Workshop summary report—mitigation of protected species bycatch in commercial fisheries

Final report for MIT2020– 03, prepared by Dragonfly Data Science for the Conservation Services Programme, Department of Conservation.

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EXECUTIVE SUMMARY

Protected species that are incidentally captured in New Zealand fisheries include seabirds, marine mammals, some bony fish, sharks and rays, marine reptiles, and marine invertebrates. Recognition of the threats posed by fisheries for some protected species, in addition to potential impacts on biodiversity has led to specific bycatch reduction goals in New Zealand's recently-updated biodiversity strategy, Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020. These goals include zero bycatch of non-target species by 2050.

Supporting this goal are ongoing efforts to mitigate bycatch of non-target (including protected) species in New Zealand waters. Existing mitigation approaches include area closures, and technical and operational changes to fishing operations and gear. Nevertheless, the diversity of bycaught species, and the range of New Zealand commercial fisheries make it difficult to develop effective mitigation measures, particularly as their success is often species- and fisheries-specific. The latter aspect was highlighted in comprehensive reviews and recent assessments in New Zealand and elsewhere that were focused on bycatch mitigation of different species groups and fisheries.

In view of existing studies, the current project was aimed at identifying gaps in current bycatch mitigation within the context of New Zealand's commercial fisheries. The initial goals of the project were an assessment of existing mitigation tools, the identification of significant gaps in mitigation techniques and practices, and an appraisal of potential new technologies that may be used to support reductions in protected species bycatch. Within these goals, the project was predominantly based on stakeholder engagement to capture knowledge and input through stakeholder participation in two workshops. The workshops had the overall aim to develop a a matrix of protected species and mitigation gaps across different commercial fisheries.

Guided by stakeholder input, however, the project's direction changed to documenting the discussions, notes, and questions from the initial workshop. This documentation is provided here, with information pertaining to bycatch mitigation presented by protected group species and fishery.

1. INTRODUCTION

Non-target species that are incidentally captured in New Zealand fisheries include a wide range of protected species groups, such as all species of seabird (except black-backed gull *Larus dominicanus*), all marine mammals, marine reptiles, and corals, two species of bony fish, and five shark and two ray species (New Zealand Government 1953, 1978, Miskelly 2014, 2016).

For some of these species, fishing-related mortalities pose a serious threat, leading to population declines and impacting on the overall sustainability of their populations. Recognition of this threat and the potential impacts on New Zealand's biodiversity has led to specific goals pertaining to fisheries bycatch in New Zealand's biodiversity strategy (Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020; Department of Conservation 2020). This strategy was developed and recently updated by the Department of Conservation (DOC); goals in this strategy include that:

- "the number of fishing-related deaths of protected marine species is decreasing towards zero for all species" by 2025 (under Objective 12.2.1);
- "the direct effects of fishing do not threaten protected marine species populations or their recovery" by 2030 (Objective 12.2.2); and
- "the mortality of non-target species from marine fisheries has been reduced to zero" by 2050 (Objective 12.2.3).

Similarly, a recent, comprehensive report on the future of commercial fishing in Aotearoa New Zealand includes recommendations "to support a movement towards 100% sustainably managed oceans" (New Zealand Government 2021). Corresponding with the bycatch reduction goals in New Zealand's biodiversity strategy, this report highlights the need for "bespoke management and innovation solutions" for bycatch mitigation, such as specific use of gear and the addition of equipment that helps deter non-target species (and reduces benthic impacts).

Ongoing efforts to mitigate the bycatch of protected species in New Zealand and elsewhere include permanent and temporal spatial closures, modifications to fishing gear, and changes in fishing practices. Mitigation measures and techniques are generally aimed at preventing or deterring interactions with fishing gear or at reducing the severity of interaction outcomes (e.g., Leaper & Calderan 2018). Nevertheless, the difficulty of testing mitigation measures means that their performance and effectiveness are often unknown. This aspect has been highlighted in recent expert workshops and assessments that focused on bycatch reduction measures for different species groups; these studies also noted that the performance (or success) of mitigation measures is often fishery- or species-specific (How et al. 2015, Werner et al. 2015, Wakefield et al. 2017, FAO 2018, Hamilton & Baker 2019).

Recent research in New Zealand has focused on gaining a better understanding of existing and also new mitigation methods for marine mammals and seabirds across different commercial fisheries (Childerhouse et al. 2013, Laverick et al. 2017, Parker & Rexer-Huber 2019, Tremblay-Boyer & Berkenbusch 2020). The present project was aimed at augmenting these earlier studies by identifying information gaps concerning the mitigation of protected species bycatch in New Zealand commercial fisheries. It

was focused on enhancing the understanding of existing mitigation approaches and on identifying potential improvements and innovations for reducing protected species bycatch. Its focus included stakeholder engagement to seek information that is otherwise difficult to obtain.

Initially, the project had the following objectives:

1. "To provide an assessment of the level of bycatch reduction that existing mitigation tools can achieve for protected marine species (i.e. seabirds, corals, marine mammals, fish, and reptiles)."
2. "To identify the most significant gaps in mitigation technology/practice that will need to be filled in order to achieve further reductions of protected species bycatch."
3. "Identify and discuss the use of potential new technologies that could be adopted by the fishing industry to enhance bycatch reduction rates."

2. METHODS

The overall objective of this project was to determine the efficacy and effectiveness of existing mitigation techniques for reducing protected species bycatch across different species groups and fisheries. This objective included the identification of significant gaps to provide potential priorities for future bycatch mitigation efforts and approaches. The present assessment also aimed to focus on the potential of current mitigation techniques to further reduce bycatch if they were "fully deployed across relevant fisheries".

The general research approach of this project was based on two stakeholder workshops aimed at developing and refining a matrix of protected species and mitigation gaps across different commercial fisheries. The purpose of the initial workshop was to introduce the project to fishery stakeholders and to gain an understanding of their knowledge of the effectiveness of protected species mitigation methods currently in use in New Zealand's commercial fisheries; any known gaps in protected species bycatch mitigation; and of the data available to assess the effectiveness of bycatch mitigation of protected species (see list of workshop participants in Appendix A). The initial purpose of the second workshop was to present a progress update, and provide an opportunity to discuss preliminary findings, before developing the final matrix.

For the initial workshop, a bycatch mitigation worksheet was used as a framework to guide discussions (see Appendix B). This worksheet is a matrix of different fishing methods and protected species groups. Each protected species group (seabirds, marine mammals, bony fish, sharks and rays, marine reptiles, corals) was discussed in view of mitigation gaps for each of the fishing methods. Initially, the fishing methods included trawl, surface longlining, bottom longlining, trot lining, trolling, squid jigging, seining, dredging and mechanical harvesting, set netting, potting, ring netting and inshore drift netting, drop and dahn lining, hand lining and pole and line, diving, and hand gathering. The term "mitigation" was used broadly and in the context of supporting DOC's zero-bycatch 2050 strategic goals. Within this context, mitigation included any measure aimed at reducing bycatch numbers, e.g., spatial management.

The workshop attendees were asked to address the following questions for each combination of protected species group and fishing method, as listed below.

What data are available (by fishery management area) to assess:

1. the current levels of bycatch?
2. the current mitigation methods?
3. the effectiveness of current mitigation?
4. the potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?

Between the two workshops, there was some expectation that stakeholder contributions towards developing the matrix would be facilitated; however, this process was not explicitly developed. Furthermore, at the request of several stakeholders, the second workshop was truncated to a shorter meeting, and used to discuss the intent and utility of the project. For this reason, it was not possible to develop a matrix of protected species and mitigation gaps across species groups and commercial New Zealand fisheries. Owing to this change in focus, the current report provides a summary of notes from the discussions in the first workshop, which may guide further research into the mitigation of protected species bycatch in New Zealand fisheries.

3. RESULTS

This section provides a summary of the workshop discussions. During the initial workshop, it was decided to omit several fishing methods from the discussion to focus on the main methods or method groups considered to interact with protected species. From the initial list of fishing methods, the following methods were omitted, including the reasoning:

- Eeling: Outside of the project's scope.
- Handlining, pole & line, diving, hand gathering: Considered to pose minimal risk to protected species.
- Ring netting, inshore drift netting: No longer used by New Zealand's commercial fishing sector.
- Troll fishing: Considered to have low interaction rates with protected species (main target species tuna). Occasionally seabirds are caught; seals have been captured, but have usually been released alive or freed themselves; there is no information about the capture of reptiles (i.e., turtles).
- Squid jigging: Not currently used in New Zealand; if used in the future, it should be considered. The main interaction with protected species is considered to be the attraction of seabirds by night lighting of vessels (including in this project in general).

3.1 Summary tables by protected species group

Following these omissions, the workshop discussions were based on seven fishing methods or method groups: trawl, surface longlining, lining, seining, netting, potting, and dredging. Trawl included bottom trawl, bottom pair trawl, midwater trawl, midwater pair trawl, precision bottom trawl and precision midwater trawl (trawl gear developed under the Primary Growth Partnership Precision Seafood Harvesting Programme); lining included bottom longlining, drop or dahn lines, and trot lines; seining included beach seine and drag nets, lampara, purse seining, danish seine-pair, danish seine-single, dip netting, and scoop nets; netting included inshore drift netting, ring nets, set netting (including gill nets), and pair set netting; dredging included mechanical harvesting.

The notes from the discussions are presented here by protected species group (Tables 1 to 5). The notes are qualitative in nature and intended to provide a summary of expert opinion. Also included are the responses to the questions of data availability for assessing: current levels of bycatch; current mitigation methods; the effectiveness of current mitigation methods; and the potential to reduce bycatch rates by expanding the application of current mitigation methods. The notes are included here to inform the next steps for research into mitigation, such as a literature review. Owing to the qualitative aspect of these summaries, there are few references to published research.

For some of the protected species groups, not all fishing methods were included, as some fishing methods are not applicable to the bycatch of a particular protected species group. These fishing methods were, therefore, not part of the discussion. Examples are surface longlining, seining and potting methods that were not included in the discussion of the bycatch of invertebrates (i.e., coral; see Table 5).

3.1.1 Bycatch mitigation gaps – seabirds

There are a number of documents that are pertinent to seabird bycatch, including Fisheries New Zealand's "National Plan of Action – Seabirds 2020. Reducing the incidental mortality of seabirds in fisheries" and supporting document (Fisheries New Zealand 2020a, 2020b). This National Plan of Action is supported by assessments of the risk from New Zealand commercial fisheries to seabirds, which identifies the species most at risk (see most recent Richard & Abraham 2020).

In the context of bycatch mitigation, there have been a number of studies that included or specifically focused on this protected species group, including in New Zealand (e.g., Parker 2017, Parker & Rexer-Huber 2019). The workshop discussion noted that there is considerable literature available, warranting a review to ascertain the key findings and information gaps (Table 1). Other topics in the workshop discussion were the varied nature of seabird-fisheries interactions and some of the challenges of fisheries observers for recording seabird captures.

Table 1: Summary of discussion points from the stakeholder workshop aimed at identifying bycatch mitigation gaps for seabirds. The notes are by fishing method, as applicable to this group of protected species.

Fishing method	Protected species group: seabirds
Trawl	*1. Current levels of bycatch?* Estimates of captures from fisheries and observer data. *2. Current mitigation methods?* Tori lines, bird bafflers, warp deflectors, warp management, fish waste management, net binding, gear depth management (during shooting, hauling, and vessel turning), avoidance. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • There is sufficient information for this group of protected species to warrant a literature review. • A recent New Zealand study provides a stocktake of mitigation measures for the incidental capture of seabirds in New Zealand commercial fisheries (Parker 2017), with a compendium report to Fisheries New Zealand (Southern Seabird Solutions Trust 2017). **Comments, questions, and suggestions from the group discussion** • There is a lot of information on seabird bycatch, and mitigation methods recorded. Information about mitigation methods depends on the fleet, target species, and the different parts of the gear involved. Mitigation needs to be considered in the context of the interactions between bird attraction and fishing operation, which is dynamic and complex. • Different bird species are more at risk from different parts of gear (e.g., warp strike for albatross species, net captures for petrel species). There is more knowledge about mitigation of warp strike than net strike. • Net capture poses a considerable gap in the mitigation of seabird bycatch. • The key for trawl fisheries is the management of fish waste discharge. Batch discarding of fish waste is an important mitigation technique, and there is a move to extend the time between discarding and gear deployment from 30 to 50 minutes. • Observers are no longer able to observe the warp-water interface and are not able to observe warps or trawl doors; there is potential for bycatch to be unrecorded even when observers are onboard. That is, bycatch reporting is biased because the numbers reported are birds retained by the gear, and not birds killed but not retained.

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Table 1 – continued from previous page

Fishing method	Protected species group: seabirds
	• There seem to be little mitigation techniques deployed for net captures of seabirds, which is considered a complex problem. Captures occur at the net mouth and on the outside of the net, with birds being captured in both areas while the net is at the surface or just below the surface. Mitigation is likely to be different for these different situations, and also whether the gear is being shot or hauled. • In deepwater fisheries, attraction to discards is more of a problem in midwater trawl compared with bottom trawl. Generally, midwater trawls are used when bird numbers are low (e.g., West Coast hoki, West Coast southern blue whiting and West Coast jack mackerel fisheries). • It is challenging to display the effectiveness of seabird bycatch mitigation (even when observer coverage is high) given that methods for observing captures change over time. Levels of uncertainly, therefore, will also change over time. • Mitigation techniques used in the inshore fishery are poorly understood, not universally applied, and there are a variety of depth and gear setups. Also, the level of observer coverage of the inshore fleet is low. Therefore, it would be difficult to assess the effectiveness of any mitigation. What is known tends to be information from fishers, not from observer data. There is insufficient information or data to support any sort of risk assessment, and some form of monitoring is required. • It was suggested that methods that are shown to work effectively in deepwater fisheries could be transferable to inshore fisheries. However, this transfer is not straightforward. For example, waste and warp protection does not work for inshore fisheries, because the depth at which the gear operates does not provide sufficient clearance from the zone of waste discharge to mitigate bird attraction and possible capture. • It is not clear what data sources are available to monitor and assess the efficacy of any mitigation methods currently in use. There was mention of "two-thirds of legislated mitigation options are effective", but without a data source for this comment: is it anecdotal or reviewed studies? • Observer data are available for offshore fisheries, but these data would not provide information about the effectiveness of mitigation methods used, especially as fishing operations have changed over time. The deepwater fleet would provide the longest time series of any data source, but the number of vessels in operation has halved, and the amount of fish and fish waste released has reduced over time. For this reason, it is likely the interactions of seabirds with this fleet have changed over time also. How would the characteristics of mitigation effects be captured in any data that are available?

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Fishing method	Protected species group: seabirds
	• It was suggested that New Zealand's squid fishery would be a good starting point for investigating the effectiveness of mitigation, because of high observer coverage in this fishery. • It was noted that New Zealand observer data is often considered high quality, but this standard is not necessarily the case all of the time. • Other sources of information should include: expert assessments of mitigation efficacy in New Zealand fisheries, international trials and controlled studies (and how applicable these trials and studies may be to New Zealand fisheries). • Southern Seabird Solutions focused on workshops with trawl fishers and company representatives (report available), where a few ideas have been selected that are now being trialled. • There was discussion of the need to understand what methods are currently being used and how effective they are, as well as investigating mitigation use globally to learn what is working well internationally.
Surface longlining	*1. Current levels of bycatch?* Estimates of captures from fisheries and observer data. *2. Current mitigation methods?* Many methods trialled, unclear which methods are in use. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Sufficient information to warrant a literature review. • Parker 2017, report to Southern Seabird Solutions Trust, Stocktake of measures for mitigating the incidental capture of seabirds in New Zealand commercial fisheries. **Comments, questions, and suggestions from the group discussion** • Report of gaps and potential research priorities produced by Southern Seabird Solutions Trust for Fisheries New Zealand, following on from Parker 2017. • Wealth of information and research internationally (including tory lines, line weighting and hook pods; the use of proxy measures to determine effectiveness). • In New Zealand, hook-shielding devices show promising results. New data collection methods are being established for fisher- and observer-reporting systems. This data collection will help build up evidence-based information about the effectiveness of mitigation, if observer coverage is maintained or improved.

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Fishing method	Protected species group: seabirds
	• There may be some shark-seabird interaction effect, i.e., mitigation methods developed for one species or species group may affect the efficacy of mitigation for other species. • Surface-longline fisheries and mitigation methods are diverse. Lines can be set at various depths. Soak depth and soak time can vary. As an example, when swordfish is targeted, birds are caught during the soak time. One mitigation practice specifies setting during the night; however, fishers prefer to set in the afternoon when targeting this species. How do we take into account fishers' preferences and practices? Mitigation of set, on soak and on haul can all be different. (Note, Dave Goad (Vita Maris) is currently researching mitigation methods during hauling.) • There is complexity around fishery, gear type, and species that needs to be understood before a prioritisation framework for research and investment can be developed. Existing data are also diverse between inshore and deepwater vessels. Which fisheries and which areas are most at risk? What data would need to be collected to inform effectiveness of mitigation? • DOC is commissioning research to investigate post-release survival of seabirds from capture in surface-longline fisheries.
Lining	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* Hook shielding devices, management of line sink speed. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Not discussed. **Comments, questions, and suggestions from the group discussion** • Bottom longlining is a more varied fishery than surface longlining. Considerable variation in gear use, e.g., bluenose target fishery has floated gear, snapper target fishery is shallow, ling target fishery is deep. • Also, effective mitigation methods vary for different bird species. • Data availability about efficacy of any mitigation methods also varies. Good levels of data from the offshore fleet, but low levels of data available from inshore fisheries. Also, the available data were not collected specifically for measuring the effectiveness of mitigation methods, so may not be useful for this project?

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Fishing method	Protected species group: seabirds
Seining	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Not discussed. **Comments, questions, and suggestions from the group discussion** • Observer coverage of purse-seine fisheries is about 10 to 15%, and probably lower for other seining methods. Seabird interaction rates are considered to be low in these fisheries, although no information is available about possible interactions; questions were raised about their impact on penguins and shags. • Although direct bycatch is thought to be minimal, there is an issue with deck strike associated with lighting. Bycatch of seabirds in these types of fisheries is an issue overseas, and there is documented work on associated mitigation techniques.
Netting	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Not discussed. **Comments, questions, and suggestions from the group discussion** • Most bycatch is penguins and shags, and these species would be of high priority for bycatch mitigation consideration. There are some ideas about potential mitigation, but nothing has proven effective apart from spatial and temporal shifts of effort.
Potting	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* Avoidance, bait modification. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Not discussed.

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Table 1 – continued from previous page

Fishing method	Protected species group: seabirds
	Comments, questions, and suggestions from the group discussion • Shags interact with potting fishery at Chatham Islands. Fishers actively avoid shag colonies and modify how they bait pots, which successfully mitigates seabird bycatch.

3.1.2 Bycatch mitigation gaps – marine mammals

Marine mammals

There has been considerable research to increase the understanding and reducing the bycatch of marine mammals across different fisheries. Recent studies include expert workshops to assess mitigation measures, trials of mitigation techniques and reviews of available information (e.g., Werner et al. 2015, FAO 2018, Wakefield et al. 2017). Studies from New Zealand include reviews of mitigation measures across different fisheries for all marine mammals and for cetaceans only (Childerhouse et al. 2013, Laverick et al. 2017, Tremblay-Boyer & Berkenbusch 2020), and also trials and assessments of particular mitigation techniques (e.g., exclusion devices for New Zealand sea lion and New Zealand fur seal; Cleal et al. 2009, Hamilton & Baker 2015). In addition, some New Zealand fisheries, such as the North Island west coast mackerel trawl fishery have adopted operational procedures aimed at avoiding marine mammal bycatch (Deepwater Group 2018).

Discussions during the stakeholder workshop highlighted distinct differences in knowledge of mitigation measures across marine mammal species; e.g., between small cetaceans and pinnipeds, such as common dolphin (*Delphinus delphis*) and New Zealand sea lion (*Phocarctos hectori*) (Table 2). Similarly, there appeared to be differences in information across fishing methods.

Table 2: Summary of discussion points from the stakeholder workshop aimed at identifying bycatch mitigation gaps for marine mammals. The notes are by fishing method, as applicable to this group of protected species.

Fishing method	Protected species group: marine mammals
Trawl	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* Sea lion Exclusion Devices (SLEDs), managing the amount of time gear is at the surface, temporal and spatial avoidance, pingers (dissuasive devices), areas closed to fishing. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Expert workshop on means and methods for reducing marine mammal mortality in fishing and aquaculture operations (FAO 2018). **Comments, questions, and suggestions from the group discussion** • For New Zealand sea lion, there is reasonably good quality data on the effectiveness of the use of SLEDS in reducing captures. Nevertheless, there is great uncertainty associated with the survival rate of individuals that use the device to exit the net. • For New Zealand fur seal, there is a gap in knowledge of interactions with trawl fisheries. Continued on next page.

Table 2 – continued from previous page

Fishing method	Protected species group: marine mammals
	• Several years ago, SLEDs were tested for mitigating fur seal capture in trawl gear (Cleal et al. 2009). Based on this trial, the use of SLEDs was considered not to be feasible in fishing operations of the trawl fisheries that were included in the trial. Scaling SLEDs to mitigate New Zealand fur seal captures is problematic, particularly when the size of trawl gear is reduced. This reduction makes re-scaling the dimensions of the exclusion gear difficult. In this context, the dynamics of water flow, trawl operation, gear components and SLED size are difficult to separate. This area requires further investigation. • Similar to seabird bycatch mitigation, the current mitigation practice for marine mammals is based on reducing the duration of gear at the surface. For example, in the West Coast hoki trawl fishery, a significant component of reducing captures over the last 15 to 20 years has been managing the time the gear was at the surface. • Dolphins interact more broadly with trawl fisheries, including deepwater, bottom and mid-water trawling, and inshore trawl fisheries. Current mitigation includes avoidance and dissuasive devices such as pingers (acoustic deterrent devices). Operational procedures in the deepwater fleets include modifying the distance of the net headline from the surface, and changing fishing time during the day. There is evidence that the effective pinger frequency identification is different for different species. Also, there is some indication that the efficacy of pingers reduces over time. It is unclear if this decrease in efficacy is due to learned behaviour of dolphins, or a change in operational use. • Most observed common dolphin captures where in the jack mackerel fishery in 2005, at 150 common dolphin individuals per year. Mitigation efforts have had commitment from fishers, and the annual bycatch rate is currently reduced to one individual per 100 tows. There is some confidence that mitigation is effective, although there is little scientific evidence. • There was a concern raised that the use of mitigation methods that appear to be effective should not be stopped for the lack of empirical evidence of their efficacy. • For cetacean species other than common dolphin, there is not much known about mitigation measures. Large trawlers occasionally catch pilot whales, and this bycatch is more pronounced in the Japanese fleet targeting jack mackerel. No mitigation is currently being undertaken.
Surface longlining	Aspects pertaining to mitigation in surface longline are included in the trawl section (above).

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Table 2 – continued from previous page

Fishing method	Protected species group: marine mammals
Lining	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Not discussed. **Comments, questions, and suggestions from the group discussion** • Fur seals interact with bottom-longline gear, but these interactions are less challenging than they are in surface-longline fisheries. • Depredation by cetaceans occurs, but does not result in any significant bycatch.
Seining	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* For dolphins, avoidance and operational procedures. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Development of code of conduct for avoidance, and not just safe release. **Comments, questions, and suggestions from the group discussion** • Mitigation is operational (not setting nets around visible pods, it is illegal to do so), and behavioural (release net, when dolphins are seen swimming freely inside the net). • There are guidelines for not setting nets on whale sharks in the jurisdiction of the Western Central Pacific Fisheries Commission, but not in New Zealand.
Netting	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed.

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Table 2 – continued from previous page

Fishing method	Protected species group: marine mammals
	Noted research • Overseas research, expert workshop by FAO (FAO 2018), Bycatch Management Information System for oceanic tuna and billfish fisheries (BMIS; see https://www.bmis-bycatch.org). **Comments, questions, and suggestions from the group discussion** • Pingers have been used on set nets overseas to mitigate mammal bycatch, with mixed results. Trials have been conducted around the world, but largely have methodological limitations with poor, mixed, and incomparable results. For example, animals can become accustomed to novel stimulus over time, so any study that reports results after only one year of data collection may be questionable. Also, some methods can tend to attract animals rather than repel them. • Other mitigation methods include constructing nets with materials other than mono-filament; changing the depth that the net is set at; reflector spheres on gill nets. • The International Whaling Commission has information about small cetaceans being caught in set nets.
Potting	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Not discussed. **Comments, questions, and suggestions from the group discussion** • Not sure what is operational in New Zealand's potting fisheries (but see reviews in Laverick et al. 2017, Tremblay-Boyer & Berkenbusch 2020). There are several mitigation methods based on not having a downline attached from the boat to the trap for cetaceans to become entangled in. If downline is used, it is used with tension and without extra floating line.

3.1.3 Bycatch mitigation gaps – sharks & rays

Similar to seabirds, New Zealand has a strategic document for supporting the conservation of sharks, the "National Plan of Action for the Conservation and Management of Sharks 2013" (Ministry for Primary Industries 2013). Recognising the threat posed by commercial fisheries to sharks and rays (and other species within the Class Chondrichthyes) also led to a qualitative risk assessment for this species group in New Zealand (Ford et al. 2015). In the context of bycatch mitigation for protected shark and ray species, research has focused on the New Zealand purse-seine fishery for rays (Jones & Francis 2012), and there has been a review of bycatch of basking shark (Francis & Sutton 2012).

Discussions during the workshop identified that there is relatively little New Zealand research on bycatch and bycatch mitigation of species in this group (Table 3). Nevertheless, there is some anecdotal information that warrants attention, and there are also current and upcoming research efforts.

Table 3: Summary of discussion points from the stakeholder workshop aimed at identifying bycatch mitigation gaps for sharks and rays. The notes are by fishing method, as applicable to this group of protected species.

Fishing method	Protected species group: sharks & rays
Trawl	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • DOC project (POP2020-03) on basking sharks (Finucci et al. 2021). **Comments, questions, and suggestions from the group discussion** • No current active or successful mitigation for deepwater species. Approach has been based on avoidance, but needs to be based on a better understanding of the spatial and temporal distribution of each species. There has been more focus on methods to improve post-capture survival rates. • There is an obvious lack of information. Body of research in Australia, but much of this information is about protecting humans rather than sharks.
Surface longlining	*1. Current levels of bycatch?* Estimates of captures from fisheries and observer data. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed.

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Table 3 – continued from previous page

Fishing method	Protected species group: sharks & rays
	Noted research • Requires a literature review. • Research by the Western and Central Pacific Fisheries Commission. • Workshop on post-release survival of sharks (held by the National Institute of Water and Atmospheric Research, NIWA). **Comments, questions, and suggestions from the group discussion** • There are no obvious shark mitigation tools in use in New Zealand's surface-longline fisheries. • The magnitude of the bycatch of protected shark species in surface-longline fisheries is unknown. • The Western and Central Pacific Fisheries Commission has introduced a ban on the use of wired tracers, but this ban is primarily targeting the bycatch of non-protected shark species (which is outside the scope of this project).
Lining	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Not discussed. **Comments, questions, and suggestions from the group discussion** • There is no awareness of any reported captures of protected shark species in bottom-longline fisheries. There is potential for deepwater nurse sharks to be at risk. There are currently no mitigation methods in use, and there has been no need identified for mitigation. • White pointer sharks are caught occasionally.
Seining	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* Avoidance. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Not discussed.

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Table 3 – continued from previous page

Fishing method	Protected species group: sharks & rays
	Comments, questions, and suggestions from the group discussion • Devil ray interactions are a challenge in purse-seine fisheries. If they are seen by spotter planes, gear is not deployed. A question was raised as to whether this approach was documented as best practice in the industry. • There have been two DOC projects investigating devil ray bycatch and mitigation methods. Photos taken by observers confirmed devil ray interactions, and failed to identify manta rays. Whale shark interactions are rare. • There is no information about interactions of other protected sharks with bottom seining.
Netting	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed.
	Noted research • Not discussed.
	Comments, questions, and suggestions from the group discussion • White pointer sharks are caught in set nets, predominantly off the coasts of Taranaki and South Island. Major mitigation gap.

3.1.4 Bycatch mitigation gaps – marine reptiles

For marine reptiles in New Zealand waters, a recent study examined bycatch data to assess interactions with commercial fisheries and suggest potential mitigation measures (Godoy 2016). Within this group, different species of marine turtle, sea snake and krait have been reported in New Zealand's Exclusive Economic Zone, with bycatch data limited to marine turtles (e.g., see Abraham et al. 2021).

The workshop discussion considered that there were generally few interactions between marine reptiles and commercial fisheries, and also that data were scarce for some fisheries were interactions with sea turtles may occur (Table 4).

Table 4: Summary of discussion points from the stakeholder workshop aimed at identifying bycatch mitigation gaps for marine reptiles. The notes are by fishing method, as applicable to this group of protected species.

Fishing method	Protected species group: marine reptiles
Trawl	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Review of marine reptile populations and interactions with commercial fisheries in New Zealand's Exclusive Economic Zone (Godoy 2016). **Comments, questions, and suggestions from the group discussion** • Bycatch not considered to occur frequently in deepwater fisheries (three observed captures since 1990). • There is some bycatch of turtles in inshore trawl fisheries, but there is a lack of observer coverage that would allow the detection of these captures; therefore, there is little confidence in the numbers of actual captures reported. The increase in observer coverage in these fisheries in recent years may provide more information. There is concern that there will be an increase in captures associated with habitat change or extension due to the effects of climate change. • The amount of data required to quantitatively assess capture rates and mitigation efficiency may be prohibitive to collect, especially for seasonally distributed leatherback turtle (*Dermochelys coriacea*). Given data limitations, a risk assessment may be a more effective form of analysis.

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Table 4 – continued from previous page

Fishing method	Protected species group: marine reptiles
	• A search of international literature is recommended to investigate mitigation methods for turtle bycatch in trawl and longline fisheries, given that their capture in New Zealand waters is rare, and there is little information available about mitigation methods here. Also, turtle exclusion devices that are used internationally in shrimp fisheries may not be applicable for use in trawl gear in New Zealand fisheries.
Surface longlining	*1. Current levels of bycatch?* Estimates of captures from fisheries and observer data. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Review by Godoy (2016). • A number or reports from Fisheries New Zealand (e.g., bycatch estimates for turtles, e.g., Abraham et al. 2021). • Bycatch Management Information System for oceanic tuna and billfish fisheries (BMIS; see https://www.bmis-bycatch.org) by the Western and Central Pacific Fisheries Commission. **Comments, questions, and suggestions from the group discussion** • Surface longlining is the main fishery of interest for bycatch of turtles. • Consideration of research on de-hooking and maximising post-release survival. • Current mitigation techniques tend to focus on fishing depth, hook type, and bait type. • There is ongoing debate about hook-shielding devices that may mitigate turtle bycatch. • It would be worthwhile to collate best-practice approaches from overseas examples to provide to project stakeholders, in view of the lack of evidence and the scarcity of fisheries-specific data from New Zealand.
Lining	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed.

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Table 4 – continued from previous page

Fishing method	Protected species group: marine reptiles
	Noted research Review by Godoy (2016). **Comments, questions, and suggestions from the group discussion** • One capture recorded by observers in the last 20 years, not considered to occur frequently, but noted that it does happen.
Seining	• No observed captures. Not discussed further.
Netting	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Not discussed. **Comments, questions, and suggestions from the group discussion** • Capture of turtles is thought to be rare, but occurs in grey mullet and flatfish set nets. Observer coverage is low, so it is possible that captures may not be reported.

3.1.5 Bycatch mitigation gaps – marine invertebrates

Marine invertebrates that have a protected species status in New Zealand are all species (in four families) of coral. Their benthic mode means that coral bycatch is generally associated with fishing impacts from bottom gear; for this reason, mitigation of their bycatch is generally included in approaches that are aimed at reducing benthic impacts of fishing (e.g., see Eayrs et al. 2020). A recent review of current knowledge of New Zealand deep-sea corals included comprehensive information about stressors including bycatch, and also mitigation strategies (Tracey & Hjorvarsdottir 2019). Similarly, an earlier study considered the distribution of corals in New Zealand waters, and included the identification of areas where deep-water corals are at highest risk from fishing impacts (Baird et al. 2013). Corals were also included in an analysis of bycatch samples from bottom trawls throughout New Zealand's Exclusive Economic Zone (Blom et al. 2009).

Table 5: Summary of discussion points from the stakeholder workshop aimed at identifying bycatch mitigation gaps for corals. The notes are by fishing method, as applicable to this group of protected species.

Fishing method	Protected species group: corals
Trawl	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* Spatial fishing restrictions, e.g., marine protected areas (MPAs) and "move-on" rules. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • Review of mitigation techniques to reduce benthic impacts of trawling (Eayrs et al. 2020). • A current Fisheries New Zealand project is focusing on improvements to benthic bycatch from bottom trawling in in New Zealand's Exclusive Economic Zone. **Comments, questions, and suggestions from the group discussion** • Benthic bycatch is not necessarily a reliable indicator of the benthic impacts of trawl fishing. • Is the goal of mitigation to reduce or to remove the impact? • Suggestion that New Zealand fisheries should be using mechanisms similar to those used by the South Pacific Regional Fisheries Management Organisation (SPRFMO). Furthermore, New Zealand fisheries should have higher aspirations than mitigation goals developed by SPRFMO. • There is a need for a more dynamic way to manage bycatch mitigation as fishing footprint moves into new areas. There is no evidence of any gear modification in deepwater fisheries to reduce benthic bycatch; contact with benthic protected invertebrates damages gear, so areas containing them are actively avoided.

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Table 5 – continued from previous page

Fishing method	Protected species group: corals
	• There is a real concern for inshore fisheries that there is no baseline distribution of protected invertebrates, with limited information available to understand and quantify their bycatch. Available information is generally only from observer records.
Lining	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* Spatial, e.g. marine protected areas (MPA) and move on rules. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed. **Noted research** • None. **Comments, questions, and suggestions from the group discussion** • There is a need to separate mitigation methods for bottom longlining and trotlining as some methods differ between the two fishing methods. • There are not active mitigation methods currently in place. Invertebrate bycatch is reported by observers. Fisheries New Zealand is providing an analysis of the impact of bottom longlining on invertebrates in the near future. • The bottom-longlining fishery is subject to closures which provides mitigation. • Note, the Commission for the Conservation of Antarctic Marine Living Resources and SPRFMO (for some areas) have "move on" rules related to longlining fisheries and the capture of some benthic species. • Impact of bottom longlining on invertebrate bycatch is limited compared with impacts from trawling.
Dredging	*1. Current levels of bycatch?* Not quantified. *2. Current mitigation methods?* None. *3. Effectiveness of current mitigation methods?* Not quantitatively assessed. *4. Potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods?* Not assessed.

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Table 5 – continued from previous page

Fishing method	Protected species group: corals **Noted research** • Not discussed. **Comments, questions, and suggestions from the group discussion** • Invertebrate bycatch occurs in oyster and scallop dredge fisheries. Bycatch is quantified in surveys of these fisheries. Questions arose as to the bycatch of protected species (corals) in either fishery.
Netting	Sparse interaction. Not discussed further.

4. DISCUSSION

Guided by stakeholder input, the project's direction shifted from developing a matrix of protected species mitigation gaps to documenting the discussions, notes, and questions from the initial workshop. The workshop focus was on discussion and not on providing an authoritative review of mitigation measures (comprehensive reviews and assessments already exist).

The documentation provided in this report, with information pertaining to bycatch mitigation presented by protected group species and fishery, is intended to help refine future research directions for the mitigation of protected species bycatch in New Zealand.

5. ACKNOWLEDGMENTS

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APPENDIX A WORKSHOP PARTICIPANTS

Table A-1: Participants in the workshop held for bycatch mitigation.

Organisation	Participant
Department of Conservation	Karen Middlemiss (Science advisor and Workshop facilitator)
	Igor Debski
Dragonfly Data Science	Philipp Neubauer (Workshop chair)
	Kath Large
	McKenzie Tornquist
Deepwater Group	Aaron Irving
	Geoff Tingley
	Richard Wells
Environment and Conservation Organisations of Aotearoa New Zealand	Barry Weeber
Fisheries Inshore	Tom Clark
Fisheries New Zealand	Tiffany Bock
	William Gibson
	Charlotte Mortimer
	Ben Sharp
National Institute of Water and Atmospheric Research	Emma Jones
Parker Conservation	Graham Parker
Pisces Research Ltd.	David Middleton
Southern Seabirds Solutions Trust	Janice Molloy
Te Ohu Kaimoana	Tamar Wells
	Jesse Rihia
Vita Maris	Dave Goad

APPENDIX B WORKSHOP MATRIX

BCBC2020-03 Mitigation gaps analysis towards reducing protected species in commercial fisheries
Stakeholder Workshop, 16 February 2021

Data available to assess:

*1. **current levels of bycatch**
*2. **current mitigation methods**
*3. **effectiveness of current mitigation**
*4. **potential to reduce bycatch rates by increasing the coverage of fisheries with current mitigation methods**
***by FMA: target species and management area**

Fishing Methods		Protected Species					
Group	FNZ Code	Invertebrates	Reptiles	Finfish	Sea Birds	Sharks & Rays	Marine Mammals
		Black corals	All	Giant grouper	All, except:	Oceanic whitetip shark	All
		Gorgonian corals		Spotted black grouper	Black backed gull	Basking shark	Pinnipeds
		Stony corals				Deepwater nurse shark	Cetaceans
		Hydrocorals				White pointer shark	
						Whale shark	
						Manta Ray	
						Spinetail devil ray	
Trawl							
	BT, BPT						
	MW, MPT						
	PRB, PRM						
Surface Longlining							
	SLL						
Bottom Longlining and Trot Lining							
	BLL, TL						
Trolling							
	T						
Squid Jigging							
	SJ						
Seining (Ex. Dip Netting and Scoop Netting)							
	BS						
	L						
	PS						
	DPS						
	DS						
Seining (Dip Netting and Scoop Netting)							
	DPN, SCN						
Dredging and Mechanical Harvesting							
	D, MH						
Setnetting (including Gill Netting) and Pair Set Netting							
	SN, PSN						
Potting and Eeling							
	CP, CRP						
	OCP						
	RLP						
	SCP						
	POT						
	EP, EFN						
	FN, FP						
Ring Netting and Inshore Drift Netting							
	RN, DN						
Drop/Dahn Lining							
	DL						
Handlining and Pole and Line							
	HL, PL						
Diving							
	DV						
Hand gathering							
	H						

Figure B-1: Bycatch mitigation gaps worksheet used to direct discussion at the initial stakeholder workshop held on 16th February 2021.