondents had. Respondents were given the opportunity to revise their replies, including survival estimates, following workshop discussions. To avoid skewed results, answers from respondents with only minimal experience (1 year or less) were removed.

The workshop identified that preliminary results should be presented to CCAMLR at WG-FSA in October 2023 because most of the experts working on Patagonian toothfish would be present, of which, many had failed to respond to the request. This was done at WG-FSA under 'Other business' and resulted in ten additional responses to the questionnaire.

The final respondent estimates were analysed and aggregated to derive expected survival probability ranges for each factor category in accordance with the methods described in Section 2.4 below. Results were presented to the Fisheries New Zealand Antarctic Working Group (online) on 21 November 2023.

## 2.4 Fishery survival probability estimation

The approaches of McKenzie et al. (2024) and Moore & Finucci (2024) were used to derive at-release, post-release, and combined (at-release × post-release) survival probability intervals for Patagonian toothfish. A Monte Carlo simulation approach was employed to derive 95% confidence ranges on the expected survival (mean survival) from the questionnaire responses (n = 18) for each factor (e.g., soak time, fishing depth) combination and for overall (i.e., combined) survival estimates for each factor, following the approach reviewed and agreed by the Fisheries New Zealand Inshore Working Group (McKenzie et al. 2024). 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 3).

At the request of Fisheries New Zealand, three separate analyses were conducted:

1. Analyses based on at-release (immediate) survival ($p$[IS]) only.
2. Analyses based on post-release survival ($p$[PRS]) only, assuming that 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 95% probability density bound,
*ub* upper 95% probability density bound,

$\mu$ expected mean survival, and
$\alpha$ 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 factor category component probability were derived from the range values of the questionnaire responses. In the absence of information on survival from the literature, $\mu$ was set at the midpoint of *lb* and *ub*, and $\alpha$ was set at 1. This parametrisation derived a Beta bootstrap density that was approximately uniform between *lb* and *ub* (Appendix 3). Where suitable survival estimates from the literature were available, these were used as the 'expected mean survival', with the Beta distribution *u* set to this value and the alpha parameter changed to 4 corresponding to greater confidence in this estimate (Appendices 3–4).

Data collected by fishery observers were initially examined for use as the expected mean survival, but data were lacking observations of released individuals in the last five years (Table 2).

**Table 2: Numbers of observed releases/discards with life status information (e.g., returned to sea alive) available for Patagonian toothfish as recorded by fishery observers from within New Zealand's Exclusive Economic Zone, 2017–18 to 2021–22.**

| | Fishing year | | | | |
|---|---|---|---|---|---|
| | 2018 | 2019 | 2020 | 2021 | 2022 |
| Bottom longline | 19 | 0 | 0 | 1 | 1 |

Overall survival by factor level (i.e., incorporating both at- and post-release survival estimates) were computed as the product of the random draws from the Beta distributions. Finally, an overall release survival estimate for each factor 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 profile (proportional occurrence averaged over the most recent three fishing years; Appendix 5). Because information on many of these parameters were lacking in the New Zealand data, SPRFMO and CCAMLR information were used. Some of these factors were not recorded in the data but had been compiled by the CCAMLR Secretariat for some of the vessels in the CCAMLR fishery (CCAMLR Secretariat 2023a); these data were used for e.g., capture hook use, time out of water, height of release.

Final survival determinations were based on the lowest estimated survival probability for each factor, using the decision rules outlined in Table 3 and presented in Figure 2.

**Table 3: Description of the 95% confidence interval categories on mean survival.**

| Survival probability | Description |
|---|---|
| High | Lower 95% CI greater than 0.50 |
| Medium-high | Lower 95% CI greater than 0.25 but lower than 0.50, upper 95% CI exceeds 0.75 |
| Medium | Lower 95% CI greater than 0.25, upper 95% CI less than 0.75 |
| Low-medium 1 | Lower 95% CI less than 0.25, upper 95% CI greater than 0.25 but less than 0.75 |
| Low-medium 2 | Lower 95% CI greater than 0.25, upper 95% CI less than 0.50 |
| Low | Upper 95% CI does not exceed 0.25 |
| Uncertain | Survival probability range crosses all four probability quartiles |

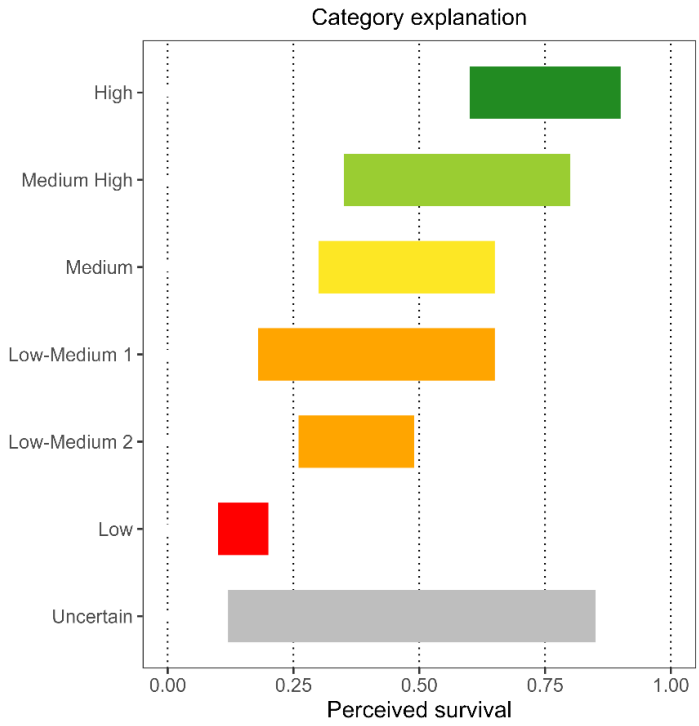


**Figure 2: Graphical representation of the 95% survival probability confidence interval.**

# 3. RESULTS

## 3.1 Fishery characterisations

The annual mean total catch, including landed and discarded/released components, of Patagonian toothfish within the NZ EEZ in the three-year period from 2019–00 to 2021–22 was 6 t (Table 4). Annual average discards in 2005–2022 were less than 1 t or 3% of the total landings, except in 2017 and 2022 (Table 4). Sixty-five percent of Patagonian toothfish discards from bottom longlining have been attributed to disposal code A (i.e., QMS species abandoned at sea or accidental loss), with the rest attributed to disposal code D (i.e., non-QMS species abandoned in or accidentally lost at sea). The use of disposal code D was likely to have been a recording error. These codes do not allow for differentiating between lost (could be either dead or alive) or returned (implies alive), therefore 'A' and 'D' were interpreted as alive at release. No Patagonian toothfish were released under disposal code 'X' (i.e., QMS species returned to sea (except 6A)) (Appendix 1).

Bottom longline accounted for most (99%) of the Patagonian toothfish commercial captures and discards, with most of the catch being taken in September–October and January–February (Figure 3), which would have been before and directly after vessels were fishing in the CCAMLR bottom longline fishery for toothfish. Patagonian toothfish were mainly the target species, although a small amount of catch (< 1 t in total) were from the ling target fishery. The majority of the Patagonian toothfish catch and discards by bottom longline were from just inside the NZ EEZ on the Macquarie Ridge. Very small amounts of catch were taken throughout the southern part of the NZ EEZ, but it was likely that another Notothenid species was misidentified as Patagonian toothfish. Smallscaled cod (*Notothenia microlepidota*), for instance, is easily confused with juvenile Patagonian toothfish and was very likely mistaken for it on the Campbell Plateau and east coast South Island regions.

Since 2007, over 167 bottom longline sets within the NZ EEZ that caught Patagonian toothfish were observed by fisheries observers, of which, 68 sets discarded or released fish (Table 5). Of those fish, only one was discarded alive (likely to survive) and one was noted as returned, which could be assumed

likely to survive. Fish noted as lost or accidentally lost by observers may have been likely to survive because these fish would have fallen off the hook, which meant that the hook injury was likely not severe (i.e., not in the gills or swallowed/in the gut), but from the mouth. Observers did not record information on hooking location, life status at hauling, or size of discarded / released fish within NZ EEZ waters.

**Table 4: Estimated catches (tonnes) of Patagonian toothfish within New Zealand's Exclusive Economic Zone by weight and proportion for disposal code and fishing year, 2004–05 to 2021–22. Code A or D refers to disposal codes specifying abandoned / accidentally lost / returned to the sea for QMS and non-QMS species.**

| Fishing year | Landed | Code A or D | Proportion landed | Proportion code A or D |
|---|---|---|---|---|
| 2005 | 0.01 | – | 1 | – |
| 2006 | 0.00 | – | 1 | – |
| 2007 | 0.00 | 0.00 | 0.999 | 0.001 |
| 2008 | 0.06 | 0.00 | 0.999 | 0.001 |
| 2009 | 19.01 | 0.02 | 0.999 | 0.001 |
| 2010 | 0.00 | – | 1 | – |
| 2011 | 22.21 | 0.25 | 0.989 | 0.011 |
| 2012 | 33.62 | – | 1 | – |
| 2013 | 26.78 | 0.08 | 0.997 | 0.003 |
| 2014 | 0.00 | – | 1 | – |
| 2015 | 34.14 | 0.17 | 0.995 | 0.005 |
| 2016 | 3.89 | 0.00 | 0.999 | 0.001 |
| 2017 | 20.31 | 3.31 | 0.860 | 0.140 |
| 2018 | 12.77 | 0.01 | 0.999 | 0.001 |
| 2019 | 0.00 | – | 1 | – |
| 2020 | 0.01 | – | 1 | – |
| 2021 | 0.00 | – | 1 | – |
| 2022 | 6.08 | 1.95 | 0.757 | 0.243 |

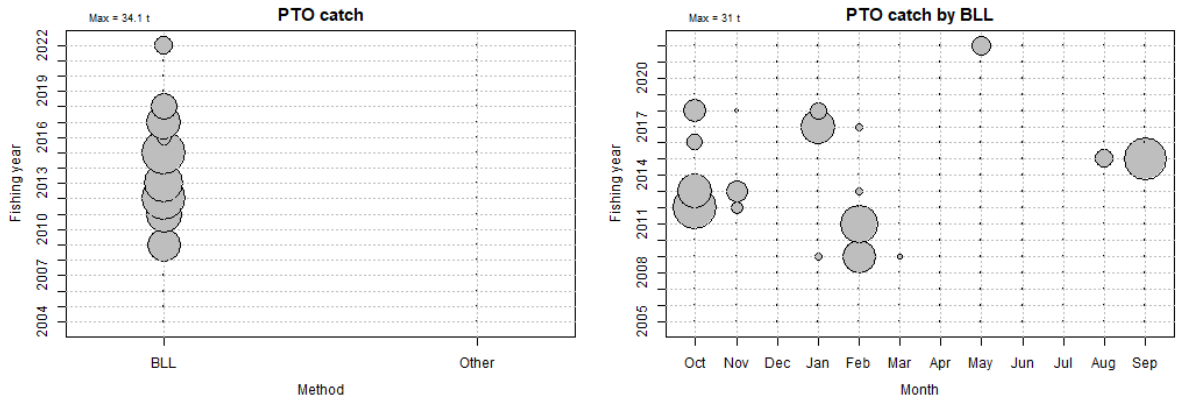


**Figure 3: Catch of Patagonian toothfish (PTO) by (left) fishing method and (right) month for bottom longline (BLL) from within New Zealand's Exclusive Economic Zone from 2005 to 2022.**

**Table 5: Greenweight (t), number of fish, and number of sets for Patagonian toothfish observed to have been discarded or released within New Zealand's Exclusive Economic Zone, 2005 to 2022.**

| Fishing year | Discard status | Green weight | Number of fish | Number of sets |
|---|---|---|---|---|
| 2011 | Discarded | 799 | 65 | 20 |
| 2011 | Lost | 347 | 27 | 17 |
| 2012 | Discarded | 2023 | 137 | 31 |
| 2012 | Lost | 164 | 18 | 5 |
| 2017 | Accidental loss of whole fish | 132 | 9 | 7 |
| 2018 | Accidental loss of whole fish | 33 | 2 | 2 |
| 2021 | Returned | 1 | 1 | 1 |
| 2022 | Discarded alive (likely to survive) | 12 | 1 | 1 |

## 3.2 Review of at-vessel and post-release survival studies

### 3.2.1 Biology

Patagonian toothfish is a long-lived, slow growing, late maturing species with low fecundity and protracted spawning periods that occur mainly during the winter (Laptikhovsky et al. 2006, Collins et al. 2010). Patagonian toothfish can grow up to 2.3 m in length and 200 kg in weight, mature at over 10 years of age, and live up to 50 years (Collins et al. 2010, Welsford et al. 2011). They are associated with cold water and are found around the sub-Antarctic and South America, including on surrounding islands, seamounts, and on continental shelves, but are limited in their southward distribution by the lack of antifreeze glycoproteins that are present in other Southern Ocean nototheniids (Belchier & Collins 2008, Collins et al. 2010). Adults are found in waters deeper than 500 m to a maximum depth of 2500 m, although maximum depth varies geographically (Collins et al. 2010). Juveniles are associated with shallower waters on the continental slope (Lee et al. 2018, Toomey et al. 2016). Tagging studies have demonstrated strong site fidelity in adults and a lack of cyclic migratory movements, although long distance movements (greater than 120 km) have been recorded for some individuals (Collins et al. 2010, Lee et al. 2022, Troccoli et al. 2023, Welsford et al. 2011).

*Dissostichus* species do not possess a swimbladder and therefore do not suffer barotrauma injuries when brought to the surface, even from great depths (Agnew et al. 2006). They are generally considered robust, which makes them a prime candidate for tagging studies and mark-recapture methods of assessment (e.g., within CCAMLR) since their release mortality is considered low.

### 3.2.2 Studies assessing immediate (at-vessel) survival

Only one study has directly assessed at-vessel survival of Patagonian toothfish, which found overall survival was 90%, but when only fish in good condition were assessed, survival was 95% (Table 6). (Agnew et al. 2006). Several factors that might impact survival, including condition/injury state, liveliness state, holding tank characteristics, length of time in the tank, depth of capture, fish length, and evidence of previous (now healed) injuries that were likely damage from hook or predation. Factors significantly related to survival were fish length, where survival decreased markedly in fish larger than 90 cm, and fish condition; 66% of fish in poor condition survived (data were from one vessel that selected poor condition fish for the experiment). Survival increased to 90% and 95% of fish in average and good condition, respectively (Agnew et al. 2006).

### 3.2.3 Studies assessing post-release survival

Patagonian toothfish mark-recapture studies have been ongoing for many years around Heard, Macquarie, Kerguelen, Crozet, and South Georgia Islands and in the Ross Sea, but the only indication that fish have survived were reports of injuries (or lack of), robust and lively behaviour upon release, and (for some individuals) recapture after some time at liberty. Patagonian toothfish have been recaptured after as many as 16 years at liberty from around South Georgia (Marsh et al. 2022) and 15 years at Kerguelen Island (Burch et al. 2019). Fish that have suffered serious injuries, from puncture wounds in the head/jaw to missing eyes, have been recaptured with healed injuries and in good condition, indicating that severe trauma may not necessarily result in low post-release survival (Agnew et al. 2006). Patagonian toothfish around Heard Island have been found to survive repeated release and recapture events (Burch et al. 2019). Fish in good condition after capture with a bottom trawl or using pots have also been tagged and released, and subsequently recaptured, indicating that toothfish captured with this method may also have high post-release survival (Collins et al. 2010, Marlow et al. 2002, Troccoli et al. 2023).

There have been no dedicated studies assessing post-release survival in Patagonian toothfish following capture by bottom longline, but two studies have used PSATs to study movement and stock connectivity, from which post-release survival might be able to be inferred (Table 7). Brown et al. (2013) tagged 30 Patagonian toothfish with PSAT tags near the Falkland Islands. All fish survived the initial post-capture period, but only 17 tags remained on the fish between 48 to 180 days; tags were programmed to pop off immediately if the fish stopped moving (i.e., was dead). This indicated a survival estimate of 53% for larger fish between 127 and 155 cm in length. Fifty Patagonian toothfish between 97–139 cm were released with PSAT tags, of which, 44 remained attached to live fish until pop-off (10–487 days) (Kim & Lam 2023). This indicated a post-release survival estimate of 88%.

**Table 6: Summary of studies examining at-vessel survival of Patagonian toothfish captured with bottom longline (BLL). Factors in bold font had a significant influence on survival, italicised factors were nearly significant.**

| Method | Region | Sample size | Survival estimate | Factors examined / affecting survival | Comments / caveats | Reference |
|---|---|---|---|---|---|---|
| Commercial BLL, holding tanks (8) | CCAMLR Subarea 48.3 | 396 | 90% overall<br>95% if fish in good condition and not held in holding tank<br>66% if fish in poor condition (1 vessel) | Liveliness, **condition/injury state**; holding tank characteristics; length of time in tank; *depth of fishing (shallower had greater survival)*; **fish length** (> 90 cm, survival declined quickly) | Kept in holding tank 12 hours post-tagging; tanks were on deck or in factory; most had running seawater; fish were captured from 500–1760 m; eyes 'greyed over' around 12 hrs in the tank (exposure to light) | Agnew et al. 2006 |

**Table 7: Summary of studies examining post-release survival of Patagonian toothfish from research and commercial fisheries. BLL = bottom longline; POT = potting; BT = bottom trawling; EEZ = exclusive economic zone. Factors in bold font had a significant influence on survival.**

| Method | Region | Sample size | Time at liberty range | Survival estimate | Factors examined / affecting survival | Comments / caveats | Reference |
|---|---|---|---|---|---|---|---|
| Commercial BLL: T-bar tags | Falkland Islands, slope around southern Chile | 4 418 | 232 recaptured; 22 days – 5.2 years | | Fish length, time at liberty, direction of movement, difference in depth between release and recapture, sex of fish, month of recapture, position of release, fish condition, fate at release | Movement study; recapture rate 5.25% | Lee et al. 2022 |
| Commercial BLL, Commercial BT; T-bar tags | Argentine EEZ | 5 528 BLL; 379 BT | 121 recaptured fish; 3 days to 8.66 years | | **Fish length**, time at liberty, tagging depth, **sector of release, season of release** | Movement study; 75% of fish were juveniles; GAM model indicated time of tagging and depth of release were not significant factors for movement (of fish that survived); recaptured fish were in good condition | Troccoli et al. 2023 |
| Research BT; commercial POT; commercial BLL; T-bar tags | CCAMLR Area 48.3 | 1 045 BT; 688 POT; 410 BLL | 50 recaptured from potting and longline releases | | Fish length, depth of capture | Movement study; fish caught by trawl were held in holding tank prior to release; fish were 16–130 cm; no recaptured fish from trawl-caught releases | Marlow et al. 2002 |
| Commercial and research BLL; Pop-off satellite tags | Falkland Islands | 30; 8 did not work | 17 PSAT worked > 6 months | 53 | | Movement study; Spanish longline; capture depths 750–1460 m; | Brown et al. 2013 |
| Commercial BLL; Pop-off satellite tags | FAO Area 41, adjacent to CCAMLR Area 48 | 50; various pop-off times (1–16 months) | 44 reported data (10–487 days) | 88 | | Movement study; fish held 5–30 minutes before release to ensure would survive | Kim & Lam 2023 |

***Expert elicitation***

Twenty-two individuals responded to the questionnaire, including 3 fishers, 10 fishery observers (national and international), 1 compliance officer, and 8 scientists, ranging from 1 to over 15 years of experience fishing for *Dissostichus* species. Of these, 4 observers and 2 scientists left many of the at-release questions blank or selected 'unsure/don't know' responses. Of the post-release survival questions, 4 observers, 1 fisher, and 1 scientist chose to not answer the questions. Respondents with only 1 year of experience with Patagonian toothfish were removed. This removed 2 fishery observers and 2 scientists.

***Reasons for release***

Stakeholders advised that the most common reason for releasing Patagonian toothfish, outside of tagging programmes, was accidental loss or misidentification; toothfish were too profitable to discard intentionally. Patagonian toothfish may be released if they are caught in the ling target fishery and the company or vessel does not have sufficient quota. Stakeholders stated that if only one fish had been caught, it will be sent to the galley and marked as eaten on board because of the additional requirements for CCAMLR inspection for all landed toothfish (to deter landings from IUU fishing).

***Feedback on the use of the capture hook (gaff)***

Stakeholders agreed that the capture hook was not used if the intention was to release the toothfish. Furthermore, if a capture hook was used, it would not be used on the body of the fish as that would result in a lower grade and affect the price but would be through the gill plate for lifting the fish onboard. Toothfish were discussed as being quite robust, even to high levels of trauma, including from colossal squid and killer whales, and had been reported to heal from severe injuries, such as from the capture hook (Agnew et al. 2006). While participants thought that while some fish were indeed quite hardy and postulated that up to 35% might survive wounds from a capture hook, many were thought likely to die from secondary causes, e.g., infection from wounds or starvation because of mouth injuries. Participants suggested that it would be more precautionary to assume 100% of toothfish did not survive when a capture hook was used.

This information meant that capture hook estimates of at- and post-release survival were removed from further analyses. Fish were not assumed alive at time of release.

***At-release survival***

The question 'What percentage are in the following condition at release?' may have been misinterpreted by several individuals. Two individuals with many years of experience fishing in the CCAMLR area selected 'less than 10%' of Patagonian toothfish were in the condition of 'no injuries' and 'minor injuries' at release. However, these responses were not removed from the analysis as the intent was difficult to discern. Sixteen respondents answered questions, but not all respondents answered all questions.

Survey respondents gave a wide range of estimates of the proportion of Patagonian toothfish that were released with no to minor injuries (< 10% – > 90%), but agreed that only a small percentage of fish were released with severe injuries (< 25%) or dead (< 10%) (Figure 4).

Survey respondents indicated that most Patagonian toothfish were returned alive when caught at depths up to 2000 m, but at greater depths, respondents were unsure (Figure 4). Workshop participants indicated that they rarely fished at those depths. Questions about soak time, time out of water, and release height suggested that most (> 75%) were returned alive for lower times and heights, but there was greater uncertainty around higher values (Figure 4), participants noted that this was because they did not have personal experience with longer soak/fish out of water times or with greater release heights. Respondents indicated that fish taken by predators or hooked in the gills/gut were less likely to survive, but that regardless of fish size, survival was high at release. Many respondents indicated uncertainty around survival when using a capture hook (or gaff) and at air temperatures less than -5 ˚C, but that survival was generally > 50% at temperatures higher than -5 ˚C (Figure 4). Workshop participants indicated that this was because they often are not fishing for Patagonian toothfish at such low

temperatures where Antarctic toothfish (*Dissostichus mawsoni*) is the dominant species, and that a capture hook is not used when release is intentional to prevent injury to the fish; intentional releases were typically for tagging purposes, mainly conducted outside of the NZ EEZ (Agnew et al. 2006, Burch et al. 2019, Marsh et al. 2022). Where release was not intentional, it was due to the fish falling off the hook (i.e., accidental loss), which typically occurred before the capture hook could be used.

***Post-release survival***

Sixteen respondents answered questions, but not all respondents answered all questions (Figure 4). Three factors did not include post-release responses; fish in those categories were assumed to not have survived capture or release (e.g., predated, dead at capture, hooked in the gut/gills). Overall, survey respondents considered survival of Patagonian toothfish to be high when released with no or minor injuries, soak time was short (< 24 hours), time out of water was short (< 2 minutes), release heights were < 2 m, and fish were under 1 m in length (Figure 4). When compared to similar factors, post-release survival responses had greater variability (or range of responses) than at-release survival, including more 'unsure/don't know' responses.

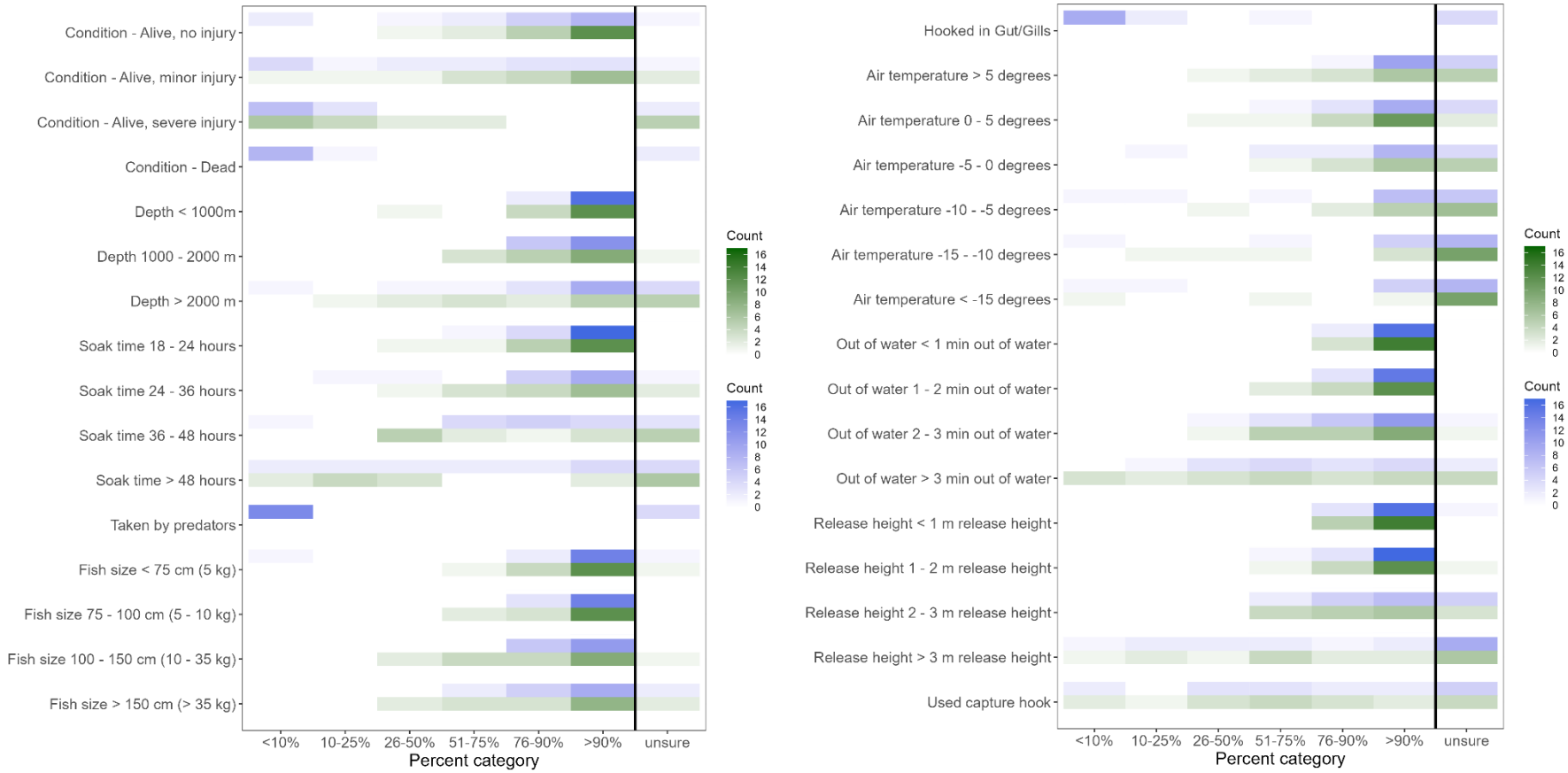


**Figure 4: Results from the expert elicitation questionnaire for Patagonian toothfish caught by bottom longline. Responses to each factor for both at-release and post-release survival questions are stacked. Blue: responses to questions on at-release survival. Green: responses to questions on post-release survival. Darker colours indicate a greater number of responses. Questions as in the questionnaire are in Appendix 2.**

## 3.3 Fishery survival probability estimates

For release condition, expected mean survival was derived from Agnew et al. (2006) (Appendix 4). Information on post-release survival, as used for the CCAMLR Patagonian stock assessments (e.g., CCAMLR Secretariat 2023b) or inferred from PSAT studies (Brown et al. 2013, Kim & Lam 2023), was used to generate expected mean survival for several of the more well-studied factors, such as fish length and condition (Appendix 4).

***At-release survival only***

Combining the survey responses with known mean survival estimates derived from the literature review, for at-release survival only, resulted in high perceived survival probability estimates for Patagonian toothfish for most factor category combinations except for those fish released with injuries or from great heights (Figure 5). But once factor category combinations were combined with information from the fishery profile (Appendix 5) and grouped at the factor level, the survival intervals for all were high (Figure 5).

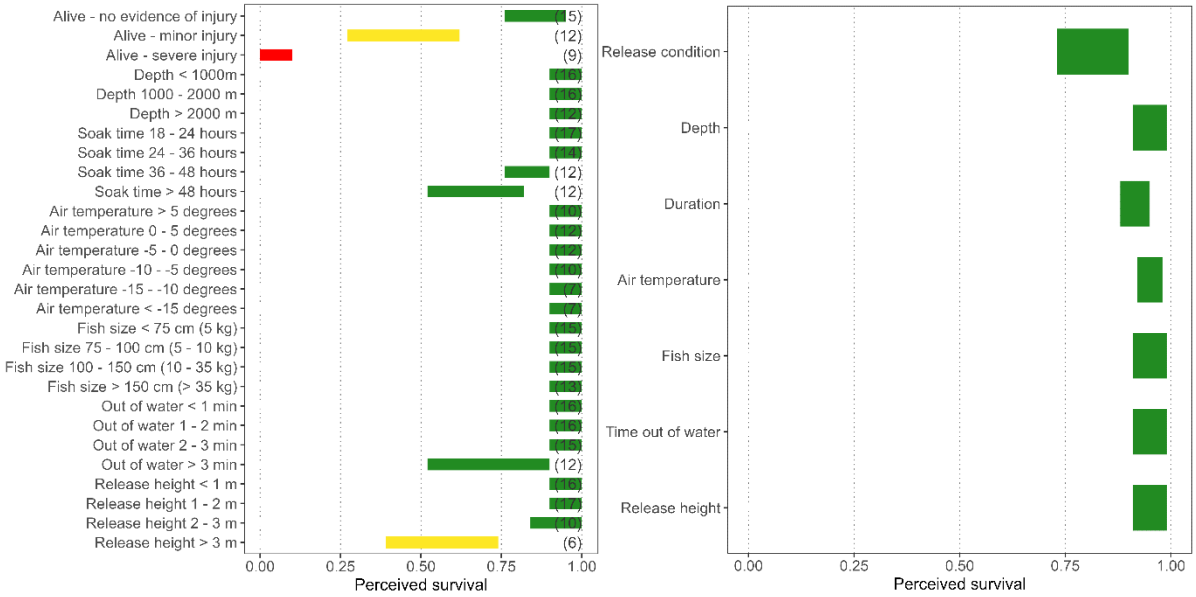


**Figure 5: 95% confidence intervals on perceived at-release mean survival estimates for Patagonian toothfish following release from bottom longline in New Zealand waters by (left) factor-category and (right) apportioned across recent commercial fishery ranges. Note that this plot assesses at-release survival only and no expected mean survival estimates were applied to these particular categories. The number in parentheses indicates the number of survey respondents.**

***Post-release survival only***

Combining the survey responses with known mean survival estimates derived from the literature review resulted in high perceived survival probability estimates for Patagonian toothfish for most factor category combinations except for those fish released with injuries or with longer soak times (Figure 6). When the expected mean survival was applied (Appendix 4), the perceived survival estimates of the two larger fish size categories became ‘medium’, the bootstrapped interval of the smallest size increased, and the bootstrapped intervals of the condition at time of release narrowed for the two best condition categories (Figure 6). The most injured condition category shifted from low to high perceived survival probability. This was because all released fish were assumed to have the same post-release survival probability in the stock assessments (e.g., CCAMLR Secretariat 2003b), which is likely to be an oversimplification. Once combined with information from the fishery profile (Appendix 5), the survival probabilities for all factors were initially high, including condition of fish (Figure 7). When the expected mean survival was applied, perceived survival probability for fish length changed from high to medium; this meant that the overall fishery survival expectation was classified ‘medium’ (Figure 7).

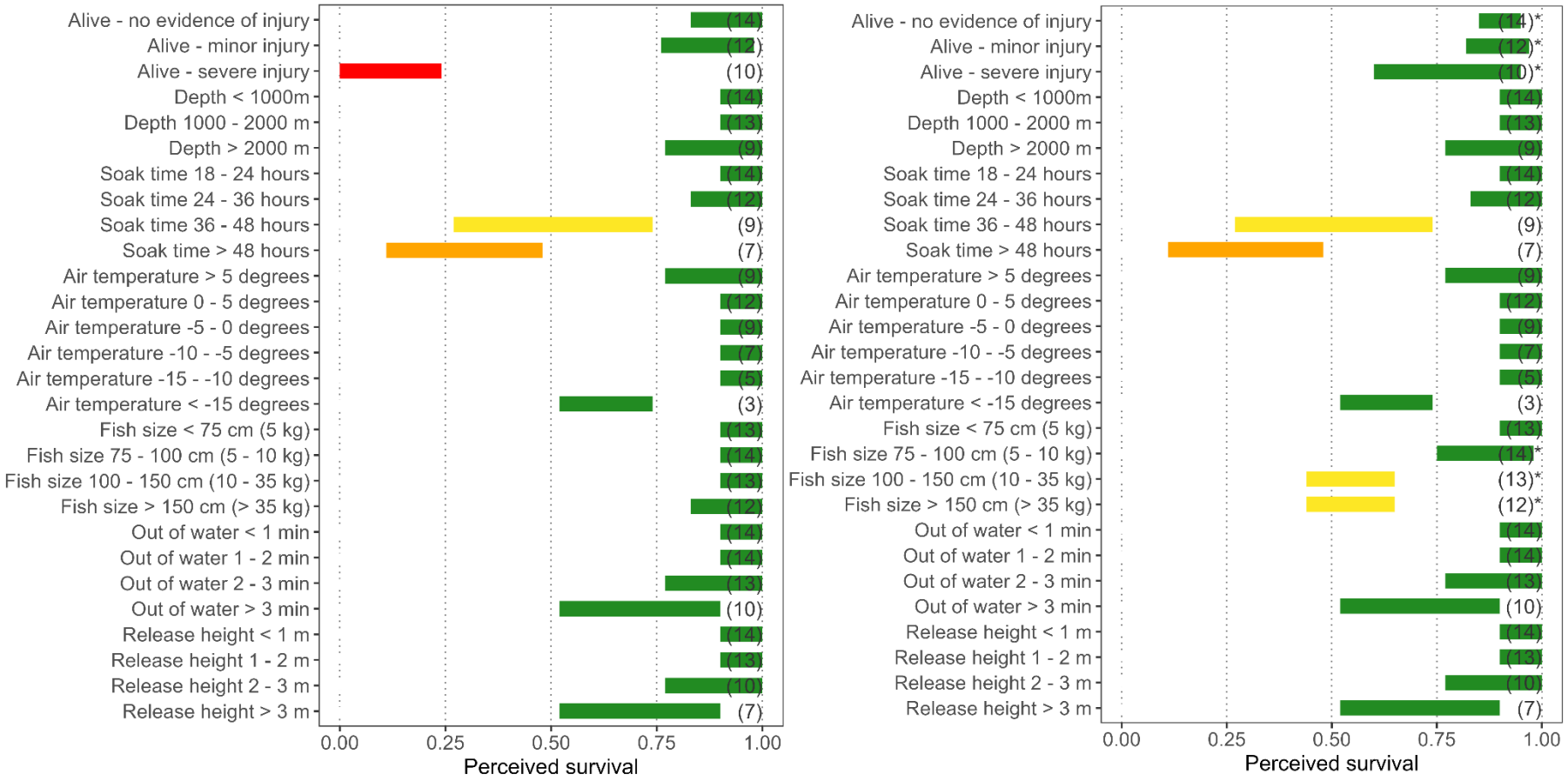


**Figure 6: 95% confidence intervals on perceived post-release mean survival estimates for Patagonian toothfish following release from bottom longline in New Zealand waters by factor category combinations. Note this plot assumes all individuals released are alive at the time of release and does not account for condition at release. Left: without expected mean survival applied; right: with expected mean survival applied. * denotes those factor categories informed by expected mean survival. The number in parentheses indicates the number of survey respondents.**

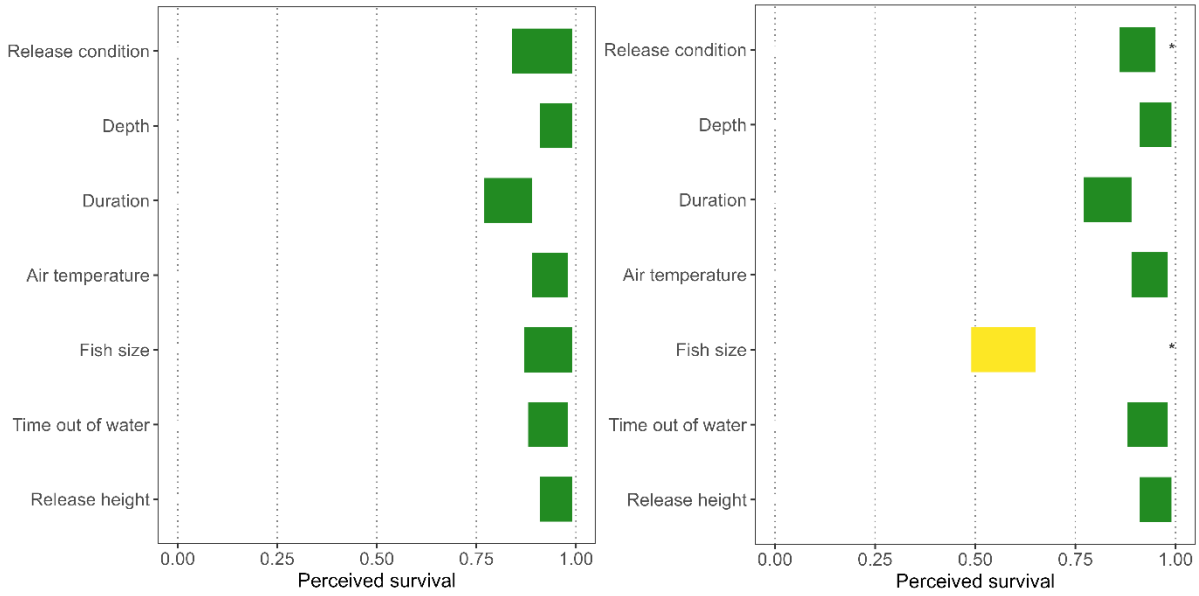


**Figure 7: 95% confidence intervals on perceived post-release mean survival estimates for Patagonian toothfish following release from bottom longline in New Zealand waters apportioned across recent commercial fishery ranges. Note this plot assumes that all individuals released are alive at the time of release and does not account for condition at release. Left: without expected mean survival applied; right: with expected mean survival applied. * denotes those factors informed by expected mean survival.**

### *At-release and post-release survival combined*

Perceived survival had larger bootstrapped intervals when survey responses for at-release survival and post-release survival were combined, indicating greater uncertainty, and the intervals had shifted slightly lower for most factor category combinations (Figure 8). One notable change was that the perceived survival of fish released with severe injury was greatly reduced and perceived survival of several factor category combinations declined from high to medium or low-medium (or from medium to low-medium) (Figure 6, Figure 8).

When the expected mean survival was applied (Appendix 4), the perceived survival estimates of the two larger fish size categories became ‘medium’, the bootstrapped interval of the smallest size increased, and the bootstrapped intervals of the condition at time of release narrowed for the best condition category (Figure 8). The second-best condition category shifted from low-medium to high perceived survival probability, while the category of ‘severe injury’ shifted to ‘medium-high’. This was again because all released fish were assumed to have the same post-release survival probability in the stock assessments, which is unlikely.

Combined with information from the fishery profile (Appendix 5), the perceived survival intervals for all factors were high, but all intervals increased and shifted slightly lower, reflecting greater uncertainty (Figure 9). When the expected mean survival was applied, perceived survival declined for fish length, while the interval for condition tightened. The overall fishery survival expectation was classified ‘medium’ (Figure 9).

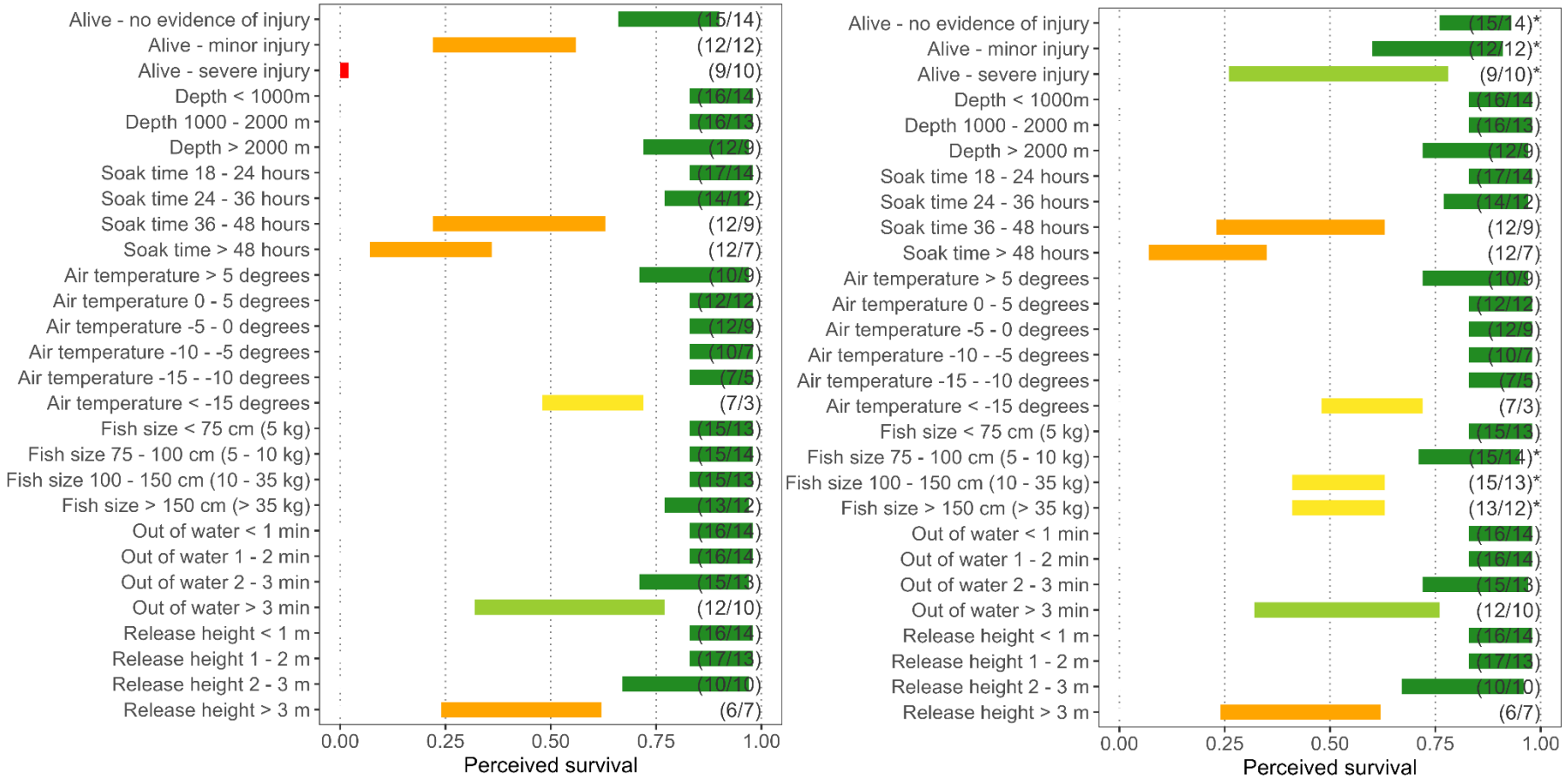


**Figure 8: 95% confidence intervals on perceived combined at-release and post-release mean survival estimates for Patagonian toothfish following release from bottom longline in New Zealand waters by factor category combinations. Note this plot assumes all individuals released are alive at the time of release and does not account for condition at release. Left: without expected mean survival applied; right: with expected mean survival applied. * denotes those factor categories informed by expected mean survival. The number in parentheses indicates the number of survey respondents (at-release / post-release).**

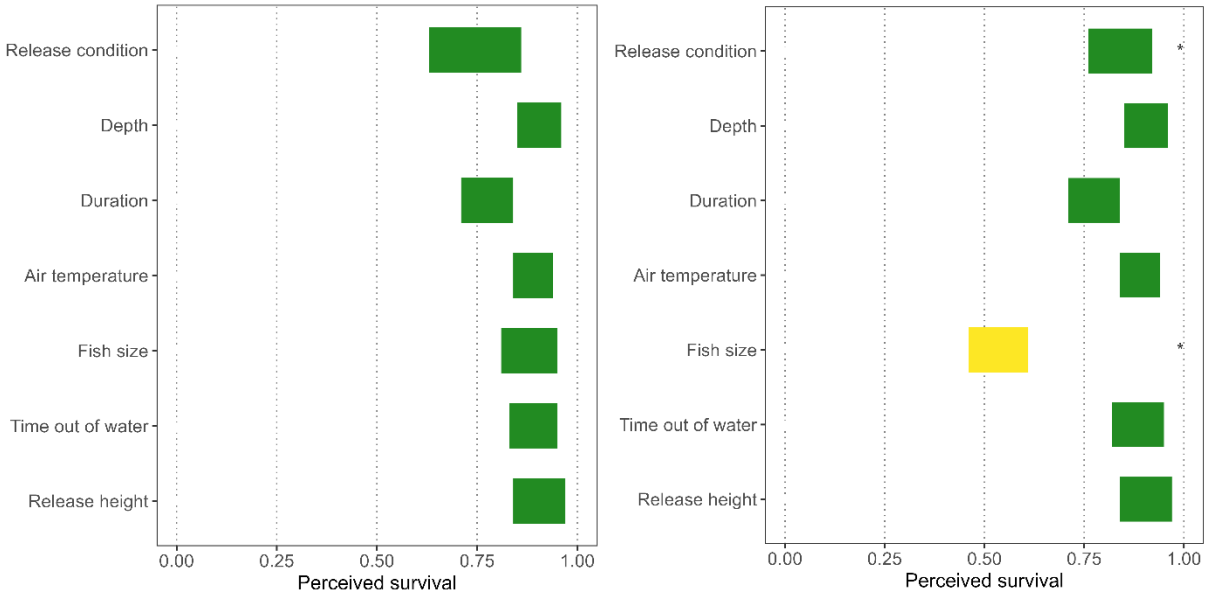


**Figure 9: 95% confidence intervals on perceived combined at-release and post-release mean survival estimates for Patagonian toothfish following release from bottom longline in New Zealand waters apportioned across recent commercial fishery ranges. Note this plot assumes all individuals released are alive at the time of release and does not account for condition at release. Left: without expected mean survival applied; right: with expected mean survival applied. * denotes those factors informed by expected mean survival.**

## 4. KEY ASSUMPTIONIONS AND UNCERTAINTIES

Key assumptions made in this study included:

1. The respondents had experience with Patagonian toothfish, which meant that they had taken part in the CCAMLR fisheries or scientific research conducted in the CCAMLR area, where tag and release of both Antarctic and Patagonian toothfish was a routine aspect of their work. To avoid potentially biasing responses with those that lacked experience with this species, individuals with only one year of experience were removed; this left respondents with between 3 to 15+ years of experience (average 7.5 years).
2. The effects of post-release mortality were immediate, i.e., occurred within 6 months of release. Toothfish are known to respond negatively to release from tagging studies within the CCAMLR area, such as by growth retardation ('tag shock') for up to the first year post-release (Collins et al. 2010), but whether fish suffer delayed mortality is not known. Studies using PSAT tags were used to infer that delayed mortality was not an issue, but only two studies on Patagonian toothfish have been published (Brown et al. 2013, Kim & Lam 2023). Several additional studies using PSAT tags on Antarctic toothfish, a species with similar life history characteristics, also indicated that delayed mortality may not be an issue (Parker et al. 2014, Delegation of the Republic of Korea 2016, Jones & Parker 2017).
3. The use of information from toothfish mark-recapture studies to infer survival rates was not thought to introduce a positive bias because the existence of recaptured fish e.g., in the CCAMLR tagging programme, indicated that overall survival could be considered high. This assumption could have created a slight positive bias when setting the expected mean survival for certain categories and such an effect was seen for fish released in poor condition. There is no additional information to inform the analysis except for reports of healing from severe trauma by Agnew et al. (2006) and anecdotal information.
4. Tagging studies tend to release fish in good condition or likely to survive (and for which a capture hook was not used). CCAMLR tagging protocols state to only tag fish in good condition and to avoid the use of a capture hook if releasing the fish, but whether these protocols are followed is difficult to monitor. Attempts have been made to identify vessels

with poor protocols (i.e., those vessels whose tags have not been recovered by other vessels and thus appear to have high post-release mortality rates; Mormede & Dunn (2013)), but that information could not be incorporated into this study. However, New Zealand vessels have been shown to have high post-release survival rates (Mormede & Dunn 2013).

5. Studies that were designed to determine movement and connectivity of Patagonian toothfish using PSAT tags were used to infer post-release survival estimates. Methodologies for movement and connectivity studies, including time of tag release and type of tag used, might influence results and bias the inferred post-release survival estimates (the direction of that bias is unknown).

Key uncertainties included:

1. The expected mean survival estimates were highly uncertain because only one study of at-vessel survival (Agnew et al. 2006) and no studies on post-release survival have been conducted for Patagonian toothfish or the closely related Antarctic toothfish. Including information from conventional mark-recapture or PSAT studies to infer an expected mean survival resulted in increasing the uncertainty around fish length and condition.
2. How long a toothfish had been hooked was unknown. Soak time, a proxy for this information, was used and may be an overestimate. Soak time is the amount of time a line has been in the water and is calculated as the difference between hauling and setting the line.
3. Predation was a large unknown for this species. When released in tagging programmes, training protocols state that fish must be observed during release and any predation recorded (e.g., attack by seabirds or marine mammals). But other predation may go unobserved, including predation by sharks, large whales, or scavenging amphipods at depth while the fish is on the hook, all of which stakeholders have reported as having occurred.
4. The effects of predation and soak time interact. Longer soak times mean that fish are available for possible predation for longer. Interactions could not be accounted for with the current methodology.
5. The post-release survival of re-released tagged fish (i.e., repeated recapture and release) is largely unknown. Some fish have been recaptured multiple times (Burch et al. 2019), in low numbers and with evidence of healed injuries, but these recaptured and healed fish have not been quantified.

## 5. DISCUSSION AND POTENTIAL RESEARCH

Survival probability determinations for Patagonian toothfish for at-release, post-release, and overall (i.e., combined) were generally high for individual factors. The overall application of the survival probabilities to the recent fishery profile ((proportional occurrence averaged over the most recent three fishing years; Appendix 5) indicated that the estimated at-release-only survival was high, while post-release-only and combined survival was medium.

Explicitly accounting for factor-category crossed effects was not possible with the approach used here. Survey respondents were therefore required to provide survival estimates for each factor category combination, assuming other factors were at their least likely to cause harm level. In reality, factors affecting at- or post-release survival are likely to interact with other factors, including biological, environmental, and fishery-related variables.

Where expected mean survival estimates were applied in the survival probability estimations, these typically increased the uncertainty and shifted the survival probability estimates towards lower values. This suggests that survey respondents provided a more optimistic view of survival compared to the data-informed estimates, which may be because Patagonian toothfish is monitored in the CCAMLR area using mark-recapture experiments (i.e., tagging) and is generally considered to have low tagging mortality (or high post-release survival).

A key limiting factor of this work is that there was only one study that provided information on condition at hauling and none on post-release survival. Expected mean survival estimates were instead inferred from conventional and PSAT tagging studies. At the post-workshop review with the ANTWG in November 2023, concern was raised that the expected mean survival information was too uncertain for most of the factor category combinations and instead, no information should have been used. As a result, expected mean survival was retained for only condition and fish length survival factor category combinations as these factors had been examined and found to significantly affect survival by Agnew et al. (2006).

Observers onboard commercial vessels are not currently required to document condition at-release for Patagonian toothfish. Instead, data from other areas, such as SPRFMO and CCAMLR were used to assess condition for fish that were released. Observer data requirements could be modified to collect this information, to better quantify the condition at-release survival of Patagonian toothfish caught in New Zealand's fisheries.

Workshop participants and questionnaire respondents highlighted that Patagonian toothfish are rarely released because of their high economic value. Questionnaire respondents also indicated a number of other factors that were important to consider when assessing at-release and post-release survival, including the presence and predation by birds, predatory amphipods (sea lice) and marine mammals (such as seals and sealions eating toothfish), sea state at time of hauling, the presence of sea ice, the experience of those working in the hauling room, and whether specialised equipment was used to bring the fish onboard, such as a cradle or net (Figure 10). Several of these factors have been compiled by the CCAMLR Secretariat for each vessel (CCAMLR Secretariat 2023a), with the intention that data will continue to be collected as part of the fishery notifications and that it will be made available for future studies on at- and post-release survival (WG-SAM-2023, paragraph 12.1(i)).

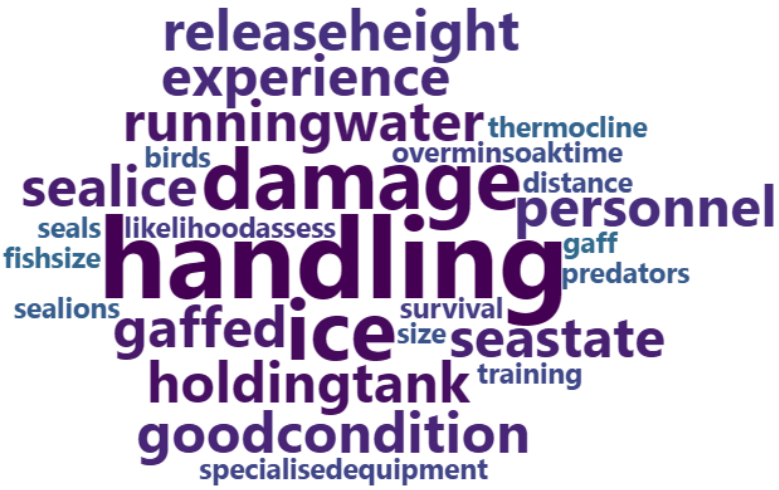


**Figure 10: Factors from comments in the questionnaire that participants thought played a role in at-release and post-release survival of Patagonian toothfish following release from bottom longline. The larger the size of the word indicates the greater number of times it appeared in the comment fields.**

## 5.1 Potential research / data needs

This research highlighted some key areas where data are lacking or further research is needed to quantify at- and post-release survival. This includes, but is not limited to:

1. Better quantification of the influence of soak time on at-vessel condition and post-release survival. Soak time for Patagonian toothfish is confounded with predation by large sharks, marine mammals, and scavenging amphipods, since longer soak times put a hooked animal at

increased risk of predation (and thus poorer condition). Soak time does not provide an accurate measure of how long an individual was caught on the line because it is simply the time between setting and hauling. Hook timers (Somerton et al. 1988) might be useful to define soak times, but can be triggered by fish striking and not taking the bait or if the longline drags along the bottom.

2. Data on the key parameters thought to influence at-release and post-release survival need to be collected before data are available for additional analyses. These factors should be identified (e.g., condition at release, including noting wounds that have healed) and observer data requirements updated to ensure that they are collected.
3. Encouragement of further research with PSATs to better quantify post-release survival. Currently, most tagging studies using PSATs are focused on movement and connectivity, and few have included quantification of post-release survival. Studies could be designed with this specific objective. While presenting this work to WG-FSA, several of those currently conducting tagging studies using PSAT tags on both Antarctic and Patagonian toothfish (and skate species) agreed that incorporating the post-release survival aspect should be part of their future research.
4. Continued improvement of handling and release practices, through the use of training materials (e.g., videos that the crew can watch while steaming to the fishing grounds) and best practice guidelines in pictorial format that can be hung in the hauling room.

## 6. BROADER OUTCOMES

The project involved developing collaborations and capability in the research sector, by fostering collaboration between NIWA, international researchers, fishing industry, fishery observers, and government. Fishing industry stakeholders were able to directly contribute to the research through the workshop and presentation to CCAMLR. The work further highlighted to regional management organisations, e.g., CCAMLR, and associated scientists the need to understand more fully release survival of a trophically important species in Antarctic and sub-Antarctic waters (Pinkerton & Bradford-Grieve 2014).

## 7. ACKNOWLEDGEMENTS

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## APPENDIX 1 DISPOSAL CODES IN THE LANDING DATA

**Appendix Table 1: Disposal codes in the landing data for Patagonian toothfish from within New Zealand's Economic Exclusion Zone. Data labelled 'Landed" and 'Discarded' detail how information was used in characterisation.**

| Disposal code | Description | Used in characterisation |
|---|---|---|
| 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. | Released |
| D | Fish or fish product of a stock not managed under the QMS that are returned to the sea, abandoned in the sea, or accidentally lost at sea | Released |
| E | Eaten | Landed |
| F | Section 111 Recreational Catch | Landed |
| L | Landed in NZ | Landed |
| S | Seized by Crown | Landed |

## APPENDIX 2 QUESTIONNAIRE QUESTIONS

**Question and type (see Section 2.3) for at-vessel and post-release capture events. Information in square brackets in the question column indicates the category within that factor.**

| Question | Capture/release event | Type of question |
|---|---|---|
| What best describes your job? | | |
| In your own words, please describe the reasons why Patagonian toothfish caught by bottom longline are released in New Zealand (if you are unsure then leave this blank). | At-vessel | Open-ended questions |
| What percentage are in the following condition at release? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [Alive - no evidence of injury] | At-vessel | Multi-level Likert categorical questions |
| What percentage are in the following condition at release? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [Alive - minor injury but not immediately life threatening] | At-vessel | Multi-level Likert categorical questions |
| What percentage are in the following condition at release? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [Alive - severe injury] | At-vessel | Multi-level Likert categorical questions |
| What percentage are in the following condition at release? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [Dead] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea after being caught from the following depths? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< 1000 m] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea after being caught from the following depths? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [1000–2000 m] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea after being caught from the following depths? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 2000 m ] | At-vessel | Multi-level Likert categorical questions |

| Question | Capture/release event | Type of question |
|---|---|---|
| From your personal experience, what percentage are alive when returned to the sea after being caught with the following soak times?<br>Please click multiple boxes to indicate a wider range (i.e., 50–100%)<br>[18–24 hours] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea after being caught with the following soak times?<br>Please click multiple boxes to indicate a wider range (i.e., 50–100%)<br>[24–36 hours] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea after being caught with the following soak times?<br>Please click multiple boxes to indicate a wider range (i.e., 50–100%)<br>[36–48 hours] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea after being caught with the following soak times?<br>Please click multiple boxes to indicate a wider range (i.e., 50–100%)<br>[> 48 hours] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are hooked in the gut/gills prior to being returned to the sea after being caught? | At-vessel | Likert categorical questions |
| From your personal experience, what percentage are observed taken by predators when returned to the sea? | At-vessel | Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea when air temperature is:<br>Please click multiple boxes to indicate a wider range (i.e., 50–100%)<br>[> 5 degrees] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea when air temperature is:<br>Please click multiple boxes to indicate a wider range (i.e., 50–100%)<br>[0–5 degrees] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea when air temperature is:<br>Please click multiple boxes to indicate a wider range (i.e., 50–100%)<br>[-5–0 degrees] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea when air temperature is:<br>Please click multiple boxes to indicate a wider range (i.e., 50–100%)<br>[-10– -5 degrees] | At-vessel | Multi-level Likert categorical questions |

| Question | Capture/release event | Type of question |
|---|---|---|
| From your personal experience, what percentage are alive when returned to the sea when air temperature is: Please click multiple boxes to indicate a wider range (i.e., 50–100%) [-15– -10 degrees] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea when air temperature is: Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< -15 degrees] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage in the following size classes are alive when returned to the sea? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< 75 cm (5 kg)] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage in the following size classes are alive when returned to the sea? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [75–100 cm (5–10 kg)] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage in the following size classes are alive when returned to the sea? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [100–150 cm (10–35 kg)] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage in the following size classes are alive when returned to the sea? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 150 cm (> 35 kg)] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea when time out of water is: Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< 1 min out of water] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea when time out of water is: Please click multiple boxes to indicate a wider range (i.e., 50–100%) [1–2 min out of water] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea when time out of water is: Please click multiple boxes to indicate a wider range (i.e., 50–100%) [2–3 min out of water] | At-vessel | Multi-level Likert categorical questions |

| Question | Capture/release event | Type of question |
|---|---|---|
| From your personal experience, what percentage are alive when returned to the sea when time out of water is: Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 3 min out of water] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea with the following release heights? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< 1 m release height] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea with the following release heights? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [1–2 m release height] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea with the following release heights? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [2–3 m release height] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea with the following release heights? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 3 m release height] | At-vessel | Multi-level Likert categorical questions |
| From your personal experience, what percentage are alive when returned to the sea when a capture hook (gaff hook) is used to lift the fish onboard? Please click multiple boxes to indicate a wider range (i.e., 50–100%) | At-vessel | Multi-level Likert categorical questions |
| How confident are you in your overall estimates for release condition? | At-vessel | |
| If there are additional factors you feel are important to the condition of Patagonian toothfish when returned to the sea after capture by bottom longlining, please comment below. | At-vessel | Open-ended questions |
| From your experience or knowledge, what percentage survive post-release when caught and are assessed in the following condition at release? Please click multiple boxes to indicate a wider range (i.e., 51–100%) [Alive–no evidence of injury] | Post-release | Multi-level Likert categorical questions |

| Question | Capture/release event | Type of question |
|---|---|---|
| From your experience or knowledge, what percentage survive post-release when caught and are assessed in the following condition at release? Please click multiple boxes to indicate a wider range (i.e., 51–100%) [Alive–minor injury but not immediately life threatening] | Post-release | Multi-level Likert categorical questions |
| From your experience or knowledge, what percentage survive post-release when caught and are assessed in the following condition at release? Please click multiple boxes to indicate a wider range (i.e., 51–100%) [Alive–severe injury] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught from the following depths if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< 1000 m] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught from the following depths if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [1000–2000 m] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught from the following depths if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 2000 m ] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught with the following soak times if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [18–24 hours] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught with the following soak times if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [24–36 hours] | Post-release | Multi-level Likert categorical questions |

| Question | Capture/release event | Type of question |
|---|---|---|
| From your personal experience or knowledge, what percentage survive post-release when caught with the following soak times if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [36–48 hours] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught with the following soak times if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 48 hours] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught with the following differences between air and sea temperature if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 5 degrees] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught with the following differences between air and sea temperature if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [0–5 degrees] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught with the following differences between air and sea temperature if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [-5–0 degrees] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught with the following differences between air and sea temperature if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [-10– -5 degrees] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when caught with the following differences between air and sea temperature if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [-15– -10 degrees] | Post-release | Multi-level Likert categorical questions |

| Question | Capture/release event | Type of question |
|---|---|---|
| From your personal experience or knowledge, what percentage survive post-release when caught with the following differences between air and sea temperature if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< -15 degrees] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage in the following size classes survive post-release, if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< 75 cm (5 kg)] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage in the following size classes survive post-release, if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [75–100 cm (5–10 kg)] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage in the following size classes survive post-release, if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [100–150 cm (10–35 kg)] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage in the following size classes survive post-release, if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 150 cm (> 35 kg)] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release with the following time out of water if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< 1 min out of water] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release with the following time out of water if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [1–2 min out of water] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release with the following time out of water if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [2–3 min out of water] | Post-release | Multi-level Likert categorical questions |

| Question | Capture/release event | Type of question |
|---|---|---|
| From your personal experience or knowledge, what percentage survive post-release with the following time out of water if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 3 min out of water] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release with the following release heights if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [< 1 m release height] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release with the following release heights if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [1–2 m release height] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release with the following release heights if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [2–3 m release height] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release with the following release heights if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) [> 3 m release height] | Post-release | Multi-level Likert categorical questions |
| From your personal experience or knowledge, what percentage survive post-release when a capture hook (gaff hook) is used to lift the fish onboard if all other factors were omitted? Please click multiple boxes to indicate a wider range (i.e., 50–100%) | Post-release | Multi-level Likert categorical questions |
| How confident are you in your overall estimates of post-release survival? | Post-release | |
| If there are additional factors you feel are important to the post-release survival of Patagonian toothfish when caught by bottom longline, please comment below. | Post-release | Open-ended questions |
| How many years of experience do you have with Patagonian toothfish? | Post-release | Open-ended questions |

## APPENDIX 3 THE BETA PARAMETRIC PROBABILITY DENSITY FUNCTION

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

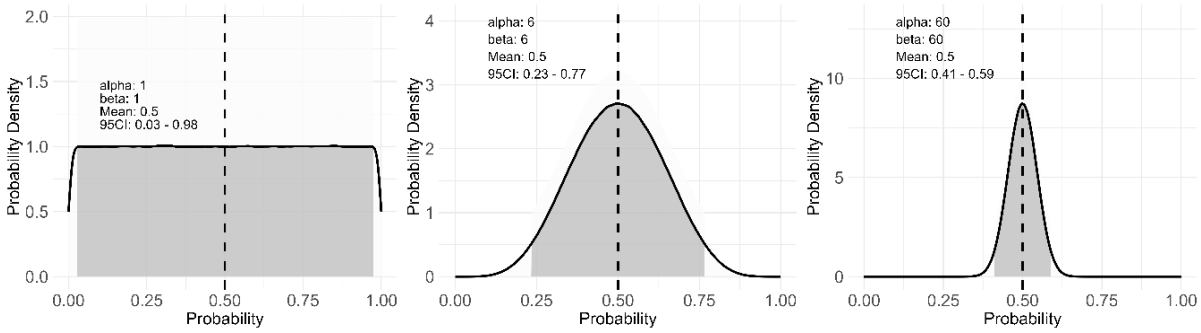
$$f(x;\alpha,\beta) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} x^{\alpha-1}(1-x)^{\beta-1}$$

where Γ is the 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 $\alpha$ and $\beta$ 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 95% percentile range.**

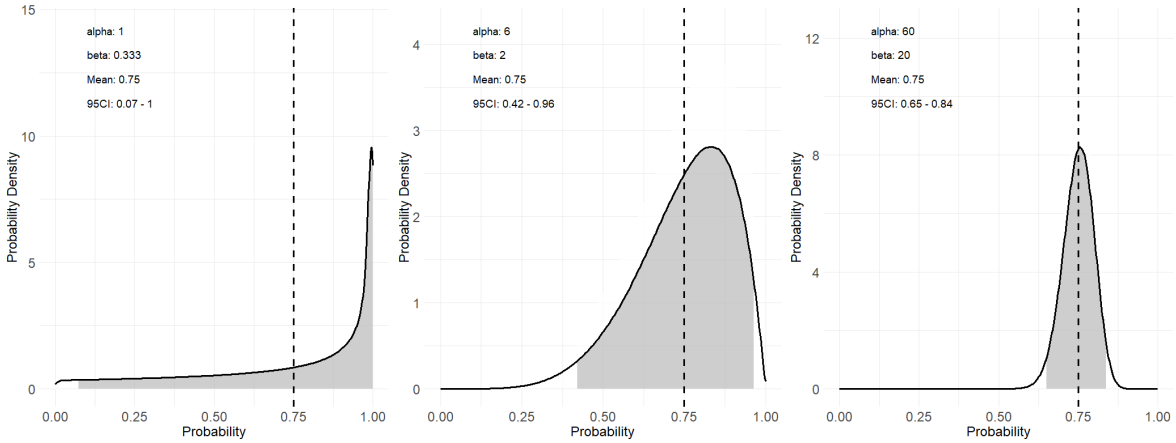
If $\alpha \neq \beta$ the mean $\mu$ of the Beta distributional range will shift above or below the mid-point depending on the ratio of the two parameters:

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

It is possible to approximate the probability density for any random variate *x* with mean $\mu$ using a Beta parametric distribution by specifying an appropriate $\alpha$ shape parameter. Note: given $\mu$ and $\alpha$:

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

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




**Appendix Figure 2:** **Beta probability distributions for μ = 0.75 and α = {1,6,60}. Shaded areas show the 95% percentile range.**

## APPENDIX 4 LITERATURE-BASED VALUES USED FOR PRIORS FOR PATAGONIAN TOOTHFISH

| Method | Mortality component | Factor-category | Expected mean survival | Source |
|---|---|---|---|---|
| BLL | RELEASE | Alive–no evidence of injury | 0.95 | Agnew et al. 2006 |
| BLL | RELEASE | Alive–minor injury | 0.90 | Agnew et al. 2006 |
| BLL | RELEASE | Alive–severe injury | 0.66 | Agnew et al. 2006 |
| BLL | RELEASE | Dead | 0 | |
| BLL | RELEASE | Depth < 1000m | | |
| BLL | RELEASE | Depth 1000 – 2000 m | | |
| BLL | RELEASE | Depth > 2000 m | | |
| BLL | RELEASE | Soak time 18 – 24 hours | | |
| BLL | RELEASE | Soak time 24 – 36 hours | | |
| BLL | RELEASE | Soak time 36 – 48 hours | | |
| BLL | RELEASE | Soak time > 48 hours | | |
| BLL | RELEASE | Hooked in Gut/Gills | | |
| BLL | RELEASE | Release height < 1 m | | |
| BLL | RELEASE | Release height 1 – 2 m | | |
| BLL | RELEASE | Release height 2 – 3 m | | |
| BLL | RELEASE | Release height > 3 m | | |
| BLL | RELEASE | Used capture hook | | |
| BLL | RELEASE | Out of water < 1 min | | |
| BLL | RELEASE | Out of water 1 – 2 min | | |
| BLL | RELEASE | Out of water 2 – 3 min | | |
| BLL | RELEASE | Out of water > 3 min | | |
| BLL | RELEASE | Taken by predators | 0 | |
| BLL | RELEASE | Fish size < 75 cm (5 kg) | | |
| BLL | RELEASE | Fish size 75 – 100 cm (5 – 10 kg) | | |
| BLL | RELEASE | Fish size 100 – 150 cm (10 – 35 kg) | | |
| BLL | RELEASE | Fish size > 150 cm (> 35 kg) | | |
| BLL | RELEASE | Air temperature > 5 degrees | | |
| BLL | RELEASE | Air temperature 0 – 5 degrees | | |
| BLL | RELEASE | Air temperature -5 – 0 degrees | | |
| BLL | RELEASE | Air temperature -10 – -5 degrees | | |
| BLL | RELEASE | Air temperature -15 – -10 degrees | | |
| BLL | RELEASE | Air temperature < -15 degrees | | |
| BLL | POST | Alive–no evidence of injury | 0.90 | CCAMLR Secretariat 2023a |
| BLL | POST | Alive–minor injury | 0.90 | CCAMLR Secretariat 2023a |
| BLL | POST | Alive–severe injury | 0.90 | CCAMLR Secretariat 2023a |
| BLL | POST | Depth < 1000m | | |
| BLL | POST | Depth 1000 – 2000 m | | |
| BLL | POST | Depth > 2000 m | | |
| BLL | POST | Soak time 18 – 24 hours | | |
| BLL | POST | Soak time 24 – 36 hours | | |

| Method | Mortality component | Factor-category | Expected mean survival | Source |
|---|---|---|---|---|
| BLL | POST | Soak time 36 – 48 hours | | |
| BLL | POST | Soak time > 48 hours | | |
| BLL | POST | Release height < 1 m | | |
| BLL | POST | Release height 1 – 2 m | | |
| BLL | POST | Release height 2 – 3 m | | |
| BLL | POST | Release height > 3 m | | |
| BLL | POST | Used capture hook | | |
| BLL | POST | Out of water < 1 min | | |
| BLL | POST | Out of water 1 – 2 min | | |
| BLL | POST | Out of water 2 – 3 min | | |
| BLL | POST | Out of water > 3 min | | |
| BLL | POST | Fish size < 75 cm (5 kg) | | |
| BLL | POST | Fish size 75 – 100 cm (5 – 10 kg) | 0.88 | Brown et al. 2031 |
| BLL | POST | Fish size 100 – 150 cm (10 – 35 kg) | 0.53 | Kim & Lam 2023 |
| BLL | POST | Fish size > 150 cm (> 35 kg) | 0.53 | Kim & Lam 2023 |
| BLL | POST | Air temperature > 5 degrees | | |
| BLL | POST | Air temperature 0 – 5 degrees | | |
| BLL | POST | Air temperature -5 – 0 degrees | | |
| BLL | POST | Air temperature -10 – -5 degrees | | |
| BLL | POST | Air temperature -15 – -10 degrees | | |
| BLL | POST | Air temperature < -15 degrees | | |

## APPENDIX 5 Summary of breakdown of the fishery "profiles" used to apportion perceived survival estimates for Patagonian toothfish

| Method | Factor-category | Proportional weighting | Data source |
|---|---|---|---|
| BLL | Alive–no evidence of injury | 0.913 | NZ observer data |
| BLL | Alive–minor injury | 0.087 | NZ observer data |
| BLL | Alive–severe injury | 0.000 | NZ observer data |
| BLL | Depth < 1000m | 0.702 | Catch and effort[1] |
| BLL | Depth 1000 – 2000 m | 0.297 | Catch and effort[1] |
| BLL | Depth > 2000 m | 0.001 | Catch and effort[1] |
| BLL | Soak time 18 – 24 hours | 0.430 | Catch and effort[1] |
| BLL | Soak time 24 – 36 hours | 0.355 | Catch and effort[1] |
| BLL | Soak time 36 – 48 hours | 0.158 | Catch and effort[1] |
| BLL | Soak time > 48 hours | 0.057 | Catch and effort[1] |
| BLL | Release height < 1 m | 0.90 | CCAMLR Secretariat 2023a |
| BLL | Release height 1 – 2 m | 0.08 | CCAMLR Secretariat 2023a |
| BLL | Release height 2 – 3 m | 0.02 | CCAMLR Secretariat 2023a |
| BLL | Release height > 3 m | 0 | CCAMLR Secretariat 2023a |
| BLL | Used capture hook | 0.142 | CCAMLR Secretariat 2023a |
| BLL | Out of water < 1 min | 0.061 | Expert group |
| BLL | Out of water 1 – 2 min | 0.682 | Expert group |
| BLL | Out of water 2 – 3 min | 0.257 | Expert group |
| BLL | Out of water > 3 min | 0 | Expert group |
| BLL | Fish size < 75 cm (5 kg) | 0.037 | NZ observer data |
| BLL | Fish size 75 – 100 cm (5–10 kg) | 0.029 | NZ observer data |
| BLL | Fish size 100–150 cm (10–35 kg) | 0.255 | NZ observer data |
| BLL | Fish size > 150 cm (> 35 kg) | 0.679 | NZ observer data |
| BLL | Air temperature > 5 degrees | 0.573 | Inferred–months of fishery, location |
| BLL | Air temperature 0 – 5 degrees | 0 | Inferred–months of fishery, location |
| BLL | Air temperature -5 – 0 degrees | 0.001 | Inferred–months of fishery, location |
| BLL | Air temperature -10 – -5 degrees | 0 | Inferred–months of fishery, location |
| BLL | Air temperature -15 – -10 degrees | 0.204 | Inferred–months of fishery, location |
| BLL | Air temperature < -15 degrees | 0.222 | Inferred–months of fishery, location |

[1] Catch and effort data were from all data sources, as outlined in Sections 2.1.1 and 2.1.2.