Characterising discharge management in small-vessel trawl and longline fisheries

Kalinka Rexer-Huber and Graham C. Parker

Report to Conservation Services Programme for project MIT 2017-02

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Characterising discharge management in small-vessel trawl and longline fisheries

Report to Conservation Services Programme for project MIT 2017-02: characterisation and development of offal management for small vessels

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Executive summary

Discharge is a major driver for seabirds to attend fishing vessels, increasing the risk of interactions and seabird captures. Discharge (material including unwanted whole fish, invertebrates, baits and fish processing waste) and its management has had extensive research effort, reflected in best-practise guidelines and regulatory frameworks, but most studies to date have involved large-vessel fisheries. Discharge management practises and effects in smaller-vessel fisheries (<28m vessel length) remain relatively unknown. In New Zealand, discharging practises are highly variable. Despite lack of regulation and potential operational constraints, discharge is actively managed in parts of the smaller-vessel fleet. To reduce risk to seabirds it is important to understand discharge practises in smaller-vessel fisheries, what factors influence discharging practises, and how discharging practises influence seabird bycatch.

This work characterises discharging practises on observed trawl and longlining vessels smaller than 28m and explores whether and how discharging practises influence seabird bycatch events. Information reviewed was collected by government fisheries observers on 108 trawl, 45 bottom/demersal longline, and 40 surface/pelagic longline trips over the period October 2013–December 2016 in New Zealand. All vessels were <28m in overall length. These data have several limitations: observer placement is not random, with spatial and temporal data skews which limit representativeness; observer data are prone to quality and consistency issues; and observations cover only a small proportion of all fishing effort. Together, these limitations mean the data are not robust enough for quantitative statistical analyses. Rather, this work is an exploratory review of existing observer data, aiming to identify patterns and trends that may be informative to explore further.

Observer data showed that haul discharging was actively managed in 25–35% of longline operations, and discharge was always retained during setting. Trawlers rarely discharged material during hauling and actively managed discharge to reduce seabird risk in about 40% of trawl fishing reviewed. Most active management of discharging reported for bottom longline (BLL) operations involved offside discharging, or on the haulside in hauling breaks. On surface longline (SLL) trips, discharge management primarily involved discharging in batches or in haul breaks, on both sides offside and haulside. Most trawl operations limited discharging to the tow stage, but about 15% also discharged during shooting. Discharge batching was documented more often for SLL than for BLL (18% cf. 7% of trips, respectively), and was documented for 11% of trawl trips. Mitigation device use and the extent of other operational mitigation practises (e.g. night setting, line weighting, net cleaning) was roughly in line with previous studies.

Seabird captures recorded by observers were mostly albatrosses but also petrels and shearwaters and showed clear effects of discharge on capture rates. In general, any steps taken by fishers to manage discharge reduced seabird capture rates. Discharge location was important for both bottom and surface-lining, with lower seabird capture rates with offside discharging than haulside discharging, and holding untaken baits during hauling also reduced capture rates. In observed trawl fishing, seabird captures rates were lowest when a bird baffler was used, and appeared lower with net cleaning, illustrating the combination approach required for effective seabird mitigation. However, discharge management practises were not consistent within fleets or between trips of the same vessel, so bird capture risks will also vary.

Recommendations include a range of discharge management actions for liaison programmes to reinforce or progress with relevant fleets, and suggestions for next steps to advance discharge management work in smaller-vessel fisheries. Recommendations are also provided for enhancing data collection to improve understanding of the nature and extent of discharge management and protected species bycatch in New Zealand's smaller-vessel fisheries.

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Introduction

Interactions with commercial fisheries remains the most prominent and ongoing risk to many species of Southern Hemisphere seabirds (Croxall et al. 2012; Phillips et al. 2016). Discharge of offal and fish is a major feature attracting seabirds to fishing vessels, increasing the risk of interaction (e.g. Bull 2009; Løkkeborg 2011). Managing discharge can reduce the risk of protected species interactions, and has been subject to extensive research in larger-vessel fisheries (>28m vessel length) since the late 1990s (e.g. Brothers et al. 1999; McNamara et al. 1999; Weimerskirch et al. 2000). Regulatory frameworks and operational practises reflect the importance of discharge mangement for reducing seabird interactions in these larger-vessel fisheries (NZ Government 2010; ACAP 2017a, b, c).

Discharging practises in smaller-vessel fisheries are relatively poorly understood. There has been less research into discharging practises than for larger vessel operations, and little is known about how small-vessel discharging practises influence seabird captures. In New Zealand, discharging practises are highly variable within and across fleets (e.g. Goad 2017; Pierre 2018). Discharging practises are sometimes affected by size-related operational constraints; for example, small-vessel operators sometimes cite stability concerns or lack of space as the reason discharge is not held aboard the vessel (Pierre 2018), with discharge volume influenced by catch rates, levels of unwanted fish bycatch, and levels of onboard fish processing. The current lack of regulations likely also plays a role in the variability of discharging practises across small-vessel operations.

Despite the lack of regulation and potential operational constraints, discharge is actively managed by some operators across sectors of the smaller vessel fleet. Since effective discharge management can substantially reduce the risk to seabirds (Weimerskirch et al. 2000; Pierre et al. 2013), it is important to understand how discharge management is successfully implemented in smaller-vessel fisheries, what factors influence discharging practises, and how discharging practises influence seabird bycatch events.

The scope of this work is to characterise discharging practises and seabird captures in New Zealand small-vessel fishing operations (surface longline, bottom longline and trawl fishing on vessels smaller than 28m). Hence, this report:

- characterises discharging practises on observed trawl and longlining vessels <28m;
- explores how discharging practises influence seabird bycatch events; and
- provides recommendations on discharge management strategies for smaller vessels.

To characterise discharging practises and their influence on seabird captures, we focus on observations and data recorded by government fisheries observers. Unobserved sectors of small-vessel fisheries (that is, which have not had observer coverage) are outside the scope of this report, except to note relevant observations from fishers in those sectors.

Methods

Defining discharge management

In this project we define **discharge** broadly as any biological material discharged overboard, including offal, fish heads, unwanted whole fish (live or dead), invertebrates, minced material, and baits. **Discharge management practises**, or DMP, are defined generally as the control of the *timing* of discharge relative to fishing operations (discharging during set, haul, shoot, tow; discharging in batches, continuously, or holding), and the *position* of discharging relative to fishing gear (offside, stern). For this work we view DMP relative to practicality and effectiveness at reducing the risk of seabird bycatch.

Data sources

This project compiles existing information on discharge management practises from fisheries observer reports and diaries, observer and fisher data, and international literature (published and grey literature).

The primary source of information was trip reports from fisheries observers. Documentation from observed trips was provided by Conservation Services Programme (CSP) and Ministry for Primary Industries (MPI). Documentation was available from 193 of the 287 observed small-vessel trips in the 2013–14 to 2016–17 period. Documentation received was primarily edited trip reports, but also included unedited trip reports, excerpts of observer diaries, photographic logs, and information collected by observers to support the CSP seabird liaison programme. Documentation included scans, Microsoft Word and PDF documents.

We also used data collected by fisheries observers and fishers that are held in MPI databases. Fishing event data, seabird bycatch data, and commercial fishing data were requested from MPI. A complete extract of data tables related to protected species bycatch data was obtained (MPI replogs 11402 and 11676) which included all fishing events and seabird bycatch data collected during the 2013–14 to 2016–17 fishing years. Tables included station information, information on discharging, and data on mitigation devices used. Protected species capture information included trip number, capture date, species, life status, mode of capture, and the comments field from the observer non-fish bycatch form. Data tables were then refined to include only small-vessel fishing events (filtering data on vessel length smaller than or equal to 28m), by fishing year to include only the most recent four years of data received, and by fishing method to include only bottom longline (BLL), surface longline (SLL) and trawl (TWL) fishing. The first observed fishing event in the refined dataset took place 1 October 2013 and the last observation on 31 December 2016.

International published literature and unpublished 'grey' literature was sourced via online literature search engines, and contact with representatives of relevant fisheries management organisations.

Data extraction

Information relevant to discharge management and seabird captures was extracted from observer documentation and observer data tables from the Centralised Observer Database (COD) and compiled in a trip review data document. Trip reports were randomised, read systematically, and relevant contents documented in the trip review document (categories with yes/no/unknown values, or text strings for relevant observations). Appendix 1 contains all category and header definitions used in the trip review, and the source(s) where information for each category was extracted from. For every trip report, any associated observer data in COD were compared and categorised. Where information in the COD data and observer report did not contain the same information or 'disagreed', the source with the most detail was used.

Extracting discharge management

Trawl discharge management

Information on discharge management practises (DMP) during observed trawl fishing was summarised by trip, using both data in COD tables and observer reports. The fishing event form in COD allowed for the discharge action (none, held, discharged) of two discharge types (offal, whole fish) to be recorded for each stage (shoot, tow, haul) of every fishing event. To allow comparison with the level of detail available for other fishing methods (bottom- and surface longline, only trip-level data), fishing-event data for trawl trips were pooled during data extraction to give a single discharge-related value for each category in the trip review. Trip-level values extracted into the trip review document for trawl fishing included: discharge type (fish, offal), stage discharged (shoot, or tow, or haul), and holding (discharge code "H") reported at any stage. The cutoff for inclusion as vessel practise during a given trip was two fishing events or 10% of all fishing events in a trip. For example, discharging while gear was shot had to occur in two or more fishing events for disc_shoot to be categorised 'yes'. This cutoff was based on data inspection to exclude rare events and instead better reflect standard vessel practise.

Trip-level trawl discharge summaries based on COD data were then checked against observer reports. For trawl trips where information was available in both reports and observer data (COD tables), the source with the most detail was used to characterise DMP for a given trip, populating trip review categories. For example, batch-discharging and management of deck loss could not be inferred from COD tables but was sometimes documented in observer reports. Deck loss refers to fish or offal washed off the deck and batching refers to material held for discharge in batches within a fishing stage (for example batch discharging during haul; does not include material held for discharge at different fishing stage e.g. held shoot then later discharged tow). For trips where no relevant COD data were available (entries all "<null>"), trip review categories were completed as much as possible from information in the observer report, with missing information indicated by 'unknown' (u/unkn).

Based on the discharge-related categories in the trip review for each trawl trip, a single value was assigned to characterise a vessel's discharging practises on that trip. DMP classes for small-vessel trawl operations are defined in Table 1. Trawl DMP classes are based primarily on the timing of discharging relative to fishing stage (tow, haul, shot, no discharging during any stage of fishing). DMP classes are roughly ordered based on increasing risk to seabirds attending a vessel. For example, there is thought to be less risk to seabirds when discharging during tow (main risk posed by warps' guillotine action) than when discharging during shoot or haul (net and doors available as well as warps, with added attraction from net stickers or net-escapees). Discharging during shoot is classed higher than haul-discharging because birds entangled in the net during shooting will drown, while birds caught on the warp during shooting are likely to be dragged beneath the surface as warps pay out and are unlikely to stay on the warps until hauling (Abraham and Thompson 2009; Koopman et al. 2018). The highest-risk discharge stage recorded in an observed trip is then used to characterise the discharge type. For example, if discharging was documented during shoot but unknown or unclear for other fishing stages, DMP trawl class 4 was assigned in the absence of any indication that more careful discharge management was intended or utilised.

Table 1. Discharge management classes for small-vessel trawl fishing.

Class DMP trawl	Definition
0	No discharged material any stage, *or* held until after fishing
1	Discharge of anything (offal and/or fish) during tow, no discharge shoot or haul
2	Discharge anything during tow and haul, no discharge shoot
3	Discharge anything during shot and tow, no discharge haul
4	Discharge anything during shooting, no disc tow and haul
5	Discharge anything all stages shooting, towing and hauling
u	Unknown
d	Disagreement - report in conflict with COD, cannot be resolved

Longline discharge management

Information on BLL and SLL discharge management was primarily extracted from fisheries observer documentation, since very little information on discharging practises by small longliners was available in observer data (COD tables). Data extracted into the trip review included what material was produced (offal, fish heads, fish), whether untaken baits were retained on board, batching of discharge, and whether deck losses were managed or not. Trip review categories were completed as much as possible from information in the observer report, with missing information indicated by 'unkn'.

As for trawl trips, a single DMP class was determined for each longlining trip to summarise the vessels' discharging actions on that trip (Table 2). Longlining DMP classes are based on the timing of discharging (none, tow, shoot), handling (batched, continuous), and location (offside, haulside) of discharging. Classes are roughly ordered based on increasing availability of discharge and risk to seabirds attending a vessel. For example, material discharged continuously provides a continuous attractant to seabirds, so is ranked more highly than when discharged in batches or breaks in hauling. Discharging material on the haulside (same side of the vessel as the hauling station) attracts seabirds to the area where gear is being hauled, so is ranked higher than when material is discharged offside or over the stern, which is thought to distract birds from the hooks being hauled. The highest discharge type category recorded in an observed trip is then used to characterise the discharge type. For example, when discharge location or handling is unclear, the precautionary approach taken; i.e. if baits were discharged during haul but discharging location was not recorded nor whether bait discharging was batched or continuous, DMP lining class 4 was used in the absence of indication that more robust management of discharging was intended or utilised.

Table 2. Discharge management classes for small-vessel longline fishing.

Class DMP lining	Definition
0	No discharged material any stage, *or* held until after fishing
1	Discharge of anything (offal, baits and/or fish) during breaks in haul *or* batches in haul, offside/in wake
2	Discharge anything in breaks/batches haul, haulside
3	Discharge anything continuously in haul, offside/in wake
4	Discharge anything continuously in haul, haulside
5	Any discharge during setting
u	Unknown

Extracting seabird mitigation

Data on further actions aiming to mitigate the risk of seabird captures were extracted. Mitigation equipment was characterised by the primary mitigation device used: tori line(s), bird baffler, warp scarer, other, and none. 'Other' included devices like floats on warps, towed buoylines, and protection of the longline hauling station via water curtains, but Other was also occasionally used in COD tables without any further device description. For trips where mitigation device information was available from both reports and observer data (COD tables), the source with most detail was used to characterise the mitigation used on a given trip. For trips where no relevant COD data were available (entries all "<null>"), trip review categories were completed as much as possible from information in the observer report, with missing information indicated with 'unkn'.

A range of operational approaches to seabird mitigation could not be defined from COD data tables but were extracted from observer reports, when mentioned for a given trip. The main operational mitigation actions categorised were cleaning net stickers or entangled fish from the net before shooting again (trawl); setting gear at night, and line weighting (lining). A range of other approaches to minimise seabird interactions (reviewed in Pierre 2016) were mentioned less regularly so were simply noted, including use of thawed or dyed baits, slower setting speed, setting with slack line or snoods, and setting into the wake.

Line weighting for bottom longline fishing was categorised as y/n/unkn, based on whether the observer report stated that line weights for seabird mitigation were used or not, and if a gear diagram identified extra weights used. More line weighting detail could be extracted from observer reports for surface longline fishing. Categories recorded the type of line weighting used on SLL gear: weighted swivel on snood (closer to hook than clip); weighted swivel at clip (generally 60g weight); weighted backbone; lumo leads; hook shield device; other; none; unknown (not enough information). Weighted clips have little influence on the sinking speed of hooks at the other end of long SLL snoods (D. Goad pers. comm.), and weighted clips were not included among seabird-mitigating line weights in SLL summaries.

Extracting seabird bycatch

Data preparation involved merging the two COD data tables referring to seabird capture data (from the fishing event form and non-fish bycatch form) to provide a single consistent set of capture data. Where captures were recorded on both the fishing event form and the non-fish bycatch form, the non-fish bycatch data were accepted as authoritative. The study's scope includes review of factors influencing all interactions including deck strikes, or interaction of birds with the deck or superstructure of vessels, because deck strikes necessarily only occur when fishing vessels are present, and are documented only when vessels are actively fishing (i.e. deck strikes occurring while vessel on anchor or steaming not recorded). Deck strikes ("I" or "O" reporting codes) were retained in overall interaction data (identified as 'overall'), while captures on fishing gear ("H", "T", "N" and "S" capture mode codes) were extracted separately and identified as 'gear' to distinguish the gear-capture subset from overall interactions.

Capture data were summarised by trip, and seabird capture data from COD compared with information in observer reports: whether any seabirds captured or not; numbers of individuals captured, numbers captured dead, capture method (numbers captured in each category net, warp or door, hooked, tangled on lines, impact/deck strike, other). Reports of injured and uninjured live-captures were considered together following Pierre (2018), given the uncertainty of outcomes after release.

If seabird capture information in the observer report was different to the data recorded in COD, this was also recorded. Valid seabird captures missing from COD data tables were added to the seabird capture data for analyses. Captures were valid only if occurring during fishing operations (i.e. not while steaming or on anchor), and deck strike or 'Other' interactions were only valid if the bird had to be assisted off the boat.

Quality control

Following data extraction, ~25% of extractions were checked for consistency. The 30 observer reports read first were checked to ensure consistency of notation and content assessment with later reports. Reports were re-read where trip review information had missing or ambiguous information. Focus was on values missing in note fields for mitigation, discharging practises, and bird captures. Secondary checks were conducted where values were missing from 'COD nulls' field. Checks for ambiguous recording focused on fields requiring y/n/unkn values where cell had other text (e.g. 'Y partly').

Summary and analysis

To characterise discharging practises across small-vessel operations, information was summarised and tabulated. For example, summaries characterised discharging practises in lining and trawl fleets and characterised the use of mitigation devices and operational mitigation practises by fishing method. All characterisations separate bottom longline, surface longline and trawl fishing. Characterisations are provided at the level of trips, rather than events, to align with the source information (observer trip reports provide trip-level information). Overall, event- and trip-level summary figures differed only marginally and the general patterns remained the same; the number of events is provided in summary tables throughout. Summaries are necessarily broad, pooling target fish species within each fishing method (despite operational differences between fisheries), and pooling seabird mode of capture (hook/tangle and net/warp/tangle), because further splitting made sample sizes too small to detect useful patterns.

Exploratory analyses of factors influencing seabird capture rates confirmed that data were not adequate for quantitative assessment of DMP against bycatch events, largely because of the qualitative and sometimes subjective nature of information extracted from observer reports. Instead, we used extracted data as background and context to qualitative assessments, by tabulating DMP and seabird capture data to explore patterns in the data available. Since bycatch incident data tables provide event-level information, factors influencing seabird captures could be explored as capture rates, expressed as captures per 100 fishing events. Exploratory analysis included consideration of seabird capture rates when different DMP were used in each of trawl, surface and bottom longline fisheries. Exploratory analysis also assessed captures in relation to mitigation device used, the proportion of seabirds captured dead amongst total captures, and mode of capture (hook, net, warp strike, etc.). Exploratory analyses and summaries were conducted in the R software package (R Core Team 2016).

Results

Data summary

Refining observed trawl and longline fishing to include only fishing in the period from 1 October 2013 to 31 December 2016 (3.5 years) by vessels smaller than 28m left 287 observed trips. Observer trip documentation was available for 193 of the observed trips. All 193 sets of observer documentation were reviewed in detail for relevant information. Observer documents spanned trips by 93 different vessels, ranging in size from 8.5–27m (Table 3).

The full observer data COD extract had a total of 114,792 records of observed fishing events. Refining to include only records from trawl and lining vessels smaller than 28m in the 2013–2016 fishing years left 9,789 observation records for comparison with observer trip documentation.

The number of observed trips and fishing event observations are summarised by fishing method in Table 3. Bottom longlining and surface longlining had a similar number of trips, but bottom longlining accounted for more fishing events. Trawling accounted for about half of the small-vessel trips and the large majority of fishing events that were observed. Vessel numbers were similar in each fishing method (Table 3), but repeat voyages by the same vessels occurred more in our dataset for trawlers than for longlining vessels. A similar range of vessel sizes was represented in review of each fishing method.

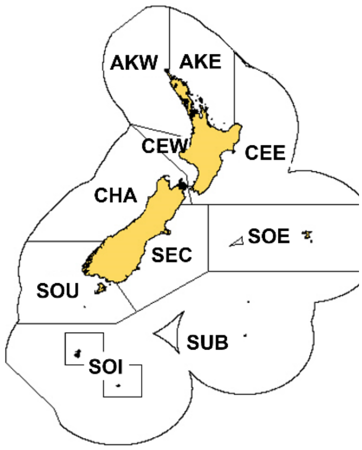
Importantly, this work focuses on observed small-vessel fishing, using information solely from small longliners and trawlers where there was a government fisheries observer on board. Observers are not placed at random over fisheries, and coverage varied in our focal period. Small-vessel fisheries were observed to some extent in most fishing areas (fisheries management areas or FMA), although not equally (Table 4). There was almost no observer coverage on small-vessel surface longliners operating off the southern and eastern South Island (SOU and SEC), and no trawl effort observed off SOU (Table 4). The majority of fishing effort observed took place off the upper North Island's east coast (AKE) for all fishing methods,with fishing in AKE accounting for 42–53% of observed fishing (Table 4). In these FMAs, species assemblages are expected to be different, so capture profiles and associated risk factors are also expected to be different.

Table 3. Observed fishing by longlining and trawl vessels smaller than 28m between October 2013 and December 2016, showing the number of trips, the number of vessels and their size range (length overall or LOA), and the number of fishing events reviewed.

	trips	vessels	size range (m)	events
bottom longline	45	31	8.5 – 25.4	1756
surface longline	40	23	13.8 – 23	639
trawl	108	39	12 – 27	7394
Total	193	93		9789

Table 4. Observed fishing on longline and trawl vessels smaller than 28m across fisheries management areas October 2013–December 2016. Events is the number of fishing events observed, expressed as a percentage of all observed events in that fishing method (%).

	Bottom longline		Surface longline		Trawl	
	events	%	events	%	events	%
AKE	772	44.0	267	41.8	3886	52.6
AKW	77	4.4	22	3.4	1976	26.7
CEE	124	7.1	167	26.1	572	7.7
CEW	348	19.8			21	0.3
CHA	86	4.9	179	28.0	182	2.5
SOU	118	6.7	4	0.6		
SEC	120	6.8			113	1.5
SOE	54	3.1			429	5.8
CET	57	3.2			12	0.2
SOI					199	2.7
SUB					4	0.1
Total	1756		639		7394	



Characterising small-vessel lining and trawl practises

Discharge management

Discharging practises used during a fishing trip are characterised here by the timing, type and location of discharging. DMP documented on observed longlining boats most frequently involved continuous discharge of material during haul on the same side of the vessel as the hauling station (haulside; 20% of BLL trips and 50% of SLL trips) (Table 5). Some vessels managed discharging more actively to mitigate seabird risk, with 35% of BLL trips and 25% of SLL trips discharging in DMP classes 1–3. Most of the active DMP on observed BLL trips involved continuous discharging on the offside, keeping discharge away from the hauling station (13% of BLL trips), following New Zealand BLL regulations (NZ Government 2010). Discharging from the haulside, but in breaks in hauling or in batches rather than continuously, was equally common (also 13% of trips). Active DMP on observed SLL trips mostly involved discharging in batches or breaks from the offside (10% of observed trips) and haulside (a further 10%) (Table 5), in part because NZ regulations do not prohibit haulside discarding (NZ Government 2011). A similar proportion of BLL and SLL trips had no documented information of any type on discharging (27% and 23% of trips, respectively). However, BLL and SLL operations diverge sharply in the no-discharge category (no discharge overboard in any form at any stage of fishing): no discharging was recorded on 18% of BLL trips but just one SLL trip (3% of trips). This is likely related to production, since BLL operations rarely process fish to any great extent, compared with SLL where most fishing involves processing (D. Goad pers. comm.). Discharging during setting was not documented for any longlining trip (Table 5), in line with NZ regulations and international best practice (Kellian 2003; ACAP 2017a, b; NZ Government 2010, 2011), but incidental discharge of bait fragments during shooting is known to occur in some BLL fisheries domestically and internationally (Brothers et al. 1999; Pierre et al. 2013).

DMP on observed trawl trips primarily involved discharging while gear was being towed (39% or 42 trips) (Table 5). A further 14% of trips discharged material while gear was being shot as well as during tow. Discharging during the haul was rare (3% of trips, DMP classes 2 and 5), as was discharging just during shooting (3% of trips). About a quarter of observed trawl trips recorded no discharge overboard during any fishing stage (26% of trips). A smaller proportion of trawl trips lacked information on discharging than for longlining trips, with 16% of trawl trips having unknown DMP compared to about a quarter of longlining trips (Table 5).

Looking specifically at batch discharging, we see that batching was mentioned in observer reports least for BLL operations (7% of trips), when compared to 18% of SLL trips and 11% of trawl trips (Table 6). A further 2–9% of reports make it clear that material was discharged continuously, so we infer that batching is not occuring. Both figures (batching and continuous discharge) are likely underestimated since the large majority of trip reports have no information on batching of discharge (Table 6), making it difficult to understand how common batching is.

The frequency that different discharge types were documented during observed fishing events is shown in Table 6. The three main types of discharge are whole fish, offal, and returned baits. Offal from fish processing was the most common discharge type across all fishing methods, with offal discharged on 58–65% of observed trips. Trawlers discharged whole fish and offal on a similar proportion of trips (56% fish, 62% offal), while it was less common for longlining vessels to discharge whole fish (alive, dead or damaged) than offal (24% of BLL and 15% of SLL discharged fish).

Untaken or returned baits are an important contributor to discharge on observed longlining trips. For example, on two trips observers recorded 60kg to more than 80kg of baits discharged and documented behavioural change in seabirds as discharging progressed (discharged continuously during hauling). Untaken baits tend to be returned to the vessel more in SLL operations than from BLL gear (Goad 2017), as reflected in bait discharging: baits are discharged more in SLL trips than BLL trips (Table 6). At least 40% of SLL vessels and 27% of BLL vessels discharged baits during haul. Although higher than recorded for SLL elsewhere (e.g. Pierre 2016), this should be considered a bare minimum since a further 35% and 42% of trip reports had no information on whether baits were held or discharged, or where discharged from (SLL and BLL, respectively).

Deck losses were rarely mentioned in observer trip reports (Table 6). We have assumed that this is because observers include deck losses in overall whole-fish and offal discharge categories for trawl fishing events. Deck losses are relevant to managing discharge because deckwash can move edible material overboard in unpredictable pulses. Some fishers made efforts to manage deck losses via gratings across scuppers, or by picking up deck spills (3 trawl trips, 7%). However, the contribution of managing deck loss to a vessel's overall DMP cannot be assessed from current discharge categories in observer data.

A precision seafood harvesting PSH codend was used for at least part of 30 trips, or 28% of all observed trawl trips. A PSH net replaces the conventional mesh lengthener and codend gear of a trawl with gear intended to reduce flow and turbulence in the net. We include trips where PSH was used for only part of fishing as 'PSH trips' because on a given trip, trawls with standard gear do not occur in isolation from fishing events with a PSH codend. That is, if there is a difference in bird behaviour around a PSH codend at haul, we assume that bird behaviour at the subsequent set could be affected, whether the next set uses standard or PSH codends.

Table 5. Discharge management practises DMP in observed small-vessel longlining trips and trawl trips.

Longlining		BLL			SLL		
Lining DMP class		events	trips	%BLL trips	events	trips	%SLL trips
no discharge any fishing stage	0	161	8	18	7	1	3
disc in breaks/batches haul offside	1	47	4	9	62	4	10
disc breaks/batches haul haulside	2	158	6	13	46	4	10
disc continuous haul offside	3	172	6	13	23	2	5
disc continuous haul haulside	4	189	9	20	242	20	50
disc set and haul	5	0	0	0	0	0	0
unknown	U	181	12	27	109	9	23
Total		908	45		489	40	

Trawl				
Trawl DMP class		events	trips	%TWL trips
no discharge any fishing stage	0	1195	28	26
disc tow, none shot & haul	1	2125	42	39
disc tow & haul, none shot	2	27	2	2
disc shot & tow, none haul	3	1215	15	14
disc shot, none tow & haul	4	236	3	3
disc all stages	5	30	1	1
unknown	U	783	17	16
Total		5611	108	

Table 6. Batch discharging and discharge type as recorded in observer documentation for small-vessel longlining and trawl trips. Bait discharging records include known records followed by the number or percentage of trips where baits were not mentioned in brackets (unkn bait discharge). Deck losses can be any combination of offal, whole or damaged fish and baits.

	BLL		SLL		TWL	
	trips	%BLL trips	trips	%SLL trips	trips	%TWL trips
Batch discharging						
batch discharging mentioned	3	7	7	18	12	11
no batching, or continuous disc mentioned	4	9	2	5	2	2
batching unknown	38	84	31	78	94	87
Discharge type						
baits discharged (unkn bait discharge)	12 (19)	27 (42)	16 (14)	40 (35)		
fish heads	3	7	1	3		
whole fish	11	24	6	15	60	56
offal	26	58	26	65	67	62
deck losses					3	3

Seabird interactions

Observer data included 705 records of seabird interactions on small trawl and lining vessels, from 72 observed trips (after missing records added from observer documentation). Across all trips, the 705 bird interactions were recorded in 270 fishing events. The most recent capture included in the dataset received was reported on 20 December 2016. Most observed captures involved *Thalassarche* albatrosses, with 158 albatrosses caught in small-vessel operations (22% of all captures, at a rate of 1.6 albatrosses/100 fishing events) (Table 7). Buller's albatrosses were most often observed caught (58 individuals), followed by 45 white-capped albatross capture records. Appendix 2 gives a species-level breakdown of observed interactions, with scientific names and MPI species codes. Shearwaters and the smaller petrels (*Puffinus* spp. and the *Pterodroma* petrels) were the next most-represented group, at 1.3 captures/100 events, while recorded captures of the larger *Procellaria* petrels such as black and white-chinned petrels occurred at a rate of 0.8 petrels/100 events (Table 7).

Table 7. Seabird interactions recorded in small-vessel trawl and longlining operations 2013–2016. Capture rate is the number of birds caught per 100 fishing events. Values in parentheses include seabirds from a single large deck-strike interaction event of 302 individuals.

species	birds caught	capture rate
Buller's, white-capped & other albatrosses	158	1.614
Shearwaters and mid-sized petrels	124	1.267
Black petrels & other *Procellaria* petrels	78	0.797
Diving petrels, storm petrels & prions	30 (332)	0.309 (3.391)
Other: black-backed gull & Northern giant petrel	6	0.061

About a third of observed trawl trips recorded one or more seabird interaction(s) (31%, considering just captures on trips for which observer documentation was available) (Table 8). Seabird interactions were documented in 60% of surface longlining trip reports, and 42% of bottom longlining trips recorded interactions with one or more seabirds (Table 8). Refining this summary to consider the number of individuals and fishing effort, we see that seabird interactions were recorded at the highest rate in bottom longlining operations at 38 birds/100 fishing events, and at the lowest rate in trawl fishing (2 birds per 100 events). These are the raw interaction rates, which include all seabird interactions (captures on gear as well as deck strikes).

Most observed interactions involved single animals (73% of fishing events where birds were captured; Table 9), in line with work restricted to longliners that also showed most interactions were captures of single animals (Pierre 2018). Capture events generally involved ten seabirds or less per fishing event, but single fishing events where 16, 25, 27, 69 and 125 individuals were recorded also occurred (Table 9). There were no seabird captures on most (63%) observed trips, but observers reported interactions ranging from capture of one bird per trip to as many as 302 seabird interactions per trip (Table 9).

Deck strike is included in this study on seabird interactions with small-vessel fisheries, but have potential to obscure useful gear-related capture patterns. We therefore provide capture figures excluding deck strike numbers ('gear' includes only birds caught on or entangled in fishing gear), as well as capture figures including all interactions recorded ('overall' includes captures on gear as well as deck strikes) (Table 8, and throughout report). Excluding deck-strikes, seabird captures in surface longline fishing remain high (25 captures/100 fishing events) and trawl captures remain low (1 seabird caught/100 events) (Table 8). Bottom longline fishing shows the most marked effect of excluding deck strikes, decreasing from an overall capture rate of 38 captures/100 events to 4 captures/100 events (Table 8).

Table 8. Summary of seabird interactions recorded in observed small-vessel trawl and longlining operations. Trips with interactions is the number of trips with at least one seabird interaction. Birds caught is the number of individuals captured in fishing gear (gear) or the number recorded in all interactions including gear captures and deck strike (overall). Capture rate is the number of birds caught in per 100 fishing events in fishing gear (gear) or in deck-strike/gear interactions (overall).

	events	trips	trips with interactions	%trips with interactions	Birds caught		Capture rate	
					gear	overall	gear	overall
BLL	908	45	19	42	37	348	4.1	38.3
SLL	489	40	24	60	122	131	24.9	26.8
TWL	5611	108	33	31	43	91	0.8	1.6
Total	7008	193	76		202	570		

Table 9. Frequency of seabird interactions recorded in a fishing trip, and frequency of captures of one or more individuals in a single fishing event, for small-vessel trawl and longlining operations. Interactions include deck strikes with gear captures.

n individuals	n trips	n events
0	121	
1	27	199
2	14	30
3	10	11
4	0	9
5	6	5
6	1	4
7	7	3
8	2	0
9	0	1
10	1	1
11	0	2
14	1	0
15	1	0
16	0	1
25	0	1
26	0	0
27	0	1
43	1	0
69	0	1
125	0	1
302	1	0

Retrieval location, alive or dead

Seabird interactions were classified according to mode of capture based on retrieval location (hook, tangled in lines, recovered from net or warp, deck strike/impact, other, unknown mode of capture) (Table 10). Most seabirds interactions in small-vessel trawl fisheries were of seabirds caught in the net (34% of seabirds caught in trawl operations) or subject to deck strike (37%). The number of warp captures was relatively small (8% of captures), but warp captures are likely underestimated (Abraham and Thompson 2009; Koopman et al. 2018). The majority of seabird interactions recorded during surface longlining were caught on the hook (88% of seabirds caught in SLL fishing), with few deck strikes (five seabirds, or 4% of SLL captures). In contrast, several large-scale deck strike events occurred during BLL fishing (in this case recorded as ‘other’ by the observer, Table 10), where up to 125 seabirds had to be assisted off the vessel during a single fishing event (Table 9). These mass interactions obscure location patterns in the remaining data, so we separate them here and throughout. Excluding the 302 birds involved and considering the remaining BLL capture locations separately shows that the majority of other BLL captures were hooked (70% of all captures, Table 10).

Tangling on lines—typically snoods wrapped around the wing—was more frequently seen in BLL fishing (11% of captures, 5 birds) than SLL fishing (5%, 7 birds) (Table 10). These numbers are minima, since tangling is more likely during setting, when snoods are slack at the surface (D. Goad pers. comm.), and birds caught during set have to stay tangled for set, soak and haul to be recorded.

The timing of captures, set or haul, is important to gauge the potential for undetected mortalities and our confidence in the completeness of data, but capture timing is rarely known with certainty. We use life status on retrieval as a proxy for capture timing following Pierre (2018), where birds retrieved dead indicate captures occurring during setting, while live animals were most likely caught during haul. The extent that a bird is waterlogged can also provide insight, but these data are only beginning to be recorded more regularly (Pierre 2018). Similarly, captures and the rate of undetected captures during trawl operations are expected to relate to the fishing stage, with net captures more likely to be recovered alive during hauling than if captures occurred during setting or towing. Warp captures during shooting are less likely to be detected than during tow and haul. However, warp captures at hauling can easily be fatal, as the warps are moving towards the warp block, and the distance between where birds typically entangle (at the warp-water interface) and the block is short. Winch operators can mitigate warp captures at the haul if they have a line of sight with the warps, or deck crew quickly communicate to winch operators. Solo trawl operators in particular report stopping winches during the haul when a bird comes into contact with warps (pers. comm. to G.P.).

Tangling captures here suggest that tangling did mostly occur while gear was set, as expected, with 65% of tangled birds retrieved dead (indicating tangling during set) and 35% retrieved alive, suggesting tangling during hauling (Table 11). Similarly, most hooked birds appear to have been hooked while setting (85% hooked birds dead), with only 14% recovered alive indicating a lower proportion hooked during the haul. In trawling operations, net captures appear to occur mostly during hauling, with 76% of birds caught in the net removed alive. Birds caught on the warp were almost all dead (96% dead, Table 11), suggesting that warp captures mainly occurred at earlier fishing stages, but also highlighting the problem of retaining warp captures long enough for detection (e.g. Watkins et al. 2008; Abraham and Thompson 2009; Parker et al. 2013; Koopman et al. 2018).

Further information on captured seabirds is available from the observer non-fish bycatch forms, including the sex and age, but the data are incomplete so were not analysed further.

Table 10. Retrieval location of seabirds interacting with observed small-vessel trawl and longline fisheries 2013–14 to 2016–17. The number of birds caught is shown as a percentage of the total number of recorded captures in that fishing method. Values in parentheses for BLL include seabirds from a single large deck-strike interaction event of 302 individuals.

Retrieval location	Code	BLL		SLL		TWL	
		n	%of BLL	n	%of SLL	n	%of TWL
caught in net	N					31	34.1
caught on warp or door	S					7	7.7
caught on hook	H	32	69.6 (9.2)	115	87.8		
tangled on lines	T	5	10.9 (1.4)	7	5.3	5	5.5
deck strike or impact against vessel	I	7	15.2 (2.0)	5	3.8	34	37.4
other	O	1 (303)	2.2 (87.1)	3	2.3	10	11.0
unknown	U	1	2.2 (0.3)	1	0.8	4	4.4
totals		46 (348)		131		91	

Table 11. Seabirds caught dead and alive relative to capture location in small-vessel trawl and longline fishing, as percentage of total birds captures recorded at each location. Values in parentheses include seabirds from a single large deck-strike interaction event of 302 individuals.

	alive	% alive	dead	% dead	Other	% other	Total
caught in net	34	76	9	20	2	4	45
caught on warp or door	1	4	22	96			23
caught on hook	32	14	190	85	1	0	223
tangled on lines	7	35	13	65			20
deck strike or impact against vessel	47	100					47
other	16(318)	89(99)	2	11(1)			18(320)
unknown	4	57	3	43			7

Mitigation

Mitigation devices

The frequency of use of different bird mitigation devices during observed small-vessel longline and trawl fishing is shown in Table 12. Most BLL and SLL trips involved single or paired tori lines (62% and 73% respectively). A smaller proportion of trawl fishing used mitigation: 40% of trips used a device of some kind, mostly bird bafflers (27 trips, or 63% of trawl trips where a mitigation device was used). The majority of small-vessel trawlers used no mitigation equipment at all (58% of observed trawl trips recorded as using no mitigation device). Fewer longliners failed to use mitigation devices: 22% of observed BLL and SLL trips recorded that no mitigation equipment of any kind was used (Table 12).

Observers on longline vessels documented a range of reasons why fishers did not deploy tori lines. Fishers mostly chose not to deploy tori lines because gear was set at night (six BLL trips and four SLL trips), or the operator considered other mitigation actions at set sufficient (one further SLL trip). Poor weather was cited as the reason for not using tori lines on only two BLL and two SLL trips. A further 4–5% of longlining trips had unknown device use, with no information available, and there were no trawl trips with undocumented mitigation device use (Table 12).

Other mitigation devices—improvised or non-standard devices—were reported on 11% of BLL trips, mostly involving a towed line with up to three mid buoys or windy buoys during setting (five trips, Table 12). One BLL vessel jury-rigged a baffler-type device to surround the hauling station, and one documented occasional use of fireworks to scare birds away. Non-standard and improvised devices were also mentioned in SLL observer reports. SLL operations occasionally used water curtains at the hauling station (two trips), swung a buoy on a line over the haul station (one trip), or used bird lasers over the wake on bright nights (two trips). These do not appear as 'other' in Table 12 because they were used on vessels where tori lines were the primary mitigation device used. Trawlers used a greater diversity of improvised devices: improvised baffler-type devices with streamers instead of droppers (two trips), a 'bird bar' of floats to prevent access to warps by birds (one trip), and a range of devices used mainly when processing and discharging. These included improvised warp-scarer type devices (using road cones, windy buoys or long buoys, five trips); a line of floats as a barrier around scuppers (one trip); an improvised single tori-type line (one trip); and a life ring on a rope (one trip). Some devices classed as tori lines in trawl documentation lacked key features like streamers and were strung under the warps (two trips); these would better have been categorised as 'other'.

Table 12. Mitigation equipment used on observed small-vessel longlining and trawl trips.

		BLL			SLL			TWL		
	code	events	trips	%BLL trips	events	trips	%SLL trips	events	trips	%TWL trips
baffler	b							1631	27	25
warp scarer	w							72	1	1
tori	t	557	28	62	341	29	72.5	700	10	9
other	o	127	5	11				217	5	5
none	n	205	10	22	119	9	22.5	2956	63	58
unknown	unkn	19	2	4	29	2	5			
Total		908	45		489	40		5611	108	

Operational mitigation

Operational mitigation refers to practises used by fishers intended to reduce the risk of seabird captures other than mitigation devices and management of discharge. The main operational factor discussed in reviewed trawl trip documentation was the removal of stickers from the net before it was re-shot, to reduce the attractiveness of the net before it sinks out of seabird diving range. Sticker removal may have other purposes (for example to recover commercial species) but was only recorded in observer documentation as part of operators' seabird mitigation response. Stickers were cleaned from nets in 22% of trawl trips reviewed (Table 13). Net cleaning mostly occurred before the net was shot again, but the timing (during or after haul) was only clear from one trip report, where the vessel removed stickers continuously as the net was being hauled. At least 1% of trips did not remove net stickers, and 77% of trip documentation provide no information on sticker removal (Table 13).

Some trawl fishers actively tried to minimise the time that the net spent at surface (mentioned in five reports), but information on how long the net remained at the surface was rare (seven reports gave time doors-up to net on deck; most other times provided were from fishing depth to doors-up). There was no information on what was done to reduce net surface time. Some operators minimised deck or stern lighting when trawling at night to reduce seabird attendance, but the extent of this practise was unclear since lighting was rarely documented (lighting mentioned in 4% of trawl observer reports).

A suite of operational mitigation practises was reported on small-vessel longliners that fishers considered part of their seabird mitigation response. The most-mentioned approaches were setting gear at night and extra line weighting. Other strategies sometimes used to reduce seabird interactions included dyed baits (one BLL trip, four SLL trips), setting hooks directly under the tori (two SLL trips), moving away from concentrations of birds for the next set (two SLL trips), hauling fast to keep the hooks down (one BLL trip), and a range of measures to improve hook sink time. Measures to help sink hooks faster included thawed baits (two BLL and eight SLL trips), setting with slack snoods or reduced mainline tension (six SLL trips), slow set speed (one BLL, three SLL trips), and setting into the wake (three SLL trips). Some approaches were described as reactive mitigation, or planned actions if birds are particularly abundant or captures occur: doubled line weights, extra tori line, clipping suspended until birds leave, and ceasing operations entirely (Pierre 2016). Reducing deck lighting, avoiding stern lights and light containment has been reported as standard practise on longlining vessels (Kellian 2003); for example, lighting was managed on three-quarters of SLL vessels (Pierre 2016). Lighting was rarely mentioned in observer reports (mentioned in 25% of SLL reports but no BLL reports), but this seems to be a reporting artefact.

Observers recorded gear being set at night specifically to minimise the risk of seabird captures in 40% of observed BLL trips and 78% of SLL trips (Table 13). These figures may be higher in practise (e.g. high rate of night setting reported in ling BLL; Kellian 2003) or inflated if 'night' was used for setting in the darkness of nautical dawn/dusk as well as for strict nautical darkness (between 0.5 hours after nautical dusk and 0.5 hours before nautical dawn; NZ Government 2010). However, the accuracy of night-setting data cannot be gauged from observer documentation.

Table 13. Operational mitigation: night setting, line weighting and net cleaning practises for seabird mitigation in trip documentation for small-vessel trawl and longlining. Percentages are based on 45 bottom longline BLL trips, 40 surface longline SLL trips and 108 trawl trips.

Longlining	BLL events	trips	%BLL trips	SLL events	trips	%SLL trips
Night setting	338	18	40	358	31	78
Night setting not practised	166	6	13			
unknown night setting	404	21	47	131	9	23
BLL gear weighted for seabirds	144	11	24			
no gear weighted	245	8	18	218	21	53
unknown line weighting	519	26	58	150	11	28
SLL gear weighted for seabirds				121	8	20

Trawl	events	trips	%TWL trips
stickers removed before net shot	1161	24	22
net stickers not removed	84	1	1
unknown sticker removal	4366	83	77

Line weighting for seabird mitigation focuses on adding extra weights to fishing gear to sink baited hooks away from the surface as fast as possible. Line weighting was documented in 24% of BLL trips and 20% of SLL trips (Table 13). About 18% of BLL trips recorded that no extra line weighting was used, while the majority remained unknown (58% of BLL trip reports lacked information on line weighting). Conversely, more than half of SLL trip documentation recorded that no line weighting was in use (53%), and 28% of SLL trips line weighting remained unknown (Table 13).

Line weighting used in observed SLL trips mostly involved weights on the snood, using lumo leads, hook pods and weighted swivels fitted closer to the hook than the clip. In most instances, weights were fitted within 4m of the hook per NZ line weighting regulations for surface longlining (NZ Government 2011). Weights at or near the clip are not considered part of line weighting for seabirds in SLL fishing, being too far from the hook to increase hook sink rates, but were recorded on 40% of observed SLL trips (cf. majority of SLL gear set weighted at the clip; Goad and Williamson 2015).

In observed BLL trips, seabird-mitigation line weighting (that is, which operators considered line-weighting part of seabird mitigation response) included: 5–10kg per 100m; 1.2kg every 30m; 1kg every 12m; 'double-up' weighting for higher-risk daytime sets variably recorded as 2kg every 60m or 0.5–1kg every 30–35m. This range of weighting approaches is similar to that recorded by Pierre (2016). However, unless sink rates associated with use of these line weightings are tested, the usefulness of a given weighting setup for reducing seabird captures cannot be assessed. For example, sink rate tests on two trips confirmed that doubling their gear weighting during high-risk periods (when birds are around, or during daytime sets) sunk gear notably faster, but in some cases sink rates are slower with seabird weights than for standard gear weighting (D. Goad pers. comm). Only one of the examples above meets New Zealand line weighting regulations for bottom longline fishing (1kg every 12m) (NZ Government 2010). None of these examples meet the international minimum standard of >5kg at maximum 40m spacing (ACAP 2017a), but the standard is based on testing with much larger vessels so its relevance to smaller operations is unclear.

Seabird capture rates vary

Capture rates by discharge management

Across all trawl and longlining trips reviewed, seabird capture rates were influenced by discharging: the highest seabird capture rate in each fishing method was seen on trips where fewest actions were taken to limit discharging overboard (least discharge management, lining DMP class 4 and TWL class 5; Table 14). Any steps taken by fishers to manage discharge are referred to here as the 'discharge management strategy', represented by DMP classes 0–3 for longlining and classes 0–4 trawling (Table 14).

In observed SLL trips, the location where material was discharged from appeared important. Seabird capture rates were lowest when discharging on the offside (away from the hauling station) in batches or hauling breaks (6.5 seabirds/100 events), and the rate doubled with haulside discharging in breaks/batches (17.4 seabirds/100 events) (Table 14). Continuous discharging on the haulside produced the highest seabird capture rate in observed SLL trips (34.7 seabirds/100 events). This pattern remained when gear-related captures were re-aggregated with deck strikes (overall capture rate, Table 14). There were not enough data to compare this continuous discharging on the haulside with continuous offside discharging (only 23 fishing events) (Table 14).

In observed BLL trips, discharge location also appears important. Continuous offside discharging was associated with lower bird capture rates (0.6 birds/100 fishing events) than continuous haulside discharging (5.3 birds/100 events) (Table 14). When discharging on the haulside, discharging in breaks/batches was linked to lower bird capture rates (1.3 captures/100 events) than continuous discharging (5.3 captures/100 events). Including deck strike data made no difference to these patterns (Table 14). Seabird captures during BLL operations were lower while discharging on the offside than when no discharge was produced at all (5 seabirds/100 events), pointing to the usefulness of targeted discharging in distracting birds from hauling operations. Offside discharging is expected to reduce occurring during haul (more likely to be brought aboard live) but not captures occurring during set or soak (generally brought aboard dead); in contrast, batching should have a greater effect on numbers brought aboard dead as it is thought to influence bird capture in the subsequent shoot. This could not be explored further since there were insufficient captures in each category to split into live and dead captures. To better understand the different effects of discharging location and frequency on bird captures, using live/dead status as proxy for when captures occurred per Pierre (2018), requires further research.

Observed bird capture rates remained higher in SLL than BLL operations, across DMP classes (Table 14). This may in part be because SLL boats fish closer together than BLL vessels and birds are thought to fleet-scan, so discharge management in other parts of the fleet could also influence a vessel's bird capture rates (D. Goad pers. comm.). In other regions, fleet-scanning appears to occur more widely yet; longline seabird captures in the Mediterranean increased during periods when trawlers were not working (e.g. García-Barcelona et al. 2010).

Holding unused returned baits on board during hauling reduced seabird captures in observed longline trips (Table 15). Bait retention by BLL vessels halved the seabird capture rate seen on trips where baits were discharged during hauling, with 5.5 captures/100 events with baits discharged and 2.9 birds/100 when baits were retained. Bait retention also decreased capture rates in SLL, from 30.1 seabirds/100 events on trips where baits were discharged to 18.2 birds/100 when baits were retained on board (Table 15).

Small trawler DMP were better documented than DMP for longliners, with discharging actions unknown for only 16% of trips compared to 23% for BLL and 27% for SLL (Table 14). Bird captures occured least when discharging during tow but holding material during haul (classes 1 and 3, 0.6 and 0.1 captures/100 trawls respectively). The highest capture rate was recorded from trips where there was no record of discharging at any fishing stage (2.1 captures/100 events) (Table 14). Capture rates were also high when discharging occurred during shooting (1.3 captures/100 trawls), despite the likelihood of poorer retention of birds captured while gear is shot (e.g. warp captures) than if captured at a later stage in fishing. Discharging over all stages of fishing was associated with a high rate of interactions, all recorded as 'other' or deck strikes, but this category was also represented by least fishing effort (30 trawls).

Batch discharging was mentioned in 11% of trawl trip reports reviewed (Table 6), but unlike longlining, did not seem to reduce bird capture rates. Batch discharging appeared linked to 1.5 captures/100 trawls, compared to zero captures for the small number of trips where it is known that discharging was continuous. The only interactions occurring while continuous discharge was documented were deck strikes (three birds), but these were excluded from gear capture rate calculations. Batching effectiveness should not be inferred from these data since the large majority of fishing events had no information on batching of discharge (4,625 events batching unknown; 87% of trawl trips, Table 6). Given that a proportion of these unknowns are likely to include batch discharging and the capture rate when batching unknown was 0.7 captures/100 trawls, we expect that the contribution of bird captures occurring during undocumented batch discharging could substantially shift capture rates.

Observers reported a PSH codend on at least part of 30 of the 108 small-vessel trawl trips included in this review. Observed seabird interactions were higher on trips where a PSH codend was used (2.2 interactions/100 tows) than when standard gear was used (1.4 interactions/100 tows) (Table 16). That pattern held when including only birds caught on fishing gear (excluding deck strikes), with 1 gear capture/100 when a PSH codend was used and 0.7 captures/100 with a standard codend. Considering only birds caught in the net, the capture rate remained higher when a PSH codend was in use than with standard gear (1 capture/100 PSH compared to 0.4 captures/100 standard gear) (Table 16). Observer reports noted seabirds diving on fish escapees from the codend, and that the PSH codend seemed to provide extra fish from the escape ports. Some of the 1,620 events comprising 'PSH trips' involved tows with standard gear, so this figure could be affected by data from subsequent shots with standard gear.

This should be investigated further, to tease out direct PSH effects on seabird behaviour and captures from follow-on effects if standard gear is used after a PSH codend.

Table 14. Seabird capture rate, as captures per 100 fishing events, grouped by trip-level discharge management class. Birds caught is the number of individuals captured in fishing gear (gear) or the number recorded in all interactions including gear captures and deck strike (overall). Capture rate is the number of birds caught per 100 fishing events in fishing gear (gear) or in deck-strike/gear interactions (overall). Averages are only shown for device-discharge combinations represented by more than 30 fishing events.

		BLL					SLL				
			Birds caught		Capture rate			Birds caught		Capture rate	
DM class		events	gear	overall	gear	overall	events	gear	overall	gear	overall
no discards any stage	0	161	8	8	5.0	5.0	7	0	0		
disc in breaks/batches haul offside	1	47	0	1	0	2.1	62	4	5	6.5	8.1
disc breaks/batches haul haulside	2	158	2	304	1.3	192.4	46	8	9	17.4	19.6
disc continuous haul offside	3	172	1	2	0.6	1.2	23	0	0		
disc continuous haul haulside	4	189	10	16	5.3	8.5	242	84	85	34.7	35.1
disc shoot or haul	5										
unknown	U	181	16	17	8.8	9.4	109	26	32	23.9	29.4
Total		908	37	348			489		131		

			Birds caught		Capture rate	
DM class TWL		events	gear	overall	gear	overall
no discards any stage	0	1195	25	25	2.1	2.1
disc tow	1	2125	13	44	0.6	2.1
disc tow & haul	2	27	0	3		
disc shot & tow	3	1215	1	7	0.1	0.6
disc shot	4	236	3	3	1.3	1.3
disc all stages	5	30	0	5	0	16.7
unknown	U	783	1	4	0.1	0.5
Total		5611		91		

Table 15. Bait retention and capture rate of seabirds in small-vessel longlining. Bait retention refers to whether unused returned baits are retained on deck during hauling. Birds caught is the number of individuals observed captured in fishing gear (gear) or the number recorded in all interactions including gear captures and deck strike (overall). Capture rate is the number of birds caught per 100 fishing events in fishing gear (gear) or in deck-strike/gear interactions (overall).

		BLL					SLL				
			Birds caught		Capture rate			Birds caught		Capture rate	
		events	gear	overall	gear	overall	events	gear	overall	gear	overall
baits retained	y	208	6	7	2.9	3.4	137	25	27	18.2	19.7
baits not retained	n	236	13	20	5.5	8.5	183	55	56	30.1	30.6
unknown	unkn	464	18	321	3.9	69.2	169	42	48	24.9	28.4
Total		908	37	348			489	122	131		

Table 16. Codend type and capture rate of seabirds in observed small-vessel trawl fisheries. Birds caught is the number of individuals observed captured in the net (net), in fishing gear including warps and nets (gear), or overall including gear captures and deck strike (overall). Capture rate is the number of birds caught per 100 fishing events in nets only (net), all fishing gear (gear), or in deck-strike/gear interactions (overall).

		Birds caught			Capture rate		
	events	net	gear	overall	net	gear	overall
PSH codend used	1620	16	16	36	1.0	1.0	2.2
Standard codend used	3991	15	27	55	0.4	0.7	1.4

Capture rates by mitigation

Mitigation devices

Seabird capture rates in observed trawl fishing were lowest when a bird baffler was used (0.1 birds per 100 events), lower than when no mitigation device was used (0.9 seabirds/100 trawls; Table 17). By comparison, trawl trips using tori lines involved bird captures at a rate of 1.6 seabirds/100 events (Table 17). Only one observer report documented tori lines in use while the codend was at the stern. Note seabird capture rates are calculated using all gear capture modes (net, warp and line tangles, omitting deck-strike interactions), rather than with warp captures alone, since captures occur not only on the warp but also in a vessel's other lines (Table 10). Intermediate seabird capture rates were observed when 'Other' devices were used (0.7 captures/100 events) (Table 17). Other devices were grouped together here because they were comparatively rarely used, and included warp scarers, lines with floats, buoys or a life-ring strung below the warp, water curtains or a line of floats at the discharging point and improvised bafflers (streamers instead of droppers).

Seabird captures during longline fishing were recorded at higher rates when tori lines were used during setting than on trips where there was no mitigation device used, for both BLL and SLL operations (Table 17). Seabird captures during BLL fishing occurred most frequently when 'other' mitigation devices were used (generally mid buoys or windy buoys towed on a 25m line; 5.5 captures/100 events). Other mitigation devices used for BLL were commonly rigged as a form of reactive mitigation (i.e. improvised bafflers around the hauling station when captures occurring or birds abundant) and not used if birds were not present, potentially creating a bias for captures to be recorded with device use. Observers also documented tori lines only being deployed when bird numbers increased, creating a similar bias for capture records when tori lines were in use. When most captures are of a single bird per trip as seen here (Table 9), Pierre (2018) points out that using reactive mitigation methods after a capture will not necessarily reduce the number of captures overall. This would suggest that most reactive mitigation must have been in response to bird abundance.

Table 17. Capture rate of birds by mitigation device in observed trawl and longline fisheries. Birds caught is the number of individuals observed captured in fishing gear (gear) or the number recorded in all interactions including gear captures and deck strike (overall). Capture rate is the number of birds caught per 100 fishing events in fishing gear (gear) or in deck-strike/gear interactions (overall). Averages are only shown for device-discharge combinations represented by more than 50 fishing events.

	BLL					SLL				
		Birds caught		Capture rate			Birds caught		Capture rate	
	events	gear	overall	gear	overall	events	gear	overall	gear	overall
baffler										
tori	557	20	324	3.6	58.2	341	110	116	32.3	34.0
other	127	7	7	5.5	5.5					
none	205	3	9	1.5	4.4	119	11	13	9.2	10.9
unknown	19	7	8			29	1	2		
Total	908	37	348			489		131		

TWL		Birds caught		Capture rate	
	events	gear	overall	gear	overall
baffler	1631	2	14	0.1	0.9
tori	700	11	23	1.6	3.3
other	289	2	10	0.7	3.5
none	2956	28	44	0.9	1.5
unknown					
Total	5611	43	91		

The capture rate of birds, grouped by discharge type and mitigation device, in observed trawl and longline fisheries is shown in Table 18. In BLL, the highest capture rates occurred when discharge was least managed—continuous discharging on the haulside—despite tori line use on subsequent sets (4.6 seabirds/100 events) (Table 18). This suggests seabird captures occurred mostly during hauling, when discharging occurs, and less frequently during setting, when a tori line could reduce captures. Seabird captures were lower when discharging in breaks/batches with a tori line (0.7 captures/100 events), with batch discharging thought to reduce the interest of seabirds during subsequent set. BLL captures of seabirds were lowest when discharging occurred on the offside even without mitigation device use (0.6 captures/100 trawls no mitigation device), again pointing to skew of haul captures, so offside discharging can be a functional distraction. There were too few data to compare different mitigation device categories within a DMP class.

SLL fishing indicated that tori line use had less influence on bird capture rates than DMP. When tori lines were in use, the highest rate of seabird captures occurred when discharge was managed least (8.5 captures/100 events, class 4), and seabird captures reduced to 6.5 captures/100 when discharging was limited to breaks or batches on the offside (Table 18). The lowest capture rate was seen with continuous discharging and no mitigation device use (3.3 captures/100 trawls), where discharged material was presumably enough to distract birds from baited hooks.

Observed trawl fishing indicated that in general, a bird baffler reduced capture rates, across discharge management strategies (Table 18). For example, when no discharging occurred during fishing, a baffler reduced captures from 3.5 per 100 tows (when no device used) to 0.4 captures/100 tows. The same reduction was seen when discharging during tow, and when discharging was unknown (Table 18). Baffler use also correlated with lower capture rates than other device types, for any given DMP class. For example, on trips where discharging occurred during tow, capture rates were higher with tori line (1.3 captures/100 trawls) and Other device use (0.9 captures/100) than with bafflers (no captures). The highest bird capture rate occurred when there was no mitigation device used, despite no discharge overboard during fishing (3.5 captures/100), and when there was discharge during shooting with tori line deployed (also 3.5 captures/100) (Table 18).

Table 18. Discharging actions and mitigation device use effects on bird capture rate. Birds caught is the number of individuals observed captured in fishing gear (gear) or the number recorded in all interactions including gear captures and deck strike (overall). Capture rate is the number of birds caught per 100 fishing events in fishing gear (gear) or in deck-strike/gear interactions (overall). Averages are only shown for device-discharge combinations represented by more than 30 fishing events

BLL	tori lines					other mit device					no device used					unknown				
		Birds caught		Capture rate			Birds caught		Capture rate			Birds caught		Capture rate			Birds caught		Capture rate	
DM class	events	gear	OA	gear	OA	events	gear	OA	gear	OA	events	gear	OA	gear	OA	events	gear	OA	gear	OA
no discards any stage	161	8	8	5.0	5.0															
disc breaks/batches offside	47	0	1	0	2.1															
disc breaks/batches haulside	145	1	303	0.7	209	11	1	1			2	0	0							
disc continuous offside	8	0	0								164	1	2	0.6	1.2					
disc continuous haulside	152	7	8	4.6	5.3	10	1	1			27	2	7							
disc shoot or haul																				
unknown	44	4	4	9.1	9.1	106	5	5	4.7	4.7	12	0	0			19	7	8		

SLL	tori lines					no device used					unknown				
		Birds caught		Capture rate			Birds caught		Capture rate			Birds caught		Capture rate	
DM class	events	gear	OA	gear	OA	events	gear	OA	gear	OA	events	gear	OA	gear	OA
no discards any stage	7	1	0												
disc breaks/batches offside	62	4	4	6.5	6.5										
disc breaks/batches haulside	26	3	6			20	2	2							
disc continuous offside	8	1	0			15	0	0							
disc continuous haulside	164	14	81	8.5	49.4	61	2	3	3.3	4.9	17	1	1		
disc shoot or haul															
unknown	74	6	19	8.1	25.7	23	7	8			12	0	1		

TWL	bird baffler					tori lines					other device					no device used				
		Birds caught		Capture rate			Birds caught		Capture rate			Birds caught		Capture rate			Birds caught		Capture rate	
DM class	events	gear	OA	gear	OA	events	gear	OA	gear	OA	events	gear	OA	gear	OA	events	gear	OA	gear	OA
no discards any stage	533	2	2	0.4	0.4											662	23	23	3.5	3.5
disc tow	678	0	9	0	1.3	614	8	20	1.3	3.3	214	2	9	0.9	4.2	619	3	6	0.5	1.0
disc tow & haul	13	0	3								14	0	0							
disc shot & tow	148	0	0	0	0						61	0	1	0	1.6	1006	1	6	0.1	0.6
disc shot	92	0	0	0	0	86	3	3	3.5	3.5						58	0	0	0	0
disc all stages																30	0	5		
unknown	167	0	0	0	0											581	1	4	0.2	0.7

Operational mitigation

In trawling operations, the seabird capture rate appears to have been substantially lower when stickers were removed from the net before shooting (0.1 birds per 100 fishing events) than on the single trip where it is known that net stickers were not removed (2.4 captures/100 events) (Table 19). For most trawl trips (77%) net sticker removal was not documented by observers, so the capture rates when stickers remain in the net should be used with caution.

A relatively common operational approach to seabird mitigation when longlining is to set gear at night, but its usefulness at reducing seabird captures is unclear from observer documentation. In observed BLL trips, it appears that the capture rate was slightly lower when night-setting than when gear was set in daylight (4.1 captures/100 events and 4.8 captures/100, respectively) (Table 19). For SLL gear, captures seem to have been higher when night-setting than when darkness at set was unrecorded (30.2 captures/100 night-setting and 10.7 captures/100 when night-setting unknown) (Table 19). This may be simply due to birds resting on the water being harder to see and avoid setting near when setting at night, but bird captures are also less likely to be detected at night. The association requires work to tease out the effects of other variables on bird capture rates at night. For example, SLL vessels are not required to use line weights when night-setting (NZ Government 2011), and vessels night-setting often do not use tori lines (13% of SLL vessels night-setting did not use a tori line). Similarly, tori lines were not used in a third of BLL trips where night fishing was recorded (six of 18 BLL trips where night setting was recorded), reflecting reports that some skippers do not feel tori lines are necessary when setting at night (Goad and Williamson 2015).

Seabird captures appeared lower when line weighting was used in observed BLL trips (2.8 captures/100 fishing events) than when no extra weights were deployed (3.7 captures/100) (Table 19). This should be interpreted cautiously since line weighting was undocumented for a substantial number of BLL events. In observed SLL trips, bird capture rates appear higher when line weights were used (22 captures/100 events) than when no line weighting was used (16 captures/100 events), but SLL trips with undocumented line weighting had almost double the capture rate (41 captures/100 events) of trips when line weights were used (Table 19).

Table 19. Seabird capture rates and operational mitigation: night setting, line weighting and net cleaning practises for seabird mitigation in trip documentation for small-vessel longlining and trawl. Birds caught is the number of individuals observed captured in fishing gear (gear) or the number recorded in all interactions including gear captures and deck strike (overall). Capture rate is the number of birds caught per 100 fishing events in fishing gear (gear) or in deck-strike/gear interactions (overall). Averages are only shown for device-discharge combinations represented by more than 50 fishing events.

	BLL					SLL				
		Bird captures		Capture rate			Bird captures		Capture rate	
	events	gear	overall	gear	overall	events	gear	overall	gear	overall
Night setting	338	14	22	4.1	6.5	358	108	115	30.2	32.1
Night setting not practised	166	8	8	4.8	4.8					
unknown night setting	404	15	318	3.7	78.7	131	14	16	10.7	12.2
BLL gear weighted for seabirds	144	4	5	2.8	3.5					
no gear weighted (BLL, SLL)	245	9	14	3.7	5.7	218	34	40	15.6	18.3
unknown weighting (BLL, SLL)	519	24	329	4.6	63.4	150	61	63	40.7	42.0
SLL gear weighted for seabirds						121	27	28	22.3	23.1

TWL		Bird captures		Capture rate	
	events	gear	overall	gear	overall
stickers removed before net shot	1161	1	4	0.1	0.3
net stickers not removed	84	2	6	2.4	7.1
unknown sticker removal	4366	40	81	0.9	1.9

Discussion

Characterising discharge management

Observer documentation for longliners <28m confirmed that discharge does not occur during setting. However, the most common haul discharge approach involved least effort to manage where and how material was discharged (continuous discharge on the same side of the vessel as the hauling station, or haulside). Continuous haulside discharging was more prevalent in SLL operations than in BLL fishing, in part reflecting differences in NZ legislation in which haulside discarding is restricted in BLL but not SLL operations (NZ Government 2010, 2011).

Using 'discharge management' inclusively to cover any actions managing discharge to mitigate seabird risk, we see that the nature and extent of DMP in longlining was mixed, in line with work both in individual fisheries and across fleets (Pierre et al. 2014; Pierre 2016, 2018; Goad 2017). Discharging was managed actively by about a third of bottom longliners. Breaking DMP into types, most discharge actions reported during BLL fishing involved discharging on the offside, aligning with NZ BLL regulations (NZ Government 2010), or on the haulside in batches/haul breaks. Active DMP was recorded in a smaller proportion of SLL trips: a quarter used some approach to manage discharge, mostly by discharging in batches or breaks in hauling (both offside and haulside). Only 15% of SLL trips involved offside discharging. Offside discharging was used much less than in SLL fisheries elsewhere (e.g. 70% of Hawaiian swordfish fishery discharge offside; Gilman and Musyl 2017), but may be overestimated here. Offside discharging has previously been documented at even lower rates in New Zealand SLL fisheries, with both smaller and substantially larger vessel numbers than reviewed here (Pierre 2016, 2018).

Batch discharging appeared to be a more important part of DMP efforts in surface- than bottom longline fishing, but this should be interpreted cautiously since most of the reports that this study is based on lacked information on discharge batching. The prevalence of batching documented here fits roughly with previous work (e.g. Pierre 2018, who included more vessels and some vessels >28m), and the extent of batching appears to have increased (cf. Pierre 2016). Batching prevalence also fits with observations from northern longline fleets (10–20% of vessels batching their discharge, D. Goad pers. comm), but more work is needed to understand how common batching is in other regions.

It was rare for SLL operations to discharge nothing during fishing but relatively common in BLL, which can be explained partly by the extent of processing. Processing in SLL fishing typically produces more offal (particularly when fishing for large fish like swordfish or tuna) than in BLL operations where most fish remain unprocessed (Goad 2017), although this can vary by fishery; some BLL fisheries can generate over a tonne of offal per set (e.g. ling BLL; Kellian 2003). Similarly, untaken or returned baits are discharged more during observed SLL trips than on BLL trips, in part because fewer baits are returned in bottom-fishing operations (Goad 2017). If SLL operations produce more offal and have more untaken baits than BLL fishing, this could partly explain why there is almost always some discharging during SLL fishing, but perhaps also why approaches like discharging in batches are more common for SLL than BLL fishing. We expect that the volume of discharge is relevant both to seabird behaviour (e.g. Koopman et al. 2018) and the practicality of various discharge management actions aboard, and that discharge volumes will differ among fisheries within each fishing method (Kellian 2003; D. Goad pers. comm). These assumptions could not be explored within the scope of this work, with little information on discharge volumes in the information available to us, and too few data after splitting target fisheries within each fishing method to produce useful patterns. The influence of discharge volume on protected species behaviour, capture rates and the discharge management actions used in specific fisheries should be explored further, particularly for southern fleets which have had less observer coverage.

Trawling was characterised by active management of discharge, primarily by managing the timing of discharging. Retaining discharge during hauling was widespread; observers documented discharging at haul for only 1% of trawls reviewed. Discharging was mostly limited to the tow stage, or not recorded at all during fishing. It was also relatively common for discharging to be recorded during both shooting and towing. When discharging occurred during shooting, it was rarely documented whether discharging took place while the net was still at the surface or discharged only after the net was submerged. Attractive material around the net when it is at the surface logically increases seabird risk, as reflected in the widespread holding of discharge during hauling. Discharge should also be withheld for a time before shooting and until it is at depth. Net cleaning for mitigation purposes, to reduce the amount of net stickers available around the net at shooting, was documented for about a quarter of trawlers. When documented, net cleaning was typically standard vessel practise, with net stickers removed before every shot.

Batch discharging, which reduces the abundance and warp strike rates of seabirds at trawlers (e.g. Pierre et al. 2010, 2012; Kuepfer and Pompert 2017), did not appear to be widely used by the small trawlers observed in this focal period. Batch discharging was occasionally recorded for the trawl trips reviewed. For most trawl trips the flow of discharging was not recorded, so continuous discharging and batch discharging could not be distinguished. Batch discharging may therefore be more common in the small-vessel trawl fleet than seen here. When batching occurred, the nature of batching could not be readily determined from the information available. Key features of batching important to its effectiveness as seabird mitigation are the holding period and swift discharge (Pierre et al. 2012; Kuepfer and Pompert 2017).

Deck losses are not often included in discussion of DMP, but can potentially provide pulses of edible material overboard if deckwash removes spilled fish or offal. Observer documentation reviewed here rarely recorded management of deck losses as part of a vessel's seabird response, but reports for three trawl trips recorded various actions (grating across scuppers, picking up deck spills). We suggest that approaches to minimise deck losses should be documented together with other parts of a vessel's discharge management strategy.

Overall, the variability in discharging actions and discharge management practises within each fishing method (trawl, bottom longline and surface longline) was driven not just by differences between fisheries and vessels but also by differences between trips of the same vessel, perhaps due to different skippers. This makes characterisation complex, but also provides insights into opportunity for improvements that could reduce bycatch risk.

Characterising mitigation

A mitigation device was used on about two-thirds of lining trips and less than half of trawl fishing. Most BLL and SLL trips involved single or paired tori lines. Fishers did not deploy tori lines for a number of reasons in longlining operations but mostly because other mitigation actions were considered sufficient; for example, gear was set at night, at slow setting speeds. Observers rarely documented that poor weather was given as the reason for not using tori lines, contrasting with other studies (e.g. Pierre 2016). Longliners ocasionally used several devices other than tori lines, including mitigation at the hauling station (buoy on a line swinging over the hauling bay, water curtain, and a 'baffler-type device' that appeared to be a modified Brickle Curtain). There was also a record of fireworks used to scare birds away, and several reports of vessels trying out bird lasers when night setting. Both approaches are unproven (for lasers see Melvin et al. 2016) and given potential bird welfare issues, not recommended (ACAP 2017b).

Trawlers mostly deployed bird bafflers as their mitigation device (about two-thirds of device use) but also deployed a diversity of untested, non-standard, improvised devices: improvised baffler-type devices with streamers instead of droppers, a 'bird bar' of floats to prevent bird access to the warp, and a range of devices used mainly when processing and discharging (warp-scarer type devices with road cones, windy buoys or long buoys; a line of floats to bar access around scuppers; improvised single tori-type lines; life ring or buoys towed on a rope).

Operational approaches to seabird mitigation on trawlers appeared limited. Net cleaning was recorded, as discussed in the discharge management context above. Some trawl fishers actively tried to minimise how long the net was at the surface, but supporting information was rarely provided (data on how long net at surface, information on what changes made to reduce time at the surface). Although there is no benefit to fishers to keep the net at the surface, when observers gave duration the net was at the surface the duration appeared to vary more than catch sizes alone would explain. Fisher awareness and good deck practises may help, and winch speed could be improved with good winch maintenance practises or require winch replacement (ACAP 2017c). Gear choices can also influence surface time. For example, an observer recorded markedly longer time to haul net from surface to deck with a PSH codend compared to the vessel's standard codend. Since net entanglement accounts for most seabird captures in NZ small-vessel trawl operations, quantifying the time that the net is available to birds at shoot and haul and exploring ways that fishers minimise net surface time could provide opportunities for reducing net captures in trawl fishing.

Observers on longliners recorded a much wider range of operational mitigation approaches, but most records were of night setting and line weighting. Fishers set at night to minimise the risk of seabird captures in three-quarters of observed surface longline trips, according to observer reports, and night setting took place in a smaller but still substantial proportion of BLL trips (40% of observed trips). Night setting rates may be higher in some fisheries; for example, Kellian (2003) recorded a high rate of night setting in the ling BLL fleet. On the other hand, night setting rates could have been overestimated here if some observers used 'night' more broadly than strictly defined (perceived darkness cf. MPI definition of 30 min after nautical dusk and 30 min before nautical dawn) (NZ Government 2010) when reporting night setting. It is possible to extract accurate setting times from fishing event data and classify these using the MPI definition of night. It is a fisher's intent when night setting that is of interest for this study (night setting for seabird mitigation purposes or not), which cannot be extracted from event time records.

Line weighting was documented in around a quarter of longlining trips, for both surface and bottom methods. More than half of SLL trip documentation recorded that no line weighting was used, lending some confidence to estimates of weight usage since the proportion of SLL fishing with unknown line weighting was substantially lower. The extent of line weighting documented by observers on SLL trips aligns with other work showing ~20% of SLL vessels used snood weights (Pierre 2016). SLL line weighting mostly involved weights on the snood, using lumo leads, hook pods and weighted swivels fitted closer to the hook than the clip. Weights were mostly within 4m of the hook per New Zealand line weighting regulations for surface longlining (NZ Government 2011), but research has shown progressively greater effectiveness as weights were fit closer to the hook (Gianuca et al. 2013; Robertson et al. 2013), and current international minimum recommended standards are to use at least 80g within 2m of the hook (ACAP 2017b). Some fishers have shown interest in trialling a small weight on the hook itself (Goad and Williamson 2015), but there was no record of weights at the hook in this study.

The nature and extent of weighting regimes in small-vessel BLL fishing is less clear than for observed SLL trips. Seabird-specific line weighting was recorded on a quarter of observed trips, but most BLL reports lacked information on line weighting so seabird weighting could be more widespread. BLL weighting identified as part of a seabird mitigation response was highly variable, ranging from 1kg every 12m to 5–10kg per 100m. Some weightings were identified as 'double-up' weighting for higher-risk daytime sets (e.g. 0.5–1kg every 30–35m). Comparative sink-rate tests were rarely reported, but on two vessels double-up weights increased sink rates relative to standard gear. Most BLL line weight combinations lacked associated sink rate testing, so the effectiveness of these highly variable weighting practises remains hard to compare. Only one of the weighting approaches documented in observer reports met New Zealand line weighting regulations for bottom longline fishing (NZ Government 2010). None met the international BLL standard (>5kg at maximum 40m spacing) (ACAP 2017a), but the standard was developed and tested on much larger vessels so its relevance to smaller operations is unclear. A 'toolbox' for smaller-vessel mitigation is being progressed by ACAP.

Characterising seabird interactions

Bird captures were observed at higher rates in longlining than in trawl operations. This remained the case when deck strikes were included or excluded, and was consistent across trip- and event-level calculations (i.e. capture rates calculated as captures per trip, or as captures/100 events). Most capture records involved *Thalassarche* albatrosses, generally Buller's albatross and white-capped albatross, but also the large wandering albatross species. Wandering albatross captures included three records of Antipodean albatross captures (species ID validated). Shearwaters, particularly flesh-footed shearwaters, and the smaller *Pterodroma* petrels were the next most-caught group, followed by the larger *Procellaria* petrels such as black petrels and white-chinned petrels. Diving petrels, storm petrels and prions were recorded less often, but as deck strike occasional records of very large numbers (as many as 125 individuals in a single fishing event recorded as deck strike) occurred in bottom longline and trawl fishing.

Seabird assemblages in captures partly reflect where observers were placed: observer coverage was skewed to northern regions, where observers are more likely to encounter e.g. white-capped albatross than white-chinned petrels. This illustrates a broader observer-placement bias in this study, where the reasons observers were placed (e.g. for specific fisheries, or for areas or times of year where a seabird species is abundant) resulted in a data skew that means observations are not representative of all FMAs and target species year-round. However, since observers provide our best source of independent data for small-vessel operations at this stage, the information warrants exploratory review to identify patterns and trends that can then be investigated more rigorously.

Most seabird captures recorded in trawl operations were entangled in the net (34% of seabirds caught trawling) or released from the deck (37%). Captures from warp or door impact, or line entanglement, were less frequently observed but are more prone to bird losses and undetected mortality (Sullivan et al. 2006; Watkins et al. 2008; Abraham and Thompson 2009; Parker et al. 2013; Koopman et al. 2018) so warp and line capture rates are likely underestimated. The majority of seabirds caught in longlining operations were hooked, after accounting for the large number recorded as deck strike in BLL. Tangling on lines was observed less frequently but is prone to undetected mortality since tangling is more likely during setting (when slack snoods are at the surface) and birds caught during set are less likely to be recorded (set captures must stay caught through set, soak and haul to be recorded). Tangled birds and gear are also harder to see when night-setting, and captures during setting are more likely to be lost to predation (for example, by sharks in winter; D. Goad pers. comm.). Tangling was observed more in BLL than SLL. The higher risk of tangling posed by the long snoods used in SLL fishing may be balanced, here, by lower detection of tangling issues at night, given 78% of SLL fishing set gear at night.

If we use life status on retrieval as a proxy for capture timing—live birds most likely caught during haul and birds retrieved dead caught during setting, following Pierre (2018)—then longline captures mostly occurred during setting. The large majority of hooked and tangled seabirds were brought aboard dead, and a smaller proportion retrieved alive. This suggests that longline mortalities are likely underestimated, considering the lower likelihood that seabirds hooked or tangled during setting will stay caught and be brought aboard, relative to birds caught while hauling. In contrast, trawl captures appear to mostly have involved hauling since the majority of captures were removed alive from the net. Warp captures are more problematic: although recorded relatively rarely, almost all warp captures were retrieved dead suggesting that warp captures mainly occurred at earlier fishing stages. If that is the case, warp mortalities are likely underestimated because of bird losses while fishing. Retaining warp captures long enough to be detected is important to understand the extent of warp-mortality problem, especially given the very high mortality among warp captures. Warp captures are more likely to be detected in unbound warp splices (some evidence of a capture like feathers or bone being more likely to be retained), or potentially with an experimental device (Parker et al. 2013). Warp captures at haul can also be mitigated operationally on smaller vessels to some extent, if winch operators have line of sight with warps, or have communications with the deck crew.

Seabird capture influences

Discharge management

Across all trawl and longlining trips reviewed, seabird capture rates were influenced by discharging: seabird capture rates were highest on trips where fewest actions were taken to limit discharging overboard. Any steps taken by fishers to manage discharge are referred to here as the 'discharge management strategy', and generally reduced seabird capture rates. For example, holding untaken returned baits on board during hauling halved the capture rate on longlining trips, relative to trips where baits were discharged, and fishers generally view retaining baits as effective (Goad and Williamson 2015).

Globally there is a swathe of evidence that managing fish waste and bait discharge reduces seabird abundance and bycatch rates (e.g. McNamara et al. 1999; Weimerskirch et al. 2000; Bull 2007; Løkkeborg 2011; Gilman 2011; Pierre et al. 2013; Gilman et al. 2014; Maree et al. 2014). Location of discharging is an often-discussed factor (McNamara et al. 1999; Petersen et al. 2009; Pierre 2018). In this study, seabird capture rates in SLL fishing records were lowest when discharging on the offside and doubled with haulside discharging, but observers recorded offside discharging on only 15% of trips. Similarly, in observed BLL fishing offside discharging was associated with lower bird capture rates than haulside discharging. These findings align with domestic and international recommendations that if waste retention is not possible and/or if fishing during daylight, discharging should take place away from the hauling station (Petersen et al. 2009; Pierre et al. 2013; Goad and Williamson 2015; ACAP 2017a, b). Offside discharging is linked to lower seabird capture rates than when no discharge is produced at all in BLL operations, pointing to the usefulness of targeted/strategic discharging in drawing birds from the hauling zone. Some observers reported hooks discharged with processing waste and baits, so systems to ensure all hooks are removed before discharging are required (Brothers et al. 1999; ACAP 2017b; Pierre 2018).

If discharging on the haulside, discharging in batches or breaks during hauling reduces capture rates compared to continuous haulside discharging, for both BLL and SLL operations. The effectiveness of offside batching was not assessed (insufficient data), but should be explored further as batching is thought to influence subsequent sets thus affect the proportion of birds caught dead (birds caught during shot generally recovered dead, and the large majority of birds caught longlining were recovered dead). Offside batching should be tested for effectiveness at reducing captures both during hauling and the subsequent set.

The idea that seabirds are more likely to focus on baited hooks if nothing is discharged during haul (McNamara et al. 1999; Goad and Williamson 2015) leads to strategic discharging to draw birds away from hooks. Strategic discharging is sometimes part of recommended practise (e.g. Hawaii SLL) (McNamara et al. 1999) but when used during setting, can involve risks if not used cautiously (ACAP 2017a, b). These risks potentially apply to strategic discharge while hauling: that is, unless strategic discharging can be maintained throughout hauling (with sufficient discharge and relatively short line hauling time), birds periodically drawn away from the hauling station will likely return. In addition, discharging any material at any time is thought to reinforce seabird attraction to vessels for food, which could have longer-term consequences that outweigh short-term benefits from strategic discharging (Gilman 2011; Gilman et al. 2014; Goad and Williamson 2015; Pierre 2018).

Bird capture rates were higher for surface longline than bottom longline operations in the period examined, across discharge management strategies. This is influenced by a range of factors, including that active discharge management is less frequent in surface- than bottom longline fisheries (SLL 25% active DMP and 50% no DMP, compared to BLL 35% active and 20% no DMP), and that SLL vessels typically produce more offal and have a greater proportion of baits returned. Another factor could be that SLL boats fish closer together than BLL vessels and birds may fleet-scan, so discharge management (or lack of) in other parts of the fleet could potentially influence a vessel's bird capture rates (D. Goad pers. comm.).

Discharging influenced seabird capture rates in trawl operations, as documented elsewhere (Abraham and Thompson 2009; Løkkeborg 2011; Maree et al. 2014). In trawl operations, bird capture rates were lowest when discharging during the tow and material was retained during during haul. Seabird captures tended to occur more frequently when discharging occurred during gear shooting, despite logic dictating that birds captured while gear is shot are less likely to be retained than if captured at a later stage in fishing. Captures were recorded most frequently when there was no discharge during fishing operations. This could result from discharge outside of fishing operations (while nets are aboard, for example) attracting birds to the vessel which remain and are caught, but this could not be tested as discharging information available for this work were only recorded while gear was being fished.

Mealing material to be discharged was highly effective at reducing seabird numbers (Abraham 2008) and if material must be discharged, is the main discharge management approach advocated internationally (ACAP 2017c), but mealing may be logistically difficult or simply not possible for the small vessels discussed here (or e.g. trawl fishery offloading fresh catch in Argentina; Favero et al. 2011). Mincing material before discharge was also tested, but mainly influenced the larger *Diomedea* albatrosses (Abraham 2008; Abraham et al. 2009). Compared to mealing or mincing, holding material to discharge in batches is an easier discharge management action to implement on smaller trawlers. Batching influenced both current bird behaviour (fewer warp contacts) and overall bird abundance (Pierre et al. 2010, 2012; Kuepfer and Pompert 2017). In this study we could not assess the effect of trawl batching on seabird capture rates since our information was constrained by a high proportion of trips with unknown batching, and when batching was mentioned, we could not assess how it was conducted from the information available. This is important because the way batching is conducted can be influential, with length of the storage period and swiftness of the discharge mechanism important in trials in the Falkland Island trawl fleet (Kuepfer and Pompert 2017). The timing, location and efficacy of small-trawler batching should be investigated further.

There was some indication linking use of a PSH codend to higher seabird capture rates (net captures, and pattern persisting when considering all gear captures, and all interactions). Observers noted seabirds diving on net escapees at the surface and targeting fish "washed...through the escape ports in the PSH codend", and that the PSH took longer to haul from surface to deck than the conventional net. Work is required to assess the influence of associated gear characteristics, which could not be assessed from the data here, and assess the influence of mixed PSH and standard codend use.

Mitigation devices

Seabird capture rates in observed trawl fishing were lowest when a bird baffler was used, higher when other devices were in use, and highest with tori or streamer lines. 'Other' devices were grouped together because of relatively rare occurrence, but included assorted mitigation devices from warp scarers and improvised baffler-type devices to simple towed buoys or lifering on a line. This capture rate pattern is partly explained by coverage: while bafflers appear to have been deployed for most of the period gear was at depth (later stages shooting, towing, and early haul), observer comments suggest that tori lines and the assortment of other devices were generally only deployed briefly during high-risk periods (i.e. discharging). Most seabird captures recorded during trawling were caught in the net, though, so it is not entirely clear why a warp mitigation device like bafflers should reduce captures overall.

In longline fishing seabird capture rates were generally lower on trips where no mitigation device was used than when tori lines or other devices were used. Higher capture rates with mitigation than without could occur if mitigation timing does not coincide with capture timing; that is, mitigation used only during set (e.g. a tori line) cannot effectively mitigate captures effectively that occur during hauling. Haul capture mitigation was treated extensively in Pierre (2018). High capture rates with mitigation device use could be explained if devices were deployed ad hoc as reactive mitigation when bird abundance increased or captures occurred (as recorded in BLL; improvised bafflers around the hauling station, tori line on the next set) and not used if birds were not present, introducing a capture bias. Lower capture rates in the absence of devices could also arise if other mitigation approaches that are effective in reducing seabird captures (like discharge management) were used instead of tori lines.

Since effective seabird mitigation tends to involve multiple tools (ACAP 2017c; Goad 2017), haul mitigation (reviewed by Pierre 2018), reactive mitigation and the contribution of other mitigation efforts require further exploration. In practise, haul mitigation together with set mitigation and active discharge management may prove the most successful mitigation approach. Focusing efforts on just one aspect can simply shift the problem; for example, in the Hawaiian swordfish fishery set mitigation dramatically reduced seabird captures, shifting captures to now mostly occur during hauling (Gilman et al. 2014). Gilman & Musyl (2017) and Pierre (2018) review haul mitigation being explored both domestically and internationally in longline fisheries.

Operational mitigation

Cleaning the net before shooting appeared to reduce the seabird capture rate when trawling, but for most trawl trips it is unknown whether net stickers were removed, not removed, or partially removed, so the effectiveness of sticker removal needs better assessment than what was possible from these data. Minimising the time the net was available at the surface holds promise, given that most trawl captures occur in the net, but capture rates could not be linked to duration of time net at surface (insufficient information) or actions to reduce net surface time.

Night setting was the most common operational mitigation approach for longlining, but it is unclear how effective it is at reducing seabird captures. Night setting appears linked to higher bird capture rates in reviewed SLL trips, despite captures during setting being less likely to be seen and recorded in darkness than daylight. Night setting on BLL vessels had a similar capture rate to events where the set occurred during the day. Higher capture rates when night setting could be due to vessels not using tori lines or line weights when setting at night (Goad and Williamson 2015), but the association requires work to tease out these potential effects, particularly since night setting is generally a central part of longlining regulations and best-practise recommendations (Weimerskirch et al. 2000; NZ Government 2010; Gilman 2011; Pierre et al. 2013; ACAP 2017a, b).

Unshielded deck and stern lighting may also influence captures during night setting, particularly in regions where night-foraging birds like white-chinned petrels and grey petrels occur, or near the breeding islands of species that are prone to deck strike (diving petrels, storm petrels, sooty shearwaters). Some longlining operations already use minimal lighting (Kellian 2003), and SLL observers sometimes report restricted lighting during night setting as part of a vessel's seabird response. Lighting is also of interest because of its potential to mitigate deck strikes (e.g. Montevecchi 2006; Depledge et al. 2010), given the regular and occasionally very large deck strike events recorded in bottom lining and trawl fishing here. Deck strikes could impact on species with small populations, few or single breeding sites, and high threat classification (for example NZ storm petrels and South Georgian diving petrels). However, too little data were available for this study to explore whether lighting management could reduce captures at setting or deck strikes.

Seabird captures appeared lower when line weighting was used in observed BLL trips than when no extra weights were deployed, despite the limited information available and limited testing. Seabird weighting was generally deployed during risk periods (birds abundant or captures occurring) which could be expected to skew capture rates toward periods when weighting used. Conversely, capture rates were higher in SLL when line weight use was recorded than when no line weighting was used. For both longlining methods, the contribution of unknown line weighting practises likely obscures the real effect of line weights on seabird captures, highlighting an important area for further investigation.

Recommendations

Based on findings in this study and the wider pool of research into seabird mitigation, we provide a range of recommendations. Discharge management recommendations focus on best-practise guidelines for discharge management and potential refinements that could reduce the risk of seabird captures. Mitigation recommendations deal with seabird mitigation devices and practises other than discharge management. Mitigation recommendations are framed around the adequacy of the level of mitigation used in the study period, and potential for alternative mitigation approaches. Some mitigation actions have been implemented since the study period, with other actions planned (CSP, MPI). We focus on proven methods or devices (e.g. ACAP 2017a, b, c), and identify where an approach shows promise but needs testing.

Discharge management actions: longlining

1. **Retain during fishing --** Hold/store material on board during fishing, including untaken used baits and fish processing waste (Pierre et al. 2013; ACAP 2017b). Considering size, deck configuration and processing extent, should be possible for most bottom and some surface liners (just operational changes required), but some surface liners or small bottom liners which process while hauling may not have the space to hold processing waste (D. Goad pers. comm.). Potential for stability issues on smaller vessels must be considered.
2. **Hold during setting --** Continue practise to always avoid discharging during line setting (no vessels recorded discharging during set). Aligns with domestic and international best practise for reducing seabird bycatch. Care to reduce incidental discharge, like those from auto-baiting machines and poor quality unwanted baits when baiting by hand.
3. **Offside discharging when hauling --** If discharging must occur during hauling, it should take place on the side of the vessel opposite to where lines are being hauled, ideally in a hauling break when hooks are not near the surface (this study, Pierre et al. 2013). Requires changes in procedure, which should include a system to ensure all hooks removed before material is discharged (Brothers et al. 1999; ACAP 2017a, b). A proportion of vessels may require modification to enable offside discharging.
4. **Haulside batches?** If haulside discharging is unavoidable, discharging in breaks or batches during hauling appears better than continuous haulside discharging (this study), provided material is discharged well aft of the point where hauled hooks surface. This requires at-sea testing for validation, and to determine best discharge intervals to reduce the risk that birds shift to baited hooks while waiting.

Mitigation recommendations: longlining

1. **Tori + other device/practise --** Set mitigation is important (most birds caught dead, suggesting hooked/tangled during set or soak), but tori line during set not adequate on its own for seabird mitigation (this study). Set mitigation via tori lines should be supplemented with other mitigation devices or practises, such as methods to increase hook sink rates (D. Goad pers. comm.) or active discharge management (this study). Tori lines at set together with active discharge management (i.e. limiting discharging to the offside, ideally in batches or hauling breaks; avoid discharging in the hour before setting) decreases vessel bird capture rates (this study).
2. **Haul mitigation --** Haul mitigation devices and practises should be explored since some captures occur during haul (this study), and focus mainly on set mitigation can shift captures to haul in the same fishery (Gilman et al. 2014). Haul mitigation should include offside discharging, which reduced seabird capture rates here, tested together with devices that protect the hauling bay (reviewed Pierre 2018).
3. **Night-setting + other device/practise --** Night setting alone was not adequate for seabird mitigation (this study), similar to tori lines alone. Night setting should be supplemented with other devices or practises to reduce seabird capture rates.

Discharge management actions: trawl

1. **Tow discharging --** If discharging during fishing unavoidable, discharge during tow and not during hauling or shooting (this study). A baffler or other form of warp mitigation should be in place while discharging (this study; Parker and Rexer-Huber 2019), and material should be discharged away from the warps.
2. **Batch discharging?** Batch discharging can be a useful refinement to discharging practises (e.g. Pierre et al. 2012) but in this study its effectiveness for smaller vessels could not be assessed, so validation is needed. Testing should involve effectiveness at bycatch reduction relative to holding duration, discharge duration and timing (Pierre et al. 2010; Kuepfer and Pompert 2017).

Mitigation recommendations: trawl

1. **Baffler effective --** Bird bafflers are effective at reducing seabird captures and relatively widely used in the fleet (this study; Parker and Rexer-Huber 2019). The extent of baffler use in the fleet could be increased. Empirical testing needed to confirm effectiveness and design parameters.
2. **Warp captures --** Mortality is very high among warp captures that are detected (this study), so other/additional warp mitigation should be explored. Devices protecting the warp throughout fishing, like bafflers, are best (e.g. Koopman et al. 2018). Apart from tori lines, there is not enough evidence that other types of warp mitigation are effective or safe to be used (ACAP 2017c; Koopman et al. 2018). Part-time warp mitigation should cover high-risk periods (e.g. when discharging), but devices need careful testing before being applied widely: mitigation used for brief high-risk spells seem linked to higher capture rates (this study), and most devices that fishers employ when discharging are untested or inadequately tested (Parker 2017) including cones on warp cables (González-Zevallos et al. 2007). Testing is crucial because untested or badly-implemented devices can themselves cause bird mortality or otherwise be dangerous (Koopman et al. 2018). Good deck practise may also help reduce mortality from warp captures that occur during hauling (Parker and Rexer-Huber 2019).
3. **Net cleaning --** Cleaning stickers out of the net before shooting again appears to reduce seabird capture rates when trawling (this study). Since most seabird captures occur in the net (this study; Parker and Rexer-Huber 2018), net cleaning should be explored further. Validation required to confirm effectiveness across more fishing events.

4. **Time at surface?** Minimising the time the net is available at the surface holds promise since most trawl captures occur in the net, but the effect of net surface time on seabird captures could not be assessed here.

Next steps: identifying areas to progress

Here we pull together areas identified throughout this report where further work is required. Recommended steps focus mainly on ideas for progressing work on small-vessel discharge management, but also touch on other mitigation areas.

The fishing-method level approach in this study enables broad characterisations, provides overview of a range of opportunities and leads, and acknowledges that trawl, surface and bottom lining fisheries are not independent of each other (in terms of seabird interactions) (e.g. García-Barcelona et al. 2010). However, pooling fisheries within a fishing method could also obscure operational differences between fisheries that may prove important for seabird mitigation (e.g. snapper vs. bluenose BLL) (Goad and Williamson 2015; Goad 2017). In particular, operational factors influencing the extent and type of discharge management are expected to vary by fishery, as well as other operational effects on seabird capture rates. Progressing work at the level of fisheries, to ensure that actions are practical and appropriate in a given fishery, gives the best chance that best-practise advice will be implemented.

As for fishery-level analyses, many areas requiring further work require a larger underlying number of observations. Target fish species were pooled within each fishing method because further splitting made sample sizes too small to detect useful patterns. Similarly, seabird mode of capture (hook/tangle and net/warp/tangle) was pooled because split samples were insufficient to assess the efficacy of alternative mitigation measures.

Progressing lining discharge management

Batch discharging? The extent and the effectiveness of batching as a discharge management approach for small-vessel liners was difficult to gauge since most trip reports reviewed had no information on batching of discharge (this study). The extent of batching is well documented in northern longline fleets (e.g. Pierre 2016), but more work is needed to understand how common batching is in other regions. The effectiveness of batch discharging for reducing seabird captures in small-vessel operations needs to be tested, comparing batch location (haulside, offside) and discharge type (offal, whole fish, baits) with continuous discharging and no discharging.

Volume of discharge? Discharge volume is expected to influence seabird behaviour and capture rates (e.g. Koopman et al. 2018) as well as affect the discharge management options for specific fisheries. This was not explored in this work but should be routinely recorded by observers and explored further. Likewise, discharge type (offal, whole fish, different bait types, etc.) could influence behaviour and capture rates if birds show preference (e.g. Furness et al. 2007), although discharge type appeared to have more influence on marine mammal captures than seabird captures in a trawl study (Parker and Rexer-Huber 2019).

Other mitigation questions -- Capture rates were lower on longline trips where no mitigation device was used than when tori lines or other devices were used (this study). We show that discharge management did reduce seabird captures when no mitigation device was used, but a range of other factors could contribute. Haul mitigation (developing suggestions in Pierre 2018), reactive mitigation and the contribution of other mitigation efforts require accurate description in observer data and further exploration.

Night setting appears linked to higher bird capture rates in SLL operations. This could be driven by vessels not using tori lines or line weights when setting at night, but weighting and/or using tori lines during daytime sets (this study; Goad and Williamson 2015), but there are a range of other potential explanations. These potential effects should be explored further, particularly since night setting is often a central part of longlining regulations and best-practise recommendations (Weimerskirch et al. 2000; NZ Government 2010; Gilman 2011; ACAP 2017a, b)

Although line weighting in longlining operations is shown to reduce seabird mortality (e.g. Jiménez et al. 2010; Robertson et al. 2013), the nature, extent and effectiveness of line weighting remains unclear for BLL and SLL operations in this study. Most trip reports lacked the requisite information and these unknown line weighting practises are expected to have obscured the real effect of line weights on seabird captures.

Progressing trawl discharge management

Zero-discharge captures – It is unclear why capture rates were high when no discharge was produced during fishing (this study). Captures may be related to discharge outside of fishing operations (i.e. while gear on deck, while steaming) that could not be assessed here as data were not available. Retaining all discharge material during fishing operations is a central part of international best-practise recommendations (e.g. ACAP 2017c), so it is important to understand if the effect of zero discharge truly differ in small-vessel operations and why.

Other mitigation questions -- Cleaning the net before shooting appeared to reduce the seabird capture rate (this study) but sticker removal (or not) and extent of net cleaning was unknown for most trawl trips reviewed. The effectiveness of sticker removal for seabird bycatch mitigation needs better assessment than what was possible from these data.

Trips where a PSH codend was used for at least some events had higher seabird capture rates, and higher interaction rates overall, than with standard-codend gear. Work is required to assess the influence of associated gear characteristics, whether duration at surface influences PSH bird captures, and assess the influence of PSH codend use when used before or after standard gear.

Minimising the time the net was available at the surface holds promise, given that most trawl captures occurred in the net. This study could not link capture rates to duration of time net at surface because of insufficient information. When observers gave time from doors up to net on deck, net surface time appeared to vary more than catch sizes alone would explain. Fisher awareness and good deck practises may help, and winch speed could be improved with good winch maintenance practises or winch replacement (ACAP 2017c).

Almost all warp captures were recovered dead, suggesting that warp captures mainly occurred during shot or tow. Detection of of birds captured on the warp is expected to be poor (Abraham and Thompson 2009; Parker et al. 2013; Koopman et al. 2018), and the probability of losing a bird caught during shooting is higher than if it was caught during haul. Given the high mortality of birds caught on the warp (this study; Parker and Rexer-Huber 2019), it is important to explore ways to improve estimates by retaining warp captures and improving detection via warp strike studies, cameras, and experimental devices (e.g. Parker et al. 2013).

Vessel lighting may be a major driver of deck strikes in NZ fishing operations, as it is elsewhere (Ryan 1991; Black 2005; Montevecchi 2006), but vessel lighting effects could not be explored here since lighting was rarely documented in observer information used for this study. Deck strike events occur frequently and occasionally in very large numbers in bottom longline and trawl fishing reviewed here, and could impact on species with small populations, few or single breeding sites, and high threat classification (e.g. NZ storm petrel, South Georgian diving petrels). Light management should be explored as a potential way to mitigate deck strikes, with focus on high-risk areas (around islands with high levels of endemism like the titi islands, Hauturu/Little Barrier, and Whenua Hou/Codfish).

Refining discharge and capture data collection

This section primarily deals with the observer information used in this study, identifying data gaps and making suggestions to improve the accessibility of relevant information.

Data coverage

The characterisation of discharge management and associated seabird captures presented in this report is based on observer records, as a proxy for captures occurring in unobserved areas, fisheries and vessels. However, observer information available for this report were numerically skewed to fisheries in the north-eastern and north-western North Island. No observer data were available for this work from surface longlining on the South Island East Coast, South Coast or Chatham Rise (SEC, SOU and CHA), or from the western North Island CEW. For trawling, SOU and CEW could not be included. In these FMAs, species assemblages are expected to be different, so capture profiles and associated risk factors are also expected to be different. This assumption could be tested by prioritising observer coverage in unobserved fishery-areas.

Data completeness

In observed areas, government fisheries observers already collect a broad range of information from at-sea observations of trawl and longline fishing (Sanders and Fisher 2015). Making observer records as complete, consistent and reliable as possible maximises the value of these data (Goad 2017; Pierre 2018).

Efforts to characterise what is going on in a fishery, for example, hinge on observers reporting when something is *not* happening as well as when it is. For example, a "<null>" entry in the database for the fields mitigation_equipment or mitigation_event is much less useful than None (or its code), and <null> for offal or fish discharge fields is similarly less useful than "N" for none.

The data collected on seabird captures was particularly valuable for this work, so incomplete or missing seabird capture data stood out. In more than a third of trips where reports and COD data were reviewed (36% or 69 of the 193 trips), information about seabird captures in observer reports was different to that in COD data tables. This was mostly differing seabird numbers (e.g. two dead captures entered in COD but not the three deck strikes mentioned in the report that had to be assisted off). Occasionally captures occurred outside of fishing (i.e. when on anchor or steaming), and there is no field in COD to document such captures. Occasionally information was recorded by observers but was not available to us (relevant seabird capture information edited out of the MPI trip report before it was made available to the Department of Conservation, or captures were recorded just on the form and not in the report), and for nine trips, captures mentioned in observer reports were not entered in COD data at all (no record in x_bycatch_incident_catch table for total of 20 individuals).

Information accessibility

In many cases, information relevant for this study appeared to be restricted to mention in observer documentation (reports and diaries) mainly because relevant data fields or codes were not available. For example, some information on discharge in bottom longline set and haul logs collected by observers (as discussed in Pierre et al. 2013) does not appear to be entered into COD, so data collected were unavailable for this work. Some observers entered such information as notes in COD (e.g. comment_catch_weight field; line weighting sometimes mentioned in hook_type_name field). Notes in data fields were more useful than no information at all but are likely laborious to enter and interpretation of notes can be subjective for a user.

To make best use of information recorded by observers, we suggest several ways that existing observer data collection could be developed. The following information types could benefit from codes or a tick-box field to routinely and systematically record observations:

Discharging

- Lining: the way offal, unused bait and whole fish are dealt with in each fishing event requires structured fields like those for trawl events. Needs the discharge type (offal/bait/whole fish), the location of discharging relative to the hauling bay (i.e. offside, haulside into the hauling bay, haulside clear of the hauling bay), and some indication of amount.
- Trawl: H (discharge held) code used variably, sometimes interchangeably with N (no discharge)
- Structure required for batch discharging (if occurring, and how). Needs categories: is it happening; if so, what fishing stage, amount in batch, interval between batches or storage period, where relative to fishing operations (offside, haulside, between warps, other), some indication of how swift the discharge mechanism is (i.e. how long it takes for batch to go overboard)
- Deckloss: if fish and offal losses included as part of general discharge categories cannot assess effect of irregular pulses/batches of material off the deck. Separate category (what fishing stage, where relative to fishing operations).

Seabird captures

- When seabird capture occurred: during shooting (i.e. actually observed taking place during shot, not when the observer detected it), during tow, during haul, other, or unknown.
- Deck strikes: location codes variably used, deckstrike mostly called I (impact or deck strike) but sometimes O (other). Information on when event occurred (night/day, fishing stage) would help
- Trawl: Indicators of animal captured but lost during fishing (e.g. feathers in the warp or warp splice, or at the door)
- Could observer view the warps/hooks during hauling or not?
- Some way to indicate captures occurring outside of fishing (e.g. while steaming, while on anchor); these interactions should be documented as they are part of fishing operations in an area.

Mitigation devices

- Category needed to record when mitigation device used (shot only? Entire fishing operation?)
- Lining: tori line info that are most crucial are how the bait entry point is covered, and aerial extent. But mitigation_event codes for these rarely used consistently, and the code only tells us when aerial extent not adequate, or lines not covering bait entry point. Fields needed to record whether bait entry point covered/not, some indicator of tori line extent, and some metric of tori line performance (like the number of attacks or dives on baits, and where these are happening).

Operational mitigation practises

- Lining: whether line weighting is intended as part of seabird mitigation response needs category in COD (y/n/unkn), with record of weight on the line to gauge effectiveness (e.g. weight, distance from hook, weight interval, floats, sink rate tests, change in line weighting during a set)
- Lining: whether night setting is intended as part of seabird mitigation response/not needs category in COD, and cloud cover also affects available light.
- Trawl: Period when net at surface (time doors up to net on deck) rarely reported, but of more relevance to understanding seabird captures than time from fishing depth to doors-up (mostly what is reported). Need category for time in mins from doors up to net on deck.

- Trawl: Sticker removal from net needs category in COD, including some indication of frequency (before all shots/before some shots) and extent (all net stickers/some net stickers).
- Some indication of deckloss management (grating or scupper boards, spills picked up, etc.)

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Appendices

Appendix 1

Categories and headers in discharge management trip review document. Sources: OR fisheries observer report and documentation, COD observer data table x_fishing_event, CODb observer data table x_bycatch_incident_catch

Column headers	Defined	Source
trip_number	observer trip report number	OR, COD
fishing_events_n	number of fishing events in the trip	COD
fishing_method	TWL, SLL or BLL	OR, COD
LOV COD	Vessel length (m)	OR, COD
FMA main	Main Fisheries Management Area(s)	OR
Target main	Main fish target species	OR
COP_used	Code of practise (COP, VMP, SMP) mentioned (y)	OR
PSH_used	PSH codend used for some/all fishing (y)	OR
CODnulls_mostly	COD record not completed, most data fields value <null> (y/n)	COD
Night_setting	Lining gear set at night for seabird mitigation (y/n)	OR
lighting_mentioned	Vessel lighting mentioned (y)	OR
line_weighting	Line weights for seabird mitigation (BLL: y/n/unkn; SLL: n/unkn/wsc/wss/ll/hp/wbb/o)	OR
stickers_removed	Net cleaned of stickers (small/damaged fish caught up in meshes) before shot (y/n)	OR
mit_used_rept	Mitigation equipment use mentioned in report (y/n/unkn)	OR
mit_rept=COD?	Mitigation equipment use the same in report and COD (y/n)	OR, COD
mit_equip_used	Mitigation equipment used (b, n, o, t, w, unkn)	OR, COD
bait_retained	Unused baits returned during haul retained on board during haul (y/n/unkn)	OR
offal_produced_disc	offal produced and discharged during fishing at any stage (y/n/unkn)	OR, COD
fish_heads_produced	fish heads produced, discharged any fishing stage (y/n/unkn)	OR, COD
fish_whole_disc	whole fish discharged any fishing stage (y/n/unkn)	OR, COD
shot_disc_any	Discharging of any material during setting or shooting (y/n/u)	OR, COD
tow_disc_any	Discharging of any material during tow (y/n/u)	OR, COD
haul_disc_any	Discharging of any material during haul (y/n/u)	OR, COD
hold_anystage	Holding of any material any fishing stage (y/n/u)	OR, COD
batching_any stage	Batch-discharging of material at any fishing stage (y/u)	OR
deckloss	Loss of material (fish, offal, baits) off vessel via deckwash, occurred (y) or managed (n)	OR
DM_rept_describes	Discharge management described in report (y/n)	OR
DM_COD_describes	Discharge management data in COD (y/n)	COD
DM_rept=COD?	Discharge management information the same in report and COD (y/n)	OR, COD
DM_class	Discharge management class characterising discharge actions (values specific to lining and trawl)	OR, COD
seab_bycatch_rept	Seabird bycatch documented in report (y/n)	OR
seab rept=COD	Seabird capture records the same in report and COD (y/n)	OR,COD, CODb
bird_interact_records_n	Number of bird interaction records for this trip (all including deck strike, other and capture method unknown)	CODb
bird_capture_records_n	Number of bird capture records on fishing gear (caught on hook, net, warp, door, or tangled in lines)	CODb
dead_bird_capt_records	Number of birds captured dead for this trip	CODb
I_capts	Number of birds recorded as impact/deck strike for this trip	CODb
H_capts	Number of birds hooked for this trip for this trip	CODb
T_capts	Number of birds tangled for this trip	CODb
N_capts	Number of birds caught in the net for this trip	CODb
S_capts	Number of birds caught on warp or doors for this trip	CODb
O_capts	Number of birds caught in other way for this trip	CODb
U_capts	Number of birds where capture method unknown for this trip	CODb

Appendix 2

Seabird interactions observed in small-vessel trawl and longline fishing in period October 2013–December 2016. Capture rate is the number of birds per 100 fishing events

	Species	MPI code	n individuals	capture rate
Diving petrels, storm petrels & prions			**332**	**3.391**
common diving petrel	*Pelecanoides urinatrix*	XDP	295	3.013
prions (Pachyptila generic)	*Pachyptila* spp.	XPN	17	0.174
storm petrels (generic)	*Hydrobatidae*	XST	7	0.072
fairy prion	*Pachyptila turtur*	XFP	6	0.061
white-faced storm petrel	*Pelagodroma marina*	XWF	5	0.051
grey-backed storm petrel	*Garrodia nereis*	XGB	2	0.02
Buller's, white-capped & other albatrosses			**158**	**1.614**
Buller's albatross	*Thalassarche bulleri bulleri*	XBM	58	0.592
White-capped albatross	*Thalassarche steadi*	XWM	45	0.46
Salvin's albatross	*Thalassarche salvini*	XSA	13	0.133
albatrosses unidentified		XAL	13	0.133
snowy or wandering albatross	*Diomedea exulans, D. antipodensis* sspp., *Diomedea* spp.	XAS, XWA, XGA	8	0.082
Gibson's albatross	*Diomedea antipodensis gibsoni*	XAU	5	0.051
Southern royal albatross	*Diomedea epomophora*	XRA	4	0.041
Southern black-browed albatross	*Thalassarche melanophrys*	XSM	4	0.041
Antipodean albatross	*Diomedea antipodensis antipodensis*	XAN	3	0.031
Campbell albatross	*Thalassarche impavida*	XCM	3	0.031
Grey-headed albatross	*Thalassarche chrysostoma*	XGM	1	0.01
Smaller albatrosses	*Thalassarche* spp	XMA	1	0.01
Shearwaters & mid-sized petrels			**124**	**1.267**
flesh-footed shearwater	*Puffinus carneipes*	XFS	83	0.848
shearwaters (Puffinus generic)	*Puffinus species*	XSW	11	0.112
grey-faced/great-winged petrel	*Pterodroma macroptera*	XGF	8	0.082
sooty shearwater	*Puffinus griseus*	XSH	6	0.061
mottled petrel	*Pterodroma inexpectata*	XMP	5	0.051
fluttering shearwater	*Puffinus gavia*	XFL	4	0.041
Buller's shearwater	*Puffinus bulleri*	XBS	3	0.031
Pterodroma petrels (generic)	*Pterodroma* spp.	XPT	2	0.02
Cook's petrel	*Pterodroma cookii*	XKP	1	0.01
Mid-sized petrels/shearwaters	*Pterodroma, Procellaria, Puffinus* spp.	XPM	1	0.01
Black petrels & other Procellaria petrels			**78**	**0.797**
black petrel	*Procellaria parkinsoni*	XBP	37	0.378
white-chinned petrel	*Procellaria aequinoctialis*	XWC	15	0.153
Westland petrel	*Procellaria westlandica*	XWP	15	0.153
Procellaria petrels (generic)	*Procellaria* spp.	XPC	7	0.072
petrels (generic)	*Procellariidae*	XPE	4	0.041
Other seabirds			**6**	**0.061**
black-backed gull	*Larus dominicanus*	XBG	4	0.041
Northern giant petrel	*Macronectes halli*	XNP	2	0.02