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Short communication

Sink rate of baited hooks during deployment of a pelagic longline from a New Zealand fishing vessel

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Abstract The sink rate of baited hooks during the deployment of a pelagic longline was determined using time depth recorders. This study was undertaken to determine how long baited hooks are within the known diving ranges of seabirds. During the vessel's normal fishing operations the unweighted baited hooks reached a mean depth of 5.57 m, 30 s after being deployed. The tori line aerial section covered the longline for a mean time of 29.3 s. With the addition of a 60 g lead swivel, the mean baited hook depth attained more than doubled to 13.44 m, and a further trial using a lead core cord in the snood configuration showed a small but significant increase in hook depth over the unweighted control (7.27 m). An increase in wind speed caused the baited hooks to sink faster (0.54 m for each Beaufort unit increase in wind speed). There was also evidence that the apparent wind direction while the vessel is setting also has an effect on the depths realised, but swell height had no detectable effect. The temperature of the bait also significantly affected the hook depth: partially thawed baits sank faster than thawed baits. A 1°C rise in bait temperature reduced the depth by 0.19 m. During normal line setting on this vessel using unweighted branchlines and a tori line, a considerable proportion of the baited hooks are within the known diving range of sooty shearwaters (*Puffinus griseus*), white chinned petrels (*Procellaria aequinoctialis*), shy albatross (*Thalassarche cauta*), black browed albatross (*T. melanophrys*), grey headed albatross (*T. chrysostoma*), and light mantled sooty albatross (*Phoebetria palpebrata*). The addition of a 60 g weight removes the baited hooks from the recorded diving range of all of these species except sooty shearwaters. Investigating the behaviour of different gear configurations along with evaluating the effect that environmental conditions have on the deployment of a longline will greatly add to our understanding of why some seabirds are caught.

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INTRODUCTION

Pelagic longline fisheries principally target tunas. The fishery is worldwide with fleets of both inshore and high seas vessels. The pelagic longline is a drifting longline that can be set to fish different depths through the top of the water column depending on the target species. Deep bottom features such as seamounts and canyons that create current convergence zones and upwellings are targeted as are sharp shifts in sea temperature gradients and areas of proven catches (Michael et al. 1987, 1989).

The incidental capture of seabirds in pelagic longline fisheries has been well documented (Brothers 1991; Murray et al. 1993; Skilman & Flint 1997) and there is strong evidence that some albatross and petrel populations are declining as a result (Weimerskirch & Jouventin 1987; Weimerskirch et al. 1997; Croxall et al. 1998; Waugh et al. 1999). Seabird mortality has also been recognised in demersal longline, trawl, and gill net fisheries (Bartle 1991; Ryan & Boix-Hinzen 1999; Darby & Dawson 2000).

Seabirds are attracted to the longline operation by bait and offal discards (Alexander et al. 1997). The primary cause of their mortality is drowning after seizing and becoming caught on baited hooks while the longline is being set. A widely used method for reducing these seabird mortalities is the use of a bird scaring line (tori line). This is a line with suspended streamers that is towed behind the vessel, usually over the point where the bait enters the water, and prevents seabirds from gaining access to baits for a short period while the baited hooks begin their descent. Numerous other seabird mitigation measures are employed and these measures are extensively reviewed in Brothers et al. (1999).

The objective of this study was to determine the sink rate of baited hooks during a normal setting operation and to compare this with rates achieved when weight is added to the branchline. Weighting regimes and their effect on line sink rate have been investigated on different types of demersal longliners with promising results (Agnew et al. 2000; Robertson 2000). This information, combined with knowledge of the diving behaviour of various seabirds, should allow us to assess whether some gear configurations afford seabirds greater protection from baited hooks than others.

VESSEL AND EQUIPMENT

The trials were conducted off the south-east coast of the South Island on board F.V. *Daniel Solander*, a 60 m ex-Japanese pelagic longliner owned by Solander Bluefin Partnership, in April–May 1999. The vessel uses a monofilament pelagic longline system developed by Lindgren-Pitman, Inc (http://www.lindgren-pitman.com) that can set and retrieve 3000–3600 hooks on 75 nautical miles of line during each 24-h period. The target species was southern bluefin tuna (*Thunnus maccoyii*).

The longline backbone was a single strand of monofilament, 4 mm in diameter. The longline was set using a line shooter which pulled the backbone from the reel and deployed it astern of the vessel at a greater speed than that of the vessel. The ratio of line setting speed to vessel speed is one of the variables used to get the hooks to the target depth. The longline was made up of a series of “baskets”, a basket being the section of longline between two surface floats with the backbone being suspended at 250–300 m intervals. The greater rate of backbone being deployed over vessel speed allows the backbone to sink as a catenary between the surface floats. The distance between floats was determined by the vessel speed and the number of branchlines in a basket. The number of hooks per basket varies between target fisheries: this vessel used a 10 hook per basket configuration.

During the trials, the vessel’s target depth for the deepest hook in a basket was 140 m. Vessel speed during setting was 7.0 knots with the longline backbone being set at 9.8 knots.

Branchlines were monofilament, 2.0 mm in diam., 15 m long. Two other branchline configurations were used. The first used branchlines with the same configuration as above, but a 60 g lead swivel was placed 5 m above the hook. The second trial used branchlines composed of 10 m of 3 mm lead core cord, a small brass swivel, then 5 m of 2 mm monofilament to the hook. All terminal tackle was crimped. Hooks were traditional Japanese style “Mustad” 6/0 tuna hooks, ringed with the point bent towards the right (18–20°). Branchlines were attached to the backbone with “sharkclips”.

The tori line used during the setting operation was towed from a point 14.4 m above sea level. It was connected to a mizzen mast at the stern on the centre line of the vessel. The tori line could be deployed in all weathers and was composed of several different materials. From the towing point, the initial section was about 14 m of 22 mm rope, the rest of the line being 260 m of 8 mm rope. As the line was deployed, streamers (8 mm rope) were clipped onto the aerial section at 3 m intervals. Light swivels were spliced into the backbone of the tori line to prevent twisting and to act as “breakaways” if the line became tangled with a float. The first light swivel was placed c. 75 m from the towing point.

Time depth recorders

Time depth recorders (TDRs) were used to collect data on hook depth over time. They were Mk7s manufactured by Wildlife Computers, Redmond, WA, United States. Each measured $95 \times 24 \times 17$ mm and weighed 12 g in sea water.

METHODS

Before deployment, each TDR was checked (calibration of the internal clock and setting for water activation). The TDRs were configured to record the depth to within 0.5 m every second once activated. Six TDRs were used during the trials, with two being lost to sharks during the voyage. Each TDR was lashed and taped onto the monofilament branchline 1 m from the hook.

Branchlines with TDRs attached were soaked in a bucket of sea water to allow the sensors to stabilise.

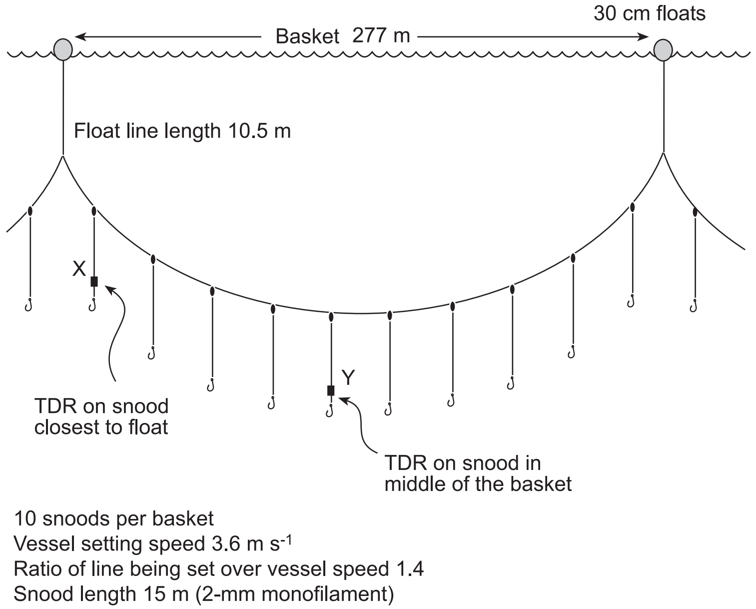


Fig. 1 F.V. *Daniel Solander* pelagic longline configuration. (TDR, time depth recorder.)

This presoak period also allowed us to record a zero offset for pressure and temperature so that the recorded data could later be calibrated.

Each TDR was deployed directly from this presoak to keep the sensors as stable as possible and to ensure that the snoods did not tangle. Hooks were baited and then hand-thrown clear of the vessel from the stern port quarter by one of the crew, while another clipped the branchline to the backbone. The time the TDR entered the water was recorded as a cross check on its internal clock.

The TDRs were retrieved the next day when the line was hauled aboard, and the data from each TDR were downloaded to a personal computer. The first 5 min of data from each TDR were kept and formatted into a spreadsheet using Microsoft Excel.

Branchline trials

Trials using unweighted branchlines were carried out on 18 sets. TDRs were deployed at least 2 h into the setting operation: six TDRs were deployed for each set.

Branchlines with TDRs attached were placed in pairs in three baskets of each set: the first pair was deployed, a basket was skipped, the second pair was deployed, another basket was skipped, and finally the last pair was set. The first TDR in each basket was placed closest to the float (Branchline X, Fig. 1) and the second TDR was clipped on to the deepest section of the basket, either the fifth or sixth branchline (Branchline Y, Fig. 1). The total weight of the unweighted branchline including TDR was 128 g.

Trials were conducted to assess the effect of the addition of a 60 g lead swivel in the branchline, 5 m above the hook. Eight sets were completed with six TDRs and seven sets were with four TDRs only.

The same basket sequence was used for these trials. The first pair of snoods with TDRs attached was deployed with no lead swivels, the next pair was deployed in a basket with every branchline weighted with a lead swivel, and in the final basket only the branchlines with TDRs attached had lead swivels. The total weight of the branchline including TDR and lead swivel was 192 g.

The third trial used branchlines composed of lead core cord. Ten sets were completed using four TDRs. The first pair deployed were in a basket where only the branchlines with TDRs attached were of lead core cord and the second pair were in a basket where all the branchlines were of lead core cord. The total weight of the lead core cord branchline including TDR was 227 g.

Aerial coverage of the tori line

The length of the aerial section of the tori line is an important factor in its effectiveness in reducing seabird mortality. It was determined by timing surface floats as they were released from the stern until they passed the point where the tori line met the water. The vessel sets the longline at an average speed of 3.6 m s^{-1} (speed over the ground 7 knots). The sampling was carried out over 10 sets to get a cross section of the different environmental conditions encountered: 100 floats were timed.

Bait

The bait used during these trials was squid (*Nototodarus* spp.) with an average weight of 140 g. The temperature of the bait was recorded before each deployment.

Environmental conditions

The environmental conditions including true wind direction and swell height were recorded at the time the TDRs were deployed. Wind speed was recorded as wind force on the Beaufort scale. Wind direction and the vessel's course were recorded to show the quarter of the vessel the wind was on while the TDRs were being deployed.

Statistical methods

The sink rate of the two weighting treatments (lead swivel and lead core) in baskets where all branchlines were weighted were compared with those in baskets where only some were weighted. There was no detectable difference within weighting treatments, so these data were combined to form two groups: those weighted with a swivel and those weighted with a lead core cord. The mean sink rates of snoods for the three treatments (unweighted, weighted with a swivel, and weighted with a lead core cord) were determined for the first 30 s after the snood was set. The mean depth was also estimated at 30 s, the average time at which a baited hook moved beyond the protection of the aerial section of the tori line and was therefore potentially available to seabirds.

The time the baited hook took to reach 20 m was also calculated for the three treatments, and the effect of environmental factors on the sink rate of baited hooks was assessed. We chose the 20 m depth point for further analysis as we have assumed that most seabirds would not be able to reach the baited hooks from beyond this point (see Table 4). Rather than analyse time taken to achieve this depth, we used the reciprocal, the sink rate, as this is statistically better behaved (more equal variances and more normal error distribution), but the results are given as the more informative time since leaving the protection of the tori line. We are therefore analysing the harmonic mean of the times to critical depth rather than the arithmetic mean.

Because TDRs may occasionally give anomalous readings due to sensor instability, the first 10 s of data after deployment were excluded in the analysis. We are confident of the accuracy of the depths recorded by the TDRs after this point.

The data set is structurally complex, with a number of different levels of sampling: sets are random variables as are hooks and (in some parts of the data) baskets. These factors enter the analysis of variance model (ANOVA) as random effects, whereas others (such as the weighting method) enter as fixed effects. The random factors have variance components associated with them; the fixed factors have means. This suggests we should employ Linear Mixed Modelling Methods (Searle et al. 1992) which model and estimate both the random and fixed effects in an efficient and extremely flexible fashion. In particular, in some analyses it becomes apparent that some weighting methods lead to greater between-hook variation than others. Linear Mixed Models using REML (Residual Maximum Likelihood) have the ability to test for such heterogeneity, to incorporate it explicitly into the

Table 1 Means and differences between mean depths after 30 s for the three weighting strategies. Tests for the pairwise differences between means are performed using Tukey's test that corrects the type I error rate for the number of tests performed. (SE, standard error.)

	Mean depth (m)	SE	*P* value	Mean sink rate (m s^{-1})	SE
Unweighted (U)	5.57	0.51		0.185	0.017
Lead weights (LW)	13.44	0.74		0.448	0.025
Lead core lines (ML)	7.27	0.63		0.242	0.021
U – LW	–7.87	0.96	<0.0001		
U – ML	–1.71	0.78	0.0405		
LW – ML	6.16	0.87	<0.0001		

model, and then estimate it. The analysis was performed using PROC MIXED in SAS version 7. Satterthwaite's method was used to give the correct degrees of freedom in the significance tests (Littell et al. 1996). A good design in experiments of this type is imperative. In evaluating weighting regimes on a demersal longliner, Agnew et al. (2000) also highlighted the fact that though conditions can remain constant within the trials, you must have the ability to separate treatment effects from other sources of variation such as environmental factors.

RESULTS

Tori line protection

From 100 observations made under various environmental conditions we estimated that the protection afforded by the tori line lasts an average of 29.3 s (SE = 0.6) from the launching of the bait, with a standard deviation of 3.1 s.

Analysis of variance (ANOVA) shows that there is significant variation among the sets sampled (variance 2.7, SE = 1.62, $P < 0.05$), but it is small relative to the variance within each set between the replicates (variance 7.4, SE = 1.1). The mean varies between sets, but only on average by the standard deviation, i.e, c. 1.6 s. There is more variation within a set than between sets. The low between-set variation may reflect the narrow range of conditions sampled. At the usual setting speed of 7 knots we estimate the mean aerial coverage to be 105 m.

Hook depth at 30 s

The first task of the analysis was to investigate possible sources of variation that could influence the results. We therefore used the unweighted (but well replicated) control data to examine variation between branchlines and between identical baskets. There was no evidence that the position of the branchline within the basket had any influence on the sink rate ($F_{1,85} = 0.16$, $P = 0.69$). Branchline position was therefore dropped in subsequent analyses. It was checked in combination with other variables and was always insignificant. Similarly, there was no evidence that baskets differ in their sink rate ($F_{2,85} = 0.48$, $P = 0.62$). Any effect that the catenary formed by the mainline may have had on subsequent sink rate and hook depth is not evident in the time frame we are studying.

There was, however, clear evidence for between-set variation (variance(set) = 2.94, SE = 1.17, P = 0.006), and much random between-hook variation within each basket (variance(hook) = 2.77, SE = 0.42, $P < 0.0001$). This suggested that influential environmental conditions may vary between sets.

There was clearly an effect of weighting the branchline ($F_{2,40.1} = 40.57$, $P < 0.0001$), but the two weighting strategies were clearly not the same (Table 1). The lead weights had a major effect on the sink rate, but there seems to be little effect from using the lead core cord branchlines.

However, the effect of weighting is not confined to the mean depth: it also affects the variability among the hooks within a basket. In particular, it seems to show that the variability of the depths the hooks have attained is profoundly influenced by the weighting strategy. The variance of the hooks is significantly different for the three weighting strategies (–2log likelihood (2 d.f.) = 22.9, $P <$ 0.0001). The model was therefore fitted with heterogeneous variances (Table 2).

Although at first sight this might be a trivial result of the variance increasing with depth (as might be expected), standard residual analysis gives no hint of this. We conclude that irrespective of the depth achieved, the lead-weighted hooks are simply more vertically scattered (Fig. 2). This suggests that though the mean depth for, say, the fully weighted basket was 13.41 m, when the hooks in this basket clear the tori line they are spread over a range of depths (roughly 95% of them between 8.7 and 18 m). Thus the number of baits vulnerable to birds may be more than the average depth achieved implies.

Time to 20 m

If we accept that 20 m marks the effective maximum depth for most diving seabirds then Table 3 shows that the lead weighted branchlines are available for an estimated 17.80 s (95% confidence interval (CI) 13.20–23.41), less than half the time of either the lead core cord branchline 56.4 s (95% CI 50.58–63.22) or the unweighted branchlines at 49.5 s (95% CI 43.43–59.20).

Table 2 Variance estimates between the depths achieved by the hooks under the three weighting strategies after 30 s. (SE, standard error.)

	Variance estimate	SE	*P* value
Unweighted	0.41	0.18	0.012
Lead weights	8.41	3.31	0.005
Lead core lines	2.03	0.32	<0.0001

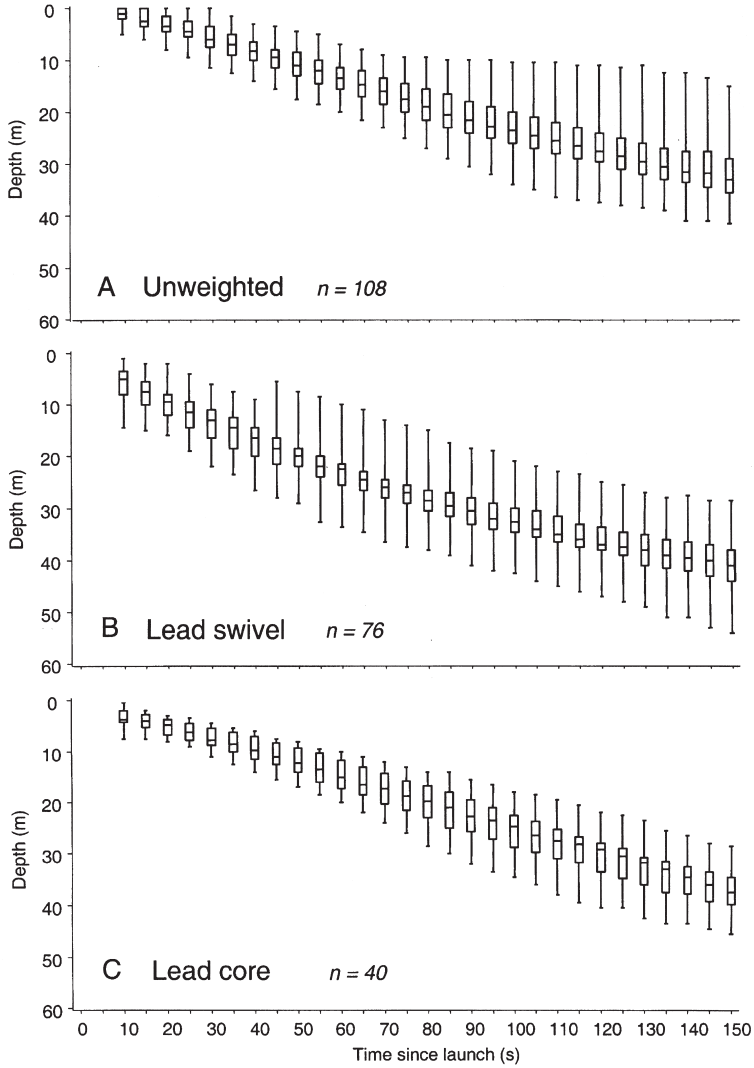


Fig. 2 **A**, Hook sink profile for unweighted snoods; **B**, hook sink profile for lead swivel weighted snoods; and **C**, hook sink profile for lead core cord snoods. (Box is between the quartiles of the data, the median is marked as a line.

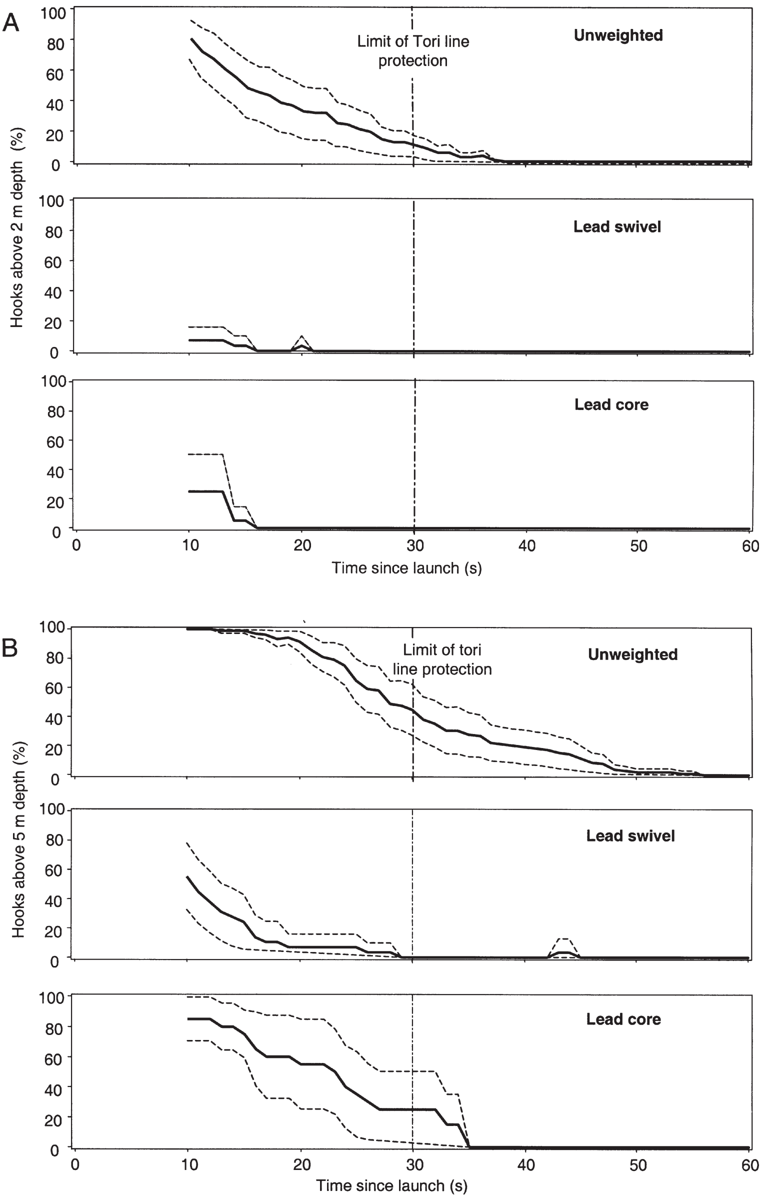
Table 3 Mean times to reach 20 m once out of the protection of the tori line. (CL, confidence limit.)

	Mean time to 20 m	Lower 95% CL	Upper 95% CL
Unweighted	49.55	43.43	59.20
Lead weights	17.76	13.20	23.41
Lead core cord	56.44	50.59	63.22

Effects of environmental factors

The high between-set variability found in the earlier analyses suggests that the depth the hooks attain may depend on environmental factors. In order to use all the available environmental data, all the groups of treatments analysed separately above were pooled. Since the effects of the treatments were no longer of interest, they were estimated and corrected for in the analysis of the data before looking for relationships with the environmental variables. In

Fig. 3 **A**, Percentage of hooks potentially available to birds above 2 m (±2 × SE) for the three weighting schemes; and **B**, percentage of hooks potentially available to birds above 5 m (±2 × SE) for the three weighting schemes.



this way 38 sets under different conditions could be analysed.

Swell height (mean 2.2 m, range 1–5 m) had no detectable effect (P = 0.9), and was dropped from the analysis to clarify the remaining relationships.

Wind direction in relation to the vessel's setting course clearly had an effect on the mean depth at 30 s ($F_{7,27}$ = 2.96, P = 0.019).

Wind speed (Beaufort scale, mean 4.0, range 1–9) showed a positive relationship with depth. Higher speeds caused the hooks to sink faster, 0.54 m for each Beaufort unit increase in wind speed (SE = 0.18, P = 0.005).

Bait temperature (mean 3.3°C, range –2.0–11.0°C) also affected the depth attained, each degree rise in temperature reducing the depth attained by 0.19 m (SE = 0.071, P = 0.013).

At least some of the between-set variation seemed to be due to the environmental variables. Without these variables this data set produced a σ^2_{sets} = 3.82

(SE = 1.11, $P < 0.0001$). With the environmental variables incorporated into the model this was reduced to 1.98 (SE = 0.68, $P < 0.0001$), suggesting that there are still a number of as yet unmodelled factors causing variation between the sets.

Depth trajectories

The patterns of the descent of the hooks under the different weighting schemes are shown in Fig. 2. Variability among the hooks is considerable and merely looking at the mean performance of the hooks will not describe the availability of baits to birds adequately. For this reason the percentage of baits above 2 and 5 m are shown (Fig. 3). These outliers are of concern because it may be that these shallower hooks are the ones that the attendant birds are consistently becoming hooked on.

Although the mean depth for the unweighted branchlines was over 5 m at the end of the tori line, many of them are shallower. About 10% were still above 2 m, which is probably sufficient for most seabirds to access (Table 4). Around 45% of the hooks were still above 5 m. All of the branchlines with lead swivels were below 5 m as they cleared the protection of the tori line whereas the lead core cord branchlines had c. 25% above 5 m. Hooks above 2 m are accessible to all albatross and petrels for which diving depths are known and even hooks above 5 m are available for all species except wandering albatross (*Diomedea exulans*).

DISCUSSION

The mean depth of unweighted branchlines in this trial was 5.57 m, 30 s or 100 m behind the vessel (this is the depth the TDRs attained, the actual hook depth being ±1 m). This compares closely with the mean depth of 5.85 m, 100 m behind the vessel attained in a similar experiment using similar materials aboard the New Zealand vessel ATU-S (O'Toole & Molloy 2000). Recent hook sink trials aboard smaller (<25 m) domestic pelagic longliners achieved a mean depth of 3.79 m, 30 s after deployment (C. Keith, Department of Conservation pers. comm.). These smaller vessels use similar materials in the makeup of their longline as do the larger vessels, but few use a line shooter. This may explain the difference in hook depth because the backbone is deployed with very little slack without a line shooter. Keith also noted that the mean baited hook depth 50 m behind the vessel (the effective protective cover afforded by the tori line) was only 1.83 m. Smaller vessels may not achieve the same aerial coverage as the larger vessels, primarily because they cannot tow their tori lines from as high a point as the *Daniel Solander* (14 m).

Although this vessel used a very effective tori line (probably at its design limit, S. Anderson pers. obs.) which protected the baited hooks for at least 100 m after deployment, there is evidence that a significant percentage of hooks (Fig. 3) may still be accessible to all species listed in Table 4 except for wandering albatross. Sooty shearwaters regularly dive to over 20 m (Table 4) and would appear to be able to still access most of the hooks on the three different types of branchline well past the end of the tori line. There are very few reports on the diving abilities of seabirds and more research needs to be continued into assessing the diving behaviour of seabirds. There are many anectodal accounts describing the diving abilities of other species of seabirds not mentioned in this study, but more research is required to verify their diving abilities. TDRs have been used on albatross giving the profile of the dive, maximum depth, the duration of the dive, and the actual time when seabirds are feeding. In the near future, when TDRs become small enough, there will be an opportunity for further research on the diving behaviour of the smaller seabirds.

Table 4 Known diving depths for petrels and albatrosses.

	Max depth (m)			
Species	Mean	SD	Range	Reference
Sooty shearwater (*Puffinus griseus*)	38.7	–	2–67	Weimerskirch & Sagar (1996)
White-chinned petrels (*Procellaria aequinoctialis*)	6.0	–	2.8–12.8	Huin (1994)
Shy albatross (*Thalassarche cauta*)	1.9	1.7	0.4–7.4	Hedd et al. (1996)
Wandering albatross (*Diomedea exulans*)	0.3	0.2	0–0.06	Prince et al. (1994)
Black-browed albatross (*T. melanophrys*)	2.5	1.3	1.4–4.5	Prince et al. (1994)
Grey-headed albatross (*T. chrysostoma*)	3.0	1.8	0.8–6.0	Prince et al. (1994)
Light-mantled sooty albatross (*Phoebetria palpebrata*)	4.7	3.4	0.7–12.4	Prince et al. (1994)

The weighting trials using lead swivels showed that the mean hook depth attained by the unweighted snood at 30 s could be more than doubled. This depth attained is out of the known maximum diving range of all albatrosses for which this information is available (Table 4). Observed catch rates of seabirds off eastern Tasmania by Japanese pelagic longliners were shown to be 65% lower when a weighted snood was used (Brothers et al. 1998a).

Although adding weight to snoods is a very effective means of minimising the time baited hooks are available to seabirds, most pelagic longline vessels in New Zealand do not use them because of crew safety concerns, although branchlines weighted with lead swivels are routinely used in the Hawaiian tuna longline fishery (B. McNamara, Garcia & Associates pers. comm.) to maximise fish catch rates. There has been one human fatality and several serious injuries in the New Zealand fishery when taught branchlines with weighted swivels have fired back towards the vessel and hit crew during the hauling process. Research into safe ways of weighting branchlines is needed if this is to become a widely accepted mitigation measure.

The lead core cord overcomes most of the safety concerns, but gave an increase of only 1.17 m in our mean hook depth at 30 s compared with the unweighted control. The total weight of a lead core branchline was 215 g, compared with 180 g for the lead swivelled branchline, but it sank only marginally faster than the unweighted branchline and took longer to sink to 20 m than the unweighted branchline. This would suggest that the total weight of the branchline is not directly related to an increase in hook depth. It is possible that resistance due to the larger diameter of the lead core cord (3 mm) and the possibility of air being trapped in the lay of the cord cause its slow descent.

To obtain maximum hook depth, any weight added to the branchline should be close to the hook. Satani & Uozumi (1998) found that the addition of a 5 m length of weighted line ("sekiyama", weighing 40 g) in the branchline increased the sinking speed c. 0.1 m s^{-1} over the vessel's normal rate. If different snood weighting regimes are to be an acceptable measure in reducing seabird bycatch, fishers must first have confidence that altering present branchline designs will not be detrimental to the target catch.

As in this study, O'Toole & Molloy (2000) found that mean hook depth usually remains constant within a set, but there is a large variation in hook depth between sets, also suggesting that factors such as environmental conditions are influencing the sink rate.

It appears that the higher the wind strength during the setting of the line, the greater the hook depth attained within 30 s. Swell height usually increases with wind strength but there was no effect on hook depth by swell height. It is possible that the increased depth we are associating with wind strength is related to some other variable. Brothers et al. (1998b) found that seabirds were more likely to be caught as the wind speed and sea height increased: seabird catch rate rose 19% for each unit rise in the Beaufort scale and 32% for each increased metre of sea height. They also suggested that the increase in seabird catch may be due to greater turbulence keeping the bait near the surface and increased seabird abundance in windier conditions.

We found that, contrary to previous studies, partially thawed bait sank faster than completely thawed bait. Brothers (1991) and Brothers et al. (1995) suggested that frozen baits sank more slowly than thawed ones and Duckworth (1995) found a non-significant lower bycatch rate when thawed baits were used. Brothers et al. (1998a) found that during 1997 most birds were caught when baits were partially thawed, with frozen or well thawed baits showing a similar bycatch rate. Analyses of the effect of bait thaw state on seabird catch have not been bait species-specific. Our observations may be particular to squid or it is possible that some frozen baits are denser that sea water, i.e., brine frozen (L. Head, Vancouver Shipyards Co. Ltd pers. comm.).

Studies to measure the effectiveness of line weighting in reducing seabird bycatch in different geographic areas with different suites of seabirds present is a high priority.

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