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

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Client Report for the Department of Conservation, Conservation Services Programme

9 October 2024

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Citation: Hickcox, R.P. Meyer, S., and MacKenzie, D.I. (2024). Effects of hook and bait type on commercial longline fisheries bycatch (MIT2023-01). Report for the Department of Conservation, Conservation Services Programme, Proteus Client Report: 187. Proteus, Outram, New Zealand.

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Contents

Executive Summary

Hook size and bait type affect seabird and sea turtle bycatch risk in longline 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 surface longline (SLL) fishers via the Department of Conservation, are presented 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, squid, fish, or a combination are primarily used as bait in longline fisheries. 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.

A review of bycatch data obtained from several sources, which includes observer-reported data, fisher-reported data, and necropsy data, revealed that data are may be insufficient to conduct 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 could prevent a comparison of bycatch rates across different baits and hooks. It will also take considerable effort to link all the different tables across the different databases.

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.

Based on this review, recommendations in international guidelines adhere to the most current knowledge of the most effective hook and bait type for seabird and/or sea turtle bycatch mitigation. Typical recommendations include the use of large circle hooks (16/0 or larger) with offsets less than 10° and the use of fish bait where possible. It is also commonly suggested to use additional 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. More research is required to determine if dying bait is effective at reducing turtle and seabird bycatch

It is also recommended that New Zealand electronic catch and effort reporting for both surface and longline fisheries be at the trip and station level (not just associated with a protected species capture) and include additional information on hook type, size, offset, and manufacturer, along with information on bait species, hooking method, and bait state.

Lastly, more research is required to understand how bait and hooks influence bycatch rates for both sea turtles and seabirds in New Zealand. Future analyses should quantify catch rates of target and non-target species using fish versus squid as bait and smaller versus larger circle hooks, considering different combinations of hooks and baits that are currently being used on longline vessels.

1. Introduction

In commercial surface longline (SLL) and bottom longline (BLL) 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 (Peat et al., 2024; 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, including small albatross (*Diomedeidae*), shearwaters, and petrels (*Procellariidae*), 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, such as line weighting, night setting, and bird scaring lines/tori lines (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 longline fisheries. While the particular focus is on surface longlining, the scope of the project was extended to include bottom longlining as well. International best practices were 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 (hence the focus on SLL literature). The questionnaire was administered by John Cleal, Department of Conservation Liaison Officer.

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. 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. Additional sources suggested during the review process have also been included.

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 Data sources for New Zealand bycatch

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. This review is intended to support future data analysis of these datasets, rather than to conduct data analysis. Thus, the databases are described below, but no further data summaries or analyses were completed. 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 longline fisheries catch and effort information, sample size, data limitations, confounding factors, and available level of detail.

2.2.1 Observer and fisher-reported data

Data collected by the MPI Observer Services Programme are stored in the Centralised Observer Database (COD) (Sanders & Fisher, 2024), and data reported by fishers are stored in the Enterprise Data Warehouse (EDW). Database extracts for 2010-2021 were provided by MPI on 6 March 2024 for SLL and 19 September 2024 for BLL events. The relevant COD data for this project were catch and effort information or observed commercial fishing vessels, tables containing bait or hook information for fishing events, as well as data on protected species bycatch.

2.2.2 Protected species captures data

The Protected Species Captures (PSC) Database (Abraham & Berkenbusch, 2019) 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 EDW. The PSC database is often used for risk assessments and estimations of protected species captures within New Zealand's Exclusive Economic Zone (e.g., Abraham et al., 2017). The entire PSC database (up to 2021-2022 fishing year) was provided by MPI on 6 March 2024.

For this review, turtle and seabird captures data from the PSC database were extracted, and the COD was used to expand the PSC database with information on hook size and bait type, which are attributes that are not originally contained within the PSC database. No additional data cleaning was completed with the COD and PSC databases. See Results section 3.5.1 for descriptions of specific tables related to hook and bait type in longline fisheries.

2.2.3 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). Data extract from January 2020 to March 2024 was received from DOC/WMIL on 14 April 2024. This 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 investigating trip number and fishing event information were not investigated, although this information exists in the native database and could be used in future studies, as has been done for CSP INT2023-08 investigating albatross diet.

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 DOC to ensure wording, question types, and question topics were correct and sufficient to obtain the desired information. John Cleal, DOC 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 four 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 (v. 4.3.2)(R Core Team, 2023) using *tidyverse* packages (Wickham et al., 2019). Plots were made using *ggplot2* (v3.5.0) (Wickham, 2016). 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), 30 published articles or reports were reviewed (Table 3.1). Of these, nine examined the effects of dyed bait on sea turtle and seabird bycatch rates (Boggs, 2001; Cocking et al., 2008; Gilman et al., 2003; Lydon & Starr, 2004; Minami & Kiyota, 2004; Minami & Kiyota, 2006; 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), seven studies for turtles (Bolten & Bjorndal, 2005; Cambiè et al., 2012; Lima et al., 2023; Pacheco et al., 2011; Piovano et al., 2012; Read, 2007; Sales et al., 2010), 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).

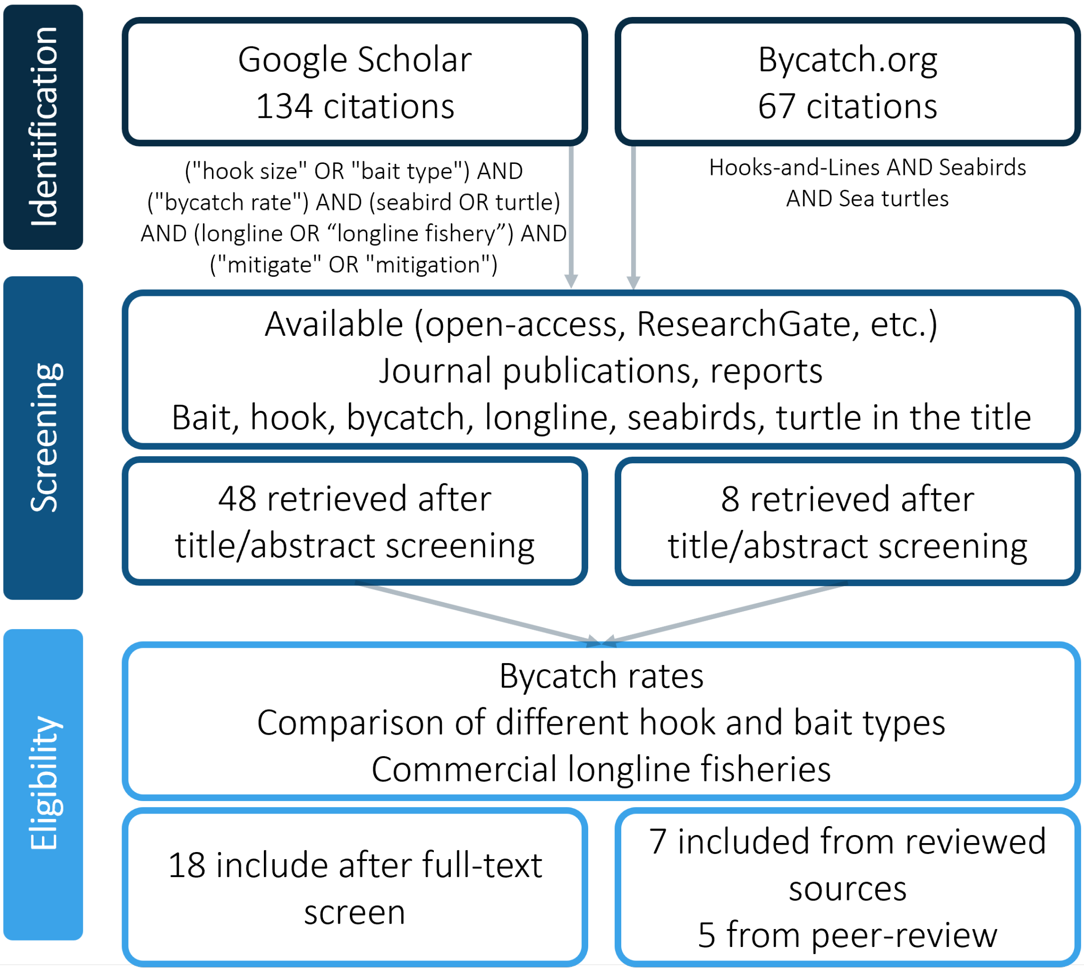

Figure 3.1: Diagram of the systematic review screening process.

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					
Boggs (2001)	U.S. Pacific (Laysan Island, HI)	S	1999	1	SB
Ochi et al. (2011)	South Africa	T	2001-2002	3	SB
Minami and Kiyota (2004)	South Africa	T	2001-2002	2	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
Gilman et al. (2003)	U.S. Pacific (Laysan Island, HI)	S; T	2003	1	SB
Minami and Kiyota (2006)	South Africa	T	2003-2004	1	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
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
Sales et al. (2010)	Brazil	S; T	2004-2008	4	LH; LB; GR
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
Sullivan et al. (2018)	South Africa; Brazil; Australia	S; T	2011-2015	7	LH; LB; SB
Bait + hook type					
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

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
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 used in international longline fisheries is squid (*Loligo spp., Illex spp.*) and fish (mackerel *Scomber spp., Trachurus spp*.; pilchard/sardine *Sardinops spp., Sardinella spp.*). Some fisheries including the U.S. Atlantic (Swimmer et al., 2017) Mediterranean Sea (Báez et al., 2010) swordfish fisheries, and New Zealand tuna fishery 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 fishers also use artificial lures made of various materials, although this is less common.

3.2.1 Dyed bait

Bait dying with non-toxic colouring (typically blue) is a common international practice that is thought to decrease the visibility of bait when in the water, thus 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 thirteen sources that looked at seabird bycatch rates (out of the 30 reviewed sources), half compared captures using dyed and undyed bait. Seven out of the nine sources that presented data on dyed bait focused on seabirds. Based on vessel management plans, it is common in New Zealand to have blue dye onboard longline vessels but to only dye bait around full moon days or if there is high seabird attendance around the vessel (J. Cleal, pers. comm.).

Studies on the effectiveness of bait dying showed mixed results. 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. However, they also found a lower target species catch rate per unit effort when dyed bait was used. In the Japanese bluefin tuna fishery operating in South Africa, (Minami & Kiyota, 2004) reported a reduction in seabird capture rates when using dyed fish and squid mixed bait, which was further reduced when tori lines were simultaneously used. This study was repeated two years later and found the same results (Minami & Kiyota, 2006). However, these reports did not provide enough information about methods or results to determine accurate rates. Boggs (2001) reported a decrease in the contact rates of two albatross species when dyed squid was used as bait in the Laysan Island swordfish fishery. For black-footed albatross (*Phoebastria nigripes*), contacts per bird per 1000 hooks declined from 0.83 to 0.46 with dyed bait (decline of 95%); for Laysan albatross (*Phoebastria immutabilis*), contacts per bird per 1000 hooks declined from 0.69 to 0.039 with dyed bait (93%).

Another study from the Laysan Island swordfish and tuna fishery furthered this study by testing "seabird avoidance methods" including side setting, dyed bait, and underwater setting chutes (Gilman et al., 2003) . With dyed bait, there were on average 0.61 albatross contacts and 0.03 captures per 1000 hooks/bird (tuna fishery) and 2.37 albatross contacts and 0.08 captures per 1000 hooks/bird (swordfish fishery). However, there was no control to compare these rates to. Rather, Gilman et al. (2003) further discussed advantages and disadvantages to using dyed bait. They found that crew perceived that blue-dyed bait was effective at avoiding captures but not effective enough. This is especially true if the bait is thawed more, which happens when dying bait, so birds are able to remove bait from hooks more easily, reducing interaction time. However, fishers tend to prefer slightly frozen bait for this reason, as its retention on hooks is higher and it is easier to bait the hook. The efficacy is also highly dependent on the darkness of the dye, setting methods, weather, number of birds in attendance, and other factors. They note that pre-dyed bait is not commercially available, which makes dying bait inconvenient for the crew.

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. 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, 2001) (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. (2003), Gilman et al. (2007), and Watson et al. (2005) suggested that bait type did not significantly affect target species catch rates, although Watson et al. (2005) indicated a lower catch rate for their secondary target species, bigeye tuna. Minami & Kiyota (2004) and Minami & Kiyota (2006) also found a non-significant decrease in tuna catch rates using dyed bait.

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.

In the Brazilian tuna and swordfish fishery, captures of sea turtles also significantly declined with the use of mackerel baited 18/0 circle hooks compared to 9/0 J hooks (Sales et al., 2010). The probability of capturing a loggerhead decreased by 55% (0.1.605 turtles/1000 J hooks to 0.727 turtles/1000 circle hooks). The probability of capturing a leatherback decreased by 65% (0.274 turtles/1000 J hooks to 0.096 turtles/1000 circle hooks).

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 four 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; Sales et al., 2010). Brazner & McMillan (2008) reported a significant decrease in sea turtle captures that had swallowed a J hook (10.1%) or circle hook (3.5%), and Sales et al. (2010) reported a decrease in deep-hooking of loggerhead turtles from 25% to 5.8% with circle hooks. 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). Three studies presented mixed results (swordfish, Watson et al., 2005; swordfish and tuna, Domingo et al., 2012; Sales et al., 2010). 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 (see also Howard, 2015). 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. A review Howard (2015) on shark bycatch mitigation in New Zealand longline fisheries showed varied success in use of squid or fish bait to reduce bycatch due to species-specific differences but ranked the use of squid the highest.

As mentioned previously, switching to fish bait might reduce shark bycatch (e.g., Boggs, 2001) or increase shark bycatch rates (K. Middlemiss, pers. comm.).

3.3.5 Hookpods as shielding devices

Hookpods, a type of hook-shielding device, 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. Hookpods were trialed as a mitigation measure in the New Zealand SLL fleet, and, as of October 2024, will be mandatory (unless three other mitigation methods are used simultaneously).

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 of turtles combined and for leatherback, and loggerhead turtles individually. 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).

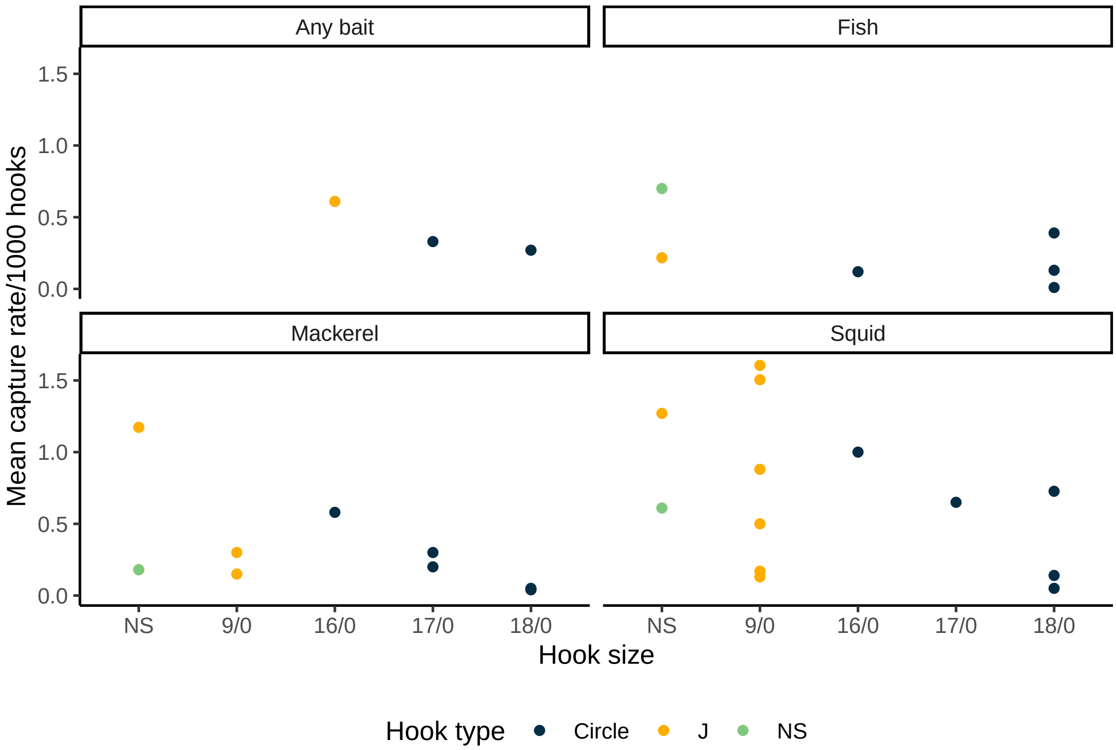

Figure 3.3: Loggerhead turtle estimated capture rates per 1000 hooks from reviewed sources. Rates are compared for different bait types by different hook types (shape) and sizes (size and colour). Capture rates where bait type was not specified or not considered are grouped as 'Any bait'. NS means 'not 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.

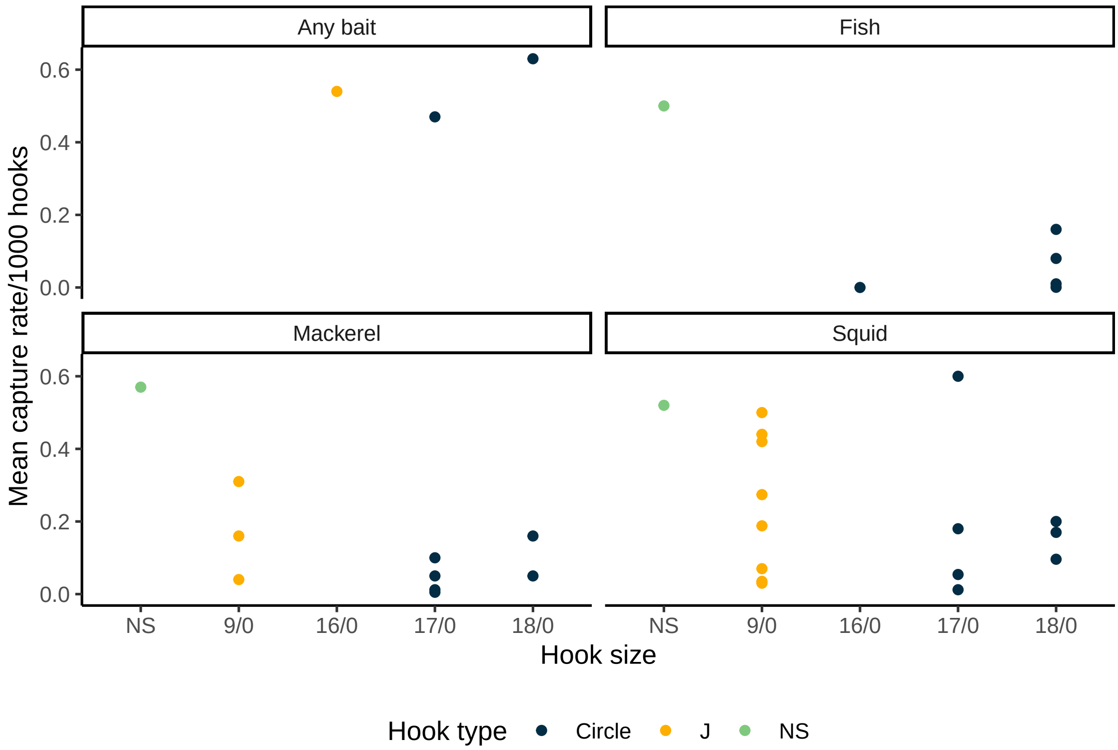

Figure 3.4: Leatherback turtle estimated capture rates per 1000 hooks from reviewed sources. Rates are compared for different bait types by different hook types (shape) and sizes (size and colour). Capture rates where bait type was not specified or not considered are grouped as 'Any bait'. NS means 'not 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.

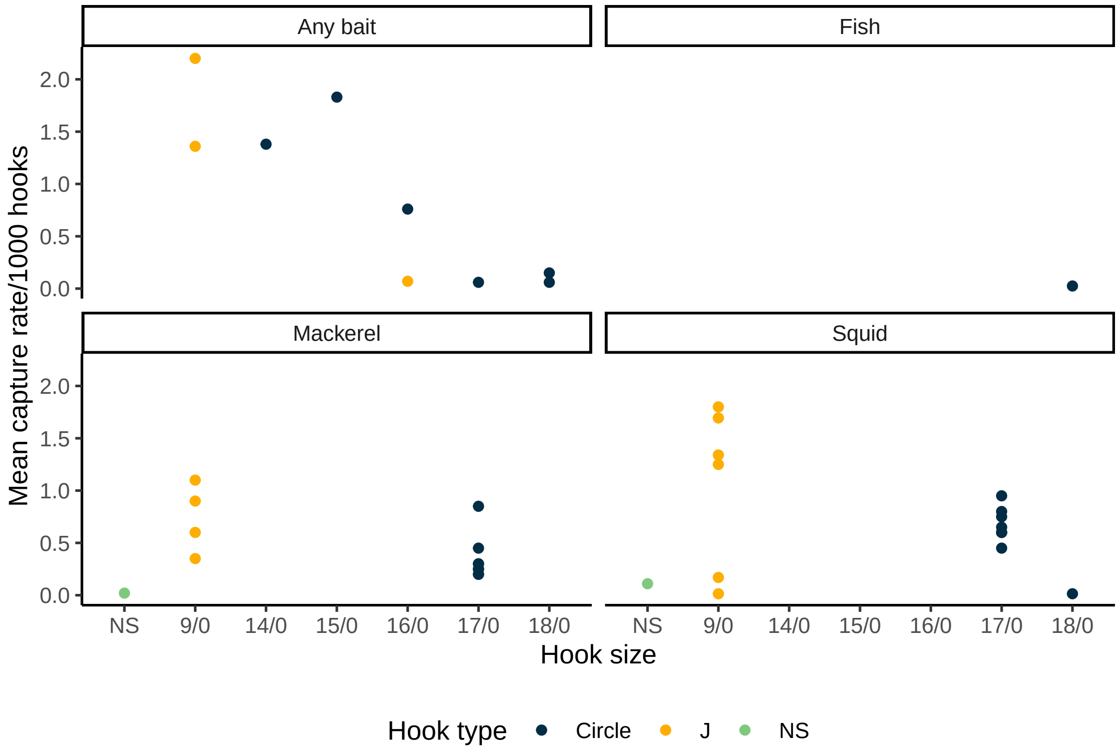

Figure 3.5: Estimated capture rates per 1000 hooks for all turtles combined (excluding studies that provided capture rates for leatherback and loggerhead independently). Rates are compared for different bait types by different hook types (shape) and sizes (size and colour). Capture rates where bait type 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 leatherback and loggerhead 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.

Seven studies presented capture rates of seabirds (Appendix Table A.6). Some studies presented them as captures/1000 hooks, while others reported rates as captures or contacts per 1000 (Gilman et al., 2003) or 100 (Boggs, 2001) hooks per bird. Due to this, a graph is not presented as data are incomparable.

3.5 Data sources for New Zealand bycatch

3.5.1 Protected species captures and observer data

The following is a summary of available data sources for fisher and observer bycatch but does not incorporate data analysis. Hook type and bait type are reported by MPI observers for each protected species capture event, more consistently since 2017-2018. This information, recorded in the PSC database, can be 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.

The three tables in the PSC database are (Table 3.2):

- ***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).
- ***catch_effort_t*:** Table containing fisher-reported catch effort data that is linked to *observer_effort_t.*

The tables from COD and their attributes are fully explained in Sanders & Fisher (2024). Tables required for linking captures and fishing events include (Table 3.2):

- ***x_trip*:** Top-level table that contains records for each observed fishing trip. The primary key, *trip_key,* is a unique system-generated attribute that can be linked to several of the other COD tables to obtain *trip_number*. This table contains data for both SLL and BLL events and is used to expand the following tables by trip number (if needed), to link to the PSC database tables.
- ***x_fishing_event*:** Table with information associated with fishing events, containing the columns *fishing_event_key, station_number,* and *trip_key* for both SLL and BLL events. It can be used to expand the other tables by station number (if needed), to link to the *x_trip* and PSC database tables.
- ***x_surface_lining_effort*:** Table with fishing effort for observed tuna SLL events. This table also includes bait condition (i.e., thawed or frozen) and whether a mechanical bait thrower was used. It contains both *trip_number* and *trip_key* so

can be linked to both the PSC database and other COD tables (e.g., *x_fishing_event*).

- ***x_bottom_lining_effort:*** Table with fishing effort for observed BLL events. It also contains columns for bait species and the percentage of hooks that were baited. It contains *trip_key* so can be linked to other COD tables. There is no *trip_number* column.

Table 3.2: Tables in the Centralised Observer Database (COD) and the Protected Species Captures Database (PSCDB) that contain hook and/or bait information or contain fields necessary for linking captures to fishing events. The column Primary indicates the main field in the database table that links to other tables. The columns Join and Data indicates extra fields in the database that provide additional identifying information across tables and fields with relevant data, respectively.

DB	Table	Primary	Join	Data
COD	*x_trip*	*trip_key*	*trip_number*	*start_date* *end_date*
COD	*x_fishing_event*	*trip_key*	*station_number* *fishing_event_key*	*fishing_method*
COD	*x_surface_lining_effort*	*trip_key*	*trip_number* *set_number* *event_key* *fishing_event_key*	*bait_thrower_used_yn* *bait_condition_code* *bait_condition_code* *bait1_species* *bait2_species* *hooks_baited_percentage*
COD	*x_sll_baskets*	*trip_key*	*trip_number*	*hook_type*
COD	*x_surface_lining_bait*		*trip_number* *set_number*	*bait_1_species* *bait_1_composition* *bait_1_state* *bait_1_dyed_yn* *bait_2_species* *bait_2_composition* *bait_2_state* *bait_2_dyed_yn* *bait_3_species* *bait_3_composition* *bait_3_state* *bait_3_dyed_yn*
COD	*x_snood_usage*	*trip_key*	-	*hook_colour_name* *hook_type_name*

Table 3.2: Tables in the Centralised Observer Database (COD) and the Protected Species Captures Database (PSCDB) that contain hook and/or bait information or contain fields necessary for linking captures to fishing events. The column Primary indicates the main field in the database table that links to other tables. The columns Join and Data indicates extra fields in the database that provide additional identifying information across tables and fields with relevant data, respectively. *(continued)*

DB	Table	Primary	Join	Data
COD	*x_bait_usage*	*trip_key*	-	*bait_number* *bait_code*
COD	*x_bll_gear*	*trip_key*	*trip_number*	*hook_type* *hook_size* *bait_method*
PSCDB	*catch_effort_t*	*event_key*	-	*method* *fishing_year* *start_datetime* *end_datetime* *fishery* *target*
PSCDB	*observer_effort_t*	*event_key*	*trip_number* *station_number*	*method* *fishing_year* *start_datetime* *end_datetime* *fishery* *target*
PSCDB	*all_captures_t*	*event_key*	*trip_number* *station_number*	*method* *fishing_year* *start_datetime* *end_datetime* *fishery* *target* *species* *alive* *injuries* *autopsied*

The specific tables that contain bait type or hook type data (Table 3.2):

- ***x_sll_baskets**:* Table containing information on SLL gear, with detail on baskets and hook types deployed for fishing events, from SLL gear form Version 3, August 2018. This table contains hook type per fishing trip. It has *trip_number* and *trip_key* for linking with other COD and PSC database tables. There is no *station_number.*
- ***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. It has the columns *trip_number, trip_key, fishing_event_key,* and *set_number* for linking to other COD tables. There is no *station_number.*
- ***x_snood_usage**:* Table with hook colour and hook type per snood used on observed sets per tuna SLL fishing event. This table only has *trip_key,* so must be linked with other tables (e.g., *x_fishing_event, x_trip)* to obtain *trip_number, station_number,* or other columns that can then be linked to the PSC database. Cleaning of the *hook_colour_name* and *hook_type_name* columns is required as well to ensure a standardised way of describing hooks (e.g., spelling, size and type description, etc.).
- ***x_bait_usage**:* Table with *bait_code* and *bait_number* based on observed sets per fishing event. This table only has *trip_key,* so must be linked with other tables (e.g., *x_fishing_event, x_trip)* to obtain *trip_number, station_number,* or other columns that can then be linked to the PSC database. All *bait_code* values can be linked to the *y_sll_bait_code* table for further interpretation.
- ***y_sll_bait_code**:* Table bait codes used in SLL tables. Required to link to *x_bait_usage* to understand what bait was used for certain events.
- ***x_bll_gear**:* Table containing information on BLL gear, from BLL gear form Version 1, June 2019. It contains both *trip_number* and *trip_key*, so can be linked to both the PSC database and other COD tables. This table provides information on hook type, size, and bait method.

Several other tables contain columns with additional bait and hook information. For instance, *x_fishing_event_catch_specimen* has observer data for protected species captures on tuna SLL vessels. However, NAs comprise 99.7% of the relevant *bait_code* column and 99.4% of the *hook_location* column, making this table largely unusable for linking purposes.

The table *z_bll_set* also contains information on bait type per BLL set and can join to *x_fishing_event* on *trip_number* and *set_number.* Although BLL bait information is only included in this table, this table is preliminary and does not go through validation. Thus, the information is essentially lost when depending on the reporting tables (prefixed with *x_*). See Sanders & Fisher (2024) for more information.

Moreover, tables from the original *l_line* database with historic SLL observer data were integrated into the COD. Several tables contain pertinent bait and hook data for certain trips, including:

- ***z_sll_snoods***: Historic data similar to *x_snood_usage*. To link data from this table to the PSC database on a fishing event level, the additional column *station_number* is required (extracted from COD table *x_fishing_event)* based on the *trip_number* column. Cleaning of the hook colour and hook type is required as well to ensure a standardised way of describing hooks (e.g., spelling, size and type description, etc.).
- ***z_sll_bait***: Historic data similar to *x_bait_usage*. To link data from this table to the PSC database on a fishing event level, the additional column *station_number* is required (extracted from COD table *x_fishing_event)* based on the *trip_number* column. All *bait_code* values can be linked to the *y_sll_bait_code* or *z_sll_bait_code* tables for further interpretation.

These tables would also need a thorough review to determine if the data were integrated into *x_snood_usage* and *x_bait_usage* already. Additionally, a similar approach to the other COD tables would be required to link events to protected species captures. The *z_sll_trip* table, containing *trip_number* and associated vessel information for certain fishing events, might also be needed to link both tables to fishing events in the *observer_effort_t* and *all_captures_t* table from the PSC database. This could be complicated by problems with unique trip numbers when integrating the tables from *l_line* database into the COD (refer to Sanders & Fisher, 2024 for more information).

3.5.2 Linking tables

To summarise turtle and seabirds captures per bait type, bait composition data from the COD (i.e., *x_surface_lining_bait*) can be linked to the *observer_effort_t* table in the PSC database. This can be done by first joining *x_surface_lining_bait* with *x_fishing_event* and *x_trip* to add the columns *trip_number* and *station_number*. Next, tables *x_bait_usage*, *x_snood_usage*, or *x_bll_gear* can be linked similarly to obtain bait and hook information, if it exists, for certain trips. *Trip_number* and *station_number* can then be used to join *observer_effort_t* with *x_surface_lining_bait*. Then, species group-specific captures from *all_captures_t* can be summed by *trip_number* and *station_number* and added to *observed_effort_t*.

For hook type contained in table *x_sll_baskets*, *station_number* was not recorded or cannot be joined to other tables contained in COD. Hence, data from *x_sll_baskets* can not be directly linked to the PSC database. Instead, species group-specific captures in the PSC database can be summed by fishing year and fishing trip (i.e., *trip_number*). Similarly, the hook type and the bait type per fishing trip can be extracted (this also includes fishing trips that had no hook type and bait type recorded) and added to the total trip-based captures for comparison.

For BLL events, *bait_method, hook_type,* and *hook_size* are consistently reported by observers, but there are only 190 events in the *x_bll_gear* table currently. This table can be linked to fishing events (as well as bait type and composition) and then to protected species captures following similar linking methods to the SLL tables.

From 2017-2021, hook and bait type were reported for most fishing events; prior to this, hook and bait type were not often recorded in the *x_surface_lining_bait* (bait type) and *x_sll_baskets* (hook type) tables. Meyer & MacKenzie (2022) conducted an analysis of SLL fishing events on small, domestic vessels from 2006–2007 to 2018–2019. They summarised the tables provided in the COD for data completeness and indicated that bait species was not reported for most fishing events (2 244 events, 87% total events) and that, if reported, squid or a mix of squid and fish bait were used. Similarly, only 13 events used dyed bait. Hook type was not analysed. Likewise, based on preliminary data summaries of the COD, squid was used on all observed trips that reported hook and/or bait type and had a protected species capture since 2018. Moreover, circle hooks have been used exclusively since 2018, ranging from 14/0 to 18/0 in size, although size 16/0 hooks are used most often. Based on these observations, data obtained from the COD and the PSC database alone would be insufficient to make comparisons between capture rates, hook type, and bait type. There could be a comparison of catch rates with different hook sizes, but the sample size required to conduct robust statistical analyses would need to be determined.

3.5.3 Fisher-reported data

The extract of the EDW provided non-fish protected species captures reported by fishers linked to catch effort and fishing event reported data. In this dataset, there were columns for the percentage of hooks baited with squid, fish, artificial bait, or other. No information is provided on hook type or size.

Longline fishers report catch effort, landings, and other metrics to Fisheries NZ. Historically, paper forms were used, but fishers were not required to report hook or bait type for longline fishing events. Based on the EDW data, there are three form types that provide relevant information (Ministry of Fisheries, 2010):

- **TUN (TLCER) - Tuna Long-lining Catch Effort Return**. Records effort, processing, and environmental data for tuna and swordfish SLL events. Percentage of bait is reported on this form.
- **LCE (LCER) - Lining Catch, Effort Return**. Records effort for BLL and SLL vessels greater than 28 meters in length, introduced in January 2004. Does not report hook or bait information.
- **LTC (LTCER)- Lining Trip Catch, Effort Return**. Records effort for BLL and SLL vessels between 6m and 28m in length, introduced in October 2007. Does not report hook or bait information.

Starting in 2019, all commercial fishers are now required to report catch and position electronically. The EDW lists two electronic reporting forms:

- **ERS - Lining**. Does not report hook or bait information.
- **ERS - Tuna Lining**. Percentage of bait is reported.

Only SLL events have reported bait type percentages. BLL fishers are not required to supply this information. Currently, 24.6-43.5% of the rows in the EDW extract contain information on the percentage of hooks baited with specific bait types. Due to the data format, manual linking between protected species captures and EDW data would be required to ensure accuracy. There is also a lack of hook type or size reporting on any of the forms.

There is some additional historic data held within the *warehou* database (now called the EDW) where fishers reported bait type. The *x_ce_bait* table contains a system-generated *event_key* along with the *species_code* for bait type used during tuna

SLL fishing events, as recorded on the 1990 and 2003 version of the TLCER forms only. Bait was not recorded between 1995 and 2000 (Ministry of Fisheries, 2010).

3.5.4 CSP seabird necropsies

The CSP seabird necropsy database provides species identification for necropsied seabirds captured in all fisheries. Additional data include the location of the hook at capture reported by observer and during the necropsy, whether the hook was collected, photos, and hook size. Although there is no information about bait type associated with fishing events and seabird captures, information is recorded on stomach contents, including the presence of bait or discarded fish/squid. It would have to then be assumed that a captured bird ingested the bait from the hook prior to death, and that the stomach contents were bait and not previously eaten while foraging. No hook sizes for the necropsies in the dataset were available for this review and are only recorded if the hook was retained with captured seabirds (very infrequent occurrence). Further analysis of the effect of hook type would only be possible if captures were linked to the COD and if data on hook size, type, and bait type was reported by the observer for each capture. This could be done with the full necropsy database, but future work would require the entire dataset to accomplish this.

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.7). It should be noted though that the necropsied birds do not represent the total number of birds caught in SLL fishing gear since observers are not required to retain all specimens. This dataset 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 eight birds ingested the hook.

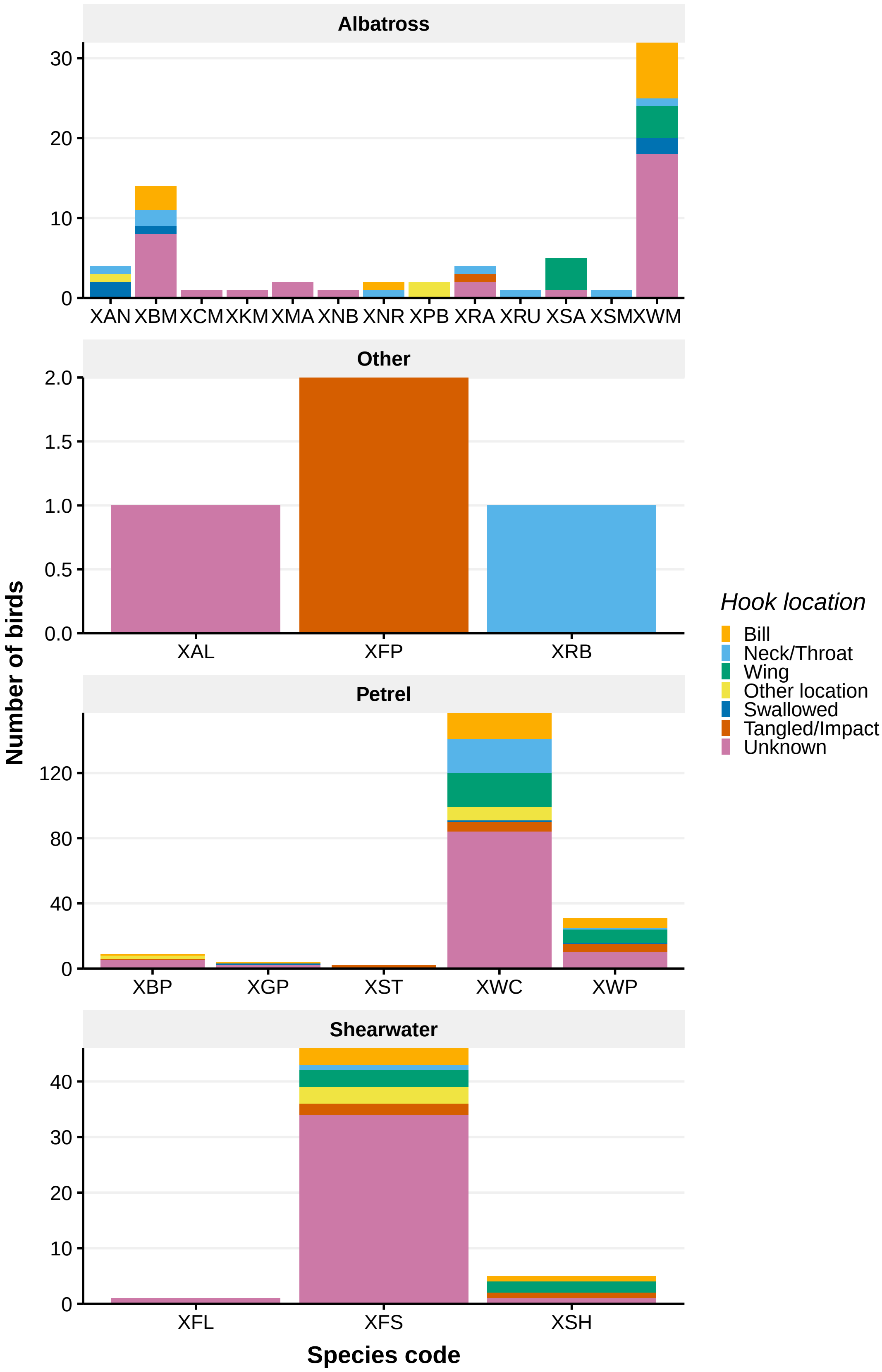

Figure 3.6: Number of necropsied seabirds from January 2020-March 2024 that were caught on surface longlines, summarised by the location of the hook position for each species. Note different y axis scales. See Appendix Table A.2 for species abbreviations.

From 1998-2005 and 2010-2024, 211 hooks of eight different types and sizes were collected during seabird necropsies by DOC. Table 3.3 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 3.3: 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 3.3: 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 17/0 or larger with an offset less than 10° and/or the use of fish 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 and surface longline fisheries, and Hookpods and other mitigation methods are used simultaneously with the main objective to reduce seabird and sea turtle bycatch. Dyed squid is also occasionally used.

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 (but not for BLL) implement at least one of the following mitigation measures: circle hooks and/or fish bait (Lee et al., 2022; Peat et al., 2024). 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 3.4): 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 (one respondent), 16/0 (fve respondents) and 14/0 circle hooks (two 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 3.4: 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 3.4). 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 (four in NI, two 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 twelve) found, to some degree, a decrease in sea turtle bycatch when fish bait was used rather than squid, although the magnitude of this change differs between hard-shelled turtles and leatherbacks. 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.

In New Zealand fisheries, it is also important to consider certain aspects like geographic location when making recommendations for best practice. For instance, turtle bycatch tends to occur more in North Island fisheries, while seabird bycatch is of particular concern in the South Island (also where there is higher fishing effort). Thus, a recommendation to use fish bait in the South Island might not be suitable. Additional studies are required, particularly in NZ, to determine the effects of fish bait on seabird captures.

The economic impacts of switching to fish bait are also 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, this might not be a suitable practice for vessels targeting tuna since target catch rates may decrease when fish bait is used (e.g., Watson et al., 2005). A decrease in target catch rates could also increase the fishing effort required to maintain target catch quotas, which could, in turn, increase the risk of bycatch.

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; Sales et al., 2010; Santos et al., 2012; Santos et al., 2013; Swimmer et al., 2017; e.g., Watson et al., 2005) and seabirds (Domingo et al., 2012; e.g., Li et al., 2012). This supports the recent mandate to use circle hooks in the New Zealand longline fleet.

The effects of offset hooks compared to non-offset hooks are unable to be conclusively quantified, in large part due 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 were twelve studies that looked at bait and hook type effects on seabird capture rates, and eight of these were looking at dyed bait (Boggs, 2001; Cocking et al., 2008; Domingo et al., 2012; Gilman et al., 2003; Li et al., 2012; Lydon & Starr, 2004; Minami & Kiyota, 2004; Minami & Kiyota, 2004; Ochi et al., 2011; Richards et al., 2012; Watson et al., 2005; Yokota et al., 2009). However, there is 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, four suggested a lower capture rate of seabirds (Boggs, 2001; Minami & Kiyota, 2004; Minami & Kiyota, 2004; Ochi et al., 2011). More studies need to be undertaken, particularly comparisons of dyed/undyed mackerel and dyed/undyed squid in New Zealand, before this method can be determined 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. A recent literature review by Peat et al. (2024) briefly summarised several studies examining dyed bait in New Zealand's SLL fleet. They presented similar sources and results to this review, and pointed out that the effectiveness is still debated. They also indicated that the lack of pre-dyed bait makes it impracticable to be used consistently. They agree that blue dyed bait could be used as a supplementary mitigation measure, but additional testing in New Zealand is required.

There are several gaps in these studies, the primary being the lack of New Zealand specific research. While there are well-established international best practice recommendations for certain bait and hook types focus on reducing sea turtle bycatch, there are only few studies looking specifically at bait species or hook size and type on seabird bycatch (Domingo et al., 2012; Li et al., 2012; Richards et al., 2012; e.g, Watson et al., 2005). Hook and bait type effects on bycatch tend to be species-specific, for instance, fish bait may significantly increase seabird captures while decreasing turtle captures (Li et al., 2012). Therefore, best practice for sea turtles may not be suitable for seabirds. Moreover, turtles in New Zealand are at higher risk in the North Island due to their distributions, while seabirds are at risk in both the North Island and South Island. Thus, mandating the use of fish across the fleet, intending to reduce turtle bycatch, could increase the risk to seabirds in the South Island despite the low risk to turtles. Targeted recommendations for hook or bait type, considering geographical distributions, target species, and non-target species, may be more suitable in New Zealand.

Furthermore, hook type, size, offset, bait type, bait preparation, mitigation methods, and other factors have a combined impact on bycatch and target species capture rates (ACAP, 2023), which make it difficult to disentangle the effects of just hook or bait type. Additional challenges occur when mixed fish and squid are used.

4.2 Data sources for New Zealand bycatch

A review of bycatch data obtained from several sources, including MPI and DOC (e.g., PSCDB, COD, EDW, fisher-reported data, necropsy database), revealed that data are likely to be insufficient to conduct statistical analyses on the effects of bait or hook type on protected species captures. Significant future work is required to link data across all these sources based on relational fields (e.g., *trip_number*, *event_key*). The way that hook and bait type data are 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.

There may be enough reported information to link bait composition to protected species captures between these sources. However, very little data exists to determine hook type for fishing events. Bait and hook data have only been recorded consistently since 2018 for some (but not all) observed trips; even so, circle hooks have been exclusively used, so there are no reported captures for events where J hooks were used. The majority of fishing events with reported hook types used 16/0 circle hooks, further limiting any meaningful comparisons.

There are also differences in the data being reported for SLL and BLL fisheries. For commercially reported data, SLL operators report bait type percentages, but linking between this data and fishing events would need to be done manually to ensure accuracy. BLL operators do not report bait compositions, neither hook type or size. For observer reported data, both SLL and BLL events may contain bait compositions, and linking can be done based on trip numbers and event keys. Hook type is only reported for SLL events. The fact that there are quite a few tables that contain information, some of which may be repeated or not validated, makes it more difficult and prone to error to link this ancillary information with fishing events and protected species captures.

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. CSP project INT2023-08 investigating stomach contents of necropsy albatross species and analysing the necropsy data and link necropsies to reported captures.

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, initially, voluntarily) adopted across the entire New Zealand SLL fleet since February 2024. 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 interaction between gear selection and fishing success in New Zealand longline fisheries.

4.4 Recommendations and conclusion

The current recommendations for bait and hook type in several international guidelines (Gilman et al., 2010; e.g., Lee et al., 2022; Morgan et al., 2015) includes the use of circle hooks greater than 17/0 in size and the use of fish bait where possible. It is important that recommendations for changes to bycatch mitigation based on findings in international studies be considered in the context of trialling their appropriateness for use in New Zealand fisheries. More research is required to determine if dying bait is effective at reducing turtle and seabird bycatch, especially in New Zealand fisheries, which is similarly recommended by ACAP (ACAP, 2023) and other studies (e.g., Peat et al., 2024). Current use of blue dye during certain higher risk times is often suggested, along with the necessity for additional research. ACAP does not specifically make recommendations for bait or hook use but provides guidance on other mitigation methods (ACAP, 2023).

After targeted consultation in 2023, circle hooks are now mandatory while surface longlining in New Zealand waters, under the Fisheries (Commercial Fishing) Amendment Regulations 2023 (Kiro, 2023). Based on fishers' feedback, currently 16/0 circle hooks and squid bait are predominantly used in the New Zealand SLL fleet. Further technical specifications for circle hooks are currently being consulted on for inclusion in a regulatory circular (K. Middlemiss, pers. comm.).

Considering the gaps in data and knowledge, it is also recommended that a more systematic, experimental study be conducted looking at bycatch rates for both sea turtles and seabirds in New Zealand. The study should focus on the catch rates of target and non-target species using fish versus squid as bait and smaller versus 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 longline 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. Bycatch mitigation should also be considered (i.e., offal discharge, location of encounters, setting/hauling procedures, mitigation methods, etc.; Clarke et al. (2014)). There should also be an economical aspect to the study to determine if the increased price of fish bait compared to squid would significantly impact fishers, and thus, effecting their willingness to change bait.

Fishers are not required to report hook or bait type, while observers typically report this information for protected species captures. Even so, data attributed to protected species captures are often insufficiently detailed; for instance, DOC liason officers are obtaining additional data from fishers after a leatherback turtle capture to fill in gaps (K. Middlemiss, pers. comm.). This type of data, however, is not currently integrated into the PSC database. Therefore, at a minimum, electronic catch and effort reporting at the trip and station level (not just associated with a protected species capture) needs to include additional information on hook type (e.g., circle), hook size (e.g., 16/0), hook offset, and hook manufacturer, along with information on bait species (e.g., arrow squid not just squid), hooking method (e.g., single), and bait state (e.g., frozen, thawed). It is also recommended that this information be included in the *x_surface_lining_effort* or *x_bottom_lining_effort* (or other appropriate, high level table), where the linking to fishing events has already been done and verified. This will allow for future comparisons of hook size and bait type on bycatch rates over a long time period and with limited effort to link events with data. Data collection by observers and fishers must be improved to ensure information on bait and hook type is recorded not only for bycatch events but for all fishing events.

It is also encouraged to continue trialing new hooks (e.g., Procella), baits, and mitigation methods as technologies improve over time. This is especially important for New Zealand, where blanket regulations or international best practices may not be appropriate, feasible, or suitable at reducing sea turtle and seabird bycatch in New Zealand waters.

5. Acknowledgements

We would like to thank Dr. Karen Middlemiss (DOC) for her management of the project and help with recording questionnaire responses. Thanks to Biz Bell and Wildlife Management International for supplying necropsy data and managing the database and to the Ministry of Primaries Industries for supplying the COD and PSCDB (replog 15593). We would also like to thank Dr. Tiffany Plencner (DOC) and Dr. Igor Debski (DOC) for their helpful feedback on early versions of the questionnaire and John Cleal (LO) for administering the questions and liaising with SLL operators. Thank you to participants at the TWG who provided helpful feedback and comments on the draft report. Lastly, we thank the fishers for taking the time to participate in the survey.

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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)
Circle	18/0	10	0.73	C	Sales et al. (2010)
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)
J	9/0	0	1.6	C	Sales et al. (2010)
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	B	Richards et al. (2012)
Circle	18/0	10	0*	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	0.5	B	Mejuto et al. (2008)
Mackerel					
Circle	17/0	0	0	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	0.1*	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	0.6*	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	0.2*	C	Watson et al. (2005)
Circle	18/0	10	0.17	B	Richards et al. (2012)
Circle	18/0	10	0.1	C	Sales et al. (2010)
J	9/0	20-25	0.5*	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)
J	9/0	0	0.27	C	Sales et al. (2010)
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	2.2	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)
Circle	17/0	0	0.45*	C	Coelho et al. (2015)
Mackerel					
Circle	17/0	10	0.85*	C	Coelho et al. (2015)
Circle	17/0	0	0.3*	B	Santos et al. (2013)
Circle	17/0	10	0.2*	B	Santos et al. (2013)
Circle	17/0	0	0.25*	C	Santos et al. (2012)
Circle	17/0	10	0.2*	C	Santos et al. (2012)
Circle	17/0	0	0.25*	C	Santos et al. (2012)
Circle	17/0	10	0.3*	C	Santos et al. (2012)
J	9/0	10	1.1*	C	Coelho et al. (2015)
J	9/0	10	0.35*	B	Santos et al. (2013)
J	9/0	0	0.6*	C	Santos et al. (2012)
J	9/0	0	0.9*	C	Santos et al. (2012)
NS	NS	0	0.02	C	Mejuto et al. (2008)
Circle	17/0	0	0.65*	C	Coelho et al. (2015)
Squid					
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	0.6*	B	Santos et al. (2013)
Circle	17/0	0	0.45*	C	Santos et al. (2012)
Circle	17/0	10	0.6*	C	Santos et al. (2012)
Circle	17/0	0	0.8*	C	Santos et al. (2012)
Circle	17/0	10	0.6*	C	Santos et al. (2012)
Circle	18/0	10	0.01	C	Sales et al. (2010)
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	1.8*	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
J	9/0	0	0.01	C	Sales et al. (2010)
NS	NS	0	0.11	C	Mejuto et al. (2008)

Table A.6: Capture and contact rates per 1000 hooks for seabird species presented in reviewed sources by bait type and hook type. Total hooks are binned as follows: <10,000 = A; 10,000-100,000 = B; >100,000 = C. Some contact and capture rates were estimated from graphs (*).

Species	Dyed	Bait	Mean contact rate	Mean capture rate	Total hooks	Source
Dyed bait						
Albatross (year 1)	Dyed	Fish	-	0	NS	Ochi et al. (2011)
Albatross (year 2)	Dyed	Fish	-	0.17	NS	Ochi et al. (2011)
Albatross (year 3)	Dyed	Fish	-	0	NS	Ochi et al. (2011)
Petrels (year 1)	Dyed	Fish	-	0	NS	Ochi et al. (2011)
Petrels (year 2)	Dyed	Fish	-	0.18	NS	Ochi et al. (2011)
Petrels (year 3)	Dyed	Fish	-	0	NS	Ochi et al. (2011)
Albatross combined	Dyed	Fish; squid	0.61[b]	0.03[b]	B	Gilman et al. (2003)
Albatross combined	Dyed	Fish; squid	2.37[b]	0.08[b]	A	Gilman et al. (2003)
Black-footed albatross	Dyed	Fish; squid	0.19[b]	0[b]	B	Gilman et al. (2003)
Black-footed albatross	Dyed	Fish; squid	0.85[b]	0.05[b]	A	Gilman et al. (2003)
Laysan albatross	Dyed	Fish; squid	0.72[b]	0.04[b]	B	Gilman et al. (2003)
Laysan albatross	Dyed	Fish; squid	3.27[b]	0.11[b]	A	Gilman et al. (2003)
Seabirds	Dyed	Fish; squid	-	0.25	A*	Minami and Kiyota (2006)
Seabirds	Dyed	Fish; squid	-	0.5	A*	Minami and Kiyota (2004)
Albatross (year 1)	Dyed	Squid	-	0	NS	Ochi et al. (2011)
Albatross (year 2)	Dyed	Squid	-	0	NS	Ochi et al. (2011)
Albatross (year 3)	Dyed	Squid	-	0	NS	Ochi et al. (2011)
Antipodean albatross	Dyed	Squid	-	0	A	Lydon and Starr (2004)
Black-footed albatross	Dyed	Squid	0.046[a]	-	NS	Boggs (2001)
Laysan albatross	Dyed	Squid	0.039[a]	-	NS	Boggs (2001)
Petrels (year 1)	Dyed	Squid	-	0	NS	Ochi et al. (2011)
Petrels (year 2)	Dyed	Squid	-	0	NS	Ochi et al. (2011)
Petrels (year 3)	Dyed	Squid	-	0	NS	Ochi et al. (2011)
Undyed bait						
Albatross (year 1)	Undyed	Fish	-	0.46	NS	Ochi et al. (2011)
Albatross (year 2)	Undyed	Fish	-	1	NS	Ochi et al. (2011)
Albatross (year 3)	Undyed	Fish	-	0.28	NS	Ochi et al. (2011)
Petrels (year 1)	Undyed	Fish	-	0	NS	Ochi et al. (2011)
Petrels (year 2)	Undyed	Fish	-	0.8	NS	Ochi et al. (2011)
Petrels (year 3)	Undyed	Fish	-	0.55	NS	Ochi et al. (2011)
Seabirds	Undyed	Fish; squid	-	0.8	B	Sullivan et al. (2018)
Seabirds	Undyed	Fish; squid	-	0.04	B	Sullivan et al. (2018)
Seabirds	Undyed	Fish; squid	-	1.1	A*	Minami and Kiyota (2006)
Seabirds	Undyed	Fish; squid	-	4	A*	Minami and Kiyota (2004)
Albatross (year 1)	Undyed	Squid	-	0.45	NS	Ochi et al. (2011)
Albatross (year 2)	Undyed	Squid	-	0.3	NS	Ochi et al. (2011)
Albatross (year 3)	Undyed	Squid	-	0.65	NS	Ochi et al. (2011)
Antipodean albatross	Undyed	Squid	-	0.4	A	Lydon and Starr (2004)
Black-footed albatross	Undyed	Squid	0.083[a]	-	NS	Boggs (2001)

Table A.6: Capture and contact rates per 1000 hooks for seabird species presented in reviewed sources by bait type and hook type. Total hooks are binned as follows: <10,000 = A; 10,000-100,000 = B; >100,000 = C. Some contact and capture rates were estimated from graphs (*). *(continued)*

Species	Dyed	Bait	Mean contact rate	Mean capture rate	Total hooks	Source
Laysan albatross	Undyed	Squid	0.69[a]	-	NS	Boggs (2001)
Petrels (year 1)	Undyed	Squid	-	0.45	NS	Ochi et al. (2011)
Petrels (year 2)	Undyed	Squid	-	0	NS	Ochi et al. (2011)
Petrels (year 3)	Undyed	Squid	-	0.85	NS	Ochi et al. (2011)

[a] Boggs (2001) = per 100 hooks/bird

[b] Gilman et al. (2003) = per 1000 hooks/bird

Table A.7: 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?**

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