MIT 2010/01 Development of mitigation strategies: inshore fisheries

Research Report

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Abstract

A survey was carried out to characterise the inshore bottom longline fishery on the southeast coast of the north island, and to discuss seabird interactions and mitigation measures with skippers. Vessels worked either an automatic or manual ‘clip on’ longline system. In both cases target fish species determined line configuration, specifically the sequence of floats and weights added to the mainline. Night-setting and tori lines were the most commonly employed mitigation measures, but were not used by all vessels or for all sets.

Time depth recorders (TDRs) were used to measure sink rates of bottom longlines on four observed vessels to quantify the availability of hooks to seabirds. For 3 vessels working ‘clip on’ gear, lines generally sank to 5 m within 60 s and 100 m behind the vessel and to 15 m within 120 s and 250 m behind the vessel. Sink times for one autoline vessel showed greater variation, with maximum sink times considerably longer than the ‘clip on’ vessels. Line set ups with multiple floats between weights, and those with the largest weight spacing produced the most variation in, and slowest, sink rates. The weight and flotation added to the line did not fully predict sink rates Setting speed and line tension helped to explain differences.

Recommendations on how to increase sink rate include the use of rope extensions for subsurface floats, and minimising line tension when possible. Further reducing the availability of hooks to seabirds may be possible by working with skippers to trial different weighting regimes to increase sink rates without adversely affecting fishing operations. Setting speed influenced how far behind the vessel TDRs sank to 5, 10 and 15 m depth and should be considered in conjunction with to tori line length.

1 Introduction

Seabirds have been shown to interact with, and are incidentally killed during, bottom longline fishing operations in New Zealand waters (Rowe 2009, Ramm 2011, Abraham et al. 2010).

A recent risk assessment by Richard et al. (2011) estimated that bottom longliners less than 34m targeting bluenose (*Hyperoglyphe antarctica*)potentially killed 1380 seabirds per year (95% C.I. 529-2870) and those targeting species other than snapper (*Pagrus auratus*) or bluenose potentially killed 1670 seabirds (95% C.I. 957-2890). These fisheries have experienced low levels of observer coverage to date (Rowe 2009, Ramm 2011) and overlap with the range of some particularly vulnerable seabird species, notably the black petrel, flesh-footed shearwater and several albatross species (Rowe 2010, NABIS 2010, IUCN 2010).

Mitigating seabird bycatch has been the subject of much discussion (e.g. Bull 2007, Lokkeborg 2008) and it is generally accepted that best practice involves a combination of mitigation measures that are tailored to suit each fishery (FAO 2009).

Legislation requiring bottom longliners to use mitigation measures is in place (MFish 2010), although the degree of compliance is not known (Rowe 2010). These measures include tori lines, night setting and line weighting for daylight sets.

Measuring the sink rate of longlines allows estimation of the temporal and spatial availability of baited hooks to seabirds. It can also help identify any increase in sink rate resulting from different line configurations, line weighting, line tension or other aspects of the shooting operation (Robertson et al. 2003, Robertson et al. 2008, Smith 2001). Sink rates have never been measured on vessels targeting bluenose. These vessels typically employ more flotation on the line than vessels targeting species such as ling and are therefore likely to have slower sink rates (Rowe 2010).

The aims of this project were to expand on the work reported in Goad et al. 2010 to cover vessels fishing in Fisheries Management Area 2 (FMA 2, shown in Fig. 1) particularly to:

> Survey fishers operating vessels fishing bottom longlines in FMA 2 to discuss fishing operations and seabird mitigation and to;
>
> Investigate the sink rates of bottom longlines on vessels carrying government observers.

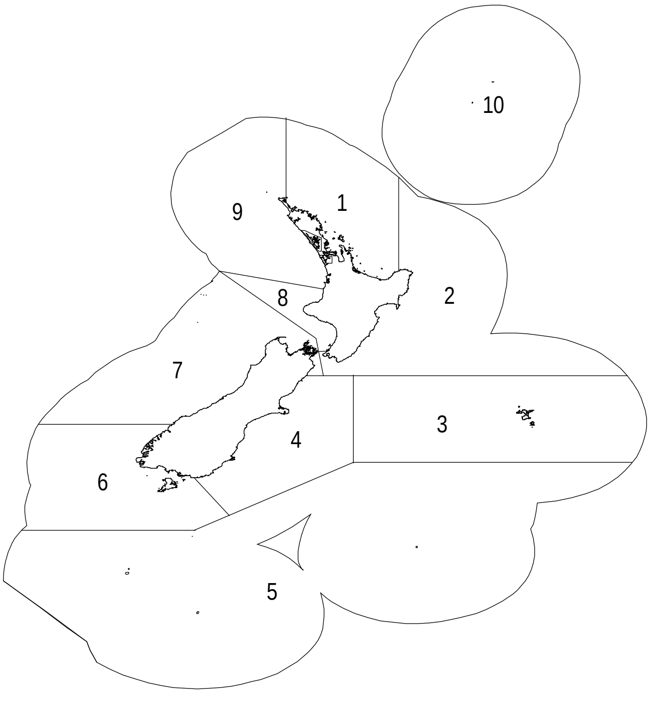

Figure 1. Fisheries management areas

2 Survey of fishers

2.1 The FMA 2 bottom longline fishery

Ling *(Genypterus blacodes)*, bluenose and hapuku / bass *(Polyprion oxygeneios, P. americanus)* were the most commonly targeted fish species, accounting for approximately 97% of the effort (Table 1). All vessels recorded more than one target species, and a total of 32 vessels recorded some effort in the period April 2010 to March 2011.

Table 1. Fishing effort by target species for inshore vessels fishing bottom longlines in FMA 2 over the year April 2010 to March 2011. For the purpose of this study 'inshore' is defined as fisheries carried out by vessels less than 36 m in overall length. 'Other' species included blue cod (*Parapercis colias)*, alfonsino *(Beryx splendens, B. decadactylus)*, tarakihi *(Nemadactylus macropterus, Nemadactylus sp.)* and one set with no target recorded.

Target Species	Number of sets	Percentage of sets	Number of hooks	Percentag e of hooks	Number of boats
Bluenose *(Hyperoglyphe antarctica)*	1761	48.8	3438342	56.7	22
Ling *(Genypterus blacodes)*	1336	37.0	1872074	30.9	24
Hapuku / bass *(Polyprion oxygeneios, P. americanus)*	439	12.2	644090	10.6	21
School shark *(Galeorhinus galeus)*	36	1.0	39050	0.6	7
Ribaldo *(Mora moro)*	27	0.7	55704	0.9	1
Other	8	0.2	9550	0.2	6
Total	3607		6058810		

The number of vessels and number of hooks targeting bluenose shows a peak in the summer months and effort for ling peaks in the spring (Fig. 2).

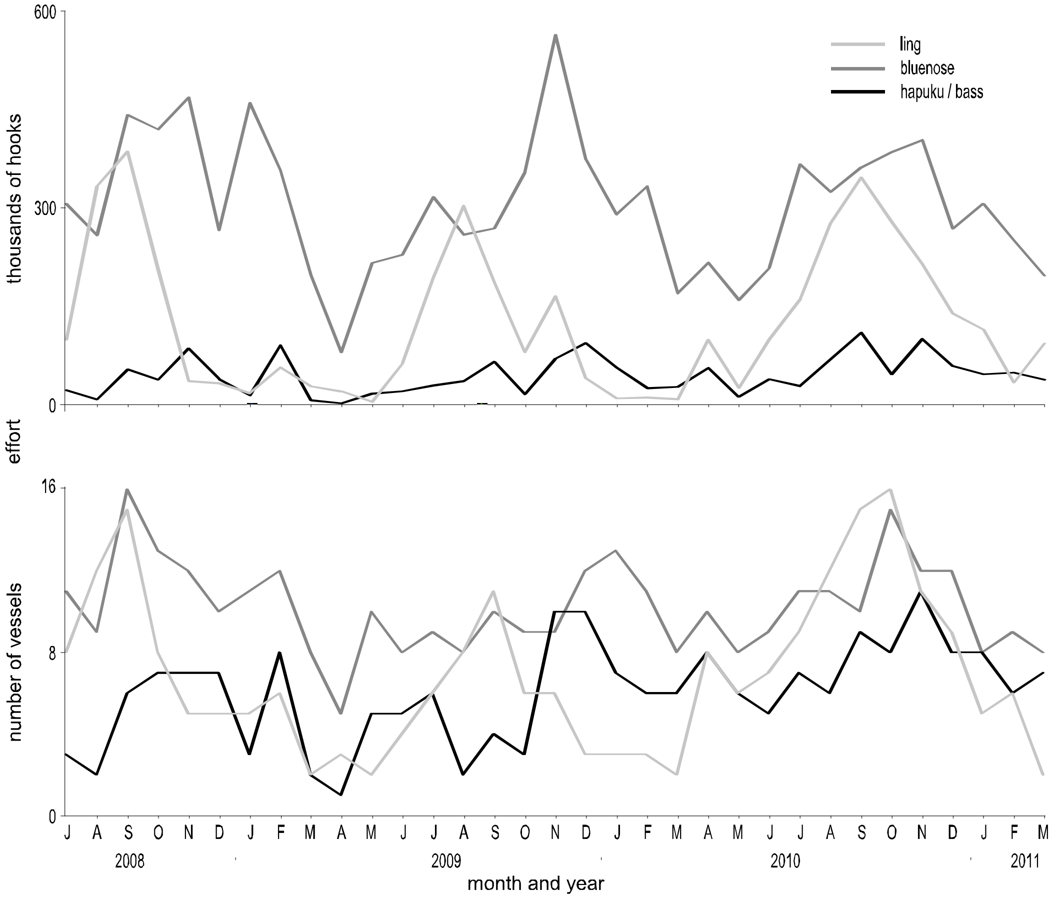

Figure 2. Number of hooks set and number of vessels recording some effort by month for vessels fishing bottom longlines in FMA 2 over the period July 2008 to March 2011.

Seasonal changes in effort can be attributed to several factors including:

- Vessels targeting different species at different times of the year, driven by market demand or because a given species is easier to catch at certain times of the year.
- Vessels spending a different portion of their time fishing in FMA 2 at different times of the year, for example vessels shifting effort targeting ling from FMA 2 to 3 around October.
- Poorer weather over the winter months limiting fishing opportunities.
- Vessels fishing using different methods, for example several surface longliners switch to bottom longlining around August.

Although the amount of effort varies with season the spatial distribution of effort for both bluenose and ling is reasonably consistent during and out of the breeding season for black petrels (Figs. 3 and 4). Concentration of effort in particular statistical areas is likely to be driven by a combination suitable fishing grounds, annual catch entitlement (ACE) availability and the most economic areas in which to catch fish.

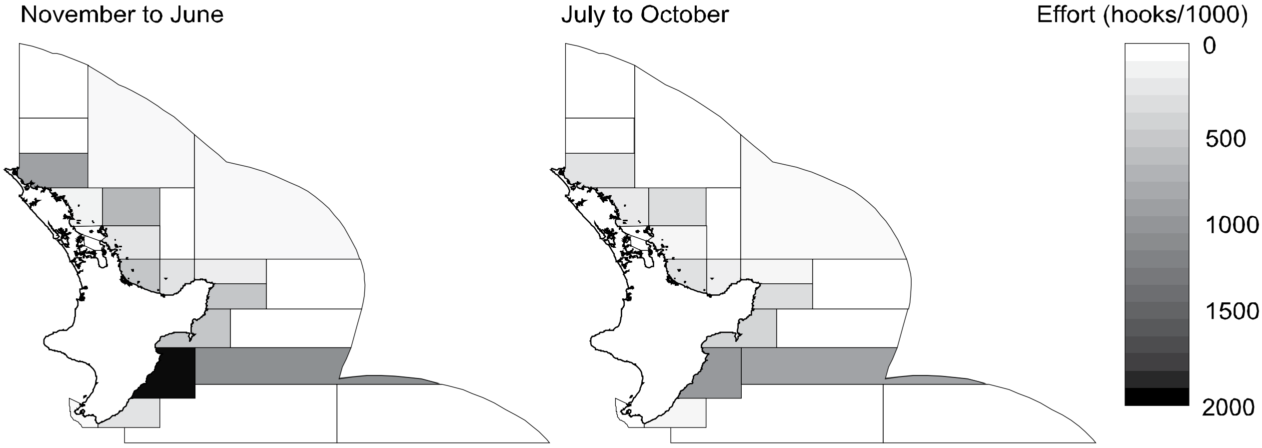

Figure 3. Spatial distribution of effort targeting bluenose by statistical area for Novemeber to June (black petrel breeding season) and July to October.

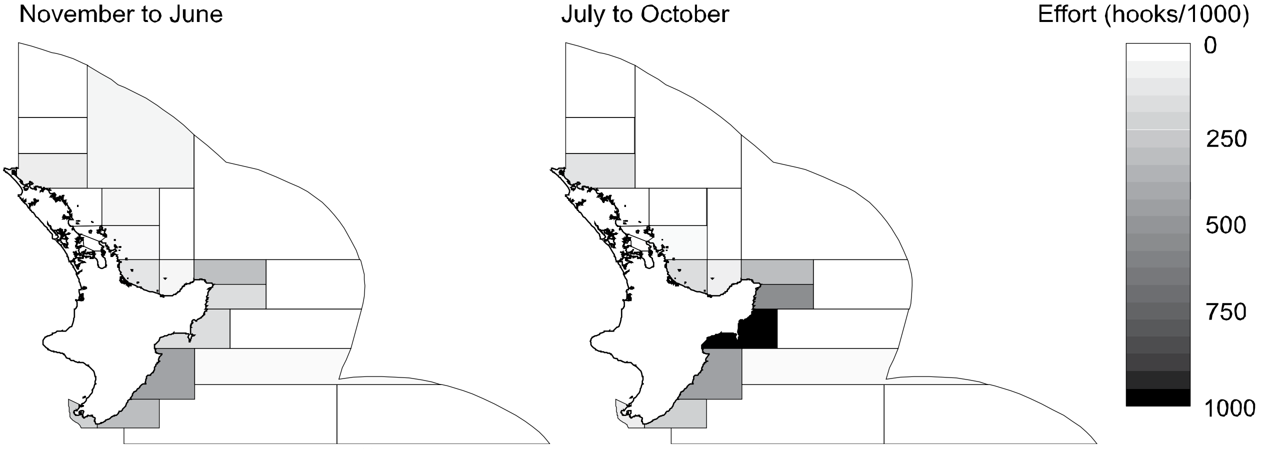

Figure 4. Spatial distribution of effort targeting ling by statistical area for Novemeber to June (black petrel breeding season) and July to October.

Prior to the 2010/2011 fishing year observer coverage on bottom longliners in FMA2 has been low (Table 2).

Table 2. Effort and observer coverage on bottom longline vessels fishing in FMA2. Data from CSP observer reports.

Year	Effort days or (lines)	Observed days or (lines)
2004/05	952	7
2005/06	855	0
2006/07	994	0
2007/08	(2443)	(62)
2008/09	(4225)	0
2009/10	(2520)	0

2.2 Methods

A combination of port visits and telephone calls were used to contact skippers of vessels who had fished bottom longlines in FMA 2 during the year April 2010 to March 2011. Fishing practices, seabird mitigation, and seabirds encountered were discussed, using the questions described in Goad et al. (2010) (Appendix 1) as the basis for the survey. Conversations ran a natural course and although all topics were covered not all boxes were necessarily filled in for every vessel, often because the information was not to hand. More time was available on observed vessels and some information gathered by observers is included here for completeness, both from trips observed in the year ending June 2011 and in previous years.

2.3 Results

2.3.1 Participation

Skippers contacted directly were generally forthcoming and shared their observations and details of their fishing practices openly as well as showing a genuine interest in the project.

Table 3. Summary of survey coverage for vessels fishing bottom longlines in FMA 2 in the year April 2010 to March 2011. Effort was quantified as number of hooks set.

Response	Number of boats	Proportion of effort (%)
Recorded information	16	67
Did not contact	12	9
Contacted but not currently fishing	3	8
Not interested	1	15

Summaries of discussions with skippers presented here represent vessels that had fished in FMA 2. Some of these vessels fished in several other FMAs and whilst fishing practices may change between areas, for example in response to the different availability of ACE, there was no indication that vessels would alter mitigation practices in response to FMA. Consequently FMAs in themselves are not particularly relevant to seabird mitigation, however it is important to recognise that seabird abundance and species composition will vary geographically.

2.3.2 Vessel characterisation

Thirty two vessels ranging between 6 and 29 m overall length fished in the inshore FMA 2 bottom line fishery in the year April 2010 to March 2011. Vessel size influenced how long vessels could stay at sea and to some extent how much weather they could work through. Some vessels worked from the beach, fishing day trips. Other ‘ice’ or ‘fresher’ boats worked multi day trips of up to 10 days, and some had freezing facilities for the catch and so could work until their holds were full, generally in the order of 30 days. Vessel size also determined the type of lining system employed, with some of the larger vessels choosing to operate an automatic lining system (autoliners). Other vessels manually clipped individual hooks onto a monofilament or rope backbone.

Splitting the group of vessels by target species helped identify how skippers wanted their gear to sit relative to the sea bed, which in turn has implications on how the gear sinks close to the surface. However most vessels targeted several different fish species and had the ability to swap target fish species easily and quickly.

Some vessels were multipurpose and switched between bottom longlining and, for example, surface longlining or crayfish potting. Some vessels worked from a fixed port whilst others landed fish into several ports depending on where they were fishing, which was related to season and/or target species.

The skipper was an important, if not the most important, aspect of a vessel's fishing behaviour, especially in terms of seabird mitigation. Although a vessels physical layout and dimensions are fixed, different skippers employ different mitigation and fish different areas at different times and in different ways. Skippers usually stay with a particular vessel for years. However some do, from time to time, change vessels or enter or leave any given 'fleet'. Some of the larger vessels had two skippers working alternate trips.

In summary there was no clean split of vessels by size or target species given the range of vessels operating in the fishery. Vessels vary from small single handed day boats fishing occasionally, and working several hundred hooks, to large autoliners working 10 000+ hooks a day, fishing almost continuously and spending the majority of their time at sea.

2.3.3 Gear characterisation

Vessels could be split into those which used an automatic lining system and those which worked a manual 'clip-on' longline system.

The autoline system used tarred polyester rope backbone, either 7 or 8 mm diameter, and had a fixed snood spacing of 1.4 m. Hooks were baited by a machine as the line was pulled from the vessel. Baiting was not 100% successful so a multiplier in the order of 0.85-1 could be applied to hook numbers when considering autoline effort, but has not been used in the data presented here. One observed autoline vessel employed size 14 J hooks with a 1.6 mm diameter 600 mm monofilament snood, which is reasonably standard. Another smaller autoline vessel fished similar gear, working up to 6000 hooks per day.

'Clip on' vessels used 4, 5 or most commonly 6 mm diameter monofilament nylon or 8 mm tarred polyester rope backbone (similar to autoline backbone). Two skippers mentioned that the rope backbone sinks faster, as it is denser than monofilament nylon. It has less stretch and is stronger than monofilament nylon, allowing more weight to be added to the line. Monofilament backbone had aluminium or twine stoppers, every metre on most vessels. Snoods were manually clipped onto the backbone as the line unwound from a drum. Generally snoods were placed every other stopper but were occasionally spread out further if required.

Most of the 'clip on' vessels contacted used size 14 circle hooks, with shark clips to suit the backbone diameter. Total snood length, including the clip, ranged from 400-600 mm with longer snoods used by some vessels fishing further south. Snoods were of heavier monofilament than the autoliners (1.8-2.2 mm diameter) and were often protected by tubing.

2.3.4 Bait

Most vessels used a combination of barracouta (*Thyrsites atun*) and squid (*Nototodarus spp.*) bait and thawed it before use. Jack mackerel (*Truchurus spp.*) was also used by some vessels. Some skippers supplemented frozen bait with freshly caught bycatch, notably ribaldo (*Mora moro*) and sea perch (*Helicolenus spp.*). The autoline vessels used partially frozen bait to meet the requirements of the automatic baiting machines (the bait did not fall apart easily).

2.3.5 Target species and line configuration

Skippers reported changing the configuration of weights and floats on the line when targeting different species, based partly on where they were thought to feed relative to the sea bed. Longlines targeting ling, ribaldo and school shark were set up with little or no floatation between weights and short, if any, suspender ropes so hooks sat close to, or on, the sea bed (Fig. 5). Lines targeting hapuku, bass, and especially bluenose, typically employed two or more floats between weights and longer suspender ropes. This allowed the line to fish a range of depths above the sea bed (Fig. 5). Some vessels would alter the configuration within a line, generally to suit seabed topography. Weight and float spacing ranged from 7-50 hooks and generally larger floats and larger weights were used in conjunction with larger spacing. Vessels setting short lines on defined features, usually targeting bluenose, tended to employ smaller hook, weight and float spacing and this, presumably, resulted in more control of how far off the sea bed hooks fished.

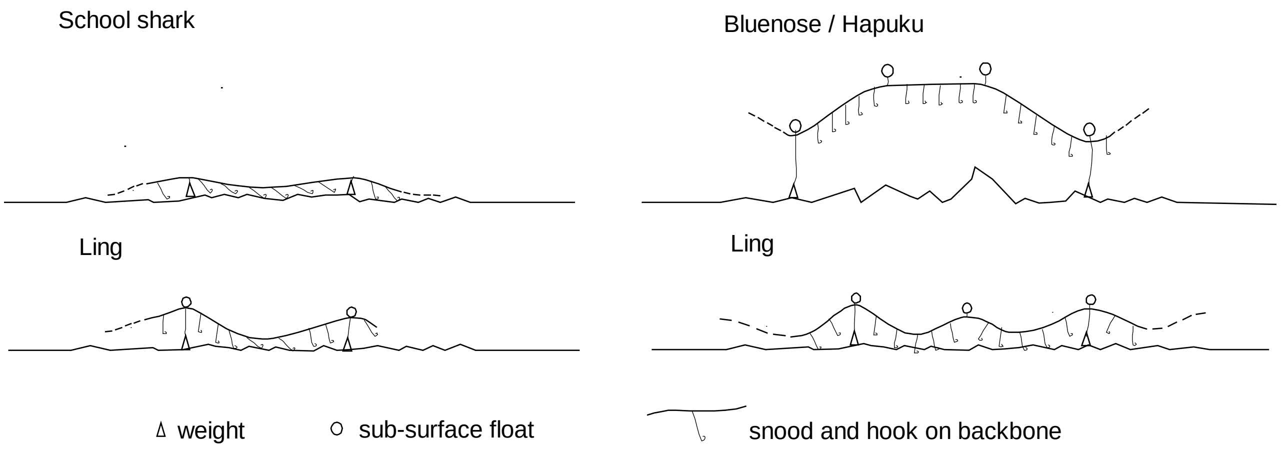

Figure 5. Examples of different line configurations employed for different target species.

2.3.6 Increasing sink rates

For most sets the skipper aimed to place the line in a precise position, generally determined by depth and the sea bed topography. This included fishing along particular depth contours, and setting lines over, around, along or across features such as ‘drop offs’, ‘knolls’ and ‘canyons’. In order to 'hit' a particular location on the sea bed a fast sinking line was deemed beneficial in that it was less likely to be affected by tide or current. Consequently heavier weights were used to increase sink rate and hold sections of the line in a particular position as it sank to the seabed including grapnels at the beginning and end of the line and large weights during turns. Extra floats were employed, on occasions, for example to lift the line over the tops of knolls.

Depth limited line weighting (i.e. fewer weights were sometimes used in deeper water) as the skipper could only 'afford' to have so much weight between the seabed and the sea surface when retrieving the line. Similarly the strength of the backbone limited the amount of weight that could be comfortably added. Too much strain on the line during hauling increased the risk of breaking the backbone (which was not uncommon) and this risk was increased with more vertical vessel movement in heavy weather.

Skippers noted that some operational changes during setting can increase sink rate, these included:

- Executing a u-shaped turn after deploying surface floats resulting in a slack buoy line, allowing the grapnel to sink faster.
- Dropping weights over the side before clipping them on ensured that suspender ropes unwound fully and when the weight was clipped onto the backbone it immediately pulled the line down.

Most skippers mentioned that line tension is an important variable and that more tension during the shot resulted in the line leaving the vessel at a shallower angle, and a slower sinking line. Generally some tension is required to clip snoods on and having the line leave the vessel reasonably close to horizontal makes this easier and safer. There were instances noted when higher line tension, and so less slack in the line on the bottom, was desirable, for example when shooting in strong tide and over the top of knolls.

Several skippers noted that snoods, clips and hooks all sink and contribute to increasing sink rate, especially those working larger and heavier gear. In the ling fishery, particularly, it was noted that snoods and hooks often come up muddy and with bottom dwelling starfish and whelks attached; indicating that the floatation added is not sufficient to hold the whole line off the sea bed.

2.3.7 *Mitigation measures*

Most skippers aimed to set all, or the majority, of their gear at night, and were aware of the need to minimise the amount of light emitted. This generally fits in well when targeting a dawn bite time, with gear fishing over daybreak.

Tori line use was variable; some skippers always used a tori line, others only for daylight or moonlit sets, and others not at all. Attitude to tori lines varied from skippers who had invested time and effort refining a design such that problems were minimal, to skippers who were reluctant to try tori lines due to the perceived problems. Problems included tangles with the backbone, time taken to deploy and retrieve and crew safety.

Some skippers were prepared to forego a fishing opportunity or move elsewhere if birds were present in large numbers and/or feeding aggressively.

Generally skippers felt that they were doing what was necessary and what can reasonably be expected.

2.3.8 *Offal management*

The amount of offal produced was determined by a combination of target species, market factors and catch rates. Bluenose, ribaldo, hapuku and bass were generally landed green. Some Licensed Fish Receivers (LFRs) preferred ling landed green and some headed and gutted. Sharks, predominantly school shark, were almost always processed to trunks. All vessels separated any processing and subsequent discharge of offal from the following set, either spatially or temporally and generally both. Some vessels would process whilst hauling and discard continuously whilst others held the offal and batch discarded at the end of the haul. Other vessels hauled and then processed all the fish relatively quickly at the end of each haul. Several skippers mentioned that they did not discard offal on fishing grounds due the belief that this would reduce future catches.

Whole fish discards were minimal and these were sometimes used as bait instead. Several skippers noted that long soak times were undesirable as fish could be damaged by lice or hagfish resulting in more discards. Lost fish attracted birds during the haul but skippers made all practical efforts to recover these.

Bait retention during the haul was variable; most vessels discarded baits at the haul, and a few skippers would routinely hold returned baits. The percentage of baits returned was variable. Autoline systems automatically stripped baits as the line came aboard.

Several skippers mentioned that offal and discarded baits were ‘feeding the birds’ and so felt that these were not a problem per se.

2.3.9 *Birds observed*

The knowledge of seabirds exhibited by skippers was very variable, however all were able to describe, to some degree, the birds encountered with some taking a keen interest. Information regarding breeding sites, migration, diving ability and population size estimates was well received and this was discussed in relation to the work of DOC. Several skippers mentioned encountering more birds in the vicinity of East Cape than when fishing elsewhere in FMA 2.

Observers reported the following species: Black backed gulls (*Larus dominicanus*), black *(Procellaria parkinsoni)*, cape *(Daption capense)*, giant *(Macronectes halli)*, grey faced *(Pterodroma macroptera)*, storm *(Oceanodroma spp.),* Westland *(Procellaria westlandica)*, and white chinned *(Procellaria aequinoctialis)* petrels, Buller’s *(Puffinus bulleri)*, flesh footed *(P. carneipes)*, and sooty *(P. griseus)* shearwaters, and black browed (*Thalassarche melanophrys*), Buller’s (*T. bulleri*), Chatham (*T. eremita*), royal *(Diomedea antipodensis)*, Salvin’s (*T. salvini*), wandering *(D. antipodensis)*, and white-capped *(T. steadi)* albatrosses.

2.4 Discussion

2.4.1 *Participation*

Most of the vessels in the fishery worked trips of a week or more and many spent a limited time in port with skippers or crew on board. Consequently meeting skippers face to face was time consuming and challenging and not all skippers were contacted. Telephone calls increased the number of vessels surveyed but most were ex-directory.

Although all areas, target species and a reasonable percentage of fishing effort is represented in the results (Table 3) this is not necessarily a random or representative sample of the fleet. Consequently there is no quantification of, for example, reported tori line use as this could be misleading.

2.4.2 *Effort*

Number of hooks set gives some indication of the potential risk to seabirds but should be considered with care. Also of importance is how, where and when the vessel is fishing and use of mitigation measures (Rowe 2010b).

Both effort and the number of vessels involved in the bottom longline fishery in FMA2 vary over time. Spatial variability in effort is also apparent (figures 3 and 4) and should be considered when analysing at the overlap with the distribution of seabirds.

2.4.3 *Bluenose quota cuts*

The proposed reduction in bluenose total allowable commercial catch (TACC) is likely to dramatically reduce the number of inshore bottom longliners operating in FMAs 1 and 2 (MFish 2011). Several skippers and owners mentioned this and noted that vessels are or will be tied up and that effort will reduce, especially that targeting bluenose. Vessels which only enter the bottom longline fishery for a small part of the year may not be able to acquire sufficient ACE to make this possible. Some effort may be displaced outside 200 nautical miles to avoid quota cuts.

2.4.4 *Characterising the fishery*

Although there is a definitive split between autoliners and ‘clip on’ vessels, this only identifies those vessels which have the potential to set more hooks per day. Generally autoliners shoot more lines and more hooks but often work similar fishing grounds. Target species can be used to identify the likely configuration of a longline in terms of the sequence in which weights and floats are added to the line. This is likely to influence sink rate and, in turn availability of hooks to seabirds.

2.4.5 *Mitigation measures*

Uptake and awareness of mitigation measures other than night setting and tori lines was rare. This is notably different from the snapper fleet fishing in FMA 1 (Goad et al. 2010). It can be attributed in part to the fact that many skippers were of the opinion that they ‘don’t have a problem with birds’ and reported low numbers attending the vessel and rare or no instances of seabird bycatch. Lower awareness of mitigation could also be attributed to less observer coverage, particularly coverage with a protected species focus, in FMA 2.

Night setting and tori lines were the most commonly stated mitigation though no vessels consistently used both. Fishers generally felt that the mitigation employed as they saw necessary was sufficient.

3 Sink rate testing

3.1 Introduction

Sink rate testing was conducted by government observers as part of Conservation Services Programme (CSP) requested coverage. Testing was carried out on commercial fishing trips sampling normal gear set ups.

3.2 Methods

3.2.1 *Time Depth Recorder (TDR) specifications*

Starr-Oddi DST Centi TDRs were used to measure sink rates. These units were chosen because they are easy to use, have relatively high depth resolution and are available at a competitive price. The units had a depth range of 0–800 m, a depth resolution of 0.24 m and a minimum sampling interval of one second. Starr-Oddi also supplied a protective housing. The units in the housing with wire strop and clip, had an effective weight of 48 g in seawater and 101 g in air. Full TDR specifications can be found in Appendix 2.

3.2.2 Data collection

At sea sampling closely followed the methods outlined in Goad et al. 2010, and details are repeated below. Data was collected by government observers on DOC requested sea days on four vessels fishing in FMA 2.

Data was collected during normal fishing trips, aiming to sample different line configurations equally if the vessel used more than one different line set up. A maximum of 7 sets of data was collected for any one vessel and line set up combination.

TDRs were programmed with a delayed start, three-stage measurement sequence, prior to each set. In stage one (before deployment), the TDRs recorded depth and temperature every 30 s for 30 min. In stage two, the TDRs recorded depth and temperature every second for 2–5 h, then in stage 3 every 20 min until recovery. The second stage or ‘shooting window’ was varied in length to maximise battery life and cover any uncertainties in the time of shooting.

After programming and before use, the TDRs were inserted into their housings and stored in an empty bucket. At least 30 min before shooting, the bucket was filled with seawater and refreshed regularly. TDRs were therefore kept as close as possible to sea surface temperature prior to deployment, in order to minimise errors in the pressure readings associated with a rapid change in temperature. TDRs were clipped onto the line backbone at predetermined random positions and in a random order during the shot. The times of attachment and entry to the water were recorded using standard time. Environmental and gear variables were recorded at the start and end of the deployment period as shown in Appendix 3.

Sampling positions on the backbone were chosen to allow different weighting regimes to be compared and provide an indication of the variability of sink rates. TDRs were spaced approximately evenly along the line, excluding two repeated patterns at the beginning and end of the line. These sections were excluded as the grapnels and end weights increased sink rates near the ends of the line. TDRs were placed adjacent to weights or floats, and midway between weights and/or floats. If different sized weights, floats and suspender combinations were used, then TDRs were deployed aiming to sample all positions equally. Between 9 and 12 TDRs were deployed on each line sampled. Examples of TDR placement are shown in Fig. 6. If any set occurred during daylight video footage was taken for a short period during line setting on board each vessel sampled.

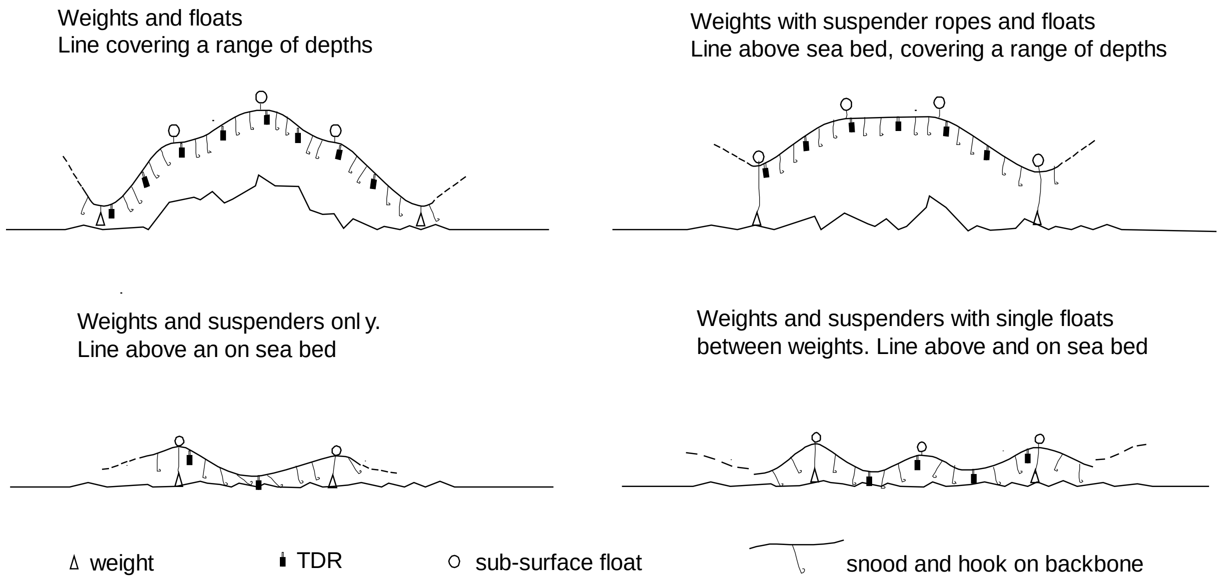

Figure 6. Examples of TDR placement on the different line set ups sampled

TDRs were recovered during the haul and the data was downloaded as soon as possible. The sequence of weights, hooks and floats was recorded as they came on board. Weights were recorded to the nearest 50 g on spring scales, and the length of dropper lines was measured to the nearest 0.1 m. If weights and droppers were of standard measurements, then each one was not measured. Estimates were made if insufficient time was available for making full measurements.

3.2.3 Data analysis

Temperature correction of pressure readings to give a depth value was carried out using Sea Star 5.25 as discussed in Goad et al. (2010). Pressure readings taken immediately after the TDR entered the water were corrected using a fixed temperature value; this estimated surface water temperature and was derived from the first steady temperature records from the TDR, above any thermocline. Adjustments were carried out individually for each TDR deployment, and substituted temperature values were used for up to 265 s. Subsequent pressure readings were corrected using the real time temperature recorded by the logger. Some records were not corrected with substituted values because ambient air temperature immediately prior to deployment was sufficiently close to the surface water temperature. For shallow thermoclines and /or fast sinking positions on the line TDRs did not reach the surface water temperature before sinking through the thermocline. For these records estimates of true surface water temperatures were taken from adjacent slower sinking TDRs on the same line, which had more time above the thermocline to acclimatise.

Offsets to adjust the pressure recorded by the TDR to actual pressure were applied when correcting the temperature readings. These offsets were calculated on a shot-by-shot basis, based on pressure readings taken every second for 60 s in a bucket of seawater prior to deployment. TDRs were soaked in the seawater for 15 minutes prior to the period used to calculate the offset. Temperature readings were stable during the 60 s used to calculate the offset, and this was generally 1-2 minutes before deployment. Exceptions to this were when this temperature was not stable, for example if the TDR was already out of the bucket in preparation for deployment. For these records pressure readings used to determine the offset were taken from an earlier 60 second period during which temperature readings were stable.

TDRs were labelled with a clip-on time, calibrated to standard time. All vessels shot over the stern, so this was designated as the time the TDR left the vessel. The time taken was recorded as the first time the TDR reached 5m, 10m or 15m depth or deeper and stayed below this depth.

Distance behind the vessel was determined by multiplying the time by the vessel speed over the ground, taken from the vessel's GPS. This allowed a duplicate set of box whisker plots to be produced showing the distance behind the vessel that TDRs reached 5, 10 and 15 m depth.

Box and whisker plots were used to display the variation in sink times. Points falling outside 1.5 times the interquartile range, above or below the third and first quartiles respectively were considered outliers.

Composite plots of a line sinking were compiled for each vessel and line set up sampled. This was achieved by taking a typical TDR record for each position on the line to give a time at depth and then using the hook spacing and hook counts to provide a horizontal distance scale.

3.2.4 Line tension

To estimate line tension a set of scales was inserted into the vessels shooting set up such that the line ran around a pulley block which was attached to the vessel via the set of scales (Fig. 7). A safety link was incorporated to stop the scales overextending being subjected to unexpectedly high loads. The reading on the scales gave a relative tension value for that vessel set up. In order to compare between vessels this relative reading was calibrated by noting the reading on the scales with a series of different sized weights hanging off the line at the 'shooting eye'. This was carried out in calm conditions so that the readings on the scales fluctuated only slightly.

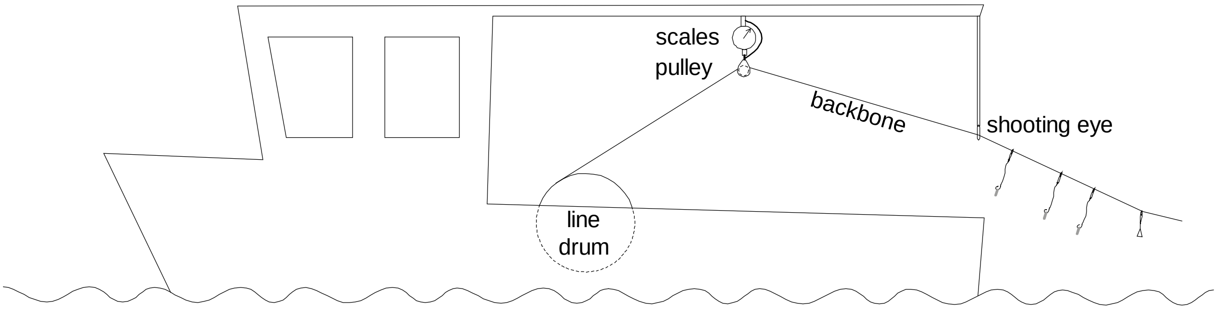

Figure 7. Arrangement for measuring line tension.

3.3 Results

3.3.1 Vessels sampled

Four vessels were sampled, totalling 29 sets and 316 TDR deployments. TDRs malfunctioned on three occasions and a total of five records were not recovered. The data represented 11 different vessel and line set up combinations, eight of these were sampled on more than one set, with between two and seven repeats, and these data are presented (280 TDR records). Details of observer coverage and sets sampled are shown in table 4.

Table 4. Observer coverage on bottom longline vessels fishing in area 2 in the 2010/2011 fishing year and sets sampled.

Vessel	Number of observed days fished	Number of different line set ups sampled by target species			Number of repeats of each setup	Total number of lines sampled
		Bluenose	Hapuku	Ling		
G	14	4	0	0	6, 2, 1, 1	10
H	11	1	0	0	7	7
J	22	0	1	1	7, 2	9
K	4	1	0	0	3	3
W	8	0	0	0	0	0

Seventy TDR records over two different line set ups from one vessel were sampled as part of project MIT2009/01 and are also presented here as this vessel also fishes FMA 2. Similarly a summary of 153 records from vessels targeting snapper with lighter gear in FMA 1 has also been included for comparison. The data from vessels targeting snapper has been grouped and includes records from five different vessels working a range of line set ups.

3.3.2 Line set ups

One vessel using an automatic lining system fished markedly different gear to the other three vessels sampled which all used a manual 'clip on' system (Table 5). The autoline system allowed more hooks to be set per day and employed fixed snoods attached to a tarred rope backbone. This system had shorter distances between snoods, and heavier weights and larger floats were used at larger spacing compared to the 'clip on' vessels. Differences between the 'clip on' vessels were largely attributable to different target species although there was no standard set up and different skippers would achieve a broadly similar result with different configurations of weights and floats, and shoot at different speeds. Changes to line configuration within vessels were most commonly associated with a change in target species, but were also noted in response to sounder marks, bottom topography or current strength and direction.

In general, when targeting bluenose, lines were fished off the seabed, covering a range of depths with more floatation and longer 'suspender' ropes. Conversely, lines targeting ling were fished close to, and partially on, the seabed with less floatation and shorter suspender ropes. Lines targeting bass or hapuku sat somewhere between bluenose and ling lines.

Full line set up details for each configuration sampled are shown in Table 5.

Vessel / set up (n)	SNA all (191)	G BNS1 (56)	G BNS2 (22)	H BNS1 (77)	K BNS / HPB (32)	J HPB1 (24)	J LIN1 (69)	F LIN1 (60)	F LIN2 (10)
repeated line sequence	variable	weight 50 hooks float 50 hooks float 50 hooks float 50 hooks float 50 hooks	weight 50 hooks float 50 hooks float 50 hooks float 50 hooks float 50 hooks	weight float 15 hooks float 15 hooks float 15 hooks float 15 hooks	weight and float 15 hooks float 15 hooks float 15 hooks	weight and float 25 hooks float 25 hooks	Weight and float 50 hooks	weight and float 35 hooks float 35 hooks	weight and float 35 hooks
float diameter (mm)	variable	180	180	180 or 135	150	180 or 135	180 or 135	150 or 120	150
weight spacing (m)	variable	280	280	195	100	105	105	150	75
weight size (kg)	variable	15	10	3.6-7.0	2.5 - >4.5	6	6	3.9-10	3.9 - 4.2
mean weight per 100m (kg)	1.0 – 5.0	5.36	3.57	3.28	4.5	5.71	5.71	3.27	5.48
weight type	steel rocks lead	steel	steel	steel	steel	steel	steel	lead	lead
suspender length (m)	0 - 7	1.5	1.5	7-12	2.5	5	5	5	5
line diameter (mm)	1.85 - 3	8	8	4	5	6	6	6	6
line type	mono	tarred rope	tarred rope	mono	mono	mono	mono	mono	mono
number of sets sampled	17	5	2	7	3	7	2	6	1
setting speed (knots)	2.2 – 5.0	4.6 - 5.1	4.5	1.8 - 2.2	2.8 - 3.0	3.6 - 3.85	3.1 - 4.1	3.5 - 3.7	3.5
shooting block height (m)	1.5 – 2.1	2.5	2.5	2	2	2.63	2.63	2.85	2.85
target species	snapper	bluenose	bluenose	bluenose	hapuku / bluenose	hapuku	ling	ling	ling
wind speed (knots)	0 - 12	0 - 25	10 - 25	5 - 20	5 - 10	10 - 15	3 - 28	8 – 20	10
swell height (m)	0 – 1.0	0.5 - 2.0	2.0 - 2.5	0.25 - 2.0	0.5 - 3.0	1.5 - 2.0	0.3 - 1.5	0 – 2.5	1.5
number of TDR records	153	56	22	77	32	24	69	60	10
line tension (kg)	not recorded	not recorded	not recorded	5 - 8	25 - >50	> 50	> 50	not recorded	not recorded

Table 5. Details of different line configurations sampled. The column identifier represents a letter for each vessel, followed by a three letter code for the target species and a number for that particular configuration. BNS denotes bluenose, LIN ling and HPB hapuku and bass.

3.3.3 Time depth profiles

Lines targeting ling tended to sink in a uniform manner in the top 15 m. Once TDRs entered the water they sank at a relatively constant rate, represented by approximately straight lines in Fig. 8. TDRs between weights entered the water slightly later and sank slightly slower than those beside weights.

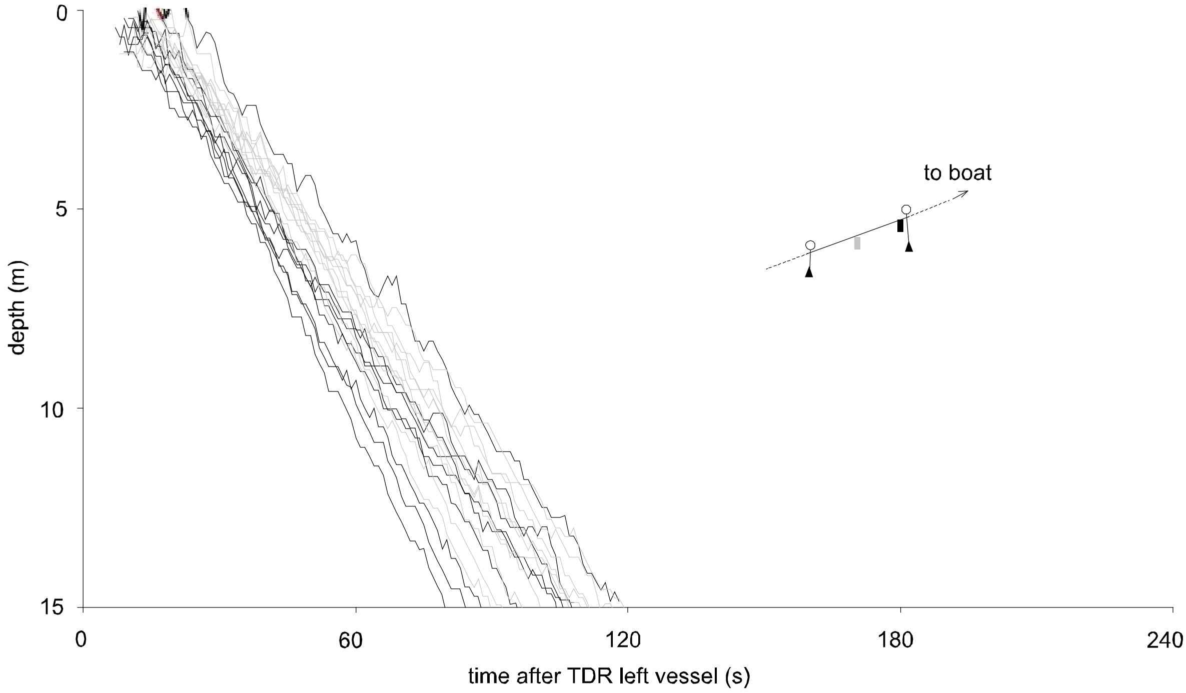

Figure 8. Time v. depth plot for TDRs deployed from vessel J, on two typical ling sets.

Lines targeting bluenose, with floats between weights, showed more variation with position on the line. TDRs midway between weights spent noticeably longer in the top 15m than those beside weights. Positions close to weights sank at a relatively constant rate whereas those further from weights tended to get held near the surface until the next weight was added to the line (Fig. 9). Similarly positions closest to weights entered the water closet to the boat and vice versa.

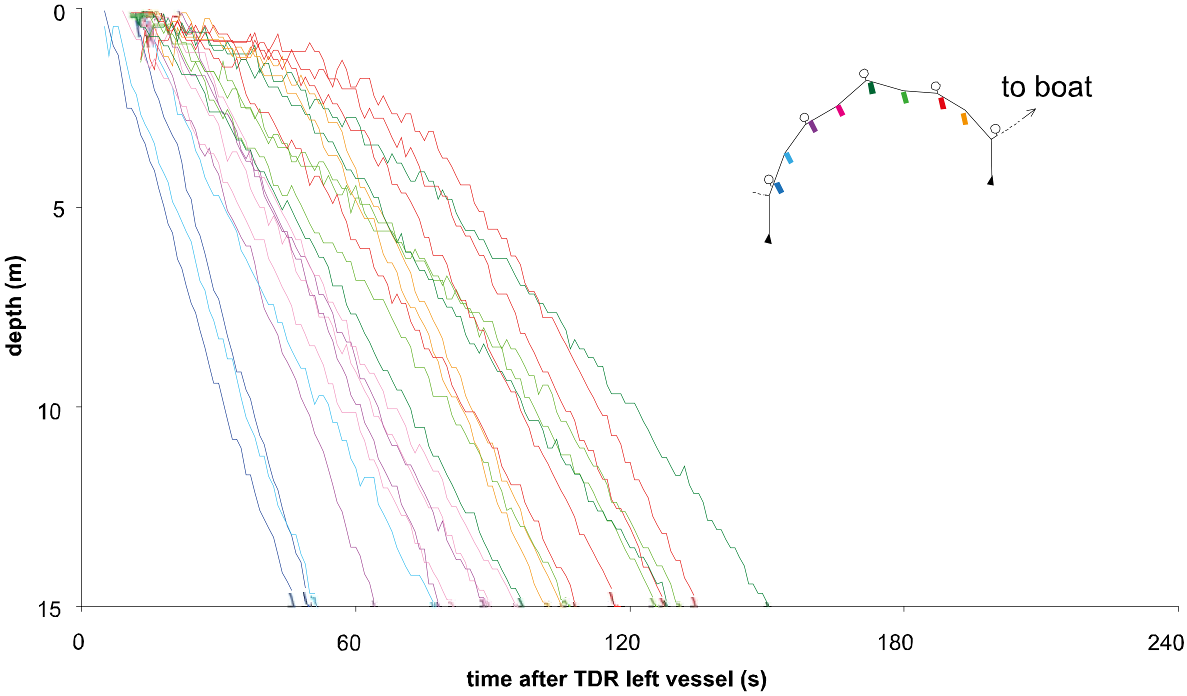

Figure 9. Time v. depth plot for TDRs deployed from vessel H, on two typical bluenose sets.

With the more complicated line configurations used targeting bluenose more TDR positions were sampled (e.g. Figs. 9 and 10) in order to represent the full variability in sink rate of the line between weights. This resulted in some or all sampling positions being represented by a single measurement on these lines. Figure 8 shows such a line with only 3 of the 8 possible positions measured twice with considerable differences between repeats, especially in positions furthest from weights. This data is from a single line on vessel G and is not included in Table 5, due to the lack of repeat measurements of sink rate at each sampling position.

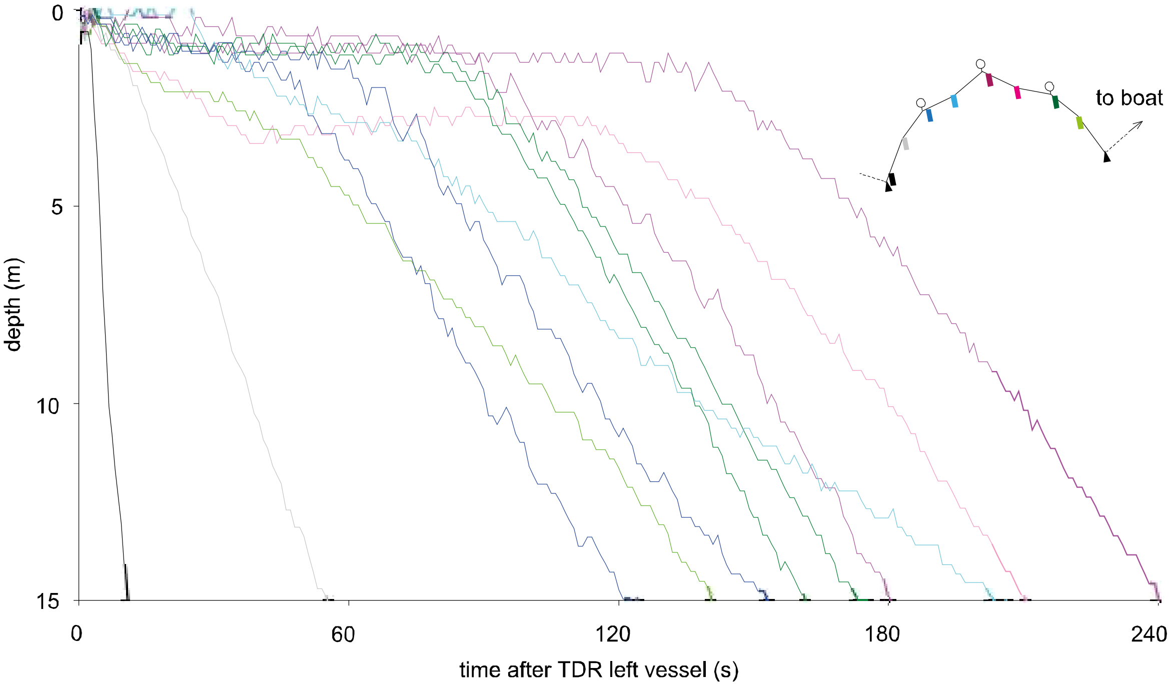

Figure 10. Time v. depth plot for TDRs deployed from vessel G, from a single bluenose set.

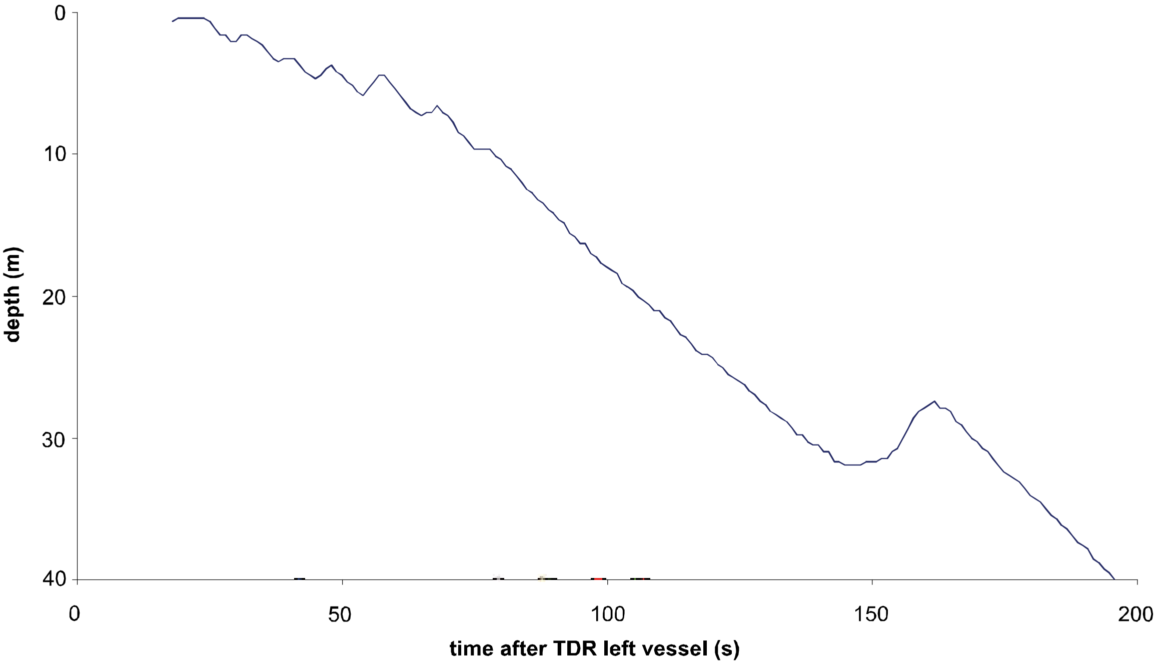

Figure 11. Time v. depth plot for TDRs deployed from vessel G, 36m before the last weight and grapnel.

Figure 11 shows a single record from a TDR placed just before the end of the line. An increase in sink rate is apparent at around 60 s which coincides with a larger than normal (8 kg) weight being added on the end of the line. There is then a marked step in the sink profile at 150 s with the TDR moving towards the surface for about 10 s. This coincides with the line being stopped to clip on the grapnel and is followed by the line resuming its relatively rapid sink rate.

3.3.4 Composite plots of lines sinking

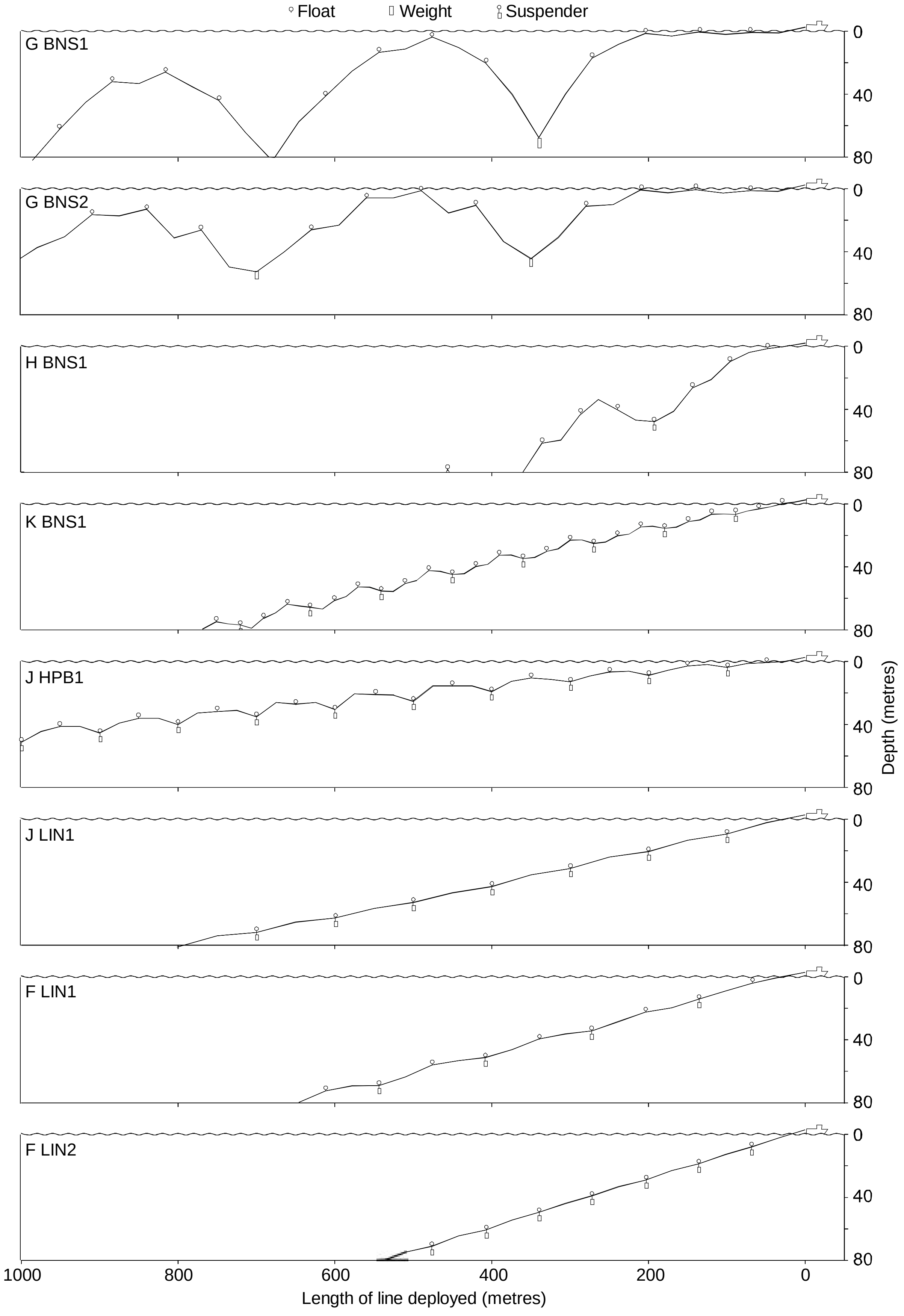

Figure 12. Composite profiles of longlines sinking behind vessels for the different line set ups shown in table 5. Labels show vessel identification, target species, set up number.

The differences in sink rate are clearly indicated in Figure 12, with bluenose lines sinking in an 'm' shape compared to ling lines. There are also considerable differences between vessels with the same target species, and between different set-ups on the same vessel.

3.3.5 *Line tension*

Measuring line tension was not easily achieved on all vessels. No method was devised for estimating tension on the autoline vessel. Finding and attaching a pulley in a suitable location was not always easy on the ‘clip on’ vessels and involved some trial and error. Estimates of the range of tensions experienced during setting were recorded for two out of the three 'clip on' vessels, and on one vessel the range of the scales was insufficient such that only a minimum value was obtained. On vessel H line tension was reasonably consistent throughout a set and relatively low compared to vessel K where recorded tension was higher and increased through the set.

3.3.6 *Sink times to 5, 10 and 15 m depth.*

Sink times to 5 m for the autoline vessel ranged from five to 307 s, with median values of 78 and 87 s. Less variability was apparent for the ‘clip on’ vessels with a range of 12 – 99 s and median values falling between 28 and 60 s (Fig. 13).

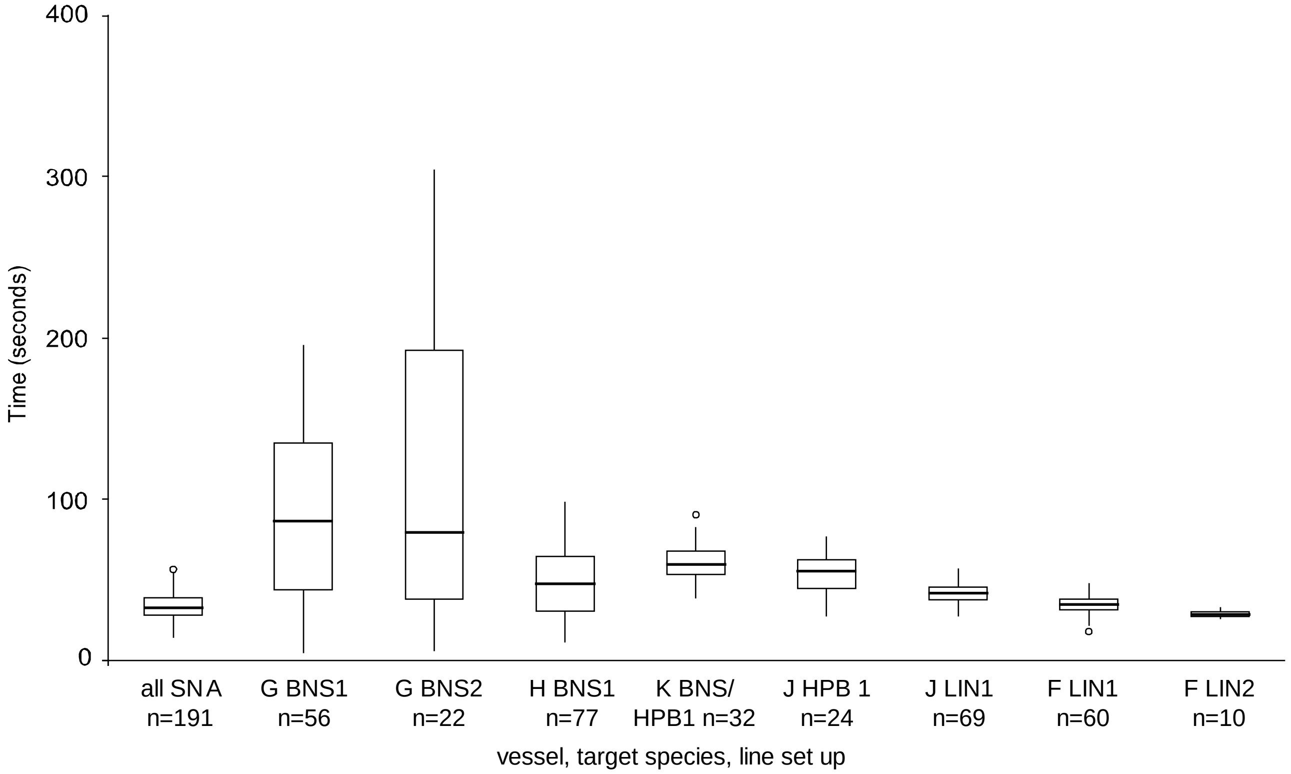

Figure 13. Box and whisker plot of the time taken for TDRs to reach 5 m depth for line set ups detailed in table 5. The number of TDR records for each setup is indicated by ‘n’.

Figures 14 and 15 show a similar pattern to figure 10, indicating that the majority of variation in sink times occurs in the top 5 m. Results from TDRs deployed on the vessels targeting snapper sink to 5, 10 and 15 m with similar times to vessels targeting ling. Variation in sink times on the vessels targeting snapper increases more markedly with depth than the vessels targeting other species.

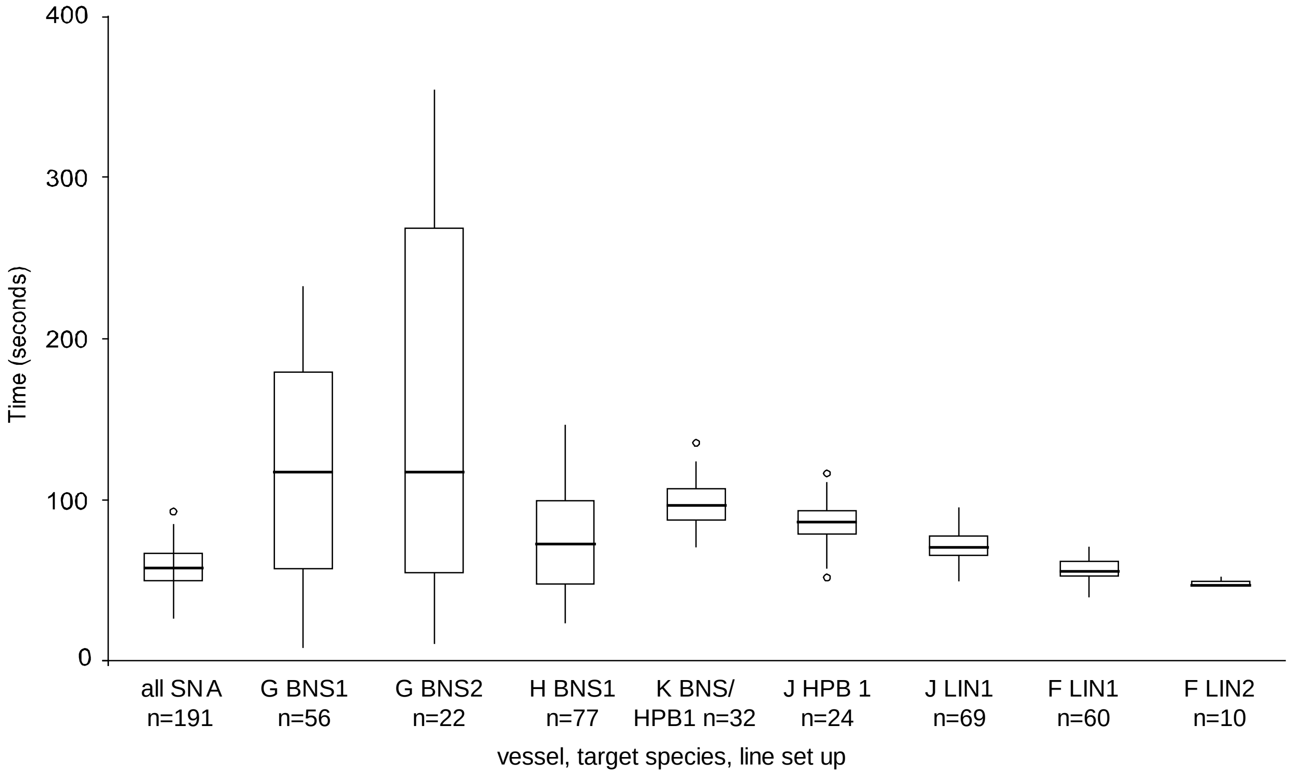

Figure 14. Box and whisker plot of the time taken for TDRs to reach 10 m depth for line set ups detailed in table 5.

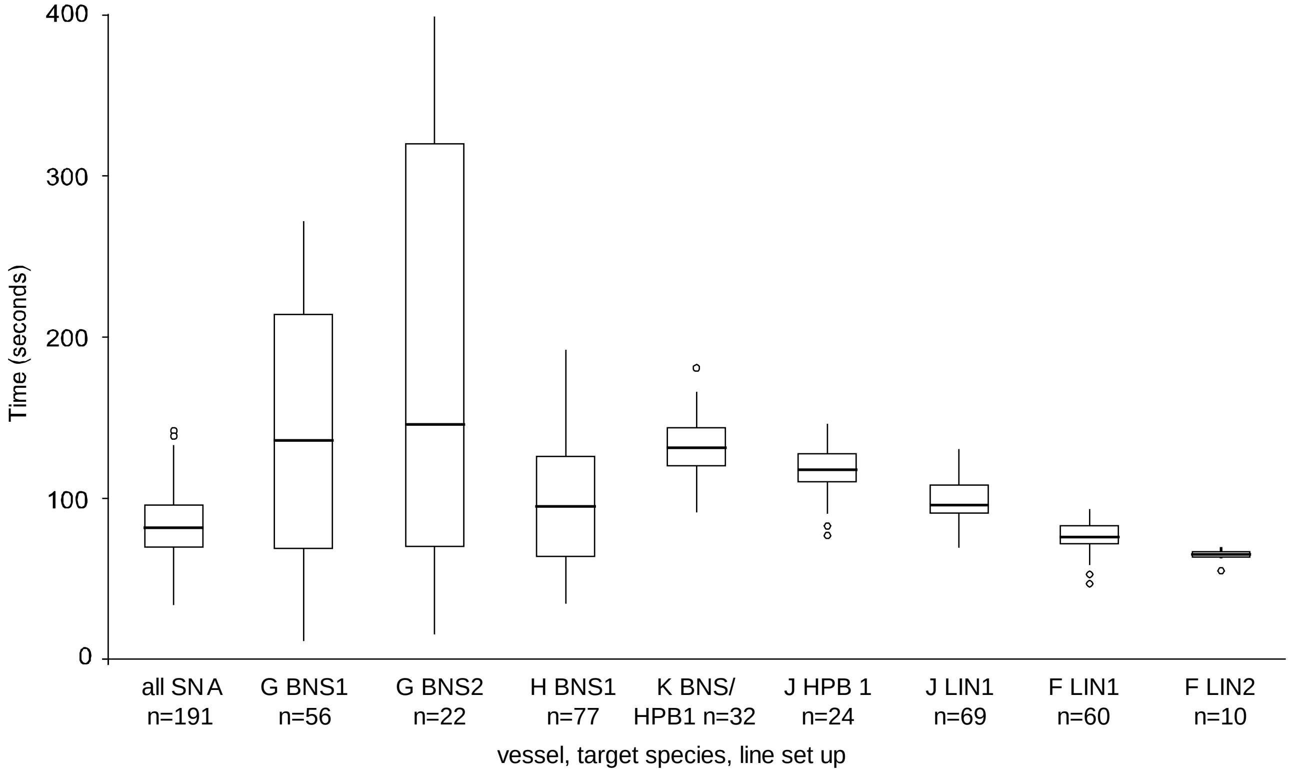

Figure 15. Box and whisker plot of the time taken for TDRs to reach 15 m depth for line set ups detailed in table 5.

3.3.7 Distance behind the vessel that TDRs reached 5, 10 and 15 m depth.

Using vessel speed as a multiplier to determine the distance taken for TDRs to reach 5 m depth gives a range of 12-727 m astern for the autoline vessel with median values of 195 and 206 m. 'Clip on' vessels had a range of 14-152 m, with median values falling between 48 and 106 m. Vessel K has a slower sinking line than vessel J (Fig. 13) but when vessel speed is considered, TDRs reached 5m depth at a similar or shorter distance behind the vessel.

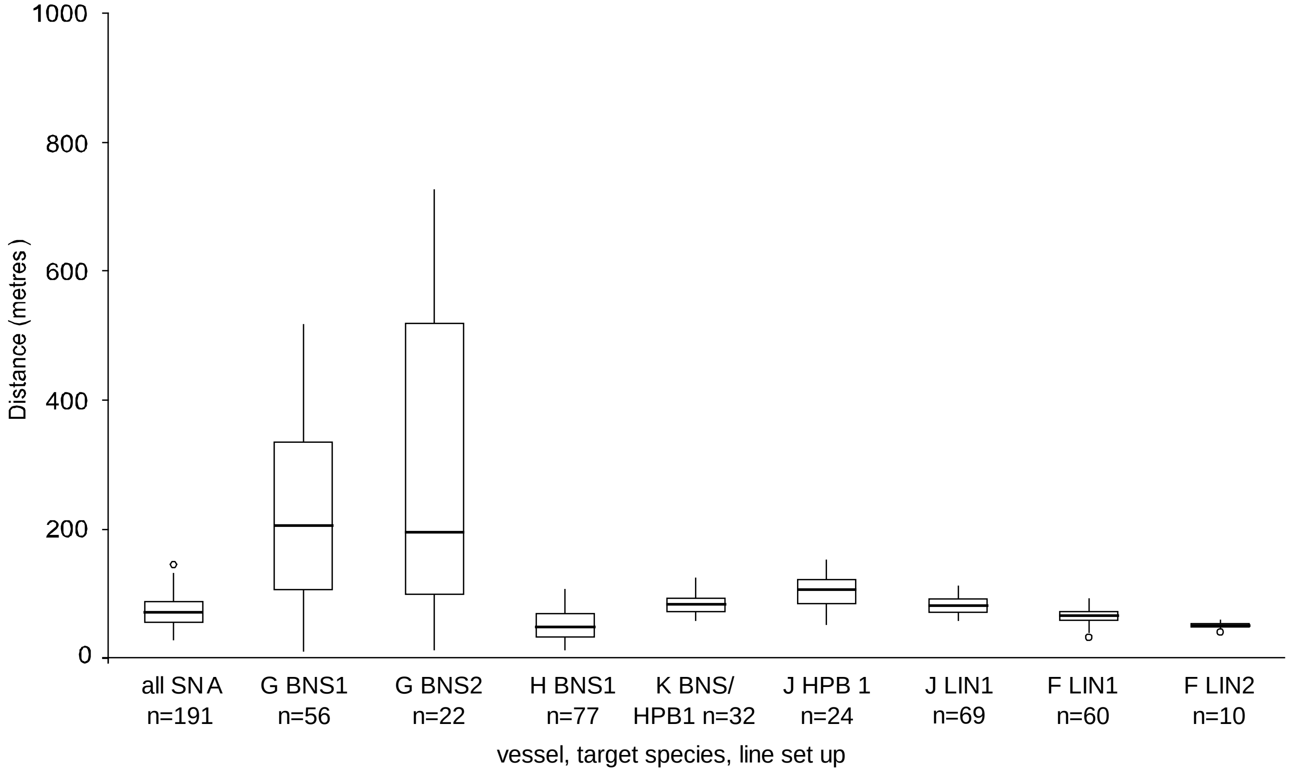

Figure 16. Box and whisker plot of the distance behind the vessel TDRs reached 5 m depth for line set ups detailed in table 5.

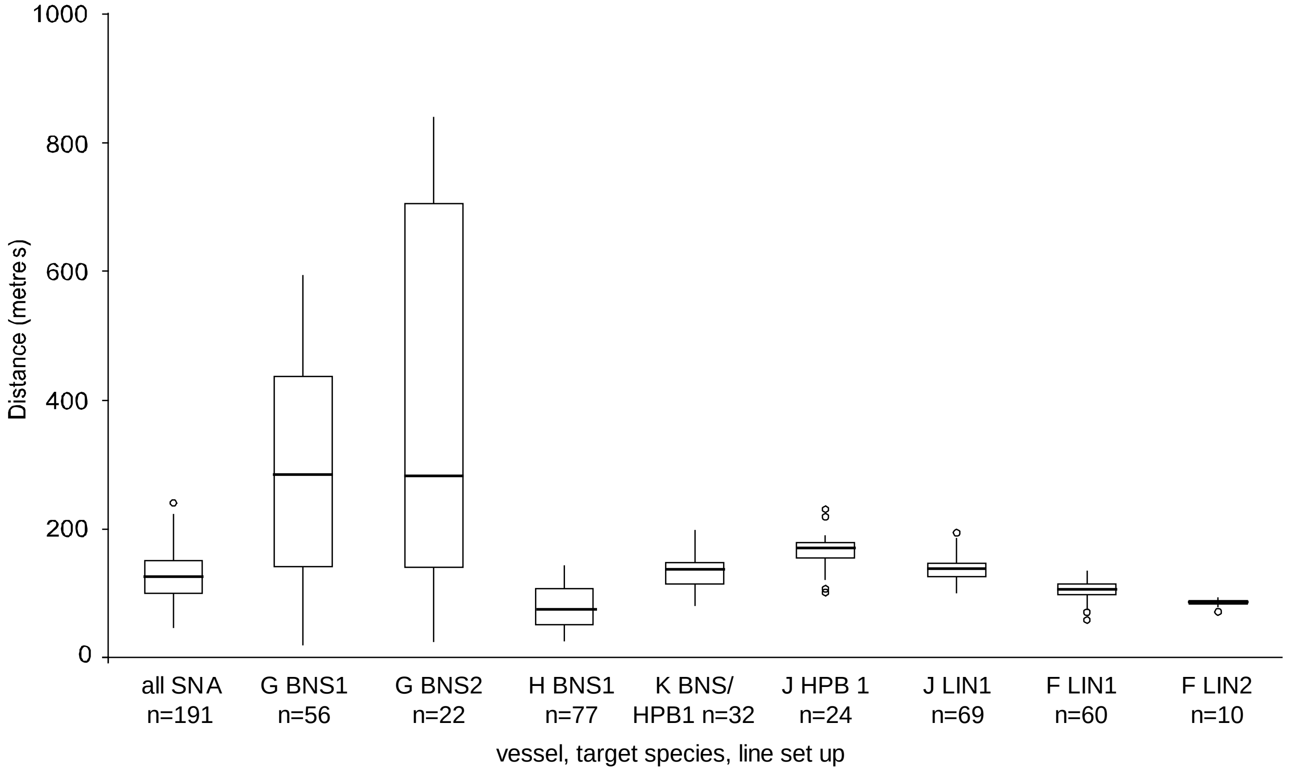

Figure 17. Box and whisker plot of the distance behind the vessel TDRs reached 10 m depth for line set ups detailed in table 5.

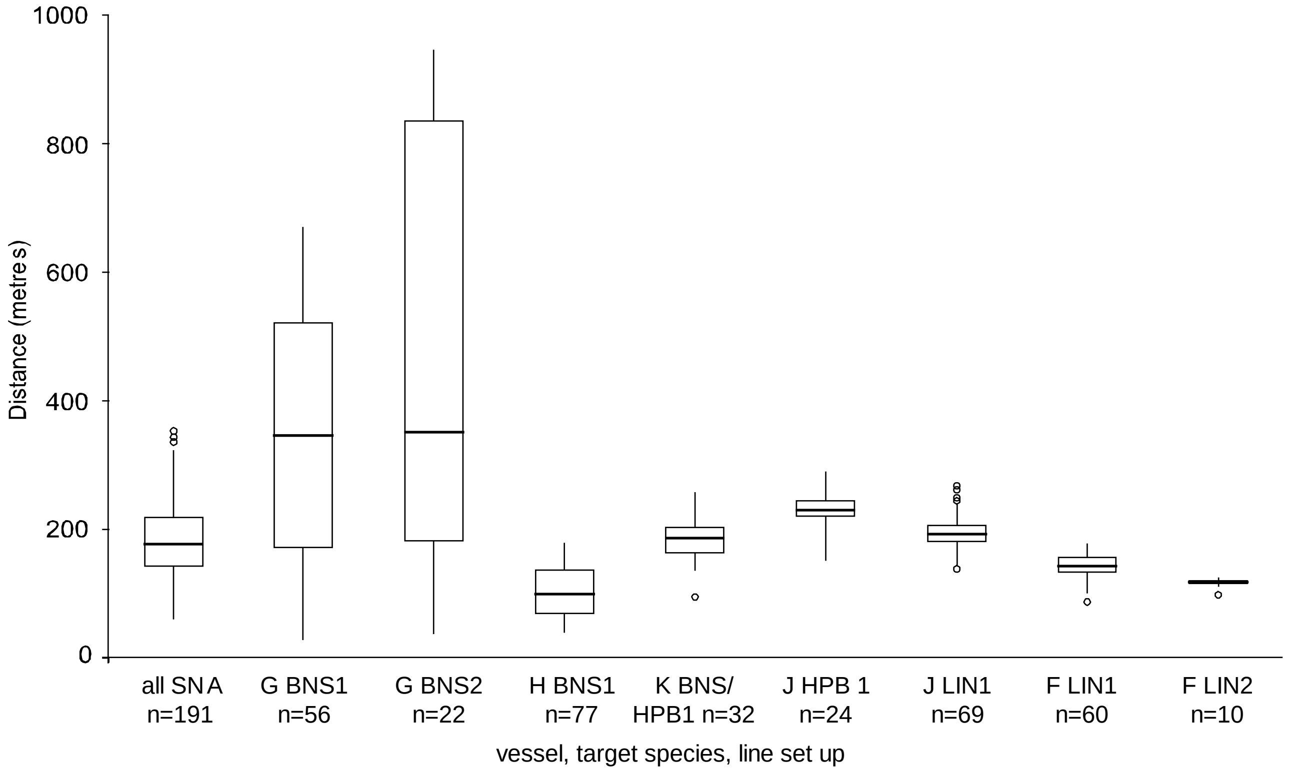

Figure 18. Box and whisker plot of the distance behind the vessel TDRs reached 15 m depth for line set ups detailed in table 5.

3.4 Discussion

3.4.1 Data analysis

Limitations of the TDR data are the same as those discussed in Goad et al. (2010). These include the assumption of well mixed surface waters in order to correct TDR pressure readings with a substituted temperature value. Also TDR housings took some time to fill with water, meaning that reliable depth records start several seconds after TDRs hit the water. Having TDRs acclimatise for 15 minutes in a bucket of water prior to deployment was sufficient to produce steady temperature and pressure readings to calculate pressure offsets.

The production of composite plots involved taking typical TDR records for each sampling position on the given vessel and set up combination and separating these by a distance derived from hook spacing. Because this distance is horizontal along the axis and in reality the line sinks at an angle, the plots tend to give a conservative estimate. However the line is under tension and so (particularly monofilament nylon) will stretch, offsetting the error above to some degree. It is not possible to determine exactly what happens to the line without any spatial data, however it seems logical that floats beside weights would get pulled towards a weight if the weight sinks much faster, as is the case for vessel G in Figure 12. It is therefore important to note that these composite plots are indicative only, that distance is not measured directly and that TDRs were not all deployed on the same short section of line. Choosing typical TDR records for each position sampled was preferable for the following reasons: Sampling two repeated sections on the line together would require up to 24 TDRs to be placed close together. This is not ideal as sections of line are occasionally lost. Also it would have been difficult to deploy so many TDRs close together and accurately record the times TDRs left the vessel and hit the water. Choosing 'typical' TDR records from similar sets from the range of data collected on each vessel and set-up combination was thought to produce a more representative indication of how the line sinks behind the vessel.

3.4.2 Vessels sampled

Data was collected during commercial fishing trips and this resulted in uneven sample sizes (Table 5). Observers sampled one set per day and chose this particular set in order to meet the following aims: Spreading samples evenly across all set-ups used by the vessel, minimising the chance of losing TDRs, and allowing sufficient time to download data and reprogram the TDRs before the following set.

All vessels worked multi day trips and were observed for between 4 and 22 fishing days (Table 4). This limited the number of different line set ups sampled, particularly when vessels fished the same set-up throughout the observer coverage. Generally it took one trip and an associated debrief for observers to become familiar with the vessel and sampling requirements and collect complete and useful sets of data, resulting in fewer repeats of the data. A maximum of 7 sets of data, or 84 records, were collected on any one set-up. This limit was imposed because the TDRs have a non-replaceable battery and are 'disposable'. Similarly each deployment involves a degree of risk in losing a TDR or section of the line. Coverage was cut short on vessel K due to breakdowns and the approaching end of the reporting year.

3.4.3 Line set-ups

To a large extent target species influenced line set-up (Table 5, Fig. 12) however avoiding other bycatch species or 'bait stealers' can also be an important factor. This may involve avoiding certain depth bands (e.g. spiny dogfish habitat) or raising the line off the sea bed (e.g. to avoid whelks and starfish ‘stealing’ baits).

The nature of the sea bed, in addition to target species, influenced line set-up. Irregular shaped, often rocky, ground is more prone to catching and breaking the backbone, hence floats and suspenders were employed. When aiming to place hooks a certain distance off the seabed the gradient of the seabed can be important whereby longer suspender ropes are necessary to hold the line the same distance off the bottom on a steeper gradient.

3.4.4 Time depth profiles

TDRs on lines targeting ling sank at a reasonably constant rate with depth (Fig. 8). Observations during shooting showed the line entering the water gradually further behind the vessel until the next weight was deployed. TDR records show that weights sank slightly quicker than midway positions. In terms of availability to seabirds, this results in hooks at progressively greater depths further behind the vessel. Hooks were all below 5 m after 60 s and below 15 m at 120 s in the case of figure 9. With two different positions sampled on the line and a small difference in sink rates between positions, variability was low (Figs. 9 and 13-18).

Lines targeting bluenose tended to be held near the surface by floats until the following weight was deployed. In the case of Figure 9 this resulted in TDRs between weights sinking at an increasing rate with depth, to 15 m. Figure 10 from a different vessel shows the TDRs between weights being held at around 2 m depth until the following weight was deployed. This is roughly the distance between the float and the TDR on the backbone, indicating that floats were on the surface until the following weight was deployed. The weight then progressively pulled the floats under. Consequently floats some distance behind the vessel were, at times, closer to the surface than the weight immediately behind the vessel. These cases highlight that weight spacing, as well as the total amount of weight and flotation added to the line, is important in determining availability of hooks.

When floats are close to the surface and are slowing the sink rate, as above, using longer ropes between the floats and backbone would allow the line to sink to a depth equivalent to the length of the rope without being slowed by the float. In the case of vessel G increasing the float rope length to 5 m could dramatically reduce the availability of hooks to surface feeding birds. Vessels tended to attach floats directly to the backbone with a short rope strop, generally less than a metre in length. Increasing the length of this rope could cause tangles during the setting of the longline and would mean extra work coiling and storing the rope at the haul, however this is standard practice in the surface longline fishery, albeit less frequently, and surface floats are routinely deployed along snapper longlines (Goad et al. 2010).

When sampling bluenose lines more positions were sampled, for example eight in the case of Figure 10. This provided fewer repeats of each position with more variability between positions (Fig. 13).

Figure 10 shows a single sample of a line set-up targeting bluenose from vessel G, with 3 floats evenly spaced between weights. Unsurprisingly TDRs beside floats two and three were held close to the surface until the following weight was deployed. However, of note in this figure is that three positions had duplicate samples and in the case of the second float position one TDR took 60 s longer to reach 15 m. This set-up is not included on Table 5 as this was the only sample taken.

It is included here to emphasize the within set variation of sink rates of the same position on the line, and the need to sample several lines to characterise a set-up accurately, especially with the multi–float configurations.

Figure 11 shows how the line can be brought closer to the surface when the brake is applied to attach grapnels, end weights or buoy lines. This is supported by observations of the line getting tighter and being pulled out of the water behind the vessel. Catch ups or jams during shooting produce similar results, and both will increase the availability of hooks to birds. Adding a weight to the line before the drum is stopped to clip on the grapnel or down line, as is the case in Figure 11, means that this occurs when hooks are already at a ‘safe’ depth. Running out some extra backbone before attaching a grapnel could have a similar, though less marked, benefit. It is also important to note that the vessel is generally moving slower than during the set when grapnels are clipped on, so the aerial extent of the tori line is likely to be less than normal.

3.4.5 Composite plots of lines sinking.

Figure 12 provides a simplified comparison of the different line set-ups shown in Table 5. It shows a snapshot of the line sinking and it represents the 'worst case scenario' just before a weight is clipped on. Therefore it is not intended to quantify availability of hooks to birds but to allow a comparison between the different line set-ups. Of particular interest are the three vessels on which two line set-ups were measured. For vessel G the difference between reducing the weight from 15 to 10 kg from set-up 1 to 2 is marked. For vessel J adding a small (135mm) float between weights makes a considerable difference, however, replacing the equivalent float with another weight on vessel F surprisingly produces a relatively small increase in sink rate. It is important therefore, to recognise that similar changes to line set-up on different vessels can alter sink rate quite differently. In this case it is likely that vessel F is close to the maximum sink rate with set-up 1, such that adding more weight has a noticeable but relatively small gain. It follows that under any given conditions adding extra weight will have diminishing returns – the line will sink faster when extra weights are added with less increase in sink rate with each reduction in weight spacing. In this case some other method of reducing the availability of hooks may be more effective, such as slowing down and/or reducing line tension.

3.4.6 Line tension

Line tension was not measured for all TDRs deployed or for all sets, however an indicative range is given in Table 5. Vessel H had a relatively low line tension (Table 5) and this is likely to have contributed to the relatively high sink rate. Low line tension may also allow the line to sink with a more exaggerated 'm' shaped profile. This results in weights having a more localised effect on sink rate, producing more variability in sink times but a faster median sink rate (Figs. 12 and 13). Having different positions on the line sinking at different rates is likely to have implications on how the line sits on or above the sea bed, influencing how ‘well’ it fishes, and may be more or less desirable for different bottom types and target species.

It is likely that setting speed and line tension will increase together. One explanation for this is that there is a limit to the speed at which the hooks can be clipped on. As vessel speed increases the crew will tend to apply more brake to the drum, thereby increasing line tension, in order to slow the line down sufficiently to enable the hooks to be clipped on. In order to clip hooks onto a moving backbone a minimum amount of tension is required, however skippers report that because line tension influences how the line sits on the sea bed, tension may be increased above the minimum in response to factors such as tide.

Line tension was measured for each TDR deployed during two sets sampled on vessel K and each showed an increase during the set. One possible explanation for this is that the smaller diameter of the line drum towards the end of the shot would provide less leverage, such that more force had to be applied to unwind the line. In this case sink rates could not be related to line tension because of the small number of repeats and the fact that different sized weights were employed along the line and these were not individually weighed at the haul. Vessel J showed a similar line tension throughout the three sets recorded.

Robertson et al. (2010) showed that surface longline lines set with a line shooter, minimal tension and extra slack spent longer in the propeller wash and so sank more slowly than those with more tension which entered the water further behind the vessel. When considering bottom longlines Lokkeborg and Robertson (2002) found that with an autoline integrated weight backbone a line shooter did not increase sink rate below 3 m. Line shooters are not suitable for manual ‘clip-on’ bottom longliners but are used by some vessels in the surface line fishery.

Further investigation would be necessary to determine whether there is a direct relationship between line tension and sink rate using a system similar to those sampled in this study. Ideally tension and sink rate should be measured on a line with regular sized weights and the same position in the sequence of floats and weights to be sampled repeatedly with different amounts of tension.

3.4.7 Sink time to 5, 10 and 15 m depth.

These box whisker plots represent all complete TDR records and not all positions for each set-up are represented by an equal number of observations. This was partly due to the number of different positions sampled not being divisible by the number of TDRs and TDR malfunction. However, more frequently, it was due to mistakes in deploying the TDRs along the line. This improved as observers became more familiar with the longline operation. No attempt was made to adjust the data for this and there is no reason to believe the positions which are over or under represented should not be a random selection.

Considering Figure 12 in relation to Figure 13 and Table 5 the degree of within set up variation can be attributed to line configuration, and lines with more floats between weights showed greater variation. Comparing figure 13 with figures 14 and 15 shows that this variation is largely determined in the top five meters.

Results from TDRs deployed on the vessels targeting snapper show that they sink to all depths in a similar time to the vessels targeting ling. Variation in sink times on the vessels targeting snapper increases more markedly with depth than the vessels targeting other species with multi float set ups (Figs. 13 – 15). This indicates that variation in sink rates between different positions on the line occurs close to the surface for multi float line set ups, but increases uniformly with depth for vessels targeting snapper.

The large difference in sink times between the autoline vessel (G) and clip on vessels may not necessarily be due to the autoline system itself and should, at least in part be attributed to relatively large weight spacing and large floats. However clipping on larger floats and weights less often is obviously faster and this could be beneficial when more hooks are set per day. Without records from other autoline vessels and different gear configurations the relatively high sink times observed on two similar set-ups on a single vessel should be treated with caution.

Smith (2001) measured sink rates on a 37.5m autoline vessel targeting ling with unweighted tarred polyester backbone. No increase was apparent, from TDR records taken midway between weights, with the addition of either 2.5 or 5 kg weights at 400m spacing. Sink rates in the middle section of the line were consistent with depth and in the order of 0.15 – 0.20ms^{-1} which equates to 25-33 s to 5m and 75-100 s to 15 m. This is considerably faster than those recorded on vessel G, but it should be noted that this vessel was not adding floats to the line.

Figures 12 to 15 indicate that the average weight per metre on a longline does not fully explain the line sink rate. For example vessel K has less flotation and more weight on the line than vessel H (table 5), but the line sinks more slowly. This may be partly attributable to higher line tension during setting on vessel H (table 5).

Box whisker plots allow some quantification of the effects of adding extra weights or floats for particular line set-ups. For example adding an extra float when targeting hapuku on vessel J changed the proportion of hooks below 5 m at 60 s from 1 to 0.5. This result is unlikely to be repeatable on other vessels but does highlight the effect of a relatively small change to line set-up.

3.4.8 Distance behind the vessel that TDRs reached 5, 10 and 15 m depth.

Calculating distance behind the vessel that TDRs reach a given depth provides a somewhat more comprehensible and useful quantification of the availability of baited hooks. For example comparing Figures 13 and 16 shows that although vessel J had a faster sinking hapuku line than vessel K, by shooting less than a knot faster vessel J had hooks reaching a depth of 5 m further behind the vessel.

Distance is also important when considering mitigation measures such as tori lines which have a limited range of effectiveness. Figures 15 to 17 indicate that there is usually the potential for interactions with birds up to 150 m behind the vessel, and in extreme cases over 800 m. To cover these distances with tori lines may not be possible, in order to improve the aerial extent of tori lines as much as possible they would need to be longer; with the inherent increase in drag and height of attachment points. This would require purpose built tori poles and some kind of winch for recovery.

4 Conclusion

Night time setting was reported as the primary mitigation method but was not used by all vessels or for all sets.

Tori lines were used by most vessels, but not for all sets.

For vessels working ‘clip on’ gear, lines generally sank to 5 m within 60 s and 100 m behind the vessel and to 15 m within 120 s and 250 m behind the vessel.

Longlines targeting ling showed less variation in sink time and faster sink rates than those targeting bluenose.

Line set ups with multiple floats between weights, and those with the largest weight spacing produced the most variation in sink time and the slowest sink rates.

The weight and flotation added to the line did not fully predict sink rates, however considering setting speed and line tension were important variables.

It is difficult to predict the effect on sink rate of changes to line set-up on different vessels.

5 Recommendations to reduce the availability of hooks

All other things being equal, adding more weight will obviously make the line sink quicker, however returns (in terms of an increase in sink rate) diminish as more weight is added. Every vessel and gear set-up will have a maximum amount of weight the skipper is prepared to use. Maximising the effect of weight added to a line can be achieved by considering the following points:

> Weight spacing: Reducing weight spacing, for example halving weight size and deploying them at half the spacing, will reduce the maximum sink times as the line will sink more evenly.
>
> Suspender rope length on weights: If long ropes are needed then crew should allow them to unwind before clipping weights on.
>
> Setting speed: This has a large influence on how far behind the vessel hooks are available to seabirds. It should be considered in conjunction with tori line length and sink rate which allows quantification of the depth to which hooks are ‘protected’ by the tori line. Generally hooks sank to a given depth closer to the vessel at slower setting speeds.
>
> Line tension: High line tension seems to reduce sink rates, and tension should be minimised where practical. For example an increase in tension brings the line closer to the surface. Skippers should avoid stopping the backbone drum (which increases line tension) to attach surface float ropes or grapnels when hooks are close to the surface. Similarly slack surface float ropes will allow grapnels, and the line, to sink faster.
>
> Rope extensions: Trialling the use of extensions to subsurface float ropes would allow the line to sink to the length of the rope before the buoyancy of the float slows the sink rate. This would be particularly effective in reducing maximum sink times for multiple float patterns with large weight spacing.
>
> Weighting regimes: Encouraging skippers to trial different weighting regimes could increase sink rate without negatively impacting on vessel operations or fish catches.
>
> Tori lines: Undertaking trials with TDRs and different tori lines could quantify the degree of protection a ‘best practice’ line weighting and tori line combination can achieve. Maximum protection is likely to be best achieved by a combination of increasing sink rate and the aerial extent of the tori line.

Appendix 1 Topics discussed and gear details recorded during port visits

Our ID Number	
Vessel name	
Skipper's name	
Owner's name	
Company landing to	
Home Port	
Other ports used	
Area fished	
Target species	

Fishing gear

Longline type (clip on / auto)	
Backbone material	
Backbone diameter (mm)	
Snood diameter	
Snood Material	
Snood length	
Hook type and size	
Hook spacing	
Bait thawed (y / n)	
Bait type	
Intermediate float used	
Weight kg	
Weight spacing (# hooks)	
Weight material	
Float type	
Float spacing (# hooks)	
Float material	
Setting speed (knots)	
Line length	
Hooks/day	
Hooks / set	
Sets / day	
Days / trip	
Observed (y / n)	

Brief notes were made on the following points:

Attitude, mitigation, offal / bycatch / old baits, birds observed, skipper experience, distributing information, other

Appendix 2 DST centi technical specifications

Sensors	Temperature and pressure (depth)
Size (diameter x length)	15mm x 46mm
Housing material	Alumina (Ceramic)
Weight (without housing)	in air: 19g in water: 12g
Battery life	7 years
Memory type	Non-volatile EEPROM
Memory capacity	174,000 measurements
Memory capacity bytes	261,819 bytes / temperature 1.5 bytes, pressure 1.5 bytes
Memory extension option	786,099 bytes (EEPROM memory)
Memory management	Custom programming - Primary and secondary parameter
Data resolution	12 bits
Temperature resolution	0.032°C (0.058°F)
Temperature accuracy	+/-0.1°C (0.18°F)
Temperature range	-1°C to +40°C (30°F to 104°F)
Temperature response time	Time constant (63%) reached in 20 sec.
Standard depth ranges	30 m, 50 m, 100 m, 270 m, 800 m, 3000 m
Depth resolution	0.03% of selected range
Depth accuracy	+/-0.4% of selected range
Depth response time	Immediate
Data retention	25 years
Clock	Real time clock Accuracy +/-1 min/month
Sampling interval	In second(s), minute(s) or hour(s)
Number of different sampling intervals	1 to 7
Communications	Communication Box, RS-232C 9 pin serial and USB
Attachment hole	0.9 mm (in diameter)
Corrosive resistance	Oil, water, salt, antifreeze, brake fluid, diesel and gasoline

Appendix 3 Line sink rate testing data collection sheet

	Start of deployment	End of deployment (cross out if no changes)	Changes during deployment period (cross out if no changes)
Environmental Variables			
Date			
Time			
Depth (m)			
Time of high water			
Tidal flow (knots)			
Tide direction (degrees true)			
Swell direction (degrees true)			
Swell height (m) estimated by eye and checked on echo sounder			
Wind speed (knots)			
Wind direction (degrees true)			
Cloud cover (0/8 to 8/8)			
Precipitation (Y or N)			
Sea state			
Visibility			
Atmospheric pressure (millibars).			
Gear variables			
Unique identifier number for vessel			
Notes on aim of gear set up from skipper’s perspective			
Beam of vessel (m)			
Length of vessel (m)			
Engine power (hp)			
Target species (as per catch return)			
Height of backbone above water at the stern of the vessel (m)			
Photo and video of propeller wash taken (Y or N)			
Estimated width of visible propeller wash (m)			
Vessel course (degrees true)			
Estimated distance astern propeller wash visible (m)			
Marker buoy description			
Downline material			
Downline length			
Grapnel or end weight description and weight (kg)			
Line length (nautical miles)			
Setting speed over the ground (knots)			
Minimum distance behind vessel backbone enters water (m)			
Maximum distance behind vessel backbone enters water (m)			
Line tension – comparative measure of line tension in kg			
Backbone material			
Backbone diameter (mm)			
Crimp type			
Crimp spacing (m)			
Snood diameter (mm) (or breaking strain in kg)			
Snood diameter (mm)			
Snood material			
Snood length (cm)			
Hook type and size			
Hook spacing (m)			
Bait thaw status (yes / no / partial)			
Bait type (species, note if frozen, salted, fresh)			
Intermediate floats used (Y or N)			
Number of intermediate floats			
Evenly spaced (Y or N) if no add comments			
Weight (kg)			
Weight spacing (# hooks)			
Weight material			
Length of dropper for weight (m)			
Subsurface float type and size			
Subsurface float spacing (# hooks)			

References

Abraham, E..; Thompson, F.; Oliver, M. 2010: Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report No. 45*. Ministry of Fisheries, Wellington, New Zealand (unpublished).

Bull, L. S. 2007a: A review of methodologies for mitigating incidental catch of seabirds in New Zealand fisheries. *DOC Research & Development Series 263.* Department of Conservation, Wellington. 57 p.

FAO 2009: Fishing operations. 2. Best practices to reduce incidental catch of seabirds in capture fisheries. *FAO Technical Guidelines for Responsible Fisheries. No. 1, Suppl. 2.* FAO, Rome. 49 p.

IUCN 2008: International Union for Conservation of Nature: Red list of threatened species. www.iucn.org.

Løkkeborg, S.; Robertson, G. 2002: Seabird and longline interactions: effects of a bird-scaring streamer line and line shooter on the incidental capture of northern fulmars *Fulmarus glacialis. Biological Conservation 106:* 359–364.

Løkkeborg, S. 2008: Review and assessment of mitigation measures to reduce incidental catch of seabirds in longline, trawl and gillnet fisheries. *FAO Fisheries and Aquaculture Circular No. 1040.* 24 p.

MFish 2010: Fisheries (Seabird Sustainability Measures—Bottom Longlines) – circular issued under authority of the fisheries (commercial fishing) amendment regulations 2010 (No. F541). Retrieved from http://www.fish.govt.nz/NR/rdonlyres/59E3D300-1BDF-43FB-BA76-A4E3C3026BDF/0/F541.pdf

MFish (Ministry of Fisheries) 2011: Review of sustainability measures and other management controls for bluenose (BNS 1, 2, 3, 7 and 8) initial position paper. Ministry of Fisheries, Wellington, New Zealand.

Nabis (National Aquatic Biodiversity Information System) 2011: www.nabis.govt.nz.

Ramm, K. 2011 : Conservation Services Programme Observer Report 1 July 2009 to 30 June 2010. Draft. Department of Conservation, Wellington, New Zealand. 122 p. Retrieved from:
http://www.doc.govt.nz/upload/documents/conservation/marine-and-coastal/fishing/draft-csp-observer-report-2009-10.pdf

Richard, Y.; Abraham, E.; Filippi, D. 2011: Assessment of the risk to seabird populations from New Zealand commercial fisheries. *Final Research Report for Ministry of Fisheries projects IPA2009/19 and IPA2009/20* (unpublished) Ministry of Fisheries,Wellington. 66 p.

Robertson, G.; Moe, E.; Haugen, R.; Wienecke,B. 2003: How fast do demersal longlines sink? *Fisheries Research 62:* 385–388.

Robertson, G.; Williamson, J.; McNeill, M.; Candy, S.; Smith, N. 2008: Autoliners and seabird by-catch: do line setters increase the sink rate of integrated weight longlines? *CCAMLR Science, Vol. 15:* 107–114.

Robertson, G.; Moreno, C.; Crujeiras, N.; Wienecke, B.; Gandini, P.; McPherson, G.; Seco Pon, J. 2008: An experimental assessment of factors affecting the sink rates of Spanish-rig longlines to minimize impacts on seabirds. *Aquatic Conservation: Marine and Freshwater Ecosystems. 17:* 102-121.

Robertson, G.; Candy, S.; Wienecke, B. 2010: Effect of line shooter and mainline tension on the sink rates of pelagic longlines and implications for seabird interactions. Agreement on the Conservation of Albatrosses and Petrels Third Meeting of the Seabird Bycatch Working Group Mar del Plata, Argentina, 8 – 9 April 2010.

Rowe, S. 2009: Conservation Services Programme Observer Report: 1 July 2004 until 30 June 2007. *DOC Marine Conservation Services Series 1.* Department of Conservation, Wellington, New Zealand. 93 p.

Rowe, S. 2010a: Conservation Services Programme Observer Report: 1 July 2007 until 30 June 2008. *DOC Marine Conservation Services Series 4.* Department of Conservation, Wellington, New Zealand. 97 p.

Rowe, S. 2010b: Level 1 risk assessment for incidental seabird mortality associated with New Zealand Fisheries in the NZ-EEZ (unpublished). Department of Conservation, Wellington, New Zealand. 75 p.

Seco Pon, J.; Gandini, P.; Favero, M. 2007: Effect of longline configuration on seabird mortality in the Argentine semi-pelagic Kingclip *Genypterus blacodes* fishery. *Fisheries Research, 85:* 101–105.

Smith, N., 2001: Longline sink rates of an autoline vessel, and notes on seabird interactions. *Science for conservation 183* Department of Conservation, Wellington, New Zealand. 32 p.

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