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Effects of hook and bait type on commercial longline fisheries bycatch (MIT2023-01)

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Contents

Executive Summary

Hook size and bait type affect seabird and sea turtle bycatch risk in surface longline (SLL) fisheries. This report reviews published and grey literature that presented comparisons of bycatch rates for different hook and bait types to assess the effectiveness of certain hooks (e.g., circle hooks) and baits (e.g., fish) at reducing bycatch of seabird and sea turtle species. Literature on international best practices for hook and bait type was also reviewed. Additionally, this report summarises data collected through the Conservation Services Programme (CSP) seabird necropsy project as well other data sources, such as the Centralised Observer Database. These datasets were assessed for their suitability to obtain complete and representative information about sea turtle and seabird bycatch in relation to hook size and bait type. Lastly, results from a questionnaire, administered to SLL fishers via the Department of Conservation, are summarised to understand current gear configurations being using the New Zealand SLL fleet and the first-hand experience of fishers using different gear in response to seabird and sea turtle bycatch.

Internationally, both squid and fish are primarily used as SLL bait, with some fisheries employing a combination of both. Fish bait, particularly mackerel, reduced sea turtle interactions in eight studies compared to squid, although the effectiveness varies. Conversely, mackerel increased the number of shearwater, gannet, and gull captures in one study and was inconclusive in another. The impact of bait type on target species catch rates was less clear, with similarly conflicting findings reported. The effectiveness of dyed bait remained mixed across studies, with some reporting lower seabird bycatch rates.

Studies consistently showed that larger circle hooks, such as 18/0, significantly decreased the capture rates of sea turtles and seabirds compared to traditional J hooks and improved post-release survival of captured turtles. However, the effectiveness of hook type and size varied depending on factors such as fishing effort, bait type, and regional differences in fishing practices. Mitigation measures such as Hookpods, which

shield the hook during setting, have shown promising results in reducing seabird and sea turtle captures, and are now required for the New Zealand SLL fleet.

International guidelines typically recommend the use of large circle hooks (16/0 or larger) with offsets less than 10° and/or the use of fish bait, alongside other methods to reduce bycatch such as single hooking fish bait, reduced gear soak time, night setting, mitigation devices (e.g., tori lines, Hookpods), line weighting, and seabird/sea turtle hotspot avoidance.

A review of bycatch data obtained from several sources revealed that data is insufficient to conduct any robust statistical analyses on the effects of bait or hook type on protected species captures. Bait type and hook type were rarely reported, and the consistency in hook type (mostly 16/0) and bait (squid) used across the fleet in recent years prevented a comparison of bycatch rates across different baits and hooks.

Based on the questionnaire responses, 17 operators in the New Zealand SLL fleet universally used circle hooks (14/0-17/0) baited with squid bait when targeting tuna and swordfish. Along with Hookpods, fishers employed various hook and line weighting and bait dying, especially during full moon phases, to mitigate seabird interaction risk. Little mitigation is focused on sea turtles at present.

1. Introduction

In commercial longline fisheries, incidental mortality of non-target species, including seabirds and sea turtles, can occur when an animal gets entangled in the line, when a baited hook is swallowed, or when another part of the body is hooked (Lydon & Starr, 2004). Bycatch of non-target species can vary with (a) fishing practice, including setting method, fish processing, offal disposal, mitigation measure, and temporal and spatial distribution of fishing (e.g., season, light level, moon phase, and weather conditions) (Lydon & Starr, 2004) and (b) species-specific traits, such as temporal and spatial species distribution, foraging behaviour, and diet preference (Cocking et al., 2008; Piovano et al., 2012; Swimmer et al., 2005).

Leatherback turtles (*Dermochelys coriacea*) are more often hooked by the flippers or become entangled in the fishing or weight line (Swimmer et al., 2005). Little is known about the captures of green turtles (*Chelonia mydas*), also commonly caught in the New Zealand SLL fisheries along with leatherbacks. In other international fisheries, loggerhead turtles (*Caretta caretta*) often get hooked in the mouth or other body parts as a result of ingesting or biting a baited hook. Seabirds often drown after becoming hooked or entangled during hauling/setting of fishing lines (Cocking et al., 2008). Bycatch mitigation measures can reduce incidental mortality of non-target species. Various bycatch mitigation strategies including line weighting, night setting, and bird scaring lines/tori lines have been developed and implemented over the past few decades (Sullivan et al., 2018). Bycatch mitigation (or the reduction in bycatch) has economic benefits as well; for instance, hook loss due to non-target species can incur extra costs (e.g., bait loss Meyer & Hickcox, 2023) and decrease target species catch rates (Bull, 2007).

There exists evidence that bait and hook type can profoundly reduce bycatch in longline fisheries. For example, for some species of turtle, fewer captures can occur when switching bait from squid to mackerel, and the strength of this effect can be influenced by hook type, usually correlated with larger hooks (e.g., Gilman et al., 2010;

Santos et al., 2013). However, this effect might depend on factors, such as the life history stage of the affected species, setting depth, etc. Further, each strategy can have different effects on different species (e.g., bait type affecting leatherback turtle bycatch versus hook size influencing loggerhead turtle bycatch)(Clarke et al., 2014).

This technical report (MIT2023-01) investigated current literature and data sources on the effect of hook size and bait type on seabird and turtle bycatch rates across surface longline (SLL) fisheries. International best practices are presented as a foundation for improved messaging on recommendations for mitigation use for reducing bycatch and to inform any future review of fisheries regulations/circulars in New Zealand fisheries.

Based on this review, a questionnaire was developed for SLL operators to identify current hook type/size and bait type being used in the New Zealand fleet. The questionnaire was administered by John Cleal, Department of Conservation Liaison Officer, in support of CSP project MIT2023-05.

Objectives:

1. Literature review of available data on hook size and bait type for seabird and turtle bycatch rates across different target longline fisheries using existing information sources to provide recommendations for improved data collection.

2. Literature review of international literature on current fisheries best practice to reduce the impact of hook size on bycatch.

3. Review of current data sources in New Zealand that report seabird and turtle bycatch and/or hook and bait type.

4. Create a questionnaire and summarise responses from interviews with SLL operators to identify preferred hook size and bait type as turtle/seabird deterrents to better inform protected species risk management plans (PSRMPs) and to help characterise current gear set-ups in SLL fisheries.

2. Methods

2.1 Literature review on hook/bait type and best practices

A systematic literature review was conducted on the effects of different hook sizes and bait types on seabird and turtle bycatch rates across different target fisheries. First, relevant sources were identified using Google Scholar and the following search terms:

("hook size" OR "bait type") AND ("bycatch rate") AND ("seabird" OR "turtle") AND ("longline" OR "longline fishery") AND ("mitigate" OR "mitigation")

Additionally, the Consortium for Wildlife Bycatch Reduction, an international consortium supporting collaborative scientific research and industrial fishing aimed at reducing bycatch of endangered species, maintains a database on Bycatch.org (https://www.bycatch.org/). The following search terms were used to identify open-access and related articles that supplemented the Google Scholar citations:

"Hooks-and-Lines" AND "Seabirds" OR "Sea Turtles"

A screening process was conducted to identify full-text and publicly available published journal articles or reports. Titles and abstracts were first assessed for relevancy, and typically contained keywords including bait, hook, bycatch, longline, seabird, or turtle. Full-texts of these sources were obtained and an additional eligibility check was conducted. Retained sources included numbers or bycatch rates of seabirds and/or sea turtles and performed some type of field experiment to compare different hook types and/or different bait types. Only sources related to longline fisheries were accepted, with particular focus on SLL fisheries.

Pertinent information such as the fishery, type of bait (e.g., mackerel, squid), the type and size of hooks (e.g., J hook 9/0, circle hook 18/0), and capture rates (i.e., the number or rates of sea turtles and/or seabirds per bait/hook combination) were summarised for each source. Sources were distinguished as those that investigated bait type, hook type, or both. To the best of our knowledge, the bait and hook types used in these studies are comprehensive and represents the breadth employed in commercial longline fisheries internationally. See Appendix Table A.1 for common and scientific names for bycatch, bait, and target species in reviewed sources.

Current international best practice for bait and hook choice to reduce bycatch was also reviewed. The reviewed papers typically provided information as to the existing best practice at the time of the study. Several additional sources informing best practice were also included, identified or cited by the reviewed sources.

2.2 Reported bycatch in New Zealand

Data on seabird bycatch in New Zealand SLL fisheries have been collected over the years primarily by government and industry; for instance, the Department of Conservation (DOC) conduct an ongoing seabird necropsy project as part of the Conservation Services Programme (CSP), and the Ministry for Primary Industries (MPI)/Fisheries New Zealand collect information from on-board observers and fishers. There are several datasets that are a compilation of these efforts, all of which are described below. These datasets were assessed for their suitability to obtain information about marine turtle and seabird bycatch in relation to hook size and bait type and their completeness, representativeness of recent SLL fisheries catch and effort information, sample size, data limitations, confounding factors, and available level of detail.

2.2.1 Protected species captures and observer data

Two databases held by MPI were considered:

- Centralised Observer Database (COD)
- Protected Species Captures Database (PSCDB)

Database extracts for 2010-2021 were provided by MPI on 6 March 2024. The COD contains data from the Observer Services Programme, with information collected by MPI observers. The relevant COD data for this project were catch and effort information for observed commercial fishing vessels, as well as data on protected species bycatch. The PSCDB contains groomed data from the COD, protected species captures that were verified via necropsies, and commercial catch effort data for all fishing effort (i.e., observed and unobserved) from the Enterprise Data Warehouse (EDW). It provides data that are relevant for the estimation of protected species captures within New Zealand's EEZ (e.g., Abraham et al., 2017). Turtle and seabird captures data from the PSCDB were extracted, and the COD was used to expand the PSCDB with information on hook size and bait type, which are attributes that are not originally contained within the PSCDB.

No additional data cleaning was completed with COD and PSCDB data. The required tables from COD were:

- *x_sll_baskets:* Table containing information on SLL gear, with detail on baskets deployed for fishing events, from SLL gear form Version 3, August 2018. This table contains hook type per fishing trip (i.e., column *trip number* in *x_sll_baskets*).
- *x_surface_lining_bait:* Table with bait species/composition (i.e., up three bait types and their percentage) used on observed sets per fishing event (column *fishing_event_key* in COD) on tuna longline vessels. To link data from this table to the PSCDB on a fishing event level, the additional columns *trip number* and *station number* (a sequential identifier of each tow or set of a trip) are required (extracted from COD table *x_fishing_event*).
- *x_fishing_event:* Table with generic information associated with a set of fishing effort, containing the columns *fishing_event_key, trip number* and *station number.*

The required PSCDB tables were:

- *observer_effort_t*: Table containing information on observed fishing effort, such as fishing method, fishing effort, trip number, and station number, etc.
- *all_captures_t*: Table containing information on individually observed protected species captures associated with each trip and station number (i.e., fishing event).

For simplicity, turtle and seabird captures were grouped similarly to other species captures projects (e.g., Richard et al., 2020). See Appendix Table A.2 for each species in the following groups:

- Turtles
- Buller's albatross
- Salvin's albatross
- White-capped albatross
- Other albatrosses
- Black petrel
- Flesh-footed shearwater
- Grey petrel
- Sooty shearwater
- White-chinned petrel
- Other birds

To summarise turtle and seabirds captures per bait type, bait composition data from the COD (i.e., *x_surface_lining_bait*) was linked to the *observed_effort_t* table in the PSCDB. This was done by first joining *x_surface_lining_bait* with *x_fishing_event*, to add the columns *trip number* and *station number*. *Trip number* and *station number* were then used to join *observed_effort_t* with data from *x_surface_lining_bait*. Next, species group-specific captures from *all_captures_t* were summed by *trip number* and *station number*, and then added to *observed_effort_t*. The expanded *observed_effort_t* table (i.e., with captures and bait composition) was used to create summaries of observed captures per fishing year and bait composition.

For hook type contained in table *x_sll_baskets*, *station number* was not recorded or could not be joined via other tables contained in COD. Hence, data from *x_sll_baskets* could not be directly linked to the PSCDB to then create hook type-specific summaries of turtle and seabird captures. Instead, species group-specific captures in the PSCDB were summed by fishing year and fishing trip (i.e., *trip number*). Similarly, the hook type and the bait type per fishing trip was extracted (this also included fishing trips that had no hook type and bait type recorded) and added to the total trip-based captures for comparison.

All table manipulation was done in R (v. 4.3.2)(R Core Team, 2023) using packages in the *tidyverse* (Wickham et al., 2019). Plots were made using *ggplot2* (v3.5.0)(Wickham, 2016).

2.2.2 CSP necropsies

A database of seabird bycatch necropsies has been maintained by Wild Press (1998-2005), National Institute of Water and Atmospheric Research (NIWA; 2005-2010), and Wildlife Management International (WMIL; 2010-2023). A data extract from January 2020 to March 2024 was received from DOC/Wildlife Management International on 14 April 2024. Data included capture date, species, observer hook position, necropsy hook position, and other relevant information and was summarised by seabird species and hook position on the body (if known). Hook size was not reported for these captures, and no trip number or fishing event information was provided, so linking to observer or fishing effort was not possible.

Additionally, the hooks that were collected with the associated deceased seabird (for necropsy) by fisheries observers from 1998-2005 and 2010-2024 were cataloged by DOC by size and type. Photographs of each type were provided.

2.3 Hook/bait type fisher questionnaire

Based on the findings of these sources, a survey was created for longline operators to determine current gear use and their observations and feelings towards different bait and hook types. The questionnaire was made using Microsoft Forms and can be found here: Preferred hook/bait in surface longline fisheries Questionnaire (see also Appendix B). All questions were single/multiple choice and free text for ease of use. MS Forms was chosen for multiple reasons. All responses can be downloaded as an Excel spreadsheet, and there is a convenient dashboard that summarises responses in real-time. The survey can be transferred to different administrators, it has a variety of question options, and it comes part of the MS software suite.

The questionnaire went through several iterations, in consultation with the Department of Conservation to ensure wording, question types, and question topics were correct and sufficient to obtain the desired information. John Cleal, Department of Conservation Liaison Officer, administered the questionnaire to a single fisher as a trial to obtain feedback on the practicality of the questions and format.

The 2024 SLL fleet consisted of 18 active vessel operators (an additional 4 chose not to fish this season). Thee questionnaire was completed by 17 of those 18 operators. When the questionnaire was administered, answers were logged on paper copies of the form and then transcribed into the MS Forms version. Then, survey data were summarised in R. A final spreadsheet of responses can be found in the separate Excel spreadsheet that accompanies this report.

3. Results

3.1 Literature review on hook/bait type

After the screening process (Figure 3.1), 25 published articles or reports were reviewed (Table 3.1). Of these, five examined the effects of dyed bait on sea turtle and seabird bycatch rates (Cocking et al., 2008; Lydon & Starr, 2004; Ochi et al., 2011; Swimmer et al., 2005; Yokota et al., 2009), and two sources compared different bait types only (Báez et al., 2010; Echwikhi et al., 2010). Hook type effects on bycatch rates were presented in one study for seabirds (Li et al., 2012), six studies for turtles (Bolten & Bjorndal, 2005; Cambiè et al., 2012; Lima et al., 2023; Pacheco et al., 2011; Piovano et al., 2012; Read, 2007), and one for both seabirds and turtles (Domingo et al., 2012). Bait type and hook type were simultaneously compared in eight studies for sea turtles (Brazner & McMillan, 2008; Coelho et al., 2015; Gilman et al., 2007; Mejuto et al., 2008; Santos et al., 2012; Santos et al., 2013; Swimmer et al., 2017; Watson et al., 2005). One study compared bait and hook type for both seabirds and sea turtles (Richards et al., 2012), and one study presented findings on the effects of Hookpods as a bycatch mitigation measure (Sullivan et al., 2018).

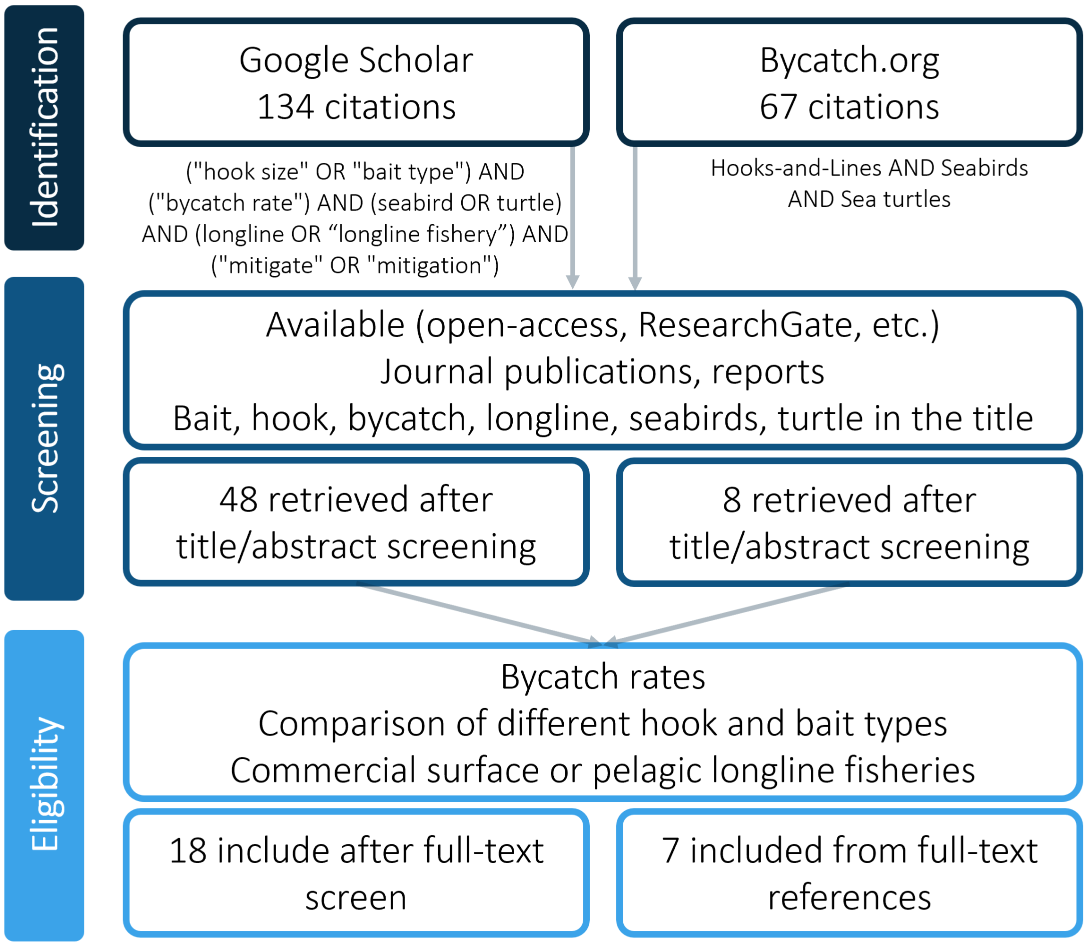

Figure 3.1: Diagram of the systematic review screening process.

Table 3.1: Reviewed sources and relevant summary information, grouped according to whether bait type, hook type, or dyed bait was assessed. The year the study took place and the number of vessels (Not reported NR) are provided. Possible target species/fishery include: tuna spp. (T), swordfish spp. (S), mahi mahi (M), shark spp. (SH). Bycatch species include: loggerhead (LH), leatherback (LB), olive ridley (OR), Kemp's ridley (KR), green (GR), seabird (SB).

Citation	Region	Fishery	Year	N	Bycatch
Dyed bait					
Ochi et al. (2011)	South Africa	T	2001-2002	3	SB
Swimmer et al. (2005)	Costa Rica	T; M	2002-2003	2	LH; KR
Yokota et al. (2009)	North Pacific	S; SH	2002-2003	1	LH; SB
Lydon and Starr (2004)	New Zealand	T	2004	1	SB
Cocking et al. (2008)	Australia	NR	2005-2006	1	SB
Bait type					
Baez et al. (2010)	Mediterranean Sea	S	NR	45	LH
Echwikhi et al. (2010)	Tunisia	S; SH	2007-2008	NR	LH

Table 3.1: Reviewed sources and relevant summary information, grouped according to whether bait type, hook type, or dyed bait was assessed. The year the study took place and the number of vessels (Not reported NR) are provided. Possible target species/fishery include: tuna spp. (T), swordfish spp. (S), mahi mahi (M), shark spp. (SH). Bycatch species include: loggerhead (LH), leatherback (LB), olive ridley (OR), Kemp's ridley (KR), green (GR), seabird (SB). *(continued)*

Citation	Region	Fishery	Year	N	Bycatch
Hook type					
Bolten and Bjorndal (2005)	Azores	S	2000-2003	1	LH; LB; GR
Lima et al. (2023)	Azores	S; SH	2000-2004	2	LH
Read (2007)	Ecuador	T; M	2004	115	LH; LB
Piovano et al. (2012)	Mediterranean Sea	S	2006-2008	5	LH
Pacheco et al. (2011)	South Atlantic	T	2006-2007	3	LH; OR; GR
Domingo et al. (2012)	Uruguay	S; T; SH	2008-2010	3	LH; LB; SB
Cambie et al. (2012)	Italy	T	2010	1	LH
Bait + hook type					
Sullivan et al. (2018)	South Africa; Brazil; Australia	S; T	2011-2015	7	LH; LB; SB
Li et al. (2012)	U.S. Atlantic	S; T	1992-2009	NR	SB
Swimmer et al. (2017)	U.S. Pacific, Atlantic	S	1992-2001; 2004-2014	NR	LH; LB
Gilman et al. (2007)	U.S. Pacific	S	1994-2002; 2004-2006	NR	LH; LB
Brazner and McMillan (2008)	Canada	S; T	1999-2006	NR	LH
Watson et al. (2005)	U.S. Western North Atlantic	S	2001-2002	13	LH; LB; SB
Mejuto et al. (2008)	Mediterranean Sea	S	2005-2006	2	LH; LB; OR
Richards et al. (2012)	U.S. Gulf of Mexico, Western North Atlantic	S; T	2005	NR	LH; LB; SB
Coelho et al. (2015)	Tropical Northeast Atlantic	S	2008-2011	1	LH; LB; OR; KR
Santos et al. (2013)	Northeast, Equatorial, Southern Atlantic	S	2008-2012	1	LH; LB
Santos et al. (2012)	Equatorial Atlantic	S	2009-2011	2	LH; LB; OR; KR

3.2 Bait type

Due to the feeding ecology of seabirds and sea turtles, different types of bait are known to reduce bycatch risk. The most common bait in international longline fisheries are squid (*Loligo spp., Illex spp.*) and fish (mackerel *Scomber spp., Trachurus spp*.; pilchard/sardine *Sardinops spp., Sardinella spp.*). Some fisheries including U.S. Atlantic (Swimmer et al., 2017) and the Mediterranean Sea (Báez et al., 2010) swordfish fisheries use a mixture of squid and fish. The bait can also be prepared in numerous ways, such as being whole, minced, thawed, frozen, or color dyed (Lee et al., 2022). Some fisheries, none of which were reviewed here, use artificial lures made of various materials.

3.2.1 Dyed bait

Bait dying with non-toxic colouring (typically blue) is a common international practice that is thought to increase the visibility for fish while also reducing bycatch (Lydon & Starr, 2004). This technique is more often used as a seabird bycatch mitigation method rather than for sea turtles. For instance, of the eight sources that looked at seabird bycatch rates (out of the 25 reviewed sources), half compared captures using dyed and non-dyed bait. Based on vessel management plans, it is common in New Zealand to have blue dye on board SLL vessels but to actually dye bait only around full moon days or if there is high seabird attendance around the vessel (J. Cleal, pers. comm.).

These studies showed mixed results for effectiveness. The Southern bluefin tuna fishery in South Africa reported a lower seabird bycatch rate for blue-dyed bait regardless of bait type (e.g., fish or squid) (Ochi et al., 2011). Capture rates of seabirds ranged from 0-0.8 captures/1000 hooks using undyed bait and 0-0.18 using dyed bait. They also found, however, a lower target species catch rate per unit effort when dyed bait was used. There was not enough data for Lydon & Starr (2004) to determine if dyed squid resulted in lower seabird catch rates in New Zealand. Similarly, there were no seabird captures when dyed squid and mackerel were used to catch swordfish on a single vessel in the North Pacific, although there were four and two captures using undyed squid and mackerel, respectively (Yokota et al., 2009). In an experimental trial of dyed bait on a single vessel in Australia, there were significantly fewer seabird interactions with the baited line per set using dyed squid (11.9 ±1.6 SE) compared to undyed squid (37.7 ± 5.4 SE). However, no hooks were used for this trial, so capture rates were not reported (Cocking et al., 2008).

For sea turtles, blue-dyed bait did not significantly reduce capture rates in the Costa Rican mahi mahi and tuna fisheries (Swimmer et al., 2005). Yokota et al. (2009) also found that blue-dyed squid or mackerel did not significantly reduce loggerhead sea turtle bycatch numbers in a North Pacific swordfish fishery. However, the use of mackerel instead of squid regardless of dye reduced bycatch by 75%.

3.2.2 Bait type effects on seabirds

Another consideration is the type or species of the bait. A number of studies have compared capture rates of both target species and bycatch species, including sea turtles and seabirds, using squid versus fish bait. For seabirds, there has been a single study to suggest that mackerel significantly increases the capture rates when compared to squid (Li et al., 2012) in western Atlantic longline fisheries targeting a variety of fish. Of the 77 bycaught seabirds, 16% were caught on sets using squid bait compared to 84% on mackerel-baited sets. It is unclear, however, the catch per unit effort for different combinations of circle or J hooks with mackerel and squid bait, so there could be a confounding interaction.

Richards et al. (2012) examined the effect of different bait types and sizes of circle hooks on sea turtle and seabird bycatch in the Gulf of Mexico and the northwestern Atlantic. However, results were inconclusive since only two greater shearwaters (*Puffinus gravis)* were caught on 18/0 non-offset circle hooks baited with mackerel (targeting swordfish) and squid (targeting bigeye tuna).

3.2.3 Bait type effects on sea turtles

It is generally accepted that fish bait reduces the likelihood of sea turtle interactions, although studies to support this show varied effectiveness. For instance, Watson et al. (2005) found that mackerel bait independently and significantly reduced loggerhead and leatherback turtle captures by 71% and 66%, respectively, in the northwest Atlantic swordfish fishery. Used in combination with a circle hook 18/0 10° barb offset rather than the J hook 9/0 (control), captures were significantly reduced by 90% and

65%, respectively.

Likewise in the western Mediterranean swordfish fishery, the capture rates (captures/1000 hooks) were 0.61 for loggerhead, 0.52 for leatherback, and 0.11 for olive ridley turtles (*Lepidochelys olivacea*) when squid was used as bait across all hook types combined. When mackerel bait was used, these capture rates decreased to 0.18 for loggerhead and 0.02 for olive ridley turtles, but slightly increased to 0.57 for leatherback turtles (Mejuto et al., 2008). Overall, the use of squid increased the interaction rates by 239% for loggerhead turtles and by 450% for olive ridley turtles compared with mackerel. Báez et al. (2010) reported this same finding in this fishery, with significant reduction in turtle capture rates for fish-only sets compared to squid and fish sets. They also indicated that mackerel bait was not an economically viable solution to reduce bycatch because of the significant reduction in swordfish catch rates as well.

Another study looking at the effects of different hook and bait type on turtle bycatch rates in a northeast Atlantic swordfish fishery found that the odds of catching a hardshell turtle species (i.e., excluding leatherbacks) decreased significantly by 55% when using mackerel bait rather than squid (Coelho et al., 2015).

In the Canadian swordfish and tuna fisheries, Brazner & McMillan (2008) found a decrease in loggerhead turtle capture rates when switching from squid (1.27 captures/1000 hooks) to mackerel (0.18 captures/1000 hooks) using J hooks; for circle hooks, captures also decreased from 1.0 to 0.58 captures/1000 hooks. This was further supported in three more studies of the swordfish fisheries in the equatorial Atlantic (Santos et al., 2012), north-eastern and southern Atlantic (Santos et al., 2013), and Hawaii (Gilman et al., 2007). When a circle hook baited with mackerel was used instead of a J hook baited with squid (control), capture rates were significantly reduced for leatherback turtles by 82.8%, 91%, and 100% (Gilman et al., 2007; Santos et al., 2012; Santos et al., 2013, respectively) and for loggerhead turtles by 87.5% and 90% (Gilman et al., 2007, respectively; Santos et al., 2013). Santos et al. (2012) also found an 85% reduction in capture rates for olive ridley turtles and an odds-ratio of capturing an olive ridley turtle decrease of 56% when using mackerel (Santos et al., 2012).

Alternatively, Richards et al. (2012) compared the effects of mackerel, sardine, and squid bait under various hooking techniques in the swordfish, yellowfin tuna, and bigeye tuna fisheries in the Gulf of Mexico and the Western North Atlantic. They found no significant reduction in sea turtle or seabird bycatch rates for different circle hooks, bait, and hooking techniques. They did allude to a 22% decrease in target species yellowfin tuna capture rates depending on the way the bait was hooked (single versus threaded). This study highlights that baiting technique should be considered in comparative studies, although that is seldom the case.

Further, switching the bait type from squid to fish can also result in bycatch of other taxa. For example, Gilman et al. (2007) found a 36% reduction in shark bycatch when switching bait from squid to fish. This finding was consistent with other studies, but the effect of bait type on shark bycatch is likely to depend on the hook type (e.g., Boggs, n.d.) (see next section). Contrarily, some New Zealand SLL fishers have anecdotally indicated they catch more shark using fish bait compared to squid.

3.2.4 Target species captures

Although not the focus of this review, several reviewed studies reported the effects of bait type on catch rates of the target species. Results were inconclusive though as to the significance of the impacts. For instance, Báez et al. (2010) found a decrease in swordfish captures when a mix of squid and fish bait was used (compared to just squid bait). On the other hand, Gilman et al. (2007) and Watson et al. (2005) suggested that bait type did not significantly affect swordfish catch rates, although Watson et al. (2005) indicated a lower catch rate for their secondary target species, bigeye tuna.

3.3 Hook type and size

There are three main types of hooks used in longline fisheries: J hooks, circle hooks, and tuna hooks (Figure 3.2)(Gilman et al., 2010; Lee et al., 2022; Serafy et al., 2012). J hooks are in the shape of a J with the point parallel to the shank. Circle hooks have an angled point at least 90° to the shank, an angled front length of the hook at least 70%-80% of the hook's total length and bent a minimum of 20° toward the shank (Serafy et al., 2012). They range in size from 8/0 to 18/0 (Swimmer et al., 2020). An offset circle hook has a point or barb that is not in line with the shank. Large offsets greater than 10° are known to increase sea turtle capture rates (Gilman et al., 2010). A tuna hook is an intermediary of both, but with a slightly elongated shape and a more pronounced inward bend (Gilman et al., 2010). Circle hooks are designed to be wider at their narrowest point than standard J and tuna hooks, making it difficult to fit into turtle or seabird mouths (Gilman et al., 2010; Lee et al., 2022). If hooking does occur, they general do so in the corner of the mouth, reducing the likelihood of deep hooking (Swimmer et al., 2020). They are often used in pelagic longline fisheries targeting species like tuna.

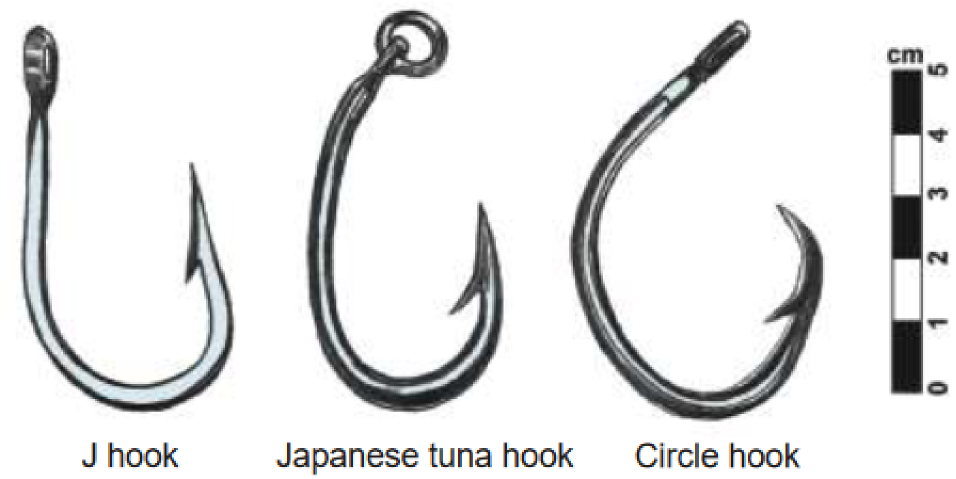

Figure 3.2: Main types of hooks used by surface longline fisheries. Reproduced from Gilman et al. (2010).

3.3.1 Hook type effects on seabirds

Hook type and size can result in reduced bycatch of both sea turtles and seabirds, as well as other taxa. For example, in the North Atlantic swordfish fishery, 18/0 circle hooks (both non-offset and 10° offset) reduced sea turtle and seabird capture rates by

57%-90% and mortality compared to 9/0 J hooks (20-25° offset) (Watson et al., 2005). The effective reduction of seabird captures using circle hooks was also found in two other studies (Domingo et al., 2012; Li et al., 2012). In the western Atlantic longline fisheries targeting a variety of fish, there was a significant decrease in seabird captures when using circle hooks; 64% of the 77 captured seabirds were hooked on 8/0 J hooks (0.8% probability), 25% on 9/0 J hooks (0.3% probability), 6% on 16/0 circle hooks (0.2% probability), and 5% on 18/0 circle hooks (0.01% probability) (Li et al., 2012). Likewise, five seabirds were captured in the Uruguayan pelagic longline fisheries using 18/0 circle hooks with a 10° offset compared to 13 captures with a 9/0 J hook (Domingo et al., 2012). Similarly to bait type, results were inconclusive for the effects of hook size and offset in the Gulf of Mexico and the northwestern Atlantic tuna and swordfish fisheries due to low catch rates.

3.3.2 Hook type effects on sea turtles

The majority of the other studies presented similar findings. Gilman et al. (2007), who assessed observer data from the Hawaii-based longline swordfish fishery, found a 83% and 90% decrease in leatherback and loggerhead turtle captures, respectively, when fish-baited 18/0 circle hooks were used rather than 9/0 J hooks. Swimmer et al. (2017) also found a two- to threefold reduction in the probability of expected loggerhead and leatherback turtles captures in Pacific and Atlantic swordfish and tuna longline fisheries when switching from 9/0 J hooks baited with squid to 18/0 circle hooks baited with fish (before and after regulation change in 2004).

Likewise, compared to 16/0 J hooks with a 10° offset, Mejuto et al. (2008) reported a 56% and 20% decrease in loggerhead and leatherback turtle catch rates, respectively, in the Mediterranean swordfish fishery for 18/0 semicircular hooks with a 10° offset and 45%, 13%, 10% decrease in loggerhead, olive ridley, and leatherback turtle catch rates for 17/0 circle hooks with an 8° offset. However, there was a 18% increase in olive ridley turtle captures using the semicircular hook.

On a single SLL vessel targeting swordfish in the northeast Atlantic, the probability of catching a leatherback turtle decreased by 55% when using a circle hook and decreased by 59% for hardshell turtles (Coelho et al., 2015). More specifically, when baited with squid, capture rates decreased from 1.34 turtles/1000 hooks for 9/0 J hooks with a 10° offset to 0.95 and 0.65 turtles/1000 hooks for 17/0 circle hooks with a 10° offset and no offset, respectively. Capture rates were further decreased when hooks were baited with mackerel; from 1.1 with J hooks to 0.85 and 0.45 for offset and non-offset circle hooks, respectively. This study also indicates that non-offset circle hooks had a significantly lower catch rates regardless of bait type.

Santos et al. (2012) and Santos et al. (2013) found a significant reduction in capture rates and odds-ratios of sea turtles in the equatorial, northeastern and southern Atlantic swordfish fisheries when using circle hooks compared to J hooks. The lowest capture rates occurred with a mackerel-baited, 17/0 circle hook with a 10° offset compared to non-offset circle hooks and 9/0 J hooks (control) and squid bait. An estimated 85.0-100% reduction in capture rates of all turtles occurred using a circle hook baited with mackerel (Santos et al., 2012; Santos et al., 2013). There was a 54% decrease (CI 33-68%) in the odds-ratio between the control and non-offset circle hooks and a 65% decrease (CI 48-77%) for 10° offset circle hooks (Santos et al., 2012). Likewise, in the southern Atlantic tuna fishery, capture rates of turtles were reduced (non-significantly) from twelve leatherback and six green turtles captured with 9/0 10° offset J hooks to four leatherback and four green turtles captured with 18/0 non-offset circle hooks (Pacheco et al., 2011). However, only one olive ridley turtle was captured with J hooks while three were captured with circle hooks; this too, was a non-significant difference in catch rate.

Read (2007) reviewed field trials, including Watson et al. (2005) and Bolten & Bjorndal (2005), but also presented unpublished data for the Equadorian SLL tuna and mahi mahi fisheries. Capture rates were higher for all hook types in the mahi mahi fishery compared to the tuna fishery. There was an estimated 2.2 turtles/1000 hooks captured using 9/0 J hooks (control), followed by 1.8 turtles/1000 hooks using the 15/0 circle hook (17% reduction), and 1.38 turtles/1000 hooks with the 14/0 circle hook (37% reduction). In the tuna fishery, capture rates were 1.36 turtles/1000 9/0 J hooks (control), followed by 0.76 turtles/1000 16/0 circle hooks with a 10° offset (44% reduction), and 0.15 turtles/1000 18/0 circle hooks with a 10° offset (89% reduction).

Just as the above study suggests that smaller circle hooks are not able to mitigate turtle bycatch, Cambie et al. (2021) found similar results where the 13/0 non-offset circle hook they trialed in a small-scale Italian pelagic longline bluefin tuna fishery resulted in nine loggerhead sea turtle captures, while fourteen were captured using a small 4/0 J hook with a 10° offset. This is a non-significant difference in capture rates, especially considering that four out of the six dead turtles were captured on the small circle hook. It should be noted, however, that this study was conducted on a single, 11-m vessel and may not be representative of larger SLL vessels.

One reviewed source surveyed Sicilian longline swordfish fishers on their willingness to use 16/0 circle hooks (10° offset) along with their opinions on sea turtle interactions and conservation (Piovano et al., 2012). Most fishers did not see longlining as a threat to turtles but suggested trawling to be the bigger concern. Most respondents also did not see an economic loss due to sea turtle bycatch, but 56% agreed to use mitigation methods for sea turtles. Only 8% of fishers were in favour of using the circle hooks, but that increased to 38% if there was an economic incentive and if hooks were provided free of charge. They also tested circle hooks on five vessels in the Mediterranean. There were nine loggerhead turtles captured with J hooks (various sizes, offsets; 0.94 turtles/1000 hooks) and only two turtles captured with circle hooks (0.11 turtles/1000 hooks) (Piovano et al., 2012).

Brazner & McMillan (2008) found conflicting results for capture rates of loggerhead turtles depending on the fishery, although experimental fishing effort (number of hooks) was different for each hook type. When swordfish were targeted, 16/0 circle hooks had a higher capture rate of 0.58 loggerheads/1000 hooks compared to 0.18 for J hooks (all baited with mackerel). Conversely, when tuna was targeted, 16/0 circle hooks decreased capture rates from 1.27 (J hook) to 1.00. Regardless of fishery, the circle hook capture rate of 0.89 turtles/1000 hooks was higher than the J hook capture rate of 0.3.

Two multi-year studies on SLL vessels (n = 1 per year per study) targeting swordfish in the Azores trialed similar hook types and found slightly different results. The first study only found a significant reduction in loggerhead turtle capture rates in one out of four trials (Bolten & Bjorndal, 2005). They trialed eight different hooks, including offset and non-offset 9/0 J hooks (0.48-1.82 turtles/1000 hooks), 18/0 and 16/0 non-offset and offset circle hooks (0.16-1.91 turtles/1000 hooks), and a Japanese 3.6-mm tuna hook (4.55 turtles/1000 hooks). The other study used the same type of hooks and found a significant 58% reduction in turtle capture rates (Lima et al., 2023) for circle hooks compared to J hooks and a 136% increase in captures using the tuna hook.

Similar mixed results occurred in the Uruguayan pelagic longline fisheries, where two loggerhead turtles were captured with both 9/0 J hooks and 18/0 circle hooks with a 10° offset. However, there was a non-significant 25% reduction in loggerhead captures, from 48 to 36 turtles, when the line was set with circle hooks (Domingo et al., 2012).

3.3.3 Hooking location and mortality

Some studies also reported the way turtles or seabirds were caught on the hooks. For instance, a turtle can swallow the hook (i.e., deeply hooked, Lima et al., 2023; throat hooked, Bolten & Bjorndal, 2005) or be hooked externally under the flipper, in the corner of the mouth, etc. (i.e., lightly hooked, Lima et al., 2023). It is generally believed hooks can be removed more easily when lightly or externally hooked, thus increasing the chance of survival, but many factors influence the difficulty and mortality rates when removing hooks. In three studies, the number of sea turtles that were deeply hooked were significantly fewer when circle hooks were used compared to J hooks (Bolten & Bjorndal, 2005; Brazner & McMillan, 2008; Lima et al., 2023). Brazner & McMillan (2008) reported a significant decrease in sea turtle captures that had swallowed a J hook (10.1%) or circle hook (3.5%). Santos et al. (2012) and Santos et al. (2013) reported significantly fewer dead turtles using circle hooks. Circle hooks can also significantly reduce the number of turtles released with hooks still attached (Gilman et al., 2007). All these results were reiterated in Pacheco et al. (2011), although not significantly; more sea turtles (about 70%) were externally hooked on circle hooks but internally hooked on J hooks (about 55%). They also reported that circle hooks appeared to reduce mortality at haulback and increase post-release survival, although it is unclear from what evidence this conclusion was drawn.

3.3.4 Target species captures

Several of the reviewed studies reported capture rates for the target species in addition to turtle or bird captures. While three studies found a lower target species catch rate when circle hooks were used (swordfish, Lima et al., 2023; Piovano et al., 2012; tuna, Read, 2007), two studies found no change or an increase in target species catch rates (swordfish, Gilman et al., 2007; tuna, Cambiè et al., 2012). Two studies presented mixed results (swordfish, Watson et al., 2005; swordfish and tuna, Domingo et al., 2012). Although Watson et al. (2005) reporting an increased catch rates for primary target species of swordfish with circle hooks, they also found that capture rates for the secondary target species tuna decreased. Conversely, Domingo et al. (2012) found a significant increase in tuna and shortfin mako shark catch rates with circle hooks but a 24% decrease in swordfish capture rates. They also suggested that vessel size influences the effects of circle hooks on target species capture rates; for instance, the reduction in swordfish with circle hooks was not significant for larger vessels but was significantly lower for smaller vessels (Piovano et al., 2012). Some studies also suggest that shark and other fish species bycatch increases through the use of circle hooks, though this may depend more on which bait is used. As mentioned previously, switching to fish bait might reduce shark bycatch (e.g., Boggs, n.d.) or increase shark bycatch rates (K. Middlemiss, pers. comm.).

3.3.5 Hookpods as shielding devices

Hookpods, a type of hook-shielding device, have been trialed as a mitigation measure, including in the New Zealand SLL fleet by all vessels in 2024. They are accepted by the Agreement on the Conservation of Albatrosses and Petrels (ACAP) as best practice (Swimmer et al., 2020). These polycarbonate capsules are attached to a monofilament branchline and encase the point and barb of the hook during setting. They have a pressure release system that opens the Hookpod to release the baited hook at a predetermined depth usually of 10 m (Sullivan et al., 2018; Swimmer et al., 2020).

A single reviewed study investigated the effects of Hookpods on seabird and sea turtle captures. Circle hooks 15/0 or 16/0 without Hookpods resulted in 24 seabird captures, two leatherback turtle captures, and 20 loggerhead turtle captures on several vessels across multiple swordfish and tuna fisheries in South Africa, Brazil, and Australia. When Hookpods were used, only one seabird, no leatherbacks, and nine loggerheads were captured. Sullivan et al. (2018) reported that it took several sets for the crew to adapt to using Hookpods, but after that setting was conducted at the normal speed. They also found that the catch rate of the target species was not significantly affected.

Another ACAP best practice device is the smart tuna hook, which has a weight at the hook that encapsulates the barb and hook point during setting. It remains attached for 10 minutes after setting and then releases the hook (Swimmer et al., 2020). No studies have investigated capture rates with this hook, however.

3.3.6 Other hooks

Alternative weighted hooks, called Procella, were first used by several New Zealand SLL fishers in 2019 (Brothers, 2021). These ‘heavy hooks’ have weighted swivels integrated into the shank of the hook (50g), to increase sink rate and reduce seabird bycatch and bait loss. It should be noted that this method increases the width of the hook and therefore likely the gape required for fish to swallow it. Brothers (2021) and Brothers (2023) provided advantages and disadvantages of using Procella hooks, and only two published articles have tested the effects of hook weighting on species catch (Gilman et al., 2020; Gilman et al., 2022), both of which did not report any seabird or sea turtle bycatch, so they were not formally reviewed. However, both studies found a reduction in target species catch rates and suggest a review of the hook design to improve catch rates while maintaining the potential significant reduction in seabird bycatch.

3.4 Capture rates

Data for catch rates of loggerhead and leatherback sea turtles based on hook and bait combinations in different international fisheries are graphically represented in Figures 3.3-3.5 (see Appendix Tables A.3- A.5 for raw tables). Note that uncertainties were not provided since they were not presented consistently in the sources. Moreover, fishing effort, an important factor when calculating bycatch rates, was poorly or not consistently reported and often measures of effort were incomparable between studies. Although not reported in the following graphs, it is important to acknowledge the effect of fishing effort on these estimates.

Relative to J hooks with squid bait, circle hooks reduce turtle bycatch by 50-90% for all species, leatherback, and loggerhead turtles. An 18/0 10° offset hook with mackerel bait had the highest reduction in catch rate for loggerhead turtles of 88% in the U.S. North Atlantic and 90% in the U.S. Pacific swordfish fisheries (Watson et al., 2005). This hook also reduced leatherback turtle captures in the U.S. Pacific swordfish fishery by 83%. In the U.S. North Atlantic, an 18/0 non-offset hook with squid bait had the highest reduction in leatherback catch rate of 75% (Gilman et al., 2010).

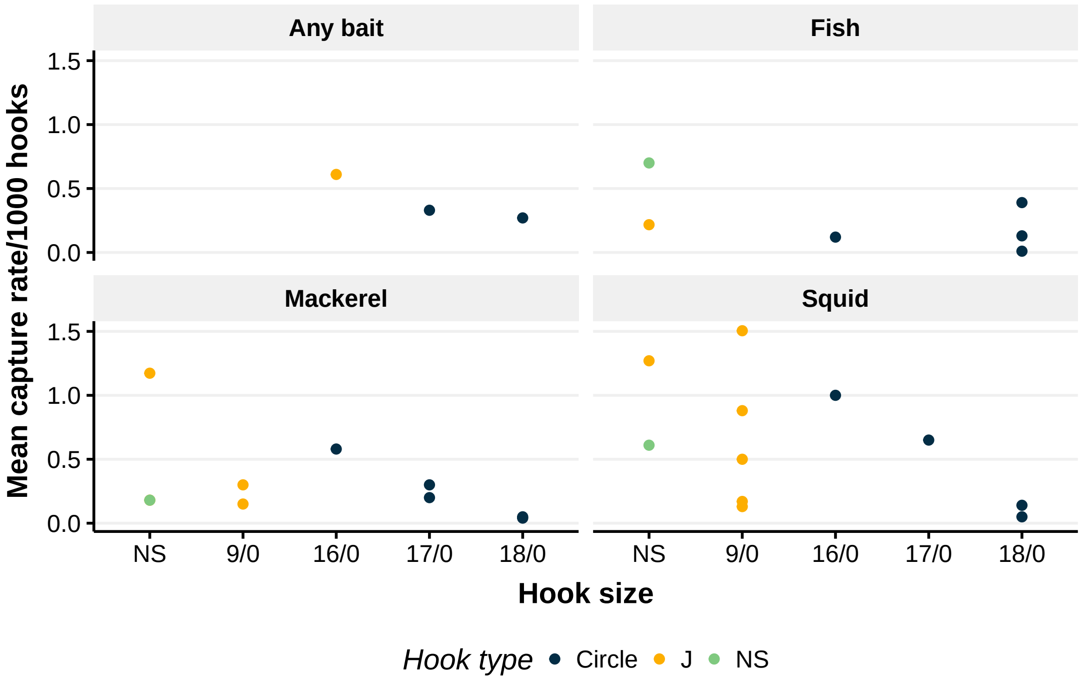

Figure 3.3: Loggerhead turtle estimated capture rates per 1000 hooks from reviewed sources. Rates are compared for different bait types by different hook types (shape) and sizes (size and colour). Capture rates where bait type was not specified or not considered are grouped as 'Any bait'. NS means 'not specified'. Note that some capture rates were estimated from figures presented in the reviewed sources, and uncertainties are not shown as they were not presented consistently in the sources.

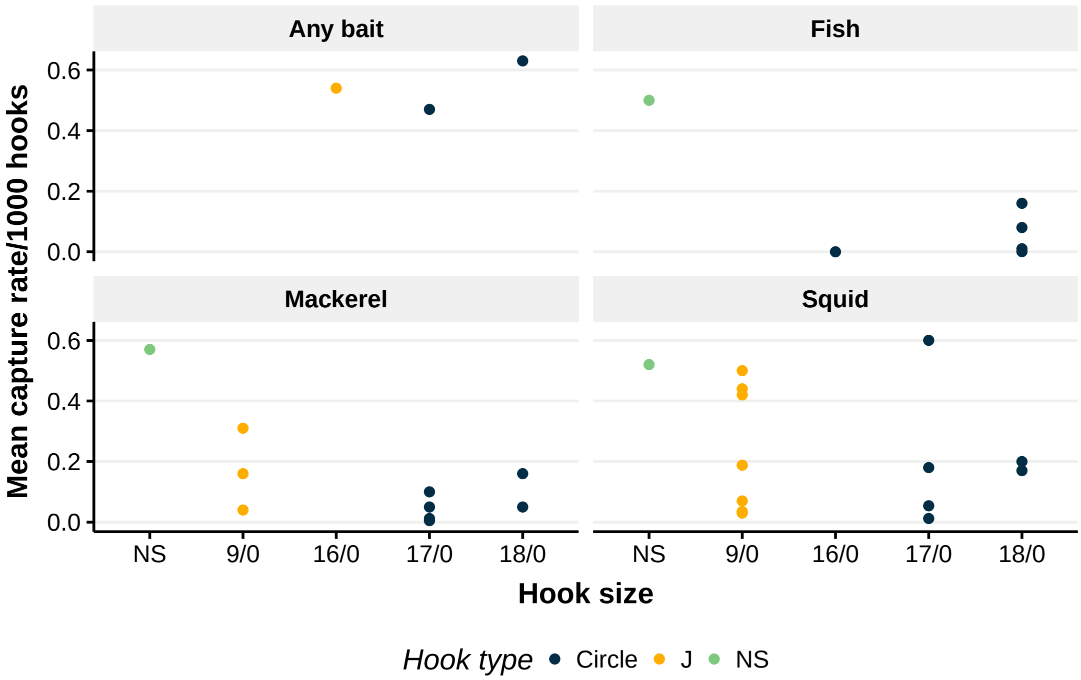

Figure 3.4: Leatherback turtle estimated capture rates per 1000 hooks from reviewed sources. Rates are compared for different bait types by different hook types (shape) and sizes (size and colour). Capture rates where bait type was not specified or not considered are grouped as 'Any bait'. NS means 'not specified'. Note that some capture rates were estimated from figures presented in the reviewed sources, and uncertainties are not shown as they were not presented consistently in the sources.

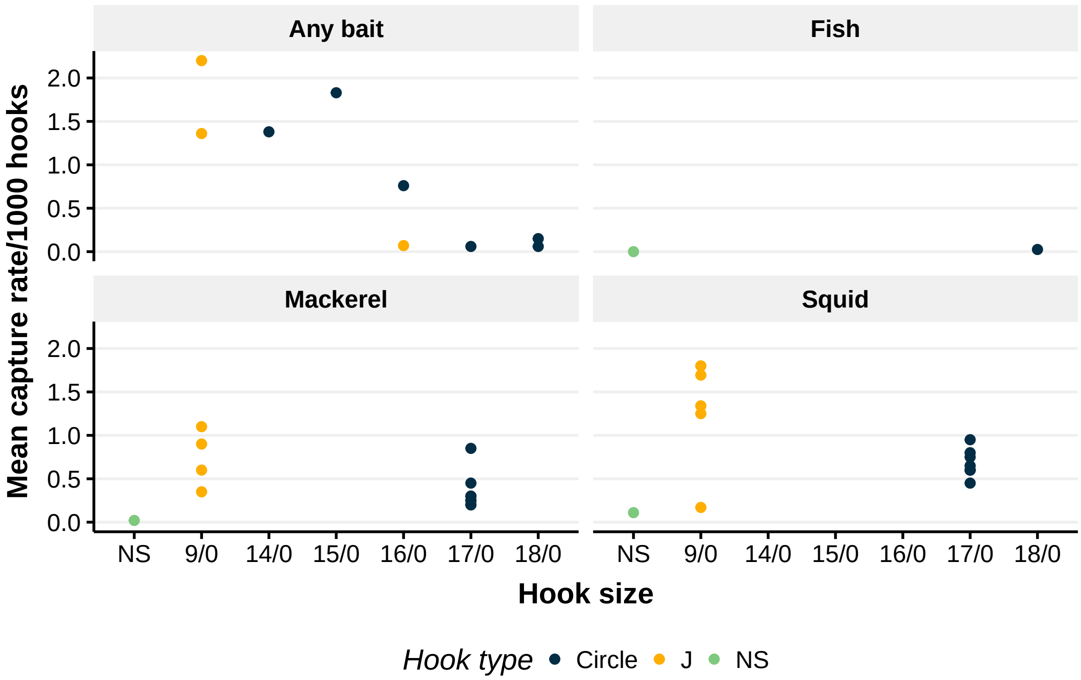

Figure 3.5: Estimated capture rates per 1000 hooks for all turtles combined (excluding studies that provided capture rates for leatherback and loggerhead independently). Rates are compared for different bait types by different hook types (shape) and sizes (size and colour). Capture rates where bait type was not specified or not considered are grouped as 'Any bait'. NS means 'not specified'. Note that some capture rates were estimated from figures presented in the reviewed sources, and uncertainties are not shown as they were not presented consistently in the sources.

Although most studies found that mackerel or fish bait reduced sea turtle capture rates compared to squid, Li et al. (2012) showed a significant increase in seabird capture rates when using mackerel rather than squid in U.S. Atlantic longline fisheries. While most studies also suggested that a combination of circle hooks and mackerel/fish bait may be the best mitigation method, particularly for sea turtles in general, Li et al. (2012) states that any decrease in seabird captures when using circle hooks may be obscured by an increase in captures when using mackerel bait.

Only three studies presented capture rates of seabirds. Ochi et al. (2011) found capture rates of albatross using undyed fish were 0.46, 1.0, and 0.28 captures/1000 hooks over three years, respectively, and 0.45, 0.3, and 0.65 captures/1000 hooks for undyed squid. For dyed fish, rates were 0, 0.17, and 0 captures/1000 hooks; for dyed squid, rates were 0 across all years. Likewise, for petrels, capture rates using undyed fish were 0, 0.8, and 0.28 captures/1000 hooks, and 0.45, 0, and 0.85 captures/1000 hooks for undyed squid across three years. For dyed fish, rates were 0, 0.18, and 0 captures/1000 hooks and for dyed squid rates were 0 across all years. Similarly, Lydon & Starr (2004) found capture rates of Antipodean albatross in the New Zealand tuna fishery to decrease from 0.4 to 0 when blue-dyed squid was used compared to undyed squid.

3.5 Reported bycatch in New Zealand

3.5.1 Protected species captures and observer data

Since 2017-2018, hook type and bait type data has been collected by MPI observers for each protected species capture event. This information, recorded in the PSCDB, is linked back to specific fishing trips/stations (for bait type) and to fishing trips (for hook type) obtained from the COD. Multiple bait types of different percent combinations of hooks are sometimes used in a single fishing event. Appendix Table A.6 summarises the number of protected species captures for various bait types/compositions. Bait type was not reported for most captures for every species or species group. Arrow squid was the most used bait. The most reported captures were of Buller's albatross and white-capped albatross.

Appendix Table A.7 summarises protected species captures during fishing events from 2017-2021, where hook and bait type were reported for most fishing events. Prior to this, hook and bait type were not recorded. There were 265 observed captures (28 sea turtles and 237 seabirds) during 31 trips with reported bait and hook type data. The majority were flesh-footed shearwaters (95), white-chinned petrels (42), and Buller's albatross (28). Since 2018, only circle hooks have been used, ranging from 14/0 to 18/0 in size. Size 16/0 hooks, however, were used during 77% of the trips with captures. Squid was used on all observed trips that had a protected species capture and a reported hook and/or bait type. Based on these observations, data are insufficient to make any comparisons between capture rates, hook, and bait type.

3.5.2 CSP seabird necropsies

From 2020-2024, necropsy data for 329 seabirds revealed white-chinned petrels (157 birds), flesh-footed shearwater (46 birds), and white-capped albatross (32 birds) to be the most frequently captured birds (Figure 3.6; Appendix Table A.8). It should be noted though that the necropsied birds do not represent the total number of birds caught in SLL fishing gear since not all specimens are returtned, but does provide a general idea as to the proportions of reported captures. The hook location for these individuals is most often unable to be determined during necropsy (172 birds), while external hooking occurred on the bill (39 birds), wing (42 birds), and the neck/throat (32). Only 8 birds ingested the hook. This dataset does not provide information about the size or type of hook associated with each capture, so further analysis of the effect of hook type is not possible.

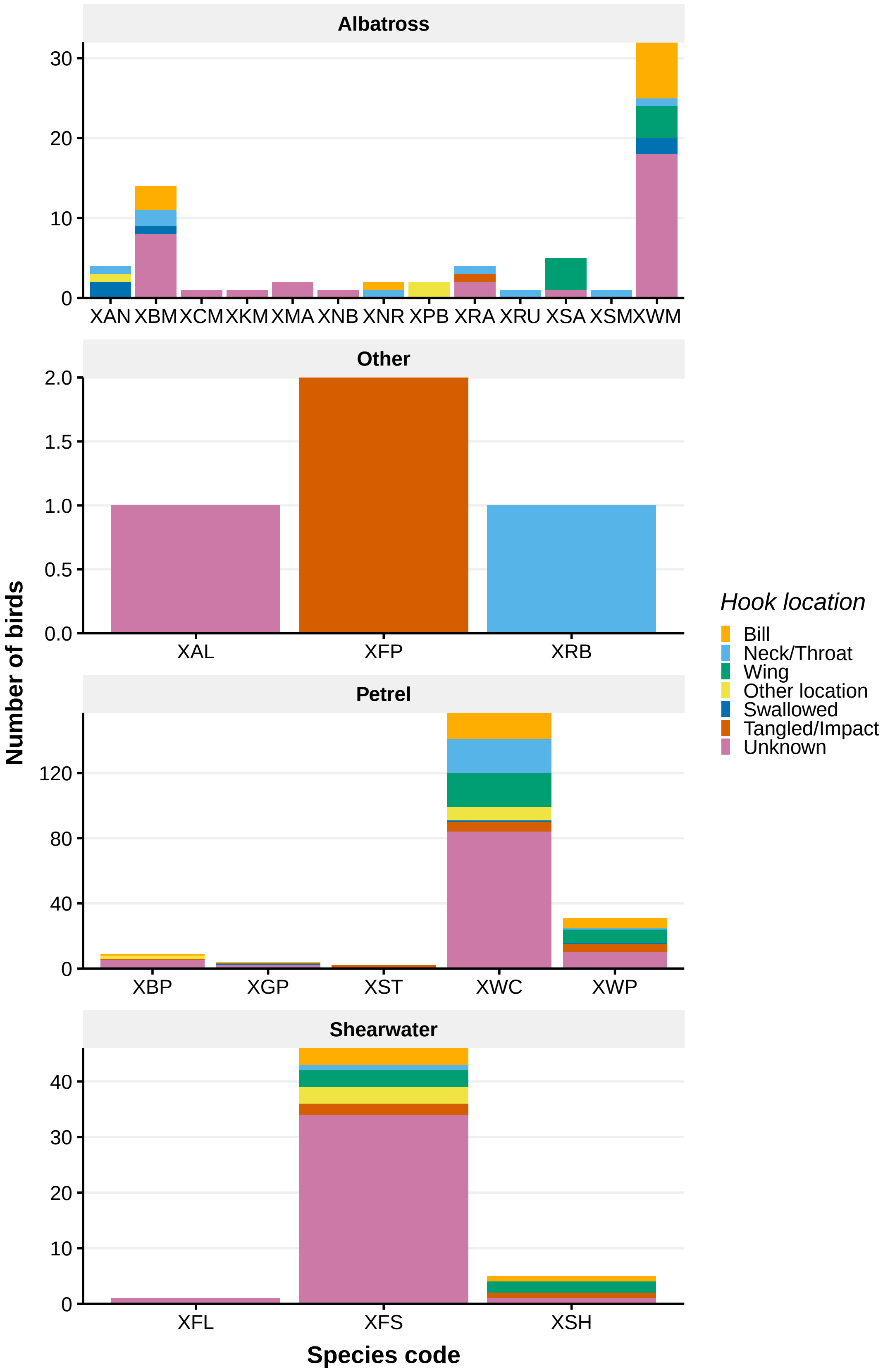

Figure 3.6: Number of necropsied seabirds from January 2020-March 2024 that were caught on surface longlines, summarised by the location of the hook position for each species. Note different y axis scales. See Appendix Table A-2 for species abbreviations.

From 1998-2005 and 2010-2024, 211 hooks of eight different types and sizes were collected during seabird necropsies by DOC. Table 3.2 presents the total number of captures per hook type/size, along with an image of the hook. Larger 17/0 circle hooks were attributed with 64 seabird captures compared with smaller 16/0 circle hooks (11 birds) in SLL. The species of seabird was not provided. It is also unknown as to the proportion of captures per hook type in relation to fishing effort. In other words, 17/0 circle hooks might be used significantly more often than smaller hooks, thus resulting in more captures. Again, this dataset provides limited information, although it does highlight common hooks used in both SLL and BLL fisheries.

Table 3.2: Number of different hooks removed from bycaught seabirds collected by on-board observers for necropsy from 1998-2005 and 2010-2024. The main species targeted by the bottom (BLL) or surface longline (SLL) fishery using a particular hook is provided.

Hook type	Hook size	Target species	Vessel	Seabird captures	Image
Circle hook	14/0	Grouper, ling, blue nose	BLL	3	
Circle hook	15/0	Grouper, ling, blue nose	BLL	2	
Circle hook	16/0	Tuna, swordfish	SLL	11	
Circle hook	17/0	Tuna, swordfish	SLL	64	

Table 3.2: Number of different hooks removed from bycaught seabirds collected by on-board observers for necropsy from 1998-2005 and 2010-2024. The main species targeted by the bottom (BLL) or surface longline (SLL) fishery using a particular hook is provided. *(continued)*

Hook type	Hook size	Target species	Vessel	Seabird captures	Image
Easier baiter J hook	12/0	Ling	Small BLL	84	
Easier baiter J hook	15/0	Ling, toothfish	Large BLL	1	
Ringed J hook	7/0	Tuna	BLL	32	
Tainawa J hook	16	Snapper	BLL	12	

3.6 International best practice

The use of large circle hooks of size 16/0 or larger with an offset less than 10° and/or the use of finfish bait have shown high efficacy at reducing seabird and sea turtle bycatch in longline fisheries internationally (e.g., Lee et al., 2022; Serafy et al., 2012; Swimmer et al., 2020; Watson et al., 2005). These mitigation methods are accepted to be widely available, affordable, easy to use, and safe for crew (Swimmer et al., 2020). In New Zealand, circle hooks are used exclusively in bottom longline fisheries. Using dyed squid is also common practice, as is the use of Hookpods or other mitigation methods.

The Food and Agriculture Organization of the United Nations (FAO) introduced 'Guidelines to Reduce Sea Turtle Mortality in Fishing Operations' in 2005 (Gilman et al., 2010). These guidelines are considered best practice (although voluntary and non-binding) to reduce sea turtle interactions with fisheries. They estimate that catch rates of loggerhead turtles range from 0-14 and 0-2.4 (0.0275 across the Pacific) for leatherbacks per 1000 hooks. In addition to recognising that the use of wide circle hooks and fish rather than squid bait can reduce turtle and seabird bycatch, they also indicate other methods that are being tested, including the use of small circle hooks (4.6 cm) rather than J or tuna hooks, single hooking fish bait (rather than multiple threading), reduced gear soak time, daytime retrieval of gear, and bycatch hotspot avoidance and seasonal closures (Gilman et al., 2010; Lee et al., 2022; Richards et al., 2012; Swimmer et al., 2020). The same best practices were also suggested by the Sustainable Fisheries Partnership for tuna longline fisheries (Morgan et al., 2015).

In 2008, the Western and Central Pacific Fisheries Commission implemented a recommendation according to the FAO guidelines to make it mandatory that SLL fisheries implement at least one of the following mitigation measures: circle hooks and/or fish bait (Lee et al., 2022). These and subsequent guidelines have also been adopted or encouraged by tuna related regional fisheries management organisations (t-RFMOs) through the establishment of conservation and management measures (CMMs) to reduce bycatch and/or interaction with ecosystem vulnerable species including sea turtles. New Zealand is a member of the WCPFC and signatory of the CMM 2018-04. Some of these t-RFMOs also include the Inter-American Tropical Tuna Commission, the Indian Ocean Tuna Commission, and U.S. Code of Federal regulations (Lee et al., 2022).

The Agreement on the Conservation of Albatrosses and Petrels (ACAP) is a multilateral agreement between 13 countries (to date) that coordinates international activity to mitigate known threats to seabird populations. They have published Best Practice Advice (BPA) for reducing the impact of SLL fishing on seabirds (ACAP, 2021; ACAP, 2023). The current BPA for mitigation methods is the simultaneous use of branch line weighting, night setting, and bird-scaring/tori lines. ACAP also recommends the use of hook-shielding devices (e.g., Hookpods) or underwater bait-setting devices. While they do not specifically outline BPA for hook type or bait type, they do indicate that there is insufficient evidence to recommend blue dyed bait as an effective mitigation method (ACAP, 2023).

3.6.1 Data collection

To assess the effects of implemented bycatch mitigation measures in SLL fisheries, existing observer data collection protocols need to be evaluated as to whether they meet "best practice" requirements for data collection. For example, a minimum set of variables to assess bycatch in longline fisheries contains (Clarke et al., 2014; Dietrich et al., 2004; Wolfaardt, 2016):

- Vessel characteristics
- Fishing trip and event characteristics (e.g., target species, trip number, event number, fishing method, gear)
- Spatial information (e.g., start and end of gear deployment and retrieval)
- Temporal information (e.g., date of gear deployment, start and end time of gear deployment and retrieval),
- Environmental/physical characteristics (e.g., moon phase, sea state, wind strength/direction)
- Total fishing effort (number of hooks set and number of hours fished)
- Total fishing effort observed (number of hooks observed and number of observer hours)
- Gear configurations, including line weighting, branchline length, distance between weight and hook
- Mitigation methods used

More specific variables to assess the effect of hook and bait type on bycatch in longline fisheries include (Clarke et al., 2014; Gilman et al., 2016; Richards et al., 2012):

- Hook type (i.e., size, type, offset)

- Bait type (to species-level if possible), preparation, dying, baiting technique, percent composition of bait
- Soak depth, time
- Sink rate
- Float or headline height

When an animal is captured, the following information should also be recorded:

- Species-level ID of bycaught animal (if possible)
- Fate upon capture and release (i.e., dead, alive, injured)
- Condition of the birds, including details on injuries or likely cause of death (e.g., drowning, broken neck, etc.)
- Photos where possible for future ID
- Measurements, age class, sex if possible
- The handling/collection of deceased animals should follow common practices of that fishery (i.e., retained for necropsy)

A recent assessment of factors influencing protected species bycatch in New Zealand longline fisheries found that some of these variables are collected by observers but only sporadically (Meyer & MacKenzie, 2022). Internationally, these data are most commonly collected through observer programmes, although like New Zealand, are collected sporadically and more opportunistically or to meet reporting standards since observer coverage remains low in many fisheries.

3.7 Hook/bait type questionnaire

In total, 17 responses (from a possible 18 operators) to the questionnaire were completed from 20 March 2024 to 21 June 2024. All vessels were 12.0-23.6 m in length. All respondents fished for southern bluefin tuna (STN), eleven in the South Island (SI) and six in the North Island (NI). Two fishers exclusively fish STN, eleven fishers also target big-eye tuna (BIG) and swordfish (SWO), and three fishers target STN, BIG, and albacore tuna (ALB). One fisher targeted STN and SWO (but not BIG). In total, 82% of respondents target BIG, 69% target SWO, and 17% target albacore (ALB).

Most reported that they use the same bait and hook combinations for all target species, except for two fishers in the NI that used 16/0 circle hooks baited with arrow squid to fish SWO while used a mixture of squid, mackerel, and artificial bait to target STN and BIG. Almost all respondents have not changed bait or hook types in the past five years.

Four types of hooks are used in the New Zealand SLL fleet (Table 3.3): circle 14/0 (17%), circle 15/0 (13%), circle 16/0 (56%), and circle 17/0 (8%). Four fishers use a combination of hook types, although 16/0 circle hooks are typically used for more than 70% set hooks. The 14/0 circle hooks are used exclusively in the SI by four respondents. While most fishers were unsure about the hook offset, four NI respondents specifically stated they use 15/0 or 16/0 10° offset hooks and another eight fishers think they may use 10-15° offset 15/0 (1 respondent), 16/0 (5 respondents) and 14/0 circle hooks (2 respondents). It should be noted here that the manufacturers supplying New Zealand fishers do not indicate or offer a choice in hook offset, hence most fishers are unaware of the offset (K. Middlemiss, pers. comm.). One fisher indicated that no one would use larger than 17/0 circle hooks for these target species. They also indicated that the underwater bait-setters are only able to set 14/0 and 15/0 hooks. Moreover, five fishers indicated they foresee a problem increasing the hook size to 16/0 or greater, three of which target albacore. Two NI fishers said they prefer 15/0 hooks.

Table 3.3: Questionnaire response summary from South Island (ID 1-11; with asterisk) and North Island (12-20) fishers. 'Yes' indicates if the respondent targets southern bluefin tuna (STN), big-eye tuna (BIG), swordfish (SWO), or albacore tune (ALB).

ID	STN	BIG	SWO	ALB	Hook type	Bait type	Dyed bait
1*	Yes	Yes	Yes	No	Circle 16/0; Circle 17/0	Squid	Yes - blue
2*	Yes	No	Yes	No	Circle 14/0; Circle 16/0;Procella	Arrow squid (SQU)	No
3*	Yes	No	No	No	Circle 16/0	Squid; Arrow squid (SQU)	Yes - blue
4*	Yes	Yes	Yes	No	Circle 16/0	Squid	Yes - blue
5*	Yes	Yes	Yes	No	Circle 16/0	Squid; Arrow squid (SQU)	Yes - blue
6*	Yes	Yes	Yes	No	Circle 16/0	Squid	Yes - blue
7*	Yes	Yes	No	Yes	Circle 14/0	Arrow squid (SQU)	No
8*	Yes	Yes	No	Yes	Circle 14/0	Arrow squid (SQU)	Yes - blue
9*	Yes	Yes	No	Yes	Circle 14/0	Arrow squid (SQU)	Yes - blue
10*	Yes	Yes	Yes	No	Circle 16/0	Squid; Arrow squid (SQU)	Yes - blue
11*	Yes	Yes	Yes	No	Circle 15/0; Circle 16/0	Arrow squid (SQU); Pilchard (PIL); Saury (SAU)	Yes - blue
12	Yes	Yes	Yes	No	Circle 16/0	Arrow squid (SQU); Saury (SAU)	No
13	Yes	Yes	Yes	No	Circle 15/0; Circle 16/0;Circle 17/0	Arrow squid (SQU); Sanma (Pacific saury)	Yes - blue
14	Yes	Yes	Yes	No	Circle 15/0	Arrow squid (SQU)	Yes - blue
15	Yes	No	No	No	Circle 16/0	Arrow squid (SQU)	No
16	Yes	Yes	Yes	No	Circle 16/0	Arrow squid (SQU); Sanma (Pacific saury); Artificial bait	No
17	Yes	Yes	Yes	No	Circle 16/0	Squid; Sanma (Pacific saury)	No

One fisher who targets albacore tuna stated a bigger hook greater than 14/0 may reduce catch rates due to the smaller size of the fish. The two other fishers targeting albacore reiterated this about the need for a smaller 14/0 circle hook to maintain catch rates. All three fishers targeting albacore exclusively use 14/0 circle hooks.

All fishers used different combinations of hook and line weights, Hookpods, and Lumo leads. Lumo leads are a luminescent weight typically attached to the snood (Gilman et al., 2020). One fisher specifically stated they use Procella hooks (53g) for about 70% of the total set hooks. Three others indicated they use a 40g lead weight welded to the top of the hook for about 70% of set hooks; the remaining 30% of hooks are fitted with Hookpods. Likewise, ten respondents in total specifically stated they use Hookpods fitted to the snood (often when weighted hooks or Lumo leads are not used). Five fishers also mentioned the use of 60g Lumo leads on all snoods.

All fishers bait with squid, with 13 (76%) indicating they use arrow squid (SQU) specifically (Table 3.3). Five NI fishers use a mix of fish (pilchards (PIL), saury (SAU), sanma, a type of Japanese mackerel), but fish-baited hooks comprise 30% or less of total set hooks. One fisher uses artificial, rubber/plastic frost fish 6-8% of the time.

Except for six respondents (4 in NI, 2 in SI), all dye squid blue (64%). Nine specifically stated they use dyed bait during full moon phases, usually 6-8 days per month, when seabird interaction risk is highest. One said they have dye on the vessel, but since they do not fish during the full moon they do not dye bait. One fisher also indicated they use dye occasionally to make bait last longer rather than mitigation purposes. Dyed bait is typically used in response to higher seabird risk or interactions.

All fishers foresee problems changing from squid to fish bait (eight 'maybe') mostly due to the expected reduction in catch rates of target species (four specifically stated). Two mentioned the high price of fish/mackerel bait compared to squid. Five also indicated that squid is preferred for SWO and a mix of fish/squid is better for STN. One fisher also indicated that fish cannot be dyed.

When asked what protected species are they most concerned about interacting with fishing gear, 12 respondents (70%) said both seabirds and sea turtles (including all NI operators), and an additional four (23%) said seabirds only (all SI operators). All said they would or do change their fishing practices in the presence of both seabirds and sea turtles (88%) or just seabirds (11%) in an attempt to mitigate bycatch risk. For instance, some specifically stated that they dye squid if many seabirds are in the area (one respondent), move to a new area with lower bycatch risk (three respondents), increase line/hook weighting and sink rate (four respondents), add Hookpods (two respondents), or set at night in deeper water during full moon (two respondents). One NI skipper targeting STN and SWO said they prefer to throw old/used baits back to the birds when hauling rather than hold/or batch discharge on other side of boat. They observe seabirds feeding on this old bait rather that interacting, often aggressively, with baited hooks during hauling and has noticed differences in seabird bycatch rates using this method.

4. Discussion

This review summarised current literature and data sources that examined the effect of hook size and bait type on seabird and turtle bycatch rates across SLL fisheries. In addition, results from a survey of SLL operators in the New Zealand swordfish and tuna fisheries about current gear type use and effects on bycatch were presented to understand what gear is currently used and why.

4.1 Literature review

Eight studies (out of 12) found, to some degree, a decrease in sea turtle bycatch when fish bait was used rather than squid. However, there is some indication that fish bait might increase seabird capture rates (e.g., Li et al., 2012), so further consideration is needed to determine if a decrease in turtle bycatch would be offset by an increase in seabird captures. The economic impacts of switching to fish bait is unclear, particularly with regards to the capture rates of the target species. Fish bait could be recommended on vessels exclusively fishing for swordfish, due to the negligible change in swordfish capture rates (Gilman et al., 2007; e.g., Watson et al., 2005); however, vessels targeting tuna may be more reluctant to switch to fish bait since target catch rates may decrease (e.g., Watson et al., 2005).

This was further reiterated in a recent meta-analysis, which included several studies reviewed here (Bolten & Bjorndal, 2005; Cambiè et al., 2012; Coelho et al., 2015; Gilman et al., 2007; Santos et al., 2012; Santos et al., 2013; Yokota et al., 2009), that compared the effect of fish versus squid bait and circle versus J hooks on sea turtle and target species captures. Although retention rates were lower for all sea turtle species, there was a 60-76% reduction in tuna retention rates (Santos et al., 2023). New Zealand fishers also pointed this out in the survey responses, with many indicating a switch to fish would decrease target species catch rates, suggesting they may be unlikely to switch.

Santos et al. (2023) reported in that same meta-analysis that circle hooks could reduce sea turtle and target swordfish retention rates while also increasing retention rates for tuna. A similar conclusion can be drawn from this literature review, where the majority of studies reported lower capture rates of sea turtles (Coelho et al., 2015; Gilman et al., 2007; Mejuto et al., 2008; Piovano et al., 2012; Read, 2007; Santos et al., 2012; Santos et al., 2013; Swimmer et al., 2017; e.g., Watson et al., 2005), seabirds (Domingo et al., 2012; e.g., Li et al., 2012). This supports the recent mandate to exclusively use circle hooks in the New Zealand longline fleet.

The effects of offset hooks compared to non-offset hooks is unable to be conclusively quantified, in large part to the confounding effects of hook type, size, and bait type in the reviewed sources. It is generally accepted that a 10° offset circle hook is the most effective at reducing bycatch of both turtles and seabirds; however, large offsets greater than 10° are known to increase sea turtle capture rates (Gilman et al., 2010).

Non-offset circle hooks reduced capture rates of sea turtles more significantly than 10° offset circle hooks on a single SLL vessel in the northeast Atlantic targeting swordfish (Coelho et al., 2015).

There is also not enough evidence to support the use of dyed bait as a bycatch deterrent in SLL fisheries. In New Zealand, squid is typically the only type of bait that is dyed. Out of the relatively few studies that compared dyed versus undyed bait, only one suggested a lower capture rate of seabirds. More studies need to be undertaken, particularly comparisons of dyed/undyed mackerel and dyed/undyed squid, before this method could be recommended as a viable mitigation method. Based on observations, dyed bait may also be more effective for seabirds rather than sea turtles and could be used as an adaptive mitigation method (Clarke et al., 2014); in other words, when significant numbers of seabirds are attending the vessel upon hauling, dyed bait may be used as a deterrent.

In practice, hook type, size, offset, bait type, bait preparation, and mitigation methods have a combined impact on bycatch and target species capture rates (ACAP, 2023), so it is difficult to disentangle the effects of just hook or bait type. For most fisheries, a circle hook greater than or equal to 16/0 baited with fish is the most commonly recommended and used combination.

Despite the extremely high risk for capturing seabirds, there were only eight studies that looked at bait and hook type as if effects capture rates, and four of these were looking at dyed bait (Cocking et al., 2008; Domingo et al., 2012; Li et al., 2012; Lydon & Starr, 2004; Ochi et al., 2011; Richards et al., 2012; Watson et al., 2005; Yokota et al., 2009). It is unknown why there are so few studies examining this, but this gap means that most recommendations for certain bait and hook types come from sea turtle bycatch. There is even evidence that fish bait, while decreasing turtle captures, may significantly increase seabird captures (Li et al., 2012). Considering the gaps in data and knowledge, it is recommended that a more systematic, experimental study looking at bycatch rates for both sea turtles and seabirds, focusing on the catch rates of seabirds using fish verse squid and smaller verse larger circle hooks. This study should be designed with treatment groups considering different (and all, if possible) combinations of hooks and baits that are currently being used on SLL vessels. It should have a large sample size of vessels and trips and use international best practice for data collection while determining capture rates of both target and non-target species.

4.2 Reported bycatch in New Zealand

A review of bycatch data obtained from several sources, including MPI and DOC (e.g., PSCDB, COD, necropsy database), revealed that data is insufficient to conduct any statistical analyses on the effects of bait or hook type on protected species captures. Since bait/hook data has only been recorded since 2018 for some (but not all) observed trips and from then circle hooks have been exclusively used, there are no reported captures for events where J hooks were used. The majority of fishing events (77%) with reported hook types used 16/0 circle hooks, further limiting any meaningful comparisons. Moreover, the way that hook and bait type data is collected and reported in the COD means that hook type can only be linked at the trip level while bait type can be linked at the station level.

Necropsy data underscored frequent captures of white-chinned petrels, flesh-footed shearwaters, and white-capped albatross, albeit without specific hook details, precluding deeper insights into hook effects. Future data collection for both the COD and the necropsy project should include not only hook size and type but also bait type to facilitate analyses on bycatch risk. Additionally, while not included in this report, initial findings from necropsies going back to 1996 showed that petrels were over represented in being hooked in the wing compared to other seabird groups and hook locations. This could be an area for future research to investigate petrel-specific mitigation methods to reduce wing hooking.

4.3 Hook/bait type questionnaire

The questionnaire responses provided valuable insights into current fishing practices within New Zealand's SLL fleet targeting tuna and swordfish. Bait and hook preferences are generally consistent across target species. Four primary circle hook sizes dominate the fleet: mostly 16/0 circle hooks (56%), followed by 14/0 (17%), 15/0 (13%), and 17/0 (8%) circle hooks. Moreover, all fishers use squid as bait, although some use a mix of fish and squid and one fisher used artificial bait occasionally. The use of squid is primarily due to cost (mackerel is expensive) and target species catch rates.

When asked what protected species are they most concerned about interacting with fishing gear, 12 respondents (70%) said both seabirds and sea turtles (including all NI operators), and an additional four (23%) said seabirds only (all SI operators). However, there were concerns over hook size and bait change, particularly among fishers targeting albacore tuna, fearing potential catch rate reductions with larger hooks, reinforcing a preference for smaller 14/0 circle hooks.

Additionally, Hookpods have been widely (and voluntarily) adopted across the entire New Zealand SLL fleet since February 2024 and could now be considered best practice. The use of either Hookpods or the simultaneous use of three mitigation methods (use of tori lines, weighted lines, and night setting) will become mandatory in October 2024, which follows best practice proposed by ACAP (ACAP, 2023).

At the time of this report, data for bycatch rates in years before 2024 (before the use of Hookpods) and during 2024 onwards (after the fleet-wide use of Hookpods) were not available. If this data could be obtained, an investigation could be conducted in the future to assess the effectiveness of Hookpods as a mitigation method in New Zealand.

Overall, while there is a predominant trend towards standardised bait and hook types, nuanced variations exist based on target species and regional preferences, suggesting a complex interplay between gear selection and fishing success in the New Zealand SLL fishery.

4.4 Recommendations and conclusion

The most common reason for using a specific bait or hook type is an economical one. Squid is generally less expensive and thought to increase target species captures (especially swordfish). Moreover, target species catch rates, like bycatch rates, are impacted by the type of hook, and catch rates are always maximised where possible. Thus, uptake of or changes to different types of hook and bait by fishers to reduce bycatch rates will only occur if target catch rates remain the same (or increase). Flexibility in regulations must also be considered for the compliance of operators who alter gear type depending on costs.

While gear modification is often the most favoured approach to bycatch mitigation, it alone is often not enough to reduce interaction rates sufficiently. Not only is better reporting of sea turtle and seabird bycatch highly recommended (especially the gear they interacted with) to determine the overall effect of specific gear, like hook and bait type, on bycatch rates, but additional aspects of bycatch mitigation should be considered in tandem (i.e., offal discharge, location of encounters, setting/hauling procedures, seasonal closures of fisheries, etc.)(Clarke et al., 2014).

Based on this literature review and international best practices, from a bycatch perspective, it is recommended to exclusively use larger circle hooks at least 17/0 in size (in addition to Hookpods, weighted hooks/lines, and night setting) when possible. Some flexibility in this could be considered for target species such as albacore who require hooks 16/0 or smaller based on the size of the mouth of the target species. Fish bait should also be used when and where possible, while considering the economic factors. However, based on fishers' feedback, currently 16/0 circle hooks and squid bait are predominantly used. Along with improved data collection for bycatch events, it is also encouraged to continue trialing new hooks (e.g., Procella), baits, and mitigation methods as technologies improve over time.

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A. Appendix A

Table A.1: Scientific names for bycatch, bait, and target species in reviewed sources.

Common name	Scientific name
Bait	
Pacific saury	*Cololabis saira*
Redbait	*Emmelichthys nitidus*
Argentine shortfin squid	*Illex argentinus*
Sailfish	*Istiophorus platypterus*
Arrow squid	*Nototodarus sloanii; N. gouldi*
Sardinella	*Sardinella aurita*
Brazilian sadinelle	*Sardinelle brasileiensis*
Pilchard	*Sardinops sagax*
Blue mackerel	*Scomber australasicus*
Chub mackerel	*Scomber japonicus*
Atlantic mackerel	*Scomber scombrus*
Saury	*Scomberesox saurus*
Japanese common squid	*Todarodes pacificus*
Greenback jack mackerel	*Trachurus declivis*
Jack makerel	*Trachurus murphyi; T. novaezealandia*
Yellowtail jack mackerel	*Trachurus novaezelandiae*
Sea turtles	
Loggerhead	*Caretta caretta*
Green	*Chelonia mydas*
Leatherback	*Dermochelys coriacea*
Kemp's ridley	*Lepidochelys kempii*
Olive ridley	*Lepidochelys olivacea*
Seabirds	
Subantarctic skua	*Catharacta antarctica*
Pintado petrel	*Daption capense*
Cape petrel	*Dation capense*
Antipodean wandering albatross	*Diomedea antipodensis*
Gibson's albatross	*Diomedea antipodensis gibsoni*
Tristan albatross	*Diomedea dabbenena*
Southern royal albatross	*Diomedea epomophora*
Wandering albatross	*Diomedea exulans*
Northern royal albatross	*Diomedea sanfordi*
Kelp gull	*Larus dominicanus*
Silver gull	*Larus novaehollandiae*

Table A.1: Scientific names for bycatch, bait, and target species in reviewed sources. *(continued)*

Common name	Scientific name
Black-browed albatross	*Lassarche melanophrys*
Southern giant petrel	*Macronectes giganteus*
Cape gannet	*Morus capensis*
White-faced storm petrel	*Pelagodroma marina*
Common diving petrel	*Pelecanoides urinatrix*
Imperial cormorant	*Phalacrocorax atriceps*
Laysan albatross	*Phoebastria immutabilis*
Black-footed albatross	*Phoebastria nigripes*
White-chinned petrel	*Procellaria aequinoctialis*
Grey petrel	*Procellaria cinerea*
Spectacled petrel	*Procellaria conspicillata*
Black petrel	*Procellaria parkinson*
Cook's petrel	*Pterodroma cookii*
Grey-faced petrel	*Pterodroma macroptera*
Buller's shearwater	*Puffinus bulleri*
Flesh-footed shearwater	*Puffinus carneipes*
Great shearwater	*Puffinus gravis*
Sooty shearwater	*Puffinus griseus*
Short-tailed shearwater	*Puffinus tenuirostris*
Northern gannet	*Sula bassanus*
Buller's albatross	*Thalassarche bulleri*
Southern Buller's albatross	*Thalassarche bulleri bulleri*
Indian yellow-nosed albatross	*Thalassarche carteri*
Atlantic yellow-nosed albatross	*Thalassarche chlororhynchos*
Grey-headed albatross	*Thalassarche chrysostoma*
Chatham Island albatross	*Thalassarche eremita*
Campbell albatross	*Thalassarche impavida*
Shy-type albatross	*Thalassarche spp.*
White-capped albatross	*Thalassarche steadi*
Target species	
Sandbar shark	*Carcharhinus plumbeus*
Mahi mahi	*Coryphaena hipparus*
Shortfin mako shark	*Isurus oxyrinchus*
Blue shark	*Prionace glauca*
Albacore tuna	*Thunnus alalunga*
Yellowfin tuna	*Thunnus albacares*
Bigeye tuna	*Thunnus obesus*
Atlantic bluefin tuna	*Thunnus thynnus*
Swordfish	*Xiphias gladius*

Table A.2: Abbreviated codes and names for turtle and seabird species and the aggregated species groups used to summarise various datasets.

Group	Species code	Common Name	Scientific name
Black petrel	XBP	Black petrel	*Procellaria parkinsoni*
Buller's albatross	XPB	Bullers albatross and Pacific albatross	*Thalassarche bulleri*
	XBM	Southern bullers albatross	*Thalassarche bulleri bulleri*
Flesh-footed shearwater	XFS	Flesh-footed shearwater	*Puffinus carneipes*
Grey petrel	XGP	Grey petrel	*Procellaria cinerea*
Other albatross	XAL	Albatross (unidentified)	*Diomedeidae*
	XAN	Antipodean albatross	*Diomedea antipodensis antipodensis*
	XAG	Antipodean and Gibsons albatross	*Diomedea antipodensis*
	XKM	Black-browed albatross (unidentified)	*Thalassarche melanophris & T. impavida*
	XCM	Campbell albatross	*Thalassarche impavida*
	XCI	Chatham island albatross	*Thalassarche eremita*
	XAU	Gibsons albatross	*Diomedea antipodensis gibsoni*
	XGA	Great albatrosses	*Diomedea spp.*
	XGM	Grey headed albatross	*Thalassarche chrysostoma*
	XIY	Indian yellow-nosed albatross	*Thalassarche carteri*
	XLM	Light-mantled sooty albatross	*Phoebetria palpebrata*
	XNR	Northern royal albatross	*Diomedea sanfordi*
	XNB	Pacific albatross	*Thalassarche bulleri platei*
	XRU	Royal albatrosses	*Diomedea sanfordi & D. epomophora*
	XMA	Smaller albatrosses	*Thalassarche spp.*
	XSM	Southern black-browed albatross	*Thalassarche melanophris*
	XRA	Southern royal albatross	*Diomedea epomophora*
	XAS	Wandering albatross	*Diomedea exulans*
	XWA	Wandering albatross (unidentified)	*Diomedea exulans & D. antipodensis sspp.*
	XAP	Antarctic petrel	*Thalassoica antarctica*
	XPR	Antarctic prion	*Pachyptila desolata*

Table A.2: Abbreviated codes and names for turtle and seabird species and the aggregated species groups used to summarise various datasets. *(continued)*

Group	Species code	Common Name	Scientific name
	XFT	Black bellied storm petrel	*Fregetta tropica*
	XBG	Black-backed gull	*Larus dominicanus dominicanus*
	XPV	Broad-billed prion	*Pachyptila vittata*
	XBS	Bullers shearwater	*Puffinus bulleri*
	XCC	Cape petrel	*Daption capense*
	XCP	Cape petrels	*Daption spp.*
	XDP	Common diving petrel	*Pelecanoides urinatrix*
	XCR	Crested penguins	*Eudyptes spp.*
	XFP	Fairy prion	*Pachyptila turtur*
	XFC	Fiordland crested penguin	*Eudyptes pachyrhynchus*
	XFL	Fluttering shearwater	*Puffinus gavia*
	XFU	Fulmar prion	*Pachyptila crassirostris*
	XGT	Gannet	*Morus serrator*
	XTP	Giant petrel (unidentified)	*Macronectes spp.*
	XGF	Great-winged petrel	*Pterodroma macroptera gouldi*
	XGB	Grey-backed storm petrel	*Garrodia nereis*
	XLB	Little blue penguin	*Eudyptula minor*
	XPM	Mid-sized Petrels & Shearwaters	*Pterodroma, Procellaria & Puffinus spp.*
	XMP	Mottled Petrel	*Pterodroma inexpectata*
	XNP	Northern giant petrel	*Macronectes halli*
	XPE	Petrel (unidentified)	*Procellariidae*
	XXP	Petrels, Prions and Shearwaters	*Hydrobatidae, Procellariidae & Pelecanoididae*
	XPS	Pied shag	*Phalacrocorax varius varius*
	XPN	Prion (unidentified)	*Pachyptila spp.*
	XPC	Procellaria petrels	*Procellaria spp.*
	XPT	Pterodroma petrels	*Pterodroma spp.*
	XRB	Red-billed gull	*Larus novaehollandiae scopulinus*
	XSB	Seabird	*<null>*

Table A.2: Abbreviated codes and names for turtle and seabird species and the aggregated species groups used to summarise various datasets. *(continued)*

Group	Species code	Common Name	Scientific name
Other birds	XSL	Seabird large	*<null>*
	XSS	Seabird small	*<null>*
	XSG	Seagull	*Larus spp.*
	XHG	Shag	*Phalacrocoracidae*
	XSW	Shearwaters	*Puffinus spp.*
	XTS	Short-tailed shearwater	*Puffinus tenuirostris*
	XCA	Snares cape petrel	*Daption capense australe*
	XSP	Southern giant petrel	*Macronectes giganteus*
	XPP	Spotted shag	*Stictocarbo punctatus*
	XSI	Stewart Island shag	*Leucocarbo chalconotus*
	XST	Storm petrel	*Hydrobatidae*
	XWP	Westland petrel	*Procellaria westlandica*
	XWF	White-faced storm petrel	*Pelagodroma marina maoriana*
	XWH	White-headed petrel	*Pterodroma lessonii*
	XWS	Wilsons storm petrel	*Oceanites oceanicus*
	XYP	Yellow Eyed Penguin	*Megadyptes antipodes*
Salvin's albatross	XSA	Salvins albatross	*Thalassarche salvini*
Sooty shearwater	XSH	Sooty shearwater	*Puffinus griseus*
Turtles	GNT	Green turtle	*Chelonia mydas*
	LBT	Leatherback turtle	*Dermochelys coriacea*
	LHT	Loggerhead turtle	*Caretta caretta*
	TLE	Turtle	*Chelonioidea*
White-capped albatross	XWM	White capped albatross	*Thalassarche cauta steadi*
White-chinned petrel	XWC	White-chinned petrel	*Procellaria aequinoctialis*

Table A.3: Capture rates per 1000 hooks for loggerhead turtles presented in reviewed sources by bait type, hook type/size, and offset. Total hooks are binned as follows: <10,000 = A; 10,000-100,000 = B; >100,000 = C. Some capture rates were estimated from graphs (*).

	Hook type	Hook size	Offset	Mean capture rate*	Total hooks	Source
Any bait						
	Circle	17/0	8	0.33	C	Mejuto et al. (2008)
	Circle	18/0	10	0.27	C	Mejuto et al. (2008)
	J	16/0	10	0.61	B	Mejuto et al. (2008)
Fish						
	Circle	16/0	0	0.12	B	Richards et al. (2012)
	Circle	18/0	0	0.01	B	Swimmer et al. (2017)
	Circle	18/0	0	0.13	A	Swimmer et al. (2017)
	Circle	18/0	0	0.39	NS	Swimmer et al. (2017)
	J	NS	0	0.22	B	Echwikhi et al. (2010)
	NS	NS	0	0.7	B	Mejuto et al. (2008)
Mackerel						
	Circle	16/0	0	0.58	NS	Brazner and McMillan (2008)
	Circle	17/0	0	0.3*	B	Santos et al. (2013)
	Circle	17/0	10	0.2*	B	Santos et al. (2013)
	Circle	18/0	10	0.04*	B	Watson et al. (2005)
	Circle	18/0	10	0.05	B	Richards et al. (2012)
	J	NS	0	0.18	NS	Brazner and McMillan (2008)
	J	NS	0	1.17	B	Echwikhi et al. (2010)
	J	9/0	20-25	0.15*	B	Watson et al. (2005)
	J	9/0	10	0.3*	B	Santos et al. (2013)
	NS	NS	0	0.18	C	Mejuto et al. (2008)
Squid						
	Circle	16/0	0	1	NS	Brazner and McMillan (2008)
	Circle	17/0	0	0.65*	B	Santos et al. (2013)
	Circle	18/0	10	0.05*	C	Watson et al. (2005)
	Circle	18/0	10	0.14	B	Richards et al. (2012)
	J	NS	0	1.27	NS	Brazner and McMillan (2008)
	J	9/0	20-25	0.5*	C	Watson et al. (2005)
	J	9/0	0	0.13	A	Swimmer et al. (2017)
	J	9/0	0	0.17	A	Swimmer et al. (2017)
	J	9/0	0	0.88	NS	Swimmer et al. (2017)
	J	9/0	10	1.5	B	Santos et al. (2013)
	NS	NS	0	0.61	C	Mejuto et al. (2008)

Table A.4: Capture rates per 1000 hooks for leatherback turtles presented in reviewed sources by bait type, hook type, hook size, and offset. Total hooks are binned as follows: <10,000 = A; 10,000-100,000 = B; >100,000 = C. Some capture rates were estimated from graphs (*).

	Hook type	Hook size	Offset	Mean capture rate	Total hooks	Source
Any bait						
	Circle	17/0	8	0.47	C	Mejuto et al. (2008)
	Circle	18/0	10	0.63	C	Mejuto et al. (2008)
	J	16/0	10	0.54	B	Mejuto et al. (2008)
Fish						
	Circle	16/0	0	0.00	B	Richards et al. (2012)
	Circle	18/0	10	0.00	C*	Gilman et al. (2007)
	Circle	18/0	0	0.01	B	Swimmer et al. (2017)
	Circle	18/0	0	0.08	A	Swimmer et al. (2017)
	Circle	18/0	0	0.16	NS	Swimmer et al. (2017)
	NS	NS	0	0.50	B	Mejuto et al. (2008)
Mackerel						
	Circle	17/0	0	0.00	B	Santos et al. (2013)
	Circle	17/0	10	0.01	B	Santos et al. (2013)
	Circle	17/0	0	0.05	C*	Santos et al. (2012)
	Circle	17/0	10	0.10	C*	Santos et al. (2012)
	Circle	18/0	10	0.16	B*	Watson et al. (2005)
	Circle	18/0	10	0.05	B	Richards et al. (2012)
	J	9/0	20-25	0.16	B*	Watson et al. (2005)
	J	9/0	10	0.04	B	Santos et al. (2013)
	J	9/0	0	0.31	C*	Santos et al. (2012)
	NS	NS	0	0.57	C	Mejuto et al. (2008)
Squid						
	Circle	17/0	0	0.60	B*	Santos et al. (2013)
	Circle	17/0	10	0.05	B	Santos et al. (2013)
	Circle	17/0	0	0.01	C*	Santos et al. (2012)
	Circle	17/0	10	0.18	C*	Santos et al. (2012)
	Circle	18/0	10	0.20	C*	Watson et al. (2005)
	Circle	18/0	10	0.17	B	Richards et al. (2012)
	J	9/0	20-25	0.50	C*	Watson et al. (2005)
	J	9/0	0	0.04	C*	Gilman et al. (2007)
	J	9/0	0	0.03	A	Swimmer et al. (2017)
	J	9/0	0	0.07	A	Swimmer et al. (2017)
	J	9/0	0	0.44	NS	Swimmer et al. (2017)
	J	9/0	10	0.19	B	Santos et al. (2013)
	J	9/0	0	0.42	C*	Santos et al. (2012)
	NS	NS	0	0.52	C	Mejuto et al. (2008)

Table A.5: Capture rates per 1000 hooks for all turtles combined (excluding studies that provided capture rates for leatherback and loggerhead independently) presented in reviewed sources by bait type, hook type, hook size, and offset. Total hooks are binned as follows: <10,000 = A; 10,000-100,000 = B; >100,000 = C. Some capture rates were estimated from graphs (*).

	Hook type	Hook size	Offset	Mean capture rate	Total hooks	Source
Any bait						
	Circle	14/0	0	1.38	NS	Read (2007)
	Circle	15/0	0	1.83	NS	Read (2007)
	Circle	16/0	10	0.76	NS	Read (2007)
	Circle	17/0	8	0.06	C	Mejuto et al. (2008)
	Circle	18/0	10	0.15	NS	Read (2007)
	Circle	18/0	10	0.06	C	Mejuto et al. (2008)
	J	9/0	0	1.36	NS	Read (2007)
	J	9/0	0	2.20	NS	Read (2007)
	J	16/0	10	0.07	B	Mejuto et al. (2008)
Fish						
	Circle	18/0	10	0.03	C*	Gilman et al. (2007)
	NS	NS	0	0.00	B	Mejuto et al. (2008)
Mackerel						
	Circle	17/0	0	0.45	C*	Coelho et al. (2015)
	Circle	17/0	10	0.85	C*	Coelho et al. (2015)
	Circle	17/0	0	0.30	B*	Santos et al. (2013)
	Circle	17/0	10	0.20	B*	Santos et al. (2013)
	Circle	17/0	0	0.25	C*	Santos et al. (2012)
	Circle	17/0	10	0.20	C*	Santos et al. (2012)
	Circle	17/0	0	0.25	C*	Santos et al. (2012)
	Circle	17/0	10	0.30	C*	Santos et al. (2012)
	J	9/0	10	1.10	C*	Coelho et al. (2015)
	J	9/0	10	0.35	B*	Santos et al. (2013)
	J	9/0	0	0.60	C*	Santos et al. (2012)
	J	9/0	0	0.90	C*	Santos et al. (2012)
	NS	NS	0	0.02	C	Mejuto et al. (2008)
Squid						
	Circle	17/0	0	0.65	C*	Coelho et al. (2015)
	Circle	17/0	10	0.95	C*	Coelho et al. (2015)
	Circle	17/0	0	0.75	B*	Santos et al. (2013)
	Circle	17/0	10	0.60	B*	Santos et al. (2013)
	Circle	17/0	0	0.45	C*	Santos et al. (2012)
	Circle	17/0	10	0.60	C*	Santos et al. (2012)
	Circle	17/0	0	0.80	C*	Santos et al. (2012)
	Circle	17/0	10	0.60	C*	Santos et al. (2012)
	J	9/0	0	0.17	C*	Gilman et al. (2007)
	J	9/0	10	1.34	C	Coelho et al. (2015)
	J	9/0	10	1.69	B	Santos et al. (2013)
	J	9/0	0	1.25	C*	Santos et al. (2012)
	J	9/0	0	1.80	C*	Santos et al. (2012)

Table A.5: Capture rates per 1000 hooks for all turtles combined (excluding studies that provided capture rates for leatherback and loggerhead independently) presented in reviewed sources by bait type, hook type, hook size, and offset. Total hooks are binned as follows: <10,000 = A; 10,000-100,000 = B; >100,000 = C. Some capture rates were estimated from graphs (*). *(continued)*

Hook type	Hook size	Offset	Mean capture rate	Total hooks	Source
NS	NS	0	0.11	C	Mejuto et al. (2008)

Table A.6: Sea turtle and seabird captures in surface longlines reported in the Protected Species Captures Database from 2010-2021, grouped by bait type. Bait mean % is the composition of hooks baited with a specific bait, averaged across all fishing events. SQU, arrow squid; SQX, squid spp.; FIS, fish spp.; JMD: greenback jack mackerel; JMA, jack mackerel; RBT, redbait; PIL, pilchard; SAP, Pacific saury; SAU, saury. See Table A.1 for scientific names.

Fishing year	Bait 1	Bait 2	Bait 3	Bait 1 mean %	Bait 2 mean %	Bait 3 mean %	Turtles	Other albatross	Other birds	Buller's albatross	Black petrel	Flesh-footed shearwater	Grey petrel	Salvin's albatross	Sooty shearwater	White-chinned petrel	White-capped albatross
	-	-	-	-	-	-	4	4	3	11	10	3	0	0	0	2	29
	SAP	SQU	-	20.0	80.0	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	-	-	100.0	-	-	0	2	5	6	0	0	0	0	0	0	23
17/18	SQU	PIL	-	95.0	5.0	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	SAN	-	82.5	17.5	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	SAU	-	75.7	24.3	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	SAU	JMD	73.3	18.3	8.3	0	0	0	0	0	0	0	0	0	0	0
	FIS	SQX	-	10.0	90.0	-	0	0	0	0	0	0	0	0	0	0	0
	SAP	SQU	-	40.0	60.0	-	0	0	1	0	0	0	0	0	0	0	0
	SAU	SQU	-	30.0	70.0	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	-	-	100.0	-	-	0	1	8	17	0	2	0	0	0	4	22
	SQU	FIS	-	84.5	15.5	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	FIS	SQU	75.0	16.7	8.3	0	0	0	0	0	0	0	0	0	0	0
18/19	SQU	JMA	-	90.0	10.0	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	PIL	-	81.1	18.9	-	0	0	0	0	3	0	0	0	0	0	0
	SQU	SAN	-	80.2	19.8	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	SAU	-	72.0	28.0	-	0	6	0	1	2	0	0	0	0	0	0
	SQX	-	-	100.0	-	-	0	0	0	0	0	0	0	0	0	0	0
	SQX	FIS	-	90.0	10.0	-	0	0	0	0	0	0	0	0	0	0	0
	SQX	SAN	-	68.6	31.4	-	0	0	0	0	0	0	0	0	0	0	0

Table A.6: Sea turtle and seabird captures in surface longlines reported in the Protected Species Captures Database from 2010-2021, grouped by bait type. Bait mean % is the composition of hooks baited with a specific bait, averaged across all fishing events. SQU, arrow squid; SQX, squid spp.; FIS, fish spp.; JMD: greenback jack mackerel; JMA, jack mackerel; RBT, redbait; PIL, pilchard; SAP, Pacific saury; SAU, saury. See Table A.1 for scientific names. *(continued)*

Fishing year	Bait 1	Bait 2	Bait 3	Bait 1 mean %	Bait 2 mean %	Bait 3 mean %	Turtles	Other albatross	Other birds	Buller's albatross	Black petrel	Flesh-footed shearwater	Grey petrel	Salvin's albatross	Sooty shearwater	White-chinned petrel	White-capped albatross
19/20	JMA	-	-	100.0	-	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	-	-	100.0	-	-	1	0	2	0	0	0	0	0	0	1	1
	SQU	RBT	-	60.0	40.0	-	0	0	0	0	0	0	0	0	0	0	1
	SQU	RBT	JMA	57.1	34.4	8.4	2	6	0	0	0	0	0	0	0	0	0
	SQU	SAN	-	70.6	29.4	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	SAP	-	78.6	21.4	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	SAU	-	69.2	30.8	-	0	1	0	0	5	6	0	0	0	0	0
	SQX	SAN	-	49.5	50.5	-	0	0	0	0	0	0	0	0	0	0	0
20/21	SAP	SQU	-	28.6	71.4	-	2	0	0	0	3	0	0	1	0	0	0
	SQU	-	-	100.0	-	-	6	2	5	6	3	1	0	0	0	4	19
	SQU	PIL	-	91.7	8.3	-	0	0	0	0	0	0	0	0	0	0	0
	SQU	PIL	SAU	80.0	10.0	10.0	0	0	0	0	0	0	0	0	0	0	0
	SQU	SAN	-	61.4	38.6	-	2	0	1	0	0	0	0	0	0	0	0
	SQU	SAU	-	91.7	8.3	-	0	0	0	0	0	0	0	0	0	0	0
	SQX	-	-	100.0	-	-	7	1	0	1	2	0	0	0	0	0	0
	SQX	SAN	-	50.0	50.0	-	4	0	0	0	0	0	0	0	0	0	0

Table A.7: Annual sea turtle and seabird captures for surface longline fishing events where hook and bait type were reported in the Protected Species Captures Database from 2017-2021. SQU, arrow squid; SQX, squid spp.; FIS, fish spp.; JMD: greenback jack mackerel; JMA, jack mackerel; RBT, redbait; PIL, pilchard; SAP, Pacific saury; SAU, saury. See Table A.1 for scientific names.

Fishing year	Hook type	Bait type	Trips	Turtles	Other birds	Other albatross	Buller's albatross	White-chinned petrel	White-capped albatross	Black petrel	Flesh-footed shearwater	Grey petrel	Salvin's albatross	Total
17/18	16/0 circle	SQU	1	0	3	1	0	1	0	0	7	0	0	**12**
	Circle (tuna)	SQU	1	0	2	1	0	5	0	0	16	0	0	**24**
18/19	14/0 circle	SQU	1	0	0	1	0	1	0	4	1	0	0	**7**
	16/0 circle	SQU	3	0	8	0	0	15	2	0	20	0	0	**45**
	16/0 circle	SQU; SAP; SAP	1	0	1	0	0	0	0	0	0	0	0	**1**
	16/0 circle	SQU; SAU	1	0	0	6	2	1	0	0	0	0	0	**9**
	16/0 circle (tuna)	SQU	1	0	0	0	0	1	0	0	1	0	0	**2**
	18/0 circle (tuna)	SQU; PIL	1	0	0	0	3	0	0	0	0	0	0	**3**
19/20	16/0 circle	SQU	3	0	2	0	0	0	0	1	1	0	0	**4**
	16/0 circle (tuna)	SQU; SAP; RBT; JMA	1	3	0	6	0	0	0	0	1	0	0	**10**
	17/0 circle	SQU; SAU	1	0	0	1	5	0	6	0	0	0	0	**12**

Table A.7: Annual sea turtle and seabird captures for surface longline fishing events where hook and bait type were reported in the Protected Species Captures Database from 2017-2021. SQU, arrow squid; SQX, squid spp.; FIS, fish spp.; JMD: greenback jack mackerel; JMA, jack mackerel; RBT, redbait; PIL, pilchard; SAP, Pacific saury; SAU, saury. See Table A.1 for scientific names. *(continued)*

Fishing year	Hook type	Bait type	Trips	Turtles	Other birds	Other albatross	Buller's albatross	White-chinned petrel	White-capped albatross	Black petrel	Flesh-footed shearwater	Grey petrel	Salvin's alba-tross	Total
20/21	14/0 circle	SQU	1	0	0	1	0	1	0	4	2	0	0	**8**
	15/0 circle	SQU	1	0	0	1	0	0	0	0	2	0	0	**3**
	16/0 circle	SQU	2	1	1	0	0	0	0	0	7	0	0	**9**
	16/0 circle	SQU; SAP; SAP	1	7	1	0	1	0	0	0	0	0	0	**9**
	16/0 circle	SQX; SAP	1	11	0	1	2	1	0	0	0	0	0	**15**
	16/0 circle (tuna)	SQU; SAP; SAP	1	2	0	0	5	0	1	0	0	0	1	**9**
	16/0 offset circle	SQU	1	0	2	0	0	0	0	0	1	0	0	**3**
	17/0 circle	SQU	1	0	2	0	0	5	0	0	7	0	0	**14**
Total			**31**	**28**	**25**	**23**	**28**	**42**	**12**	**11**	**95**	**0**	**1**	**265**

Table A.8: Summary of the location of hook position for necropsied seabirds from January 2020-March 2024 for each seabird species.

Species Code	Common Name	Bill	Neck/Throat	Wing	Other location	Swallowed	Tangled/Impact	Unknown	Total
XAN	Antipodean albatross	0	1	0	1	2	0	0	**4**
XKM	Black-browed albatross (unidentified)	0	0	0	0	0	0	1	**1**
XBM	Buller's albatross	3	2	0	0	1	0	8	**14**
XPB	Buller's and Pacific albatross	0	0	0	2	0	0	0	**2**
XCM	Campbell albatross	0	0	0	0	0	0	1	**1**
XWM	New Zealand white-capped albatross	7	1	4	0	2	0	18	**32**
XNR	Northern royal albatross	1	1	0	0	0	0	0	**2**
XNB	Pacific albatross	0	0	0	0	0	0	1	**1**
XRU	Royal albatross (unidentified)	0	1	0	0	0	0	0	**1**
XSA	Salvin's albatross	0	0	4	0	0	0	1	**5**
XMA	Small albatross (unidentified)	0	0	0	0	0	0	2	**2**
XSM	Southern black-browed albatross	0	1	0	0	0	0	0	**1**
XRA	Southern royal albatross	0	1	0	0	0	1	2	**4**
XAL	Albatross (unidentified)	0	0	0	0	0	0	1	**1**
XFP	Fairy prion	0	0	0	0	0	2	0	**2**
XRB	Red-billed gull	0	1	0	0	0	0	0	**1**
XBP	Black (Parkinson's) petrel	1	0	0	2	0	1	5	**9**
XGP	Grey petrel	1	0	0	0	1	0	2	**4**
XST	Storm petrel (unidentified)	0	0	0	0	0	2	0	**2**
XWP	Westland petrel	6	1	8	0	1	5	10	**31**
XWC	White-chinned petrel	16	21	21	8	1	6	84	**157**
XFS	Flesh-footed shearwater	3	1	3	3	0	2	34	**46**
XFL	Fluttering shearwater	0	0	0	0	0	0	1	**1**
XSH	Sooty shearwater	1	0	2	0	0	1	1	**5**
Total		**39**	**32**	**42**	**16**	**8**	**20**	**172**	**329**

B. Appendix B

The following is the Microsoft Forms questionnaire delivered to 17 SLL operators in New Zealand. The survey can be accessed online at: Preferred hook/bait in surface longline fisheries questionnaire.

Preferred hook/bait in surface longline fisheries in New Zealand

This project MIT2023-01 is a pilot study as part of the Department of Conservation's (DOC) Conservation Services Programme. The effect of hook size and bait type on seabird and sea turtle bycatch rates are being investigated across different target longline fisheries. The aim of this questionnaire is to understand current gear being used across the surface longline fleet.

Proteus Research and Consulting has been contracted to prepare this a questionnaire for surface longline (SLL) operators to identify preferred hook size and bait type. This questionnaire is administered on behalf of DOC.

INSTRUCTIONS:
For any multiple choice field with a CIRCLE, please select only one answer.
For any multiple choice field with a SQUARE, you can select multiple answers, if appropriate.

Operator information

1. Name of operator

2. Vessel name

3. Vessel length (m)

Hook and bait type when targeting STN

Answer all questions about the gear you currently use unless otherwise stated.

4. Do you target southern bluefin tuna?

- ◯ Yes
- ◯ No

5. What **hook type/size** do you currently use when targeting STN?

Select multiple options if more than one type/size is used.

- ☐ Circle 7/0
- ☐ Circle 9/0
- ☐ Circle 12/0
- ☐ Circle 13/0
- ☐ Circle 14/0
- ☐ Circle 15/0
- ☐ Circle 16/0
- ☐ Circle 17/0
- ☐ Circle 18/0
- ☐ Other

6. What is the proportion of each hook type/size when targeting STN?

E.g., Circle 15/0 60% and circle 18/0 40%.

7. Describe the type/configuration of any weights that are integrated into the hook

E.g., swivels with leads, weighted shanks. Leave blank if not used.

8. What **barb offset angle** of the hook do you use when targeting STN?

- ☐ None
- ☐ 10 degrees
- ☐ Don't know/unsure
- ☐ Other

9. What **bait species** do you use when targeting STN?

- [ ] Squid (species unknown)
- [ ] Arrow squid (SQU)
- [ ] Fish (species unknown)
- [ ] Mackerel (species unknown)
- [ ] Jack mackerel (JMA)
- [ ] Pilchard (PIL)
- [ ] Saury (SAU)
- [ ] Artificial bait
- [ ] Other

10. **In a single set,** what **percentage of hooks** are **baited with SQUID** when targeting STN?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

11. **In a single set,** what **percentage of hooks** are **baited with FISH (e.g., mackerel)** when targeting STN?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

12. **In a single set,** what **percentage of hooks** are **baited with ARTIFICIAL BAIT** when targeting STN?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

13. Does the composition of the baited line (i.e., percentage of squid v. fish) **change between sets**? If so how/when?

E.g., yes, 50% of sets baited with squid and 50% of sets baited with fish depending on lunar cycle

14. Do you use **dyed bait** when targeting STN?

If colour other than blue is used, select 'Other' and indicate what colour.

- ○ Yes - blue
- ○ No
- ○ Other

15. How frequently do you use dyed bait when targeting STN?
E.g., 6 days/month based on lunar phase

16. If you have changed the **HOOK TYPE/SIZE** in the last 5 years, how do you think it has affected the **catch rate of STN?**

- ◯ I have not changed hook size/type in the last 5 years
- ◯ Increases catch rate
- ◯ Decreases catch rate
- ◯ Neither increases or decreases
- ◯ Unsure
- ◯ Other

17. If you have changed the **HOOK OFFSET** in the last 5 years, how do you think it has affected the **catch rate of STN?**

- ◯ I have not changed hook offset in the last 5 years
- ◯ Increases catch rate
- ◯ Decreases catch rate
- ◯ Neither increases or decreases
- ◯ Unsure
- ◯ Other

18. If you have changed the **BAIT COMPOSITION** in the last 5 years, how do you think it has affected the **catch rate of STN?**

- ◯ I have not changed bait composition in the last 5 years
- ◯ Increases catch rate
- ◯ Decreases catch rate
- ◯ Neither increases or decreases
- ◯ Unsure
- ◯ Other

Hook and bait type when targeting BIG

Answer all questions about the gear you currently use unless otherwise stated.

19. Do you target bigeye tuna?

If hook/bait type is the same as previously answered, skip to next section.

- ◯ Yes, and hook/bait type is different for all target
- ◯ Yes, and hook/bait type is the same for all target species
- ◯ No

20. What **hook type/size** do you currently use when targeting BIG?

Select multiple options if more than one type/size is used.

- ☐ Circle 7/0
- ☐ Circle 9/0
- ☐ Circle 12/0
- ☐ Circle 13/0
- ☐ Circle 14/0
- ☐ Circle 15/0
- ☐ Circle 16/0
- ☐ Circle 17/0
- ☐ Circle 18/0
- ☐ Other

21. What is the proportion of each hook type/size when targeting BIG?

E.g., Circle 15/0 60% and circle 18/0 40%.

22. Describe the type/configuration of any weights that are integrated into the hook

E.g., swivels with leads, weighted shanks. Leave blank if not used.

23. What **barb offset angle** of the hook do you use when targeting BIG?

- ☐ None
- ☐ 10 degrees
- ☐ Don't know/unsure
- ☐ Other

24. What **bait species** do you use when targeting BIG?

- [ ] Squid (species unknown)
- [ ] Arrow squid (SQU)
- [ ] Fish (species unknown)
- [ ] Mackerel (species unknown)
- [ ] Jack mackerel (JMA)
- [ ] Pilchard (PIL)
- [ ] Saury (SAU)
- [ ] Artificial bait
- [ ] Other

25. **In a single set,** what **percentage of hooks** are **baited with SQUID** when targeting BIG?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

26. **In a single set,** what **percentage of hooks** are **baited with FISH (e.g., mackerel)** when targeting BIG?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

27. **In a single set,** what **percentage of hooks** are **baited with ARTIFICIAL BAIT** when targeting BIG?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

28. Does the composition of the baited line (i.e., percentage of squid v. fish) **change between sets**? If so how/when?

E.g., yes, 50% of sets baited with squid and 50% of sets baited with fish depending on lunar cycle

29. Do you use **dyed bait** when targeting BIG?

If colour other than blue is used, select 'Other' and indicate what colour.

- ○ Yes - blue
- ○ No
- ○ Other

30. How frequently do you use dyed bait when targeting BIG?

E.g., 6 days/month based on lunar phase

31. If you have changed the **HOOK TYPE/SIZE** in the last 5 years, how do you think it has affected the **catch rate of BIG?**

- I have not changed hook size/type in the last 5 years
- Increases catch rate
- Decreases catch rate
- Neither increases or decreases
- Unsure
- Other

32. If you have changed the **HOOK OFFSET** in the last 5 years, how do you think it has affected the **catch rate of BIG?**

- I have not changed hook offset in the last 5 years
- Increases catch rate
- Decreases catch rate
- Neither increases or decreases
- Unsure
- Other

33. If you have changed the **BAIT COMPOSITION** in the last 5 years, how do you think it has affected the **catch rate of BIG?**

- I have not changed bait composition in the last 5 years
- Increases catch rate
- Decreases catch rate
- Neither increases or decreases
- Unsure
- Other

Hook and bait type when targeting SWO

Answer all questions about the gear you currently use unless otherwise stated.

34. Do you target swordfish?

If hook/bait type is the same as previously answered, skip to next section.

- ◯ Yes, and hook/bait type is different for all target species
- ◯ Yes, and hook/bait type is the same for all target species
- ◯ No

35. What **hook type/size** do you currently use when targeting SWO?

Select multiple options if more than one type/size is used.

- ☐ Circle 7/0
- ☐ Circle 9/0
- ☐ Circle 12/0
- ☐ Circle 13/0
- ☐ Circle 14/0
- ☐ Circle 15/0
- ☐ Circle 16/0
- ☐ Circle 17/0
- ☐ Circle 18/0
- ☐ Other

36. What is the proportion of each hook type/size when targeting SWO?

E.g., Circle 15/0 60% and circle 18/0 40%.

37. Describe the type/configuration of any weights that are integrated into the hook

E.g., swivels with leads, weighted shanks. Leave blank if not used.

38. What **barb offset angle** of the hook do you use when targeting SWO?

- ☐ None
- ☐ 10 degrees
- ☐ Don't know/unsure
- ☐ Other

39. What **bait species** do you use when targeting SWO?

- ☐ Squid (species unknown)
- ☐ Arrow squid (SQU)
- ☐ Fish (species unknown)
- ☐ Mackerel (species unknown)
- ☐ Jack mackerel (JMA)
- ☐ Pilchard (PIL)
- ☐ Saury (SAU)
- ☐ Artificial bait
- ☐ Other

40. **In a single set,** what **percentage of hooks** are **baited with SQUID** when targeting SWO?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

41. **In a single set,** what **percentage of hooks** are **baited with FISH (e.g., mackerel)** when targeting SWO?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

42. **In a single set,** what **percentage of hooks** are **baited with ARTIFICIAL BAIT** when targeting STN?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

43. Does the composition of the baited line (i.e., percentage of squid v. fish) **change between sets**? If so how/when?

E.g., yes, 50% of sets baited with squid and 50% of sets baited with fish depending on lunar cycle

44. Do you use **dyed bait** when targeting SWO?

If colour other than blue is used, select 'Other' and indicate what colour.

- ○ Yes - blue
- ○ No
- ○ Other

45. How frequently do you use dyed bait when targeting SWO?

E.g., 6 days/month based on lunar phase

46. If you have changed the **HOOK TYPE/SIZE** in the last 5 years, how do you think it has affected the **catch rate of SWO?**

- I have not changed hook size/type in the last 5 years
- Increases catch rate
- Decreases catch rate
- Neither increases or decreases
- Unsure
- Other

47. If you have changed the **HOOK OFFSET** in the last 5 years, how do you think it has affected the **catch rate of SWO?**

- I have not changed hook offset in the last 5 years
- Increases catch rate
- Decreases catch rate
- Neither increases or decreases
- Unsure
- Other

48. If you have changed the **BAIT COMPOSITION** in the last 5 years, how do you think it has affected the **catch rate of SWO?**

- I have not changed bait composition in the last 5 years
- Increases catch rate
- Decreases catch rate
- Neither increases or decreases
- Unsure
- Other

Hook and bait type when targeting OTHER

Answer all questions about the gear you currently use unless otherwise stated.

49. Do you target other species?

If hook/bait type is the same as previously answered, specific species and skip to next section.

- ○ Yes, and hook/bait type is different for all target species
- ○ Yes, and hook/bait type is the same for all target species
- ○ No

50. What species?

[ ]

51. What **hook type/size** do you currently use when targeting OTHER SPECIES?

Select multiple options if more than one type/size is used.

- ☐ Circle 7/0
- ☐ Circle 9/0
- ☐ Circle 12/0
- ☐ Circle 13/0
- ☐ Circle 14/0
- ☐ Circle 15/0
- ☐ Circle 16/0
- ☐ Circle 17/0
- ☐ Circle 18/0
- ☐ Other

52. What is the proportion of each hook type/size when targeting OTHER SPECIES?

E.g., Circle 15/0 60% and circle 18/0 40%.

[ ]

53. Describe the type/configuration of any weights that are integrated into the hook

E.g., swivels with leads, weighted shanks. Leave blank if not used.

[ ]

54. What **barb offset angle** of the hook do you use when targeting OTHER SPECIES?

- [ ] None
- [ ] 10 degrees
- [ ] Don't know/unsure
- [ ] Other

55. What **bait species** do you use when targeting OTHER SPECIES?

- [ ] Squid (species unknown)
- [ ] Arrow squid (SQU)
- [ ] Fish (species unknown)
- [ ] Mackerel (species unknown)
- [ ] Jack mackerel (JMA)
- [ ] Pilchard (PIL)
- [ ] Saury (SAU)
- [ ] Artificial bait
- [ ] Other

56. **In a single set,** what **percentage of hooks** are **baited with SQUID** when targeting OTHER SPECIES?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

57. **In a single set,** what **percentage of hooks** are **baited with FISH (e.g., mackerel)** when targeting OTHER SPECIES?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

58. **In a single set,** what **percentage of hooks** are **baited with ARTIFICIAL BAIT** when targeting OTHER SPECIES?

If percentages vary per set, provide an average percentage or rough estimate

The value must be a number

59. Does the composition of the baited line (i.e., percentage of squid v. fish) **change between sets**? If so how/when?

E.g., yes, 50% of sets baited with squid and 50% of sets baited with fish depending on lunar cycle

60. Do you use **dyed bait** when targeting OTHER SPECIES?

If colour other than blue is used, select 'Other' and indicate what colour.

- ◯ Yes - blue
- ◯ No
- ◯ Other

61. How frequently do you use dyed bait when targeting OTHER SPECIES?

E.g., 6 days/month based on lunar phase

62. If you have changed the **HOOK TYPE/SIZE** in the last 5 years, how do you think it has affected the **catch rate of OTHER SPECIES?**

- ◯ I have not changed hook size/type in the last 5 years
- ◯ Increases catch rate
- ◯ Decreases catch rate
- ◯ Neither increases or decreases
- ◯ Unsure
- ◯ Other

63. If you have changed the **HOOK OFFSET** in the last 5 years, how do you think it has affected the **catch rate of OTHER SPECIES?**

- ◯ I have not changed hook offset in the last 5 years
- ◯ Increases catch rate
- ◯ Decreases catch rate
- ◯ Neither increases or decreases
- ◯ Unsure
- ◯ Other

64. If you have changed the **BAIT COMPOSITION** in the last 5 years, how do you think it has affected the **catch rate of OTHER SPECIES?**

- ◯ I have not changed bait composition in the last 5 years
- ◯ Increases catch rate
- ◯ Decreases catch rate
- ◯ Neither increases or decreases
- ◯ Unsure
- ◯ Other

Protected species

65. Do you foresee any problems with **increasing the circle hook size to at least 16/0** to reduce the risk of seabird/sea turtle bycatch?

◯ Yes

◯ No

◯ Maybe

◯ Other

66. Do you foresee any problems with **changing the circle hook offset to 10 degrees** (and no larger) to reduce the risk of seabird/sea turtle bycatch?

◯ Yes

◯ No

◯ Maybe

◯ Other

67. Do you foresee any problems with **increasing the ratio of fish bait to squid** to reduce the risk of seabird/sea turtle bycatch?

◯ Yes

◯ No

◯ Maybe

◯ Other

68. Which protected species are you **most concerned about interacting** with your fishing gear?

◯ Seabirds

◯ Sea turtles

◯ Both seabirds and sea turtles

◯ None

◯ Other

69. Would you **change your fishing practices** in the presence of seabirds/sea turtles to attempt to mitigate bycatch risk?

- ◯ Yes - for seabirds only
- ◯ Yes - for turtles only
- ◯ Yes - for both seabirds/sea turtles
- ◯ No
- ◯ Unsure
- ◯ Other

70. How?

71. Do you have any other relevant comments about how certain types of hooks and bait affect **target or bycatch rates?**

DRAFT

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