MIT 2009/01 Development of mitigation strategies:

Inshore fisheries

DRAFT RESEARCH REPORT

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Contents

Abstract

Port visits were carried out to characterise the inshore bottom longline fishery and discuss seabird interactions and mitigation measures with skippers.

Gear employed by the smaller inshore bottom longline vessels fell into three groups, two of which worked ‘clip on’ gear. These vessels could be further split by target species: those targeting ling or bluenose worked heavier gear with larger hooks than those targeting snapper. A further group of vessels used an automatic lining system. Within these groupings there was further gear variation, most notably due to the combination, size and spacing of weights and floats added to the line.

Mitigation measures currently in use are simple, low tech and perceived by fishers to be effective under the right circumstances. Night-setting and tori lines were the most commonly employed mitigation.

Areas where further work is needed were identified and possible mechanisms for improving mitigation devices and practices were highlighted.

Time depth recorders (TDRs) were used to measure sink rates of bottom longlines from six vessels. Sink times showed considerable variation and were in the order of 20 – 60 seconds to 5m and a further 30 - 70 seconds to sink another 10m. When vessel speed was considered TDRs had generally sunk to at least 5m once 100m behind the vessel and to 15m depth 200m behind the vessel.

Increasing the amount of weight on the line increased sink rate, most appreciably below 5m. Recommendations to increase sink rate include the use of closely spaced regular sized weights and careful deployment of intermediate surface floats.

1. Summary of the current situation

1.1 Background

Legislation guiding the management of fisheries interactions with New Zealand seabirds is described in the Wildlife Act 1953 and Fisheries Act 1996. The Wildlife Act absolutely protects all but one seabird species (black-backed gull *Larus dominicanus*). However, the Act recognises and allows for the fact that fishing activity can result in the incidental capture of protected seabirds. Section 68(B) outlines a series of defences available for people who capture or kill marine wildlife, including a defence for killing wildlife in the course of fishing.

The Fisheries Act 1996 requires the adverse effects of fishing on the aquatic environment to be avoided, remedied or mitigated. The Act contains specific provisions relating to managing the effects of fishing on protected species. The Act also allows for the Crown to recover costs for providing conservation services addressing the adverse effects of commercial fishing on protected species, which are defined with reference to the Wildlife Act 1953 and Marine Mammals Protection Act 1978. Conservation services are defined in Section 2 of the Fisheries Act 1996 as:

> *"outputs produced in relation to the adverse effects of commercial fishing on protected species, as agreed between the Minister responsible for the administration of the Conservation Act 1987 and the Director-General of the Department of Conservation, including—*
>
> *(a) research relating to those effects on protected species:*
>
> *(b) research on measures to mitigate the adverse effects of commercial fishing on protected species:*
>
> *(c) the development of population management plans under the Wildlife Act 1953 and the Marine Mammals Protection Act 1978."*

A key component of the Conservation Services Programme is the statutory role to monitor and collect data on the interactions between protected marine species and fisheries. To fulfil this role, government observers are placed on commercial fishing vessels operating in New Zealand's Exclusive Economic Zone (Rowe 2009, 2010a). The Department of Conservation (DOC) employs a variety of other approaches to meet this brief including funding research projects regarding fisheries interactions, species populations and mitigation methods, organising workshops with fishers, as well as providing information, identification resources and bycatch mitigation equipment to the fishing industry.

1.2 DOC observer coverage

The objectives of the DOC observer coverage are as follows (DOC 2010):

Overall Objective:

To understand the nature and extent of protected species interactions with New Zealand commercial fishing activities.

Specific Objectives:

1. To identify, describe and, where possible, quantify[1] measures for mitigating protected species interactions;
2. To collect other relevant information on protected species interactions that will assist in assessing, developing and improving mitigation measures.

[1] Observers collect data according to defined protocols. General observations are also reported for each trip.

Policy 12 of the Conservation Services Programme Strategic Plan (DOC 2005) provides further guidance on the priorities of the observer programme as follows:

- Provide a baseline level of observation of fisheries where interactions are thought to be generally identified.
- Enhance observations in unobserved fisheries or, where interactions are not understood.
- Gather information that will facilitate understanding of the nature of fisheries interactions and lead to the development of mitigation techniques.
- Support the development and testing of mitigation techniques, and assist in the evaluation of the effectiveness of mitigation methods.
- Encourage and audit the self-reporting by fisheries of their interactions with protected species.

The Ministry of Fisheries (MFish) observer programme monitors aspects of fishing such as stocks and compliance, however DOC also contracts MFish to assist with meeting their objectives. Typically observers on any one trip will spend some of their time completing work for each agency. From 2004 until the MFish 2008/09 observer year[2], the majority of inshore observer coverage was solely at the request of DOC (for example snapper longlining in the Hauraki Gulf). However, as of 2009/10, all inshore observer coverage has been planned and delivered co-operatively between DOC and MFish to meet shared objectives.

1.3 Observing inshore vessels

DOC has been placing observers in inshore fisheries since 1997, mostly in set net, trawl and bottom longline fisheries. Less than ideal levels of coverage has been achieved due to a number of constraints both within Government and the fisheries. The historic lack of coverage has been attributed to several factors including problems establishing contacts in a relatively new fishery (MFish 2005), and conflicting priorities for a small pool of government observers (Rowe 2009). Nevertheless, this limited coverage has identified bycatch events in all fisheries monitored, which indicated a potentially large impact of such small vessel fisheries on protected species. More recently, higher levels of observer coverage have been achieved in set net and trawl fisheries through the MFish summer Hector’s observer programme and for the snapper longline fleet in FMA 1 through DOC’s observer programme (Table 1).

Although considerable levels of coverage have been achieved in some inshore fisheries for short periods of time, observations to date do not allow for robust estimates of total protected species bycatch. Abraham et al. (2010) estimated protected species captures using ratio estimates and observer bycatch reports over a 10 year period ending in 2008. Estimates were split into strata based on area, fishing method and target species; though no split was made between bottom longline inshore and deepwater vessels. However, bottom line-caught bluenose and snapper are exclusively targeted by inshore vessels, and as such bycatch estimates for these strata can be considered to represent inshore vessels. Abraham et al. (2010) estimated bycatch of white chinned petrels, white capped albatross, sooty shearwaters, 'other albatrosses' and 'other birds' for three years in both the northern snapper and the eastern bluenose fishery, as well as estimates for a further two years in other bluenose areas. Due to coverage in the order of 0.9 to 2.5 percent in the strata, estimated confidence intervals around the estimates are large. Lack of observer coverage in other years and strata prohibited estimates of protected species bycatch.

2 The observer year runs from1st July to 30th June

Table 1 Total days observed on commercial bottom longliners targeting snapper by fisheries management area (FMA) and fishing year. Data supplied by Marine Conservation Services.

	Observed days			
FMA	2004/2005	2005/2006	2008/2009	2009/2010
AKE	135	45	252	327
AKW	1			

Table 2 Total days observed on commercial longliners, less than 36m overall length, targeting ling, bluenose, hapuku or bass by fisheries management area (FMA) and fishing year. Data supplied by Marine Conservation Services.

	Observed days				
FMA	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010
AKE	18	43	54	6	22
CEE			45		
SEC	6		32	20	30
SOE	16		75		15
AKW		1	11		
Total	**40**	**44**	**217**	**26**	**67**

Due to the nature of inshore fisheries, observer placement is much harder to achieve than in the deepwater fleet for a number of reasons including:

- Inshore fishing is often weather dependent and vessels have no fixed sailing dates. They typically fish short trips with often several days between trips. This means observers have to be based in a port, often on standby, making coverage expensive per sea day.
- Many vessels are reluctant to take observers. Although most costs are recovered from all quota holders there is still some extra cost to the vessel in having another person on board.
- Safety concerns are greater on small vessels. There is less room on deck and more chance that observers will be exposed to dangers associated with fishing gear.
- Vessel size means that is difficult to find space for an observer, thus causing a greater imposition on the crew compared with larger vessels.
- A comparatively large amount of time and effort is required to arrange observer coverage in a large fleet of small vessels, many of which are owner-operated with no shore-based manager.

Lack of incentive to get the observer coverage has also been a factor in the past and because inshore observer days are hardest to achieve they tend to fall off the priority list first.

More recently, official notices under Section 221 of the Fisheries Act 1996 have been used, forcing observers on boats in order to meet MFish observer coverage targets. This approach does not encourage a co-operative relationship with fishers, or provide the most productive operating environment for collecting the type of information on marine species interactions needed to fulfil DOC objectives.

1.4 Attitudes of fishers

A fishery advisor officer was employed by DOC in the SNA1 snapper bottom longline fishery over the period April 2003 to March 2005 (Johnson 2005). Sixty skippers were contacted and the advisory officer reported a positive attitude and a desire to minimise seabird bycatch from all of the skippers. Mitigation measures mentioned by Johnson (2005) include tori lines, oil on the water, line weighting and the use of floats towed behind the vessel during daylight sets. Tori line use was more common in the day than at night, and Johnson (2005) noted that it was difficult to achieve maximum aerial coverage without a high point on the vessel. Southern Seabird Solutions Trust workshops and the Seafood Magazine were recognised as being important sources of information on mitigation measures. While Johnson (2005) briefly reported on the bluenose and hapuku fishery, there was no mention of mitigation measures.

An advisory officer was employed in the inshore ling bottom longline fishery over the period May to October 2003, with vessels being visited in Lyttelton, Greymouth and the Chatham Islands, and those fishing from Napier and Gisborne were contacted by telephone. The officer visited 13 vessels, all under 18m, and reported the use of a variety of mitigation measures including line weighting, night setting, low light levels, offal management and thawing of bait (Kellian 2004). A co-operative and constructive approach to mitigating seabird interactions was reported by Kellian (2004).

Fishing vessels that have carried observers were all reported by observers to show a good awareness of protected species interactions, and the perceived problems. Observer debriefs show that skippers were generally happy to accommodate observers, if somewhat reluctantly at first. Regarding regulated mitigation devices fishers often felt that these are not appropriate or necessary for their particular fishing practices or area. The comments ‘we don’t catch birds’ and ‘why are you spending all this money observing us’ often appear in observer reports, indicating that fishers are not fully aware of the need for and the aims of observer coverage.

1.5 Allocating observer coverage to highest risk areas

A qualitative assessment by Rowe (2010b) has assessed the risk to seabirds from interactions with New Zealand fisheries, by fishing method. This approach rated the risk to seabirds using a combination of the exposure of each species to the fishery and the consequence of this exposure. Fishing effort, fishing methods, species behaviour, distributions, life history strategies and population structure were all considered when determining risk.

Species deemed to be at extreme, high or moderate risk from bottom longlining included: Antipodean (*Diomedea antipodensis antipodensis*), Gibson’s (*D. a. gibsonii*), Southern royal (*D. e. epomophora*), black browed (*Thalassarche melanophrys*), Buller’s (*T. bulleri*), Campbell (*T. impavida*), Chatham (*T. eremita*), Salvin’s (*T. salvini*) and white-capped (*T. steadi*) albatrosses, flesh-footed (*Puffinus carneipes*) and sooty (*Puffinus griseus*) shearwaters, and black (*Procellaria parkinsonii*), grey (*P. cinerea*), Westland (*P. westlandica*), white-chinned (*P. aequinoctialis*), giant (*Macronectes* sp.) and grey-faced (*Pterodroma macroptera gouldi*) petrels.

When mitigation measures were taken into account, risks were adjusted downwards when there was a high level of confidence in the efficacy of mitigation devices, particularly in the deep sea ling bottom longline and deep sea trawl fisheries (Rowe 2010b). However, it is important to note that the ‘mitigated’ scores were based on the assumption that all regulated devices were being used according to specifications across the fleet.

Species deemed to be at moderate risk from inshore bottom longlining, after adjustment for mitigation measures assumed to be in place, included: black petrel, Chatham albatross, flesh-footed shearwater, grey petrel, Westland petrel and white-chinned petrel (Rowe 2010b). These species are represented in observed captures in these fisheries, as shown in Tables 3 and 4. One factor likely to be contributing to observed difference in captures between the trips targeting snapper and those targeting ling, bluenose, hapuku or bass, is that these fisheries operate in different areas and therefore come into contact with different species. In addition, the trips targeting ling, bluenose, hapuku and bass comprise of a mixed group of vessels. Some are similar to the smaller vessels targeting snapper with clip on gear, but several use automatic longline gear, similar to the deep sea vessels, but without integrated weight line. The capture of albatross by these vessels indicates that sink rates are potentially low (Table 4).

When comparing effort in the inshore bottom longline fishery (Figure 1) with the distribution of species deemed to be at highest risk by Rowe (2010) (Figure 2) some areas of highest overlap are apparent: Off the North East coast of the North Island snapper longliners are likely to interact with black and Westland petrels and flesh-footed shearwaters. Black petrels, flesh-footed shearwaters and also Buller’s shearwaters (*Puffinus bulleri*) (breeding on the Poor Knights

Islands) are all summer breeders, and will predominantly be foraging close to breeding grounds during the summer period (Onley & Scofield 2007). Unsurprisingly observer coverage has coincided with this period. Also of note is the potential for interactions with Chatham albatross by vessels fishing for ling on the Chatham Rise, as well as vessels fishing from the Chatham Islands. Again observer coverage has been targeted to cover this area.

Table 3 Seabirds captured during observed trips on bottom longliners, less than 36m overall length, targeting snapper by fishing year. Data supplied by Marine Conservation Services.

Species	2004/2005		2005/2006		2007 / 2008		2008/2009		2009/2010	
	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Southern royal albatross										1
Buller’s Albatross								2		
Black-browed albatross										1
Northern giant petrel										1
Australasian gannet		1								
Black petrel	1		2				8	3	11	5
Grey petrel							4			
Common diving petrel								1		
Buller's shearwater				4			1	2		1
Flesh-footed shearwater	4	5					4	12	9	8
Fluttering shearwater								1		1
Storm petrels										1
Petrels’ prions and shearwaters								1		
Petrel (unidentified)		2		6						
Seabird (unidentified small)		1								
Black backed gull							1	1		
Total	**5**	**9**	**2**	**10**			**18**	**23**	**20**	**19**

Table 4 Seabirds captured during observed trips on bottom longliners less than 36m overall length, targeting ling, hapuku, bass or bluenose by fishing year. Data supplied by Marine Conservation Services.

Species	2005/2006		2006/2007		2007 / 2008		2008/2009		2009/2010	
	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Albatross					1					
Black-browed albatross					3					
Black petrel				4	3				2	26
Buller's albatross					4		4			
Chatham albatross					12					
Cape petrel					1	3				
Grey-faced petrel					6					
Grey petrel								2		
Indian yellow-nosed albatross					1					
Salvin's albatross	1			1	22					
Seabird (unidentified)					1					
Sooty shearwater					1					
Wandering albatross						1				
White chinned petrel	8	2			4					

White-faced storm petrel										1
Total	**9**	**2**	**0**	**5**	**59**	**4**	**4**	**2**	**2**	**27**

Figure 1 Bottom longline effort for vessels between 6 and 28m length, measured in days fished for the 2008/09 fishing year (Ministry of Fisheries).

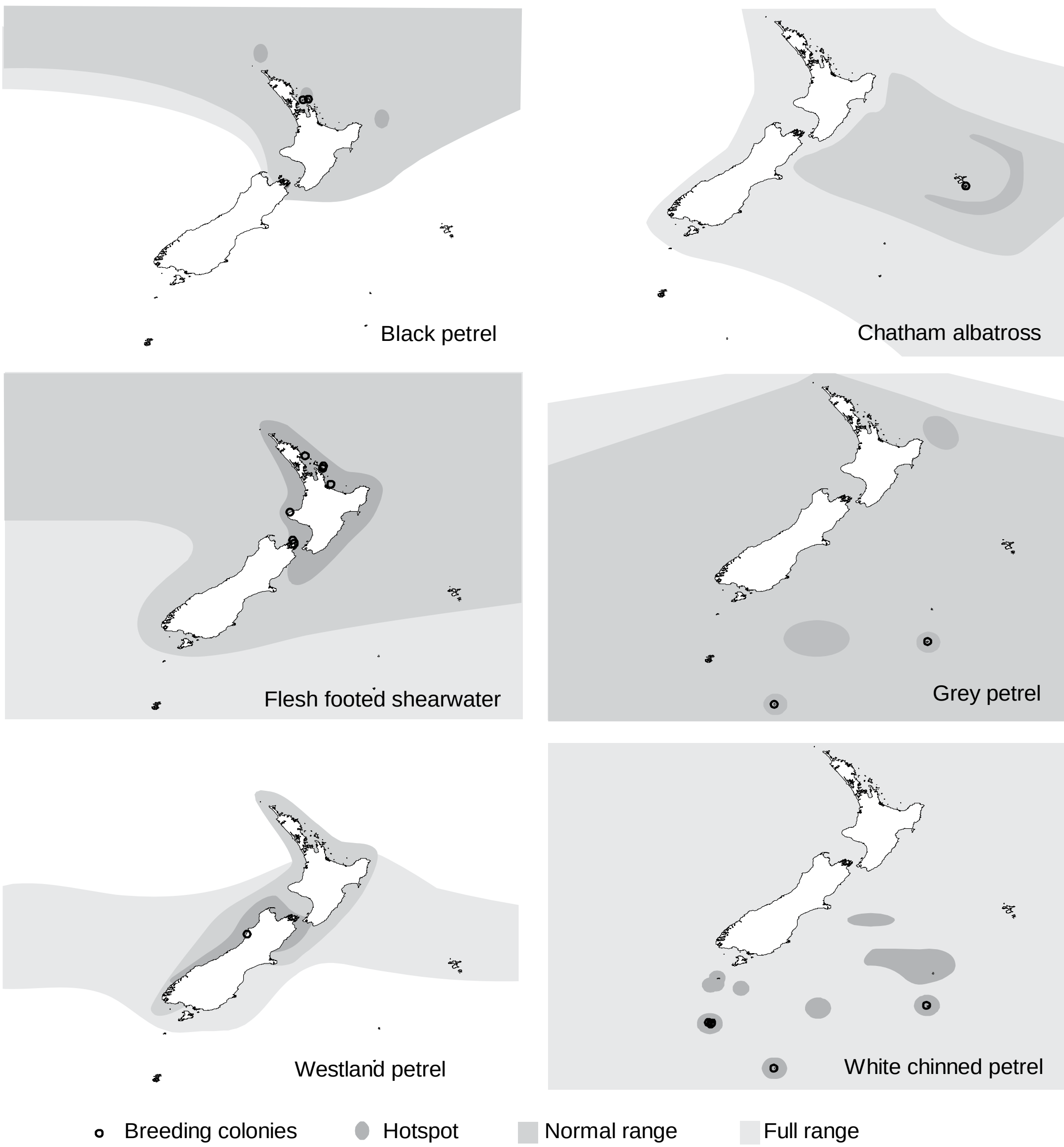

Figure 2 Seabird at sea distribution and breeding colonies. Modified from NABIS, Ministry of Fisheries.

1.6 Observer data

Because observer coverage is extremely low (Tables 1 and 2, Rowe 2009), caution must be applied when interpreting observer data regarding fisheries interactions and bycatch of protected species. Furthermore, because observer placement is not randomly distributed in space or time or between vessels, the resulting data is obtained from a non-representative sample of the fleet. Protected species observer coverage is focussed on examining interactions and so is aimed at areas perceived as most likely to have high encounter and interaction rates. The unquantified 'observer effect[3]' and variation between observers further confounds the problem. Captures can be linked to abnormal, rare events and are almost always clumped in space and time. Consequently estimating capture rates from observer data is difficult, and even interpreting summaries of data can be misleading (MFish 2007). With the small levels of observer coverage in inshore fisheries, simple ratio estimation has been used to estimate mortality rates attributable to fishing (Baird & Gilbert 2010; Abraham et al. 2010). However, with higher levels of coverage associated with deepwater fisheries, more complex models can be appropriate with associated increases in the confidence of estimates (Thompson et al. 2010).

It is difficult to assess the efficacy of mitigation devices, as it is likely to vary with environmental factors such as tide and weather, as well as with the fish species being targeted. Further variation occurs between vessels and observers as well as in space and time. All of these factors will also influence the numbers of birds recorded around the vessel and those interacting with fishing operations.

Observers can gain insights into protected species interactions over and above those recorded in formal observer reports and data forms. Reviewing observer comments and interviewing experienced observers can provide extremely valuable insights into protected species interactions, providing inappropriate extrapolations are not made. Several common themes appear when talking to experienced observers and reviewing observer trip report comments, and often capture events are perceived by observers to be related to 'abnormal' events such as those discussed below.

At times birds have been observed to feed more aggressively by observers and skippers, leading to considerable speculation regarding the possible causes for this, including lunar and tidal cycles. The general weather situation can also have a direct and indirect impact on interactions. Birds have been reported by observers to feed aggressively prior to storm events. Strong wind and large swell can result in a less than ideal mitigation measure set up, particularly on smaller vessels. The concentration of prey, for example krill, in a particular area can attract birds and fish, and consequently fishing effort. Birds have been observed to take advantage of high concentrations of prey, resulting in large numbers of birds and more aggressive feeding.

Season is an important factor when considering protected species interactions; it will affect other environmental variables, but also must be considered in relation to breeding times for seabirds. Prior to breeding, birds need to build up their fat stores. If a pair are alternating sitting on eggs then less time is available for feeding.

Temporal and spatial changes in bird feeding behaviour have been reported by observers, ranging from total disinterest in fishing operations to aggressive feeding beneath tori lines (J. Williamson pers. obs.). It is important to recognise that the overall abundance and species composition of birds present during a fishing operation is likely to influence behaviour. For example a large number of birds may lead to increased competition, both inter and intra-specific. This competition may cause aggressive feeding behaviour, resulting in a higher risk of capture. Differences in behaviour between species should also be considered. For example flesh-footed shearwaters have been observed to maintain some distance from a tori line whilst Buller's shearwaters and Cape petrels (*Daption capenses*) attempted to feed under the tori line (J. Williamson pers. obs.).

Abnormal events associated with the vessel or fishing gear have been identified by observers as potentially contributing to captures. These are often related to gear problems, for example line tangles. Similarly mitigation device problems

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[3] 'Observer effect' can be defined as a change in behaviour, in this case fishing practices, as a result of being watched or observed.

occur, for example a strong cross wind blowing a tori line away from the baited hooks. Finally breakdowns or other unusual circumstances may result in poor offal management, thereby attracting birds at a less than ideal time.

Unlike the offshore fishery where seabirds have been observed to follow a vessel for days, even if little food is provided, the inshore environment provides many more distractions and feeding opportunities. Furthermore many inshore vessels work short trips and land fish green[4], with little or no offal discarded. This indicates a lot of potential for mitigation measures and fishing practices aimed at reducing the visibility or attractiveness of the fishing operation, or other methods of deterring birds from following the vessel. Conversely, however it suggests that if a feeding opportunity is presented bird numbers may increase quickly.

1.7 Autopsy Results

The autopsy results from seabird captures on observed trips have repeatedly shown bait or offal in the stomach contents (Robertson & Bell 2002a, 2002b; Robertson et al. 2003, 2004; Thompson 2009, 2010a, 2010b). Not surprisingly, such reports conclude that 'The role of offal, discards and bait should be regarded as a principal factor in the incidental capture of seabirds in both trawl and the longline fisheries' (DOC 2008a).

Another pattern which appears throughout seabird captures is that they are not spread evenly over all trips observed in a fishery. Often large numbers of birds are reported from one fishing event or trip (Thompson 2009).

1.8 Legal regulation of mitigation measures

Following introductions of legal requirements for seabird mitigation measures in the deepwater fisheries (MFish 2006a), the Minister of Fisheries has more recently introduced regulations aimed at inshore vessels:

Amendments to the Fisheries Act in 2008 require bottom longline vessels of overall length between 7 and 20m to use a streamer line with a minimum aerial extent of 50m. There are also requirements for night setting or minimum line weighting regimes. Offal retention is required during setting, and discharge is not allowed on hauling side of vessel (MFish 2008b). The extent of compliance with these measures is largely unknown; however recent observer coverage indicates that it is not complete (Rowe 2009).

1.9 Work to date on mitigation measures relevant to inshore fisheries

Two reviews of seabird bycatch mitigation methods have been carried out for DOC; one initially covering gillnet, trawl and longline fisheries (Bull 2007a, 2007b), and more recently an update for trawl mitigation (Bull 2010). The conclusions of both these reviews include the importance of offal management as a primary mitigation strategy. The use of tori lines and line weighting is recommended for mitigating longline seabird captures.

One important recommendation of these reviews is the need for testing for the efficacy of mitigation methods under controlled conditions. This is not always easy as almost all studies need to be carried out on 'normal' fishing trips, mainly for economic reasons but also in order to study the situations in which mitigation methods operate. Under such circumstances it is not possible to control all fishing variables completely and environmental variables also vary between treatments. A further hurdle is involved when legislation is in place for minimum mitigation standards. Finally it is ethically questionable to test existing and alternative mitigation methods against a 'no mitigation' control if vessels already employ some mitigation that has been proven to be effective to some degree. Consequently it may be appropriate to adopt some other standard against which alternative mitigation strategies can be compared. Irrespective, the experimental design of any further studies should be rigorously scrutinised prior to undertaking any work at sea. Because seabird interactions, and certainly captures, are relatively rare events it is necessary to employ a proxy for interactions in order to produce meaningful results from limited experimental sea time. Significant positive correlations have been recorded between seabird abundance, contact rates and total mortalities in both longline and trawl fisheries

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4 Green fish are whole and not processed

(Gilman et al. 2003; Sullivan et al. 2006; E.R. Abraham, D.A.J. Middleton, S.M. Waugh, J.P. Pierre, N.A. Walker and C. Schroder, unpublished data). As such, the terms ‘heavy contacts’, ‘light contacts’ and ‘total contacts’ appear frequently within material associated with interactions of seabirds with fishing gear, particular for trawling.

These reviews (Bull 2007a, 2007b, 2010) provide a summary of published and unpublished data and reports on trials of mitigation measures, generally in deepwater fisheries. Some examples of work undertaken to date, and its relevance to inshore bottom longlining, are discussed briefly below.

The bycatch of seabirds by both bottom and surface longliners has attracted a lot of attention world-wide and mitigation measures are generally well understood (e.g. Brothers et al. 1999). These measures generally revolve around one of the following principles:

1. Deter birds from entering area near baited hooks (e.g. streamer lines, brickle curtains).
2. Reduce visibility of baited hooks (e.g. dyeing bait, night setting).
3. Increasing the sink rate of the gear, thereby reducing the exposure time of hooks (e.g. line weighting, thawing bait).
4. Reducing the number of birds attracted to the vessel (e.g. offal retention, reducing bait loss).

Tori line, as used by longliners, has become one of the most widely used mitigation devices and its success has been proven in many fisheries world-wide with substantial reductions in seabird bycatch (Lokkeborg 2008). When used with the combination of a lead integrated backbone (Robertson et al. 2006) and night setting (Lokkeborg 2008), seabird captures have been dramatically reduced.

The high level of success in preventing seabird captures in Convention for the Conservation of Marine Living Resources (CCAMLR) waters has largely been attributed to the series of mitigation measures, both voluntary and regulatory, and heavy penalties given for seabird captures (Waugh et al. 2008). These measures include the retention of all offal, regulated minimum sink rates and use of tori lines. Several New Zealand flagged vessels that fish for toothfish in CCAMLR waters also target ling within New Zealand waters. These vessels have achieved a reduction in seabird bycatch rates (e.g. Robertson et al. 2006) largely by employing similar mitigation levels to those required under the CCAMLR, and aided by the ability to set during darkness. It should be noted that bycatch in the ling fishery is characterised by relatively few events and dominated by small diving seabird species (Rowe 2009).

The tori lines employed by these large ‘deep sea’ auto liners cannot be replicated exactly on inshore vessels due to these vessels having a narrower beam, lower attachment points for tori lines and rolling more. These factors make it hard to maintain sufficient aerial coverage over baited hooks. Conversely, large vessels used in offshore fisheries provide a relatively wide, tall and stable platform from which to operate a tori line.

Tori lines have proved to be one of the most effective tools in the reduction of incidental deaths of many surface seizing foragers, but in mitigating captures of diving foragers they are less successful (Melvin et al. 2004). Observed captures from inshore bottom line vessels include significant numbers of species that have the ability to dive to considerable depths (e.g. flesh-footed shearwater and black petrel).

Shooting lines at night is considered a great benefit in mitigating seabird capture (Lokkeborg 2008) and observer reports indicate that the majority of sets by inshore longline vessels are carried out at night.

Bottom longlines set during daylight are required to meet minimum line weighting regulations (MFish 2008b). Prescribing minimum weighting is a relatively easy way to reduce the availability of baited hooks to birds and has been successfully employed, notably in CCAMLR waters (CCAMLR 2008). However this is backed up by extensive trials of different weighting regimes (e.g. Robertson et al. 2008) and full observer coverage to monitor sink rates. To date the sink rate of gear weighted in accordance with the regulations applicable to inshore vessels in New Zealand has not been measured.

1.10 Practical solutions over and above regulatory minimum standards

Workshops organised by DOC have revealed the use of mitigation measures developed by the industry that have yet to be thoroughly examined or documented.

One advantage of inshore fisheries is that the skipper and mate often work on deck and are therefore more likely to see species interactions, and have first hand experience with mitigation devices and practices. Inshore vessels are also able to be more reactive as conditions change, compared to the deepwater fleet where those in control are often more removed from observing species interactions.

Observers report that some inshore vessels will use alternative mitigation measures over and above the regulatory minimum standards. These are likely to be tailored to the specific vessel and more suitable to their particular fishing operation and / or environmental conditions at the time. A good example of this is the use of fish oil, developed by Alex Aitkin, as a deterrent to seabirds (Pierre & Norden 2006, Norden & Pierre 2007). Observers also report the use of cooking oil, engine oil or oily bilge water in order to produce a similar effect.

Dyeing of bait has been recorded in the surface longline fishery and is believed to reduce the visibility and attractiveness of bait to birds, and hence reduce bird captures (Lydon & Starr, 2004, Cocking et al. 2008). This method has also been employed by at least one bottom longliner, solely to mitigate seabird bycatch (J. Williamson pers. obs.).

Avoiding setting gear when large numbers of birds are present has been documented by observers as a measure taken to mitigate seabird bycatch in New Zealand, but the extent to which this occurs is unknown.

1.11 Objectives of the project

The specific objectives of this project are:

1. To work with inshore fishers to improve awareness and understanding of protected species interactions with inshore fisheries.
2. To identify characteristics of inshore fisheries that may influence the likelihood of protected species interactions.
3. To assess current use of mitigation measures, and work with fishers to develop, test, and implement measures for mitigating protected species interactions.

This project focused on seabird interactions with the bottom longline fleet operating on the North East coast of the North Island in Fisheries Management Area 1 (FMA1) and on the Chatham Rise.

For the purposes of this project, inshore fisheries are generally defined as fisheries operating in depths less than 200m and/or prosecuted by vessels less than 28m overall length. However this definition has been extended to include all bottom longliners less than 36m overall length. This allows inclusion of the smaller vessels that fish on the Chatham Rise, but using methods more similar to the inshore fleet than to the larger autoliners that also fish deeper waters both inside and outside the zone. These smaller vessels have had limited observer coverage compared to the larger autoline vessels (Rowe 2009). Interactions can be defined as ‘Any interaction between a seabird and fishing gear leading to injury or mortality’ (Rowe 2009).

2. Increasing fisher awareness and fishery characterisation

2.1 Introduction

Following a review of the current information available on mitigation employed to reduce protected species interactions in the inshore bottom longline fishery, port visits were conducted. The aims of these visits were to:

2. Collect information to characterise the fishery.

3. Discuss with skippers protected species (particularly seabird) interactions and the various options for mitigating these interactions.

4. To increase fisher awareness of the diversity of species encountered and highlight differences between species which influence their vulnerability to fishing operations.

2.1.1 Fishing effort

Initially fishing effort was examined in order to provide a broad insight into the extent of the fishery and the number of vessels involved. Bottom longline effort in Fisheries Management Area 1 (FMA1) in the 2007/08 fishing year showed that snapper was the most common target species. Bluenose, ling, hapuku and bass also made a significant contribution to the number of sets. Other target species appeared infrequently (Table 5).

Table 5 Fishing effort by vessels fishing bottom longlines in Fisheries Management Area 1 in the 2007/08 fishing year. Effort is measured in total number of lines and hooks set, for the top ten target species.

Target Species	Number of sets	Percentage of sets	Number of hooks	Percentage of hooks	Number of boats
Snapper	5503	77.7	8 325 772	75.5	52
Bluenose	844	11.9	1 454 313	13.2	30
Ling	254	3.6	424 719	3.9	15
Hapuku and/or Bass	260	3.7	383 420	3.5	26
Red snapper	62	0.9	118 300	1.1	6
Gurnard	52	0.7	77 900	0.7	7
Ribaldo	45	0.6	99 136	0.9	2
School Shark	31	0.4	101 700	0.9	7
Tarakihi	13	0.2	10 950	0.1	4
Red scorpion fish	11	0.2	16 100	0.1	1
Total	**7085**		**11 023 760**		

Sets targeting ling account for the majority of effort on the Chatham Rise, with bluenose and hapuku or bass also targeted frequently (Table 6). Fewer vessels set more hooks compared to effort in FMA 1, and this can be attributed to larger vessels with automated lining gear working longer trips on the Chatham Rise.

Table 6 Fishing effort by vessels fishing bottom longlines on the Chatham Rise in the 2007/08 fishing year. Effort is measured in total number of lines and hooks set, for the top four target species.

Target Species	Number of sets	Percentage of sets	Number of hooks	Percentage of hooks	Number of vessels
Ling	1296	63	5 814 218	75	16
Bluenose	497	24	1 235 750	16	12
Hapuku and/or Bass	214	10	590 953	8	
School Shark	56	3	142 200	2	6
Total	**2063**		**7 783 121**		

2.2 Methods

Port visits were made during November and December 2009 and January 2010 in an attempt to contact as many skippers as possible of small bottom longline vessels operating in FMA1 or on the Chatham Rise. A total of 26 days were spent contacting vessels fishing out of the following ports: Hohora, Monganui, Opua, Russel, Tutukaka, Whangarei, Marsden Point, Leigh, Warkworth, Auckland, Coromandel, Whitianga, Tauranga and Lyttelton (Figure 3).

Initially, a standard set of questions was used (Appendix1) to characterise the fishing gear used, target species and areas fished. This moved on to a more general discussion of the mitigation measures used on the vessel and additional options available. A bird guide (DOC 2007) was given to each skipper and time was taken to highlight the species relevant to their particular fishing operation. Seasonal distribution and behaviour of the different seabird species was also discussed. Notes were taken under the following general headings: gear employed, mitigation, attitude, regulations, offal management, discarding, birds encountered, distributing material, whether the vessel has taken government observers.

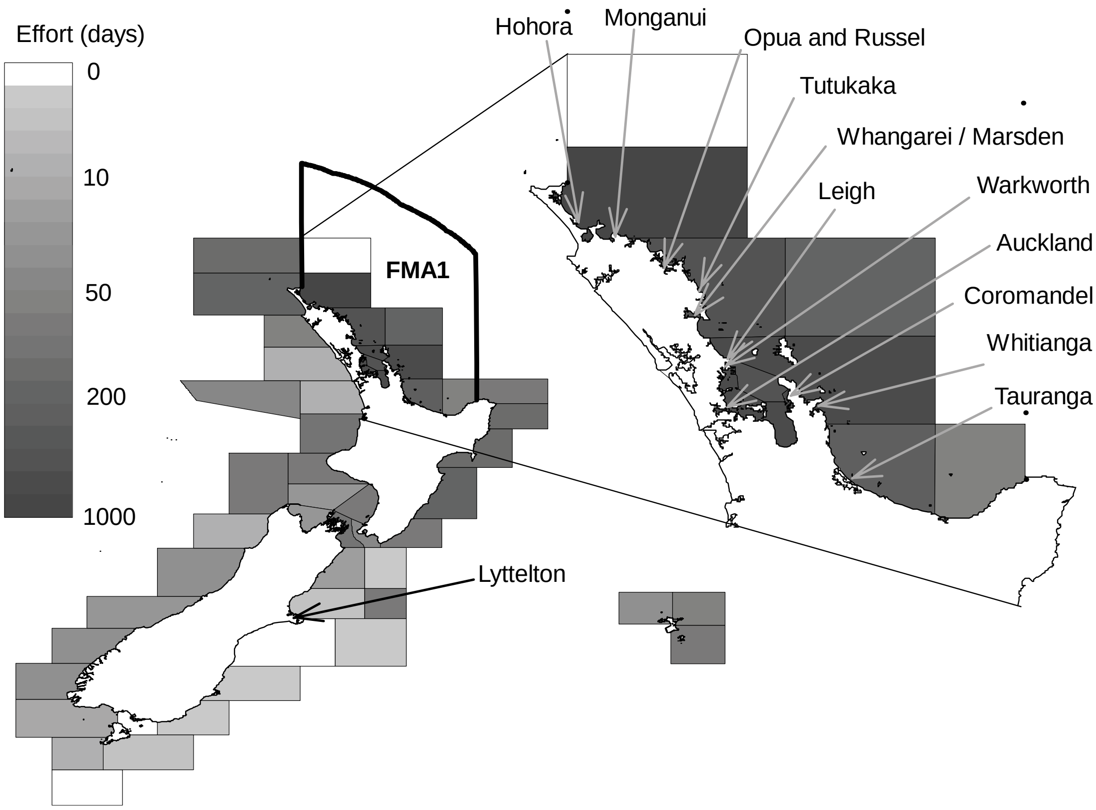

Figure 3 Bottom longline fishing effort for the 2007/08 fishing year measured in days fished. Location of FMA1 and ports visited.

2.3 Results

A summary of all discussions follows below.

2.3.1 Participation

Of the 85 vessels fishing in FMA 1 in the 2007/08 fishing year, 55 were contacted. The numbers of responses received are shown in Table 7. Fewer boats than in FMA 1 represented the majority of effort on the Chatham Rise. The skippers that were happy to participate in the survey represented more than half of the current effort and participation was forthcoming to some extent in all ports where vessels were contacted and represented all target species.

Table 7. Summary of responses from skippers, owners or vessel managers of vessels that fished bottom longlines in Fisheries Management Area 1 (FMA 1) or on the Chatham Rise in the 2007/08 fishing year. (Chatham Rise was defined as statistical areas 20-23, 401-412 and 49-52). Effort was quantified as number of hooks set. Some vessels were unable to be contacted as they were at sea or not fishing from the ports visited at that time.

	FMA 1		Chatham Rise	
Response	Number of boats	Percentage of effort	Number of boats	Percentage of effort
Spoke to skipper and recorded information	40	48	4	86
Not interested	7	8	2	3
Contacted but not currently fishing	9	11	5	7
Did not contact	29	33	7	4
Total	**85**	**100**	**18**	**100**

2.3.2 Gear characterisation

FMA 1

All vessels contacted used clip-on snoods, attached to a monofilament nylon backbone. Aluminium crimps or cotton whippings were used to separate snoods and provide regular spacing. The backbone of the line was shot from a free running drum with snoods, weights and floats attached to the backbone at the stern of the vessel. The backbone was retrieved onto the same drum using a hydraulic motor with snoods, weights and floats unclipped as the line came onboard.

Soak times varied but were generally in the order of 1-3 hours. Skippers generally targeted times of day which were known from experience to provide the best catches, often fishing over slack water[5].

Squid, pilchard and sanmar were the most common baits with jack mackerel, kahawai, octopus, and saury also recorded. Some skippers would exclusively purchase frozen bait whereas others supplemented frozen bait with bycatch, either fresh or salted.

There was a distinct split of gear types depending on target species. Vessels targeting predominantly snapper fished in shallow water with relatively light gear, long snoods, and small hooks (Figure 4). A smaller group, generally made up of larger vessels, targeted bluenose, ling and hapuku in deeper water with heavier gear, shorter snoods and larger hooks (Figure 4). There was very little cross over between these groups.

5 Slack water is typically one or two hours either side of high or low tide, when there is minimal tidal current.

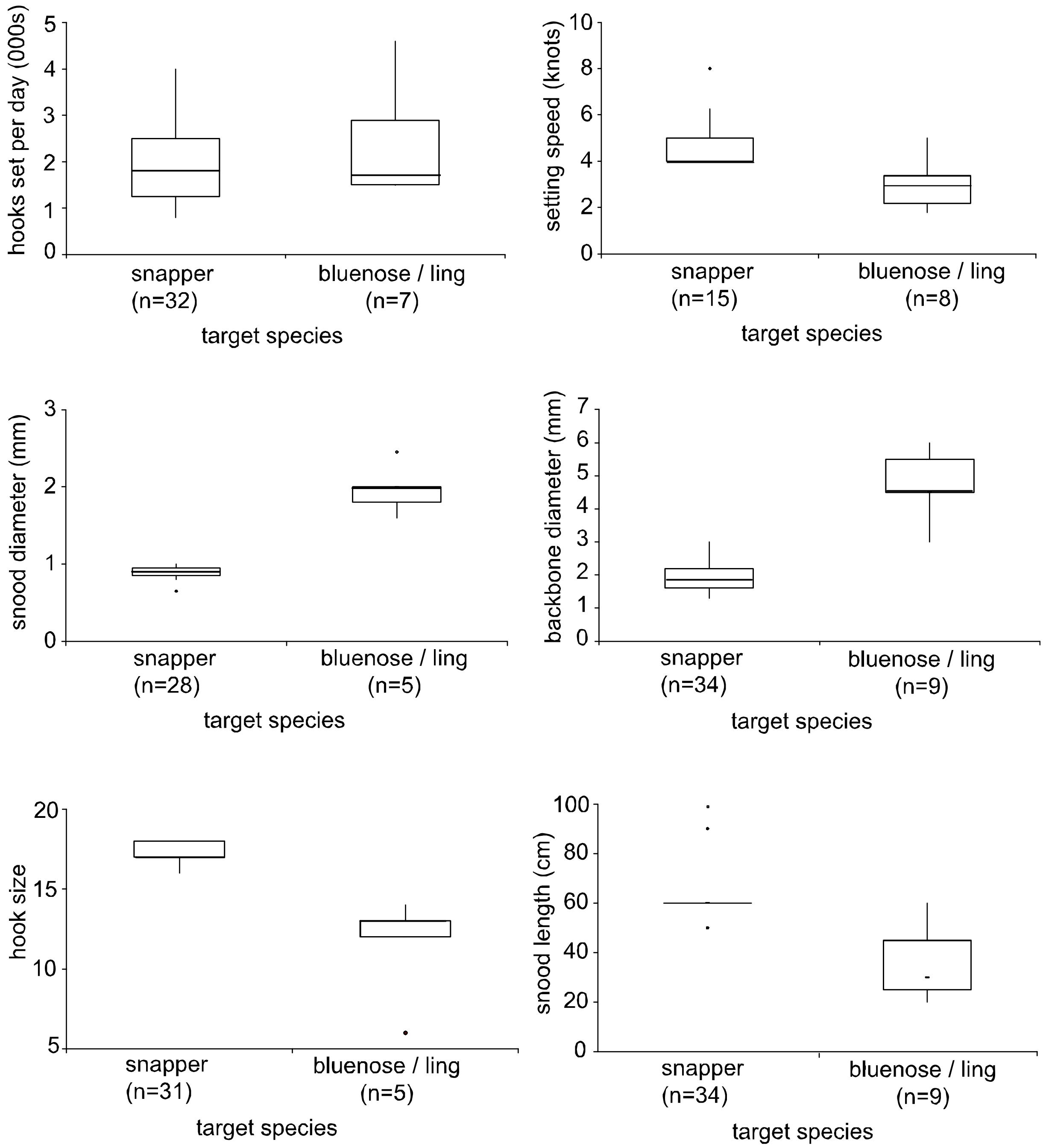

Figure 4 Box and whisker plots showing differences in some characteristic gear parameters between vessels targeting snapper and those targeting bluenose or ling.

To control the distance above the seabed that hooks fished, skippers placed weights and sometimes floats on the line. Vessels targeting snapper would often fish ‘hard’ on the bottom with weights attached directly to the backbone. Alternatively, a ‘suspender’ line attached between the weight and the backbone with a float attached directly to the backbone floated it off the bottom. Some vessels employed a mixture of weights and suspenders on the same line. As well as the three options mentioned above, vessels targeting bluenose or ling aimed to cover a greater range of depths. This was achieved by using weights on a suspender line with no float, and floats directly on the backbone with no weight, both in various combinations.

Examples of these different gear configurations are shown in Figure 5.

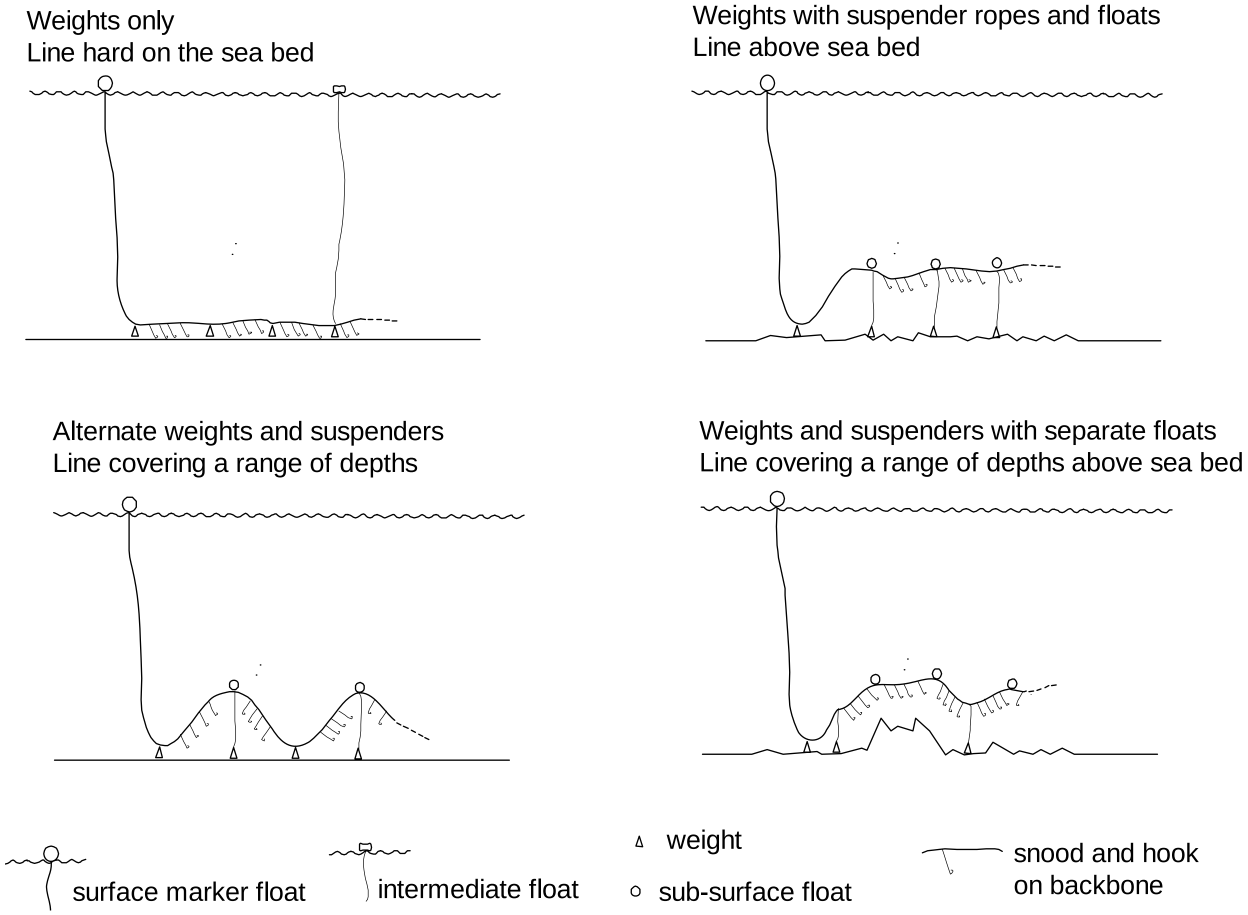

Figure 5 Examples of some different configurations of weights and floats employed by bottom longline vessels contacted, showing how lines can be fished ‘hard’ on the bottom, or suspended off the sea bed.

The amount of flotation and weight added to lines showed considerable variability, both within and between the two groups of vessels. Weights added to lines were not physically weighed during the initial vessel visits, however figures supplied by the skipper were recorded in most instances. Vessels showed a roughly even split between the use of lead and steel weights. Five vessels used bricks or rocks for some or all of the line.

Vessels targeting snapper usually added intermediate surface floats on the line. These floats were a precautionary measure to deal with breaks in the line, often caused by sharks. Intermediate surface floats were generally deployed adjacent to a weight, often larger than normal weights. The float line was wound around a ‘cotton reel’ polystyrene float, which spun as the backbone sank. Some vessels would constantly tow a float on a line behind the vessel in lieu of a tori line, and then and clip it on the backbone with the line already unwound. Alternatively a float was clipped directly onto the middle of a ‘blank’ section of the back bone, with no hooks either side of the float.

Chatham Rise

Two of the vessels contacted employed the Mustad inshore autoline system, fishing 24 hours a day. This system has a rope backbone with fixed snoods attached. The hooks are stored on magazines and as the line is shot hooks are fed through an automatic baiting machine. During hauling, hooks are retrieved and mechanically untangled from the mainline and fed onto the magazines ready to shoot. This automation removes a lot of labour involved in baiting, shooting and retrieving clip-on longlines. Consequently these vessels were able to set more gear, either approximately 12,000 or 22,000 hooks per day. Both skippers had carried observers several times, showed a very proactive approach to mitigation and felt that they were doing all that is reasonably possible. One skipper rarely used floats, targeting solely ling, whereas the other used floats when targeting bluenose but would switch to target ling with more weight and less floatation during daylight. These two vessels processed fish on board and one skipper mentioned that discarding offal and working further from shore resulted in a gradual increase in bird numbers through a trip. However with stronger backbone and more powerful winches these vessels are able to add more weight to the line, presumably increasing sink rate.

A third vessel which fished the Chatham Rise worked clip-on bottom longlines similar to those employed by vessels targeting ling and bluenose in FMA 1. The skipper was in the process of changing from rope to monofilament nylon backbone which he believes will sink more quickly.

2.3.3 Mitigation measures currently in use

Night setting

The main reported method of mitigating bird capture was setting lines during darkness, thereby reducing the visibility of the vessel and baited hooks. Very little or no visible bird activity during the set was reported as the norm. Some vessels targeting snapper would set a line over slack water during the day, depending on previous catches and weather conditions. Similarly some of the larger boats targeting predominantly bluenose or ling would work round the clock, aiming to shoot most of the lines at night but also some during the day. It is therefore likely that hooks shot at night represent the majority of the effort.

Actively avoiding birds

Several skippers mentioned that they would choose areas to fish based partly on bird distribution and would actively avoid areas where they expected to encounter large numbers of birds. This occurred on time scales varying from information of bird abundance over preceding days or weeks to seasonal bird migration patterns. Similarly some skippers would not shoot if they thought bird abundance was too high, or stop or suspend setting if large numbers of birds arrived around the vessel during a set.

Tori lines

Tori lines were carried on nearly all vessels. Some vessels reported deploying them for all sets, however several skippers said they would only deployed a tori line during daylight and/or when deemed necessary. Designs varied substantially and some skippers had put a lot of time and effort into devising an effective tori line appropriate for their vessel. Most skippers noted that it was necessary to have the tori line ready for immediate deployment if birds appeared during the set.

Variation in tori line design is summarised below, in many cases the tori line used was a modified version of that supplied by DOC several years ago.

The mainline was typically thin rope or monofilament nylon, with several skippers noting the need to keep this as thin as possible to reduce windage[6]. Towed objects employed ranged from extra line to small floats or ‘windy’ buoys to cones and thicker rope. Blue or white bait strapping, white electric fence tape, fluorescent tubing or rope was used for streamers, some of which were branched.

The use of floats on the surface of the water at the end of the tori line and along the line itself, over the baited hooks, was common. Skippers commented that these floats, with their unpredictable movement on the surface of the water, were effective in deterring diving birds. The early deployment of intermediate marker floats was commonly employed to the same effect. These were towed behind the vessel prior to clipping onto the backbone.

The presence of weak-links in the tori line was mentioned by several skippers as a way of reducing the problems caused by tangles between the tori line and hooks.

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[6] Windage can be defined as the area of object exposed the wind. In this case reducing the thickness of the rope minimises the amount the tori line is blown away from the hooks.

Vessel size and design often placed limitations on the attachment points for a tori line. Some vessels had purpose made poles, and some could move the attachment point upwind. Vessels with a larger beam[7] generally found it easier to keep the tori line over the backbone. These vessels generally had fewer problems deploying the tori line and less tangles.

Wind and sea conditions were reported as having an impact on the efficacy of a tori line; some skippers reported that they would only set into or with the wind such that the tori line was not blown away from the backbone.

The two autoline vessels reported routinely working two or three tori lines with tubing streamers, noting that sufficient aerial coverage avoided tangles with hooks or backbone. One skipper mentioned always shooting with or against the wind to ensure that the tori line remained over the baited hooks.

Oil

The current or historical use of cooking oil or mineral engine oil dripped onto the water was mentioned by four skippers, and they felt that this was, at times, very effective.

Line weighting

Skippers were well aware of the effect of line sink rate on the availability of baited hooks. Line weighting over and above that required to anchor the line was noted as a mitigation measure for several vessels. Some skippers were receptive to the idea of adding extra weight. However many raised concerns about weighting regulations with respect to carrying lots of extra weight, difficulty in retrieving the line and the breaking strain of the backbone.

Both autoline vessels aimed to shoot most lines at night. However some lines were shot during daylight in which case extra weights and less floats were used, often coinciding with a change in target species from bluenose to ling.

Reduced lighting

All skippers commented that efforts were made to reduce deck-lighting when setting in the dark. However in order to work safely a certain amount of light is necessary. Light was contained more easily on larger vessels and those with shelter decks.

Offal and used bait management

Vessels targeting snapper did not generally produce offal as the catch was landed green[8]. Small quantities of school shark were an exception, with all skippers well aware of the need to separate processing from the next set. For the smaller vessels, representing the majority of the fleet, it is not necessary to process the catch immediately prior to the next set. Most vessels would steam, drift or anchor for some time before shooting again. Vessels working continuously and processing generally either ling or bluenose would generally process after hauling, batch discard offal and typically steam some distance before shooting.

Bait retention was variable. Some vessels reported routinely retaining baits. Some vessels routinely discarded bait but would retain it if they thought it was a causing a problem. Conversely some vessels were happy to feed birds during the haul in the hope that they were not so hungry at the subsequent set.

The autoliners both processed at sea and either held offal in bins and batch discarded, or discarded on the opposite side to hauling. Discarding was suspended some time before shooting and did not commence until the set had finished.

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[7] The beam of a vessel is its width at the widest point.

[8] 'Green' fish are whole and unprocessed

2.3.4 Skipper awareness

Knowledge of bird species encountered was variable. Skippers often referred to all smaller black seabirds as ‘mutton ducks’, however many were aware of different species and breeding times. Bird identification guides were well received, though several skippers had their own.

Generally, skippers showed good awareness of variations in bird abundance, type and intensity of interactions with their fishing operation. Similarly they knew when and where they were likely to encounter the most birds and experience the most interactions. Spatial species composition changes were recorded as vessels fished further offshore. Shags, gulls and gannets were encountered inshore with petrels, shearwaters and then albatrosses encountered further from land. Location of breeding sites relative to fishing operations also influenced the number and composition of birds encountered at sea, particularly for species nesting on offshore islands.

Fishers generally showed a good awareness of behavioural differences between bird species and the need for extra vigilance when encountering diving birds. Many were particularly aware of flesh-footed shearwaters and black petrels.

2.4 Discussion

2.4.1 Participation

Port visits were undertaken because it was thought that a face-to-face conversation with skippers onboard their boats would be the best approach. This proved effective and was conducive to a productive discussion in most cases.

The cost involved in attempting to speak to all skippers was prohibitively high, and as more time was spent in a given port the returns diminished. Consequently a judgement call was made as to when to move on, meaning that inevitably some vessels were not contacted. In general, if a vessel had been observed recently then it became a lower priority to track down. Some vessels were difficult to contact for several reasons. In some cases skippers were hard to find or too busy to talk. Some vessels rarely fished and so often had no one onboard, whereas others fished longer trips and spent the majority of time at sea. Some vessels only fished for part of the year from the ports visited and were fishing elsewhere at that time.

Not involving skippers of all vessels currently bottom lining in FMA 1 or on the Chatham Rise introduced a possible source of bias into the recorded findings. A problem with the approach of voluntary participation is that resulting information tends to come from operators who are proactive towards bird mitigation, and it is not known whether their fishing operations are substantially different to operators who do not participate. As we could not access vessel owner’s names and addresses from Fish Serve[9], contacting fishers was difficult. In many cases the project was reliant on goodwill from Licensed Fish Receivers (LFRs) and fishers. Although generally helpful they were, understandably, often unwilling to pass on phone numbers. Contacting fishers following two years of relatively high levels of observer coverage in some areas increased this problem.

Skippers spoken to represented over half of the current effort in FMA 1. Although effort is a reasonable measure of a given vessel’s bird catching potential, it does not necessarily approximate its risk, particularly to the most vulnerable species. This is influenced by a host of factors, but largely determined by the area in which the vessel fishes and any mitigation employed (Rowe 2009).

Attitude of and reception from fishers varied considerably. Some were forthright in saying that they did not want to be involved whereas others were only happy to do this indirectly, which was time consuming. Some had a very wary attitude and a genuine belief that DOC and/or MFish were trying to force vessels out of the industry by over-regulation. A common complaint was that ‘this has all been done before’ through the observer programme and other initiatives and fishers had received little or no feedback. However, fishers were, in general, happy to share their knowledge and experience and were open to new initiatives, if somewhat concerned by the lack of recognition for their efforts to date.

9 Fish Serve manages fishing permits, vessel registers and fishing returns (logbooks).

Reactions to observer coverage were mixed and depended to some extent on the relationship between the skipper and observer. Many fishers felt that by taking observers and being observed not to catch birds they had proven their methods such that further coverage was unnecessary.

2.4.2 Gear variables

The relative risk posed to seabirds by different vessels and gear is extremely hard to estimate, but it is important to note some contributory factors, especially those under control of the skipper.

Line set up

Some vessels modified gear set up more frequently than others, and this was often as much a reflection of the skipper's strategy as where and when they were fishing. Some skippers used the same gear set up all year, with uniform weighting, hook spacing, line length etc. Conversely other skippers used mixed size weights randomly arranged on the line and would alter gear set up significantly over a variety of time scales. These time scales varied from seasonal changes in fishing location as fish migrate, to between set variation based on recent catches, to within set differences due to changing sea bed type.

The most common changes to gear set up were spacing and sequence of weights and floats. This could easily be altered between or during shots, whereas size and type of hooks, snoods and backbone were generally fixed for a given vessel.

Hook type

Several skippers suggested that large hooks may be less likely to catch smaller seabirds such as shearwaters and petrels as opposed to albatrosses and this is supported to some extent in the literature (Moreno et al. 2005). Similarly it was suggested by skippers that circle hooks may reduce the likelihood of a bird getting caught when taking bait compared to 'J' shaped hooks. This assumption was based on circle hooks having a less exposed barb and point due to them being somewhat protected by the curved shank of the hook.

Bait type

There was considerable speculation among skippers about which baits are more or less attractive to birds, with no clear consensus of opinion. Any preference for particular bait species or type may be confounded by differences in the visibility or availability of different types. White octopus bait, for example, may be more easily detected or visible at a greater depth than darker fish bait. Soft bait, for example pilchard versus squid, is likely to be more easily removed from the hook. Therefore pilchard may be more attractive. Similarly soft baits are more likely to come off the hook and attract birds. Whether a bird is more likely to be caught trying to remove a soft rather than a tough bait is another consideration.

Bait type may also have an effect on the percentage of hooks hauled that still have the bait attached. Returned bait is likely to act as an attractant and so influence the likelihood of interactions during the haul. This will occur both directly as hooks are brought onto the vessel and indirectly as used bait is discarded

Frozen baits were thawed prior to shooting by all skippers working clip-on gear, thereby increasing sink rate.

Factors influencing sink rate

The sink rate of baited hooks determines the amount of time they are available to birds. This is likely to be influenced by many factors but predominantly the amount of weight and floatation added to the line. Caution should be exercised when calculating the amount of weight added to a given length of line, to ensure that any floatation added to the line is included. The density and shape of the weight added to the line is also important; for example steel weights have been shown to produce faster sink rates than rocks (Robertson et al. 2008). Therefore the weight in seawater of weights added to the line must be considered. For example a 1kg rock (depending on its density) weighs a maximum of 675g in seawater whereas a 1kg lead weight weighs 909g. Therefore, the use of lead increases the amount of weight on the line in the water even though it weighs no more in the air. Similarly, the shape of weights is likely to influence sink rates.

The use of suspender lines between weights and the backbone was common when fishing over foul ground, in order to avoid the backbone catching on the seabed. These will result in a slower sink rate as it takes some time for the line to unwind before the weight starts to pull the line down.

The turbulent flow of water astern is likely to affect the line sink rate (Bull 2007a). Skippers may be able to increase sink rate by altering the position of where the line enters the water relative to the propeller wash. In practice, options on smaller boats are limited.

Setting speed may influence sink rate, and has a substantial influence on tori line effectiveness. Setting at slow speeds will allow more time for the gear to sink before it reaches the end of the tori line. It follows that a vessel setting gear at four knots requires a tori line twice the length of a vessel setting at two knots, to provide coverage of baited hooks to the same depth, assuming a constant sink rate. The force generated by propeller wash may influence the sink rate of lines differently at different speeds, and so confound the above assumption.

Some tension on the backbone whilst setting is essential to allow the snoods to be clipped on, however skippers report generally keeping this tension to a minimum, thereby allowing the line to sink as quickly as possible. The amount of tension can vary during and between shots, for example as the amount of line on the drum reduces the drum diameter, more force is required to pull the line off.

Height of the backbone at the stern of the vessel will affect sink rate and visibility of the line (Keith 1999). Hence vessels with the line entering close to the water have a ‘head start’ in sink rate and mitigation terms. One of the larger autoline vessels had fitted a tunnel and altered the vessel set up to minimise this height. This resulted in baited hooks leaving the vessel less than half a metre above the waterline. Again on small vessels options for modification are likely to be limited.

2.4.3 Mitigation

In order to be widely adopted and successful, any mitigation measure not only needs to be effective at reducing interactions but also safe, quick and easy to use and not reduce target species catch rates. Low cost is also a desirable factor. Mitigation measures that are currently in use by the inshore bottom lining fleet meet these requirements. They do not require specialist materials, significant vessel modifications or large amounts of time or effort to implement. It is worth ensuring that all skippers benefit from the experiences and ingenuity of each other, enabling the fleet as a whole to employ more effective mitigation at minimal extra cost in time or dollars.

Mitigation measures are discussed below in two groups. Firstly those that are relatively low technology and are currently in use by some vessels. A second section then investigates measures that are new to the inshore fleet,though several have been employed on larger vessels with varying degrees of success. This is partly to provide a complete view of mitigation but also to emphasise that the possibility of employing high technology mitigation measures should not be ignored. Unfortunately these high technology options are likely to be more expensive to develop, produce and purchase.

2.4.4 Low technology solutions

Abnormal events

Abnormal events with fishing gear or mitigation devices can increase the risk of interactions. These events are generally unavoidable and unforeseen. Examples include inadvertently not adding weights and tangles resulting in hooks staying near the surface for some time. Having contingency plans in place and well-briefed crew can result in rapid resolution of such problems, thereby reducing the risk of interactions. The use of weak links and spare tori lines are two examples of forward planning.

Night Setting

Shooting lines in darkness was reported by skippers as being the most effective method of reducing bird interactions.. It should be noted that, although for the majority of night-time sets bird abundance and attempts to feed on baited hooks were reported to be nil or minimal, some skippers reported large numbers of birds actively feeding at night. Examples of such reports were during moonlit nights, when several skippers would routinely deploy tori lines, and black petrels seen feeding at night shortly after migration.

Avoiding birds

The willingness to choose fishing times and locations based on the expected bird abundance and behaviour is likely to have greatly reduced the frequency of bird interactions for some vessels. Similarly, recognising the need to employ extra mitigation measures and stop or suspend setting if large numbers of birds arrive during a set would have had the same effect. This reactionary approach highlights how conditions, and particularly bird abundance, can change over the relatively short time scale of a set.

Tori lines

The two autoline vessels had the advantage of being more stable platforms with high attachment points, and employed multiple best practice CCAMLR type tori lines. The smaller vessels working clip-on gear operate in a different environment and with different bird species assemblages to those for which tori lines were developed. There was no doubt that tori lines are still effective but skippers of these vessels have modified the standard autoline or CCAMLR design to meet the needs of the inshore environments. Key differences include the size of the vessels and the addition of towed objects along the tori line on the surface of the water. Several skippers noted that perseverance was necessary in modifying a tori line, the method of deployment and attachment points to suit a particular vessel. There was some reluctance to use tori lines if no birds were present, predominantly due to the hassle factor and chance of tangles.

Tori lines have been observed to reduce interactions with inshore fishing vessels (observer reports) but are unlikely to completely eliminate interactions. The behaviour of some species, for example Buller's shearwaters and cape petrels have been observed to not change with the presence of a tori line (J. Williamson pers. obs.) Similarly, when birds are feeding aggressively then their wariness of tori lines appears to diminish (J. Williamson pers. obs.). Therefore tori lines should be considered an essential part of a suite of mitigation measures and practices, and this was emphasised by several skippers.

There is some potential for improvement to tori lines. The autoline vessels used multiple tori lines, which provide better coverage of baited hooks, particularly in cross winds and for diving birds (Melvin et al. 2004). This may be appropriate for some of the larger vessels working clip-on gear. Devices such as a surface paravane acting in a similar way to a trawl door could be investigated to hold single tori lines upwind in order to keep streamers over the baited hooks. Changing the type of streamers and floats employed may also increase efficacy. Holographic tape is commercially produced as 'irri-tape' or 'repeller ribbon' and is designed to deter birds visually and also acoustically by 'rattling' in the wind.

Line weighting

Adding extra weight to the line is a relatively cheap, easy and hassle free way of reducing the availability of baited hooks to birds. Large reductions in seabird bycatch have been documented on larger autoline vessels with a combination of integrated weight line or extra weighting and use of tori lines (Robertson et al. 2006, 2008). One advantage with this approach is that extra weight can be added to the line as a reactionary measure, as necessary and with immediate effect. However there is a practical limit to the amount of weight that can be added due to the hauling power of any given vessel's drum, and the breaking strain of the line. Further limits to weighting are dictated by target species and type of seabed fished. For example in some cases, particularly when fishing over foul ground or targeting bluenose, skippers suspend some or all of the line above the seabed using floats and/or weights on suspender lines.

Use of floats

Deploying floats on a length of line would allow the backbone to sink to the length of the line before being slowed by the float. This may be effective for surface feeding birds such as albatrosses but less so for diving birds, without several metres of line. The potential for tangles and extra work involved in deploying and retrieving such floats is likely to be unpopular with fishers.

Oil

Although shark liver oil may deter some seabirds (Pierre & Norden 2006; Norden & Pierre 2007) the use of this or other types oil during setting was not common. This is probably due to the cost and effort involved in sourcing the oil as many skippers commented they would be happy to use oil if it was supplied.

Dying bait

Dying of bait has been observed in the surface longline fishery but is not generally used by bottom line vessels. Blue dyed bait may be less visible or less attractive to birds (Lydon & Starr, 2005; Cockling et al. 2008). It is most likely to be effective with light coloured squid and octopus baits as these have the greatest contrast with the colour of seawater. Whether dyed bait would catch fish as well as un-dyed bait has not been tested in a bottom longline fishery.

2.4.5 High technology solutions

Increasing sink rate

Hydrostatic releases are used to deploy liferafts, cutting a line to release the raft if the unit is below a given depth. A reusable device would provide a mechanism by which the buoyancy of a line could be altered at depth. Suspender lines could be deployed at depth eliminating the delay in sinking due to the suspender line unwinding. Similarly a spring-loaded float could be triggered to increase in volume at depth. Although technologically possible, cost is likely to be prohibitive, particularly when it comes to testing and refining ideas.

Chutes and capsules have been developed for surface line vessels to deploy baits at depth. Examples include the setting chute (Gilman et al. 2003) and the bait capsule (Melvin & Baker 2006). However the short snoods employed on bottom longlines necessitate the whole line being deployed at depth (Lokkeborg 2008). Chutes are commercially available and have been shown to reduce bycatch (Ryan & Watkins 2001) but costs are likely to be prohibitive. The need to deploy weights, suspender lines and floats is likely to cause problems with a chute device.

One of the autoliners contacted had been specifically modified to incorporate a tunnel such that hooks left the vessel close to the water. This is rare, particularly in the inshore fleet where vessels are not purpose-built for bottom lining.

Hook design

Hook design could help reduce the likelihood of birds taking baited hooks. An example of a ‘seabird friendly hook’ is the ‘smart hook’ designed for surface liners which encloses the bait in a dissolving capsule. In this case it is not reusable and is likely to be prohibitively expensive.

Deterrents

Lasers are commercially available and have been successfully employed on airfields to reduce bird abundance, though these have not been proven to be effective with seabirds (Southern Seabird Solutions). Gas cannons and water cannons have been tested on larger vessels with limited success (Brothers et al., 1999). The high investment costs, space requirements and potentially harmful side-effects of such measures are likely to limit uptake by the inshore fleet, and long term effectiveness may be reduced due to habituation.

Treating baits to make them less attractive to birds without reducing their appeal to fish may be possible. One skipper mentioned that kerosene had been successfully used to this effect in the past but is not employed now due to contravention of pollution regulations. However either a physical barrier which dissolved in water or a specific non-toxic chemical substance (e.g. Saxton 2004) have the potential to be effective. Testing existing substances would be relatively straight forward, however research and development costs for a new chemical are likely to be prohibitively high.

Reactionary 'last resort' distractions

Several skippers reported that occasionally bird abundance increased significantly during a set, or birds were feeding very aggressively. These types of event have been noted when captures occur on observed trips. If the skipper is not prepared to forego a fishing opportunity then the perceived risk to birds may require employment of some other measure.

Dying the water would reduce the visibility of baits. Purse seine vessels routinely use set net dye which is non-toxic and could temporarily hide baited hooks from birds. However the dyed water would be very visible, and so may act as an 'I am shooting flag'.

2.5 Recommendations

A number of key areas were identified where additional information or research is needed:

- Examine the current sink rates of clip-on gear and explore the potential for increasing sink rates, particularly using extra weights if birds arrive during a shot.
- Record all variables associated with bird captures on observed trips. This may identify particular positions on the line most likely to catch birds and this could be linked to sink rate or bait types.
- Investigate the effect of dyed baits, particularly squid and octopus, on fish catches in bottom longline fisheries. Investigate potential habituation of birds to the use of dye.
- Investigate further the effects of oil deployed over baited hooks.

In addition, a number of actions identified below are likely to assist the mitigation of seabird captures in inshore bottom longline fisheries:

- Promote the sharing of effective mitigation measures, particularly successful tori line modifications, between skippers from different ports.
- Produce a calendar of moon cycle and other spatial and temporal factors that contribute to increasing the likelihood of interactions. This could be species specific and, for example, highlight the black petrel breeding time and location.
- Produce a list of available mitigation measures as a reminder, possibly including options if birds increase in abundance or start feeding aggressively during a set.
- Providing feedback on observer coverage and projects such as this one is likely to improve the relationship between DOC and MFish with fishers.
- Placing experienced observers on vessels is more conducive to getting the best value out of observer days and would have the added benefit of a greater chance of observers recognising and helping to develop effective mitigation.

3. Bottom longline sink rate testing

3.1 Introduction

Line sink rate trials were conducted on six inshore bottom longline vessels in order to quantify the availability of baited hooks to seabirds during the deployment of longlines. The effect on sink rate of adding additional weights was also examined.

3.2 Methods

3.2.1 Time Depth Recorder specifications

Starr-Oddi DST Centi time depth recorders (TDRs) were used to measure sink rates. These units were chosen due to their ease of use, relatively high depth resolution and competitive pricing. The units selected had a depth range of 0–800m, a depth resolution of 0.24m and a minimum sampling interval of one second.

Starr-Oddi also supplied a protective housing shown in Figure 6. In the housing with wire strop and clip the units weighed 48g in seawater and 101g in air. Full TDR specifications can be found in Appendix 2.

Figure 6 TDR and housing, total length including clip is 32cm.

3.2.2 Testing

Testing of TDRs prior to deployment on commercial vessels was carried out in Torea Bay in the Marlborough Sounds, in seawater between 15 and 17°C. Weather conditions were good with a light north-westerly breeze and flat sea. Water depth varied between 32-38m.

Twelve TDRs were programmed to sample temperature and depth every second and the internal clocks were synchronised with a digital watch to be used on deck.

A steel frame held the TDRs at the same depth (Figure 7), and a 4 kg lead weight was attached to the bottom of the frame. The top of the frame was attached to a 2mm spectra line marked at 1m, 2m, 4m, 6m, 8m, 10m, 15m, 20m, 25m and 30m from the level of the TDRs.

To acclimatise the TDR's to the seawater temperature they were placed in the housings and left in a bucket of seawater for 30 minutes prior to deployment.

Four of the 12 TDRs, in housings, were attached to the frame and then lowered slowly into the water, pausing for 15 seconds at each marked depth. The time the TDRs reached and left each depth was recorded from the digital watch. The TDRs were then raised to 1m depth, again pausing at each marked depth for 15 seconds. Times were recorded in a similar manner to the descent.

Figure 7: Frame used during tests.

After the first descent and retrieval the data was downloaded. In total, six descents were made for each of three groups of four TDRs. As the testing progressed the vessel was anchored due to a slight drift apparent on the preceding descent. In order to achieve six descents for each group of TDRs the time at each depth was reduced to 10 seconds. This was possible because the data from the first descent showed a very clear step with a 15-second pause.

Depth profiles for each of the three sets of drops were plotted separately, firstly using the raw data and subsequently with an offset applied. Offsets were calculated from the difference between 8m and the modal TDR depth reading from 8m during the initial test descent.

Depth offsets were checked during at sea sampling. TDRs were set to sample every second and then placed in a bucket of seawater. After the temperature sensors had acclimatised to the sea water temperature in the bucket they were removed from the bucket and immediately lowered to 6m.

3.2.3 Measuring bottom longline sink rates

TDRs were programmed with a delayed start three-stage measurement sequence, prior to each set. During the first stage the TDRs sampled every 30 seconds for 30 minutes prior to deployment. The TDRs then sampled every second for between 2-5 hours to cover the shot, and then every 20 minutes until recovery. The second stage or ‘shooting window’ of sampling every second varied in order to maximise battery life and cover uncertainties in shooting time. A digital watch for use on deck was synchronised with the TDR clocks.

Following programming, the TDRs were inserted into the housings and stored in a bucket. At least 30 minutes prior to shooting the bucket was filled with seawater, which was refreshed immediately prior to shooting.

TDRs were clipped onto the backbone during the shot at predetermined positions. TDRs were deployed in a random order generated for each shot using the 'randbetween' function in excel. The time TDRs were clipped onto the backbone and the time they entered the water was recorded from the digital watch.

Environmental and gear variables were recorded at the start and end of the deployment period as shown in Appendix 3.

For sets targeting snapper, the middle portion of the line was sampled such that the end weight had already sunk to the bottom before deployment of the first TDR. Similarly, the last TDR had sunk to fishing depth before the final weight on the line left the vessel. TDR placement covered the whole line for sets targeting ling in deeper water.

Sampling positions on the backbone were intended to allow for comparison between different weighting regimes and provide an indication of the variability of sink rates. TDRs were placed adjacent to weights or floats, and midway between weights and/or floats. If different size weights and/or floats and/or suspender combinations were used, then TDRs were deployed to sample all positions equally. Between 9 and 12 TDRs were deployed on each line sampled. Examples of TDR placement are shown in Figure 8.

Video footage was taken for a short period during line setting onboard each vessel sampled.

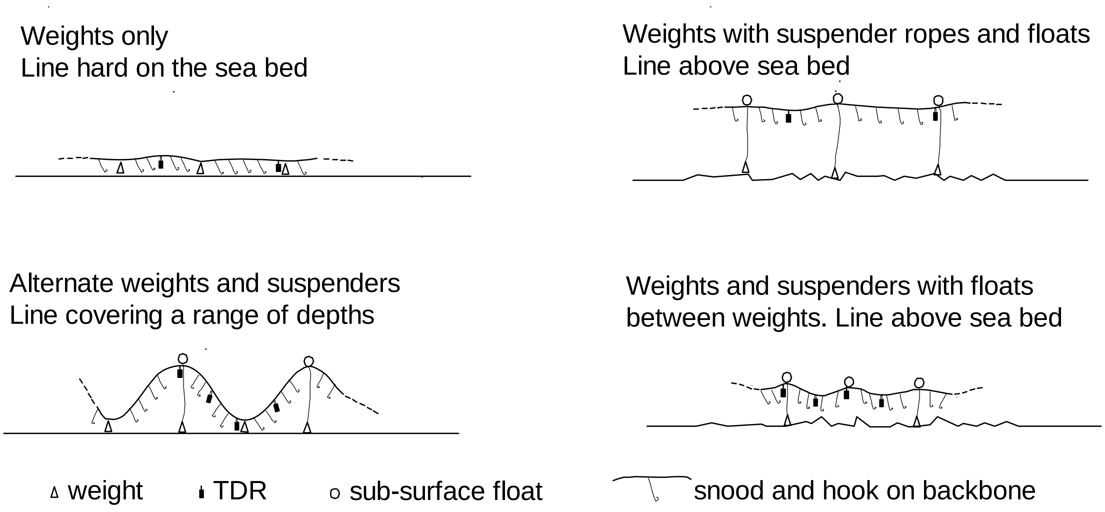


Figure 8 Examples of TDR placement on the different line set-ups sampled

TDRs were recovered during the haul and the data downloaded as soon as possible. The sequence of weights, hooks and floats was recorded as they came onboard the vessel. Weights were weighed to the nearest 50g on spring scales, and the length of dropper lines was measured to the nearest 0.1m. If weights and droppers had standard measurements then not all were measured. Similarly if insufficient time was available then estimates were made.

3.2.4 Data analysis

Temperature correction of pressure readings was carried out using Sea Star 5.0 and 5.0.5. Pressure readings immediately after the TDR entered the water were corrected using a fixed temperature value; this estimated surface water temperature was derived from the first steady temperature records from the TDR, above any thermocline. This adjustment was carried out individually for each TDR deployment, and substituted temperature values were used for up to 250 seconds. Subsequent pressure readings were corrected using the real time temperature recorded by the logger.

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 seconds in a bucket of seawater prior to deployment. TDRs were soaked in the seawater for 30 minutes prior to the period used to calculate the offset. Temperature readings were stable during the 60 seconds used to calculate the offset.

TDRs were labelled with a clip-on time, recorded from the digital watch on deck. Because all vessels shot over the stern, this was considered the time the TDR left the vessel. The time taken to reach 5m, 10m or 15m was recorded in whole seconds based on the first depth reading greater than or equal to the given depth.

Sink rates in metres per second were then calculated between 5 and 15 meters depth. For three shallow shots sink rates were calculated between 5 and 10m.

When comparing different weighting regimes between sets on the same vessel, some TDR records were randomly discarded to ensure that each sampling position was equally represented in both data sets. After ensuring equal representation of all sampling positions the maximum number of records was included in each data set such that the 'normal' weighting regime had more observations across more sets.

Box and whisker plots were chosen as a simple means of displaying the variation in sink times. Outliers were identified as points falling outside one and a half times the inter quartile range above or below the third and first quartiles respectively.

3.3 Results

3.3.1 TDR testing and offset calculation

Depth offsets based on readings at 8m during the final descent were applied to each TDR for the whole series of test data. Offsets ranged from -8.9m to +2.4m. This produced a series of depths at time for each TDR. When compared against TDRs deployed at the same time individual records were within the stated resolution (0.24m) of one another for the first descent. Some drift apart of up to a metre was apparent after multiple descents to 30m.

No independent measure of depth was used other than the length of line deployed. This line was near vertical for all deployments and depths recorded by the TDRs were always within 2m of the line length.

Offsets applied to the pressure readings during longline testing varied from 18 to 1020mBar, and these changed over time for any given TDR, most notably after deployment below 200m.

Although the TDRs had a first calibration point at a depth of 5m, records from 1-5m during the test descents appeared to have similar accuracy and precision to records below 5m. Longline sink rates measured on fishing vessels were consistent above and below 5m, adding further credibility to TDR performance above 5m.

Mid-sampling testing showed that offsets derived from a depth of 6 m after nine minutes acclimatisation to ambient temperature were similar to offsets derived from pressure readings obtained in the bucket of seawater 60 seconds prior to deployment. This consistency in offset with changing depth allowed offsets to be calculated for each deployment based on readings prior to deployment in a bucket of seawater on deck. It was not practical to measure the offset at depth prior to each set, as this required calm sea and the vessel to be stationary with no drift.

3.3.2 At sea sampling

In total 27 days were spent at sea, with 25 lines sampled on six different vessels. This provided a total of 259 separate sink rate records. Of the 25 lines sampled, two lines produced 12 TDR records, 12 lines each produced 11 records, nine lines each produced 10 records and two further lines each produced eight and nine records.

TDRs proved reliable with the exception of one failing after two shots. This was replaced; however over the course of the sampling a further two TDRs were lost. Some troubles downloading data at sea resulted in the partial loss of three records on two lines.

Not all environmental conditions were recorded. Tidal currents were often not apparent. Some vessels did not have a barometer, and visibility and cloud cover were difficult to judge during darkness. Similarly it was not always possible to record water entry time for the TDRs during darkness.

3.3.3 Typical time depth profile

Sink profiles are plotted in Figure 9. Typically, it took the line 5-10 seconds to enter the water. TDR records start slightly after this, once the housing has filled up with water.

TDRs adjacent to weights were the fastest to enter the water and sank the quickest. TDRs on the line by weights with suspenders reached 5m slightly slower but sank at a similar rate to the weight. TDRs placed midway between a weight and suspender entered the water latest and sank slowest (Figure 9).

Figure 9 illustrates a set on a day with slight sea state and no swell, with suspender ropes and floats deployed with every second weight. TDR records show an even sink rate below 5m. Some steps are apparent; however the depth resolution appears to be sufficient to provide a reliable measure of how fast the TDRs are sinking. There is slightly more noise in the sink profiles above 5m, most noticeably for the TDRs between weights. TDRs adjacent to weights sink slightly faster near the surface than at depth. Conversely TDRs placed between weights appear to sink slightly slower near the surface. Two TDRs sank noticeably slower and these were either side of an intermediate surface float.

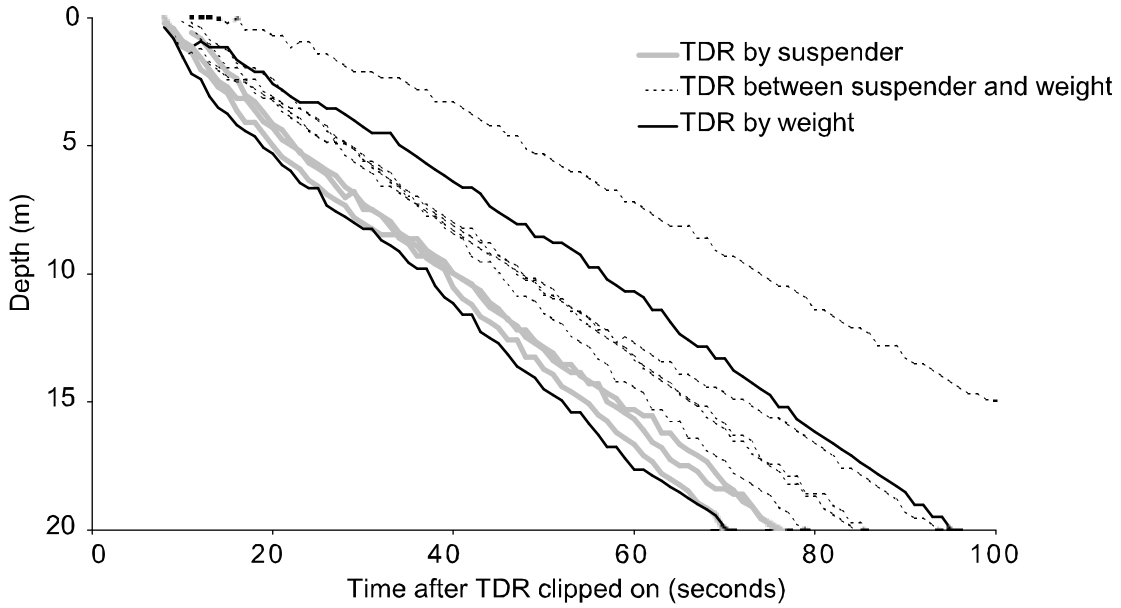


Figure 9 Time v. depth plot for TDRs deployed from vessel B on a typical snapper set, with similar sized weights deployed at regular intervals. The repeated line sequence was weight, hooks, and weight on a suspender rope with subsurface float. There are two noticeable outliers one by a weight and one midway between a weight and a suspender. These were both within 50m of an intermediate surface float.

3.3.4 Suspenders

In shallow water the use of suspender ropes and floats reduced sink rates to 15m (e.g. Figure 10). In this case, the TDRs by weights and suspenders end up at a similar depth. Although the seabed may not have been completely flat it is likely that the line by weights and suspenders was fishing a similar distance off the bottom.

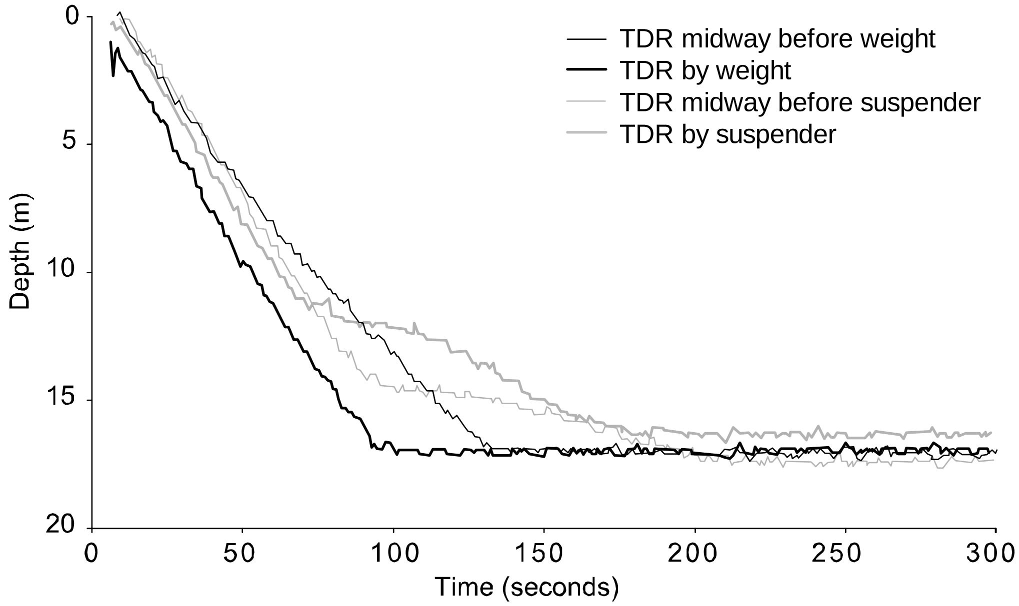


Figure 10 Time v. depth plots from vessel A for four different positions on the line. TDRs next to and midway before weights sank at a constant rate to the seabed. TDRs next to and midway before suspenders sank more slowly close to the seabed. The horizontal distance between the TDR by a suspender and the TDR by a weight was approximately 100m, based on hook counts.

Suspenders allowed the line to move vertically and fish off the seabed (Figure 11). During this set a line break briefly brought the line closer to the surface.

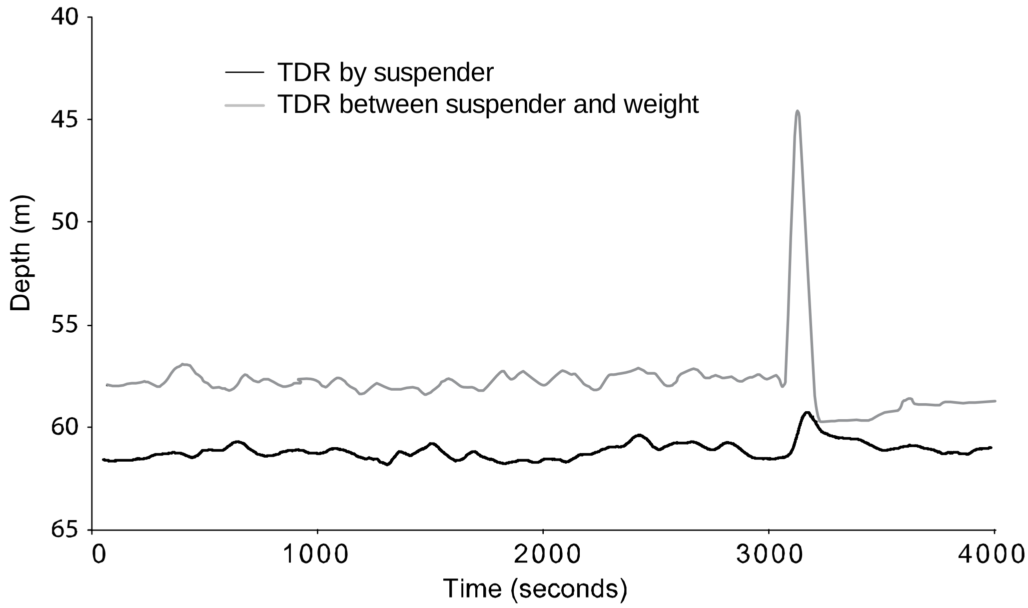


Figure 11 Plot of time against depth for two TDRs deployed from vessel A. One TDR is beside a suspender (black) and one midway between a suspender and a weight (grey). Both TDRs show vertical movement over approximately two metres. The spike occurred next to a break in the line, presumably caused by a shark. A moving average over 50 seconds was used to smooth out jumps caused by the relatively coarse depth resolution of the TDRs.

3.3.5 Intermediate surface marker floats

An intermediate surface float delayed the sinking of a line and TDR records show the line moving upwards in the water column (Figure 12). The estimated time of deployment of the float is at 125 seconds on the graph, based on hook counts and shooting speed. This suggests that the float unwound for about 40 seconds before having an effect on the sink rate of the TDRs.

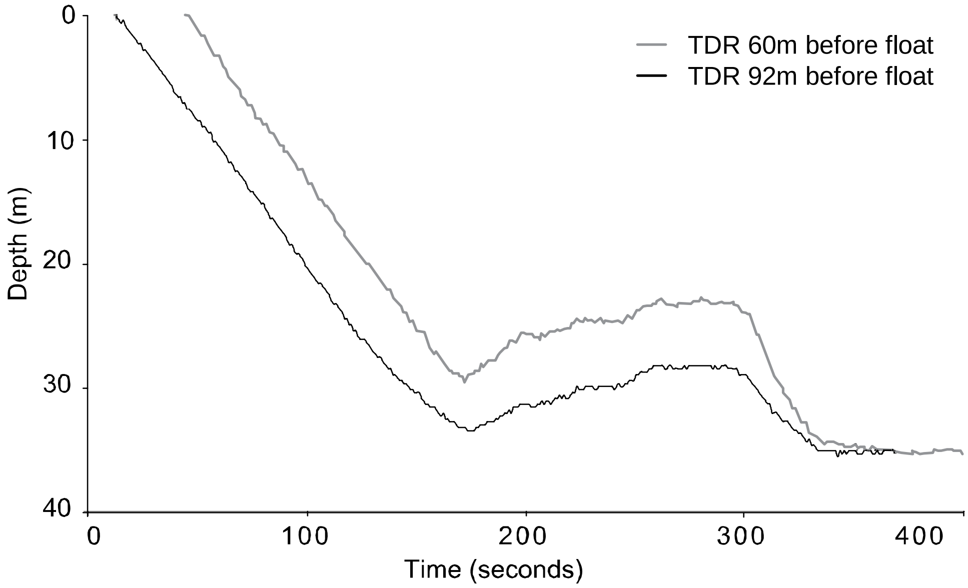


Figure 12 Time v. depth plots for two TDRs deployed 92m and 60m before an intermediate surface float on vessel C. Both positions on the line were pulled back towards the surface at the same time.

Deploying heavier weights can increase line sink rate, even when used in association with intermediate surface floats. (Figure 13).

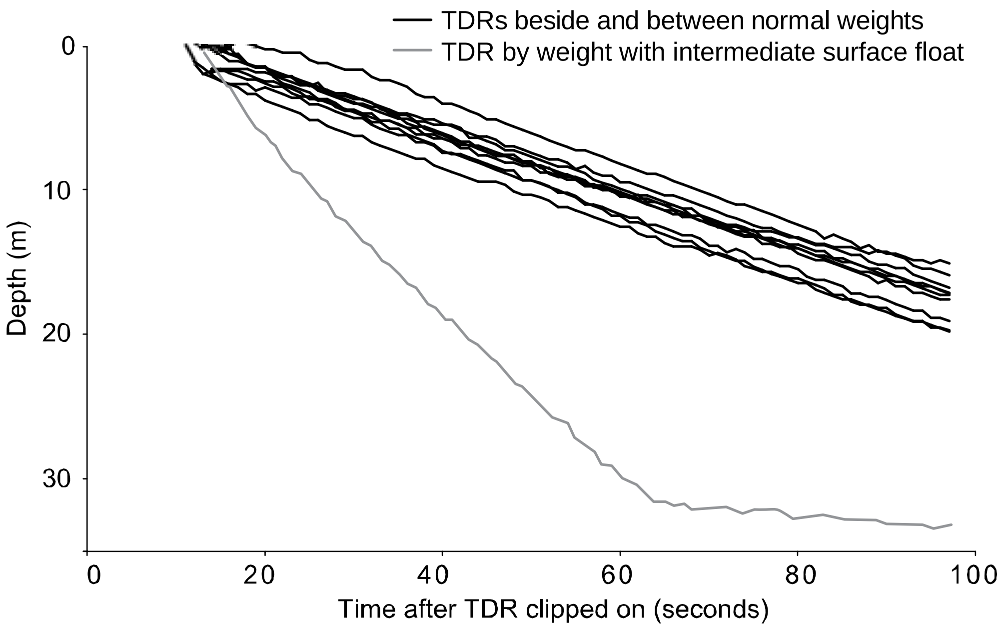


Figure 13 Time v. depth plots for all TDRs placed on a single line on vessel C. Solid lines represent the sink profiles of TDRs placed beside and between weights varying from 0.5kg to 1.3kg. The grey line shows a markedly increased sink rate of a TDR placed next to a 3.5kg weight with an intermediate surface float attached.

3.3.6 Swell

TDRs showed more upward movement near the surface during a shot with rougher sea (figure 14).

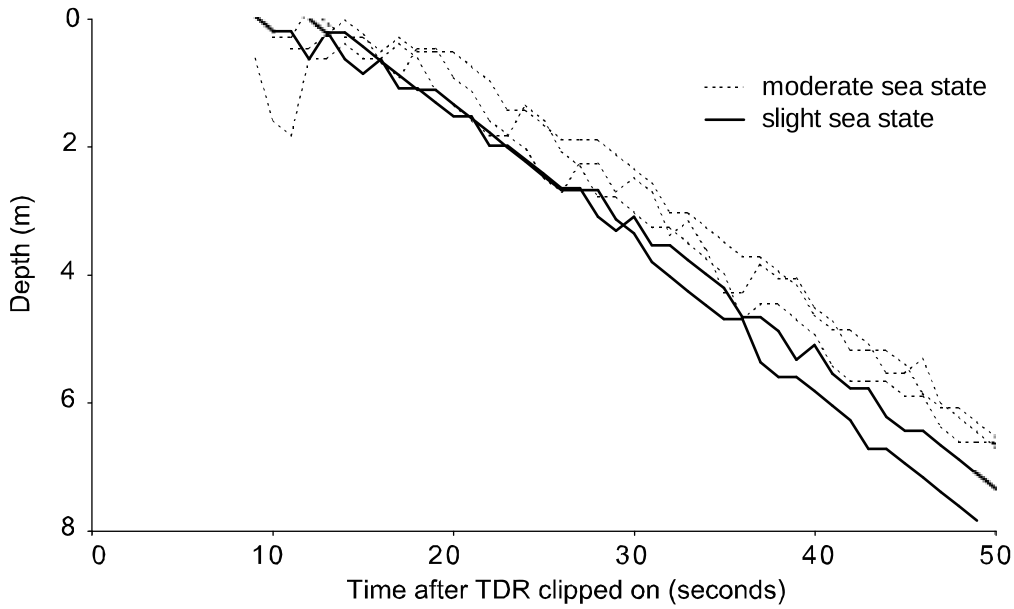


Figure 14 Time v. depth plots for TDRs adjacent to floats on two different lines set from vessel F. Dotted lines represent a line shot with a moderate sea state of two to three metres swell, and solid lines represent more consistent sink rates on a calm day with a slight sea state. Other variables were constant; however line tension was not measured.

Heavier weights entered the water sooner and sank faster (Figure 15). This vessel used 4 kg weights and 7.5kg weights in a ratio of 2:1, and occasionally used larger 10kg weights, for example when turning.

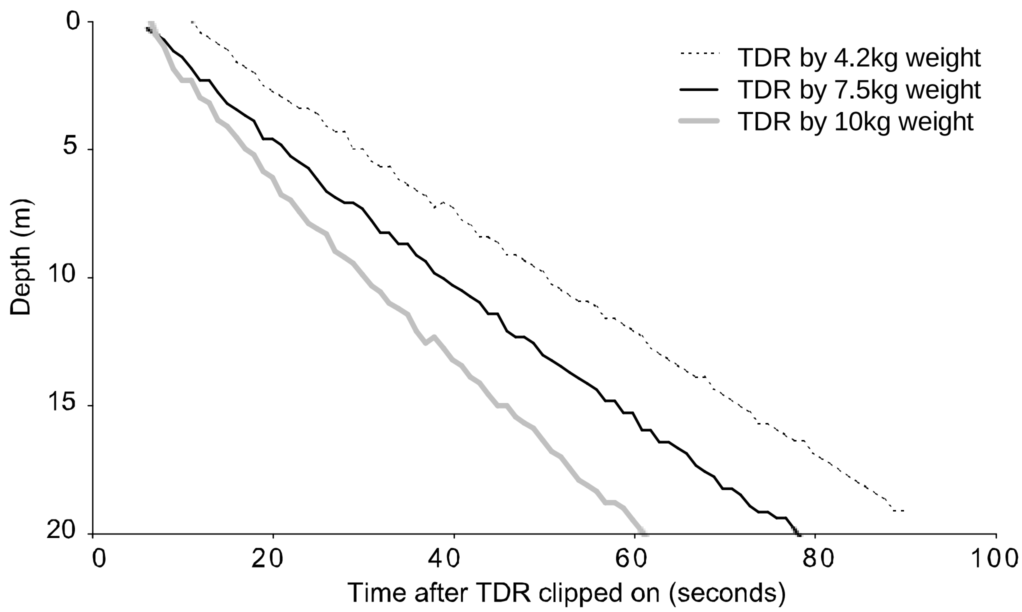


Figure 15 Time v. depth profiles for TDRs on the same line positioned next to suspenders with different sized weights. Data from vessel F.

Some lines produced a large variation in sink rates from different TDRs (Figure 16). Some of this variation is attributable to the size of weights adjacent to the TDRs. Some variation is also apparent with position on the line such that TDRs placed between weights (dotted lines) generally sink slower than those next to weights (solid lines).

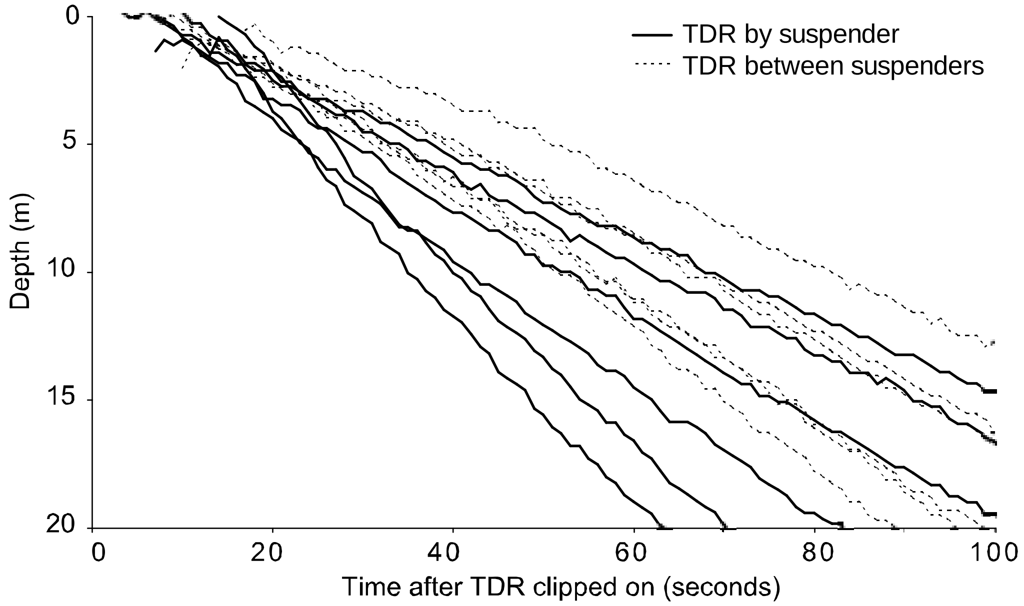


Figure 16 Time v. depth profiles for TDRs on a single line with weight sizes varying from 1.1kg to 3.5kg. All weights were with suspenders. Dotted lines show TDRs placed midway between weights and solid lines TDRs beside weights. Data from vessel A.

From a plot of weight against sink time between 5-15m, it is evident that sink times correlate well with the size of weights immediately adjacent to the TDR (Figure 17).

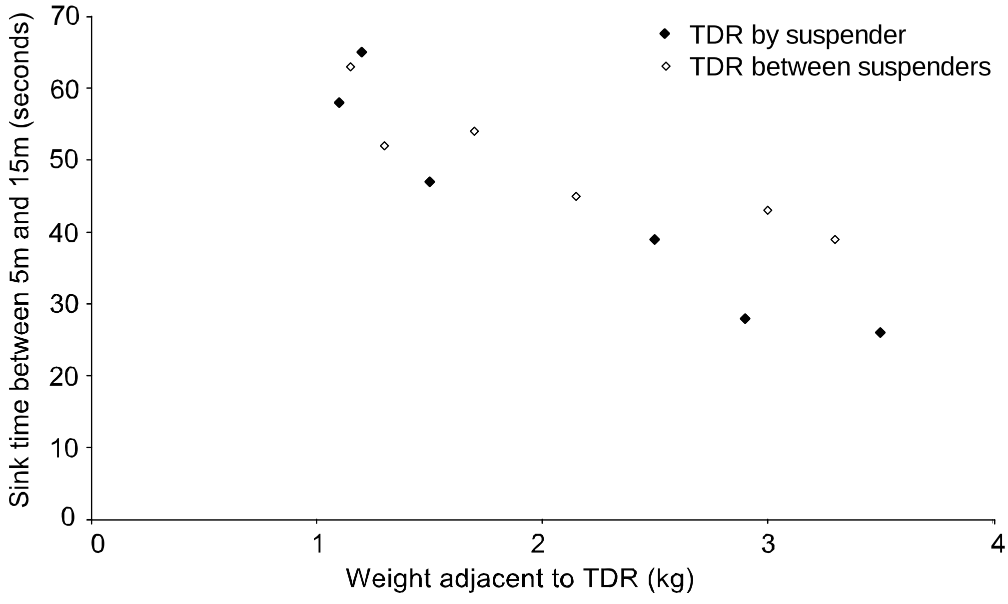


Figure 17 Plot of weight against sink time for all TDRs on the same line as figure 11. Solid points represent TDRs by suspenders and open points TDRs between suspenders. Weight is derived from the weight immediately next to the TDR for solid points and the average of the 2 adjacent weights for TDRs between suspenders.

3.3.7 Between set variation

Three sets from the same vessel each show markedly different variation in sink rates (Figure 18). Environmental conditions and line set up were similar for all sets. Tidal flow was between 0.5 and 1 knot, and sea conditions were calm with no swell. Weight spacing was consistent and two weight sizes were used in a random order for all sets.

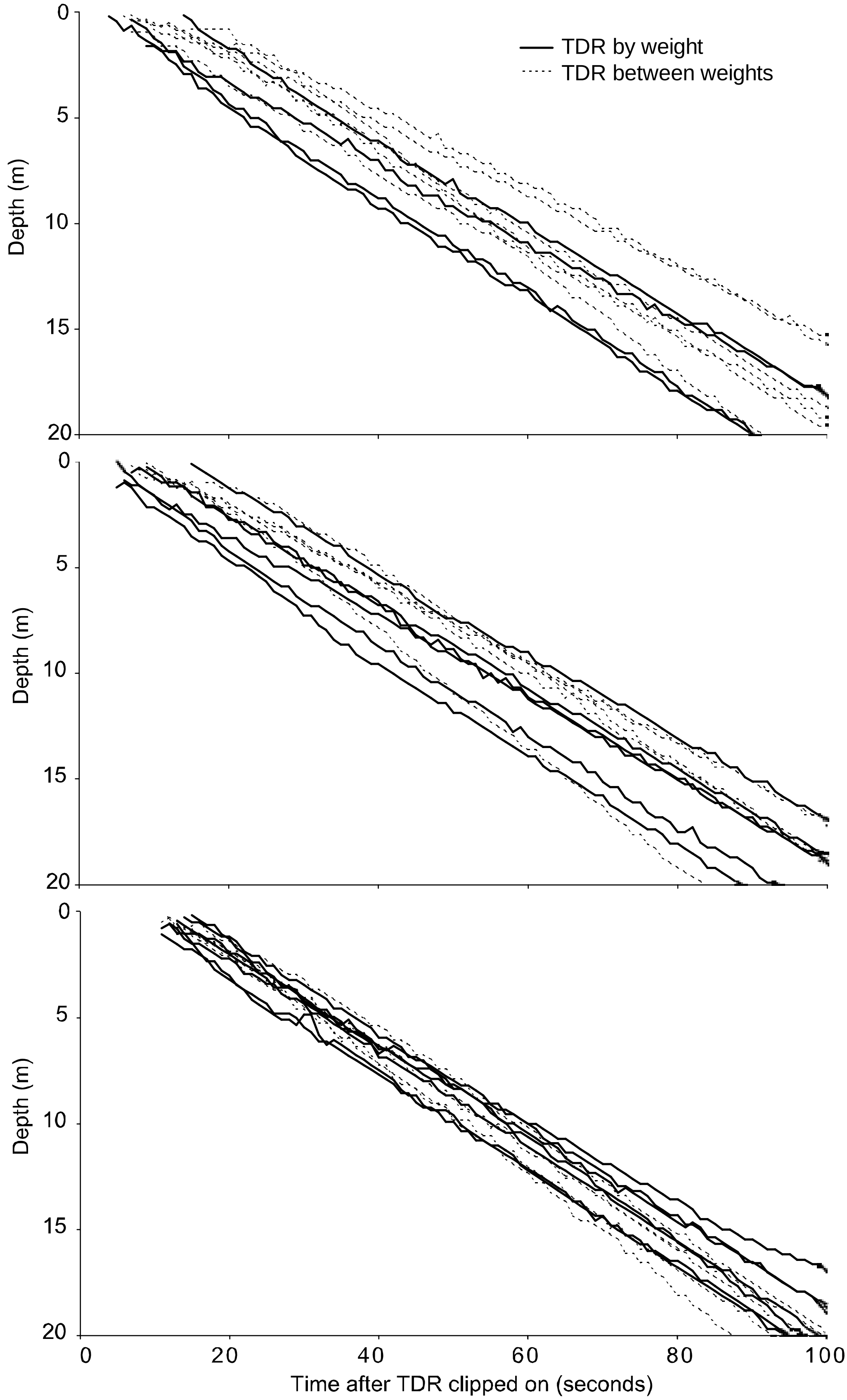


Figure 18 Time v. depth plots for TDRs from three different sets from vessel D in similar conditions.

3.3.8 Normal line set ups

Table 8 summarises the different line set ups sampled as part of normal fishing operations. Vessels A and E worked two different line set ups during sampling.

Table 8 Details of differences in gear parameters encountered when testing sink rates of vessels normal line set-up.

vessel / set up	A1	A2	B1	C1	D1	E1	E2	F1
repeated line sequence	suspender	suspender	suspender	weight	weight	weight	suspender	suspender
	hooks	hooks	hooks	hooks	hooks	hooks	hooks	hooks
	weight		weight					float
	hooks		hooks					hooks
kg weight per 100m	1.5	1.0	5.0	1.6	1.3	2.1	2.7	3.3
weight type	steel	steel	lead	rocks	lead	steel, lead	steel, lead	lead
line diameter (mm)	1.85	1.85	2.5	1.3	2.2	3	3	6
suspender length (m)	5 - 7	5 - 7	2 - 3	-	-	-	4.5	5
number of sets sampled	2	3	2	3	3	2	2	6
setting speed	4.7	4.7	2.7 - 3.6	2.2 - 3.5	4 - 4.7	5.0	5	3.5 - 3.7
shooting block height (m)	2.1	2.1	1.6	1.3	1.6	1.5	1.5	2.85
target species	snapper	snapper	snapper	snapper	snapper	snapper	snapper	ling
wind speed (knots)	5 – 10	0	5 – 10	0 - 10	0 - 12	0 - 5	0 – 5	8 – 20
swell height (m)	0.5 - 1	0	0 – 0.5	0 -0.5	0 – 0.5	0 – 1	0 – 1	0 – 2.5
number of TDR records	15	30	21	33	34	12	8	60

3.3.9 Sink time to five metres for normal line set ups

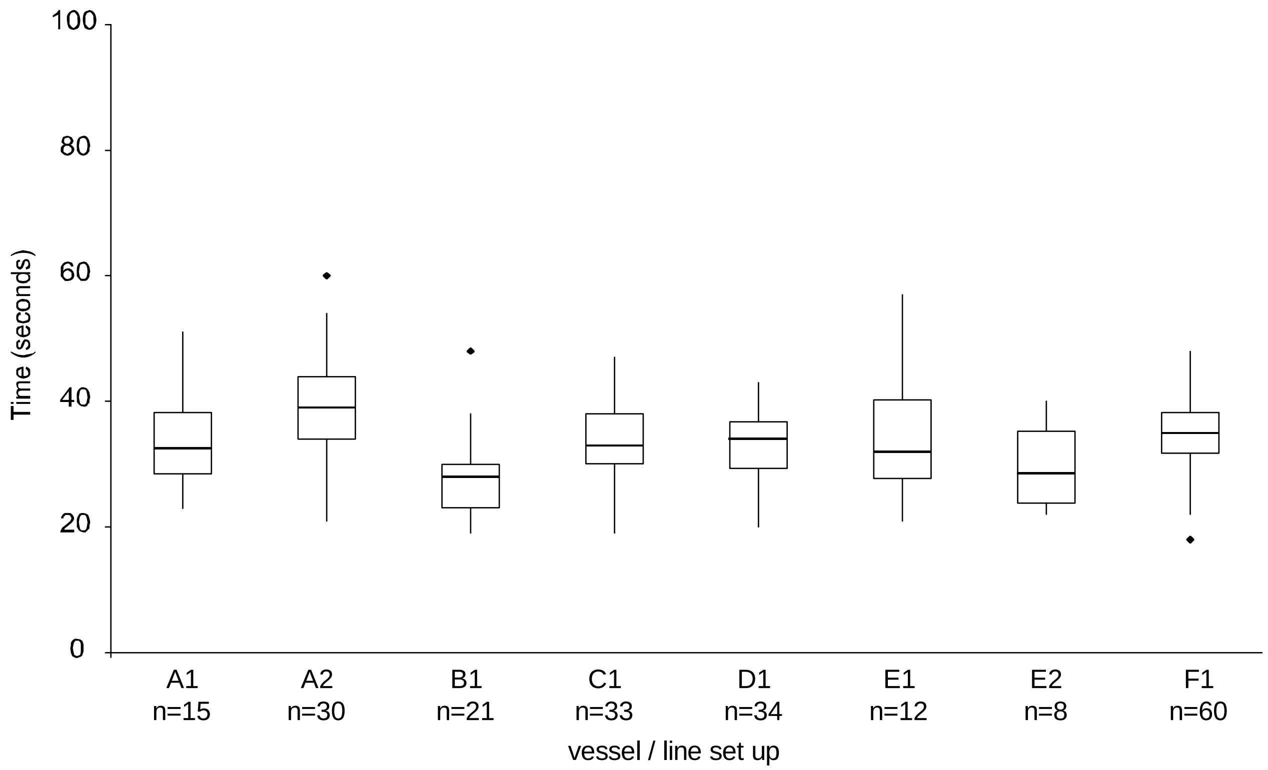


Figure 19 Box and whisker plot of time taken for TDRs to reach five metres for each line set up detailed in table 8.

The minimum time taken for a TDR to reach 5m was 20 seconds and the maximum time was 60 seconds (Figure 19). Variation at both the between set up and within set up level was high. Median values ranged from 28 to 39 seconds for all vessels. Set ups B1 and E2 both sank to 5m in less than 30 seconds and used more weight (Table 8). Two set ups were tested on vessels A and E; illustrating that changing line set up can produce markedly different sink rates from the same vessel.

3.3.10 Sink time between five metres and 15 metres for normal line set ups

Differences in the sink rate of different lines are more apparent below 5m, although within set up variation was still high (Figure 20). Median sink times compare well with weight per 100m in Table 8, however it is interesting to note that although set up B1 has 5kg per 100m of line, the sink rate is not much faster than 2.7 kg per 100m set up for E2. Vessel F, targeting ling, has a sink rate not dissimilar from the other vessels targeting snapper, despite using markedly different gear (Table 8).

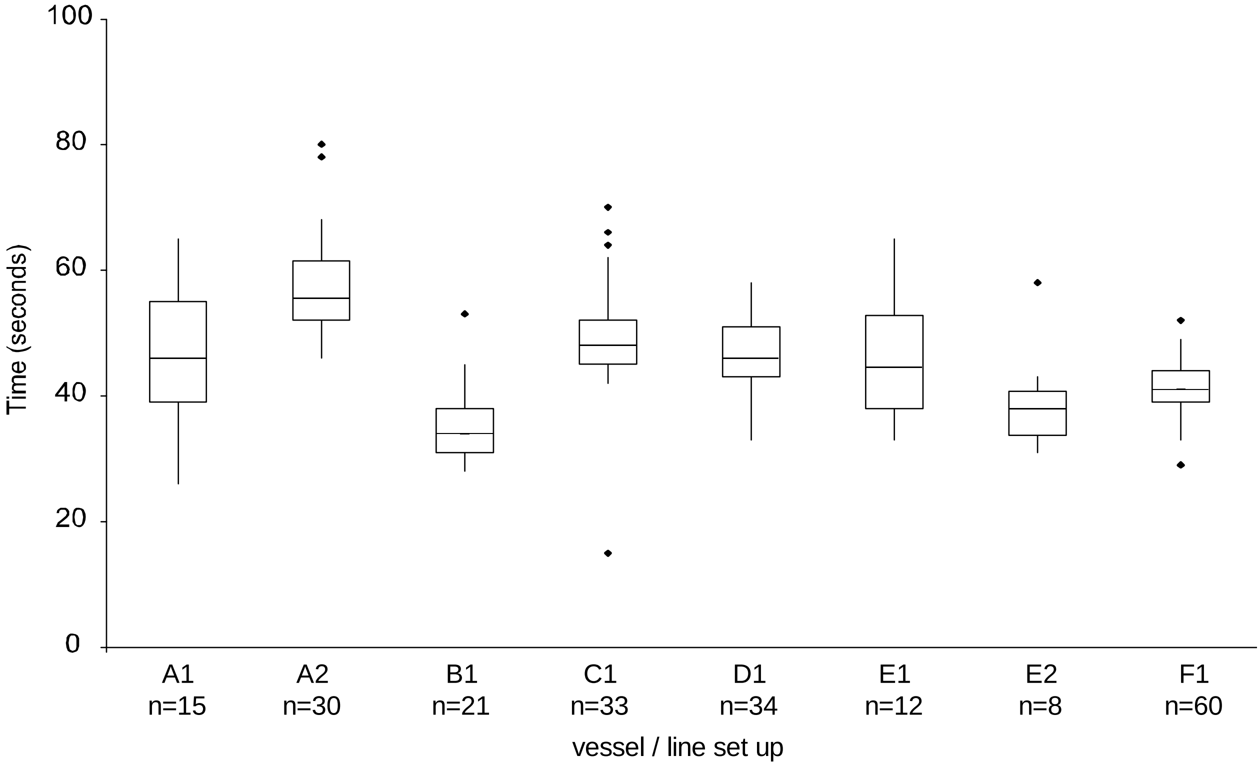


Figure 20 Box and whisker plot of time taken for TDRs to sink from 5 metres to 15 metres for each line set up detailed in table 8.

3.3.11 Distance behind the vessel that TDRs reached 5 metres, 10 metres and 15 metres.

Vessel speed was used to calculate the distance behind the vessel that TDRs reached 5, 10 and 15m. A combination of shooting speed and sink rate determined how far behind the vessel hooks remained above a certain depth (Figures 21, 22 and 23). Although set up E2 sinks relatively quickly compared with other set ups (Figure 20), due to a faster setting speed TDRs reach 5m relatively far behind the vessel. The reverse is true for vessel C, which had a relatively slow sinking line but due to a slow setting speed had TDRs below 5m relatively close to the vessel. Vessel B had TDRs reaching all depths closest to the vessel, and this can be attributed to a relatively high sink rate and slow setting speed.

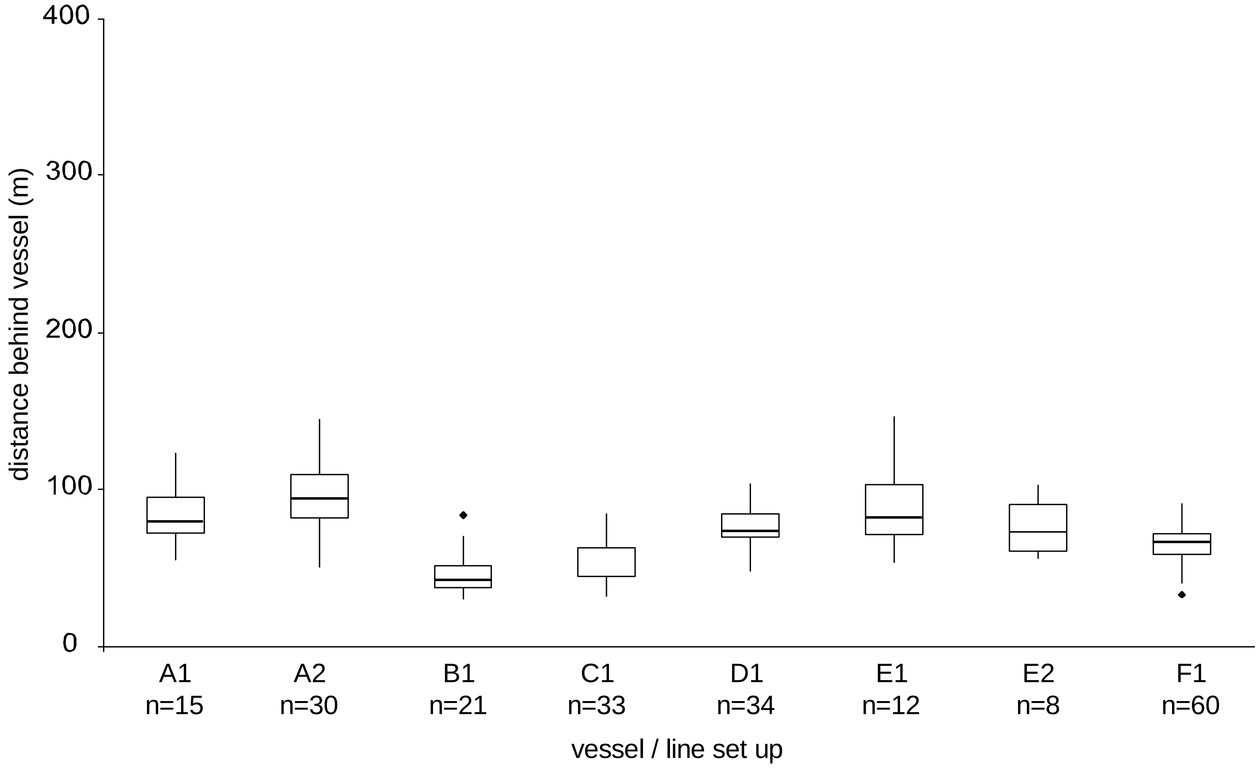


Figure 21 Box and whisker plot of distance behind the vessel TDRs reached 5 metres depth for line set ups detailed in table 8.

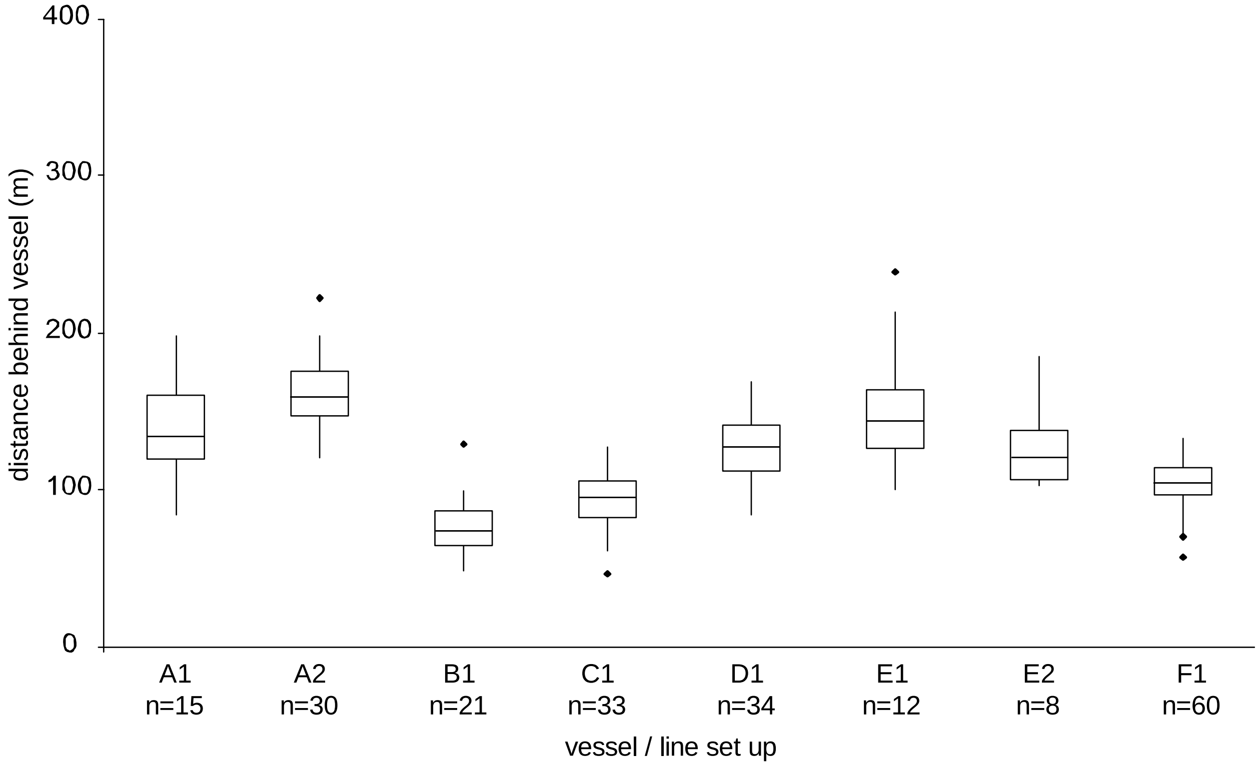


Figure 22 Box and whisker plot of distance behind the vessel TDRs reached 10 metres depth for line set ups detailed in table 8.

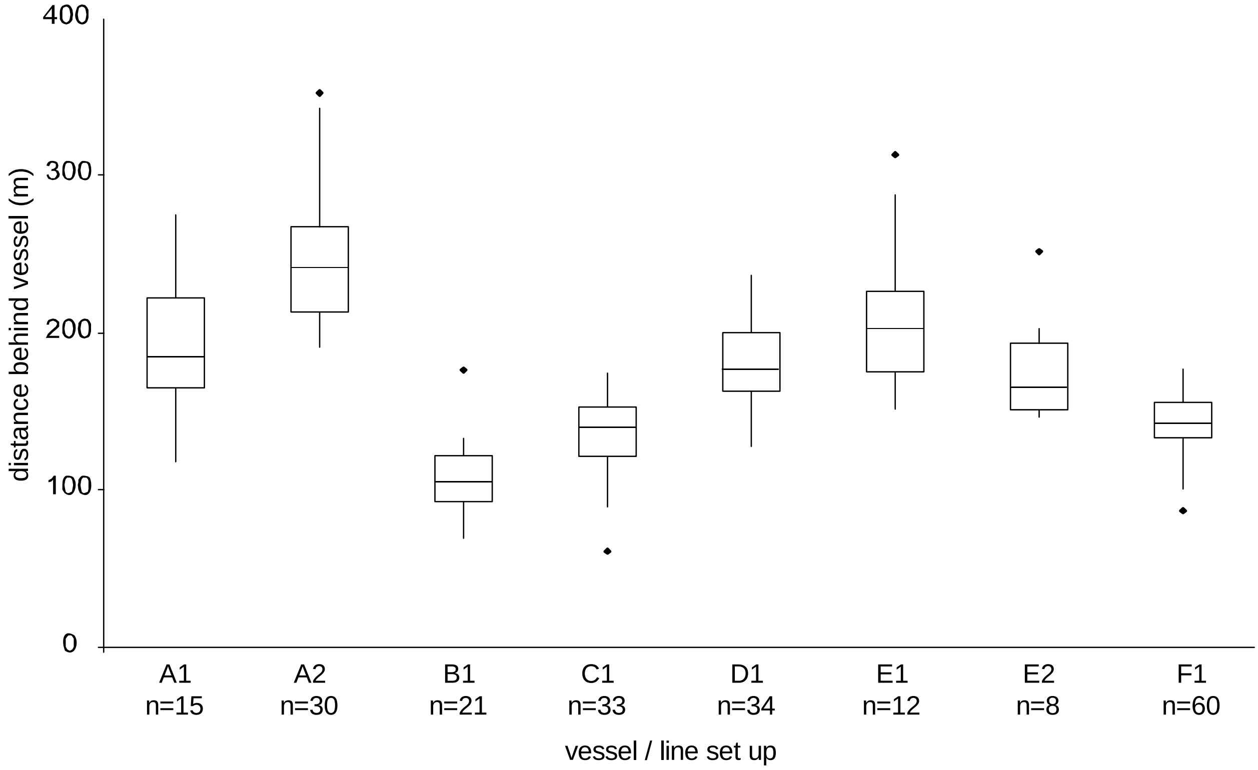


Figure 23 Box and whisker plot of distance behind the vessel TDRs reached 15 metres depth for line set ups detailed in table 8.

3.3.12 Altering weight spacing

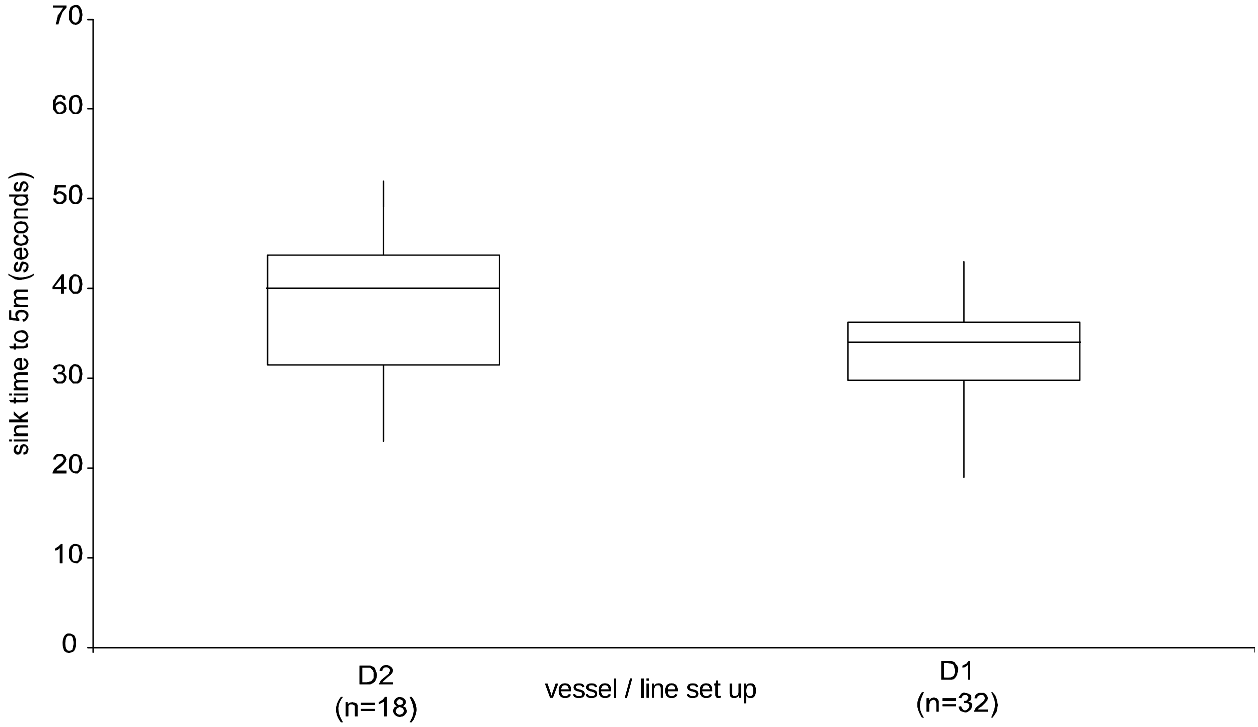
Two different weighting regimes were sampled for vessels D and F (Table 9). In both cases, the weight spacing was altered such that one set up used twice the number of weights. Vessel D used larger weights by intermediate floats during both sets, whereas vessel F used larger weights for a third of the weights with the larger weight spacing. Doubling the number of weights did not quite result in a doubling of the weight per 100m on either vessel.

Table 9 Details of differences in gear parameters when testing sink rates of lines with extra weighting.

Vessel / set-up	D2	D1	F1	F2
repeated line sequence	weight hooks	weight hooks	suspender hooks float hooks	suspender hooks
kg weight per 100m of line	0.82	1.33	3.27	5.48
weight type	lead	lead	lead	lead
suspender length (m)	-	-	5	5
Line diameter (mm)	2.2	2.2	6	6
number of sets sampled	2	3	6	1
setting speed	4.4 - 4.7	4 - 4.7	3.5 - 3.7	3.5
shooting block height (m)	1.6	1.6	2.85	2.85
target species	snapper	snapper	ling	ling
wind speed (knots)	0 - 20	0 - 12	8 – 20	10
swell height (m)	0 – 0.5	0 – 0.5	0 – 2.5	1.5

number of TDR records	18	32	48	10

Sink times to 5m were generally lower for sets with more weighting (Figures 24 and 25). Minimum sink rates were similar for both weighting regimes on both vessels, whereas median and maximum sink times were lower for set-ups



with more weight. Variability was lower for both set-ups with closer weight spacing.

Figure 24 Box and whisker plot of time taken for TDRs to reach five metres for two different weighting regimes for vessel D. Set-up D2 had twice as many hooks between weights as set-up D1.

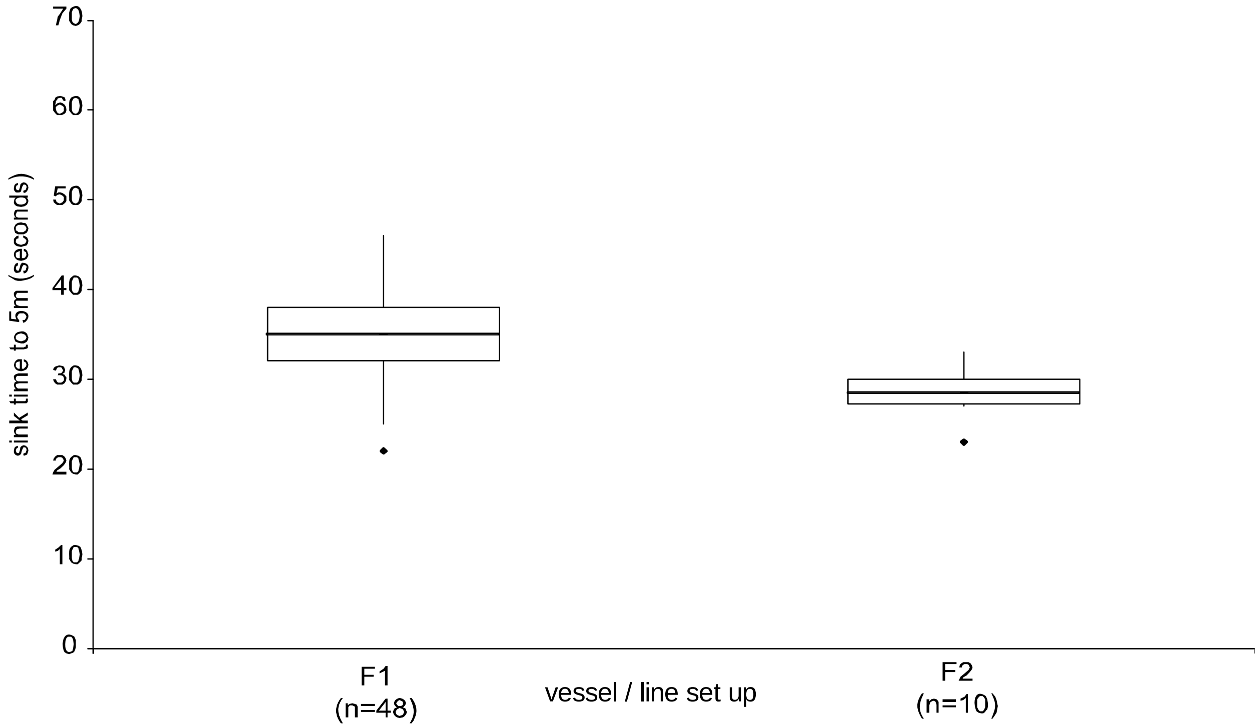
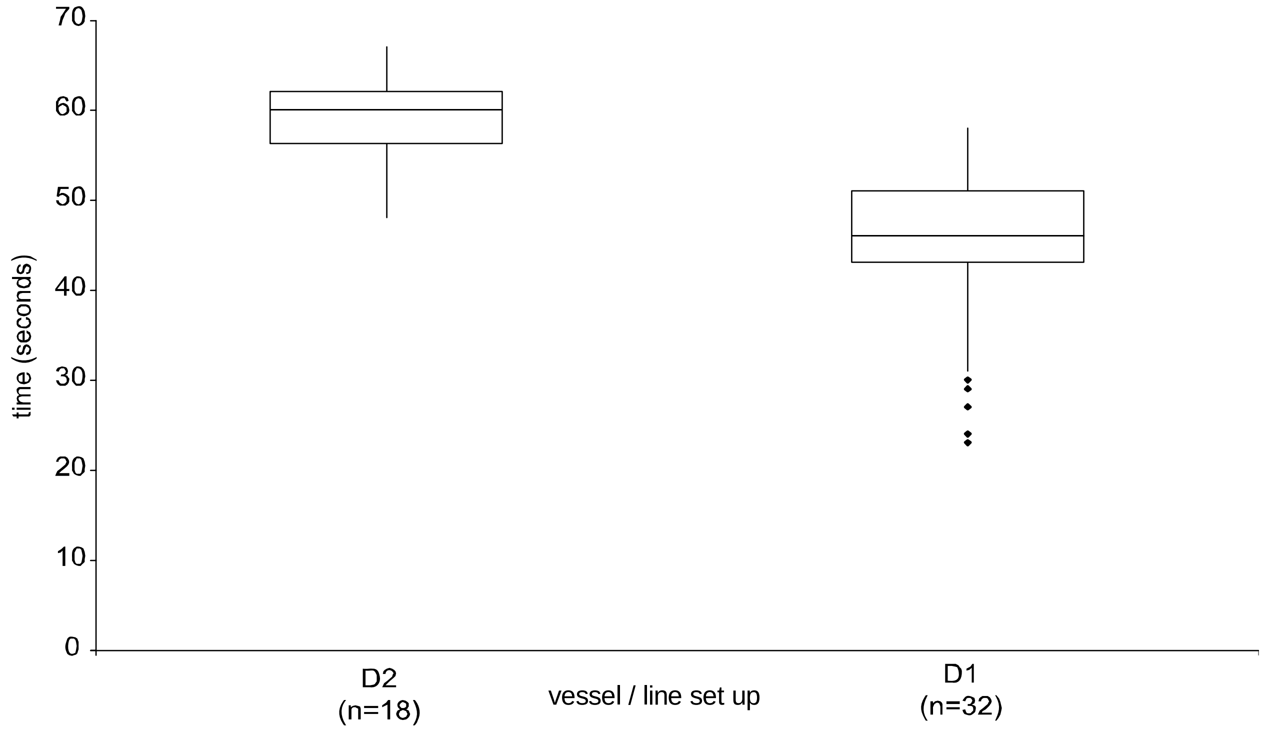


Figure 25 Box and whisker plot of time taken for TDRs to reach five metres for two different weighting regimes for vessel F. Set-up F1 had twice as many hooks between weights as set-up F2.



Sink times between 5 and 15 metres showed more marked differences than sink time to 5 metres for both vessels (figures 26 and 27).

Figure 26 Box and whisker plot of time taken for TDRs to sink from five metres to 15 metres for two different weighting regimes for vessel D. Set-up D2 had twice as many hooks between weights as set-up D1.

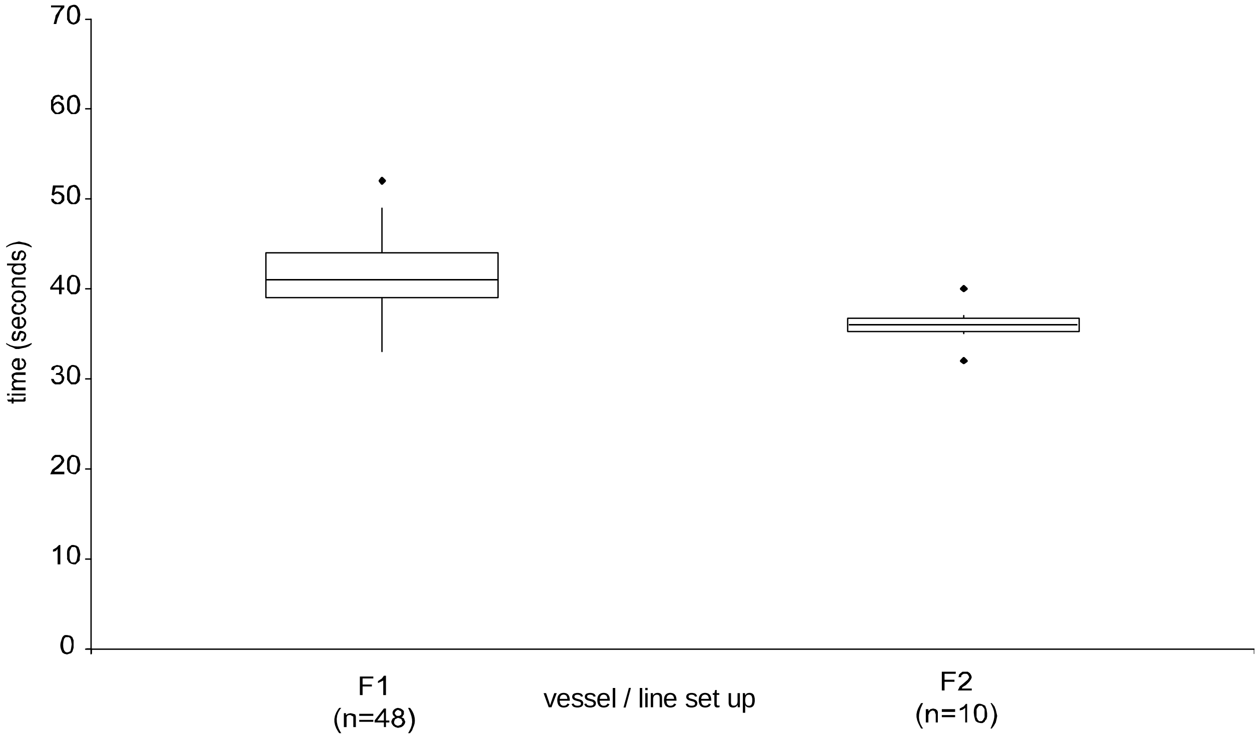


Figure 27 Box and whisker plot of time taken for TDRs to sink from five metres to 15 metres for two different weighting regimes for vessel F. Set-up F1 had twice as many hooks between weights as set-up F2.

A similar pattern is apparent when considering distance behind the vessel the line reaches 5m and 15m, such that the effect of adding more weight is more apparent when considering the distance behind the vessel at 15m depth. (Figures 28-31).

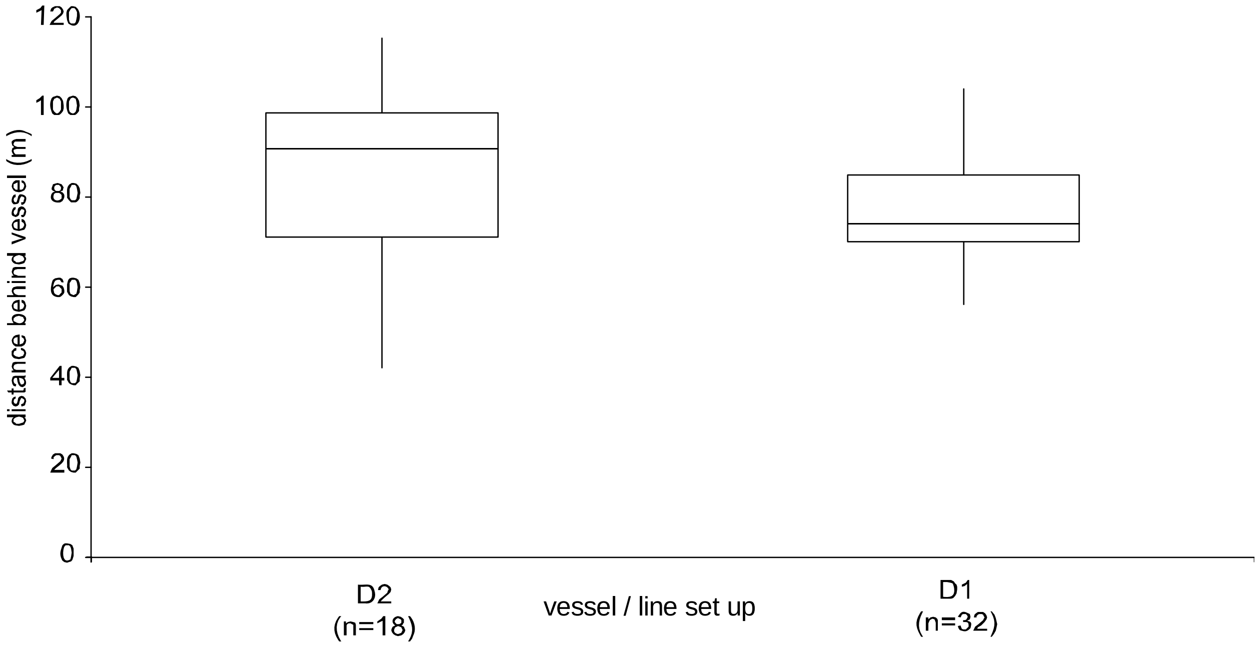


Figure 28 Box and whisker plot of distance behind vessel TDRs reached five metres depth for two different weighting regimes for vessel D. Set-up D2 had twice as many hooks between weights as set-up D1.

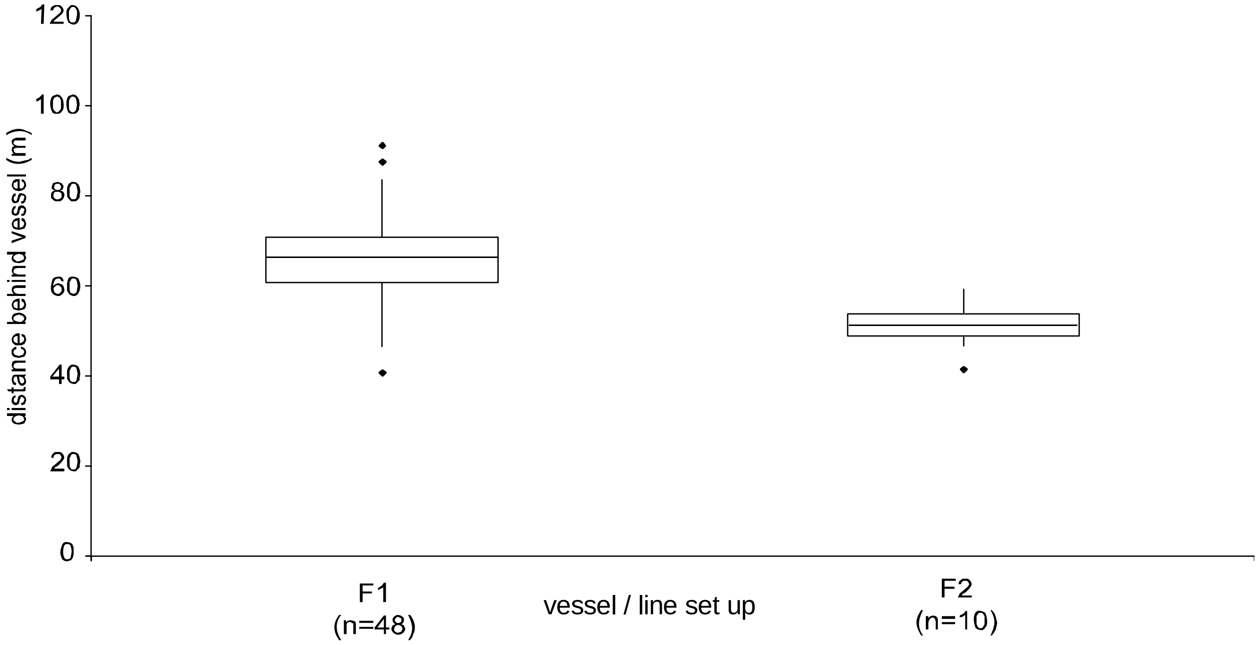


Figure 29 Box and whisker plot of distance behind vessel TDRs reached five metres depth for two different weighting regimes for vessel F. Set-up F1 had twice as many hooks between weights as set-up F2.

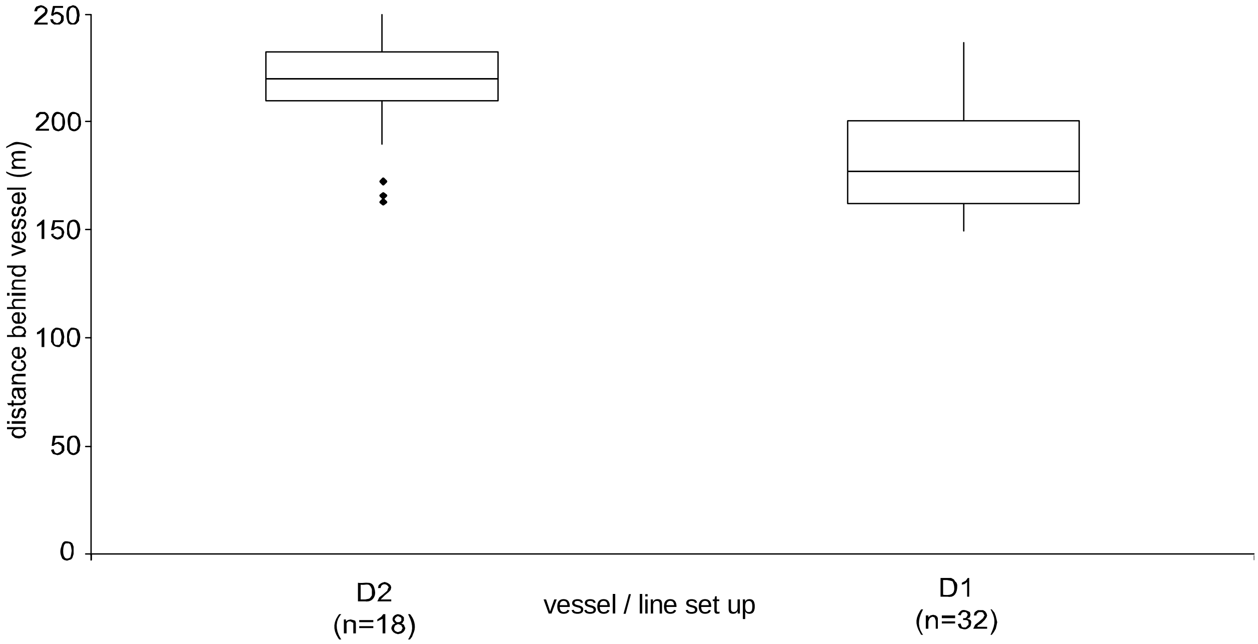


Figure 30 Box and whisker plot of distance behind vessel TDRs reached 15 metres depth for two different weighting regimes for vessel D. Set-up D2 had twice as many hooks between weights as set-up D1.

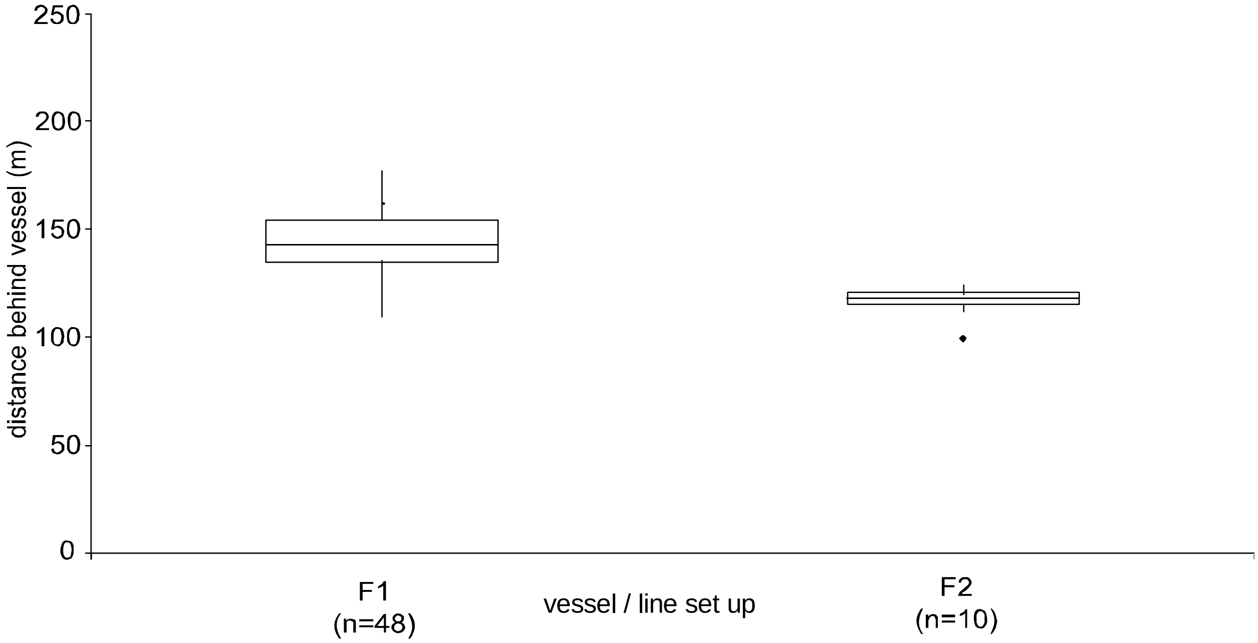


Figure 31 Box and whisker plot of distance behind vessel TDRs reached 15 metres depth for two different weighting regimes for vessel F. Set-up F1 had twice as many hooks between weights as set-up F2.

3.4 Discussion

3.4.1 Data processing

Post-collection processing of the raw TDR data applied a temperature correction to pressure readings in order to calculate depth. To minimise temperature changes on entering the water, TDRs were deployed from a bucket of seawater. However this still left several seconds during which the TDR was out of the water prior to clipping on to the backbone, and another few seconds before the TDR entered the water. Because of a lag in the response of the temperature sensors it was necessary to estimate surface water temperature to provide accurate depth readings. This approach relies on good mixing of surface waters but is assumed to be more accurate than using real time temperature records from the TDR. Correcting the depth in the above manner removed some noise in the top few metres apparent in the raw data. Adjusted records result in a more uniform sink rate with increasing depth. Without the substitution of estimated temperature values, sink rate is delayed but initially quicker. However, this is unlikely to be the case especially close to the vessel where the line is at a steeper angle and there is less weight around the TDR. Therefore, on balance, it seemed reasonable to apply this correction. Ideally monitoring seawater temperature at 2 metres and 5 metres depth to verify good mixing of the surface waters would be preferable, but this is operationally difficult behind a moving vessel.

3.4.2 Practicalities

All data was collected on normal fishing trips and gear set up was not controlled, such that each set is essentially a snapshot of sink rates for a single set. Exceptions to this include some sets for which the skippers were happy to adjust weight spacing to examine its effect on sink rate.

Clipping the TDRs on at the desired place was not always achieved, however counts at the haul identified such instances. Although some skippers worked very uniform gear set ups, this was not always the case, with some using different sized weights and on occasions unexpectedly attaching surface marker floats. Line set up was recorded at the haul, however hook counts were only made around the TDR positions. Consequently the planned or average hook numbers between weights and floats are recorded.

Not all water entry times were recorded as it was often too dark. The time between ‘clip-on’ and ‘water entry’ varied with different positions on the line and also between vessels, for example with the height above the water. TDR temperature records identified the time at which the housing filled up with water and this was generally several seconds after it first touched the water. Consequently reliable depth records start slightly below the surface of the water.

For sets targeting snapper, the middle portion of the line was sampled to eliminate variation associated with large weights or anchors on the end of the line. However on the trip targeting ling in deeper water, the whole line was sampled. For these deeper shots the first end may have only just touched the bottom, if at all, when the last end left the vessel. Consequently nearly the whole line is still sinking in the water column when the last end is deployed.

Attaching TDRs directly to the backbone essentially measures the sink rate of the backbone rather than baited hooks. For the sets targeting ling with short snoods, this should also give a good estimate of the sink rate of hooks. For sets targeting snapper with longer snoods the baited hooks may be some distance from the backbone which results in a potential source of error. For the longest snoods this could be up to a metre.

Placing TDRs midway between weights (for example) allows for a comparison between different weighting regimes. However, from observations at sea and video footage taken, it appears that slowest sink rates in the first few metres may be after half way towards the following weight, before it is clipped on and pulling the line down. Further testing would be required to estimate the absolute slowest sink rate for any given line set up.

Measuring line tension during the shot was not possible; however estimates were made in some cases by pulling line from the drum before and after the shot. Skippers will alter the friction on the drum periodically in order to allow for the diameter of the drum reducing as line is shot. Also tension will vary between and during shots to suit different environmental conditions. For example when shooting with the tide one skipper mentioned that he needed to shoot with more tension in order to avoid tangles in the backbone.

3.4.3 Typical time depth profile

As expected, TDRs placed by weights sank faster than those between weights (Figure 9). Because the suspender rope takes some time to unwind, these reach 5m slightly later but then sink at a similar rate to the weight.

TDRs appear to record more upward movement and less even sinking in the surface waters. Whether this is due to inaccuracies in the readings or a true representation of TDR movements is difficult to determine. Above 5m TDRs were operating outside of the calibration range, however no obvious bias is apparent, as profiles are consistent above and below 5m. Noise in the depth readings near the surface could be attributed to wave action or propeller wash effects.

Sink rates of weights and suspenders were faster in the top few metres than at depth. This can be attributed to weights having to gradually drag down more line with time until the next weight is deployed, thereby slowing sink rate with time in the top few metres. Conversely TDRs deployed midway between weights sank slowly until the next weight was deployed which then gradually increased the sink rate. Below five metres the sink rate of all positions on the line appears to be reasonably consistent with increasing depth.

3.4.4 Use of suspenders

As any section of line nears the seabed at some point the weight ‘below’ it will hit the seabed and so less force will be sinking the line. Depending on the tension in the line and the distance between weights, this may result in a noticeable reduction in sink rate close to the seabed. The use of suspenders further decreases the sink rate close to the seabed, as shown in Figure 10. In this case, the line continued to sink towards the seabed even though the suspender weight had hit the bottom. This can be attributed to a combination of horizontal tension in the line and the buoyancy of the suspender float relative to the weight of the line. In this case the float appears not to have had sufficient buoyancy to overcome the line tension and so did not hold the line off the seabed.

Suspenders did allow the line to move up and down above the seabed (Figure 11). The line break recorded in Figure 11 was immediately next to one of the TDRs and pulled the line upwards. In this case the line stayed below 40 m, however in shallow waters line breaks have the potential to leave the line near the surface for some time.

3.4.5 Intermediate surface marker floats

Surface marker floats with a downline are typically clipped onto the backbone with a weight several times during a set targeting snapper. These floats have a downline wound around them such that after deployment the float spins as the backbone and weight sink. Figure 9 shows two outliers that represent TDRs 50m either side of an intermediate float. It is likely that the intermediate surface float reduced the sink rate, presumably due to some resistance caused by the line unwinding from the float

Another example of an intermediate surface marker float affecting the sink rate is shown in Figure 12; in this case it appears that the float did not unwind freely. It is likely that the float unwound partially and then caught up before fully unwinding under more tension from the supported line. In this case TDRs remained below 20 metres however it is possible that closer to the float the line was held up closer to the surface

Intermediate floats deployed with larger than normal weights and line that can unwind freely can increase the sink rate, as shown in Figure 13. The amount of line that will sink faster as a result is likely to depend on the depth of water and the relative size of the weight. In this case, no appreciable increase in sink rate was observed at other TDR positions, the closest of which were 96 m both before and after the float.

3.4.6 Swell

Observations during setting in moderate to rough sea conditions indicate that swell waves move independently to the sinking line. Consequently, the line can enter the water on the top of a wave and then come out of the water as the wave passes. It follows that this effect continues as the line sinks such that 'depth' below the surface will vary as waves pass, even though the line is sinking continually towards the seabed. This observation was reflected in TDR depth records shown in Figure 14, where it appears that the line shot on a rougher day sank slower; however this could be attributable to more tension on the line.

3.4.7 Different size weights

Clearly, adding more weight to a line will increase sink rate; Figures 15 to 17 illustrate how different sized weights on the same line result in markedly different sink rates. Caution should be used when interpreting these changes in sink rate, as each TDR reading is only a snapshot of particular conditions. Using the weight immediately next to a TDR when comparing sink times as in Figure 17 is a gross over simplification of the factors influencing sink rate, however it does appear to have a strong localised affect on the sink rate. Therefore adding larger weights could be a viable option for increasing sink rate if birds arrive during a set.

3.4.8 Between set variation

Even with similar environmental conditions and weighting, within set variation can alter between sets (Figure 18). This shows the value of collecting multiple sets of data from each vessel.

3.4.9 Normal line set ups sampled

Table 8 outlines the important between vessel variables encountered during sampling and also provides an indication of how gear set up varies across the fleet. Weight per 100 m of line is an average taken over the part of the line on which TDRs were deployed, such that any given 100 m of line may have had more or less weighting than the figure stated in table 8.

3.4.10 Sink time to five metres for normal line set ups

Figure 20 provides a good indication of the variability in sink times encountered. Much of the within set variation is due to TDRs on different positions on the line taking different amounts of time to reach the surface of the water. TDRs by weights will enter the water close to the vessel whereas TDRs between weights will take longer to reach the sea surface and enter the water some distance behind the vessel (Figure 17). When measuring sink rate to five metres, between vessel variation encompasses not only different gear set-ups but also differences in the height above the sea surface TDRs were clipped onto the line. Not all set ups were sampled evenly and although all were sampled on at least two different sets, it is likely that more variation in sink times will be apparent in larger samples.

3.4.11 Sink time between 5 metres and 15 metres for normal line set ups

Examining sink time between 5 and 15 metres removes much of the between vessel variation mentioned above and also some TDR position variation due to differences in water entry time.

When comparing the median sink times with the weight per 100m in Table 8, it seems that weight is the main driver of between vessel variation. The degree of variation within a vessel and particular set up is likely to be driven by several factors. A vessel using weights of many different sizes, for example set up A1 will have larger variability, than a vessel using more regular sized weights, for example C2. Using even-sized weights at close spacing will result in a more uniform sink rate than using larger irregular sized weights with larger spacing, an example of this is set up A1 v. B1.

Outliers on this plot (figure 20) can be explained by the use of larger than normal weights, intermediate float effects and two instances where a weight was not clipped on by the TDR as planned.

3.4.12 Distance behind the vessel that TDRs reached 5 metres, 10 metres and 15 metres

Although comparing sink times quantifies the absolute time that hooks are above a certain depth, it is necessary to take into account vessel speed to determine the distance behind the vessel that hooks reach a certain depth. This allows quantification of the spatial as well as temporal availability of baited hooks. Of interest, when comparing Figures 19 and 20 with Figure 21, is that vessel C has a line set-up which results in similar sink times to vessels A, D and E, but by shooting more slowly the line sinks to a given depth much closer to the vessel. When considering mitigation measures such as tori lines, which may provide some protection of baited hooks for a limited distance behind the vessel, it is important to consider the speed of the vessel as well as the length of the tori line.

Of further note in Figures 21 to 23 is that hooks are available to birds for considerable distances behind the vessel. Whereas surface seizing foragers such as wandering albatrosses (Cherel et al 1996) and black-browed and grey headed albatross (Prince et. al. 1994) are unlikely to reach hooks below five metres some diving species, for example white chinned petrels, have been recorded diving to considerable depths (Huin 1994) and may be able to take baits or hooks several hundred metres behind the vessel. This should be considered when selectively deploying mitigation measures in relation to bird abundance, particularly in reduced visibility or at night. These results indicate that there is the potential for interaction with some baited hooks several hundred metres behind the vessel, which is likely to be difficult to observe.

3.4.13 Altering weight spacing

Halving the number of hooks between weights unsurprisingly resulted in increased sink rates (Figures 24-27). Minimum sink time to five metres was similar with extra weight, however maximum times to five metres were less. Minimum sink times to five metres are recorded beside weights and these seem to sink initially at similar rates irrespective of weight spacing. However reducing the distance between weights results in reducing the maximum sink times to five metres represented by TDRs between weights. From observations at sea this is reflected in the fact that with closer weight spacing the line enters the water, on average, closer to the vessel.

Differences in sink times between weighting regimes are more apparent below five metres. This can be explained in part by TDRs having extra weight both below and above, whereas for some time in the top five metres the extra weight is only below the TDR because the weight above has yet to be clipped onto the line. Furthermore once below the surface the line is less likely to be influenced by propeller wash and wave action.

Caution should be exercised when interpreting the degree of variation in sink rates between different weighting regimes as the different treatments are not represented by equal numbers of sets of equal numbers of observations. Although less variation is apparent with smaller weight spacing above five metres this is not the case for vessel D below five metres. This can be attributed to more between set variation within the larger weight spacing treatment (Figure 18, Table 9).

Whilst these results emphasise the benefit of increasing weight frequency for these two vessels and line set ups, these data are unsuitable for making predictions as to increase in sink rates likely to be achieved by employing similar changes to line set-up on different vessels.

3.5 Conclusions

Sink rates varied between positions on the line, between sets and between vessels. Whilst much of this variation can be attributed to line weighting other factors such as the use of suspender ropes and intermediate surface floats can alter sink times.

Line sink times recorded on normal fishing trips aboard six bottom longline vessels indicate that hooks take in the order of 20-60 seconds to reach 5m and then a further 30- 70 seconds to sink another 10-15m depth.

When taking shooting speed into account; hooks had generally sunk to at least 5m once 100m behind the vessel and 15m 200m behind the vessel.

Increasing weight frequency, and thereby increasing the amount of weight on the line, resulted in increased sink rates, most notably below five metres.

3.6 Recommendations for reducing the likelihood of interactions

Adding more weight to a line can dramatically reduce the availability of baited hooks. For any given amount of weight added to a line sink rates are likely to be more even, with less variability, if regular sized weights are deployed as often as practical. Though less convenient, using smaller weights more often results in a uniform sink rate and reduces the maximum distance behind the vessel that the hooks reach any given depth.

Setting speed should be considered in conjunction with tori line length. Reducing setting speed can significantly increase the protection afforded by a tori line, provided the aerial extent is maintained.

Careful deployment of intermediate surface marker floats is necessary to ensure they do not reduce the sink rate of the line. Using larger than normal weights is likely to help ensure that this is the case.

Any factors that can reduce the distance behind the vessel that the line enters the water will reduce the availability of baited hooks. The most obvious of these is the height above the sea surface at which the backbone leaves the vessel, and this should be minimised as far as possible.

The use of suspender ropes and associated floats reduces the sink rate of the line. Careful consideration should be given to the length of suspender ropes, especially when fishing in shallow water.

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Appendix 1 Topics discussed and gear details recorded during port visits

General

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

Environmental Variables	Start of deployment	End of deployment (cross out if no changes)	Changes during deployment period (cross out if no changes)
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)			

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