Reducing seabird bycatch in bottom-longline fisheries

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Final Research Report for Department of Conservation projects MIT2011-03 and MIT2012-01

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EXECUTIVE SUMMARY

Seabirds of conservation concern, including black petrel (*Procellaria parkinsoni*), are incidentally captured on bottom-longline fishing gear deployed in inshore commercial fisheries in northern New Zealand. These fisheries target a variety of fish species, including snapper (*Pagrus auratus*), bluenose (*Hyperoglyphe antarctica*), hapuku and bass (*Polyprion oxygeneios*, *P. americanus*), and ling (*Genypterus blacodes*). Using government fisheries observer placements conducted over 76 fishing days between December 2012 and May 2013, we investigated the efficacy of operational practices in use in these fisheries for reducing seabird bycatch risk. In addition, we explored potential new measures for reducing seabird captures. Four main components of operational practices are expected to influence seabird bycatch risk in northern bottom-longline fisheries: the time of day at which longlines are set, the sink rates of hooks, the deployment of streamer lines, and the retention of fish waste during setting and hauling. To reduce the risk of seabird captures in inshore bottom-longline fisheries in northern New Zealand, we recommend that the efficacy of line-weighting strategies in use is increased. This recommendation may involve adding more weight to lines and sinking hooks closer to the boat (e.g., using closer weight spacing, more even-sized weights, longer float-ropes, denser weights and slower setting speeds). In addition, we recommend that longlines are set prior to nautical dawn, fish waste is held on-board during hauling, the design and construction of streamer lines is improved, the improved streamer lines are deployed on all sets, and sinking longlines to 10 m depth at the end of streamer lines is considered as a minimum performance standard. In combination, these measures are expected to significantly reduce the risk of seabird captures in inshore bottom-longline fisheries.

Key words: Bottom longline; snapper; bluenose; black petrel; *Procellaria parkinsoni*; flesh-footed shearwater; *Puffinus carneipes*; bycatch mitigation

1. INTRODUCTION

Inshore bottom-longline fisheries target a complex of fish species (e.g., snapper *Pagrus auratus*, bluenose *Hyperglyphe antarctica*, hapuku/bass *Polyprion oxygeneios*, *P. americanus*, and ling *Genypterus blacodes*) with gear in a variety of configurations (Goad et al. 2010, Goad 2011, Ramm 2012). These fisheries also capture seabirds of high conservation concern, especially black petrel (*Procellaria parkinsoni*). This species breeds on Great Barrier Island and Little Barrier Island in the Hauraki Gulf and ranges out of New Zealand waters in the austral winter. Incidental mortality of black petrels in New Zealand commercial fisheries is highly likely to be above the population's sustainability limit (Richard & Abraham 2013). In addition to commercial captures, black petrel are also caught in recreational fisheries in unknown numbers (Abraham et al. 2010), and may be bycaught in fisheries outside New Zealand waters (Cabezas et al. 2012).

There are several mitigation measures available that are considered to significantly reduce the incidence of seabird captures in commercial bottom-longline fisheries. Best practice measures include line-weighting, deployment of streamer lines, and retaining fish waste on-board while longlines are set and hauled (e.g., Bull 2007). Regulations for the use of seabird bycatch reduction measures were introduced to New Zealand inshore bottom-longline fisheries in 2008, and updated in 2010 (New Zealand Government 2008, 2010). These measures incorporate elements of global best practice for reducing seabird bycatch in bottom-longline fisheries, modified to fit bottom longliners fishing in New Zealand waters, and following feedback received on gear configurations in use at the time. However, the diversity of vessels and operations, including configurations of the gear deployed in these fisheries (Goad et al. 2010, Goad 2011), makes the prescription of fleet-wide mitigation measures difficult. If the use of particular specified measures is required across different vessels and target species, at least some vessels will inevitably have to change their practices. Furthermore, given fleet-wide variation, determining the efficacy of the mitigation approaches used on any one vessel, or in a subset of the fleet, is challenging, especially using conventional approaches (i.e., data collection by human observers).

The ongoing incidence of seabird bycatch including species of high conservation concern, diversity of vessel operations, and the potential to improve the suite of mitigation measures used in inshore bottom-longline fisheries led to the development of the two projects described in this report, Conservation Services Programme projects MIT2011-03 and MIT2012-01. The overall objectives of these projects were to develop strategies to mitigate seabird captures in inshore bottom-longline fisheries by increasing line sink rates, and to experimentally test the effectiveness of seabird mitigation strategies used by inshore bottom-longline fishers. We addressed these objectives by focusing on the inshore bottom-longline fisheries targeting bluenose and snapper in Fisheries Management Area (FMA) 1. After reviewing the characteristics of the northern inshore bottom-longline fisheries and conducting a workshop with experts and practitioners involved, we focussed work in the following three areas:

- Documenting current practice
- Refining existing approaches to bycatch reduction
- Exploring new options for mitigation measures

2. METHODS

2.1 Characterisation of inshore bottom-longline fisheries in northern New Zealand

Several sources of data were used to characterise bottom-longline fishing operations in northern New Zealand. Fishing vessel and effort data, and fisher-reported seabird captures were extracted from the Ministry for Primary Industries' (MPI) Warehou database, for three fishing years from 1 October 2009 to 30 September 2012. Data collected by government observers were extracted from MPI's Centralised Observer Database (COD) for the same period. These data included information relating to fishing (e.g., numbers of hooks set), seabird captures, and mitigation practices (e.g., deployment of streamer lines).

The key operational aspects of inshore bottom-longline operations that have been identified as influencing the risk of seabird bycatch are night-setting and line-weighting (Bull 2007, Lokkeborg 2011). The deployment of streamer lines during setting and retention of used bait during hauling are additional measures that have been used on some vessels. Time of line-setting was examined for three fishing years (2009–10 to 2011–12), using records from MPI's Warehou database. "Night" sets were defined as starting more than 30 minutes after nautical dusk to until 30 minutes prior to nautical dawn (New Zealand Gazette 2010). As set end times were not available, some sets characterised as occurring at night may have continued into day.

Line-weighting involves the addition of weight along longlines to increase their sink rate. Previous research showed that skippers are aware of the need to sink lines quickly to reduce the risk of seabird captures (Goad et al. 2010). The use of this mitigation measure has been examined on a number of vessels, and this information was included in the present study.

Data sources also included previous research on the development of mitigation strategies (e.g., retention of fish waste) in New Zealand inshore fisheries (Goad et al. 2010, Goad 2011), and a review of data held by the Department of Conservation (DOC) on the use of streamer lines (also called "tori lines") observed on inshore bottom longliners (Department of Conservation 2011).

2.2 Documenting current practice

Primary data collection undertaken during this study was carried out by experienced government fisheries observers. Observers were briefed in detail prior to their deployments, and debriefed after returning from each voyage. The duration of observers' time on vessels was determined by each skipper's willingness to host them, and the potential for modifying and improving mitigation approaches.

Bottom-longline vessels were selected for inclusion in the current project based on a number of criteria, including the target fish species, the port of departure, the location and timing of fishing activities, the interest in bycatch reduction approaches, and the willingness and capacity to host observers.

Observers recorded the timing and location of all sets and hauls, fishing depth, bait type and state, fish species caught, and gear characteristics and setup. When streamer lines were deployed, their dimensions were recorded. Any seabirds caught during fishing trips were also recorded and identified to species level. This information was recorded on different paper forms used by government observers on some of the bottom-longlining trips (Table 1), with electronic data recording on the remaining trips.

All other data were captured on forms specifically designed for this project. Observers collected qualitative information in a series of question-based forms that were designed to record their impressions and skipper feedback about mitigation measures.

Table 1: Types of form used by government observers, and information recorded to document current operating practices in inshore bottom-longline fisheries in northern New Zealand.

Form	Data captured
Hauling Observations	Date, time and location of observed hauling activity Bottom depth Hooks observed Hauling speed and direction Environmental conditions (e.g., temperature, cloud cover, wind strength and direction) Species and number of fish caught, retained, and discarded
Setting Observations	Date, time and location of observed setting activity Hooks observed Setting speed and direction Details of line set Details of tori line used Discharge of offal Environmental conditions (e.g., temperature, cloud cover, wind strength and direction)
Tori Line Details	Line diameter and length Terminal object used Number and length of streamers Distance between streamers Streamer material and colour
Non-fish Bycatch	Species captured Injury and life status
Trip Report	Deck diagram Vessel and gear details Longline diagram Tori line diagram

Quantitative data were collected using project-specific data collection protocols to characterise fishing operations. Data collected included detailed quantification of longline sink rates and seabird abundances and activity astern the vessel during setting and hauling. These characteristics were the primary metrics used to quantify bycatch risk and the efficacy of mitigation measures in reducing this risk. Given the sensitive conservation status of some of the seabird species involved, and the large number of seabird captures that would have been required to directly measure the efficacy of the focal suite of mitigation approaches, conducting an experiment that explicitly increased the risk of seabird fatalities was not appropriate for this project. Previous studies of seabird bycatch reduction measures have shown that proxies for seabird mortalities can be effective in testing the efficacy of mitigation measures, even if proxies quantify bycatch risk indirectly (Pierre & Debski 2013). Based on approaches used in previous research (e.g., Pierre & Norden 2006, Pierre et al. 2012), data collection protocols were developed and refined through testing by an observer on-board a single bottom-longline vessel. Similar to past experiments on seabird bycatch mitigation measures, the simplicity of protocols increased through time (Abraham et al. 2009, Pierre et al. 2012) based on observer feedback in two main areas: the achievability of the data collection approach (e.g., time taken and the ability of a single observer to monitor the activities required) and the efficacy of the protocol in quantifying seabird activity relevant to bycatch risk. Increased simplicity was expected to support greater consistency between observers in the application of the protocols at sea.

2.2.1 Data collection during line-setting

The finalised data collection protocol assessed seabird abundance and activity during line-setting in an area 10 m by 100 m astern, centred on the setting station. Each data collection form included five observation periods. Observers were encouraged to complete as many observation periods as possible, given the limitations of light availability (due to night-setting), and the time required to complete their other duties. Details identifying the set (including date and time), covariates (vessel speed, swell height, wind strength, wind direction), and describing streamer line use, were recorded prior to the commencement of seabird observations.

Observation periods started with abundance counts of large birds (all albatrosses and giant petrels *Macronectes* spp., small birds (shearwaters, all other petrels except Cape petrel (*Daption capense*), any storm petrels, prions), and Cape petrels, made sequentially within the defined area. Abundance counts took no longer than one to two minutes.

Following the first abundance count, the number of dives was recorded for each species group. These data included the total number of dives and the number of dives when birds were seen to specifically target the longline or hooks. A dive was defined as a bird putting its head underwater, which we interpreted as the intention of foraging (Pierre & Norden 2006).

After five minutes of counting dives, observers recorded “landings” for an additional five-minute period. A landing was defined as a bird transitioning from being in flight to being on the water or moving into the sampling area by paddling on the sea surface. This behaviour was interpreted as showing an interest in the vessel (or something around it, e.g., other seabirds already in attendance, fish waste discharge, bait on the line), which could lead to foraging activity.

Two alternating five-minute periods of each of the two activity types were recorded, leading to a total of 20 minutes of observations. That is, the five-minute recording of dives was followed by a five-minute recording of landings, another five-minute recording of dives and another five-minute recording of landings. A final abundance count of each of the species groups completed that observation period, and a new observation period commenced with the same sequence of abundance and activity counts.

Longline sink rates were recorded using six to 12 time-depth recorders (TDRs, Starr-Oddi DST centi-TD, including a time stamp). Protocols for deploying TDRs were developed from previous research in bottom-longline fisheries (Goad et al. 2010, Goad 2011). TDRs were programmed, using SeaStar software, to record data for the period 30 minutes before to 45 minutes after the expected longline shooting time. Before deployment, TDRs were located in a container of seawater and recorded data every 30 seconds. Water in the container was changed at least every 10 minutes. From the earliest possible shot time and the expected time of the end of the shot, TDRs sampled every second. While the line soaked, TDRs sampled every 10 minutes. Finally, TDRs were programmed to sample once every 24 h for 2040 days if the line was lost.

Information collected before and after TDRs deployment included water depth, tidal flow and direction, weather including atmospheric pressure, wind speed and direction, swell height and direction, and vessel course. For each TDR, the TDR number, position on the line, time it left the vessel, and time it entered the water were recorded. Gear setup was also recorded in detail for each longline deployed with TDRs, including vertical and horizontal distances between the backbone at the stern and the water surface, the dimensions and order of hooks, weights and floats, snood spacing, length, diameter, material and breaking strain, and lengths of float and weight ropes used. TDRs were clipped onto the longline at setting. After hauling, TDRs were downloaded using Sea Star.

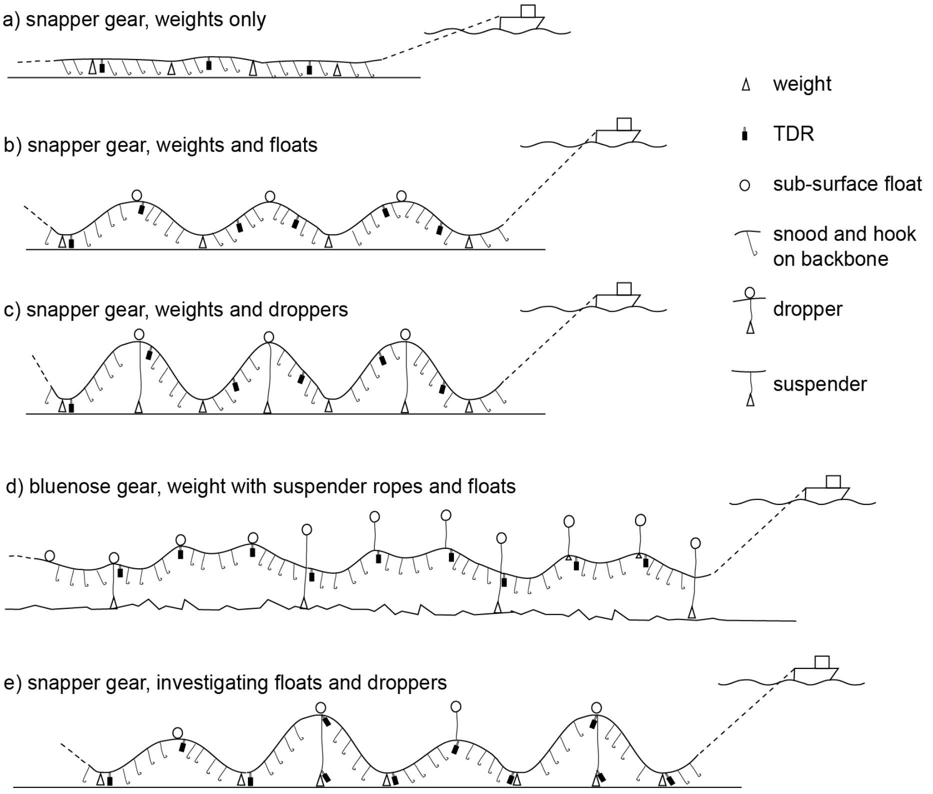

Figure 1: Position of time-depth recorders (TDRs) on bottom longlines, relative to hooks, weights and floats to investigate sinking rates in snapper (*Pagrus auratus*) and bluenose (*Hyperoglyphe antarctica*) target fisheries.

The positions of TDRs on longlines was varied, depending on the aspect of the line set that was of interest in each trial (see below). We aimed to place TDRs towards the centre part of lines, i.e., away from the larger end weights or grapnels. On sets targeting snapper, the end weights reached the seabed prior to TDR deployment. Gear targeting bluenose, which involves fishing in deeper water, was often still sinking at completion of the set. Therefore, TDR deployments commenced at least two full sections into the set – typically 100 hooks into a 300- to 800-hook set.

On snapper vessels, TDRs were used to document current practice for two or three sets, before exploring novel mitigation approaches. On the two vessels targeting bluenose, TDRs were used to document fewer standard sets owing to time limitations of observer deployments on these vessels.

When investigating current practice on vessels targeting snapper on flat ground using just weights, TDRs were positioned to estimate the fastest sinking positions (beside weights) and slowest sinking positions, considered to be either half or three quarters of the distance towards the following weight (setup (a) in Figure 1). When examining more complicated setups targeting snapper, the number of TDR positions increased to include the same positions relative to floats (setup (b) in Figure 1) and “droppers” (setup (c) in Figure 1). When sampling longline gear targeting bluenose, TDRs were placed beside weights and beside floats (setup (d) in Figure 1). To investigate the effect of floats and droppers on gear sink rate and position in the water column and relative to the seabed, TDRs were placed on the backbone beside floats and weights and also on dropper weights (setup (e) in Figure 1).

Finally during the set, observers estimated the tension on the backbone. Observers inferred tension levels in a variety of ways, including by monitoring the deflection of the backbone caused when clipping hooks on, by the way the line behaved when weights were clipped on and by the sound of the line on the drum. In some cases skipper comments alerted observers to circumstances relating to line tension, for example, the level of tension at which lines had broken in the past, when they were shooting the line at tensions as low as possible, or when they operated at increased tensions in order to clip the hooks onto the backbone of the longline. Given the exploratory nature of tension readings, line tension was categorised as low, medium or high.

2.2.2 Data collection during line-hauling

During the hauling process, seabird observations were focused in two areas around the vessel: a semi-circle of 6 m diameter that extended from 1 m forward to 5 m aft of vessel hauling stations, and a full circle of 100 m radius around the vessel, centred on the hauling station. Hauling stations were located on one side of the vessels included in this project.

Hauling observations commenced with observers documenting vessel speed, swell height and wind strength and direction. Observers also recorded whether used baits or discards were being discharged. Each observation period proceeded with a series of six abundance counts of each of the three groups of seabirds (large seabirds, small seabirds, and Cape petrels, as for line-setting) inside the 6 m-diameter semi-circle. Following these counts, the abundance of each of the three seabird groups was recorded from the 100-m radius circle around the vessel, excluding the innermost 6-m diameter circle. Each form included six observation periods comprising this series of seven abundance counts, for each of the three species groups. Observers were encouraged to record their observations for as long as possible at hauling, in accordance with the requirements of their other duties (e.g., retrieving TDRs).

Line setup details around the TDRs were checked and recorded at the haul, typically over a portion of the line from three sections before, to three sections after the TDRs were deployed.

2.3 Refining existing mitigation approaches

Aiming to improve the performance of streamer lines, observers worked with skippers and crews on two vessels (identified here as vessels “L” and “N”) to make changes to the streamer lines in use. Changes on Vessel L included the addition of a 2-kg weight near the point where the streamer line attached to the vessel to make the streamer line bounce and, thereby, scare birds away from the longline underneath. Other changes involved the positioning of two streamer lines almost directly on top of one another to increase the protection of the longline by the streamer lines above, and the threading of strapping tape through the rope that formed a loop and provided drag at the end of the streamer line, thereby creating a “bottle-brush” effect and increasing disturbance in the water. This change was aimed at dissuading birds from attending and foraging near the vessel.

On Vessel N, streamer lines were modified through the addition of floats (of the type typically used on setnets) which were placed forward of the towed object. These floats were intended to reduce entanglements of the streamer line and surface floats on the longline, while increasing drag and disturbance at the water surface. Also, glow sticks were added to the aerial section of the streamer line to improve its functionality by allowing visual assessment and adjustment of its position in the dark.

One experimental weighting regime was explored on two different vessels. The regime was deployed on two experimental lines on each vessel. The regime tested involved weights of half the normal mass being deployed at half the normal spacing. This kept the overall amount of weight consistent with the vessels’ normal setups, but the weight was spread more evenly along experimental lines. Experimental regimes were only applied when vessels were not using floats on the longline. Therefore, the gear setup sequence comprised a repeated arrangement of weights and hooks along the line.

TDRs were placed at positions immediately after the weight and halfway after the weight. On one vessel, TDRs were also placed three quarters of the way after the weight (Figure 1).

On vessels where normal practice was to discard baits and unwanted fish during hauling, basic systems (e.g., a large bucket) were devised to retain used baits and unwanted fish. When baits and discards were held, seabird observations were collected as described above for hauling, for comparison with observations collected during hauls when discharging occurred.

Under normal operations, fishing vessels are not legally able to hold undersize fish and some reef fish on-board. However, with a government observer on-board, dead fish which would normally be discarded immediately could be held for sampling purposes under the Fisheries Act (1996) s 225, part 1(f).

2.4 Exploring new mitigation measures

Investigation of new mitigation measures included improvements to the retention of bait fragments during line-setting and extending the length of ropes used on subsurface floats. Past observer coverage highlighted the issue of bait fragments flying off hooks and into the water immediately astern during the set (J. Williamson, pers. comm.). The presence of such an attractant is expected to draw birds closer to vessels and gear, thereby enhancing bycatch risk. Similarly, birds may be at risk of being caught on baited hooks when attempting to feed on loose scraps of lost bait. Attaching a board (dubbed “the splatterboard”) to the vessel transom and under the setting area is expected to catch bait fragments and retain these, thereby reducing the amount of fish material entering the water to attract birds.

Firstly, two designs of the splatterboard were trialled at sea on one vessel. Key issues included providing for straightforward deployment and retrieval and ensuring the board did not interfere with line-setting, especially during vessel turns. Then, the effect of retaining baits and bait fragments using the spatterboard was explored when the board was attached and when it was absent, by quantifying seabird abundances at setting in accordance with the data collection protocol described above.

Floats on longlines reduce the sink rate of the longline backbone (and consequently the attached hooks). Extending float-ropes may increase sink rates for the depth commensurate with the length of the float rope (Goad et al. 2010, Goad 2011).

On one vessel targeting snapper, the effect on sink rate of extended subsurface float-ropes was measured on five sets using TDRs. Normal practice for this vessel included the use of one float, or very occasionally two floats between (typically) 2 kg steel weights. The purpose of this setup was to keep hooks slightly off the sea bed. The vessel used two 60 mm diameter setnet floats tied together and clipped directly onto the longline. Ropes were added to the floats, initially with a total length of 3 m, and then 5 m. For the experimental floats, extra buoyancy was added by using one or two extra setnet floats offset by a small weight (0.1 - 0.2 kg) at the clip attached to the backbone of the longline. The addition of extra buoyancy and weight facilitated the extension of the longer float-ropes. Ten or 12 TDRs were deployed on each line, on sections with and without longer float-ropes.

Longer float-ropes were also trialled on two vessels targeting bluenose. On the first vessel, ropes were extended from 0.4 m to 5 m and trialled on eight sets. Extended ropes were trialled on normal - sized (diameter of 150 mm) floats for one set in which two floats were placed between 6 kg concrete weights. Larger floats (two floats 100 mm in diameter) with a 0.2 kg weight at the clip were trialled on a further seven sets, again using concrete weights. For these seven sets repeated line setups were three floats, 6 kg of weight, three floats, 6 kg, three floats, 12 kg (two sets), three floats, 12 kg (one set), three floats, 6 kg, two floats, 12 kg (three sets) and three floats, 12 kg, two floats, 6 kg (one set). Six or seven TDRs were deployed on each line on sections with and without longer float-ropes, aiming to cover all float and weight positions equally over the trip, with and without longer float-ropes.

On the second vessel, two sets were sampled, both with two floats between 6 kg steel weights. On both the sets, ropes were extended from 0 m to 5 m in length. On the first of these two sets, longer ropes were used with the vessel's normal-sized 150 mm diameter floats. On the second set, 5 m ropes with larger floats (two floats 100 mm in diameter) and a corresponding 0.2 kg weight at the clip were used. Twelve TDRs were placed on each line: three on a normal section (with floats directly on the backbone), followed by six along two sections with longer ropes, and then three on a normal section.

At the outset of the project, we intended to explore the development of haul mitigation measures for deployment on inshore bottom longline vessels. However, when discussed with skippers, this concept did not attract particular interest. Consequently, it was not pursued.

2.5 Data analysis

Seabird abundance (and associated covariate) data collected during observed hauls were analysed using generalised linear models with poisson distributions. The maximum abundance of birds recorded during any observation was modelled to examine the effect of discharging baits and discards during hauling. Large birds and small birds were examined. A separate fixed effect was included for each day of each trip, as follows:

$$glm(small\_birds \sim trip\_date + baits + discards, data = haul, family = "poisson")$$

Models for large birds were not stable and so are not presented here.

Data collected by TDRs were downloaded at sea. A correction to the raw TDR data was applied, following similar methods to those in Goad et al. (2010). This correction comprised two parts. First, an offset was applied such that TDR readings were 0 m at the sea surface. Second, readings of surface temperature were corrected because TDRs take some time to acclimatise to a change in temperature, and use temperature readings when converting pressure readings to a depth.

The time TDRs left the vessel was used as a start time to determine the time that TDRs took to reach a given depth. Similarly, vessel speed was used as a multiplier to estimate the distance astern TDRs reached a given depth. On one vessel the times recorded on deck were not synchronised to the TDR clocks and so a single correction was applied across all times, based on other information recorded at the set and TDR temperature records. This resulted in slightly less accurate start time, within an estimated error of 2 seconds.

Box and whisker plots were produced in a similar manner to Goad (2011). To ensure equal representation of different positions on the line, and equal representation of multiple sets as far as possible, 12 TDR records were randomly discarded. An additional two sets were not included due to incorrect TDR placement on the longline. To maintain consistency with previous work, the three-quarter TDR positions were not included. Midway positions sampled as part of previous work on bluenose gear (Goad et al. 2010, Goad 2011) are not presented here, to maintain consistency with TDR positioning in the current project.

Table 2: Bottom-longline fishing effort (number of sets, hooks) for different target species in Fisheries Management Areas (FMAs) 1, 2 and 9 for the three fishing years from 2009–10 to 2011–12. Target species included snapper (*Pagrus auratus*, SNA), bluenose (*Hyperoglyphe antarctica*, BNS), hapuku/bass (*Polyprion oxygeneios*, *P. americanus*, HPB), ling (*Genypterus blacodes*, LIN), tarakihi (*Nemadactylus macropterus*, TAR), school shark (*Galeorhinus galeus*, SCH), ribaldo (*Mora moro*, RIB), red snapper (*Centroberyx affinis*, RSN), gurnard (*Chelidonichthys kumu*, GUR). "Other" target species include blue cod (*Parepercis colias*), kahawai (*Arripis trutta*), kingfish (*Seriola lalandi*), gemfish (*Rexea* spp.), alfonsino (*Beryx splendens*, *B. decadactylus*), spiny dogfish (*Squalus acanthias*), rig (*Mustelus lenticulatus*) and trevally (*Pseudocaranx dentex*).

	FMA 1		FMA 2		FMA 9	
Target species	Sets	Hooks	Sets	Hooks	Sets	Hooks
SNA	18 972	32 997 294	12	13 050	161	342 123
BNS	2 941	4 676 978	4 187	8 706 420	684	753 708
HPB	596	727 123	1 096	1 619 392	1 319	1 139 163
LIN	749	1 214 684	3 147	5 088 013	699	906 045
TAR	127	368 042	4	7 000	105	79 400
SCH	70	90 164	128	166 806	197	161 870
RIB	37	78 224	67	139 128	0	0
RSN	80	191 560	0	0	8	22 100
GUR	180	337 797	0	0	8	12 630
Other	81	118 400	18	28 650	15	8 870
Total	23 833	40 800 266	8 659	15 768 459	3 196	3 425 909
Total no. vessels	93		57		54	
No. vessels making 90% of sets	50		15		45	

3. RESULTS

3.1 Inshore bottom-longline fisheries in northern New Zealand

Between 1 September 2009 and 30 October 2012, the bottom-longline fleet in FMA 1 consisted of many small vessels including several vessels that also fished in FMAs 2 and 9 (Table 2). Ninety percent of the sets in FMA 1 were set by about half the vessels that were active in this fishery management area. Vessels worked out of a number of ports. Typically, smaller vessels conducted one- to three-day trips targeting snapper with light "clip-on" gear (i.e., hooks are manually baited and snoods are manually clipped to the longline). Larger vessels generally conducted longer trips with heavier clip-on or autoline gear (Goad 2011). In terms of overall fishing effort, snapper target sets made up the majority of effort in FMA 1, both in the number of longline sets and the number of hooks fished. Effort targeting bluenose was also substantial in this FMA (Table 2).

Fishing effort in this period was spatially distributed throughout FMA 1, with the highest densities of hooks set in the Hauraki Gulf area (Figure 2). Other areas where particularly high densities of hooks are set are off the coast north of the Bay of Islands, and around East Cape to Hawke's Bay.

Depths fished by bottom longliners varied with target species (Figure 3). Sets targeting snapper were fished in relatively shallow water, with the majority of sets fished at less than 60 m depth. In contrast, bluenose, hapuku, bass and ling were targeted in deeper water, at several hundred metres depth. Depth profiles of sets by target species were highly consistent across the three fishing years examined (i.e.,

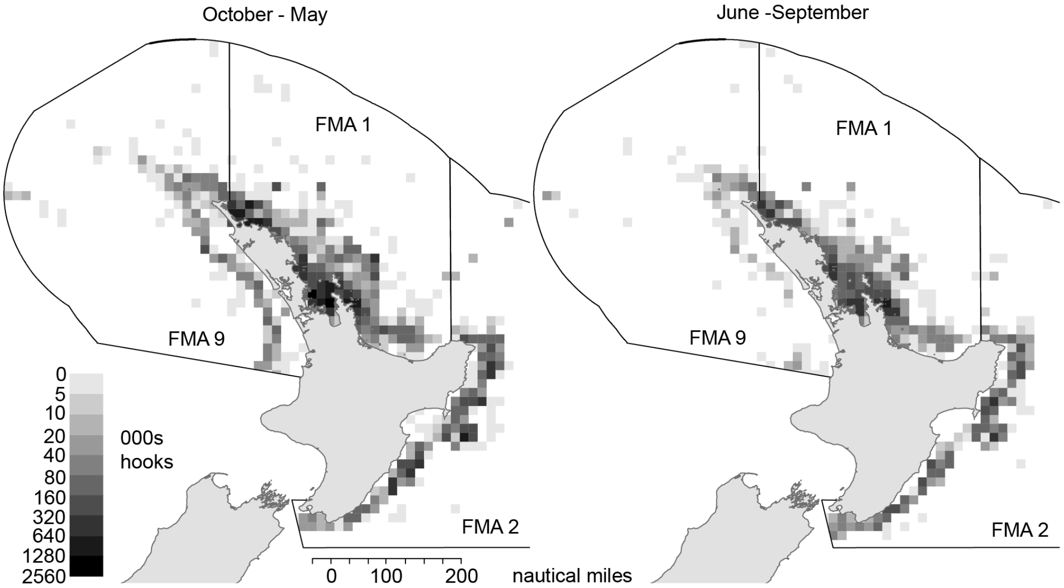

Figure 2: Total number of bottom-longline hooks set in Fishery Management Areas (FMAs) 1, 2 and 9 between October and May, when black petrels (*Procellaria parkinsoni*) are present, and between June and September, when black petrels are absent, in the period from 2009–10 to 2011–12. Data were extracted from the Ministry for Primary Industries' Warehou database, and binned into 0.2 degree rectangles.

between 2009–10 and 2011–12, year by year data not shown).

3.1.1 Seabird captures

Observer coverage of northern New Zealand bottom-longline fisheries has been very low over time and nonexistent in some years. For example, in FMA 9, no coverage has occurred in three of the nine fishing years from 2002–03 to 2010–11. In years when coverage occurred, 1.2 to 2.3% of effort was observed (Abraham & Thompson 2012d). Observers have been deployed in FMA 1 in eight of the nine fishing years from 2002–03 to 2010–11, although less than 5% of fishing effort has been covered in each of these years (Abraham & Thompson 2012a, 2012b). The highest proportions of bottom-longline fishing effort have been observed in FMA 2 from 2002–03 to 2010–11. Coverage peaked at 10.3% of effort in 2002–03, due to observers being placed on vessels targeting ling. Bottom-longline effort in this FMA has been observed at levels of 0 to 2.5% since 2007–08 (Abraham & Thompson 2012c).

In the three fishing years from 2009–10 to 2011–12, government fisheries observers reported 70 seabird captures in bottom-longline fishing operations in FMA 1 and FMA 2 (Table 3). There were no captures reported in FMA 9 during this period, coincident with little to no observer coverage. Seabirds were caught in bottom-longline fisheries targeting snapper, bluenose and hapuku. Black petrel and flesh-footed shearwater (*Puffinus carneipes*) were captured on sets deployed during the day and at night, predominantly by being hooked. Most birds were released alive (Table 3), suggesting that they were caught on the haul.

Fisher-reported captures in FMA 1, FMA 2, and FMA 9 included a wider range of seabird species than were reflected in information collected by government observers (Table 4). In addition to flesh-footed shearwater and black petrel captures, fishers reported captures of Australasian gannet (*Morus serrator*), Salvin's albatross (*Thalassarche salvini*), sooty shearwater (*Puffinus griseus*), fluttering shearwater

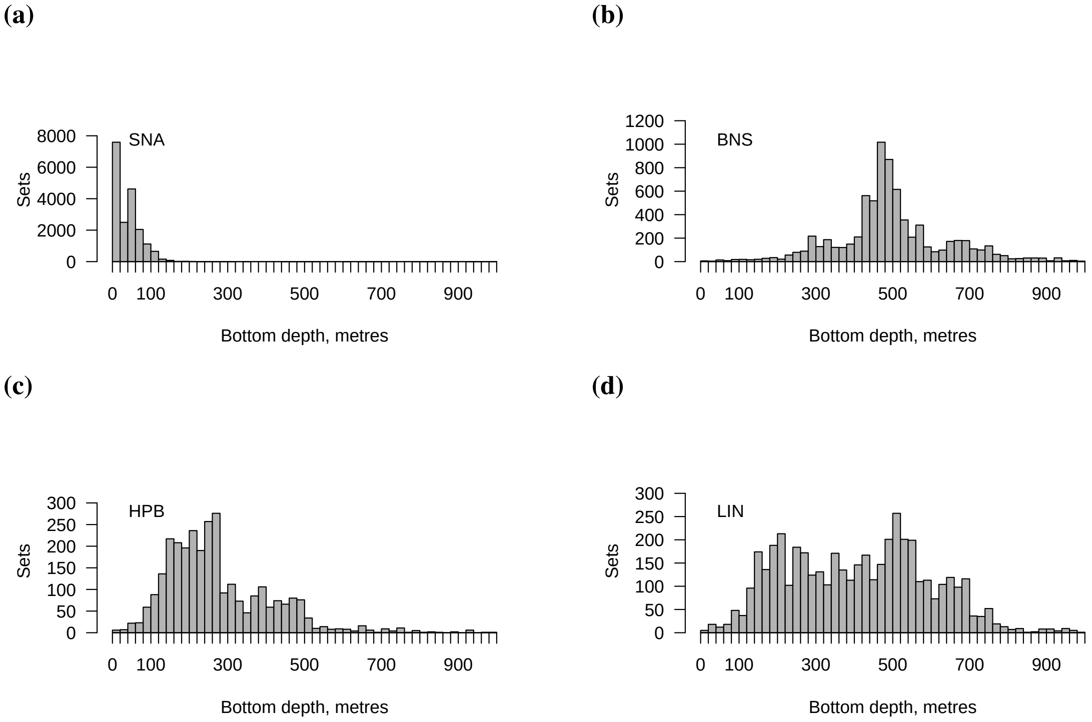

Figure 3: Depth distribution of bottom-longline sets (at the start of the set) across Fisheries Management Areas 1, 2 and 9 for the three fishing years from 2009–10 to 2011–12 (data from the Ministry for Primary Industries' Warehou database). Target species included (a) snapper (*Pagrus auratus*, SNA) (b) bluenose (*Hyperoglyphe antarctica*, BNS) (c) hapuku and bass (*Polyprion oxygeneios*, *P. americanus*, HPB) and (d) ling (*Genypterus blacodes*, LIN).

Table 3: Seabird bycatch in inshore bottom-longline fisheries reported by government fisheries observers in Fishery Management Area (FMA) 1 and FMA 2 in the three fishing years from 2009–10 to 2011–12 (data from the Ministry for Primary Industries' Centralised Observer Database). Target species included snapper (*Pagrus auratus*, SNA), bluenose (*Hyperoglyphe antarctica*, BNS) and hapuku/bass (*Polyprion oxygeneios*, *P. americanus*, HPB). Seabird species codes included black petrel (*Procellaria parkinsoni*, XBP) and flesh-footed shearwater (*Puffinus carneipes*, XFS).

Fishing year	Fishing effort		Observed seabird captures			
	Area	Target	Species	Number	Method	State after capture
2009–10	FMA 1	SNA	XBP	2	Hooked	Released alive
				17	Hooked	Dead
		SNA	XFS	10	Hooked	Released alive
				6	Hooked	Dead
				1	Tangled	Dead
	FMA 1	BNS	XBP	4	Hooked	Released alive
				1	Tangled	Released alive
2009–10	FMA 2	HPB	XBP	12	Hooked	Released alive
			XBP	1	Hooked	Dead
	FMA 2	BNS	XBP	11	Hooked	Released alive
			XBP	1	Tangled	Dead
2010–11	FMA 1	BNS	XBP	2	Hooked	Released alive

Table 4: Seabird bycatch in inshore bottom-longline fisheries reported by fishers in Fishery Management Areas (FMA) 1, 2 and 9 in the three fishing years from 2009–10 to 2011–12 (data from the Ministry for Primary Industries' Warehou database). Target species included snapper (*Pagrus auratus*, SNA), bluenose (*Hyperoglyphe antarctica*, BNS) and hapuku/bass (*Polyprion oxygeneios*, *P. americanus*, HPB). Seabird species codes included black petrel (*Procellaria parkinsoni*, XBP), Buller's shearwater (*Puffinus bulleri*, XBS), flesh-footed shearwater (*Puffinus carneipes*, XFS), sooty shearwater (*Puffinus griseus*, XSH), Cape petrel (*Daption* spp., XCC), fluttering shearwater (*Puffinus gavia*, XFL), Australasian gannet (*Morus serrator*, XGT), Salvin's albatross (*Thalassarche salvini*, XSA) and Westland petrel (*Procellaria westlandica*, XWP). Species groups were gannets and boobies (XSU), and petrels, prions and shearwaters (XXP). Classifications of "Injured", "Uninjured" and "Dead" are presented as reported by fishers.

Fishing year	Fishing effort		Observed seabird captures				
	Area	Target	Species	Caught	Injured	Uninjured	Dead
2009–10	FMA 1	SNA	XBP	31		3	28
			XBS	1		1	
			XFS	25	1	7	17
			XSH	3		1	2
			XSU	2		2	
			XXP	1		1	
	FMA 1	BNS	XBP	31	7	21	3
			XSH	7			7
	FMA 9	BNS	XXP	1			1
2010–11	FMA 1	SNA	XBP	10	1	5	4
			XCC	1			1
			XFL	1		1	
			XFS	37	2	8	27
			XXP	6		6	
	FMA 9	BNS	XXP	1			1
2011–12	FMA 1	SNA	XBP	7		1	6
			XFS	22		5	17
			XGT	1			1
			XXP	2		1	1
	FMA 2	BNS	XSA	1			1
			XWP	1			1

(*Puffinus gavia*), Buller's shearwater (*Puffinus bulleri*), Cape petrel (*Daption* spp.), and Westland petrel (*Procellaria westlandica*). As well as reporting at the species level, fishers also reported captures using generic codes for boobies and gannets, and petrels, prions and shearwaters. The highest number of capture reports was recorded from 2009–10. Fewest reports were completed in 2011–12. Both live and dead captures were reported (Table 4). Fisher reports of seabird captures were made from 12 vessels during this three-year period.

Seabird capture rates based on observed captures were difficult to compare directly with fisher-reported capture rates due to variation in observer coverage patterns over time. While fishers reported the capture of a broader range of seabird species than observers, fisher-reported capture rates were generally an order of magnitude lower than seabird capture rates estimated from observer coverage (Table 5).

Table 5: Rates of seabird captures (per 1 000 hooks) calculated using government fisheries observer data (from Abraham & Thompson (2012a, 2012b, 2012c, 2012d)) and fisher reports in Fisheries Management Areas (FMA) 1, 2 and 9 for the three fishing years from 2009–10 to 2011–12. Target species included snapper (*Pagrus auratus*, SNA) and bluenose (*Hyperoglyphe antarctica*, BNS). Fishing effort data and fisher-reported seabird captures were extracted from the Ministry for Primary Industries' Warehou database. (Note that Abraham & Thompson (2012a, 2012b, 2012c, 2012d) used two spatial areas for FMA 1: Northland and Hauraki, Bay of Plenty. Other areas were FMA 2 (east coast North Island) and FMA 9 (west coast North Island).)

	Fishing reported			Abraham & Thompson (2012a, 2012b, 2012c, 2012d)		
Fishing year	Area	Target	Capture rate	Area	Capture rate	% observed
2009–10	FMA 1	BNS	0.02	Northland & Hauraki	0.24	0.4
				Bay of Plenty	0.57	1.0
	FMA 1	SNA	0.006	Northland & Hauraki	0.07	4.9
				Bay of Plenty	0	2.8
	FMA 9	BNS	0.003	West Coast NI	0	2.6
2010–11	FMA 1	SNA	0.005			
	FMA 9	BNS	0.003			
2011–12	FMA 1	SNA	0.002			
	FMA 2	BNS	0.0009			

3.1.2 Mitigation practices used

Start times of sets targeting hapuku and bass varied between FMAs and years, with 34 to 76% of sets starting at night (Table 6). Start times of sets targeting ling showed similar variation, with 37 to 68% of sets starting at night, depending on the year and FMA.

Across all target species, there was a peak of setting activity around nautical dawn (Figure 4). The distributions of set start times around nautical dawn were consistent in summer and winter. Sets targeting snapper were mostly set after nautical dawn (Figure 4), with 23 to 28% of all sets commencing at night in FMA 1 where most effort targeting snapper occurred (Table 6). Sets targeting bluenose were mostly initiated prior to nautical dawn (Figure 4). In FMA 2, where most fishing effort targeting bluenose occurred, 56 to 71% of sets started at night. In FMA 9, up to 86% of sets targeting bluenose commenced at night (Table 6). Start times of sets targeting hapuku and bass varied between FMAs and years, with 34 to 76% of sets starting at night. Start times of sets targeting ling showed similar variation, with 37 to 68% of sets starting at night, depending on the year and FMA (Table 6). Across all target species, there was a peak of setting activity around nautical dawn (Figure 4).

Review of data held by the Department of Conservation describing streamer lines on inshore bottom longliners targeting snapper showed considerable variation in design and construction (Department of Conservation 2011). The diameter of streamer lines varied between 5 mm and 10 mm, the number of streamers used ranged from none to 23, and the aerial extent covered extending from 10 to 80 m. Streamer lines ranged from 25 m to 200 m in length and were attached at heights of 1.5 m to 8 m above the water surface. The simplest streamer lines comprised of a towed polystyrene "cotton reel" surface float, whereas the most complex setups involved multiple streamer lines, clip-on streamers, bridles for adjustment, and a distinct drag section and/or towed object. Data on the streamer line use per set was not available for all observed trips; vessels which used streamer lines for some sets were generally more likely to deploy streamer lines during the daytime sets.

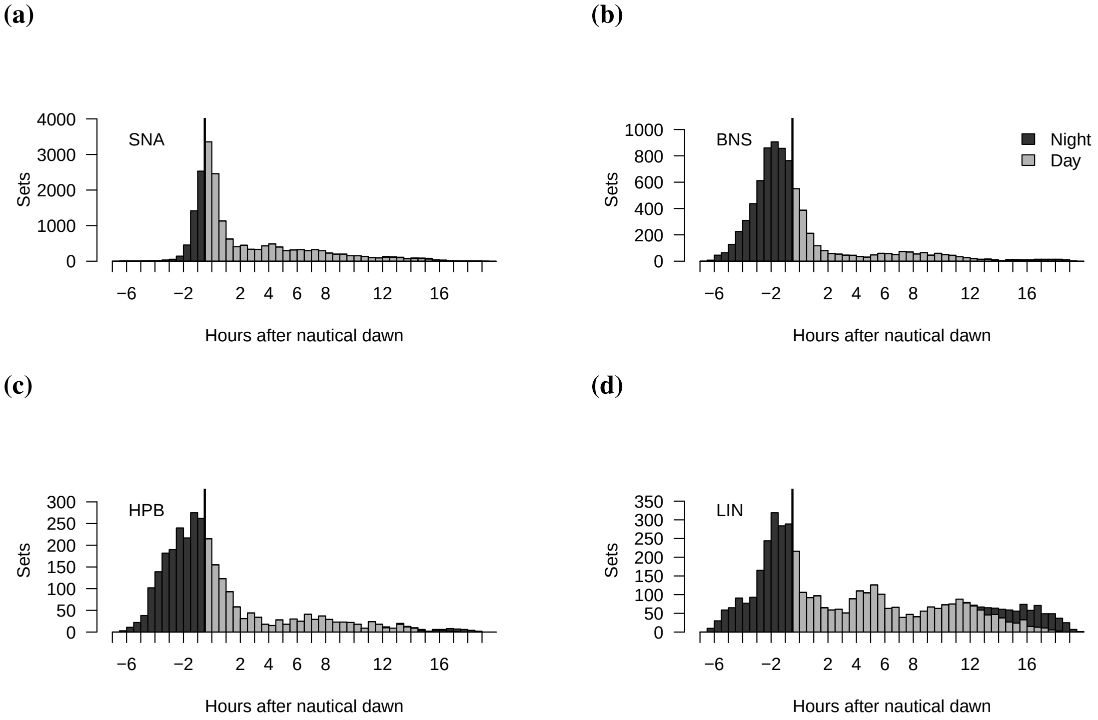

Figure 4: Number of bottom-longline sets in relation to the start time of setting around nautical dawn in the three fishing years from 2009–10 to 2011–12 in Fishery Management Areas 1, 2 and 9, as extracted from the Ministry for Primary Industries' Warehou database. Vertical line indicates 30 minutes before nautical dawn. Target species included (a) snapper (*Pagrus auratus*, SNA), (b) bluenose (*Hyperoglyphe antarctica*, BNS), (c) hapuku/bass (*Polyprion oxygeneios*, *P. americanus*, HPB) and (d) ling (*Genypterus blacodes*, LIN).

Observers and skippers noted several factors that in their views improved the performance of the streamer lines, such as irregular movement of the aerial section making the streamer line move in an unpredictable manner, so that birds were more wary of it. Similarly, irregular movement of the visible towed object makes birds wary, and one or several "cotton reel" polystyrene surface floats towed astern during snapper sets have been found to deter birds. Other factors that seem to make streamer lines more effective include splashes or noise created by the towed objects or drag section, and increased coverage through multiple streamer lines. A kind of bridle system or other modifications to the streamer line attachment system that help position the streamer line over the longline in cross winds seem to also improve streamer line performance.

Another mitigation practice involves the retention of fish waste and bait. Snapper is generally landed "green", i.e., unprocessed and only small quantities of offal are generated from bycaught species such as school shark. Offal discarding is, therefore, relatively easy to separate from fishing operations in this target fishery. Similarly, bluenose is often landed green, though hapuku, bass and ling may be landed green or processed. Some of the larger vessels targeting these species will process the catch during hauling, and then dump offal on the side of the vessel away from the hauling area (Goad 2011). The practice of bait retention at hauling is variable across vessels, and some crews will retain bait when birds are present around the vessel (Goad et al. 2010).

When interviewing fishers, Goad et al. (2010) also noted the use of oil, blue dyed bait, reduced lighting, avoiding birds when lines were set, and suspending or stopping setting altogether, as mitigation practices.

Table 6: Percentage of the total number of bottom-longline sets for which setting started at night, defined as 30 minutes after nautical dusk through to 30 minutes prior to nautical dawn. Sets are categorised by fishing year, Fishing Management Area (FMA), and target species: snapper (*Pagrus auratus*, SNA), bluenose (*Hyperoglyphe antarctica*, BNS), hapuku/bass (*Polyprion oxygeneios*, *P. americanus*, HPB), ling (*Genypterus blacodes*, LIN), Other (OTH) target species include tarakihi (*Nemadactylusma cropterus*), school shark (*Galeorhinus galeus*), ribaldo (*Mora moro*), red snapper (*Centroberyx affinis*), gurnard (*Chelidonichthys kumu*), blue cod (*Parepercis colias*), kahawai (*Arripis trutta*), kingfish (*Seriola lalandi*), gemfish (*Rexea spp.*), alfonsino (*Beryx splendens*, *B. decadactylus*), spiny dogfish (*Squalus acanthias*), rig (*Mustelus lenticulatus*) and trevally (*Pseudocaranx dentex*). Data were extracted from the Ministry for Primary Industries' Warehou database.

		FMA 1		FMA 2		FMA 9	
Fishing year	Target	Sets	% night	Sets	% night	Sets	% night
2009–10	SNA	6351	25	0	0	72	19
2010–11	SNA	6580	23	2	0	59	27
2011–12	SNA	5951	28	10	10	29	41
2009–10	BNS	988	78	1800	66	298	86
2010–11	BNS	1097	63	1324	71	256	83
2011–12	BNS	815	70	1061	56	126	83
2009–10	HPB	189	67	376	46	363	73
2010–11	HPB	208	76	422	40	441	66
2011–12	HPB	188	68	288	34	477	65
2009–10	LIN	190	52	848	39	189	60
2010–11	LIN	306	65	1411	37	318	66
2011–12	LIN	249	68	873	45	192	56
2009–10	OTH	180	38	71	17	38	32
2010–11	OTH	204	38	80	51	134	16
2011–12	OTH	168	40	56	20	148	11

3.2 Data collection by at-sea observers

3.2.1 Observer effort

Six observers were deployed across eight vessels, delivering a total of 104 observer days (Table 7). Of the 104 observer days achieved during the project, 76 were fishing days (i.e., gear was set and/or hauled) over which 123 sets were conducted (Table 7). In addition, MPI deployed observers on two vessels prior to the start of the project, for a total of 17 observer days.

The location of observed sets is shown in (Figure 5). Sets were observed in the Hauraki Gulf including close to Great and Little Barrier Islands, off the Coromandel Peninsula, and north of the Bay of Islands.

3.2.2 Bottom-longline fishing operations

When targeting snapper, one or two longlines were set per fishing day. Typically, one set started during darkness in the very early morning, and a second line (sometimes shorter and with fewer hooks) was set during the day. Lines targeting bluenose were all (except one) set at night and hauled during daylight, with between one and four lines set per day. Longlines were set in conditions ranging from calm

Table 7: Summary of observer data collected on inshore bottom-longline vessels in northern New Zealand during this project. Data for each vessel include the target species, the numbers of observer days (days at sea and days when fishing occurred), of sets fished, including day sets (defined as starting less than 30 minutes prior to nautical dawn), of sets with time-depth recorder (TDR) deployments, of sets and of hauls involving bird observations (+1 indicates that another boat's gear was hauled by the vessel participating in the project), and different mitigation techniques tested. Target species included snapper (*Pagrus auratus*, SNA), bluenose (*Hyperoglyphe antarctica*, BNS), hapuku/bass (*Polyprion oxygeneios*, *P. americanus*, HPB), ling (*Genypterus blacodes*, LIN), tarakihi (*Nemadactylus macropterus*, TAR). Mitigation methods included: SS, slower setting speed for some of the set; LW, lighter weights placed closer together along the backbone; RB, retention of bait during hauling; SL, use of a modified streamer line; SB, use of splatterboard; FR, use of float-ropes.

		Days		Sets			With bird obs		Mitigation tested, sets					
Vessel	Target	Sea	Fishing	All	Day	TDR	Sets	Hauls	SS	LW	RB	SL	SB	FR
L	SNA	23	18	31	23	9	20	31	4			2		
M	SNA	10	9	10	4	4	4	10		2				
N	SNA	33	26	32	8	16	16	15		2	8	2	5	5
O	MIX/TAR	11	8	13	4	4	0	13 + 1						
P	BNS, HAP	16	10	32	1	10	0	32			2			7
Q	BNS	3	2	2	0	2	0	2						2
R	SNA	3	2	2	0	0	0	2						
S	SNA	5	1	1	1	0	0	1						

(Beaufort scale = 0) through to when there were moderate waves and around 20 knots of wind (Beaufort scale = 5). Across all vessels, mean setting speed was 4.7 knots. While the total number of vessels is low, observed vessels targeting snapper set at higher average speeds than vessels targeting other species (Table 8). Generally, vessels appeared to set alone; no other vessels were seen during 29 sets in which seabird observations were conducted. On another 11 sets, one or two other vessels were reported during seabird observation periods.

Longlines used to target snapper tended to be longer and have more hooks than lines used to target other species (Table 8). Hooks were manually baited on all observed vessels. A variety of bait types was used, including pilchard (*Sardinops sagax*), squid (*Nototodarus spp.*), barracouta (*Thysites atun*), kahawai (*Arripis trutta*), and octopus (*Pinnoctopus cordiformis*). Bait was always thawed, and sometimes salted. Setting occurred over 20 min - 2 hours, and hauling took from just over one hour to 6 hours. The use of circle hooks and "J" hooks was reported. On all vessels, setting occurred from the stern. Discharge of offal was not observed during setting. Interruptions to the setting process occurred during nine sets of the 94 for which this information was available. Interruptions were from 3 minutes to 16 minutes in duration.

Longlines were hauled from the early morning through to late afternoon (between 06:00 and 17:45 NZST). During hauls, conditions ranged from calm (Beaufort scale = 0) to around 20 knots of wind (Beaufort scale = 5) except for one incidence of around 30 knots of wind (Beaufort scale = 7). Visibility was reported to be excellent during hauls. Across all target species, mean hauling speed was 1.3 knots, however as for setting, vessels targeting snapper tended to haul at slightly faster speeds than vessels targeting other species (Table 9). Haul speed often changed during the haul, by up to approximately 1 knot. Vessels targeting bluenose fished at much greater depths than those targeting snapper or a mix of inshore species (Table 9). Hauling was conducted from the port, starboard or stern of different observed vessels. Discharging of offal was not observed during the 95 hauls for which this information was available. Interruptions to the hauling process occurred more frequently than for setting. Forty five hauls were interrupted, of the 113 hauls for which this information was available.

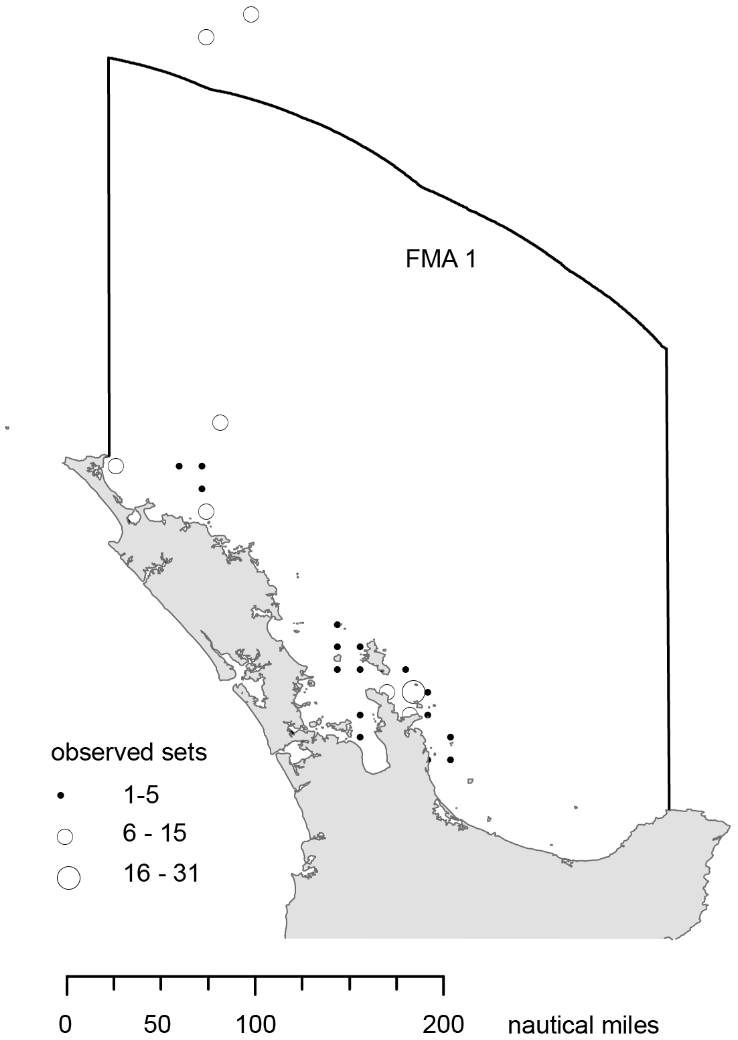

Figure 5: Location of observed bottom-longline sets on inshore fishing vessels in northern New Zealand. The boundary of Fishery Management Area (FMA) 1 is shown. There was a total of 123 observed sets, conducted from December 2012 to May 2013. The locations of observed sets are shown to within 0.2 degrees.

Table 8: Summary of bottom-longline fishing characteristics reported by observers working on 10 inshore vessels targeting three fish species or species groups in northern New Zealand waters. Target species included snapper (*Pagrus auratus*, SNA; seven vessels), a mix of target species especially tarakihi (*Nemadactylus macropterus*, MIX/TAR; one vessel), and bluenose (*Hyperoglyphe antarctica*, BNS) and hapuku/bass (*Polyprion oxygeneios*, *P. americanus*, HPB) (two vessels). Data include the mean value and range. Details on all gear attributes were not available from all sets.

	SNA			MIX/TAR			BNS/HPB		
Fishing characteristics	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Set duration (h:min)	1:03	0:40	2:00	0:30			0:25	0:20	0:30
Backbone lengths set (m)	8 188	1 300	15 000	1 177	450	2 040	1 070	680	1 430
No. hooks on longline	2 850	1 500	4 000	1 000			700	600	800
Backbone diameter (mm)	1.78	0.60	2.5	2.50			4.00		
Snood length (m)	0.64	0.60	0.7	0.60			0.35	0.29	0.4
Distance between snoods (m)	2.18	1.2	3.0	1.20			1.80	1.6	2
Setting speed (knots)	5.19	3.3	7.1	2.88	2.3	3.3	4.01	3.7	4.6

Table 9: Summary of bottom-longline hauling characteristics observed on 10 inshore vessels targeting three fish species or species groups in northern New Zealand waters. Target species included snapper (*Pagrus auratus*, SNA; seven vessels), a mix of target species mainly tarakihi (*Nemadactylus macropterus*, MIX/TAR; one vessel), and bluenose (*Hyperoglyphe antarctica*, BNS) and hapuku (*Polyprion oxygeneios*, *P. americanus*, HPB) (two vessels). Data include the mean value and range. Details on all gear attributes were not available from all hauls.

	SNA			MIX/TAR			BNS/HPB		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Haul duration (h:min)	4:06	2:30	6:00	2:00			1:27	1:10	1:45
Haul speed (knots)	1.52	0.5	2.7	1.09	0.3	1.8	0.86	0.5	1.1
Bottom depth at start of haul (m)	50.4	13	90	100.2	37	129	542.7	370	597

The duration of interruptions was also longer than when interruptions occurred during setting (mean duration of interruptions: 25 minutes; maximum duration: 1 hour 50 minutes).

3.2.3 Seabirds observed around fishing vessels

Seabird species reported attending vessels in the highest numbers (e.g., from one or two through to tens of birds) and almost daily were black petrel and flesh-footed shearwater. Amongst albatrosses, Campbell (*Thalassarche impavida*) and white-capped (*Thalassarche steadi*) albatross were the most often seen by observers, as single birds or small groups of less than 10 birds. Seabird species less frequently reported by observers were grey-headed albatross (*Thalassarche chrysostoma*), Buller's albatross (*T. bulleri*), Buller's shearwater, fluttering shearwater, sooty shearwater, great-winged (grey-faced) petrel (*Pterodroma macroptera*), common diving petrels (*Pelecanoides urinatrix*), Australasian gannet and black-backed (*Larus dominicanus*), black-billed (*L. bulleri*) and red-billed (*L. novaehollandiae scopulinus*) gulls. In addition, species groups reported included great albatross, prions, shags, terns, and Pycroft's (*Pterodroma pycrofti*) or Cook's (*Pterodroma cookii*) petrel.

Three birds were observed captured during commercial fishing operations. Two black petrels were returned dead, both hooked in the wing, from a single set targeting snapper. A streamer line was deployed part way through the set and is likely to have been in use when at least one of the captures occurred. One juvenile black-browed albatross was hooked in the beak during the haul of a bluenose line. This bird was subsequently released alive. Baits were being discarded in the vicinity of the hauling station during the haul.

A single (recreational) marlin lure was towed for a short time on one vessel, as the crew fished whilst steaming. One wandering albatross became tangled in the line, but managed to free itself when brought close to the vessel. One juvenile black-browed albatross (*Thalassarche melanophris* or *T. impavida*) was also hooked in the leg, brought back to the boat, dehooked and released alive but injured.

Northern inshore bottom-longline fisheries operate across an area in which recreational fishing is also extensive. Observers reported the attendance of petrels and shearwaters at recreational fishing vessels. Observers and skippers reported the attraction of these birds to recreational fishing lures and baited hooks deployed from commercial vessels.

Table 10: Gear parameters for normal practice line setups on inshore bottom-longline vessels targeting snapper (*Pagrus auratus*) or tarakihi (*Nemadactylus macropterus*). Vessels A to E were part of a previous study (Goad et al. 2010). Line tension was estimated by observers based on their own observations and information from skippers.

Vessel setup	Line setup	Weight (kg) per 100 m of line	Weight type	No. sets sampled	Setting speed, knots	Shooting height (m)	Line tension
A1	Droppers, weights	1.5	Steel	2	4.7	2.1	
A2	Droppers	1.0	Steel	3	4.7	2.1	
B1	Droppers, weights	5.0	Lead	2	2.7 - 3.6	1.6	
C1	Weights	1.6	Rocks	3	2.2 - 3.5	1.3	
D1	Weights	1.3	Lead	3	4 - 4.7	1.6	
E1	Weights	2.1	Steel, lead	2	5.0	1.5	
E2	Droppers	2.7	Steel, lead	2	5.0	1.5	
L1	Weights	6.2	Steel	3	4.9 - 5.5	1.6	Med
L2	Weights	5.9	Steel	1	5.0	1.6	
M1	Weights	1.3	Steel	2	5.5 - 5.8	2.0	High
N1	Weights	3.1	Steel	3	4.5-5.8	2.0	Low - med
N2	Weights, floats	2.2	Steel	3	5.2 - 5.5	2.0	Low - med
O1	Weights	2.9	Steel	4	2.3 - 3.3	2.5	Low

3.2.4 Current mitigation practice

Approaches to seabird bycatch reduction were variable between vessels. The most commonly used operational measures that influence the risk of seabird bycatch were night-setting, line-weighting, the deployment of streamer lines, and retaining old baits at hauling. However, within these practices there was significant diversity that was expected to affect efficacy in reducing bycatch risk. Observers reported that some skippers and crew kept a close watch on the behaviour of seabirds astern, looking for behavioural changes that they considered were associated with foraging activity and therefore an increased bycatch risk. Skippers tended to take a reactive approach to mitigation deployment, for example, deploying a streamer line or attaching extra weight to the longline after seabirds had appeared around the vessel. At night, such reactionary approaches are not employed given birds cannot be seen, although observers reported hearing birds around vessels prior to dawn.

Of the sets targeting snapper 53 % of sets were commenced prior to 30 minutes before nautical dawn (Table 7). All but one of the bluenose sets observed during this project were carried out earlier than 30 minutes before nautical dawn, and skippers reported that this was the norm.

Crews on snapper-target vessels reported working what they considered to be “extra” weighting on lines, over and above what would be necessary to catch fish, in order to reduce the risk of bird captures by increasing the sink rate of baited hooks. In some cases, crews added additional weights when birds appeared around the vessel. However, except in these situations, what was considered to be extra weight was unclear.

Results from sink rate testing of normal practice line setups are presented below (Table 10, Table 11). A more complete set of box whisker plots, showing the distance behind the vessel TDRs reach different depths is shown in the appendices to this report, but excluded here for clarity.

Table 11: Gear parameters for normal practice line setups on inshore bottom-longline vessels targeting bluenose (*Hyperoglyphe antarctica*, BNS), hapuku/bass (*Polyprion oxygeneios*, *P. americanus*, HPB), and ling (*Genypterus blacodes*, LIN). Vessels F to K were part of a previous study (Goad 2011). Weights in parentheses show the approximate equivalent weight of steel for lead and concrete weights in seawater (Mono., monofilament). Line tension was estimated by observers based on their own observations and information from skippers.

Vessel/ setup	Repeated line sequence	Float diameter (mm)	Weight per 100 m (kg)	Weight type	Backbone material	Number of sets sampled	Setting speed (knots)	Shooting block height (m)	Line tension
F1 LIN	Dropper, float	150, 120	3.3 (3.0)	Lead	Mono.	6	3.5 - 3.7	2.9	Med
F2 LIN	Droppers	150	5.5 (5.0)	Lead	Mono.	1	3.5	2.9	Med
G1 BNS	Weight, 4 floats	180	5.4	Steel	Tarred rope	5	4.6 - 5.1	2.5	
G2 BNS	Weight, 4 floats	180	3.6	Steel	Tarred rope	2	4.5	2.5	Med
H1 BNS	Dropper, 3 floats	180, 135	3.3	Steel	Mono.	7	1.8 - 2.2	2	Low
J1 HPB	Dropper, float	180, 135	5.7	Steel	Mono.	7	3.6 - 3.85	2.6	High
J1 LIN1	Droppers	180, 135	5.7	Steel	Mono.	2	3.1 - 4.1	2.6	High
K BNS/ HPB	Suspender, 2 floats	150	4.5	Steel	Mono.	3	2.8 - 3.0	2.0	Med-high
P1 BNS	Suspender, 2 - 3 floats	150	6.7 (4.2)	Concrete/ rock	Mono.	10	3.5 - 4.0	2.0	High
Q1 BNS	Dropper, 3 floats	150	4.5	Steel	Mono.	2	1.7 - 2.4	2.0	Low

3.2.5 Longline sink rates

The risk that longlines present to seabirds is primarily reflected in hook availability when birds are present, which we describe here in terms of depth and distance of the line astern the vessel. Amongst the setups sampled, hooks were generally well within seabird diving depths at more than 100 m astern. For two of the setups sampled, all TDRs were below 10 m at 100 m astern. For some setups quantified, hooks were at depths of 10 m or less in excess of 200 m behind the vessel (Figure 6). These distances are well beyond the aerial extents of streamer lines in use on the vessels observed (Table 12). Further, where streamer lines were deployed on vessels targeting snapper, the depth of TDRs at the end of the aerial section of streamer lines was rarely greater than 5 m (Figure 7).

By considering the time taken for TDRs to sink from 5 m to 15 m some of the vessel-specific influences (e.g. height from which the longline is deployed) on sink rate are removed. The remaining differences

Table 12: Streamer line specifications recorded for vessels observed during the project. Per vessel comments included: L: attachment height varied with bird behaviour and whether second streamer line was used, second streamer line deployed for some sets, M: streamer line used for daytime sets only, N: streamer line deployed when birds were seen, part way through some sets, O: streamer line used for the one daylight set. Target species are SNA = snapper (*Pagrus auratus*), MIX/TAR = a mix of target species focusing on tarakihi (*Nemadactylus macropterus*), BNS = bluenose (*Hyperoglyphe antarctica*).

Vessel	Target species	% sets used	Diameter (mm)	Number of streamers	Streamer type	Aerial extent (m)	Total length (m)	Height (m)	Towed object
L	SNA	100	4	13	tubing	40	120	2 - 6.6	rope loop
L	SNA	13	4	9	tubing	20 - 35	80	3	rope loop
M	SNA	40	6	17	strapping	50	56	6	500 mm float and rope
N	SNA	56	5	9 - 10	strapping	40 - 50	90	4	speargun float
O	MIX/ TAR	8	5	18	tubing	30	50	5.2	traffic cone
R	SNA	100	2	15	bin bag strips	-	66	-	polystyrene float
Q	BNS	100	4	6	strapping	15	25	5.1	300 mm float

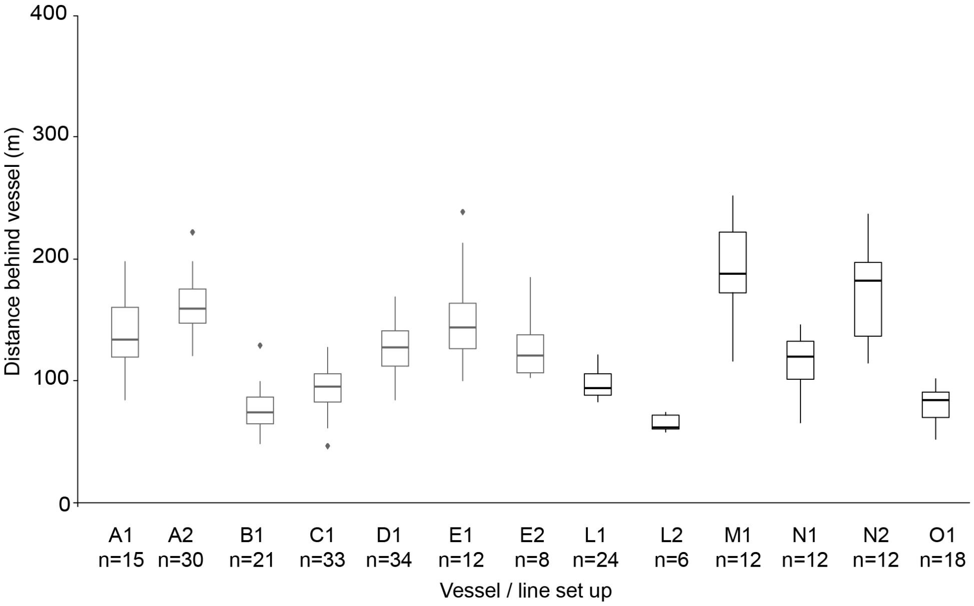

Figure 6: Box and whisker plot of distance behind the vessel time depth recorders reached 10 m depth for line setups detailed in Table 10.

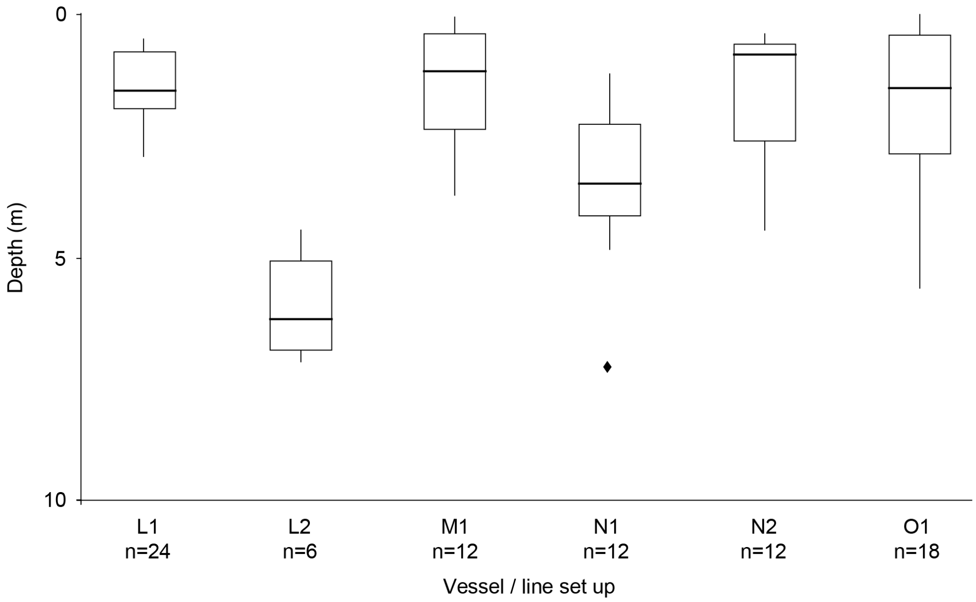

Figure 7: Box and whisker plot of depth of time depth recorders at the end of the aerial section of the streamer line for vessels L - O, line setups are detailed in Table 10.

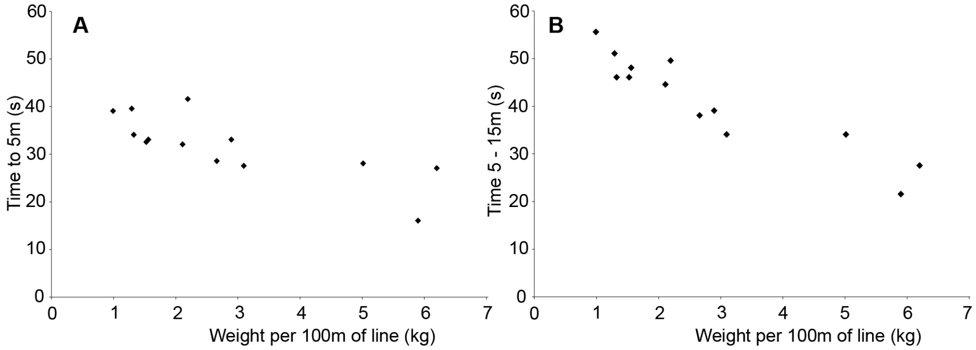

Figure 8: Plots of a) median sink time to 5 m and b) median sink time from 5 - 15 m, versus weight added per 100 m of line for vessels in Table 10.

between setups more closely represent differences in line-weighting per se. This is apparent in Figure 8 which shows a clearer relationship between weight added to the line and sink rate between 5 m and 15 m. Sink rates were more variable within 5 m of the sea surface than between 5 m and 15 m. Despite variability between lines, the use of more weight increased line sink rate at both depth ranges.

During an extended period of coverage on vessel N, variations in line setup were examined, by varying TDR placement in the course of the vessel's normal fishing practice. Variability in sink rate is driven by the position of weights on the line and also weight size. This is illustrated by a typical "flat ground" set on vessel N (Figure 9). TDRs 4868 and 4803 are located beside weights of 2.5 kg and 2.7 kg and TDR 4879 is beside a weight of 1.4 kg. Over the length of the line, weight size ranged from 1.3 to 2.7 kg, with an average of 2.0 kg on this set.

Variability in sink rate increased substantially when every second weight (or occasionally two consecutive weights) was replaced by two 60 mm diameter setnet floats clipped directly on the backbone

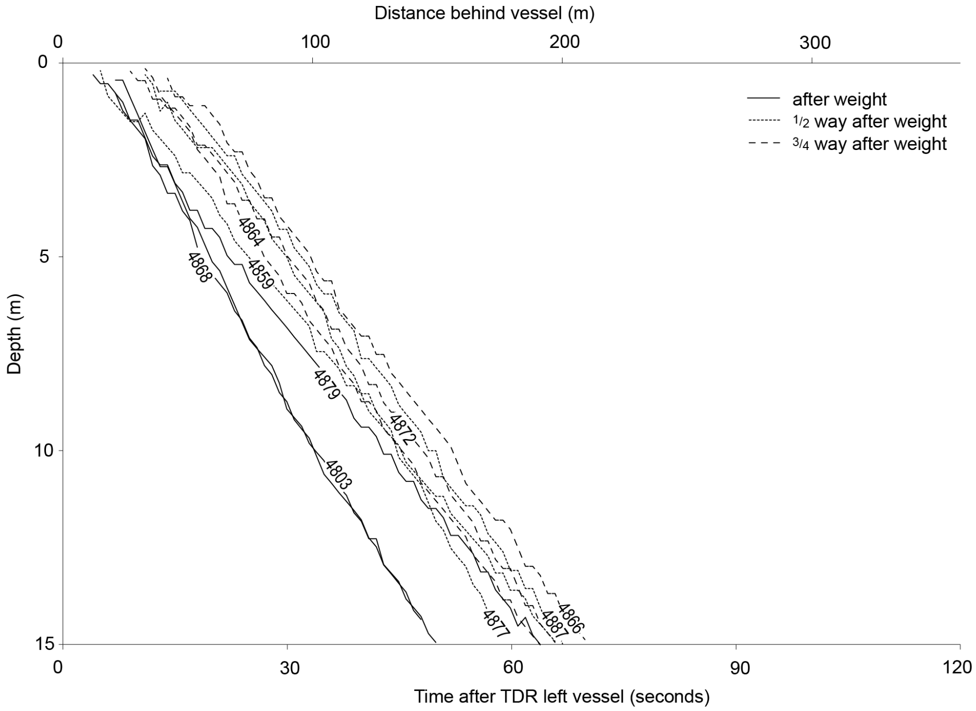

Figure 9: Time versus depth profiles for time depth recorders (TDRs) deployed during a single set on vessel N, with a repeated line sequence of weight, hooks, weight etc. Individual profiles are labelled with TDR numbers.

(Figure 10). There is no obvious explanation as to why some TDRs beside floats took much longer than others to sink.

Shallow sets can produce slow sink rates as the weights reach the seabed and then cease to pull the line down. While birds are not likely to retrieve hooks from the sea floor after the vessel has departed the area, hooks can be within the diving depth range of black petrels and flesh-footed shearwaters for the whole soak (Figure 11, Figure 12).

Detailed observations on line-weighting and seabird activity are included in the appendices to this report.

Gear setups for vessels targeting bluenose, hapuku/bass and ling are included in (Table 11). Setups included suspenders, floats, and droppers. Gear included 3.0 - 5.7 kg of weight per 100 m of line. Most vessels used monofilament backbone. Setting speeds ranged from 1.8 - 5.1 knots.

On the two bluenose vessels sampled during this project, a similar amount of weight was used on the line. However, due to differences in line tension and setting speed, sink times differed markedly between the vessels' sets. Differences were most apparent when considering the distance astern at which the TDRs reached a given depth (Figure 13). For vessel Q the gear sank relatively close to the boat with little variation, and for vessel P the gear was further behind the boat with more variation in sink times.

Unlike snapper target sets, weight added to the line during sets targeting other species did not shown a clear correlation with sink time between 5 m and 15 m (Figure 14), due to variation in float size and arrangement, and line tension.

TDR records from a single set on vessel P show considerable variation between and within different

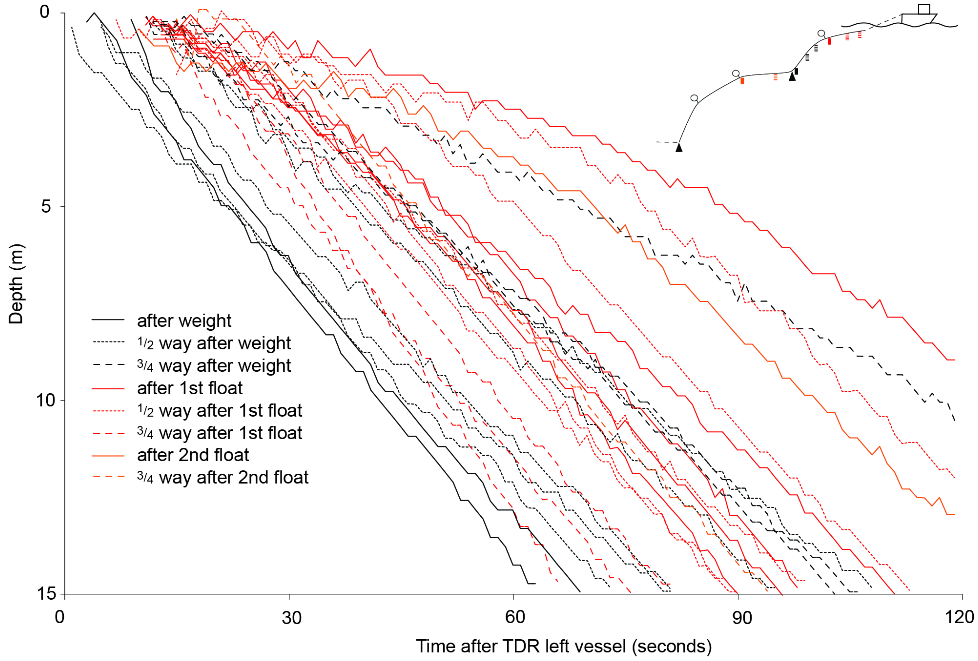

Figure 10: Time versus depth profiles for time depth recorders (TDRs) deployed during three sets on vessel N, with a variable line setup including one or two floats between weights.

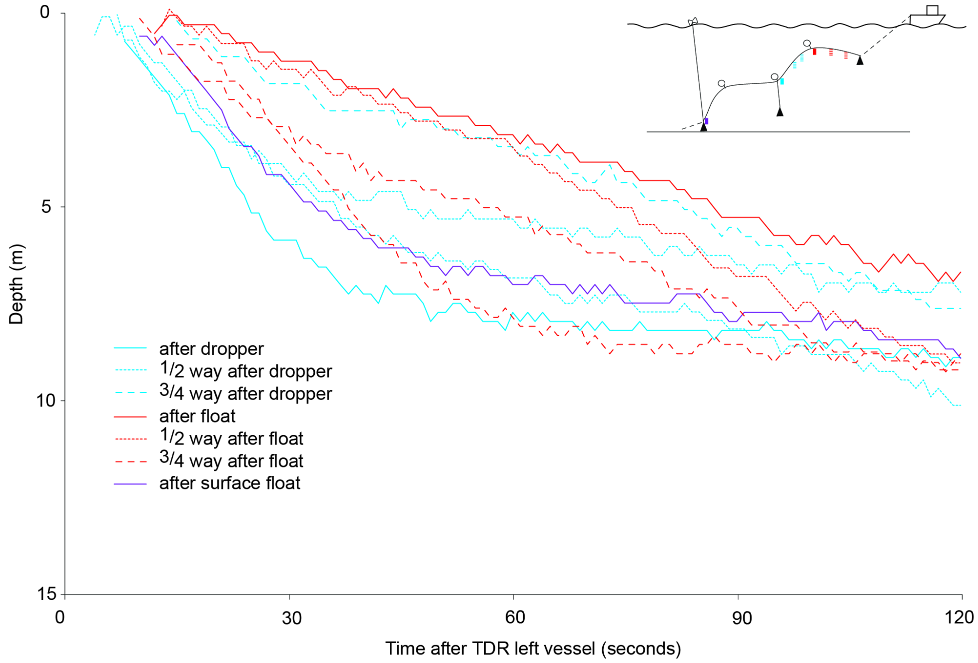

Figure 11: Time versus depth profiles for time depth recorders (TDRs) deployed during a shallow (10 m) set on vessel M, with a variable line setup of dropper, hooks, float, dropper.

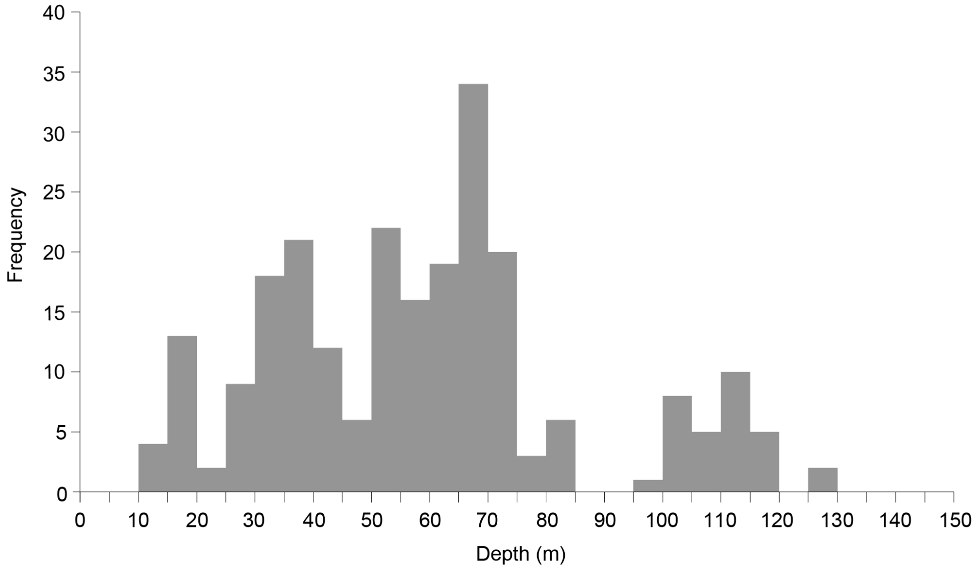

Figure 12: Frequency distribution of final depths reached by time depth recorders (TDRs) used to compile Figure 6 to Figure 11.

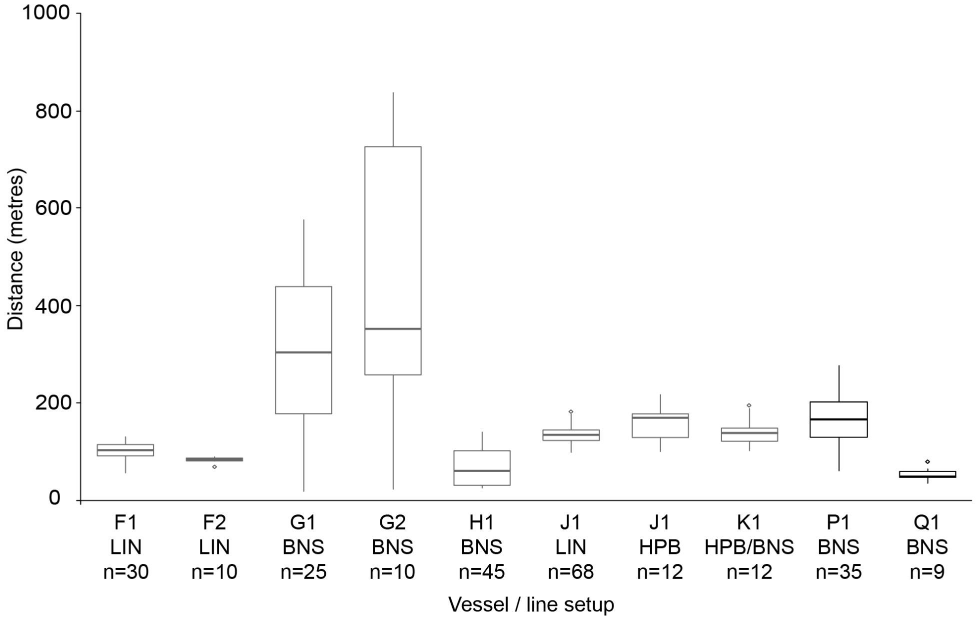

Figure 13: Box and whisker plot of distance behind the vessel time depth recorders (TDRs) reached 10 m depth for line setups detailed in Table 11.

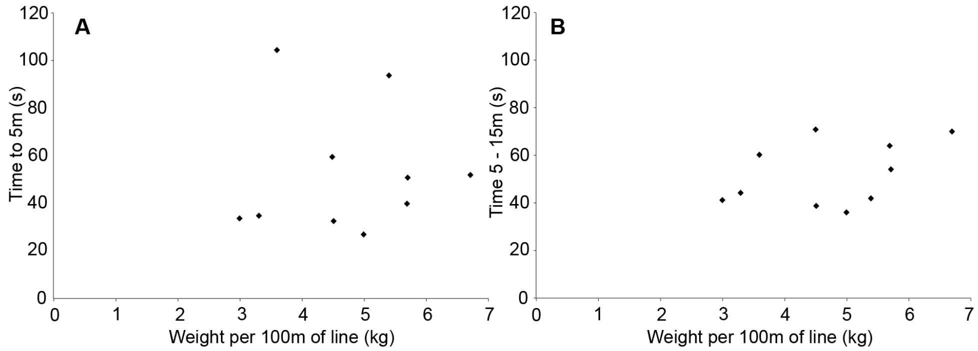

Figure 14: Plots of a) median sink time to 5 m and b) median sink time from 5 - 15 m, versus weight added per 100 metres of line for vessels in Table 11.

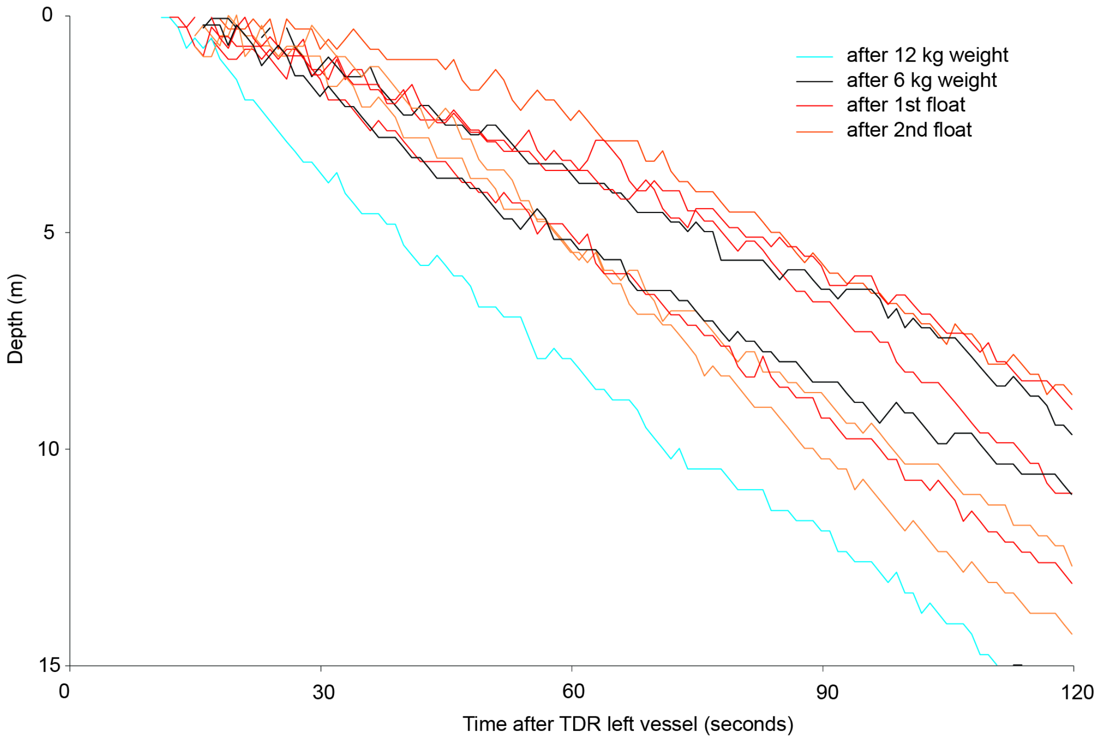

Figure 15: Time versus depth for time depth recorders (TDRs) placed on three consecutive sections of a line on vessel P. Line setup was weight on a suspender rope, float, float, with every third weight 12 kg rather than 6 kg.

positions on the line (Figure 15), with the TDRs close to the heavier weight sinking faster. Of the two 6 kg weights the one earliest in the set, and so closer to the heavy grapnel, sinks more quickly.

Vessel Q also had floats sinking a short time after they hit the water. However, due to more weight on the line, less line tension and a slow setting speed, TDRs sank more quickly and closer to the boat than those deployed on vessel P.

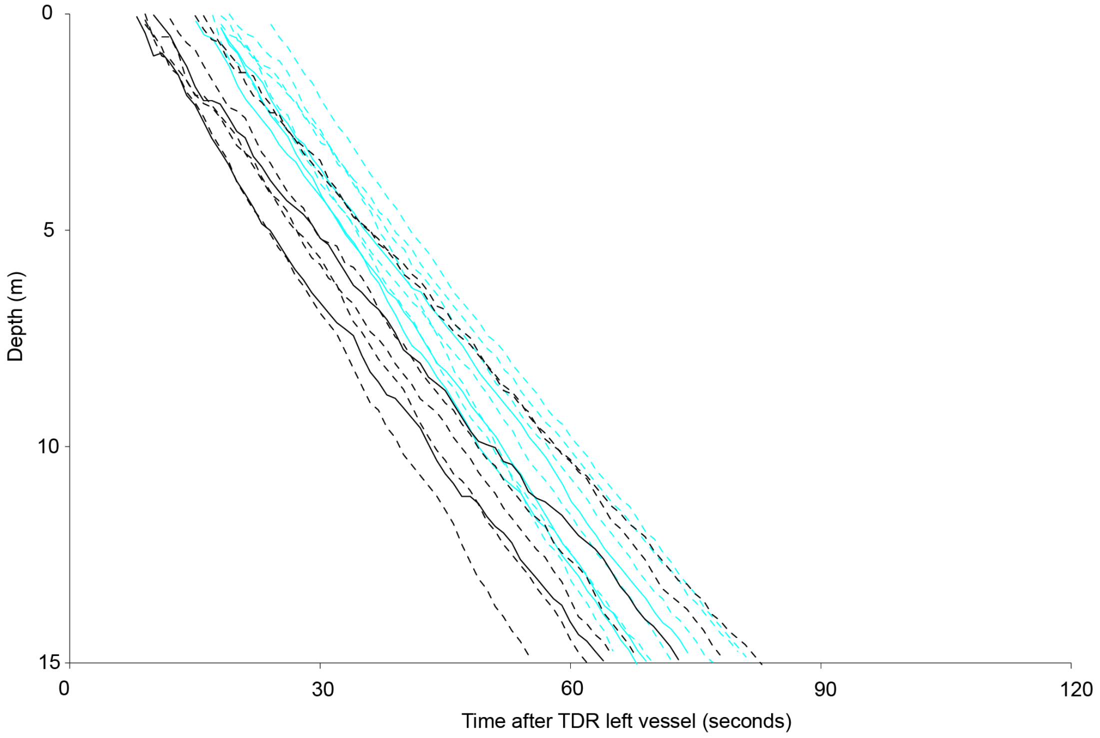

Figure 16: Plot of time versus depth for TDRs on longlines set at different speeds. Blue lines are from a set at 3.3 knots and black lines from a set at 2.3 knots. Solid lines are from TDRs beside weights and dotted lines between weights.

3.2.6 Line tension and setting speed

Estimating line tension was attempted on the four snapper-target vessels on which TDRs were deployed. The setup of the vessel and constraints on estimation methods limited findings to an approximate indication of tension on a single set for two of the vessels (M and N). On the third vessel (L), tension was estimated during four sets for which the setting speed changed part way through the set. On vessel O, tension was estimated on a single set, again at two speeds (Table 10).

Both snapper vessels returned higher tension estimates at higher setting speeds. On vessel L, variable weight sizes were deployed at variable spacings. Consequently, it was not possible to relate line tension to sink rate, as the latter was determined largely by weight size. However it was clear that although hooks sank to a given depth further behind vessel L at faster setting speeds, the sink times to depth at both speeds were comparable. Two sets on vessel O with regular weight size and spacing but set at different speeds resulted in differing sink patterns (Figure 16). The slower set showed more variability in sink rate with TDRs generally entering the water closer to the vessel stern.

Line tension estimated on two vessels targeting bluenose followed the same trend, i.e., tension was higher at faster setting speeds (Table 10).

3.2.7 Use of streamer lines

Streamer line specifications recorded during the project are shown in Table 12. One vessel used a streamer line for all sets on a purpose-built bridle system, and occasionally deployed a second streamer line for sets where the perceived risk of capture was higher. Other vessels worked a single streamer line for some sets and one deployed it part way through a set if deemed necessary. Some vessels did not use a streamer line. Streamer line usage was more common for daytime sets than at night. Of night sets, 28% were conducted with streamer lines. For day sets, this value was 85%.

On one vessel, surface floats deployed on the longline tangled with a streamer line on several occasions. This caused problems with setting the gear and also resulted in hooks being held up near the surface while the streamer line was cut free. Consequently, this vessel would deploy the streamer line at night only if the skipper thought it was necessary. Reduced visibility in the dark made it harder to see the streamer line. Consequently, the crew considered tangles to be more likely at night when deploying floats, when tangles were more difficult to identify and rectify quickly.

The two vessels covered by observers prior to the commencement of the project used streamer line-like approaches with the aim of reducing seabird interactions with gear on setting. On one vessel, centre buoys were towed astern prior to being attached to the longline. On another vessel, the crew manually flicked two centre buoy floats that were attached to ropes 50 - 60 m long.

3.2.8 Bait retention during hauling

Observers reported two of seven vessels retaining baits during hauling. Anecdotal reports from observers on the efficacy of retaining baits on hauling in terms of the short term effects on seabird behaviour were varied. Skippers who reported commonly retaining baits considered that this measure almost always diffused foraging activity around the hauling bay; birds still assembled during the haul but remained calm and did not forage aggressively. However, observers did report occasions when birds were much more active, and baits were discarded (away from the hauling bay) to satiate birds and thereby diffuse potential foraging efforts around the gear.

Observers reported that retaining all dead discards as well as bait further reduced bird abundance at the hauling station. However, eliminating all sources of available food was not possible during hauling as some old baits were still lost, occasionally fish were cut directly from hooks, and some undersized fish would float on the surface.

3.2.9 Other mitigation measures

Two skippers were asked if they avoided setting longlines in areas in which seabird abundances were perceived to be especially high. They considered that areas of particularly intense bird activity included the vicinity of the Hen and Chicken Islands and Great and Little Barrier Islands. Activity could also be intense around the Mokuhinau Islands, although was considered to be less intense than around the Hen and Chickens. One skipper reported that he did not avoid areas where he thought birds would be in especially high abundance. This was because birds occurred widely throughout much of the fishing ground. The same skipper reported that on a few (but “not many”) occasions, he had moved away from areas because bird activity was sufficiently high that he did not consider it safe to fish. An observer with considerable experience working in northern inshore fisheries considered that the Alderman Islands could also be a centre for black petrel and flesh-footed shearwater activity on occasion.

On one vessel, blue-dyed bait was used during daytime sets. Crew reported that this method had been used for a number of years, and they considered it effective in reducing seabird activity around baits during setting.

Two vessels deployed used vegetable oil as a deterrent to seabirds (flesh-footed shearwaters) attending the hauling area. The observer commented that a drip approximately every 20 seconds was sufficient to deter birds and that when oil drifted back birds returned to the hauling bay. Fishers also discussed the efficacy of shark liver oil in deterring birds. Since the commencement of this project, discharge regulations have been revised by Maritime New Zealand such that this discharge would no longer be legal (Maritime New Zealand 2012).

One skipper squirted water and dishwashing liquid on the drum axle to reduce tension during setting. Another skipper considered that a slow setting speed was effective in reducing seabird interactions, when combined with effective line-weighting.

3.3 Refining mitigation measures

3.3.1 Streamer line modifications

Streamer line modifications investigated during the project included the addition of a 2-kg weight close to where the streamer line attached to the vessel, placing two streamer lines almost directly on top of one another, and threading strapping tape through the rope to create drag at the end of the streamer line.

Modified streamer lines were deployed on four sets. The observer reported that fluctuating seabird numbers throughout sets for which changes were in place made it difficult to qualitatively assess the efficacy of the first two modifications. The third modification was perceived to have potentially increased seabird interest in the terminal end of the streamer line.

The modified streamer line setup was slightly more labour-intensive to move than the original line but otherwise did not differ in ease of use. When the strapping tape was incorporated into the terminal loop on one streamer line, crew were concerned that tangling risk may be increased. However, strapping could be incorporated into the rope loop sufficiently loosely that it pulled out when tangles occurred.

On two sets of the four during which modified streamer lines were deployed, it was sufficiently light to conduct seabird observations. Seabird counts were conducted in accordance with the data collection protocol. However, additional data collection would be required to quantitatively identify any effects of modified streamer line designs.

Changes made to streamer lines at least partially delivered the improved functionality intended. The addition of gillnet floats forward of the object towed at the end of the streamer line increased the amount of drag on the streamer line slightly. This may help reduce entanglements involving the streamer line and intermediate floats on the longline. The use of light sticks increased the vessel crew's confidence that tangles of the streamer line and surface longline floats could be avoided when using the streamer line in darkness. Glowsticks were deployed at night when seabird observations were not possible. Quantitative data on seabird interactions are needed to determine the effects of these changes.

3.3.2 Placement of weights along the mainline

Spreading weight more evenly along the longline by halving both the size of weights and the spacing between them increased sink rates and also reduced variability. Time taken for the line used by vessel N to sink from the surface to 5 m showed faster mean sink rates and less interquartile variability with the smaller weight spacing (Figure 17). On the second vessel TDR positioning was not sufficiently consistent to allow direct comparison of sink rates.

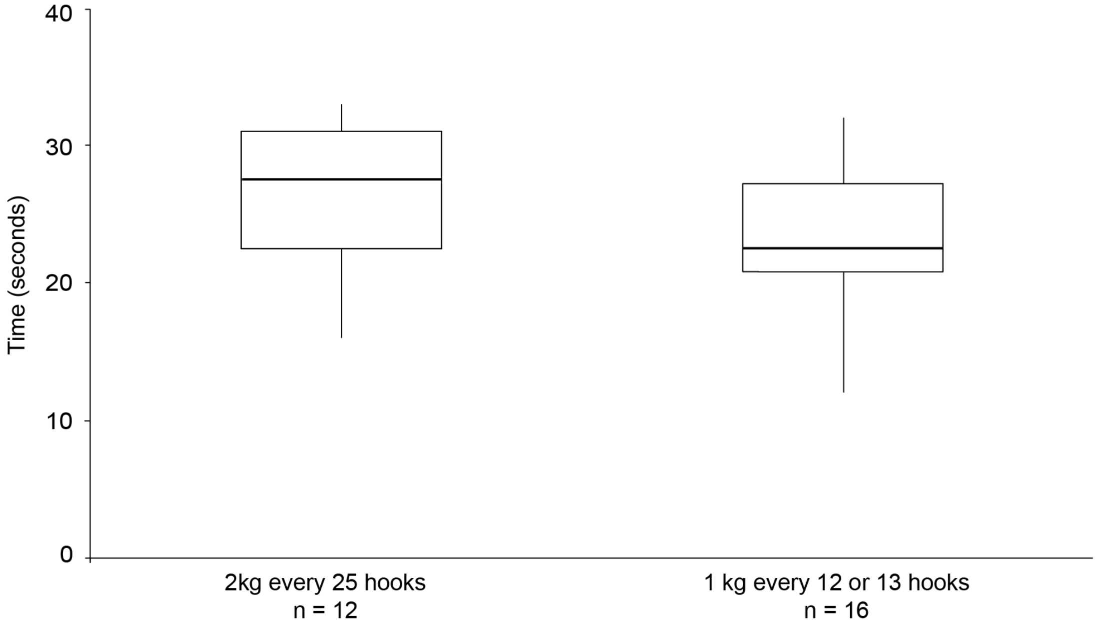

Figure 17: Box whisker plot of time time depth recorders (TDRs) took to reach 5 m depth with different weighting regimes. TDRs were placed after weights and midway between weights. Three sets were sampled for the normal weighting setup (2 kg every 25 hooks), and two sets were sampled at reduced weight spacing.

Table 13: Effect of discharging used baits and whole fish discards on seabird abundances around observed vessels.

	Mean estimate	Standard error	Significance
Baits discharged	0.28	0.09	$P < 0.0014$
Discards discharged	0.08	0.09	$P > 0.05$

3.3.3 Retention of bait and discards

GLMs show that bait retention reduced the number of small seabirds attending fishing vessels during the project. Holding discards also reduced seabird abundance but this effect was not significant (Table 13).

While model results were significant, the inherent trip-level variation in seabird abundances was high, hence the model structure required a trip-day effect. Seabird abundance by trip, and in accordance with whether or not baits and discards are being discharged, is shown in Figure 18.

3.4 Exploring new mitigation measures

3.4.1 Retaining bait fragments during line-setting

The board designed to retain bait fragments at setting was deployed on five sets on one vessel. It successfully collected bait scraps (Figure 19), odd whole baits and complete baited snoods which would otherwise been lost overboard. The design deployed was basic but functional. It was easily deployed and retrieved and could be refined to collect more of the bait splatter.

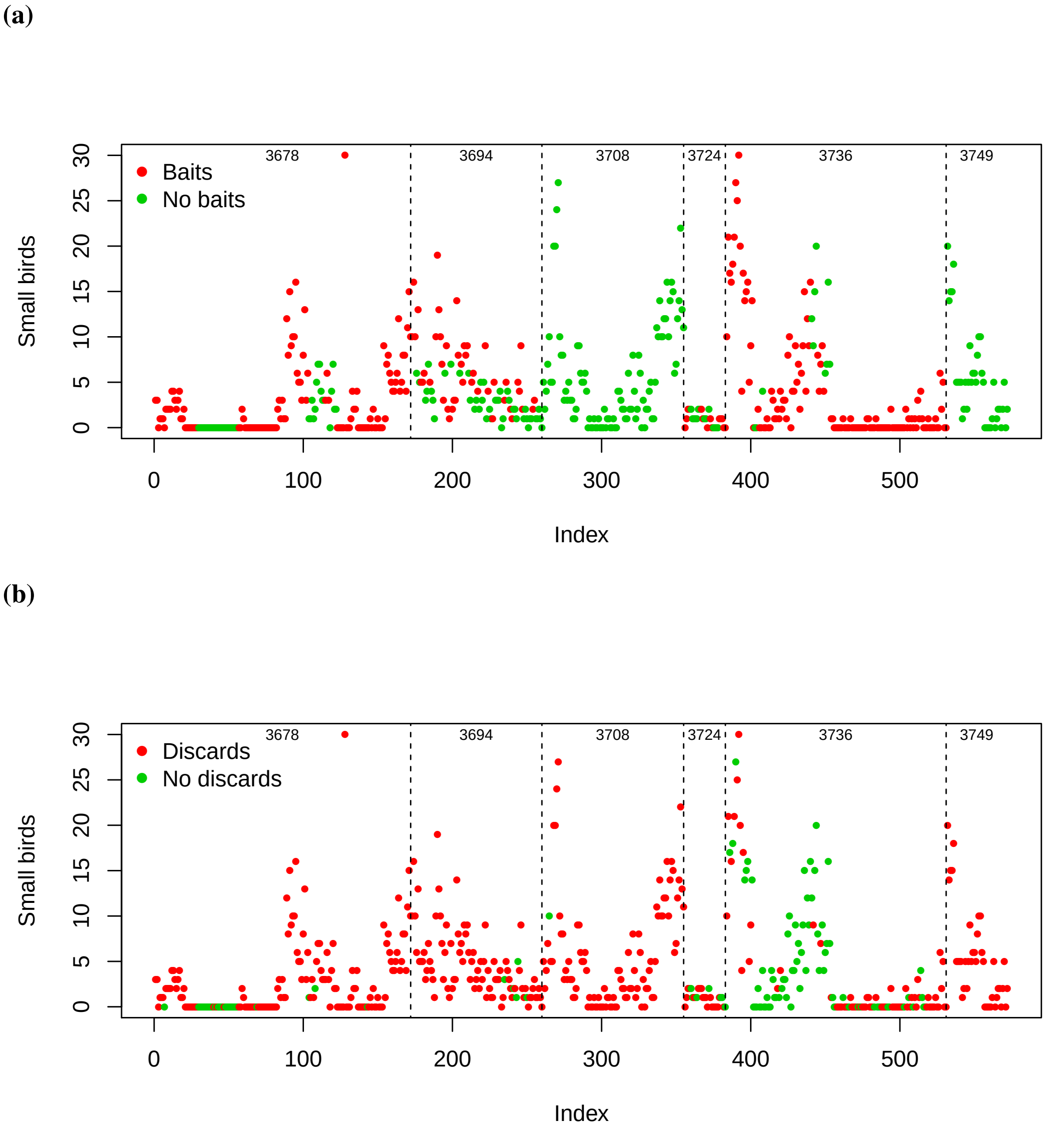

Figure 18: Abundance of small seabirds during observed trips over time (represented as a date-based index on the x axis). The top panel reflects abundance in relation to the discharge of old baits, while the borrom panel shows abundance when discards are discharged. Trips are identified with four digit codes, and the dashed vertical lines separate each trip.

The observer noted that there was variation in the degree of splatter with different bait types (e.g., no splatter with octopus bait), whether bait was salted and whether hooks were baited prior to chilling overnight or freshly baited immediately prior to setting (chilled baits splattered less than fresh baits). The skipper considered the splatterboard concept favourably as it allowed him to assess how well baits stayed on hooks at setting.

No birds were observed during trial sets so there was no opportunity to examine any effect on bird behaviour or abundance behind the vessel.

The observer considered that card design also influenced how smoothly hooks left the card and hence the amount of splatter. He suggested that changes in card design could be explored in order to retain all loose baits during setting.

Figure 19: A close up photo of some of the bait pieces collected whilst setting 1500 hooks.

3.4.2 Extending the length of ropes used on subsurface floats

On the vessel targeting snapper, the modified gear setup involving float-ropes extended to 3 m in length, and where 0.1 to 0.2 kg weights were associated with floats, delivered increased sink rates compared to when shorter float-ropes without associated weights were used (Figure 20). Subsequently, the arrangement of float-ropes extended to 5 m, combined with four setnet floats and a larger weight at the clip, showed a more pronounced increase in sink rate (Figure 21).

There was no evidence from TDR records at fishing depth to suggest that line behaved differently on the bottom with the longer float-ropes. However potential differences were difficult to identify as movement of the line was generally caused by fish.

On the vessels targeting bluenose, float rope extensions were associated with increased sink rates with some line setups. On vessel P, TDRs beside floats tended to sink with a linear profile (Figure 15). However, due to several TDRs failing after the first set it was difficult to compare like for like when trialling float-ropes. TDR records did not show any increase in sink rate when using longer float-ropes, except during the one set sampled with three floats to a 12 kg weight. During this set TDRs were placed on a normal section, followed by a longer ropes section, and those on the section with longer ropes did show a slight increase in sink rate for all three positions (Figure 22).

On vessel Q, longer float-ropes were trialled on two sets targeting bluenose. An increase in sink rate was seen for both sets, most noticeably with the larger floats and a corresponding small weight at the clip (Figure 23).

Float-ropes did tangle around the backbone on several occasions, resulting in lost time during hauling. However tangles were generally resolved quickly and because the floats stayed on the surface they were

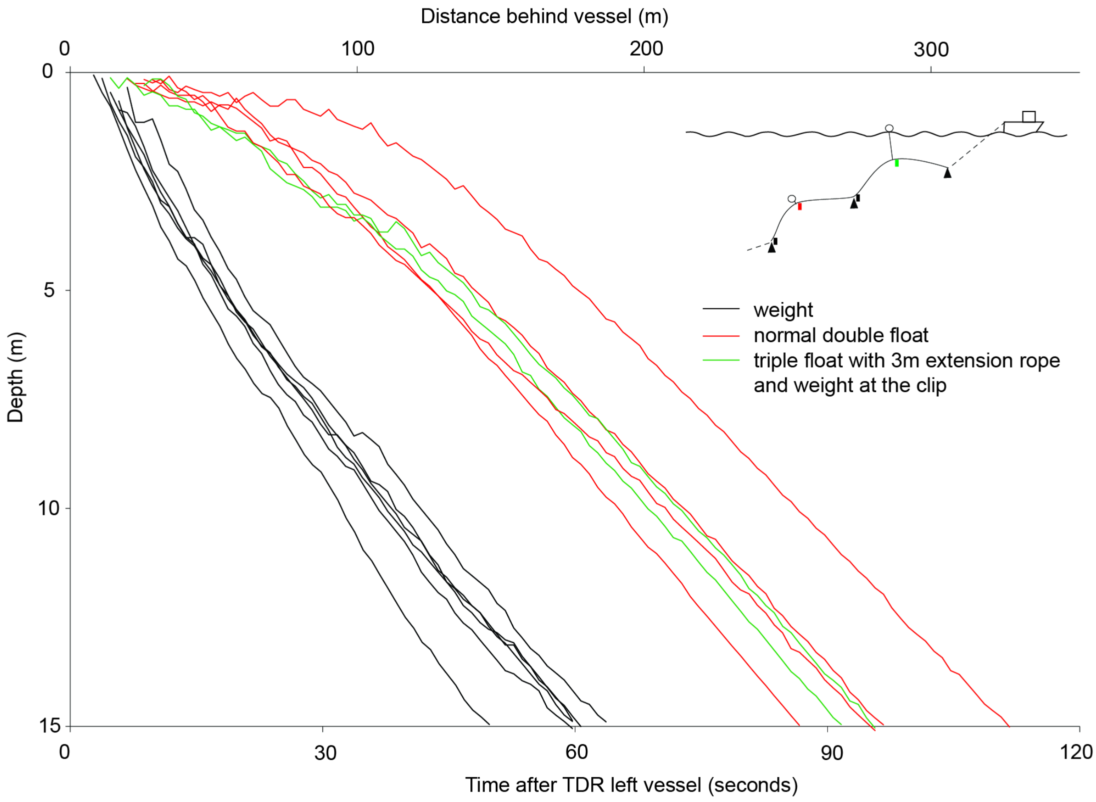

Figure 20: Time and distance versus depth for time depth recorders (TDRs) deployed on a single line beside weights, floats directly on the line and floats with 3 m rope.

less problematic than dealing with tangled weights. Having ropes wound directly around the floats made them easier to handle both at the set and the haul. Skippers on all three vessels were interested in the idea of separating the float from the backbone from a fishing point of view, and on several sets good catches were taken around the floats.

3.4.3 Study limitations

During the field component and experimental part of the present study, there were a number of limitations regarding the collection of observer data. During the project, there was a shortage of observers available for deployment, due to competing demands for observer coverage (especially to meet coverage requirements on foreign charter vessels). This shortage of observers delayed the start of the at-sea component of the study and limited the number of research days to 104 compared with the planned 150 days. While the coverage started later than was considered ideal for overlap with the seabirds of particular interest, it was within the range of previous observer coverage (Department of Conservation 2011).

In addition, only part of the inshore fishing fleet was suitable for observer placement. Approximately 30% of the vessels initially contacted for coverage were unable to carry observers due to logistics and safe ship management limitations (Maritime New Zealand 2011), including having to provide a bunk for the observer. Of the remaining 70% of vessels, several skippers refused to take observers, leaving approximately 50% of the vessels initially contacted available for observer placement (A. McKay, pers. comm.).

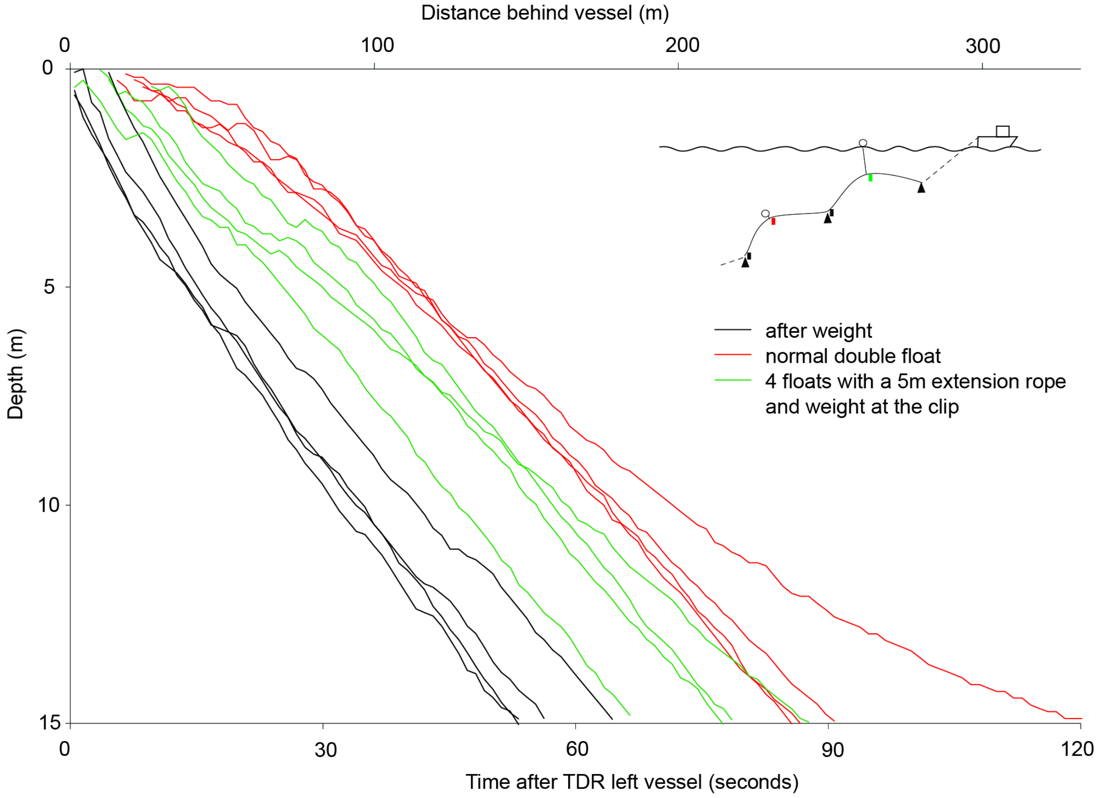

Figure 21: Time and distance versus depth for time depth recorders (TDRs) deployed on a single line beside weights, floats directly on the line and floats with 5 m rope.

There were also difficulties concerning the logistics involved with coordinating observers owing to vessel skippers frequently changing plans. The operation of smaller vessels in inshore bottom-longline fisheries is somewhat weather-dependent, requiring flexibility of the skippers, who also maintain sometimes irregular fishing schedules. Resulting short-term changes to scheduled departures made the coordination of observer deployments on fishing vessels difficult, as observers needed time to reach the different ports of departure around New Zealand. Furthermore, some of the ports are based at considerable distances from airports, further increasing the travel time of observers aiming to reach bottom-longlining vessels. In one instance, the skipper left port without notifying the observer of the trip departure time.

Other skippers showed varying degrees of willingness to carry observers, when they were contacted at the start of the project. In general, skippers of snapper-target vessels were more willing to carry observers compared with skippers of vessels targeting bluenose or hapuku. One vessel expressed a preference for hosting male rather than female observers due to the composition of the crew.

To be able to consider all project objectives, extended observer deployments were required. For this reason, the amount of time observers needed to work on vessels was significantly longer than skippers had previously been exposed to. This prolonged observer deployment resulted in some discomfort amongst skippers and there was a general reluctance to engage with observers for more than two to three weeks (including when this time period involved shore time). Some skippers considered that coverage should be equally shared amongst vessels and others commented on the cost involved in hosting observers. Three observers subsidised costs by providing money or their own supplies for some meals.

The project also relied on skippers being flexible and supporting observer efforts to improve mitigation approaches in use. Observers reported that almost all skippers and crews were very helpful and

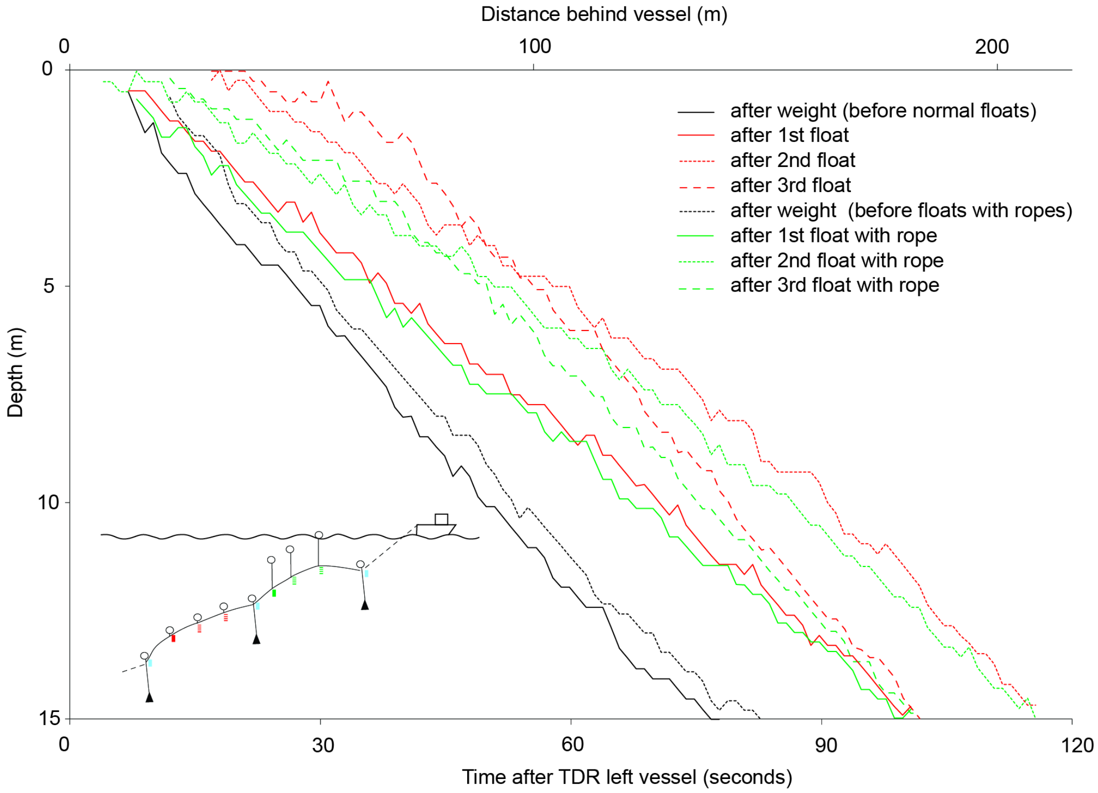

Figure 22: Time and distance versus depth for TDRs deployed on a single line beside weights, floats directly on the line, and floats with a longer rope. Data from vessel P.

accommodating, which greatly supported their work. One skipper hosted an observer, but did not agree with the observer conducting the range of activities planned in this targeted coverage (specifically, deploying TDRs). This refusal reduced the scope of the deployment as the observer could not address all experimental objectives.

Facilities available for the crew on inshore vessels vary considerably, for example with the size of the vessel. In one instance, a vessel making multi-day trips was not equipped with a shower or toilet, which dissuaded the observer from accepting the placement. In addition, most inshore vessels have a small number of crew, and replacements may not be available if a crew member is injured or absent. In one instance, the observer was supported the crew in the absence of one deckhand. This involvement reduced the amount of time the observer could spend on seabird observations, but had the advantage of continuing data collection at some level on that vessel.

Another limiting factor was the ability of observers to earn more on offshore vessels. Part of the strategy of this project was to have consistency in observer deployments on individuals vessels. Owing to the characteristics of inshore fishing, this strategy involved observers working a series of sea days interspersed with shore days (e.g., between trips or during bad weather). In contrast to this approach, observers had higher earnings when they were deployed for a continuous number of sea days, such as on an offshore vessel. For this reason, observer involvement in the current project was less fiscally rewarding than deployment on offshore fishing trips, even though their personal interest in this project may have been higher than in the tasks associated with typical observer trips.

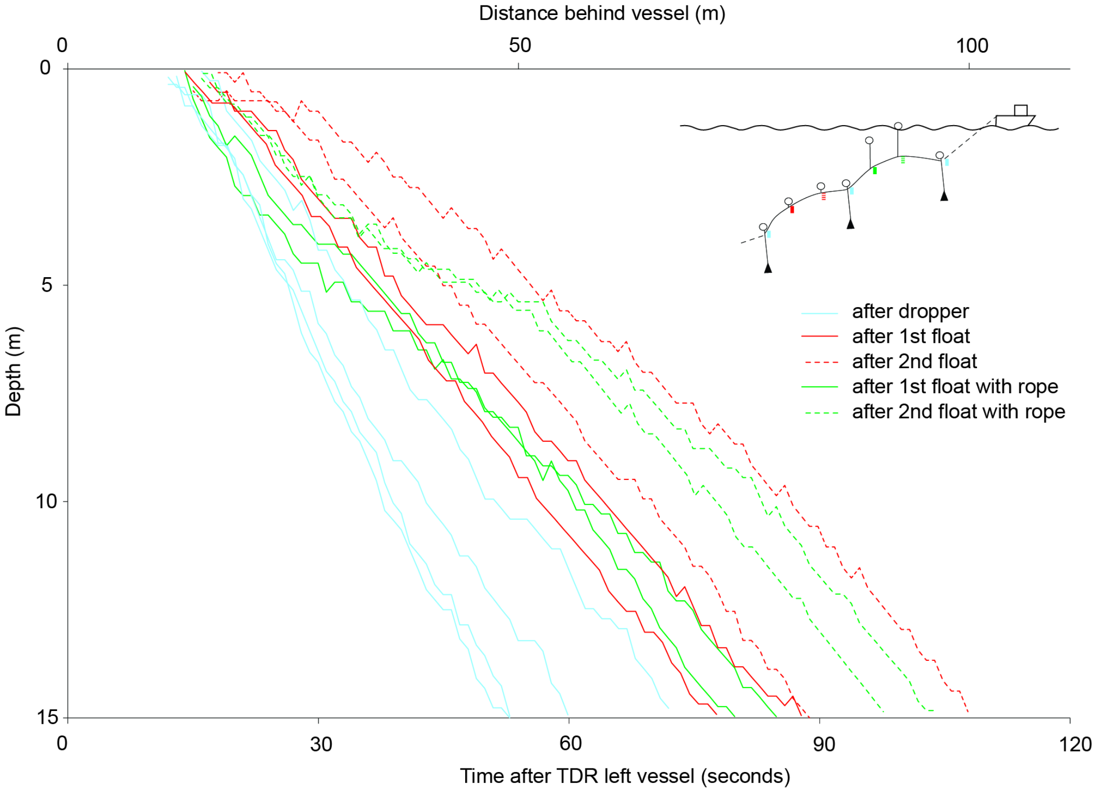

Figure 23: Time and distance versus depth for time depth recorders (TDRs) deployed on a single line beside weights, floats directly on the line, and floats with a longer rope. Data from vessel Q.

4. DISCUSSION

The Overall Objectives of the projects reported on here were:

- to develop strategies to mitigate seabird captures in inshore bottom longline fisheries by increasing line sink rates, and,
- to design a process of experimental testing, and analyse the results, to determine the effectiveness of seabird mitigation strategies used by inshore bottom longline fishermen.

With respect to the first objective, two new approaches to line-weighting were examined as potential methods for increasing sink rates. The effects of setting speed and line tension on sink rates were also explored.

Adding weight to a longline will increase sink rate. Weight can be added either by using larger weights, or by reducing weight spacing (Goad et al. 2010). However, sink times can also be reduced without increasing weighting by spreading weight more evenly over the line or using denser weights.

Extending float ropes produced faster and more even sink profiles, thereby allowing sink times to be reduced when ‘floating’ longlines above the seabed.

Reducing setting speed reduced line tension and resulted in gear sinking closer to the vessel. Assuming a streamer line is used and its aerial extent can be maintained, setting at slower speeds will result in existing streamer lines covering hooks to a greater depth.

To address the second objective, detailed investigations of current practice and preliminary examination of potential new bycatch reduction measures were conducted.

4.1 Line weighting

Line-weighting regimes and sink rates were highly variable between vessels, and also varied between longlines set on the same vessel. Floats were used on almost all vessels, and these reduce the mean sink rates attained when deployed without additional (compensatory) weights.

International best practice recommendations include that line-weighting regimes should ensure that hooks rapidly sink beyond the range of feeding seabirds (Agreement on the Conservation of Albatrosses and Petrels (ACAP) 2011). For black petrels and flesh-footed shearwaters, this means average dive depths of 7 - 13 m, and maximum dive depths 20 - 67 m, respectively (Thalmann et al. 2007, E. Bell, pers. comm.). Amongst sets sampled in this project, lines took 224 s to sink to 20 m, and 536 s seconds to sink to 67 m. When combined with sets sampled as part of previous work (Goad et al. 2010, Goad 2011), these timeframes were 384 s and 872 s, respectively. Further, some lines were set at shallow depths such that the entire water column was accessible to seabirds, given their diving capabilities. While birds do not travel to depths reflecting their maximum capability on every dive, and appear unlikely to dive on soaking lines after the vessel has steamed away from the line, having the entire line in reach throughout the set is expected to prolong bycatch risk. In addition, shallow-set lines may sink more slowly.

Amongst sets documented in this project, sink rates recorded from one vessel (L) were similar to the best practice recommendation for sink rate of externally-weighted demersal longline gear (0.3 m/s, BirdLife International and the Agreement on the Conservation of Albatrosses and Petrels (2010)). While the performance benchmark of 0.3 m/s value was derived from research conducted in larger-vessel industrial fisheries (e.g., Robertson 2000) rather than smaller-vessel inshore fisheries, it reflects sink rates desirable to significantly ameliorate seabird bycatch risk.

Due to the slower sink rates observed on other vessels, longline hooks were within seabird reach for significant periods of time and distances astern. Assuming sink rates observed during this project are at least broadly indicative of fleet-wide sink rates, increasing line-weighting (and therefore line sink rates) would significantly reduce the risk of seabird captures in inshore bottom longline fisheries. Achieving increased sink rates may require changes in both operational approaches and gear used.

4.2 Streamer lines

Some fishers used streamer lines during some sets, however bycatch risk would be reduced by all fishers using streamer lines during all sets. Using paired streamer lines instead of single streamer lines is also expected to reduce bycatch risk (Bull 2007, Lokkeborg 2011).

Changes to streamer line designs are expected to improve the performance of these bycatch reduction devices in inshore bottom longline fisheries, and identifying designs that minimise tangles is critical. For example, performance could be improved by using brightly coloured streamers that hang closer to the sea surface, and increasing the drag on streamer lines so they achieve greater aerial extents. Deploying streamer lines using a paravane or bridle such that they can be moved if a tangle appears likely, and using a different terminal object to create drag may reduce the likelihood of tangles. To minimise operational disruption should a tangle occur, a weak link (e.g., loop of thin tied rope) can be incorporated into streamer lines. This will break if the streamer line is caught up.

Ensuring the aerial extent of streamer lines is sufficient to protect longlines to depths of 10 m is an international performance benchmark (e.g., Petersen et al. 2005, Melvin et al. 2009, Papworth 2010). While seabirds attending vessels in these fisheries can dive well below 10 m, protecting longlines to 10 m on every set will provide a substantial reduction to current bycatch risk.

4.3 Bait and discard retention

The abundance of small seabirds around the hauling station increased when baits were discharged. Numbers of large birds were insufficient to support modelling approaches. Significant effects of bait discharge on small bird abundance emerged despite a large amount of inherent variation in seabird abundance within trips. A more highly manipulated experimental approach would help address this inherent variability, and would be expected to strengthen the model outputs. For example, baits (and discards) could be retained on alternate days throughout trips, producing a more balanced experimental design. Sampling a larger number of trips would also increase experimental power. However, such approaches are clearly more difficult to implement on vessels on which skippers are attending to normal fishing operations.

Continuing the exploration of the splatterboard is recommended if new mitigation measures are developed for this fishery. This approach may be effectively tested on an autoliner, for which many more hooks are set and the amount of bait fragments falling astern would be considerably greater than was seen in this project.

4.4 Reactive to proactive application of bycatch reduction measures

Fishers on some observed vessels closely monitored the abundance and activity of seabirds and deployed additional mitigation when they felt bycatch risk increased. For example, some crews added extra weight to longlines if birds arrived during setting, or ran out backbone without hooks. However, this approach does not minimise risk, in that while additional measures are deployed and take effect a situation of heightened risk may occur. Further, an unacceptable level of risk may not be effectively identified in a timely manner, especially in the dark. This reactive approach to mitigating captures also makes it impossible to quantify the efficacy of mitigation approaches. For example, in one case a streamer line was deployed part way through a set such that it was not clear whether it was deployed at the time of a bird capture. It follows that best practice would be to deploy the most effective suite of mitigation measures at all times, irrespective of conditions encountered.

4.5 Methodological approaches

This project used government fisheries observer coverage as a platform on which to base descriptive reporting and experimental work on seabird bycatch mitigation. Issues with this approach are well known and are reflected above (e.g., representativeness of coverage obtained, challenges of achieving longer deployments, etc.). Good communication between project leaders, observers and skippers, and examination of data collected during the coverage on a vessel, resulted in fluid tasking during observer deployments on-board vessels. This maximised the benefits of limited sea time across all project priorities. However, addressing multiple priorities during relatively short deployments led to compromises on the extent of experimental data collection.

Observers considered that the metrics utilised in the data collection protocols appropriately reflected the risks fishing gear presented to birds and that both forms and protocols were easy to follow. Although a more complex description of bird behaviour may be possible from larger vessels (e.g., Melvin et al. 2009), the low height of observers' eyes when working on small vessels makes inshore operations more suitable for the implementation of simpler protocols and those involving monitoring shorter distances astern. Reducing the degree of distance estimation required also facilitates the standardisation of data collection between observers. On processing data, it became apparent that numbers of seabird dives on the longline and total dives had not been consistently recorded in some cases. Therefore, eliminating the counts of dives on the longline is recommended in future.

Three seabirds were captured during the project. This emphasises the need for alternative metrics that approximate bycatch risk in order to test mitigation strategies (e.g., Pierre & Debski 2013). Further, much of the setting activity occurred in conditions of darkness. Therefore, data collection protocols that do not rely solely on human vision are required. In this study, TDR data, collected at night and during the day, were vital as a proxy for bycatch risk despite occasional challenges during deployment (e.g., due to unexpected changes in gear setups or TDR failures).

For future work, a more structured, and longer term approach to data collection is recommended. Observer coverage on vessels in the fisheries examined for this project was most effective at documenting current practice. However, while it has worked well in other fisheries (e.g., Pierre et al. 2012), testing mitigation approaches was challenging within the fisheries examined here. There were two main reasons for this: first, the extended deployments required to collect sufficient empirical data to quantify the efficacy of mitigation measures, and second, that testing measures experimentally required changes to operational practices that were at times not compatible with standard fishing operations.

Therefore, a two stage approach is recommended for future work of the type conducted during this project, with more time allocated to both stages than was available here. The first stage should involve documenting current practice, in fisheries or on vessels for which this has not been adequately achieved. This is recommended over a range of vessels for one year (or one full season if species of particular interest, e.g., black petrel, is not present in fishing areas all year). Ideally, coverage would be representative. In reality, this is seldom achievable, but coverage that thoroughly documents practices across a larger number of vessels is preferable to documenting operations on fewer vessels. The second stage would be testing selected mitigation measures, or already in use, on pre-identified vessels, using structured experiments and where the possible need for changes to normal fishing operations was acceptable over potentially significant timeframes (e.g., one month). Where skippers willing to change fishing practices for experimental work cannot be found, chartering vessels may be the most efficient option.

There is a range of potential solutions to resolve issues associated with observer deployments identified. For example, to address observer availability and earning potential, a group of observers could be recruited to conduct targeted coverage for projects such as this. This could be undertaken either in collaboration with the MPI Observer Services team, or independently from that team. The availability of those observers would be preserved for the special project of interest, and their salary would be commensurate with the skill level required. This would necessitate a departure from the structure of the current observer pay system, but would avoid issues with observers choosing to work offshore because of the amount of money that they make from offshore compared to inshore deployments.

To facilitate vessel engagement, there are also options available to improve current systems. MPI holds a substantial database of information relevant to selecting vessels for observer placements. For the work described in this report, project leaders identified a set of priority factors described in this database, to guide vessel selection by the MPI Observer Services team. However, vessel selection typically became an iterative process involving ongoing communication between Observer Services and the project leaders (and thereby placing demands on the time of the Observer Services Team). For future work, it is recommended that project leaders work with Observer Services at the start of the project to identify a list of candidate vessels to focus on through the project. Alternatively, data extracts could be given to project leaders, from which they selected a priority list of vessels for the Observer Services team to draw on. Given the time constraints of the Observer Services Team, it would be even more efficient to task project leaders with contacting vessel skippers directly.

The efficiency of vessel selection would also be increased by establishing a database of vessels that are unable to host observers due to safe ship management requirements. This would eliminate the need for MPI to contact the Maritime Safety Authority on a boat by boat basis.

Contacting vessel skippers in advance of coverage commencing may facilitate deployments when periods for which vessels will be out of action can be identified. Also, if the amount of coverage expected of each vessel, and observer duties onboard, can be advised and agreed upon in advance, deployments may be more straightforward to secure.

Finally, to maximise the efficiency of observer deployments and time spent collecting data, streamlining of observer forms in relation to bottom longlining is recommended. For example, streamer line details for bottom longliners are currently noted in diaries, trip reports and on two separate forms, with only one form keyed. If the extra fields on the unkeyed form and any other necessary details could be added to the keyed form, and this was deployed on all bottom line trips, then a clearer picture of tori line use and specifications would be readily available.

4.6 Recommendations

This project clearly identified four areas in which the application of bycatch reduction measures could be improved:

- increasing longline sink rates, by modifying line-weighting regimes and float usage
- reducing setting speeds
- retaining baits (and discards, where legal provisions allow) at hauling
- improving streamer line design and consistently deploying streamer lines, such that hooks are protected by streamer lines up to depths of 10 m

In addition, amongst snapper-target vessels, setting lines earlier, i.e., prior to nautical dawn is recommended. Sets observed during this project were deployed earlier on average than overall in this fishery, as shown by catch effort data. Despite that, observers reported hearing birds around vessels during setting. While not tested specifically in this project, night-setting is part of best practice approach to bottom longline fishing. Where morning sets occur later than 30 minutes prior to nautical dawn, we recommend a change in practice towards earlier setting to reduce bycatch risk.

Finally, while observer coverage was useful for testing mitigation approaches in the fisheries examined in this project, targeted structured experiments are still more powerful. Therefore, these should be used when the testing of mitigation measures is required.

Across the fleet, an immediate and significant reduction in the risk of seabird bycatch is expected to result from the implementation of these changes. Longer term, additional, novel measures may be available for implementation in inshore bottom longline fisheries, for example, sub-surface line-setting devices (e.g., Baker and Frost 2013). The development of mitigation measures for deployment during hauling is as yet unexplored in these fisheries, but would also reduce bycatch risk.

While challenging to address, the risk that recreational captures present to these seabirds is also significant (e.g., Abraham et al. 2010). Educational materials are available to inform fishers of the risk[*]. More targeted efforts are recommended to increase awareness and foster changes in recreational fishing practice.

4.7 Next steps

To reduce the bycatch risks present in inshore bottom longline fisheries in northern New Zealand, the following steps are recommended.

- Work with fishers on increasing the efficacy of line-weighting strategies applied to bottom longlines to reduce bycatch risk. This may involve adding more weight to lines and sinking hooks closer to the boat (e.g., using closer weight spacing, more even-sized weights, longer float-ropes, denser weights and slower setting speeds). Utilisation of gear able to bear more weight may also be required. Self-monitoring of sink rates (e.g., using bottle tests) is encouraged.
- Work with fishers to improve the design and construction of streamer lines used, thereby improving the operational feasibility (e.g., reducing tangling) and performance (e.g., increasing aerial extent) of these mitigation devices.

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[*] e.g. the card available at:
http://southernseabirds.org/fileadmin/documents/Products/Rec_anglers_card_website_version_updated_credits.pdf

- Sink longlines to 10 m at the end of the streamer line as a minimum. Aiming to sink longlines more deeply at the end of streamer lines is preferable, due to diving capabilities of seabirds encountered in these fisheries (i.e., specifically black petrels, flesh-footed shearwaters).
- Foster a proactive approach to seabird bycatch reduction, rather than a reactive one, amongst fishers (e.g., deploying streamer lines during all sets during the night and day and consistent deployment of more effective line-weighting regimes).

If these actions do not reduce commercial fisheries bycatch of seabirds of conservation concern sufficiently, the deployment of additional mitigation measures (e.g., at hauling) and more fundamental management actions (e.g., bycatch limits, spatial and/or temporal closures) may be required.

Coincident with managing commercial captures of threatened seabirds (e.g., black petrel), improved management is necessary to reduce bycatch risks amongst recreational fisheries with which these species interact.

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A. APPENDIX

Line sink rates to a range of depths are presented in this Appendix. These depths reflect seabird diving capabilities for species of conservation concern in areas where fishing effort was observed. As mentioned in the main text of this report, for black petrels and flesh-footed shearwaters, this means average dive depths of 7 - 13 m, and maximum dive depths 20 - 67 m, respectively (Thalmann et al. 2007, E. Bell, pers. comm.).

APPENDIX A.1: Summary of sink times and distances astern

Table A-1: Time taken for time depth recorders to reach 7 m and 16 m depth for setups detailed in Table 10, median values shown with maxima and minima. All sets are targeting snapper (*Pagrus auratus*).

		Distance astern at 7m			Distance astern at 16m		
Vessel	Observations	Median	Min	Max	Median	Min	Max
A1	15	44	28	65	98	51	119
A2	30	49	34	73	108	87	170
B1	21	35	25	59	66	52	104
C1	33	42	22	64	86	36	117
D1	34	43	26	54	84.5	58	104
E1	12	41.5	27	72	82.5	63	128
E2	8	36.5	29	53	69	61	104
L1	24	33	28	41	56.5	48	68
L2	6	20.5	18	25	40	38	47
M1	12	48	28	72	96.5	62	124
N1	12	33.5	20	42	69	42	83
N2	12	51	30	71	95	69	118
O1	18	42	31	47	76	63	88

Table A-2: Time taken for time depth recorders to reach 7 m and 16 m depth for setups detailed in Table 11, median values shown with maxima and minima, Obs. = number of observations.

			Distance astern at 7m			Distance astern at 16m		
Vessel	Target	Obs.	Median	Min	Max	Median	Min	Max
F1	LIN	30	43	23	53	78.5	50	98
F2	LIN	10	36	29	40	69	59	73
G1	BNS	25	106	6	203	140	13	236
G2	BNS	10	121.5	8	328	173.5	17	406
H1	BNS	45	45	16	115	94	39	236
J1	LIN	68	53	37	74	101.5	74	140
J1	HPB	12	68.5	36	88	124	83	153
K	HPB/ BNS	12	75	53	109	141.5	116	192
P1	BNS	35	67	30	104	125	65	191
Q2	BNS	9	42	30	69	75	56	113

APPENDIX A.2: Box whisker plots of the distances behind the vessel TDRs reached various depths for snapper and tarakihi target sets.

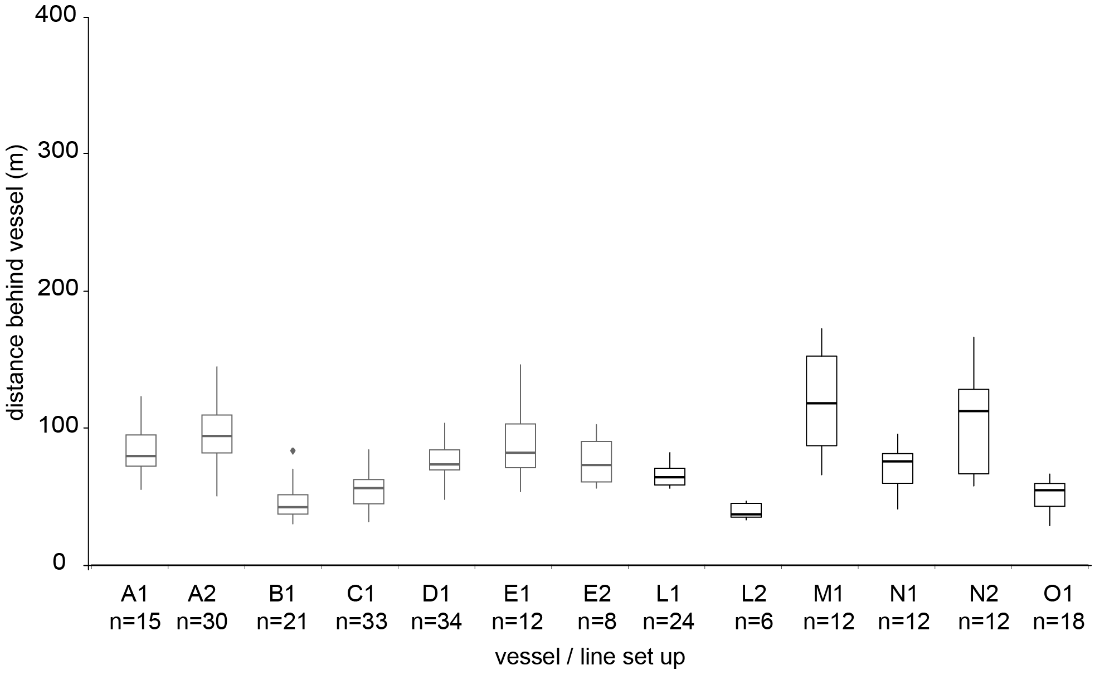

Figure A-1: Box and whisker plot of distance behind the vessel time depth recorders reached 5 m depth for line setups detailed in Table 10.

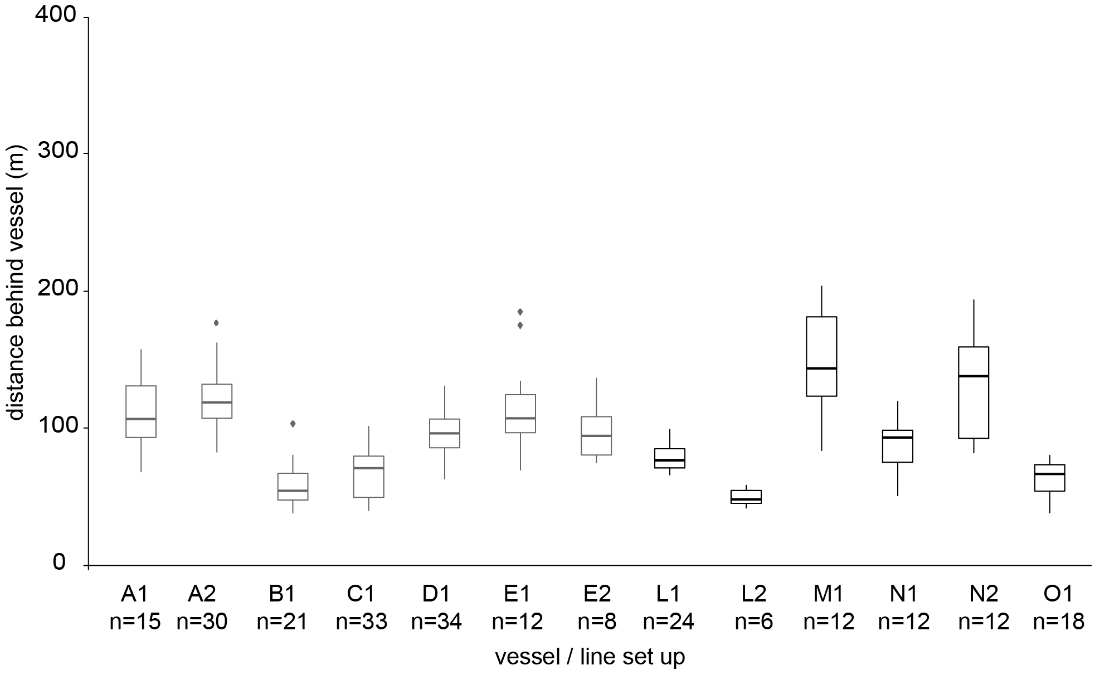

Figure A-2: Box and whisker plot of distance behind the vessel time depth recorders reached 7 m depth for line setups detailed in Table 10.

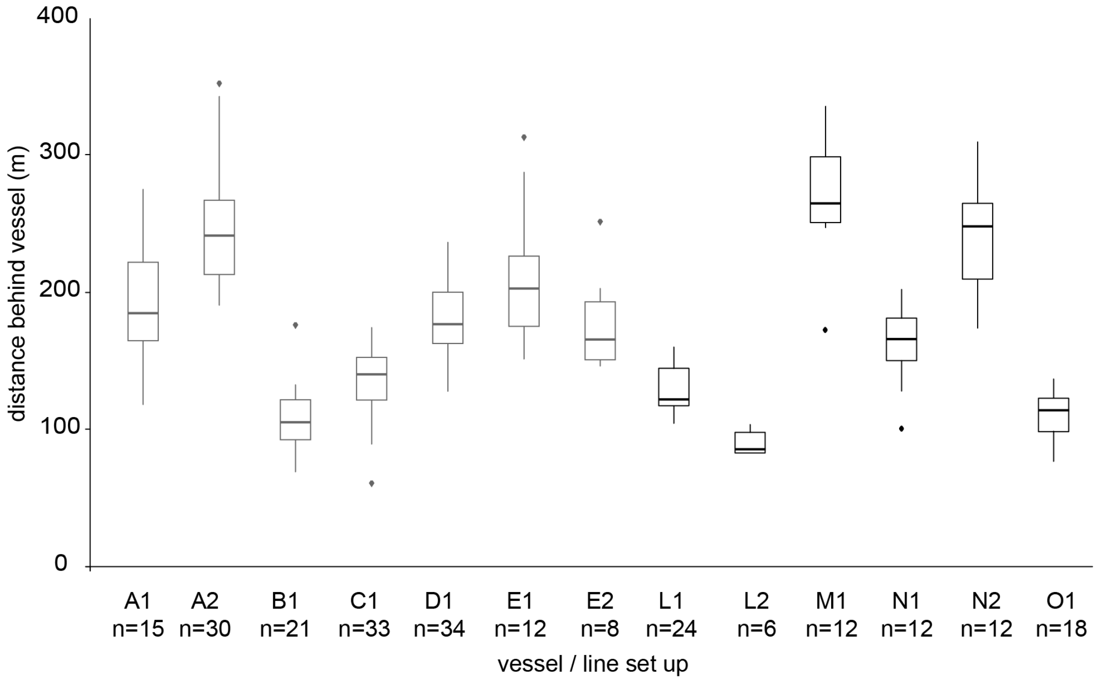

Figure A-3: Box and whisker plot of distance behind the vessel time depth recorders reached 15 m depth for line setups detailed in Table 10.

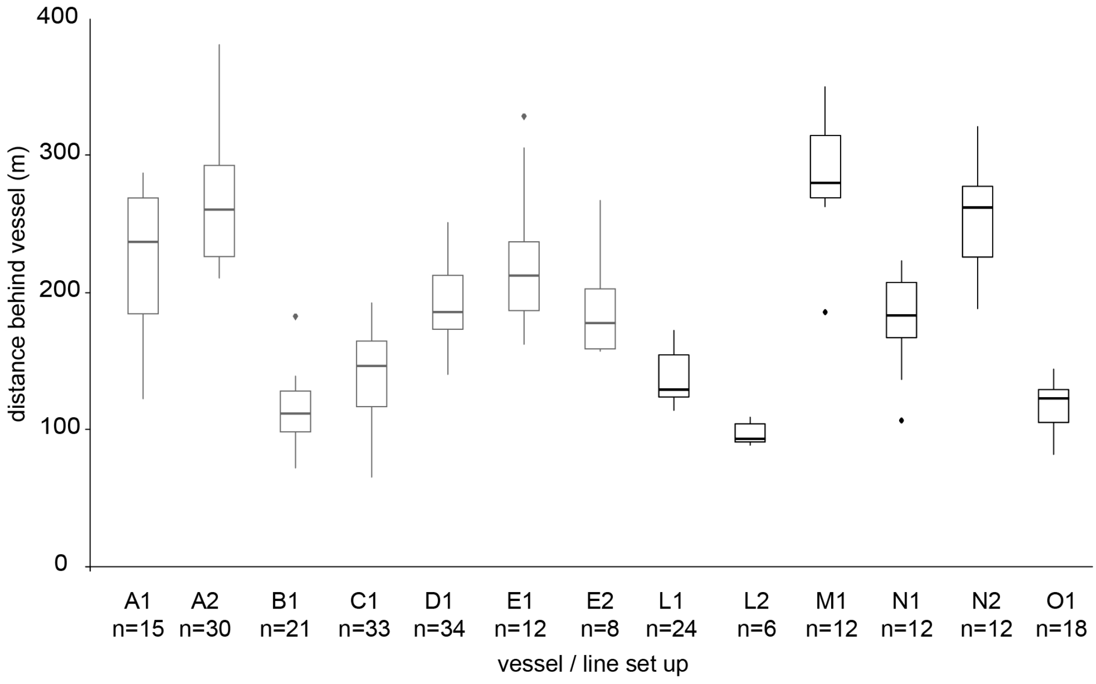

Figure A-4: Box and whisker plot of distance behind the vessel time depth recorders reached 16 m depth for line setups detailed in Table 10.

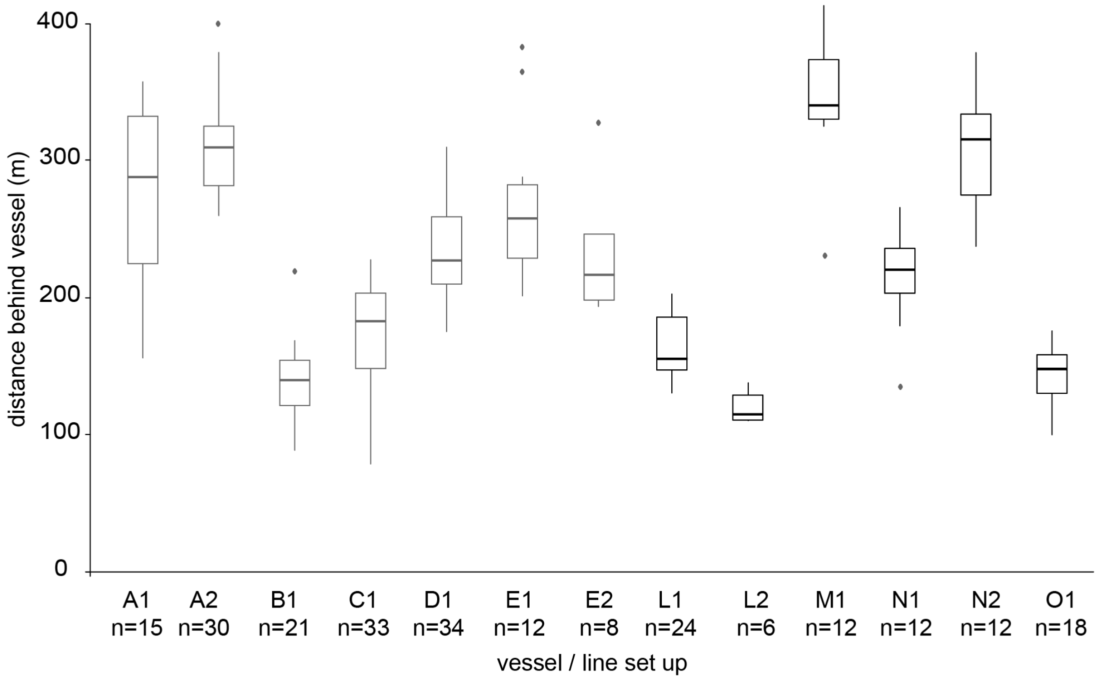

Figure A-5: Box and whisker plot of distance behind the vessel time depth recorders reached 20.1 m depth for line setups detailed in Table 10.

APPENDIX A.3: Box and whisker plots of the distances behind vessels at which time depth recorders reached various depths: bluenose, ling, hapuku and bass target sets

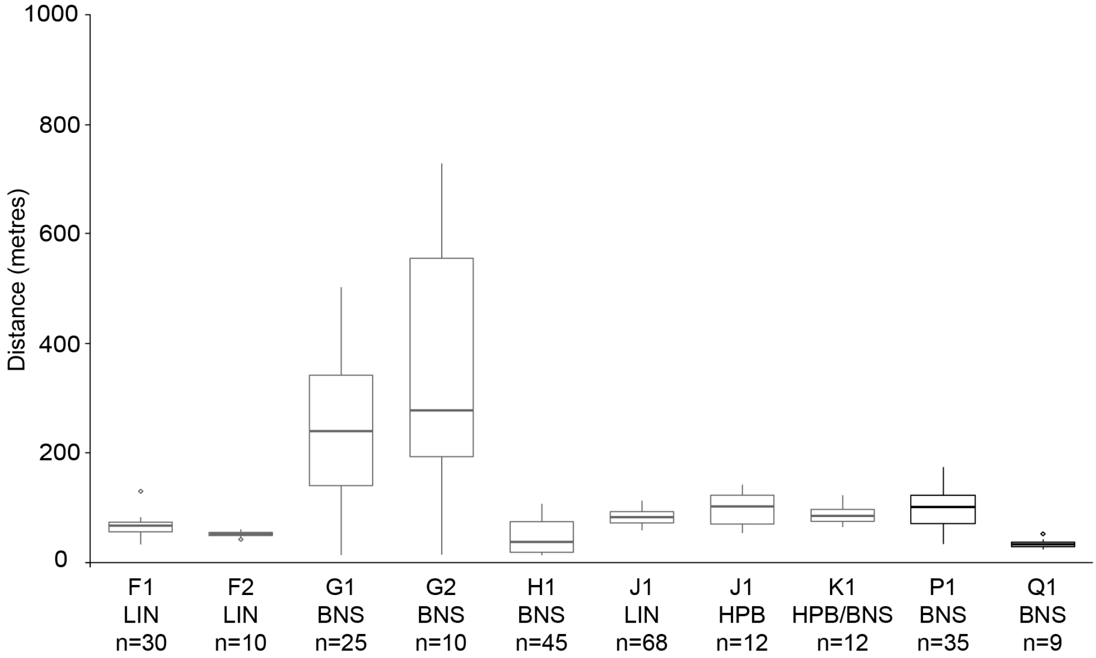

Figure A-6: Box and whisker plot of distance behind the vessel time depth recorders reached 5 m depth for line setups detailed in Table 11.

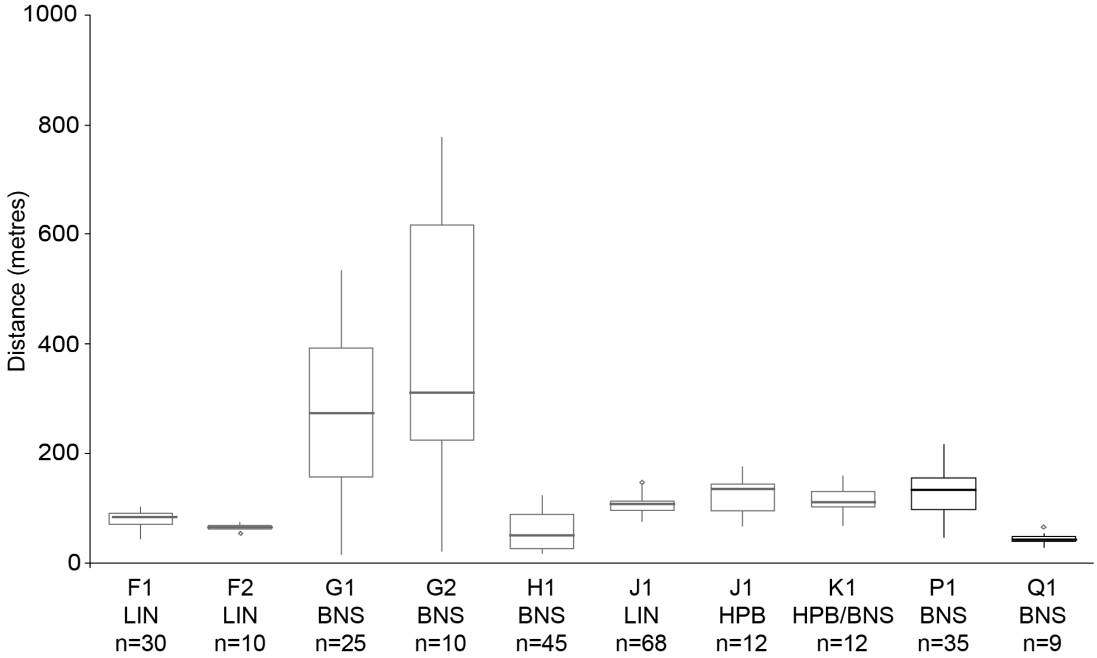

Figure A-7: Box and whisker plot of distance behind the vessel time depth recorders reached 7 m depth for line setups detailed in Table 11.

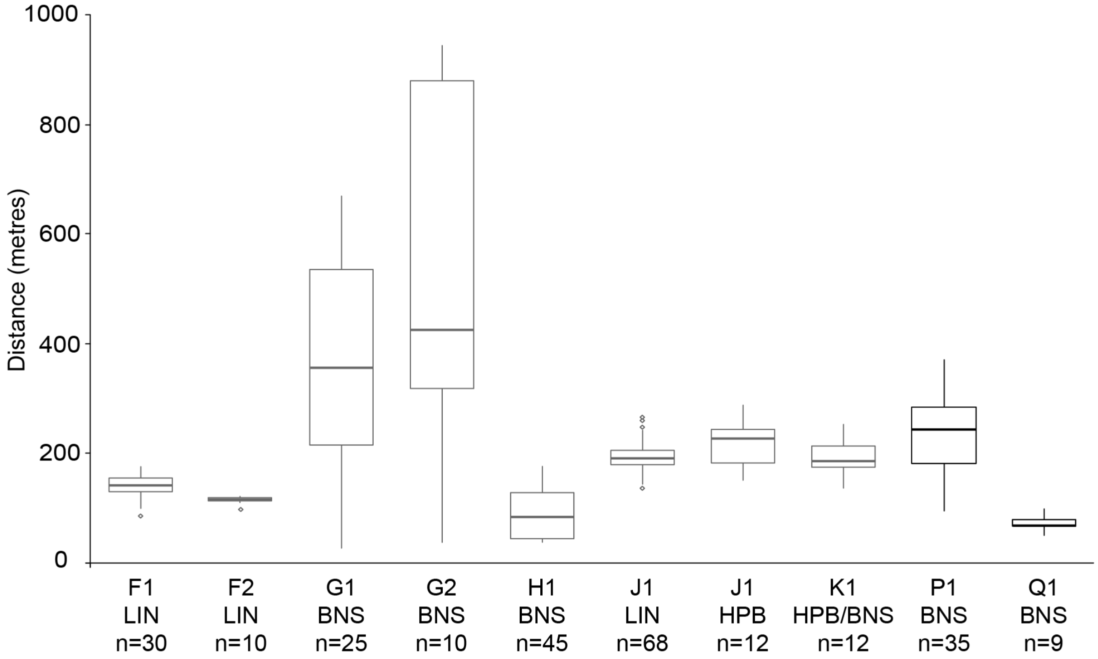

Figure A-8: Box and whisker plot of distance behind the vessel time depth recorders reached 15 m depth for line setups detailed in Table 11.

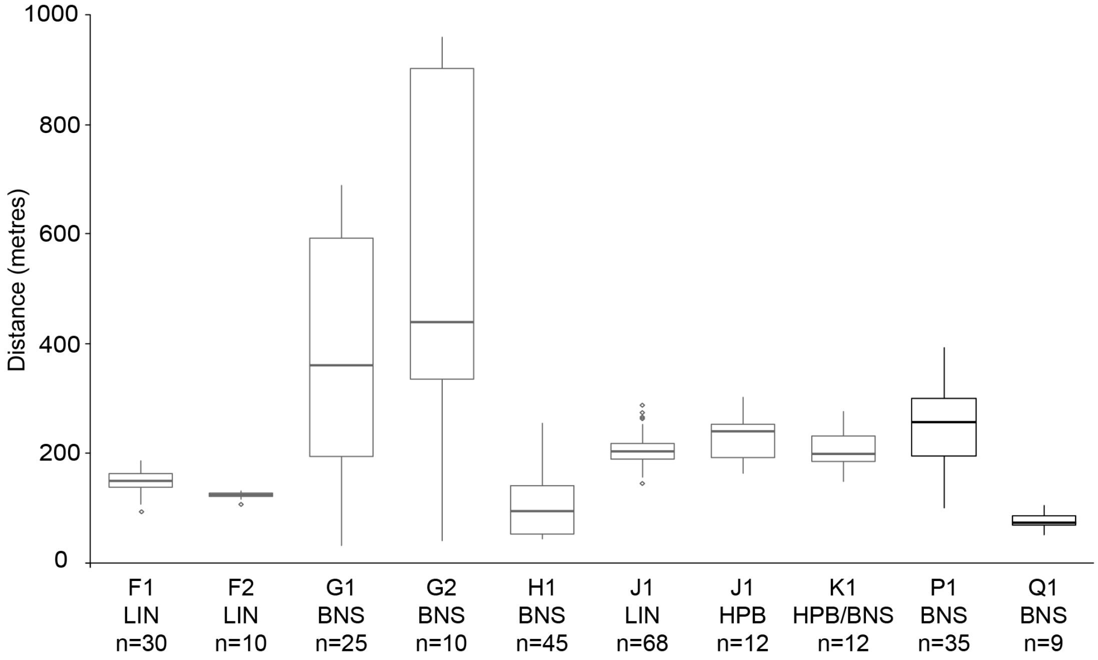

Figure A-9: Box and whisker plot of distance behind the vessel time depth recorders reached 16 m depth for line setups detailed in Table 11.

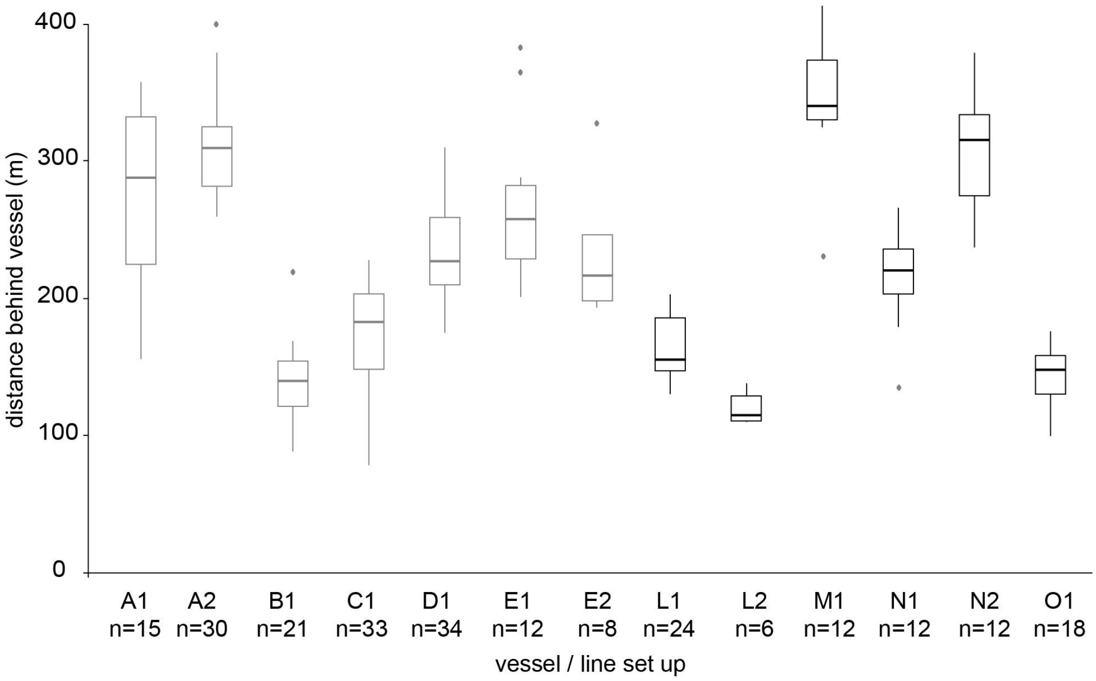

Figure A-10: Box and whisker plot of distance behind the vessel time depth recorders reached 20.1 m depth for line setups detailed in Table 11.

APPENDIX A.4: TDR deployment details

Table A-3: Time depth recorder (TDR) deployment details, including comments covering the aims for each deployment. Attempted TDR placement is coded as follows: a denotes “after”, w denotes “weight”, d denotes “dropper” (a weight on a rope with a float on the backbone), s denotes suspender (a weight on a rope), f1 denotes first float after a weight, f2 second float, * denotes a float with a rope, and ** a float with a rope and a small weight on the backbone. Refer also to Figure 4 for a pictorial description of TDR placement. Target species are SNA = snapper (*Pagrus auratus*), MIX/TAR = a mix of target species focusing on tarakihi (*Nemadactylus macropterus*), BNS = bluenose (*Hyperoglyphe antarctica*).

Vessel	Target species	Line setup	Attempted TDR positioning	TDR records	Comments
L	SNA	weights only	aw, 1/2 aw, 3/4 aw	27	normal practice
	SNA	weights only	aw, 1/2 aw, 3/4 aw	9	2 different speeds, tension measured
	SNA	weights only	aw, 1/2 aw, 3/4 aw	9	normal practice, lighter gear
	SNA	weights only	aw, 1/2 aw	9	slower, bit of brake on
	SNA	weights only	aw, 1/2 aw	20	2 different speeds, tension mesured
	SNA	weights only	aw, 1/2 aw	10	2 different speeds
M	SNA	weights only	aw, 1/2 aw, 3/4 aw	18	normal practice, didn’t hit all positions on line
	SNA	weights only	aw, 1/2 aw, 3/4 aw	18	didn’t hit all positions on line, testing reduced weight spacing
	SNA	weights only	aw, 1/2 aw, 3/4 aw	0	TDRs not sampling
N	SNA	weights only	aw, 1/2 aw, 3/4 aw	26	normal practice
	SNA	weights and floats	aw, 1/2 aw, 3/4 aw, af, 1/2 af, 3/4 af	27	normal practice
	SNA	weights, droppers, and floats	aw, af, ondw, on df	24	investigating droppers and floats
	SNA	weights, droppers and floats	ad, 1/2 ad, 3/4 ad, aw, af, 1/2 af, 3/4 af	9	normal practice, shallow set
	SNA	weights, droppers and floats	aw, af, af*, on df, on dw	53	testing float-ropes
	SNA	weights only	aw 1/2 aw	18	testing reduced weight spacing
O	TAR/MIX	weights only	aw, 1/2 aw, 3/4 aw	18	normal practice
	TAR/MIX	weights and droppers	aw, 1/2 aw, 3/4 aw, ad, 1/2 ad, 3/4 ad	18	normal, didn’t hit positions on line
P	BNS	6 kg, 2 floats, 6 kg, 2 floats, 12 kg, 2 floats	aw, af1, af2	9	normal practice
	BNS	6 kg, 3 floats, 12 kg, 3 floats	aw, af1, af2, af3, af2*, af3*	6	testing float-ropes
	BNS	6 kg, 3 floats, 12 kg, 3 floats	aw, af1**, af2**, af3**	4	testing ropes and weights
	BNS	6 kg, 3 floats, 12 kg, 3 floats	aw, af1, af2, af3	5	normal practice
	BNS	6 kg, 2 floats, 12 kg, 3 floats	aw, af1, af2, af3	7	normal practice
	BNS	6 kg, 2 floats, 12 kg, 3 floats	aw, af1, af2, af3, af1**, af2**, af3**	21	testing ropes and weight
	BNS	8 kg, 3 floats, 6 kg, 2 floats, 12 kg, 3 floats	aw, af1, af2, af1**, af2**, af3**	8	testing ropes and weight
	BNS	14 kg, 2 floats, 6 kg, 3 floats, 12 kg	aw, af2, af3, af1**, af2**, af3**	7	testing ropes and weight
Q	BNS	6 kg, float, float	ad, af1, af2, af1*, af1**, af2*, af2**	24	testing ropes and weight

APPENDIX A.5: Sink profile of deeper water sets

Because bluenose lines are set in deep water and the line is still sinking for the whole set, the sink rate varies within a set more than for shallower sets where only a section of the line is sinking at any one time. For deep sets sink rate is determined also by the influence of the end weights, and how the line sinks at different stages of the set.

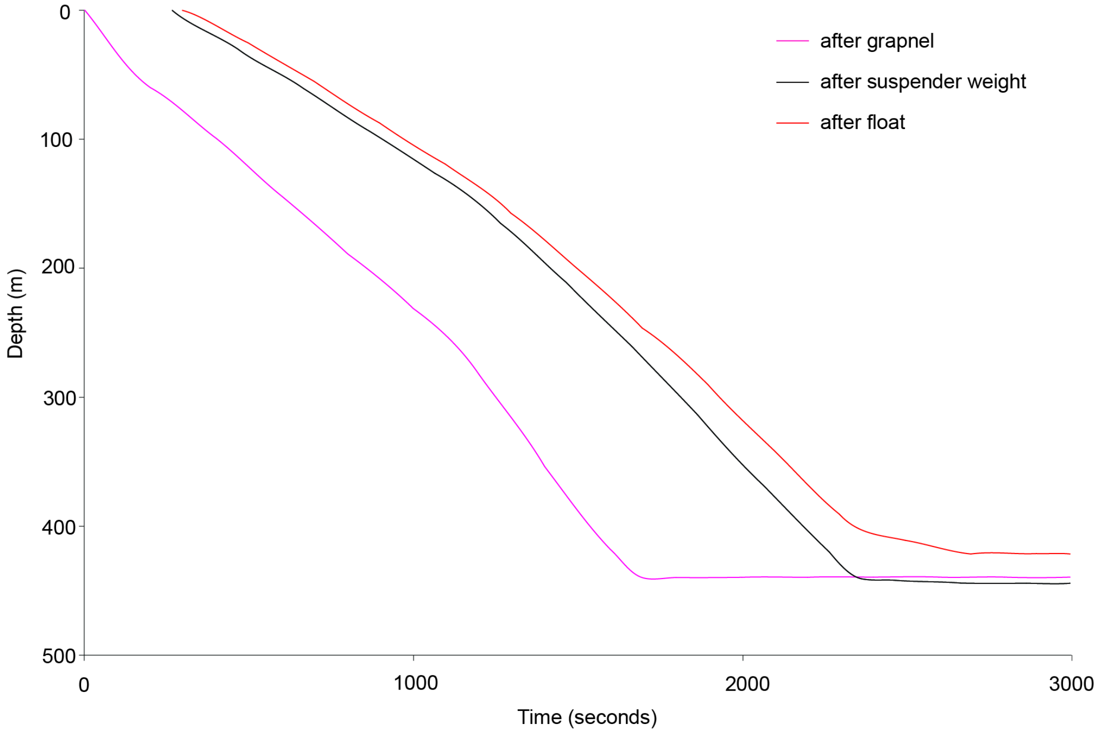

Figure A-11: Time versus depth plot from time depth recorders placed on a set from vessel P. Time starts when the grapnel was deployed.

The first grapnel over at the start of the line initially sinks quickly (Figure A-11). As it has to drag down more line the grapnel the sinks progressively more slowly, with a reasonably even "background" sink rate established at around 250 seconds once two or three weights have been deployed on the line. The sink rate is then reasonably consistent through the set and is likely to be determined by a combination of setting speed, tension and weight added. At 1100 seconds the hooks have all been clipped on and the tension on the line is reduced as the float rope is run out. At 1 250 seconds the float is deployed and the tension drops further as the line is now free from the vessel. These reductions in tension are coincident with increases in sink rate. The grapnel hits the sea bed at 1 675 seconds. At this point the forces on the line change. "Tide" or current becomes important because one end of the line is fixed to the seabed. As this line was shot with the current it tends to be laid down by the current and a marginal increase in sink rate is apparent, especially for the weight position. However for some lines the loss of the sinking effect of a heavy grapnel caused a reduction in sink rate, and this is possibly what contributed to the reduction in sink rate of the float position at this time.

APPENDIX A.6: TDR positioning to estimate slowest sink rates

Observations at the set have shown that the slowest-sinking part of a line may not be midway between weights (Goad et al. 2010), but further towards the next weight. To examine whether TDRs positioned halfway between weights provided a reasonable estimate of the slowest sink rate on a line these positions were compared with TDRs placed three-quarters of the way towards the following weight. To compare like for like as far as possible TDR records were examined to provide pairs at the half and three-quarter position from the same line with both TDRs between similar sized weights. Two vessels which worked reasonably consistent-sized weights (within 0.2 kg), and had hook spacing differences of less than two hooks, provided a total of seven pairs for comparison. On vessel N, TDRs three-quarters of the way after a weight initially sank slower than TDRs half way after the weight, with differences less apparent at depth (Figure A-12). On vessel O, TDRs at the midway position sank slowest (Figure A-13). None of the sets sampled at both half and three-quarter positions consistently showed the three-quarter position sinking slowest.

It follows that on some vessels and setups with larger weight spacing the three-quarter position may stay close to the surface slightly longer. However once the following weight is clipped on and the line sinks below the surface, the midway position is a better estimate of slowest sink rate. Therefore, if birds that can forage at depth are important and sink times to depths greater than 5 - 10 m are an appropriate measure of the availability of hooks, then the halfway position is a good approximation of the slowest sink rate. One further advantage of choosing to only sample the halfway position is that “hitting” the three-quarter position with TDR placement proved difficult and overall success rate was around 50 %, varying from 0 - 100 % per set.

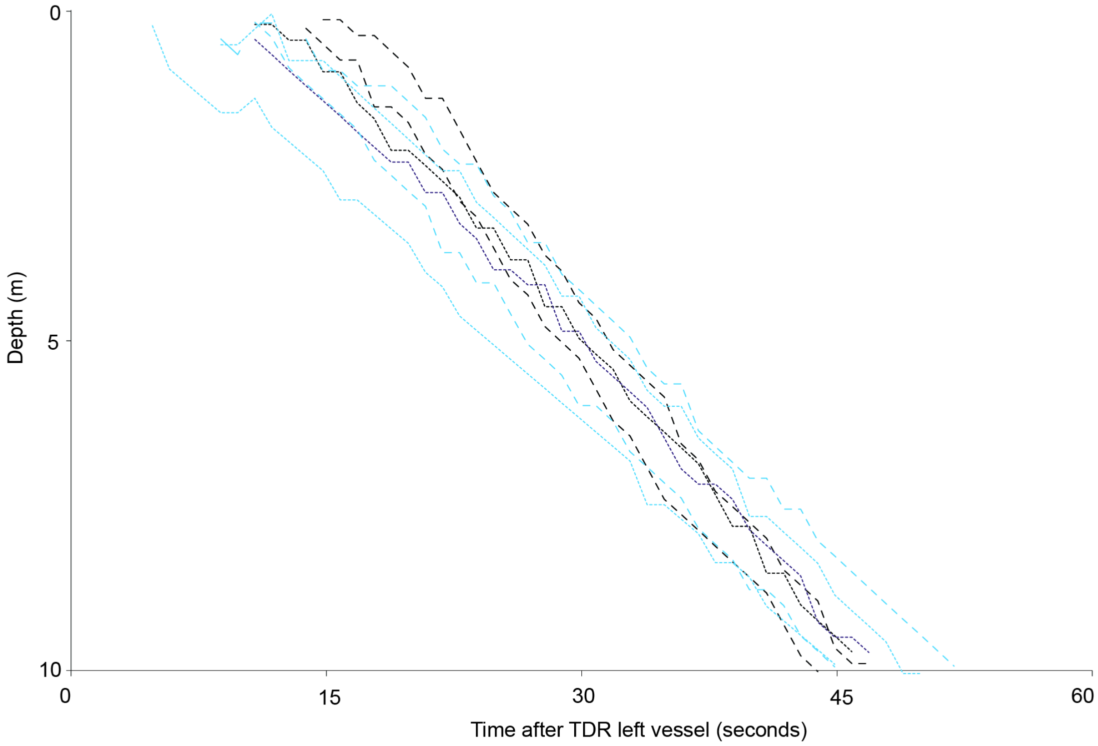

Figure A-12: Plot of time versus depth for time depth recorders halfway (dotted lines) and three-quarter way (dashed lines) after droppers (blue lines) and weights (black lines). Data from vessel N.

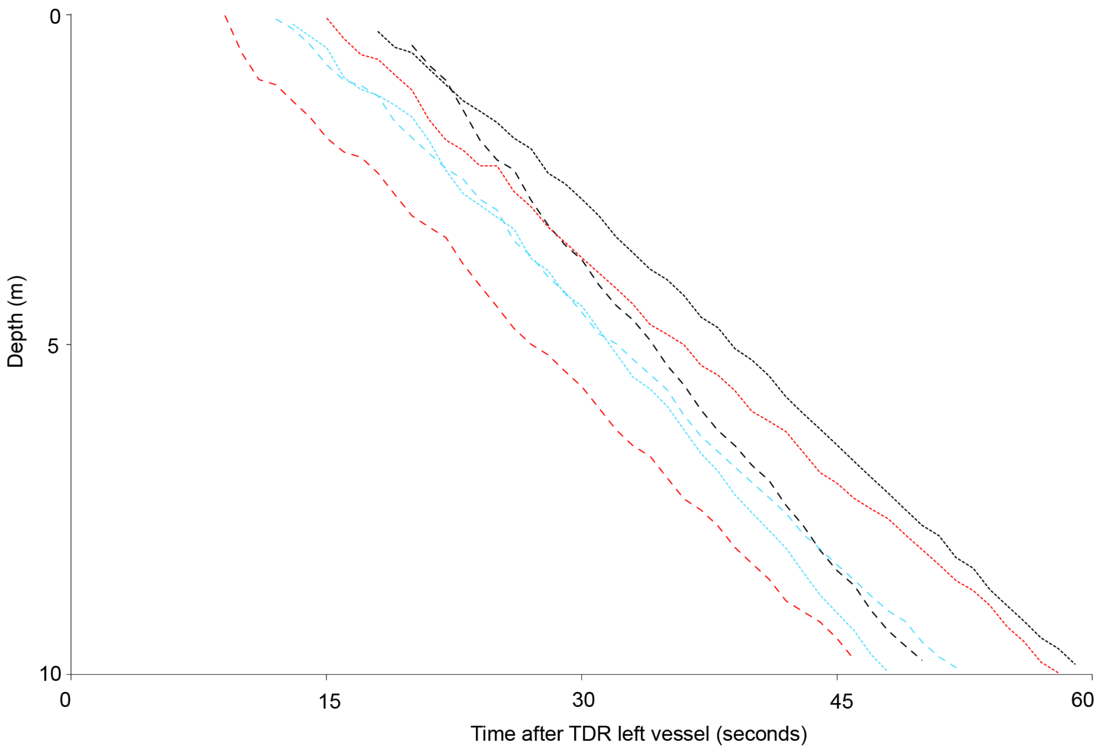

Figure A-13: Plot of time versus depth for time depth recorders (TDRs) halfway (dotted lines) and three-quarter way (dashed lines) after weights. Consecutive pairs of TDRs are shown in the same colour. Data from vessel O.

APPENDIX A.7: Case studies: Vessel L and Vessel M

Vessel L worked the most weight per 100 m of line of the vessels observed, was not observed to employ floats, and had the fastest sinking gear (Figure 6, Table 10). In addition to an early morning set, the gear was re-set during the day, allowing regular bird observations during the set. Typically bird abundance was low at 0 - 5 small birds. However during one trip up to 50 small birds (mostly black petrels and flesh-footed shearwaters) were observed at the set.

The vessel worked one or two streamer lines (70 m and 120 m in length). The observer considered that these were generally effective in deterring birds to the end of the lines' aerial extents (20 - 35 m and 40 m), especially when adjusted such that the streamers touched the water surface. Birds were recorded landing and "diving" beside the drag (in-water) sections of the tori lines although most activity was beyond the end of the shorter tori line at around 80 m. On the second day of the trip the gear was set with extra weight (more than when sampled with TDRs) and similar bird activity was recorded. No birds were observed caught on this vessel.

Vessel M worked the least weight per 100 m of line and had the gear sinking to 10 m farthest behind the vessel (Figure 6,Table 10). Lines were sometimes set during the day, and a single 56 m tori line with a 50 m aerial extent and a towed float was deployed. During one daytime set without floats the observer recorded five to seven small birds (black petrels, flesh-footed shearwaters and Buller's shearwaters) present during the set. The birds were recorded landing and diving at 60 - 80 m astern, behind the tori line. No birds were observed caught on this vessel.