Reducing seabird bycatch in inshore bottom longline fisheries

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Draft Final Report

Conservation Services Programme Projects MIT2011-03 and MIT2012-01

Abstract

Seabirds of conservation concern, including the 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 coverage, 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. These are the time of day at which longlines are set, the use of weighted longlines, the deployment of streamer lines, and the retention of fish waste. 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 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 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

Introduction

Inshore bottom longline fisheries target a complex of fish species (e.g., snapper *Pagrus auratus*, bluenose *Hyperoglyphe 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 the black petrel (*Procellaria parkinsoni*). Estimated potential mortalities of black petrel in New Zealand commercial fisheries are highly likely to be above the population's sustainability limit (Richard and Abraham 2013). In addition to commercial captures, black petrels are also caught in recreational fisheries in unknown numbers (Abraham 2010) and may be bycaught outside New Zealand waters during the austral winter (Cabezas 2012).

Mitigation measures that significantly reduce seabird captures are available for deployment in commercial bottom longline fisheries. Best practice measures include line-weighting, deployment of streamer lines, and retaining fish waste onboard while gear is in the water (Bull 2007; Lokkeborg 2011). Due to the diversity of gear and operations in inshore bottom longline fisheries (Goad et al. 2010; Goad 2011), changes to fishing practices are inevitable if mitigation measures are prescribed for use across the fleet. Further, given fleet-wide variation, determining the efficacy of the mitigation approaches used on any one vessel, or by a subset of the fleet, is challenging using conventional approaches (i.e., data collection by human observers).

Since mandatory mitigation measures aimed at seabird bycatch reduction were introduced in New Zealand inshore bottom longline fisheries in 2008 (New Zealand Gazette 2008, 2010), the uptake and efficacy of these measures has not been investigated across the target fisheries. In addition, the efficacy of any additional or alternative measures that fishers may be deploying has not been assessed. Canvassing fishers has highlighted variable levels of knowledge of seabird issues and vessel-based work to date shows varying deployment of bycatch reduction measures (Goad et al. 2010; Goad 2011). Further, longline sink patterns examined to date show that lines can still be within reach of diving seabirds at more than 1 km astern (Thalmann et al. 2007; Goad et al. 2010; Goad 2011), creating significant bycatch risk.

The ongoing incidence of seabird bycatch in inshore bottom longline fisheries, including bycatch of species of high conservation concern, combined with the diversity of vessel operations and the potential to improve mitigation measures in use 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 are:

- 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.

In addressing these objectives, we focussed on inshore bottom longline fisheries targeting bluenose and snapper in Fishery Management Area (FMA) 1.

Research approach

Our approach to the research comprised a number of components:

- a characterisation of inshore bottom longline fishing in northern New Zealand, including seabird bycatch and mitigation approaches,
- a workshop with scientists, skippers, government fisheries observers, fishery managers and environmental non-government organisations, to confirm mitigation approaches,
- identification of priorities and information needs to address project objectives,
- development and testing of at-sea data collection protocols,
- analysis of information collected, and,
- development of conclusions and recommendations for next steps.

Characterisation of inshore bottom longline fisheries operating in northern New Zealand

Several sources of data were utilised to characterise bottom longline fishing operations in northern New Zealand as they relate to seabird bycatch. 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 through 30 September 2012. Data collected by government observers were extracted from MPI's Centralised Observer Database (COD) for the same period. This included information relating to fishing (e.g., numbers of hooks set), seabird captures, and mitigation practices (e.g., deployment of streamer lines).

The fisheries

The FMA 1 bottom longline fleet consists of many small vessels including several that also fish in FMAs 2 and 9. Almost half the vessels active in FMA 1 deploy 90% of the sets in this area (Table 1) but this is still a large fleet working out of many ports. Typically, smaller vessels working 1-3 day trips target snapper with light 'clip-on' gear (i.e. hooks are manually baited and snoods are manually clipped to the longline). Larger vessels generally work longer trips with heavier 'clip-on' or autoline gear (Goad 2011). In terms of both sets and number of hooks, snapper target sets make up the majority of the effort in FMA 1. Effort targeting bluenose in this FMA is also substantial (Table 1).

Table 1: Bottom longline fishing effort in fishing years 2009/10, 2010/11 and 2011/12 in Fisheries Management Areas 1, 2 and 9 by target species. Target species are 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*(Beryxs plendens, B. decadactylus)*, spiny dogfish *(Squalus acanthias)*, rig *(Mustelus lenticulatus)* and trevally *(Pseudocaranx dentex)*.

Target Species	**FMA 1**		**FMA 2**		**FMA 9**	
	Number of sets	**Number of hooks**	**Number of sets**	**Number of hooks**	**Number of sets**	**Number of 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	28650	15	8 870
Total	23 833	40 800 266	8 659	15 768 459	3 196	3 425 909
Total number of vessels	93		57		54	
Number of vessels making	50		15		45	

up 90% of sets

Fishing effort is distributed throughout FMA1, with the highest numbers of hooks set in the Hauraki Gulf area (Figure 1).

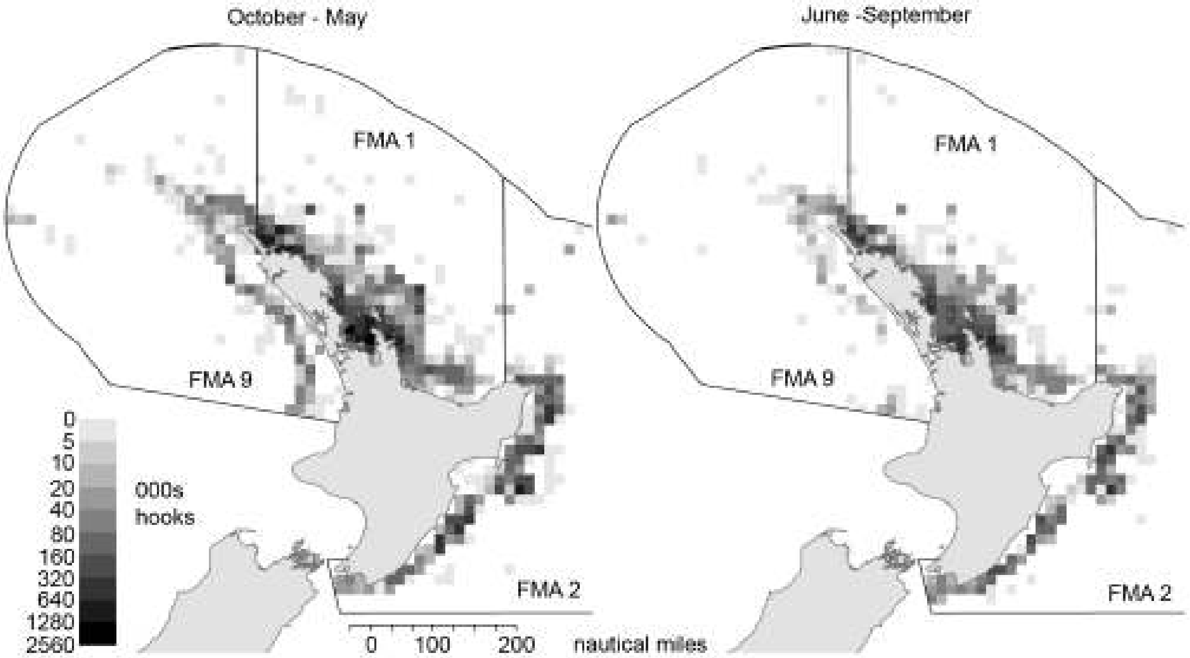


Figure 1: Total number of bottom longline hooks set in Fishery Management Areas 1, 2 and 9 between October and May and between June and September during fishing years 2009/10 - 2011/12, as extracted from the Ministry for Primary Industries' Warehou database, and binned into 0.2 degree rectangles.

Depths fished by bottom longliners vary with target species. Sets targeting snapper are located in shallower water and bluenose, hapuku, bass and ling are targeted in deeper water (

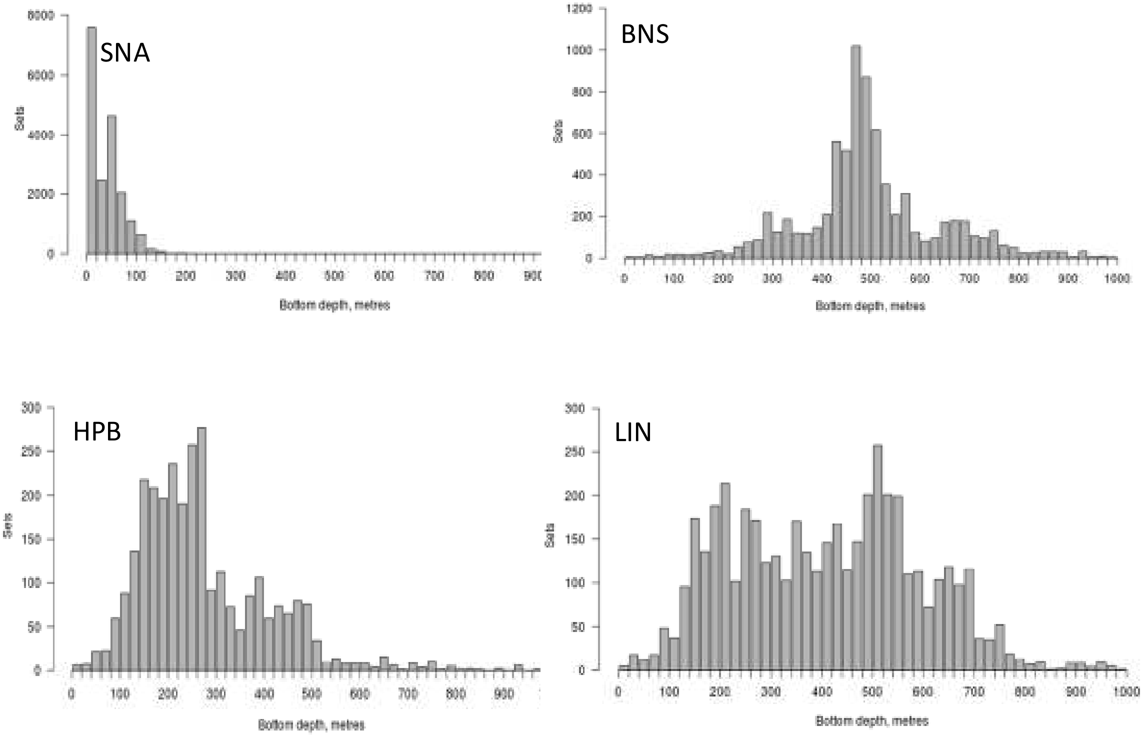


Figure 2). Depth profiles of sets by target species were highly consistent across the years examined (2009/10 - 2011/12).

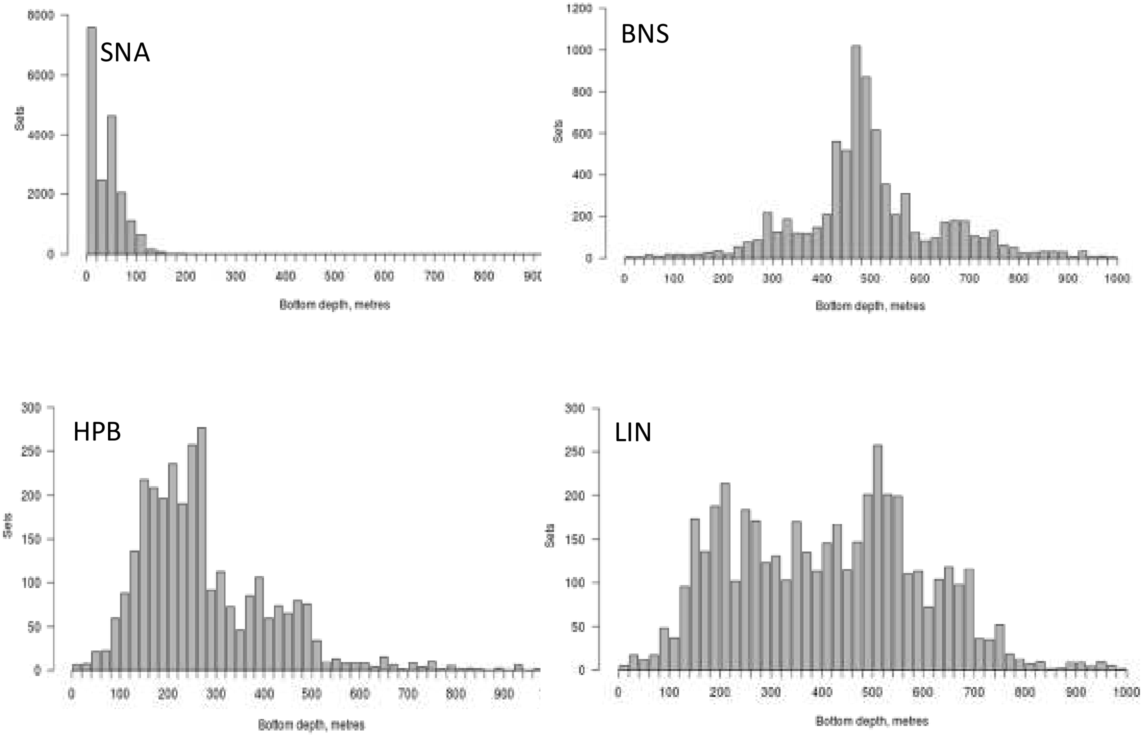


Figure 2: Depth distribution of bottom longline sets (plotted by set start location), as

extracted from the Ministry for Primary Industries' Warehou database in Fisheries Management Areas 1,2 and 9 during fishing years 2009/10 - 2011/12. Target species profiled are (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*)*.

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 - 2010/11. In years when coverage occurred, 1.2 - 2.3% of effort was observed (Abraham and Thompson 2012a). Observers have been deployed in FMA 1 in eight of the nine fishing years from 2002/03 - 2010/11, although less than 5% of fishing effort has been covered in each of these years (Abraham and Thompson 2012b, c). The highest proportions of bottom longline fishing effort have been observed in FMA 2 from 2002/03 - 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 - 2.5% since 2007/08 (Abraham and Thompson 2012d).

In the three fishing years 2009/10 - 2011/12, government fisheries observers reported 70 seabirds caught in bottom longline fishing operations in FMA 1 and FMA 2 (

Table 2). 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 petrels and flesh-footed shearwaters *(Puffinus carneipes)* were captured on sets deployed during the day and at night, predominantly by being hooked. Most birds were released alive (

Table 2), 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 3). 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 (*Puffinus gavia*), Buller's shearwater *(Puffinus bulleri)*, Cape petrel *(Daption spp.)*, 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 3).

Table 2: Seabird bycatch reported by government fisheries observers in three fishing years (2009/10 - 2011/12) in Fishery Management Area (FMA) 1 and FMA2, as extracted from the Ministry for Primary Industries' Centralised Observer Database. Target species are snapper (*Pagrus auratus*, SNA), bluenose (*Hyperoglyphe antarctica*, BNS) and hapuku/bass (*Polyprion oxygeneios, P. americanus,* HPB). Seabirds are black petrels (*Procellaria parkinsoni,* XBP) and flesh-footed shearwaters (*Puffinus carneipes,* XFS).

Year	FMA	Target catch	Seabird species	Number caught	Mode of capture	State after capture
2009/10	1	SNA	XBP	2	Hooked	Released alive
				17	Hooked	Dead
		SNA	XFS	10	Hooked	Released alive
				6	Hooked	Dead
				1	Tangled	Dead
	1	BNS	XBP	4	Hooked	Released alive
				1	Tangled	Released alive
2009/10	2	HPB	XBP	12	Hooked	Released alive
			XBP	1	Hooked	Dead
	2	BNS	XBP	11	Hooked	Released alive
			XBP	1	Tangled	Dead
2010/11	1	BNS	XBP	2	Hooked	Released alive

Table 3: Seabird bycatch reported by fishers in three fishing years (2009/10 - 2011/12) in Fishery Management Area (FMA) 1, FMA 2 and FMA 9, as extracted from the Ministry for Primary Industries' Warehou database. Target species are snapper (*Pagrus auratus*, SNA), bluenose (*Hyperoglyphe antarctica*, BNS) and hapuku/bass (*Polyprion oxygeneios, P. americanus,* HPB). Seabird species are 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 are gannets and boobies (XSU) and petrels, prions and shearwaters (XXP). Classifications of 'Injured', 'Uninjured' and 'Dead' are presented as reported by fishers.

Year	FMA	Target catch	Seabird species	Number caught	Injured	Uninjured	Dead
2009/10	1	SNA	XBP	31		3	28
			XBS	1		1	
			XFS	25	1	7	17
			XSH	3		1	2
			XSU	2		2	
			XXP	1		1	
	1	BNS	XBP	31	7	21	3
			XSH	7			7
	9	BNS	XXP	1			1
2010/11	1	SNA	XBP	10	1	5	4
			XCC	1			1
			XFL	1		1	
			XFS	37	2	8	27
			XXP	6		6	
	9	BNS	XXP	1			1
2011/12	1	SNA	XBP	7		1	6
			XFS	22		5	17

		XGT	1		1
		XXP	2	1	1
2	BNS	XSA	1		1
		XWP	1		1

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 4).

Table 4: Rates of seabird captures calculated using government fisheries observer data and fisher reports for three fishing years (2009/10 - 2011/12) in three Fishery Management Areas (FMAs). Target species are 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. Capture rates based on government fisheries observer data were extracted from Abraham and Thompson (2012b, 2012c, 2012d). Note that Abraham and Thompson (2012b, 2012c, 2012d) use two spatial areas (NOHA = Northland Hauraki; BOP = Bay of Plenty) to describe FMA 1. Other areas are FMA 2 (ECNA) and FMA 9 (WCNA).

Fishing year	FMA	Target species	Fisher-reported capture rates (seabirds per 1000 hooks)	Abraham and Thompson area	Observed capture rates (seabirds per 1000 hooks). % fishing effort observed is shown in parentheses.
2009/10	FMA 1	BNS	0.02	NOHA	0.24 (0.4)
				BOP	0.57 (1.0)
	FMA 1	SNA	0.006	NOHA	0.07 (4.9)
				BOP	0 (2.8)
	FMA	BNS	0.003	WCNA	0 (2.6)

	9				
2010/11	FMA 1	SNA	0.005		Not observed
	FMA 9	BNS	0.003		Not observed
2011/12	FMA 1	SNA	0.002		Not available
	FMA 2	BNS	0.0009	ECNA	Not available

Mitigation usage and context

To date, night-setting and line-weighting have been the key operational aspects of inshore bottom longline operations that influence the risk of seabird bycatch (Bull 2007; Lokkeborg 2011). The deployment of streamer lines during setting and retention of used baits during hauling are additional measures that have been used on some vessels.

Night setting

Time of setting was examined for three fishing years (2009/10 - 2011/12), using records from MPI's Warehou database. "Night" sets were categorised as starting more than 30 minutes after nautical dusk through until 30 minutes prior to nautical dawn (New Zealand Gazette 2010). Set start times are discussed below; set end times were not available. Therefore, some sets currently characterised as occurring at night may have continued into day. 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 3), with 23 - 28 % of all sets commencing at night in FMA 1 where most effort targeting snapper occurs (Table 5). Sets targeting bluenose were mostly initiated prior to nautical dawn (Figure 3). In FMA 2, where most fishing effort targeting bluenose occurs, 56 - 71 % of sets started at night. In FMA 9, up to 86% of sets targeting bluenose commenced at night (Table 1). Start times of sets targeting hapuku and bass varied between FMAs and years, with 34 - 76 % of sets starting at night. Start times of sets targeting ling showed similar variation, with 37 - 68 % of sets starting at night, depending on the year and FMA (Table 5). Across all target species, there was a peak of setting activity around nautical dawn (Figure 3).

Table 5: 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 species**	**Number of sets**	**% night sets**	**Number of sets**	**% night sets**	**Number of sets**	**% night sets**
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

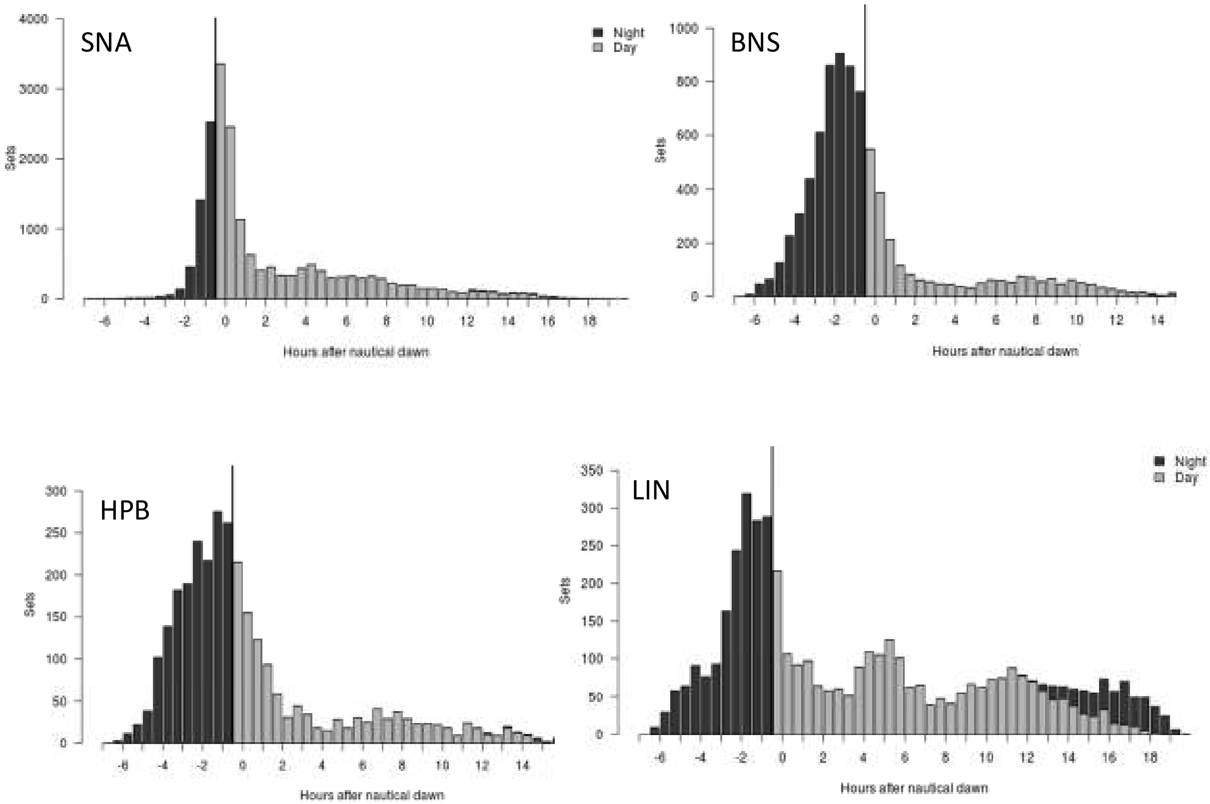


Figure 3: The start of longline setting, in relation to nautical dawn, in three fishing years (2009/10 - 2011/12) in Fishery Management Area (FMA) 1, FMA 2 and FMA 9, as extracted from the Ministry for Primary Industries' Warehou database. The vertical line shows half an hour before nautical dawn. Target species are (a) snapper (*Pagrus auratus*, SNA), (b) bluenose (*Hyperoglyphe antarctica*, BNS), (c) hapuku/bass (*Polyprion oxygeneios*, *P. americanus*, HPB) and (d) ling (*Genypterus blacodes*, LIN).

Line-weighting

The use of 'extra' weight, as a mitigation measure has been recorded on several vessels, and skippers have been reported to be well aware of the need to sink lines quickly to reduce the risk of seabird captures (Goad et al. 2010).

Streamer Lines

Review of data held by the Department of Conservation (DOC) describing streamer lines (also called tori lines) observed on inshore bottom longliners showed considerable variation in design and construction (Table 6, DOC 2011). The simplest streamer lines comprise of a towed polystyrene ‘cotton reel’ surface float, and the most complex setups involved multiple streamer lines, clip-on streamers, bridles for adjustment and a distinct drag section and / or towed object. Per set streamer line use was not available for all observed trips; those vessels which used streamer lines for some sets were generally more likely to deploy streamer lines during the daytime sets.

Table 6: Details of the range of streamer line specifications recorded by observers for sets targeting snapper (*Pagrus auratus*).

% sets used	Diameter (mm)	Number of streamers	Streamer type	Aerial extent (m)	Total length (m)	Height	Towed object
0 - 100	5 - 10	0 - 23	strapping, tubing	10 - 80	25 - 200	1.5 - 8	float / rope

Observers and skippers have noted the following factors which appear to improve streamer line performance:

- Irregular movement of the aerial section: the general consensus being that if the streamer line moves in an unpredictable manner then birds are more wary of it. ‘Jigglers’ are used routinely on large autoliners.
- Irregular movement of a visible towed object: Similarly, birds are wary of the towed object. One or more ‘cotton reel’ polystyrene surface floats towed astern have been observed to deter birds during snapper sets.
- Splashes or noise created by the towed objects or drag section.
- Multiple streamer lines to provide increased coverage.
- Some kind of bridle system or other way of altering the attachment point across the vessel, particularly to help position the streamer line over the longline in cross winds.

Discharge of fish waste

Snapper is generally landed green. In this context, only small quantities of offal are produced from bycaught species such as school shark. Offal discarding is therefore relatively easy to separate from fishing operations. 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 whilst hauling and dump offal on the side of the vessel away from the hauling area (Goad 2011). Bait retention at hauling is variable between vessels and some crews will hold baits in response to bird activity (Goad et al. 2010).

Other measures

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

Regulatory context

Regulations for the use of seabird bycatch reduction measures were introduced to inshore bottom longline fisheries in 2008, and updated in 2010 (New Zealand Gazette 2008, 2010). These incorporate some 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. Regulations require vessel operators to carry streamer lines on all bottom longline vessels 7 m or more in overall length. The use of a streamer line is required during line-setting on these vessels, and the specifications of the streamer line vary with respect to vessel size. In addition, fishers must not day-set (i.e., set bottom longlines from between 0.5 hours before nautical dawn until 0.5 hours after nautical dusk), unless they implement a prescribed line-weighting regime. Line-weights can be internal or external to the backbone. Where internal, integrated weighted line of $\geq$ 50 g/m must be used. Where external, weighting regimes are specified in accordance with the width of the longline backbone. For backbones $\geq$ 3.5 mm in diameter, a minimum of 4 kg (metal) or 5 kg (non-metal) weight must be deployed every 60 m of hook-bearing line. When backbones are $\leq$ 3.5 mm in diameter, a minimum of 0.7 kg of weight is required every 60 m of hook-bearing line. In addition, regulations prescribe that ropes used to attach weights to longline backbones must be not more than 20 m in length (New Zealand Gazette 2010).

Regulations also restrict the deployment of floats on hook-bearing longline to those smaller than 150 mm in diameter. Not more than three floats up to this size are able to be attached every 60 m, unless another 1 kg of weight is added for each additional float. Hooks cannot be deployed within 30 m each side of a marker buoy where this buoy is attached directly to the backbone (New Zealand Gazette 2010).

Finally, the discharge of offal and fish waste is not permitted during line-setting, and is only permitted during line-hauling when discharge occurs on the opposite side of the vessel to the hauling station (New Zealand Gazette 2010).

Methods

After reviewing the fishery characterisation and conducting a workshop with experts and practitioners in the fishery, we focussed work in the following three areas:

- **Documenting current practice**

This involved describing all elements of the fishing operation on observed vessels that were relevant to bycatch risk and the mitigation of that risk (e.g., gear setup and longline sink rates, deck layout, temporal fishing patterns, etc.).

- **Refining existing approaches to bycatch reduction**

Having documented the 'normal' approach to fishing, this area of work focussed on improving existing mitigation measures where they were already in place (e.g., streamer line design, weighting regimes, bait retention, etc.).

- **Exploring new options for mitigation measures**

Finally, where past work had identified potential new mitigation measures, this project provided the opportunity to conduct preliminary assessments of the feasibility of these measures.

Project implementation

Data collection at sea 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 skipper willingness to host them and the potential for modifying and improving mitigation approaches.

Vessels fishing using the bottom longline method were selected for inclusion in the project based on a number of factors:

- target fish species,
- port of departure,
- location and timing of fishing activity,
- interest in bycatch reduction approaches, and,
- willingness and capacity to host observers.

Documenting current practice

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, the dimensions of these were recorded. Any seabirds caught during trips were also recorded and identified to species level. This information was recorded on forms used by government observers on some trips in bottom longline fisheries (Table 7). (On some trips, electronic data recording is used, rather than a paper-based form).

Table 7: Forms used by government observers to document current operating practices in inshore bottom longline fisheries.

Form	Data captured
Hauling Observations form	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 form	Date, time and location of observed setting activity Hooks observed Setting speed and direction Details of line set Details of streamer line used Whether any offal was discharged Environmental conditions (e.g., temperature, cloud cover, wind strength and direction)
Tori Line Details form	Line diameter and length Terminal object used Number and length of streamers Distance between streamers

	Streamer material and colour
Non-fish Bycatch form	Species captured Injury and life status
Trip Report	Deck diagram Vessel and gear details Longline diagram Tori line diagram

All other data were captured on forms specifically designed for this project. In addition to protocols quantifying seabird activity and longline sink rates as described below, observers also collected qualitative information in a series of question-based forms that were designed to record their impressions and skipper feedback about mitigation measures.

Project-specific data collection protocols

Additional data recorded to characterise fishing operations included detailed quantification of longline sink rates and seabird abundances and activity astern of the vessel during setting and hauling. These were the primary metrics used to quantify bycatch risk and the efficacy of mitigation measures in reducing that risk. Given the sensitive conservation status 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, a lethal experiment was not appropriate for this project. Past work on seabird bycatch reduction measures has shown that proxies for seabird mortalities can be effective in testing the efficacy of mitigation measures. Proxies still quantify bycatch risk, albeit indirectly (Pierre and Debski 2013).

Drawing on approaches used in past work (e.g., Pierre and Norden 2006; Pierre et al. 2012), data collection protocols were developed and refined through testing by an observer at sea on 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.

In addition to documenting current practice, project-specific data collection protocols were also available for quantifying seabird abundance and activity, and for measuring line sink rates, when refinements were made to mitigation measures and new measures were explored, as described below.

Data collection on the set

Seabird abundance and activity

At setting, the final protocol assessed seabird abundance and activity data 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 the light availability (due to night-setting), and the time required to complete their other duties. Details identifying the set (including date and time), and covariates (vessel speed, swell height, wind strength, wind direction), 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 petrels (*Daptioncapense*), any storm petrels, prions, etc.), and Cape petrels, made sequentially within the defined area. Abundance counts took no longer than 1 - 2 minutes.

Then, the number of dives was recorded for each species group. The total number of dives was recorded as well as 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 under the water, which we interpreted as the intention of foraging (Pierre and Norden 2006).

Following five minutes spent counting dives, observers recorded ‘landings’ for an additional five minute period. A landing was 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 was interpreted as showing an interest in the vessel (or something around it, e.g., other seabirds already in attendance, fish waste discharge, baits on the line) which could lead to foraging activity.

Two alternating five-minute periods of each activity type were recorded such that a total of 20 minutes of observations occurred. That is, recording five minutes of dives was followed by recording five minutes of landings, a second five minutes of dives and second five minutes of landings. A final abundance count of each of the species groups closed that observation period, and a new observation period commenced with the same sequence of abundance and activity counts.

Observers also noted the position of any streamer lines relative to the longline.

Longline sink rates

Starr-Oddi DST Centi time depth recorders (TDRs) were deployed to document line sink rates. Protocols used for deploying time depth recorders were developed from those used for previous work in bottom longline fisheries (Goad et al. 2010; Goad 2011). TDRs were programmed, using Sea Star software, to record for 30 minutes before through 45 minutes after the expected longline shooting time. Before deployment, TDRs sampled every 30 seconds during which time they were located in a container of seawater on the vessel. 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 setup to sample once every 24 hours for 2040 days if the line was lost.

Information collected before and after TDR 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.

Placements of TDRs were varied on longlines, depending on the aspect of the line set that was of interest in each trial (see below). We aimed to locate 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, for which sets are located in deeper water, is 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 - 800 hook set.

On snapper vessels, TDRs were used to document current practice for two or three sets, before moving on to explore novel mitigation approaches. On the two vessels targeting bluenose, TDRs were used to document fewer normal sets given time limitations of observer deployments of those 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, thought to be either half or three quarters of the way towards the following weight (Figure 4a). When examining more complicated setups targeting snapper, the number of TDR positions increased to include the same positions relative to floats (Figure 4b) and ‘droppers’ (Figure 4c). When sampling bluenose gear, TDRs were placed beside weights and beside floats (Figure 4d).

To investigate the effect of floats and droppers on fishing gear on the seabed, TDRs were placed on the backbone beside floats and weights and also on dropper weights (Figure 4e).

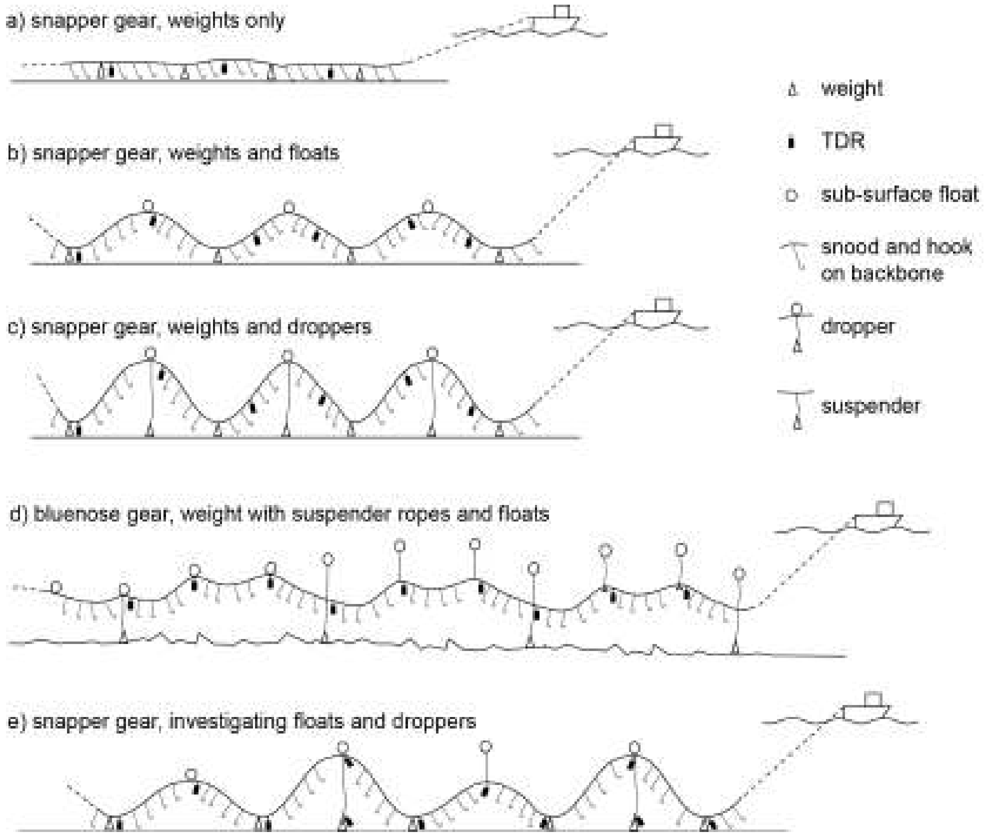


Figure 4: Position of time depth recorders (TDRs) on longlines, relative to hooks, weights and floats.

Data collection on the haul

At the haul, seabird observations were focused in two areas: 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. Then, 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 at setting) inside the 6 m-diameter semi-circle. Finally, the abundance of each of the three seabird groups was recorded from the 100 m-diameter 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.

Refining existing approaches

Streamer lines

Observers worked with skippers and crews on two vessels to make changes to streamer lines in use with the aim of improving the performance of the lines. Changes were:

Vessel L:

- addition of a 2 kg weight near the point at which the streamer line attached to the vessel

The purpose of adding this weight was to encourage the streamer line to bounce, and for the movement to scare birds away from the longline underneath.

- positioning of two streamer lines almost directly one above the other

This alignment was intended to increase the protection of the longline by the streamer lines.

- strapping tape threaded through the rope that formed a loop and provided the drag at the end of the streamer line, creating a bottle-brush effect

This change was made to create more disturbance in the water at the end of the streamer line, hopefully dissuading birds from attending and foraging nearby.

Vessel N:

- addition of setnet floats forward of the towed object

This addition was intended to reduce entanglements of the streamer line and surface floats on the longline, increase drag, and cause more disturbance on the water.

- addition of glow sticks to aerial section of the streamer line

This change was to improve functionality of the streamer line. Glow sticks allowed the location of the streamer line to be more apparent in the dark. This meant that its position could be adjusted and surface floats could be deployed to one side, in order to avoid tangles more effectively.

Weighting regimes

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 4).

Bait and discard retention

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).

Exploring new mitigation measures

Retaining bait fragments at setting

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.

Extending the length of ropes used on subsurface floats

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.

Haul mitigation

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.

Data analysis

Time depth recorders

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, with an estimated error of ± 2 seconds.

Box 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.

Haul form modelling methods

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 ~ trip_date + baits + discards, data=haul, family="poisson")
```

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

Results

Project implementation

Observers were deployed across eight vessels, delivering a total of 104 observer days (Table 8). The following issues were encountered during the implementation of the project.

- **Availability of observers**

During the project, there was a shortage of observers available for deployment, due to competing demands for coverage (especially to meet coverage requirements on foreign charter vessels). This prolonged a delay in starting the at-sea component of the work, and limited the number of days achieved to 104 of the planned 150. While the timing of coverage was slightly later than ideal in terms of overlap with the seabirds of particular interest, it was within the range of previous observer coverage (DOC 2011).

- **Not all of the fleet was suitable for observer placement**

Approximately 30 % of the vessels initially contacted for coverage were unable to carry observers due to safe ship management limitations (MNZ 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.).

- **Logistics involved with coordinating observers with vessels' frequently changing plans**

The operation of smaller vessels in these fisheries was somewhat weather-dependent, and skippers also maintained sometimes irregular fishing schedules. This led to challenges in coordinating observer deployments with vessel departures, as observers required time to move around the country. Some ports from which vessels conducting bottom longlining depart are considerable distances from an airport, resulting in significant driving times for observers in order to reach vessels.

- **Skippers leaving port without observers**

In one case, the skipper left port having forgotten to notify the observer of the trip departure time.

- **Skipper willingness to carry observers**

When they were contactable, skippers showed varying degrees of willingness to carry observers. In general, skippers of snapper-target vessels were more willing to carry observers compared to 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 consider all project objectives, extended observer deployments were required. The amount of time observers needed to work on vessels was significantly longer than skippers had previously been exposed to. This 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 involved shore time). Some skippers felt 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.

- **Skipper willingness to work with observers to explore modified mitigation approaches**

The project relied on skippers being flexible and supporting observer work to improve mitigation approaches in use. Observers reported that almost all skippers and crews were very helpful and accommodating, which facilitated the execution of observers' work tremendously.

One skipper hosted an observer, but did not agree with them conducting the range of activities planned in this targeted coverage (specifically, deploying TDRs). This reduced the scope of the deployment in that the observer could not conduct work to address all experimental objectives.

- **Facilities onboard vessels**

Facilities available for the crew on inshore vessels vary considerably, for example with the size of the vessel. In one case, a vessel making multi-day trips was not equipped with a shower or toilet, which dissuaded the observer from accepting the placement.

- **In order to continue coverage, one observer worked as the deckhand**

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 case, the observer was able to support the crew in the absence of one deckhand. This reduced the amount of time the observer could spend on seabird work, but had the ultimate advantage of continuing coverage on the vessel.

- **Observers able to earn more on offshore vessels**

Part of the strategy of this project involved maintaining consistency in observer deployments on single vessels. This involved observers working a series of sea days interspersed with shore days (e.g., between trips or in cases of bad weather). In contrast to this approach, observers were able to increase their earnings when they were deployed for a continuous number of sea days on an offshore vessel. For observers therefore, while their personal interest in the tasks required during placements for this project may have been higher than for the tasking associated with more typical trips, undertaking coverage was less fiscally rewarding than for offshore trips.

Data summary

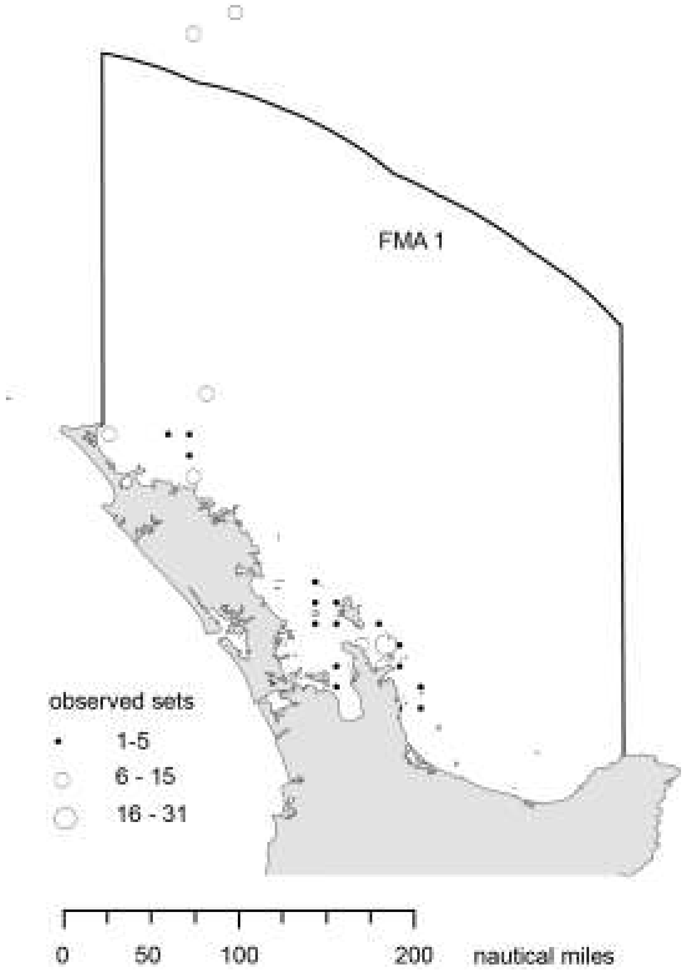


Figure 5: Location of observed sets per 0.2 degree rectangle.

Of the 104 observer days achieved during the project, 76 were fishing days over which 123 sets were conducted (Table 8). In addition, MPI deployed observers on two vessels prior to the start of the project, for a total of 17 observer days.

Table 8: Summary of target species, sea days, data collected, and mitigation tested on each vessel. +1 = another boat's gear hauled by the vessel participating in the project. Target species are snapper (*Pagrus auratus,* SNA), bluenose (*Hyperoglyphe antarctica,* BNS), hapuku/bass (*Polyprion oxygeneios, P. americanus,* HPB), ling (*Genypterus blacodes,* LIN), tarakihi (*Nemadactylus macropterus,* TAR). A 'day' set is characterised as a set starting less than 30 minutes prior to nautical dawn. 'Obs' denotes observed.

Vessel code	Main target species	Days obs	Number of fishing days	Total sets () = day	Number TDR sets	Number sets with bird obs	Number hauls with bird obs	Mitigation tested () = number of sets
L	SNA	23	18	31 (23)	9	20	31	slower setting speed for some of set (4)
M	SNA	10	9	10 (4)	4	4	10	lighter weights placed closer together (2)
N	SNA	33	26	32 (8)	16	16	15	retaining baits (8), streamer line (2), splatterboard (5), float-ropes (5), lighter weights placed closer together (2)
O	MIX / TAR	11	8	13 (4)	4	0	13+1	
P	BNS HAP	16	10	32 (1)	10	0	32	retaining baits (2), float-ropes (7)
Q	BNS	3	2	2 (0)	2	0	2	float-ropes (2)
R	SNA	3	2	2 (0)	0	0	2	
S	SNA	5	1	1 (1)	0	0	1	

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 (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 9). 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 9). 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.

Table 9: Summary of characteristics of longlines set from observed inshore bottom longline vessels targeting three fish species or species groups in northern New Zealand waters. SNA = snapper (*Pagrus auratus*) (seven vessels), MIX/TAR = a mix of target species focusing on tarakihi (*Nemadactylus macropterus*) (one vessel), BNS = bluenose (*Hyperoglyphe antarctica*) and HAP = Hapuku (*Polyprion oxygeneios*) (two vessels). Mean values are followed by minima and maxima in parentheses. (For hooks set, this is minimum and maximum mean number of hooks per vessel). Details on all gear attributes were not available from all sets.

Target species	Set duration (hours: minutes)	Longline backbone lengths set (m)	Mean number of hooks on longlines	Longline backbone diameter (mm)	Snood length (m)	Distance between snoods (m)	Setting speed (knots)
SNA	1:03 (0:40 - 2:00)	8188 (1300 - 15000)	2850 (1500 - 4000)	1.78 (0.6 - 2.5)	0.64 (0.6 - 0.7)	2.18 (1.2 - 3.0)	5.19 (3.3 - 7.1)
MIX/TAR	0:30	1177 (450 - 2040)	1000	2.5	0.6	1.2	2.88 (2.3 - 3.3)
BNS/HAP	0:25 (0:20- 0:30)	1070 (680 - 1430)	700 (600 - 800)	4	0.35 (0.29 - 0.4)	1.8 (1.6 - 2.0)	4.01 (3.7 - 4.6)

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 10). 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 10). 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. 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).

Table 10: Summary of characteristics of hauling operations observed on 10 inshore bottom longline vessels targeting three fish species or species groups in northern New Zealand waters. SNA = snapper (*Pagrus auratus*) (seven vessels), MIX/TAR = a mix of target species focusing on tarakihi (*Nemadactylus macropterus*) (one vessel), BNS = bluenose (*Hyperoglyphe antarctica*) and HAP = Hapuku (*Polyprion oxygeneios*) (two vessels). Mean values are followed by minima and maxima in parentheses. Details on all attributes were not available from all hauls.

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

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 deployed from commercial vessels.

Current mitigation practice and context

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.

Night setting

Of the sets targeting snapper 53 % of sets were commenced prior to 30 minutes before nautical dawn (Table 8). 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.

Line weighting

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.

Normal practice

Results from sink rate testing of normal practice line setups are presented below (Table 11 and 13). Data from previous work is included for comparison and is shown in a grey tint. A more complete set of box whisker plots, showing the distance behind the vessel TDRs reach different depths is shown in Appendix 1, but is excluded here for clarity.

Table 11: Gear parameters for normal practice line setups tested for vessels targeting snapper *(Pagrus auratus)* or tarakihi (*Nemadactylus macropterus)* including vessels A - E sampled as part of previous work (Goad et al. 2010).

Vessel / setup	Line setup	Kg weight per 100 m of line	Weight type	Number of sets sampled	Setting speed	Shooting height (m)	Line tension
A1	droppers and weights	1.5	steel	2	4.7	2.1	
A2	droppers	1.0	steel	3	4.7	2.1	
B1	droppers and 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 (5)
N2	weights and floats	2.2	steel	3	5.2 - 5.5	2.0	low - med (5)
O1	weights	2.9	steel	4	2.3 - 3.3	2.5	low (0.7 -

1.4)

Snapper / tarakihi target sets:

Distance behind the vessel and streamer lines

The risk that longlines present to seabirds is primarily reflected in hook availability, 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 13). 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).

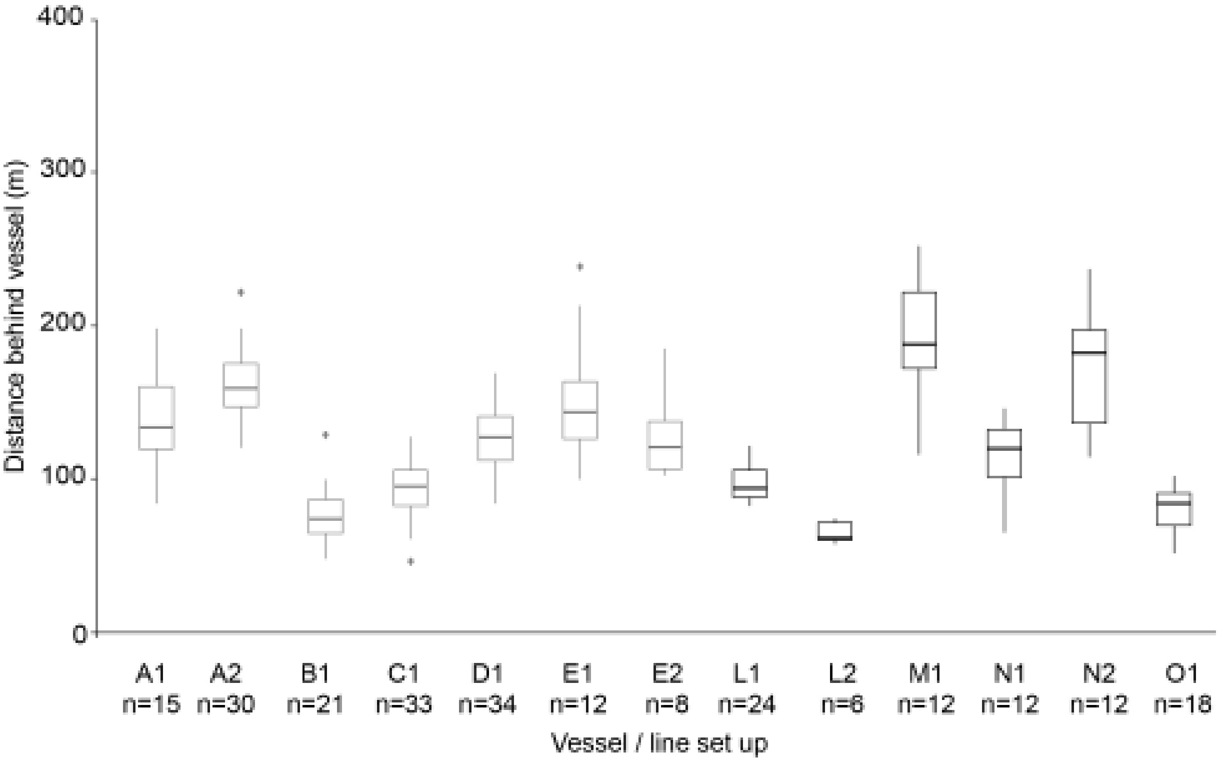


Figure 6: Box and whisker plot of distance behind the vessel time depth recorders reached 10 m depth for line setups detailed in Table 11.

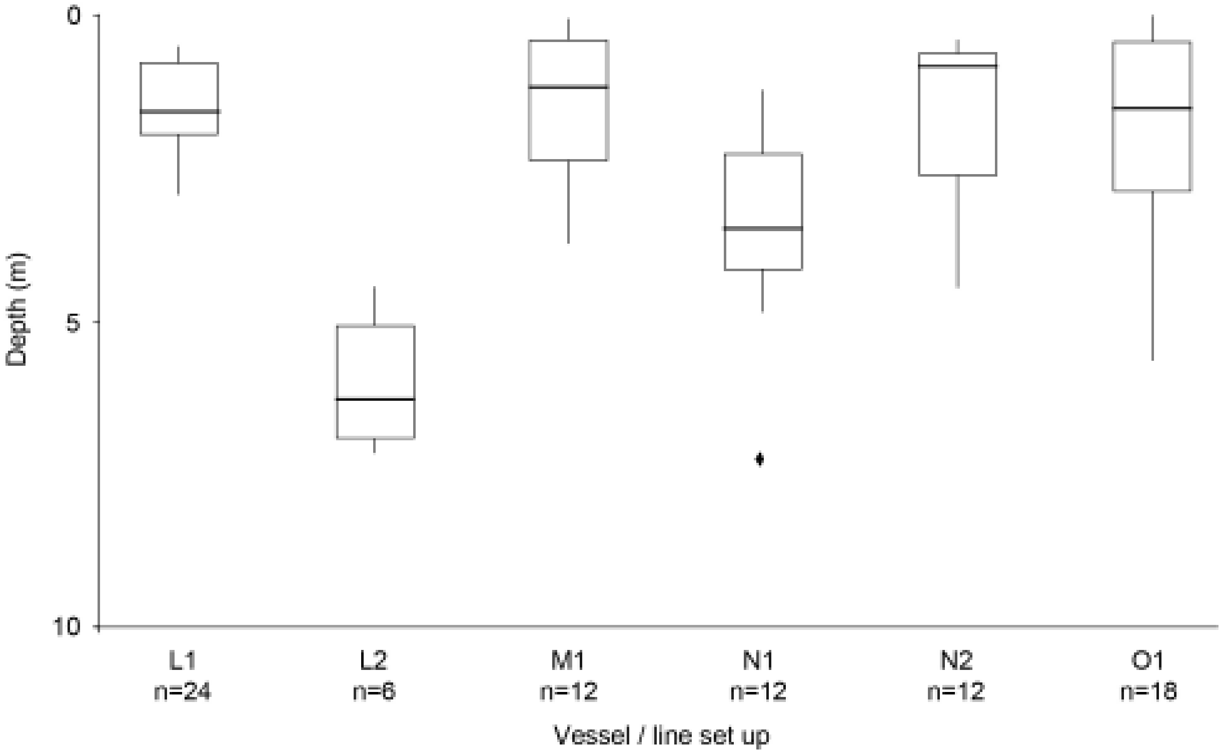


Figure 7: Box and whisker plot of depth of time depth recorders at the end of the aerial section of the streamer line for vessels L - O, line setups are detailed in Table 11.

Sink times

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 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.

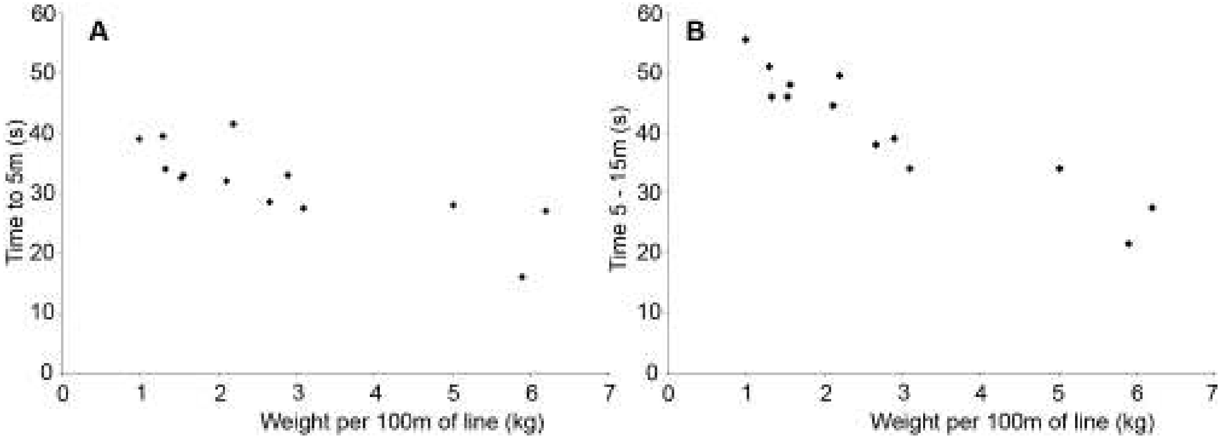


Figure 8: Plots of A) median sink time to 5 m and B) median sink time from 5 - 15 m, versus weight added per 100 m of line for vessels in Table 11.

Sink profiles with different gear setups

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.

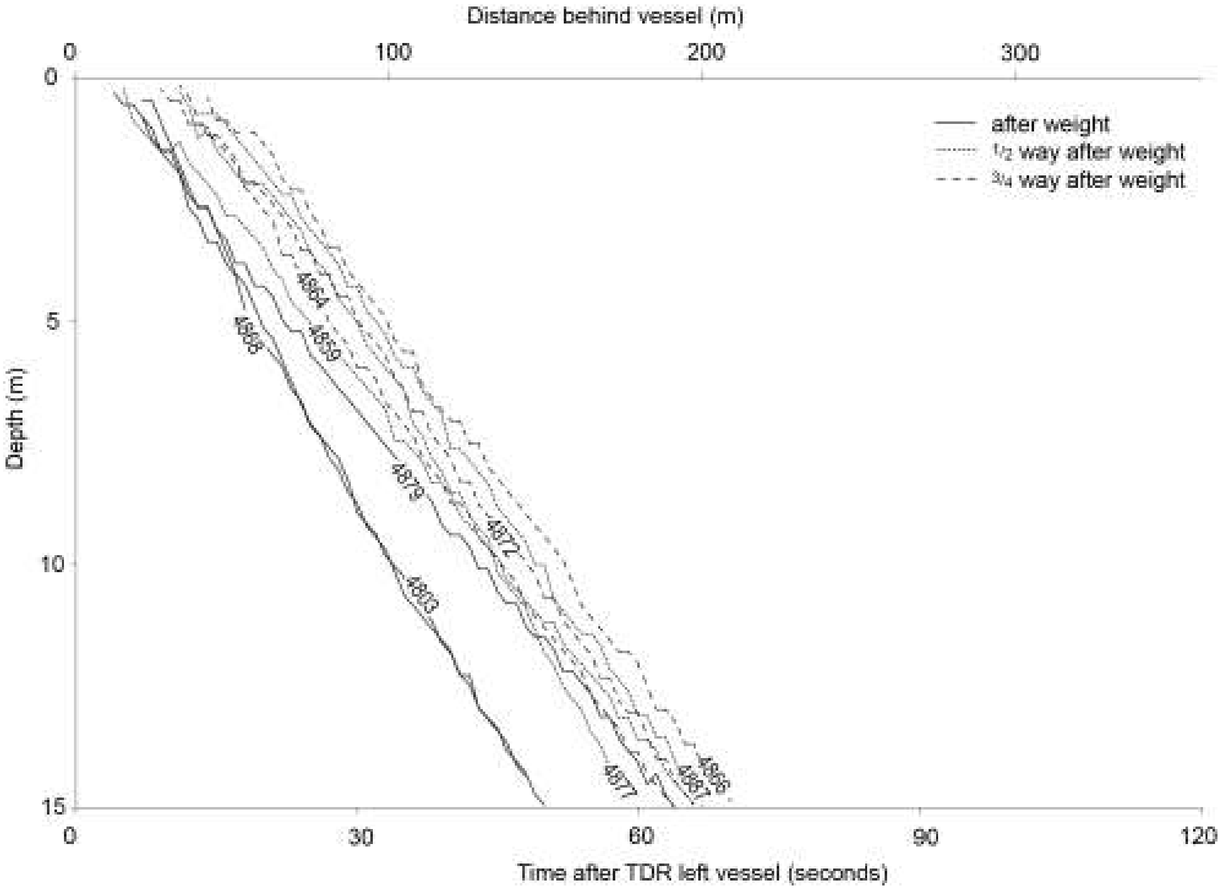


Figure 9: Time versus depth profiles for time depth recorders (TDRs) deployed during a single set on vessel N, with a repeated line sequence of weight, hooks, weight etc. Individual profiles are labelled with TDR numbers.

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

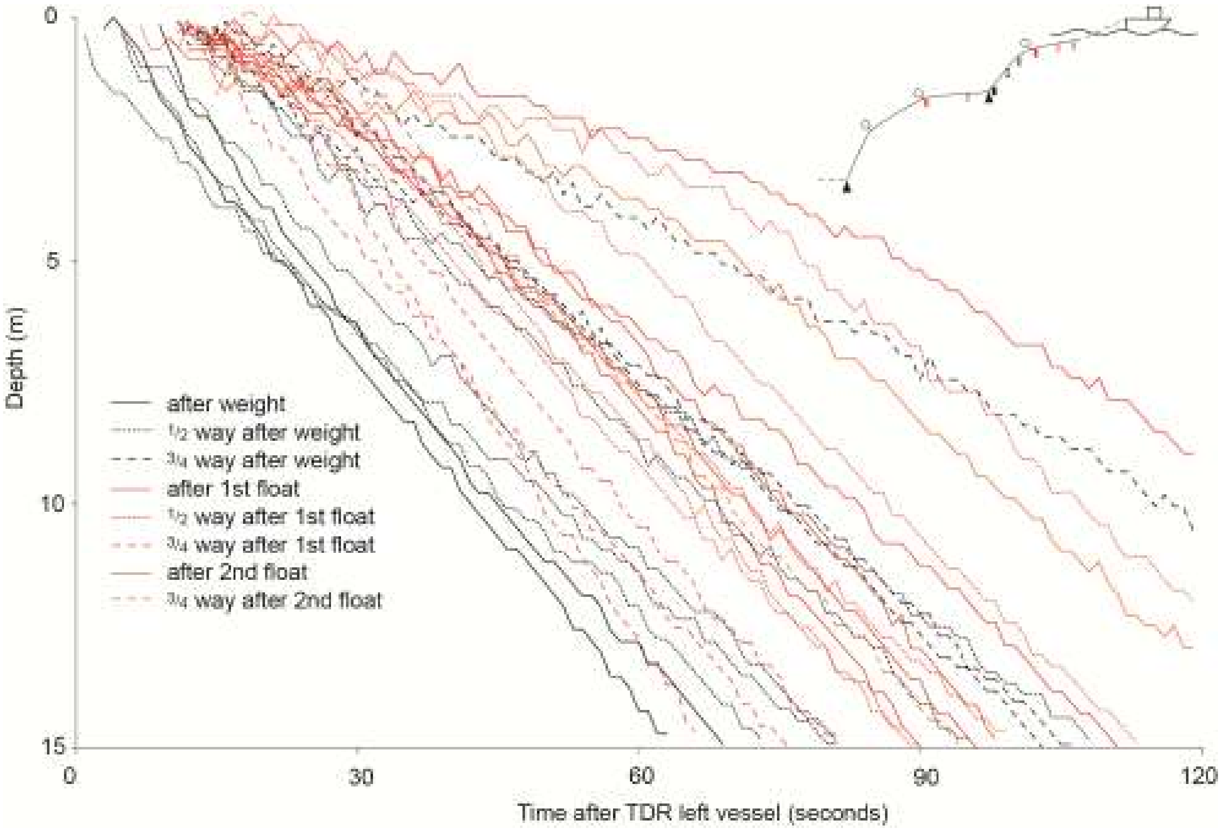


Figure 10: Time versus depth profiles for time depth recorders (TDRs) deployed during three sets on vessel N, with a variable line setup including one or two floats between weights.

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 and 12).

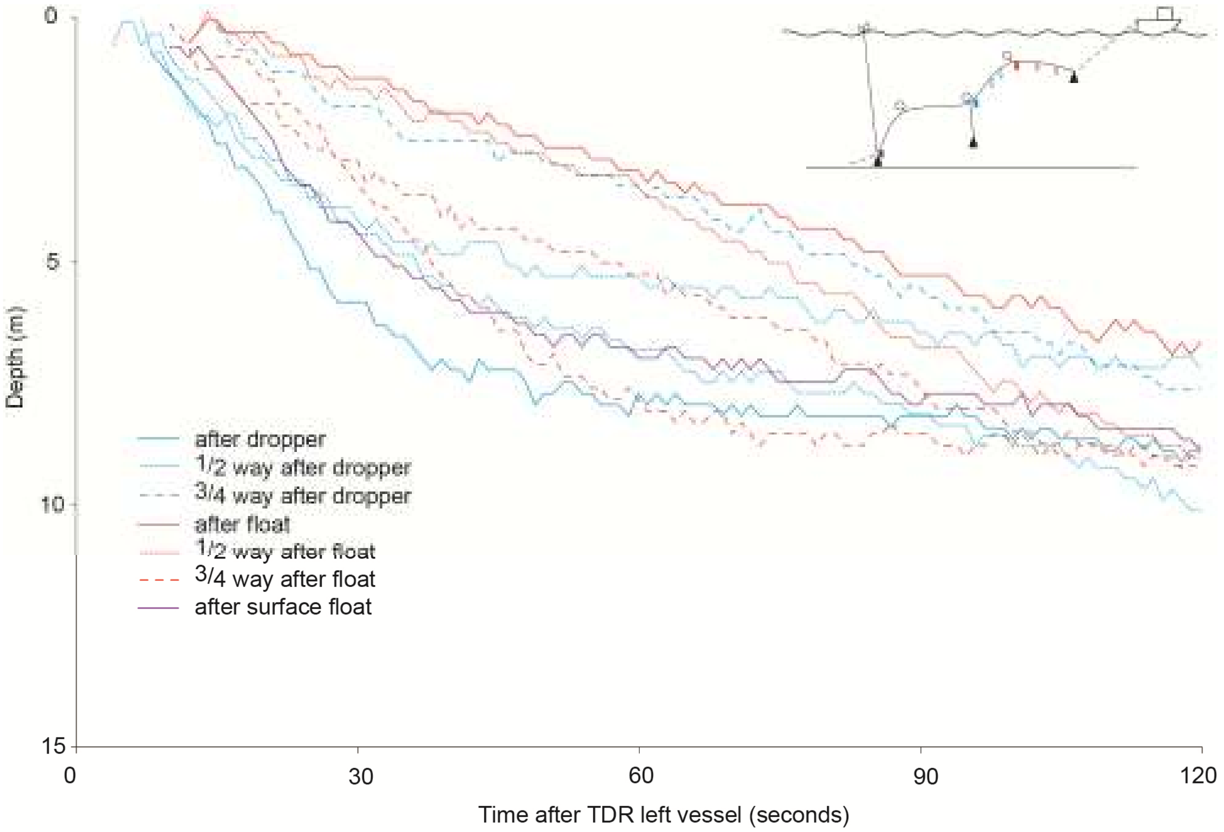


Figure 11: Time versus depth profiles for time depth recorders (TDRs) deployed during a shallow (10 m) set on vessel M, with a variable line setup of dropper, hooks, float, dropper.

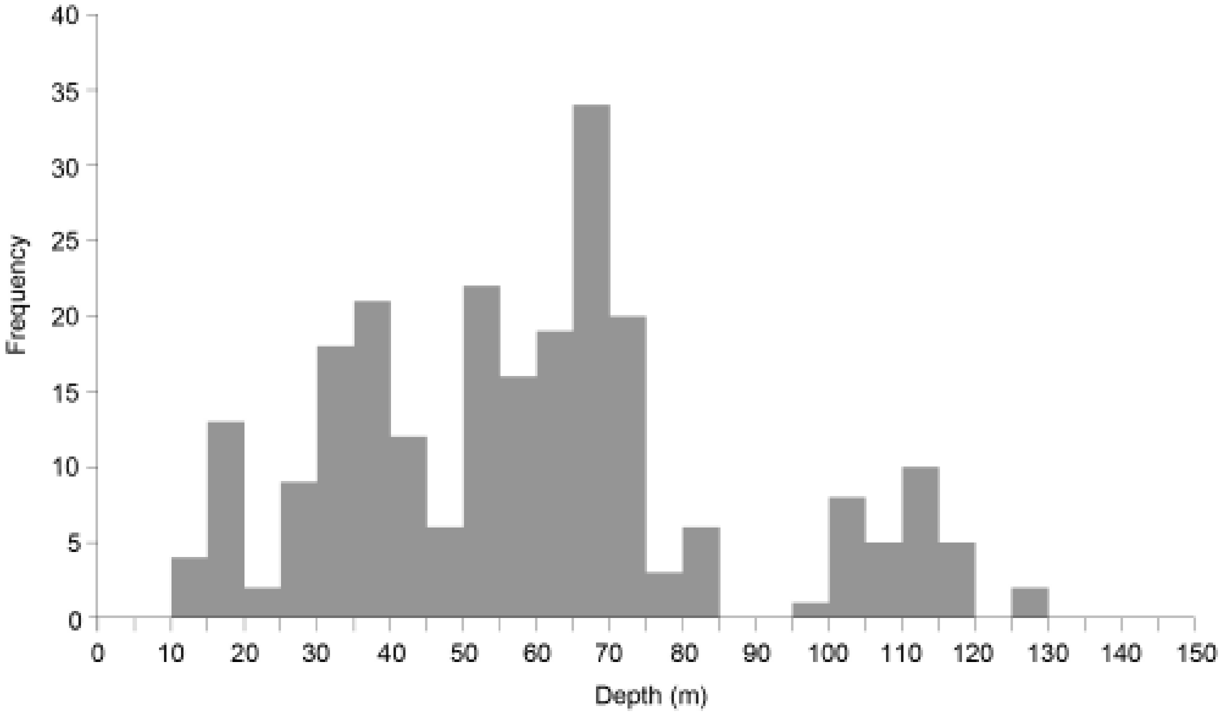


Figure 12: Frequency distribution of final depths reached by time depth recorders (TDRs) used to compile Figure 6 to Figure 10.

Detailed observations on line-weighting and seabird activity are included in Appendix 1.

Bluenose target sets:

Gear setups for vessels targeting bluenose, hapuku/bass and ling are included in Table 12. 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.

Table 12: Gear parameters for normal practice line setups tested for vessels targeting bluenose (*Hyperoglyphe antarctica,* BNS), hapuku/bass (*Polyprion oxygeneios, P. americanus,* HPB), and ling (*Genypterus blacodes,* LIN), including vessels F - K sampled as part of previous work (Goad 2011) and two vessels (P and Q) tested as part of this work. Weight figures in brackets show the approximate equivalent weight of steel, in seawater for lead and concrete weights.

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,	150, 120	3.3	lead	mono	6	3.5 -	2.9	Med

	float		(3.0)				3.7		
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	-
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
J 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

Distance behind the vessel

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.

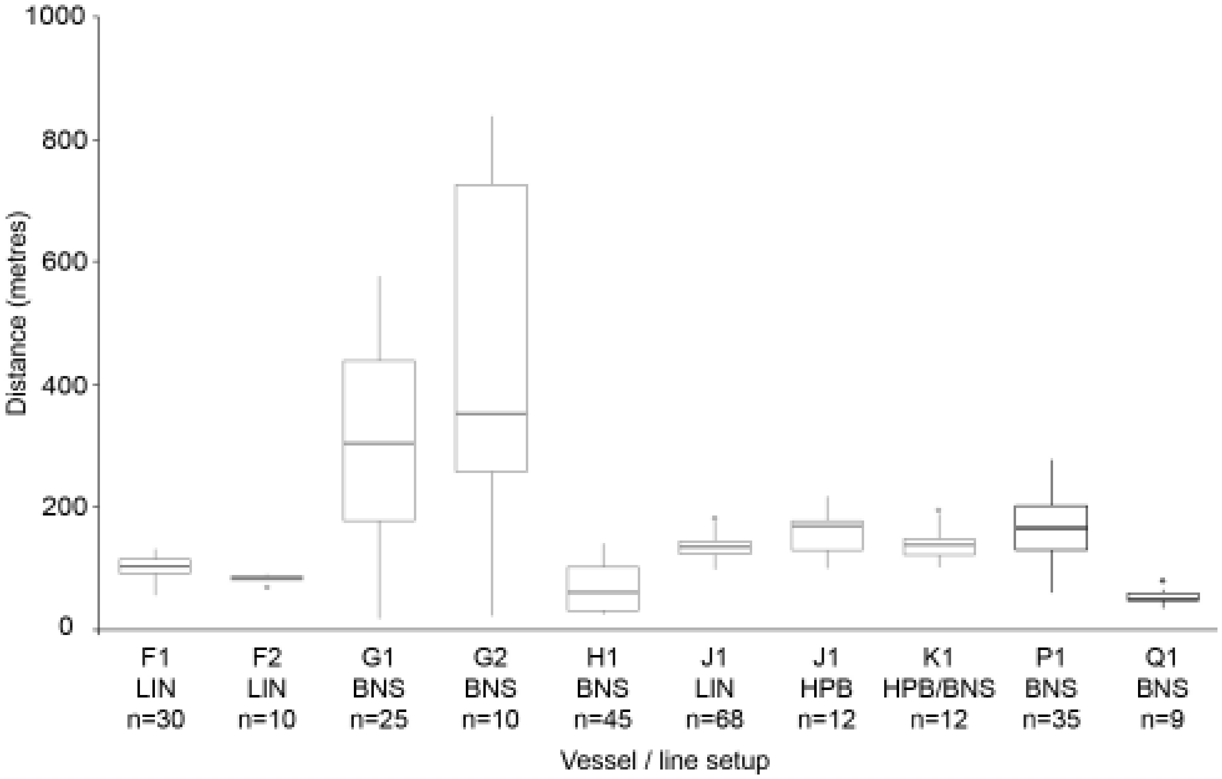


Figure 13: Box and whisker plot of distance behind the vessel time depth recorders (TDRs) reached 10 m depth for line setups detailed in Table 12.

Unlike snapper target sets, weight added to the line did not shown a clear correlation with sink time between 5 m and 15 m (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 12.), due to variation in float size and arrangement, and line tension.

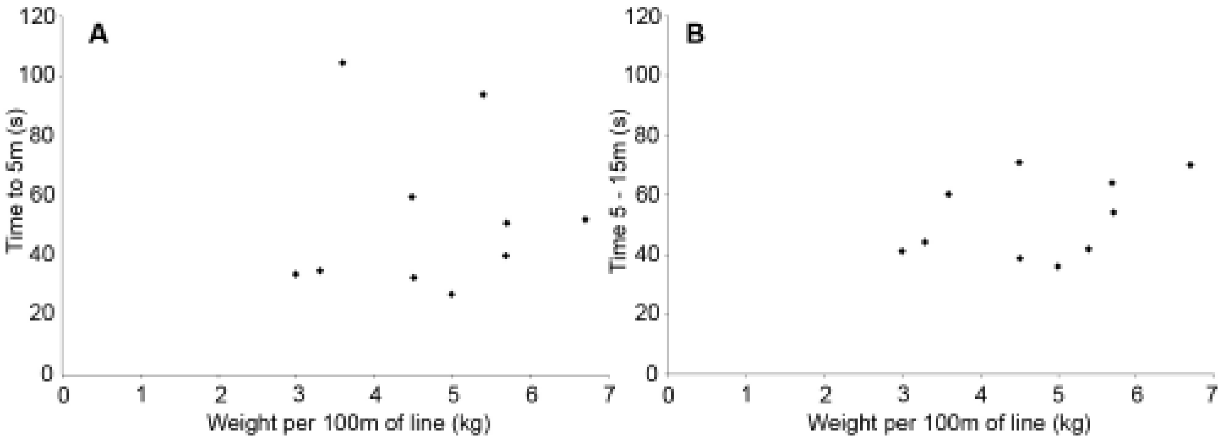


Figure 14: Plots of a) median sink time to 5 m and b) median sink time from 5 - 15 m, versus weight added per 100 metres of line for vessels in Table 12.

Sink profiles with different gear setups

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

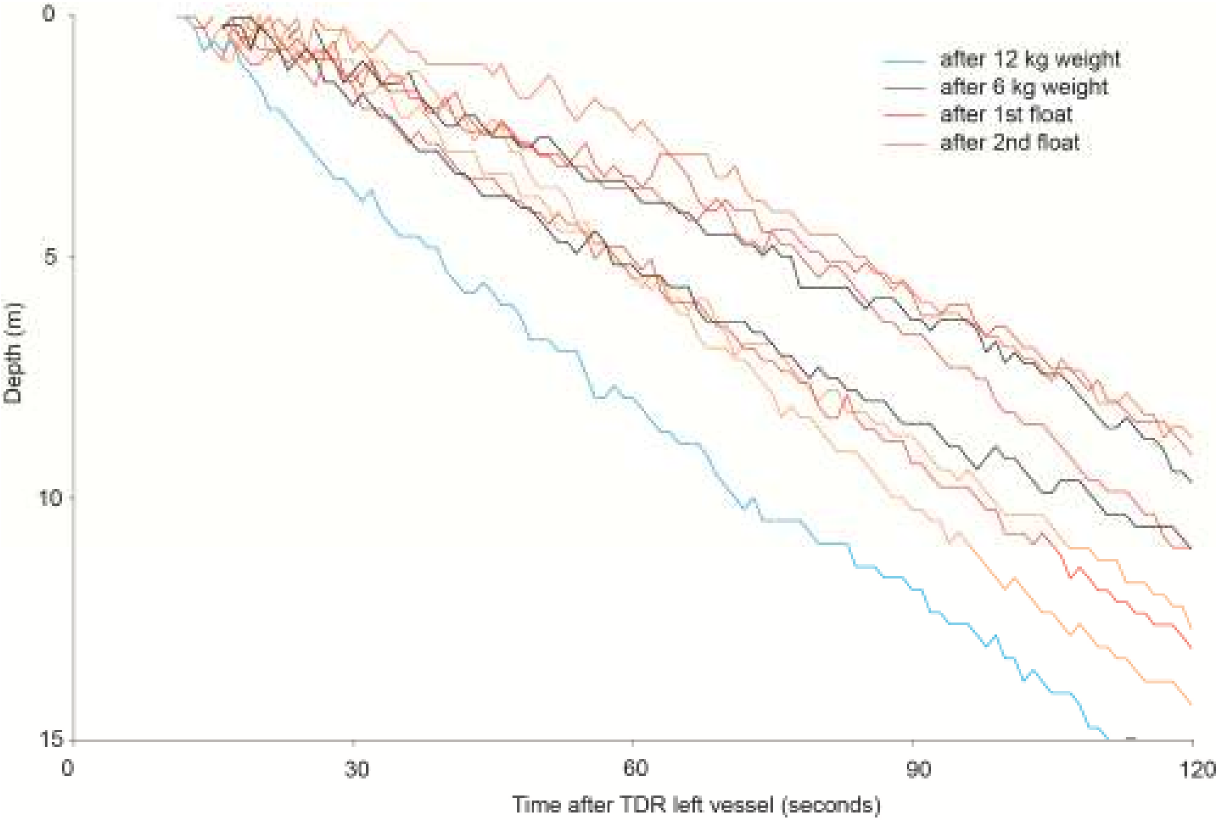


Figure 15: Time versus depth for time depth recorders (TDRs) placed on three consecutive sections of a line on vessel P. Line setup was weight on a suspender rope, float, float, with every third weight 12 kg rather than 6 kg.

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.

Line tension and setting speed

Measuring tension was attempted on the four snapper-target vessels on which TDRs were deployed. The setup of the vessel and measuring gear limited measurements to an approximate indication of tension on a single set for two of the vessels (M and N). On the third vessel (L), measurements were taken during four sets for which the setting speed changed part way through the set. On vessel O, tension was measured on a single set, again at two speeds.

Line tension could not be examined on bluenose vessels as skippers did not wish to add another block into their shooting setup. This was due to the larger loads operating on the heavier gear used to target bluenose.

Tension values presented for snapper-target sets (Table 11) are a combination of direct measurements and inferred estimates. Inferred estimates included assessments made by observers with experience on several vessels. Estimates were sometimes made indirectly, including by observers monitoring the deflection of the line caused when clipping hooks on, the way the line behaved when weights were clipped on and the sound of the line on the drum. In some cases skipper comments alerted observers to circumstances relating to line tension. For example, skippers commented on when 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 is categorised as low, medium or high (Table 12).

Both snapper vessels returned higher tension readings 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.

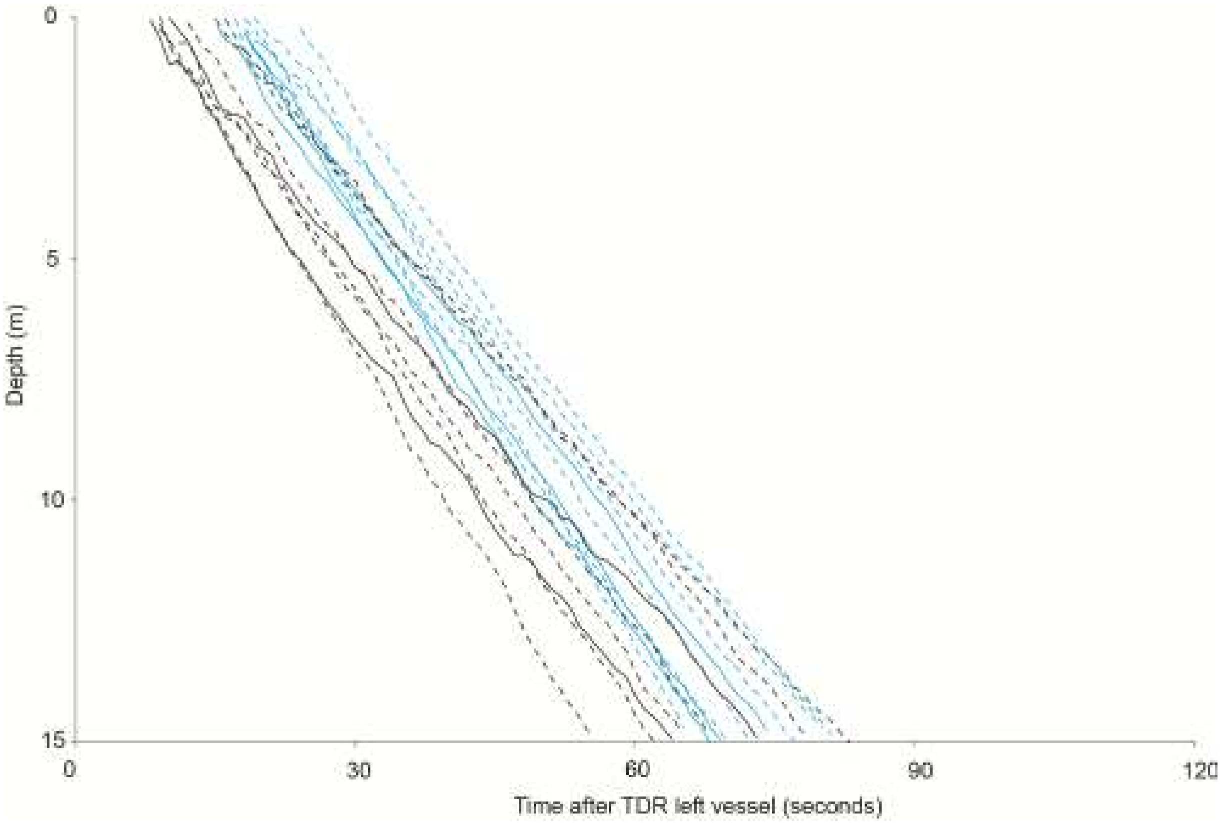


Figure 16: Plot of time versus depth for TDRs on longlines set at different speeds. Blue lines are from a set at 3.3 knots and black lines from a set at 2.3 knots. Solid lines are from TDRs beside weights and dotted lines between weights.

Streamer lines

Streamer line specifications recorded during the project are shown in Table 13. 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 lines 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, given tangles were more difficult to identify and rectify quickly.

Table 13: 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	% 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	-	poly-styrene float
Q	BNS	100	4	6	strapping	15	25	5.1	300 mm float

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.

Retaining baits at 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.

Spatial approaches to reducing bycatch

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.

Other measures

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 (MNZ 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.

Refining mitigation measures

Streamer lines

Streamer line modifications investigated during the project were as follows:

- addition of a 2 kg weight near the point at which the streamer line attached to the vessel,
- positioning of two streamer lines almost directly one above the other, and,
- strapping tape threaded through the rope that provided the 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.

- addition of gill net floats forward of the towed object
- addition of glow sticks to aerial section of the streamer line

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.

Weight spacing

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.

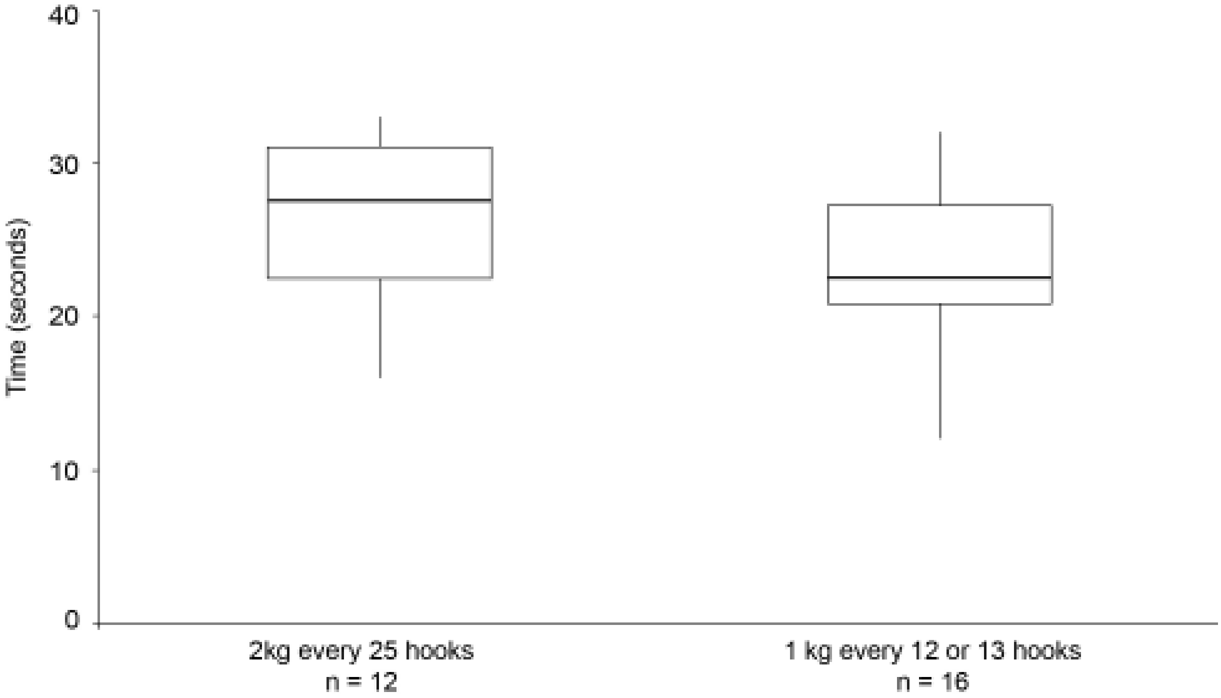


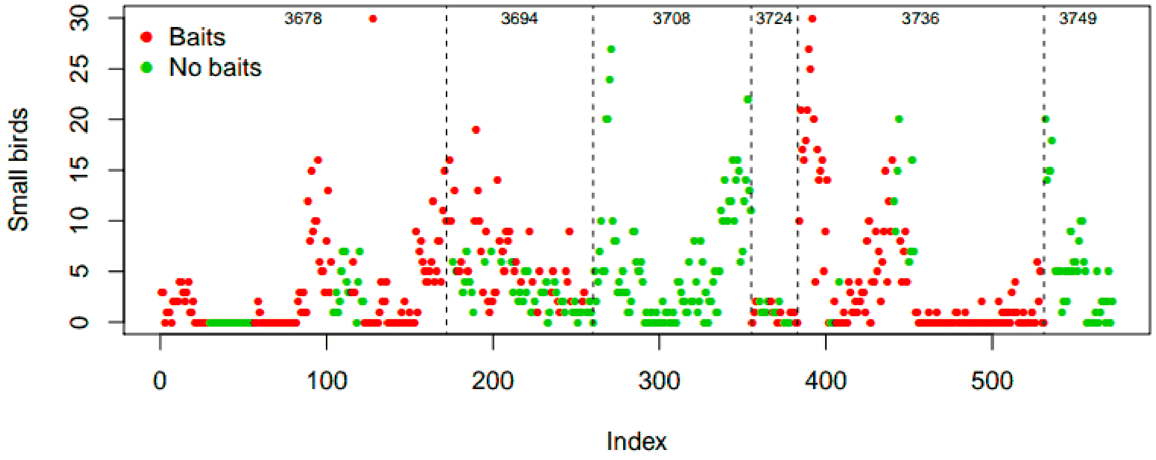
Figure 17: Box whisker plot of time time depth recorders (TDRs) took to reach 5 m depth with different weighting regimes. TDRs were placed after weights and midway between weights. Three sets were sampled for the normal weighting setup (2 kg every 25 hooks), and two sets were sampled at reduced weight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

Bait and discard retention

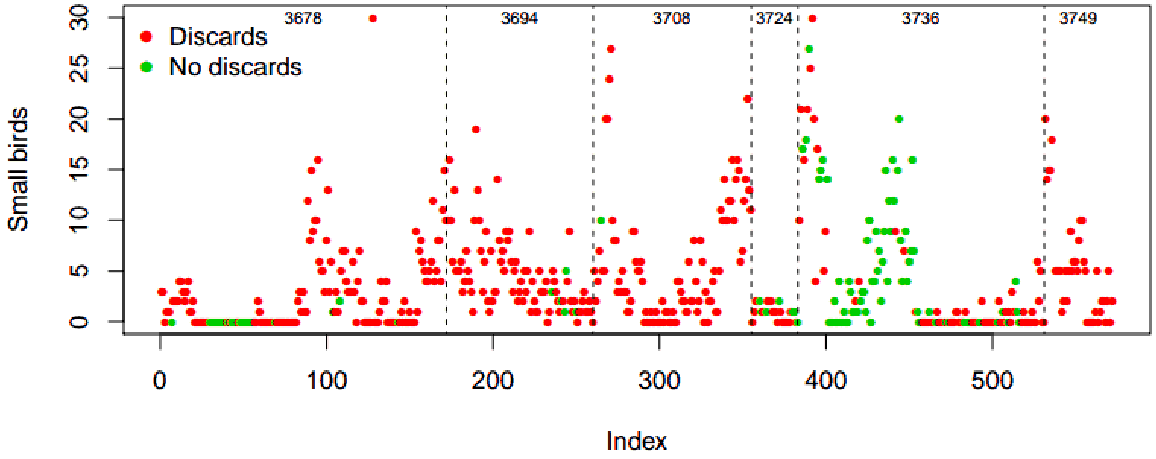
GLMs show that bait retention reduced the number of small seabirds attending fishing vessels during the project. Holding discards also reduced seabird abundance but this effect was not significant (Table 12).

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

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.



(a)



(b)

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

Exploring new mitigation measures

Retaining bait fragments at setting

The board designed to retain bait fragments at setting was deployed on five sets on one vessel.

It successfully collected bait scraps (Figure), 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 19: A close up photo of some of the bait pieces collected whilst setting 1500 hooks.

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.

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 (Figure20). 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 18).

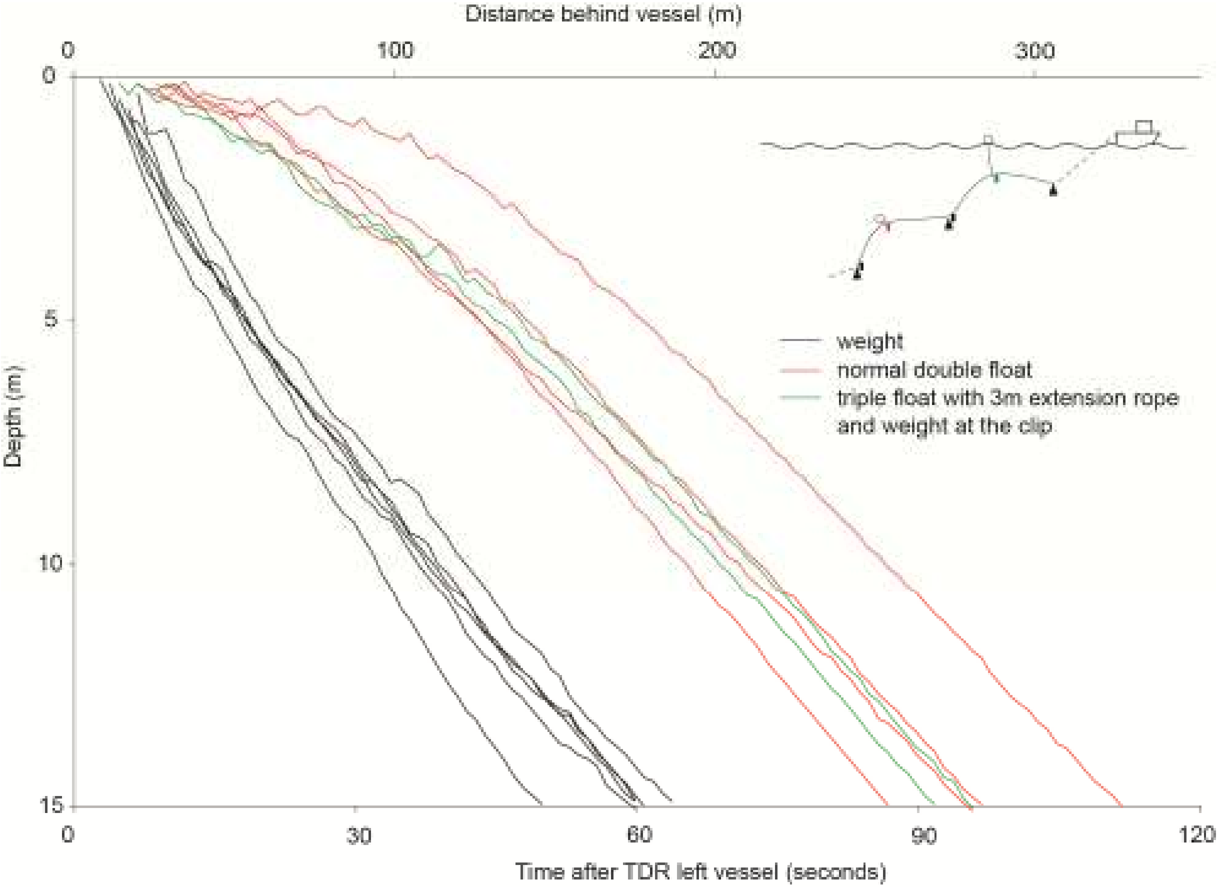


Figure 20: Time and distance versus depth for time depth recorders (TDRs) deployed on a single line beside weights, floats directly on the line and floats with 3 m rope.

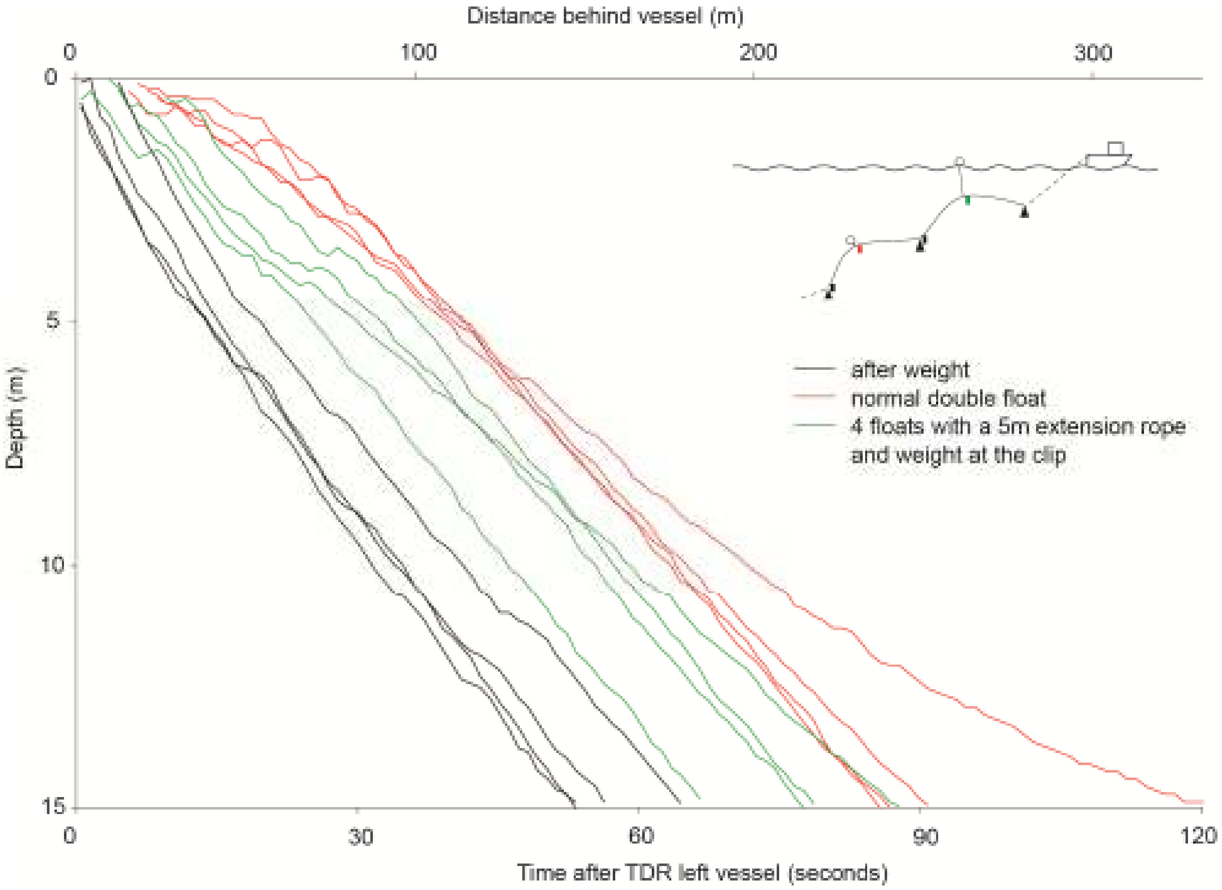


Figure 18: Time and distance versus depth for time depth recorders (TDRs) deployed on a single line beside weights, floats directly on the line and floats with 5 m rope.

There 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 19).

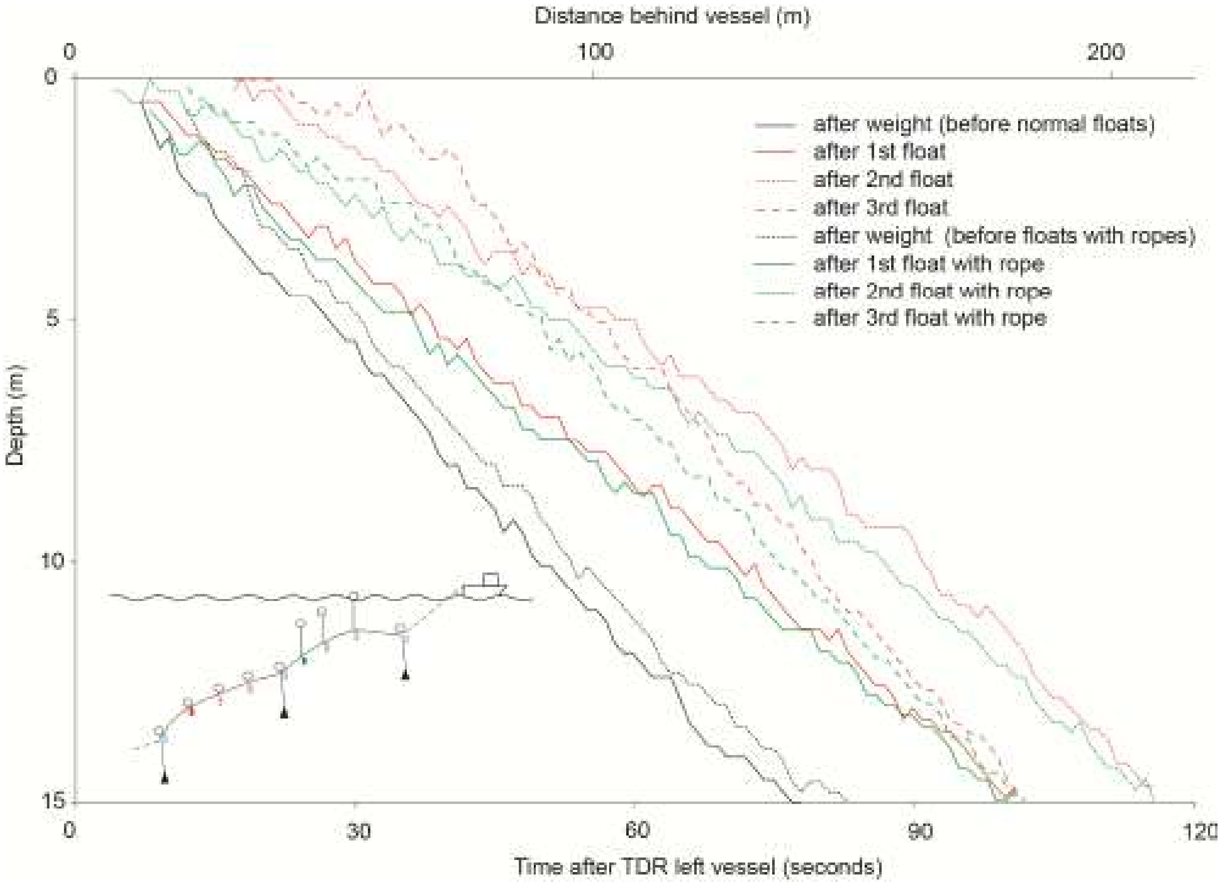


Figure 19: Time and distance versus depth for TDRs deployed on a single line beside weights, floats directly on the line, and floats with a longer rope. Data from vessel P.

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 20).

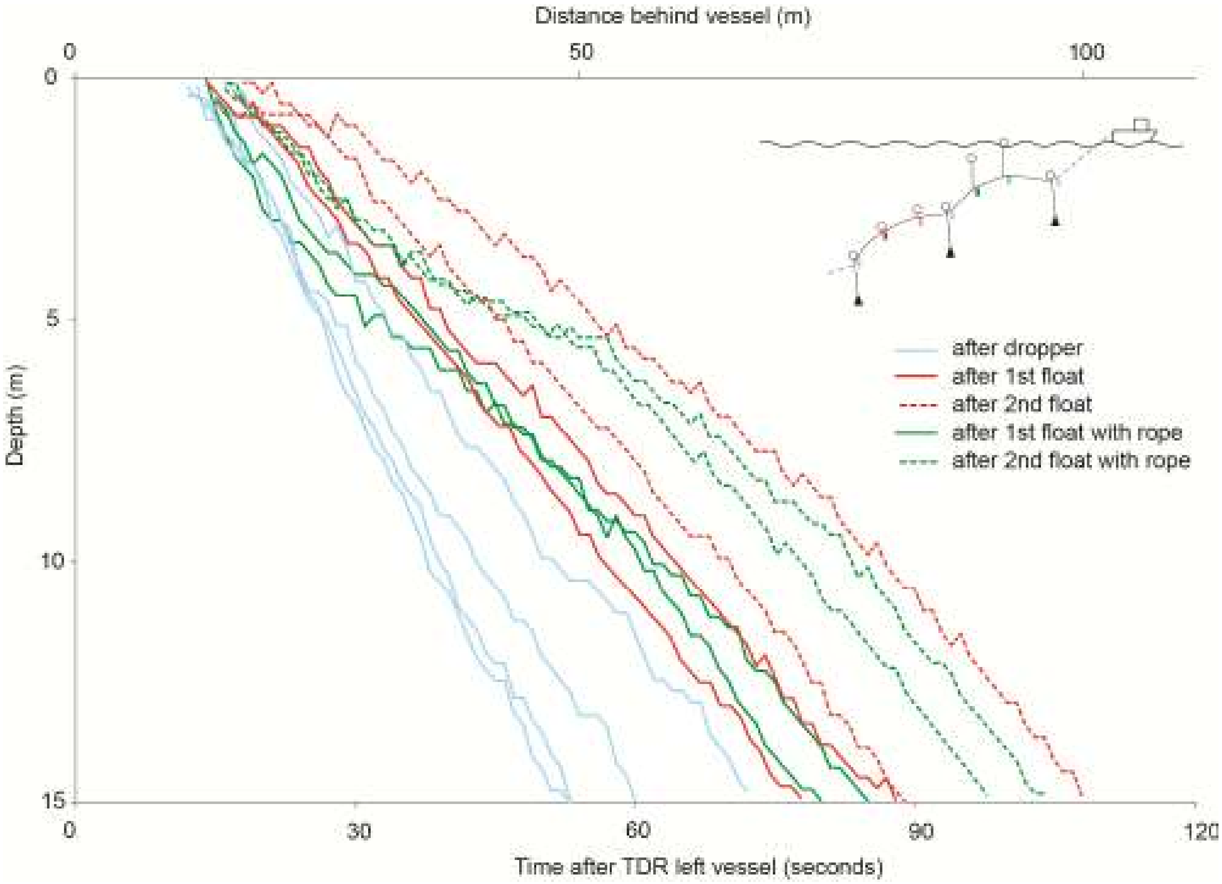


Figure 203: Time and distance versus depth for time depth recorders (TDRs) deployed on a single line beside weights, floats directly on the line, and floats with a longer rope. Data from vessel Q.

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 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.

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 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.

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 (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 demersallongline gear (0.3 m/s (BirdLife International and ACAP 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.

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 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.

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.

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.

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 and 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).

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 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.

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, night-setting is part of best practice approach to bottom longline fishing. Therefore, where setting is already conducted more than 30 minutes prior to nautical dawn, this should continue. Where morning sets occur later than that, 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 risks (e.g., the card available at: www.southernseabirds.org/f2139,115103/115103_Rec_anglers_card_website_version_updated_credits.pdf). More targeted efforts are recommended to increase awareness and foster changes in recreational fishing practice.

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.
- 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.

Acknowledgements

Many people contributed to the work described in this report. Thanks to participants in the Technical Advisory Group (I. Debski, C. Dolfing, W. Dreadon, L. Mitchell, K. Ramm, B. Sharp, J. Williamson), observers deployed (A. Blommart-Klay, S. Chalmers, S. Hornby, N. Hunia, J. Williamson), and the skippers and crews who worked cooperatively with observers at sea. Particular thanks to J. Williamson for expertise contributed during development of the data collection protocols. W. Dreadon (Whitianga Fishermen's Association) facilitated the placement of observers in that area especially in the early stages of the project. The Ministry for Primary Industries Observer Services team (A. McKay) coordinated observer placements. Data collected by observers at sea was entered by E. Edmonds, J. Marshall and T. Abraham into an interface created by R. Mansfield.

This work was funded by the Department of Conservation's Conservation Services Programme as projects MIT2011-03 and MIT2012-01, principally through a levy on the quota holders of relevant commercial fish stocks.

References

Abraham E. R., Thompson F. N. (2012a).Captures of birds in bottom longline fisheries, in the West Coast North Island area, from 2002–03 to 2010–11. Retrieved from http://data.dragonfly.co.nz/psc/v20121101/birds/bottom-longline/all-vessels/west-coast-north-island/all/, Apr 16, 2013.

Abraham E. R., Thompson F. N. (2012b). Captures of birds in bottom longline fisheries, in the Northland and Hauraki area, during the 2010–11 fishing-year. Retrieved from http://data.dragonfly.co.nz/psc/v20121101/birds/bottom-longline/all-vessels/northland-and-hauraki/2011/, Apr 15, 2013.

Abraham E. R., Thompson F. N. (2012c).Captures of birds in bottom longline fisheries, in the Bay of Plenty area, during the 2010–11 fishing-year. Retrieved from http://data.dragonfly.co.nz/psc/v20121101/birds/bottom-longline/all-vessels/bay-of-plenty/2011/, Apr 15, 2013.

Abraham E. R., Thompson F. N. (2012d).Captures of birds in bottom longline fisheries, in the East Coast North Island area, during the 2010–11 fishing-year. Retrieved from http://data.dragonfly.co.nz/psc/v20121101/birds/bottom-longline/all-vessels/east-coast-north-island/2011/, Apr 15, 2013.

Abraham, E. R.; Pierre, J. P.; Middleton, D. A. J.; Cleal, J.; Walker, N. A.; Waugh, S. M. (2009). Effectiveness of fish waste management strategies in reducing seabird attendance at a trawl vessel. Fisheries Research 95: 210-219.

Abraham, E.R.; Berkenbusch, K. N.; Richard, Y. (2010).The capture of seabirds and marine mammals in New Zealand non-commercial fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 64. 52 p.

ACAP. (2009). Species assessment: black petrel *Procellaria parkinsoni*. Agreement on the Conservation of Albatrosses and Petrels. Hobart. 10 p.

ACAP (2011). ACAP summary advice for reducing impact of demersal longlines on seabirds. Agreement on the Conservation of Albatrosses and Petrels, Hobart. Available at: http://www.acap.aq/index.php/en/bycatch-mitigation/doc_download/198-acap-review-of-mitigation-measures-and-summary-advice-for-reducing-impact-of-demersal-longlines-on-seabirds

Baker, G.B.; Frost, R. 2013. Development of the Kellian line setter for inshore bottom longline fisheries to reduce availability of hooks to seabirds Preliminary report prepared for Department of Conservation Contract 4355 MIT2011-04. Available at: www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservation-services/mit-2011-04-kellian-line-setter-development.pdf

BirdLife International and ACAP (2010). Bycatch mitigation fact-sheet 2 (Version 1).Practical information on seabird bycatch reduction measures. Demersal longline: Line-weighting - external weights. BirdLife International and the Agreement on the Conservation of Albatrosses and Petrels. Available at: www.birdlife.org/seabirds/downloads/FS_2_Demersal_LL_Line_weight_external_final.pdf

Bull, L.S. (2007). Reducing seabird bycatch in longline, trawl and gillnet fisheries. Fish and Fisheries 8: 31–56.

Cabezas, L. A.; Ruiz, J.; Yates, O; Bernal, M. (2012). The black petrel (*Procellariaparkinsoni*) in pelagic waters off northern Chile: a southern extension to the known distribution and interactions with the pelagic longline fishery. New Zealand Journal of Marine and Freshwater Research 46: 537-544.

DOC. (2011). Protected species interactions with the snapper (*Pagrus auratus*) demersal longline fishery in FMA 1.DOC Marine Conservation Services Series 7.

Goad, D. (2011). MIT2010/01 development of mitigation strategies: inshore fisheries. Research Report held by the Department of Conservation, Wellington. Available at: http://www.doc.govt.nz/publications/conservation/marine-and-coastal/conservation-services-programme/csp-reports/development-of-mitigation-strategies-inshore-fisheries/

Goad, D.; Temple, S.; Williamson, J. (2010). MIT2009/01 development of mitigation strategies: inshore fisheries. Draft Research Report held by the Department of Conservation, Wellington. Available at: http://www.doc.govt.nz/publications/conservation/marine-and-coastal/conservation-services-programme/csp-reports/development-of-mitigation-strategies-for-inshore-fisheries/

Lokkeborg, S. (2011). Best practices to mitigate seabird bycatch in longline, trawl, and gillnet fisheries - efficiency and practical applicability. Marine Ecology Progress Series 435: 285–303.

MNZ (2011). Maritime Rules Part 21: Safe Ship Management Systems. Available at: http://www.maritimenz.govt.nz/Rules/Rule-documents/Part21-maritime-rule.pdf

MNZ (2012). Safe Seas, Clean Seas: 42. Available at:www.maritimenz.govt.nz/Publications-and-forms/Safe-Seas-Clean-Seas/SSCSDec12.pdf.

Melvin, E.F.; Heinecken, C.; Guy, T.J. (2009). Tori line designs for pelagic tuna longline fisheries: South Africa. Report of work under special permit from the Republic of South Africa Department of Environmental Affairs and Tourism, Marine and Coastal Management, Pelagic and High Seas Fishery Management Division (29 September 2008). Available at : http://wsg.washington.edu/mas/pdfs/ToriLinesLR.pdf

New Zealand Government. (2008). Fisheries (Seabird Sustainability Measures - Bottom Longlines) Notice 2008 (No. F430). New Zealand Gazette 31: 712–713.

New Zealand Government. (2010). Fisheries (Seabird Sustainability Measures - Bottom Longlines) Notice 2010 (No. F541). New Zealand Gazette 76: 2120–2122.

Papworth, W. (2010). Review of Seabird Bycatch Mitigation Measures for Pelagic Longline Fishing Operations.WCPFC-SC6-2010/EB-WP-04. Western and Central Pacific Fisheries Commission Scientific Committee, Sixth Regular Session: 10-19 August 2010 Nuku'alofa, Tonga.

Petersen, S.L, Honig, M., Wissema, J., Cole, D. (2005). Optimal link sink rates: mitigating seabird mortality in the South African longline fisheries. Mitigation report: BCLME, BirdLife South Africa.

Pierre, J. P., Abraham, E. R., Cleal, J. and Middleton, D. A. J. (2012).Controlling trawler waste discharge to reduce seabird mortality. Fisheries Research 131-133: 30-38.

Pierre, J. P.; Debski, I. (2013). SBWG5-22-Rev-1: Use of lethal and non-lethal approaches for testing seabird bycatch reduction methods. Fifth Meeting of the Seabird Bycatch Working Group La Rochelle, France, 1-3 May 2013.Agreement on the Conservation of Albatrosses and Petrels. Available at: www.acap.aq/index.php/en/working-groups/doc_download/2046-sbwg5-doc-22-rev-1-use-of-lethal-and-non-lethal-approaches-for-testing-seabird-bycatch-reduction-methods

Pierre, J. P.; Norden, W. S. (2006).Reducing seabird bycatch in longline fisheries using a natural olfactory deterrent. Biological Conservation 106: 406-415.

Ramm, K. (2010). Conservation Services Programme observer report, 1 July 2008 to 30 June 2009.Final Report, Department of Conservation, Wellington, New Zealand.

Ramm, K. (2012). Conservation Services Programme observer report, 1 July 2009 to 30 June 2010.Final Report, Department of Conservation, Wellington, New Zealand.

Richard, Y.; Abraham, E.R. (2013).Application of Potential Biological Removal methods to seabird populations. New Zealand Aquatic Environment and Biodiversity Report No. 108. 30 p.

Robertson, G. G. (2000). Effect of line sink rate on albatross mortality in the Patagonian Toothfish longline mortality. CCAMLR Science 7:133-150.

Thalmann, S. J.; Baker, G. B.; Hindell, M.; Tuck, G.N. (2007). Longline fisheries and foraging distribution of flesh-footed shearwaters in eastern Australia. Journal of Wildlife Management 73: 399-406.

Appendix 1

Summary of sink times and distances astern

Table A1. Time taken for TDRs to reach 7 m and 16 m depth for setups detailed in Table 11, median values shown with maxima and minima in brackets, n= number of observations. All sets are targeting snapper.

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

Table A2. Time taken for TDRs to reach 7 m and 16 m depth for setups detailed in Table 12, median values shown with maxima and minima in brackets , n = number of observations.

Vessel / setup	**F1**	**F2**	**G1**	**G2**	**H1**	**J1**	**J1**	**K**	**P1**	**Q1**
Target species	LIN	LIN	BNS	BNS	BNS	LIN	HPB	HPB/ BNS	BNS	BNS
n	30	10	25	10	45	68	12	12	35	9
Distance astern at 7 m	43 (23 - 53)	36 (29 - 40)	106 (6 - 203)	121.5 (8 - 328)	45 (16 - 115)	53 (37 - 74)	68.5 (36 - 88)	75 (53 - 109)	67 (30 - 104)	42 (30 - 69)

Distance astern at 16 m	78.5 (50 - 98)	69 (59 - 73)	140 (13 - 263)	173.5 (17 - 406)	94 (39 - 236)	101.5 (74 - 140)	124 (83 - 153)	141.5 (116 - 192)	125 (65 - 191)	75 (56 - 113)

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

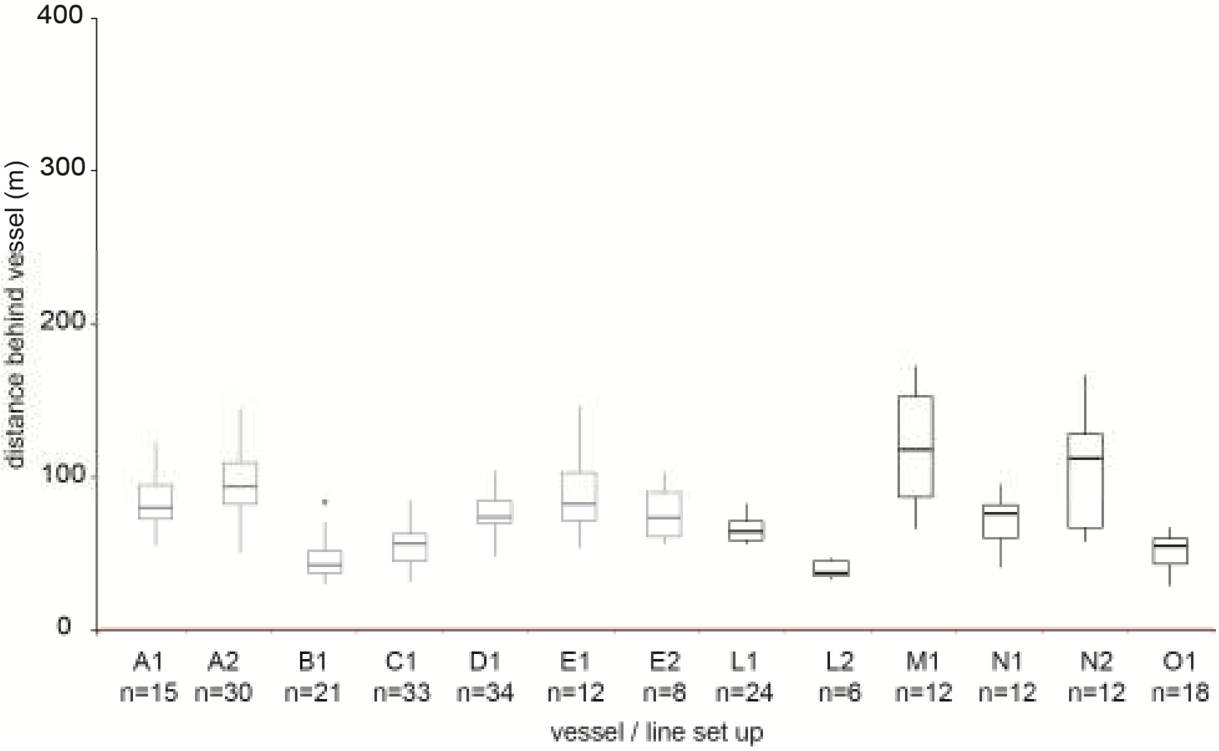


Figure A1: Box and whisker plot of distance behind the vessel time depth recorders reached 5 m depth for line setups detailed in Table 11.

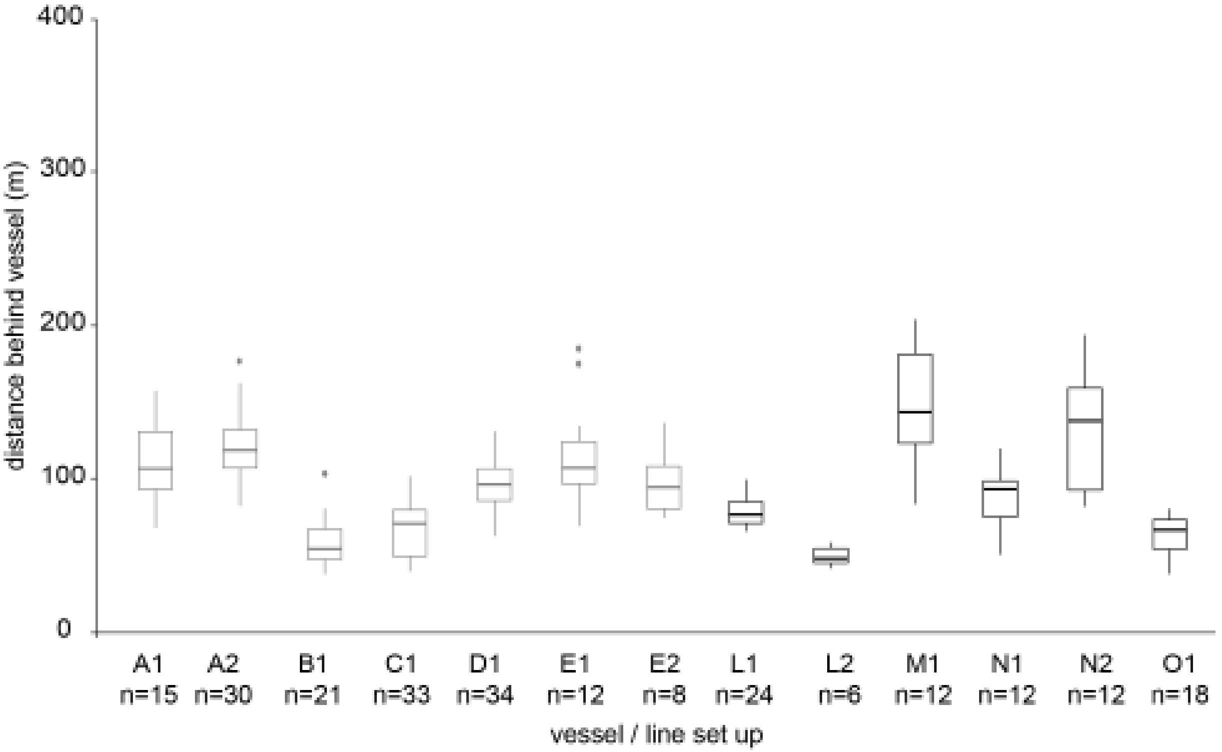


Figure A2: Box and whisker plot of distance behind the vessel time depth recorders reached 7 m depth for line setups detailed in Table 11.

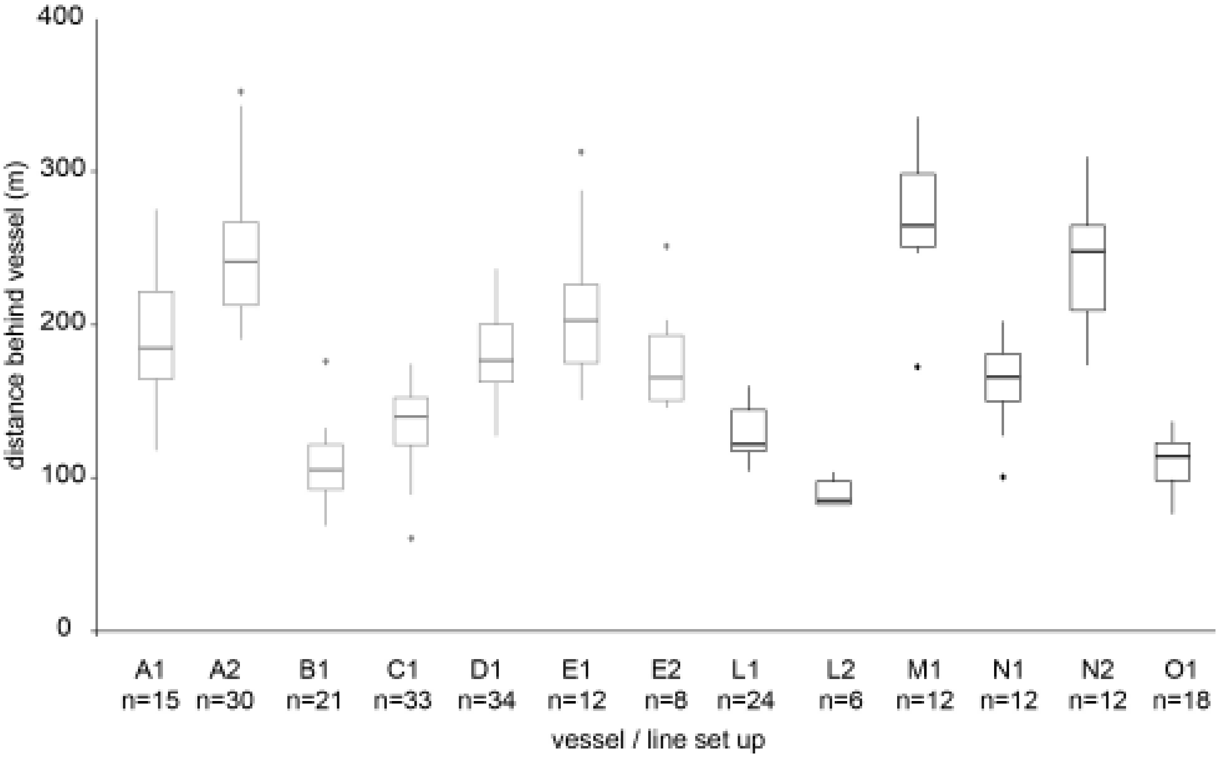


Figure A3: Box and whisker plot of distance behind the vessel time depth recorders reached 15 m depth for line setups detailed in Table 11.

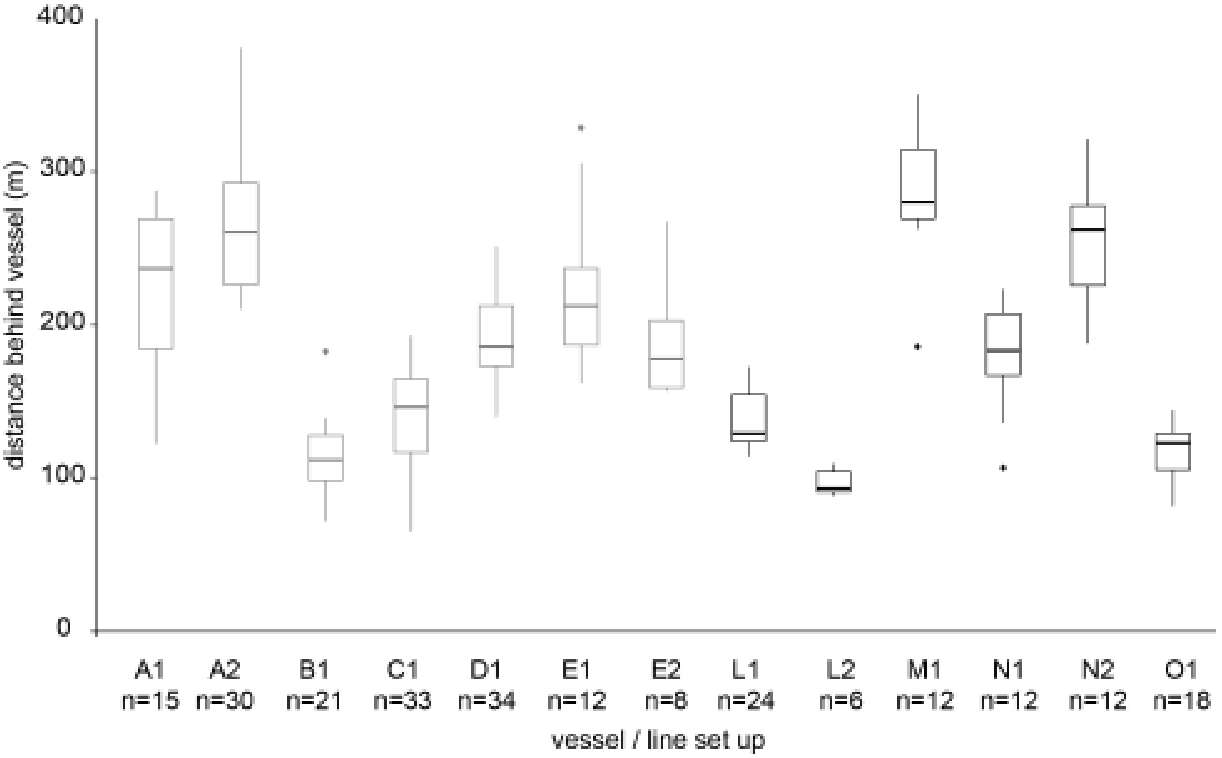


Figure A4: Box and whisker plot of distance behind the vessel time depth recorders reached 16 m depth for line setups detailed in Table 11.

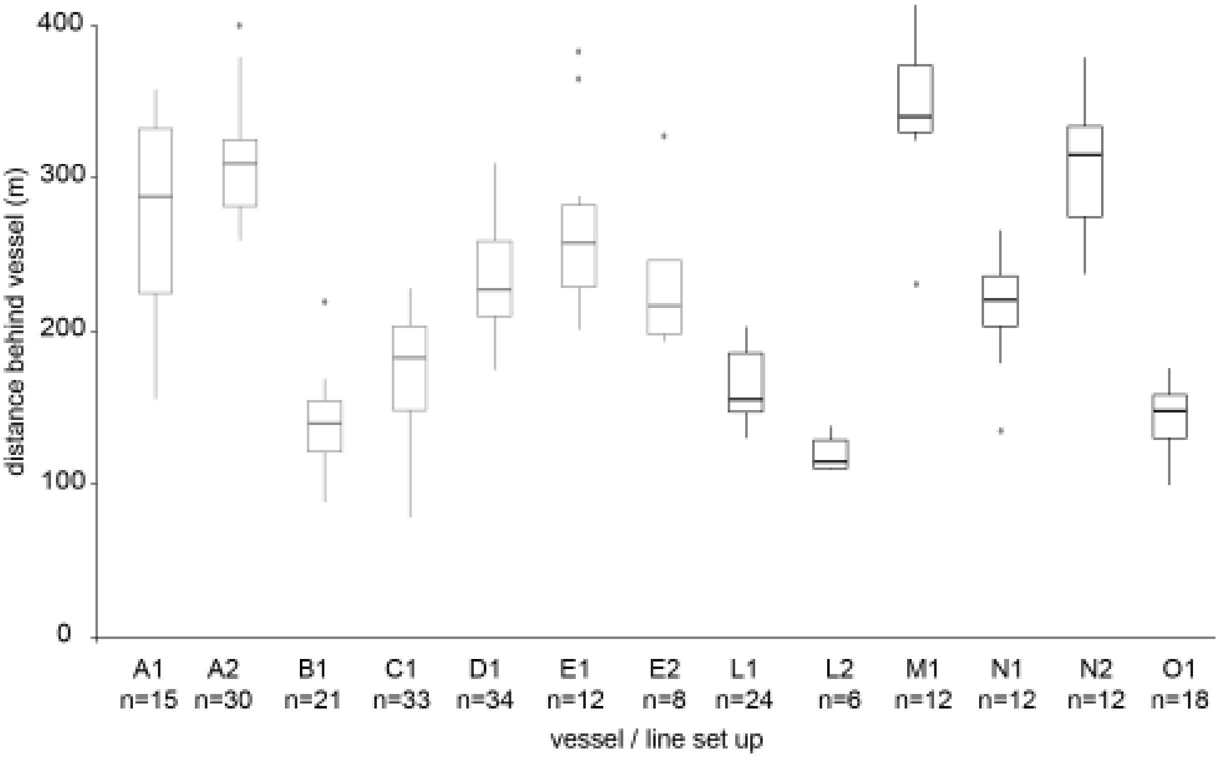


Figure A5: Box and whisker plot of distance behind the vessel time depth recorders reached 20.1 m depth for line setups detailed in Table 11.

Box whisker plots of the distances behind the vessel TDRs reached various depths for bluenose, ling, hapuku and bass target sets.

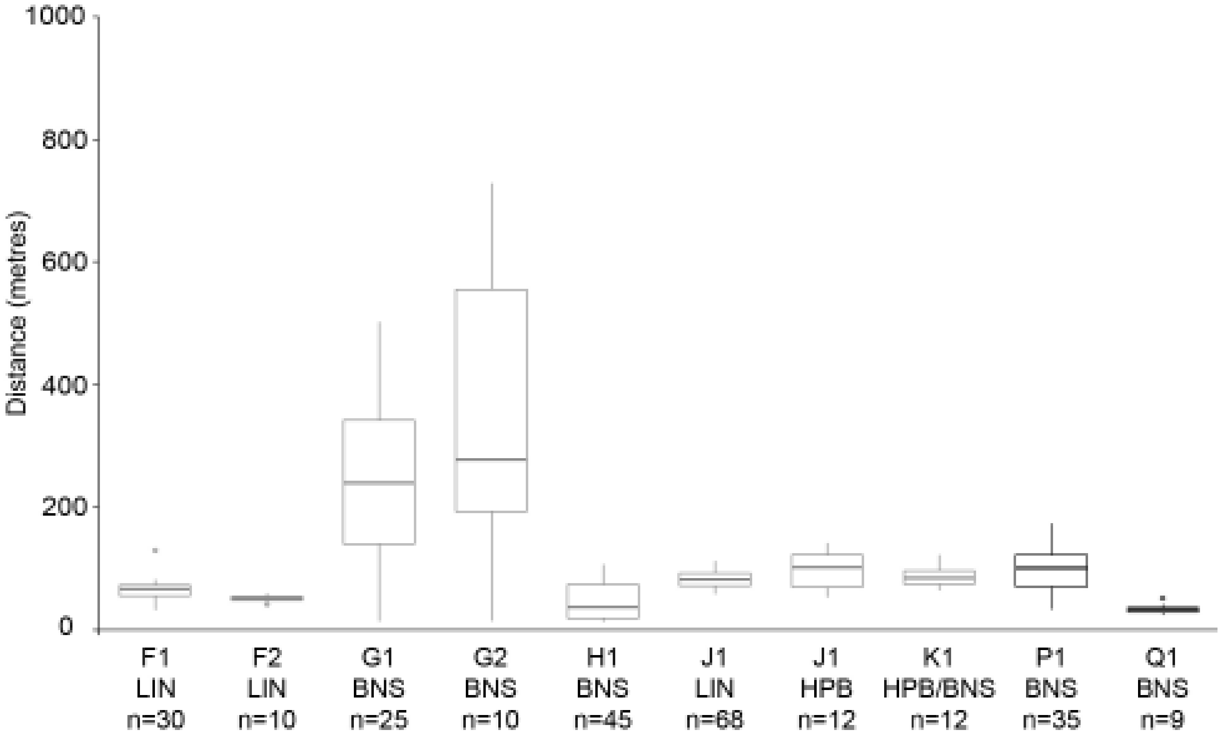


Figure A6: Box and whisker plot of distance behind the vessel time depth recorders reached 5 m depth for line setups detailed in Table 12.

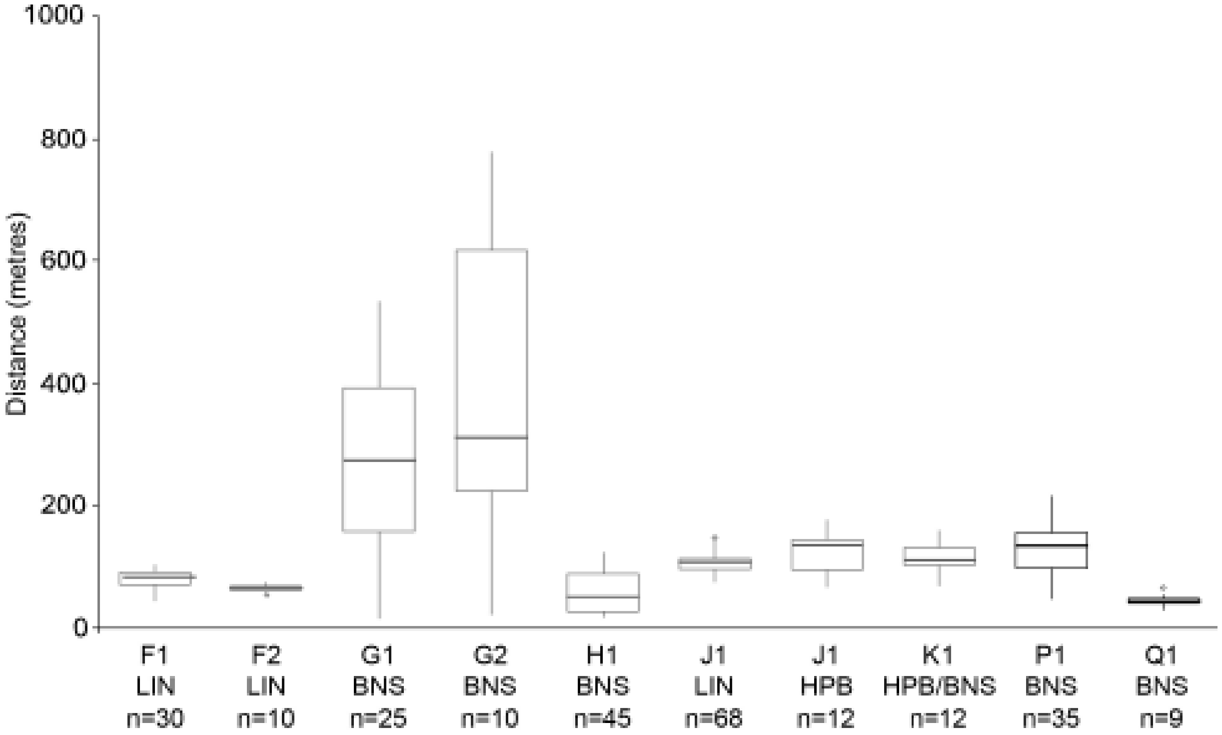


Figure A7: Box and whisker plot of distance behind the vessel time depth recorders reached 7 m depth for line setups detailed in Table 12.

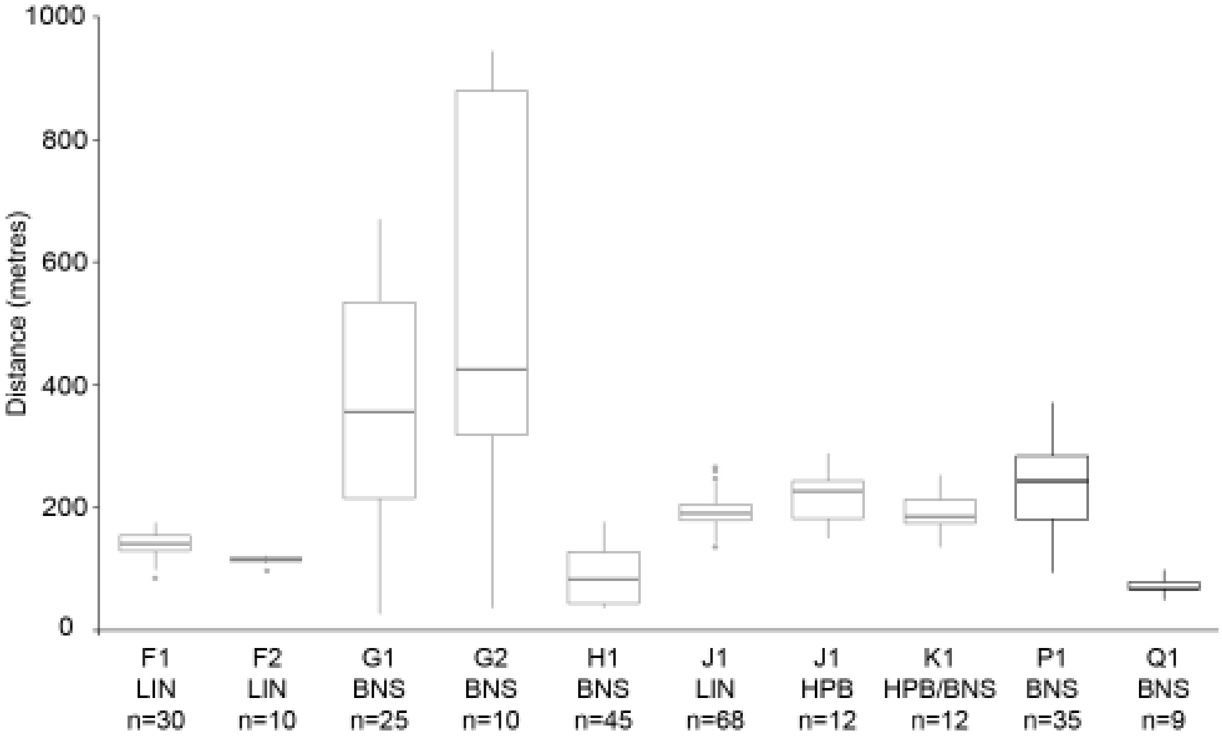


Figure A8: Box and whisker plot of distance behind the vessel time depth recorders reached 15 m depth for line setups detailed in Table 12.

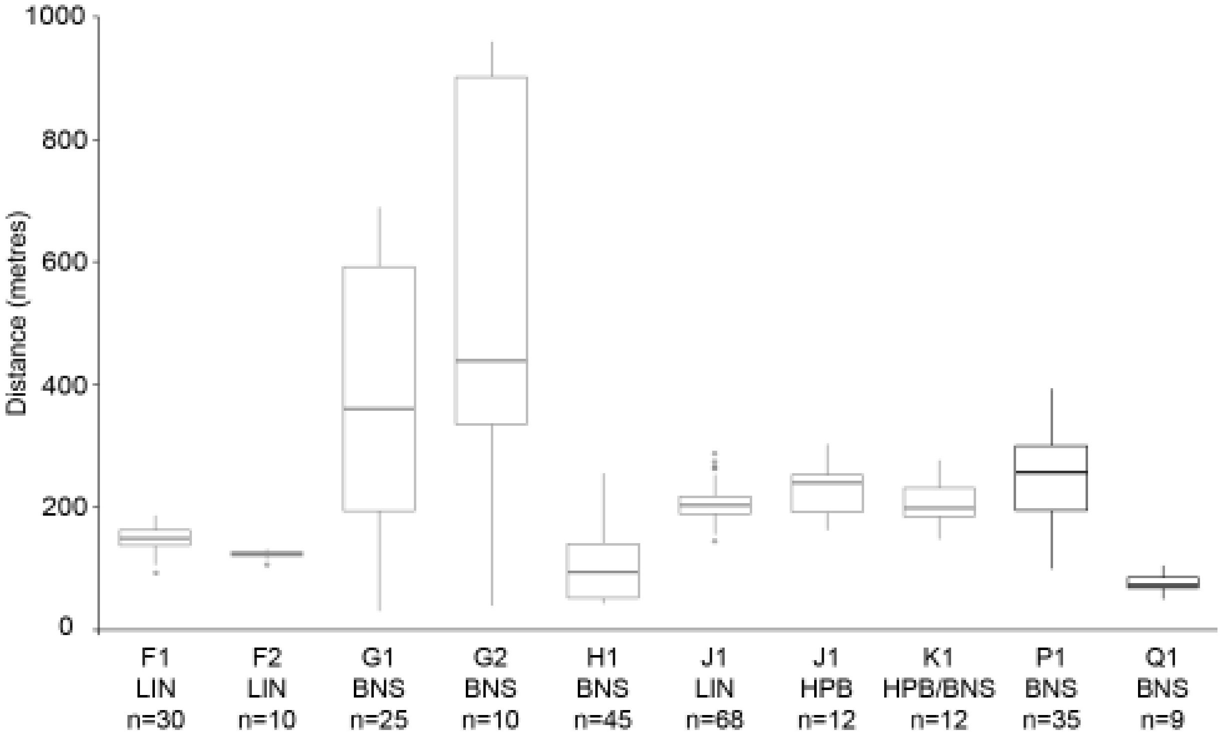


Figure A9: Box and whisker plot of distance behind the vessel time depth recorders reached 16 m depth for line setups detailed in Table 12.

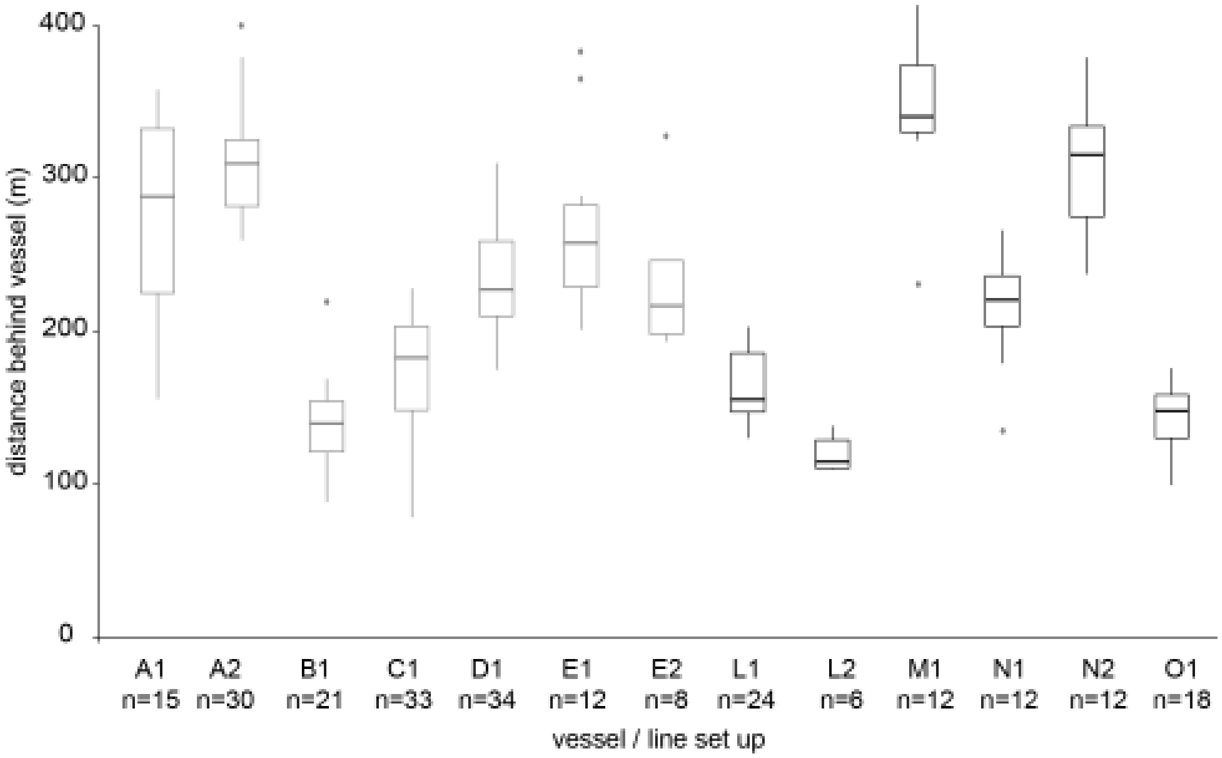


Figure A10: Box and whisker plot of distance behind the vessel time depth recorders reached 20.1 m depth for line setups detailed in Table 12.

TDR deployment details

Table A3. 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 measured
	SNA	weights only	aw, 1/2 aw	10	2 different speeds
M	SNA	weights only	aw, 1/2aw, 3/4aw	18	normal practice didn't hit all positions on line ok
	SNA	weights only	aw, 1/2aw, 3/4aw	18	didn't hit all positions on line ok, testing reduced weight spacing

	SNA	weights only	aw, 1/2aw, 3/4aw	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, 1/2ad, 3/4ad, 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, 3/4ad.	18	normal, didn't hit positions on line ok
P	BNS	6kg, 2 floats, 6kg, 2 floats, 12kg, 2 floats….	aw, af1, af2	9	normal practice
	BNS	6kg, 3 floats, 12kg, 3 floats…	aw, af1, af2, af3, af2*, af3*	6	testing float-ropes
	BNS	6kg, 3 floats, 12kg, 3 floats…	aw, af1**, af2** af3**	4	testing ropes and weight
	BNS	6kg, 3 floats, 12kg, 3 floats…	aw, af1, af2, af3	5	normal practice

	BNS	6kg, 2 floats, 12kg, 3 floats….	aw, af1, af2, af3	7	normal practice
	BNS	6kg, 2 floats, 12kg, 3 floats….	aw, af1, af2, af3, af1**, af2**, af3**	21	testing ropes and weight
	BNS	8kg, 3 floats, 6kg 2 floats, 12kg, 3 floats…	aw, af1, af2, af1**, af2**, af3**	8	testing ropes and weight
	BNS	14kg, 2 floats, 6kg, 3 floats, 12kg…	aw, af2, af3, af1**, af2**, af3**	7	testing ropes and weight
Q	BNS	6kg, float, float…	ad, af1, af2, af1*, af1**, af2*, af2**	24	testing ropes and weight

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.

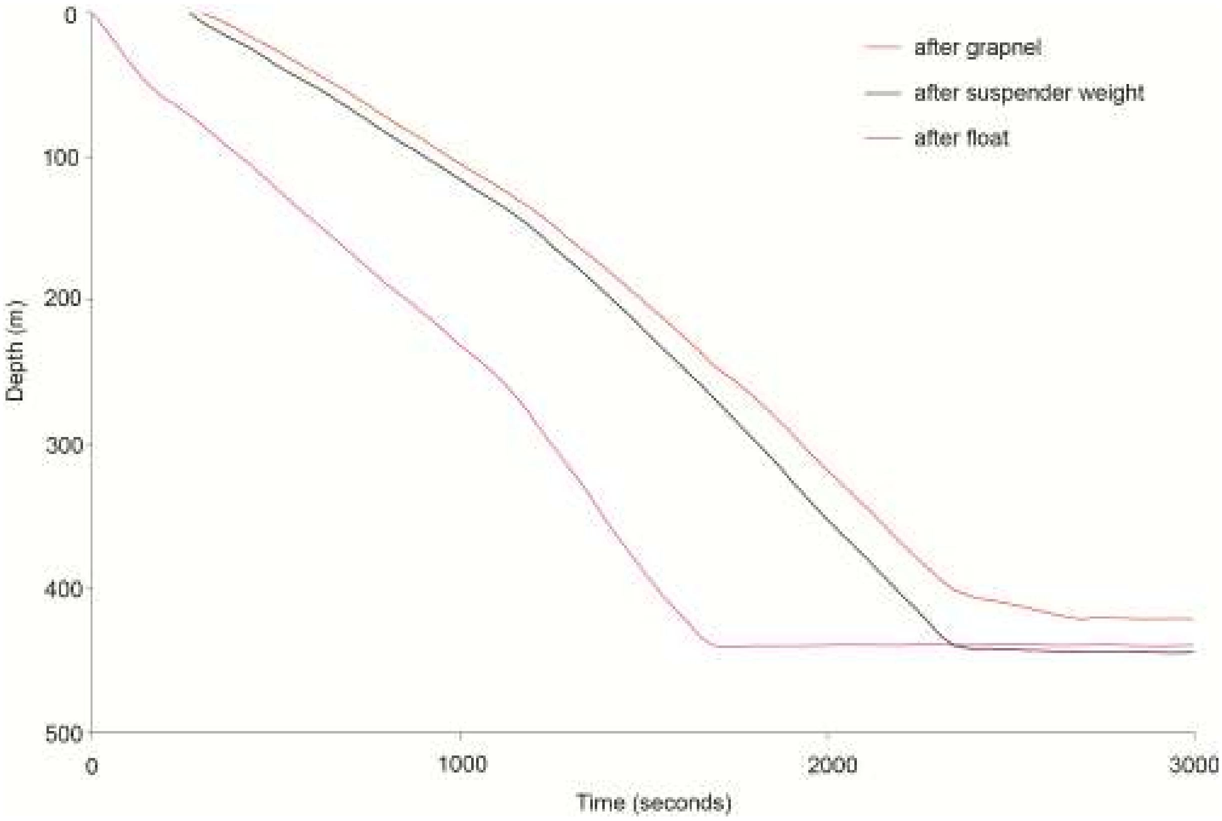


Figure A11: Time versus depth plot from TDRs placed on a set from vessel P. Time starts when the grapnel was deployed.

The first grapnel over at the start of the line initially sinks quickly (Figure A11). 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 1250 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 1675 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.

TDR positioning to estimate slowest sink rates

Weight, ½ and ¾ positions

Observations at the set have noted 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 ¾ 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 ¾ 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 2 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. On vessel O, TDRs at the midway position sank slowest. None of the sets sampled at both half and ¾ positions consistently showed the ¾ position sinking slowest.

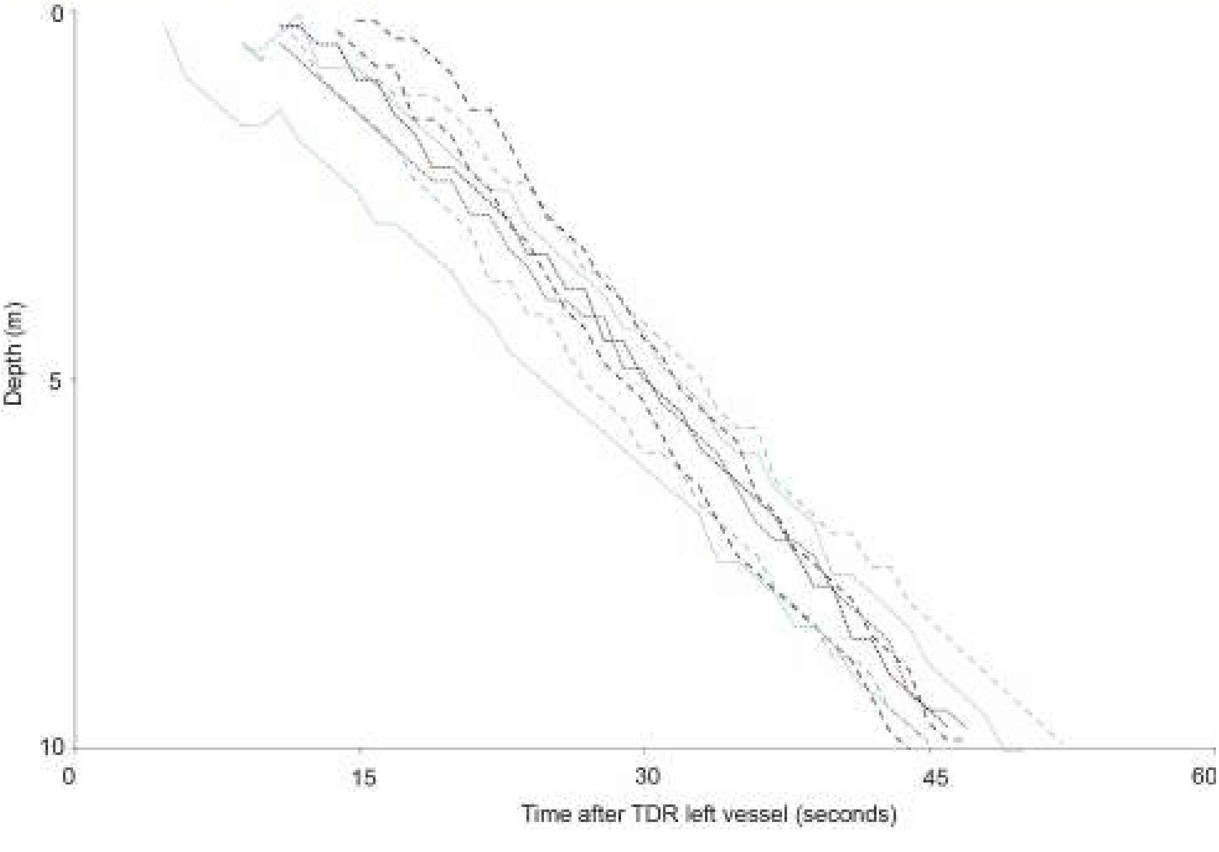


Figure A12: Plot of time versus depth for time depth recorders (TDRs) halfway (dotted lines) and ¾ way (dashed lines) after droppers (blue lines) and weights (black lines). Data from vessel N.

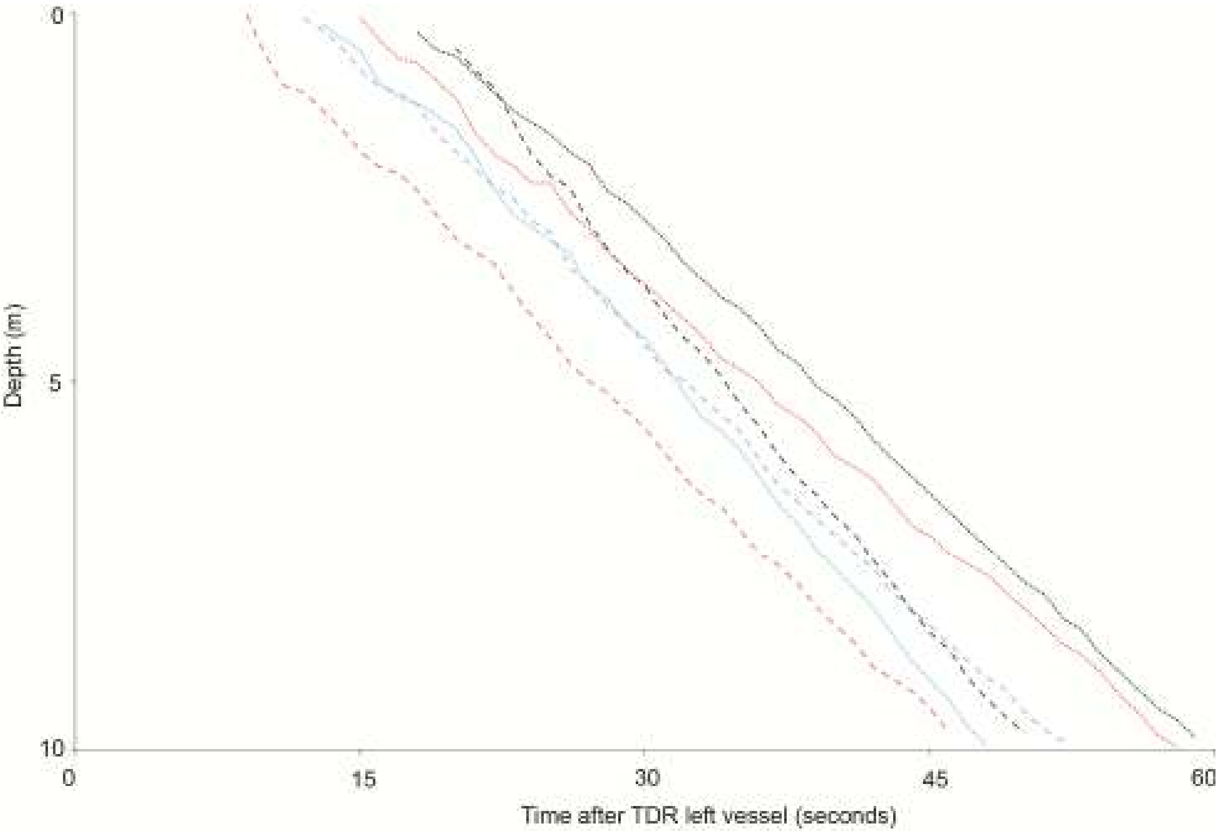


Figure A13: Plot of time versus depth for TDRs halfway (dotted lines) and ¾ way (dashed lines) after weights. Consecutive pairs of TDR are shown in the same colour. Data from vessel O.

It follows that on some vessels and setups with larger weight spacing the ¾ 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 ¾ position with TDR placement proved difficult and overall success rate was around 50%, varying from 0-100% per set.

Case studies

Vessel L

This vessel 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 (Table 11, Figure 6). 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

Vessel M worked the least weight per 100 m of line and had the gear sinking to 10 m farthest behind the vessel (Table 11, Figure 6). 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.