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# Tori line designs and specifications for small pelagic longline vessels

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**Abstract**

Tori lines are one of the most thoroughly tested seabird bycatch reduction measures available, and have been proven effective in reducing seabird bycatch in both trawl and longline fisheries. However, most of the work to date has been carried out on vessels over 20 m in length.

In WCPFC-SC12-2016/ EB-WP-10 Pierre et al reported trials conducted on land and on four different smaller vessels at sea, to explore tori line designs and materials appropriate for use during demersal and pelagic longline fishing methods. The approach was structured by vessel speed, which broadly correlates with small-vessel longline fisheries targeting different species. This report describes further work producing tori line designs suitable for use under normal commercial fishing conditions in the New Zealand pelagic longline fleet, comprising small vessels 12-25m in length. The project also sought to address any concerns raised by fishers. In particular, designs were developed that addressed safety concerns, minimised tangling, and allowed deployment at night and in poor weather conditions.

Achieving a 75 m aerial extent with a combination of long tube streamers and short tape streamers is feasible as a minimum standard, which corresponds favourably to internationally recognised best practice advice for larger pelagic vessels. Design considerations are focussed on the aerial section, the drag section and the tori poles and their attachment. Advice is provided on how to optimise each of these elements for deployment on small vessels.

In developing specifications or guidance for tori lines to be used on small vessels we recognise the need to incorporate a degree of flexibility to allow designs to be optimised to each individual vessel. For example, allowing considerable flexibility in the design of the drag section of the tori line is recommended as the method of generating drag is not important.

## 1. Introduction

Bird-scaring lines are one of the most thoroughly tested seabird bycatch reduction measures available, and have been proven effective in reducing seabird bycatch in both trawl and longline fisheries (Bull 2007; Løkkeborg 2011; Melvin et al. 2014). However, most of the work to date has been carried out on vessels over 20 m in length.

For pelagic longline vessels less than 35 metres (m) in length, international best practice advice provided by the Agreement on the Conservation of Albatrosses and Petrels (ACAP) is for a single bird-scaring line with an aerial extent of 75 m or more, attached so the bird-scaring line is approximately 7 m high over the vessel stern. Brightly coloured streamers may be short or long, or both. It is recommended that short streamers are attached at 1 m intervals along the aerial extent, and long streamers at 5 m intervals (ACAP 2016).

While some New Zealand operators of small longline vessels successfully deploy bird-scaring lines on a regular basis, others report concerns about the safety of bird-scaring lines or do not consider that current best practice specifications are operationally feasible. Observer reports and discussions with fishers have highlighted difficulties in meeting these regulations, particularly noting poor weather conditions, insufficient aerial extent, lack of high attachment points, and entanglements with fishing gear (Pierre 2016, Goad 2017).

This report builds on initial work presented by Pierre et al (2016) in WCPFC-SC12-2016/ EB-WP-10 on the development of bird-scaring line configurations suited to small vessels (approximately 12-25 m in length) operating in New Zealand's pelagic fisheries. We have further refined the bird-scaring line designs so that they are suitable for use under fishing conditions, addressed the concerns raised by fishers, and tested the lines during commercial fishing activity. Note, this research conducted in New Zealand also considered application of bird-scaring lines to small demersal longline vessels, but only the results relevant to pelagic vessels are reported here. The full findings are reported by Goad (2017). Feedback from fishers across both pelagic and demersal longliners was used in development of the designs presented here.

The configurations developed and tested aimed to be as close as possible to ACAP best practice advice, achieving maximum aerial extent feasible, whilst still allowing for safe, achievable and practical deployment and operation. We highlight where the configurations developed have varied from existing ACAP best practice advice in order to overcome operational constraints faced on small vessels, and make recommendations for amendments to ACAP's advice to recognise these practical limitations.

### 1.1 New Zealand small vessel pelagic longline fleet

Vessels operating in the New Zealand pelagic longline fishery range in size from 12 to 25 m, and set between 15 and 30 nautical miles of longline daily, with a trip length in the order of 5 – 10 sets. Snood (branchline) length typically varies from 12 m to 16 m of usually 2 millimetres (mm) monofilament nylon, attached to a 3 – 3.5 mm monofilament nylon mainline. Most vessels set straight from a free-wheeling hydraulic reel, without a line shooter, at speeds of 5 - 9 knots (typically 6 – 7 knots). Basket configuration is variable within and between vessels, and is generally what is altered to control gear depth. Surface floats and attachment rope lengths are variable, with 300 mm hard floats on 13 m ropes the most common. Vessels often employ smaller hard or soft floats to use mid-basket, and generally all floats are set on a rope or a snood of at least 6 m, so are not directly attached to the mainline. Depths fished are typically in the range of 20 – 100 m. Whole defrosted squid (*Nototodarus sloanii*) is the most common bait, although some vessels will use sanma (*Cololabis saira*) for some hooks within some sets.

Target species include bluefin tuna (*Thunnus maccoyi, T. orientails*) over the winter season, and bigeye tuna (*Thunnus obesus*) and swordfish (*Xiphias gladius*) more often during the summer months. Total fleet size is around 40 vessels, with some vessels fishing with other methods for part of the year.

Historically most vessels configured snoods without weight close to the hook, but often with weighted swivels at the clip. The use of weights close to the hook has increased, to reduce bycatch and to allow skippers to set before nautical dusk under current regulations. Other mitigation measures employed include night setting, dyed bait, slack deployment of snoods, deeper sets, thawed bait, use of squid bait, and offal management.

## 2. Methods

Vessels included those which: were not working bird-scaring lines regularly, had experienced problems in the past, were willing to be involved, were working bird-scaring lines that departed most from the regulations, or asked to be included.

Bird-scaring line designs were based on results from Pierre and Goad (2016), experience at sea, and information from discussions with skippers and crew. Bird-scaring line design was split into two components; the ‘aerial section’ and the ‘drag section’ (Figure 1), and initially the design of each section was addressed separately.

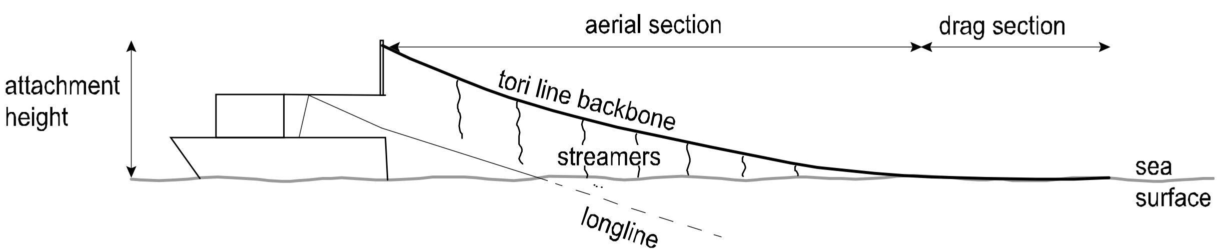


Figure 1: Bird-scaring (tori) line components

Specifications and suppliers of bird-scaring line components are summarised in Table 1 and configuration varied between fisheries.

**Table 1:** Materials used to construct standard bird-scaring lines

| Material | Size | Colour | Supplier |
|---|---|---|---|
| Plastic tubing | 9 mm | orange | Beauline |
| Plastic tubing | 5 mm | orange | Beauline |
| Plastic tubing | 5 mm | Pink | Cookes |
| Dyneema winch rope | 3 mm | Yellow | Nautilus Braids |
| Monofillament nylon | 5 mm | Clear | Maui Ocean Products |
| Braided Polyester rope | 9 mm | White | Cookes |
| Plastic cones | 50 mm diameter, 75 mm length | Black | Supply Services |
| Fibreglass pole | 52 mm diameter x 5.0 m length | Black | Kilwell Fibretube |
| Carbon fibre pole | 62 mm diameter x 3.9 m length | White | Kilwell Fibretube |
| Plastic sister clips | 4.5 mm PNP16B | White | Ronstan |
| Holographic tape | 0.25 m wide x 0.5 m double streamer | Silver | Pestguard |
| Plastic tape | 0.3 m wide x 0.5 m double streamer | Black | Bunnings |
| Road cones | 280 mm x 280 mm x 440 mm | Orange | Supercheap Auto |
| Gillnet floats | 50 mm diameter x 80 mm length | Orange | DeCoro |
| Flapper board | 800mm x 250 mm x 40 mm | Black | Fabricated for project |

### 2.1 Aerial section

A standard aerial section was produced for all bird-scaring lines, using 3 mm diameter braided Dyneema ‘winch rope’, treated during manufacture to improve durability and handling characteristics. In order to test different streamer types a hybrid aerial section was produced, incorporating four different streamer types (Figure 2). The first tubing streamer was 15 m along the bird-scaring line and was 2 m in length. Streamers were not placed close to the vessel to reduce the chances of tangles with the longline. Typically, the longline backbone enters the water in the order of 20 m behind the vessel and in the absence of any deterrent the author has observed birds to forage behind this point where baits are in the water. However, in some cases streamers were added closer to the vessel to increase protection if the skipper felt this was necessary. Tubing streamers reaching the sea surface were then attached every 5 m, giving 11 streamers along the 75 m aerial section. From 35 m to 60 m along the bird-scaring line additional alternate black and holographic tape streamers were added between the tubing streamers.

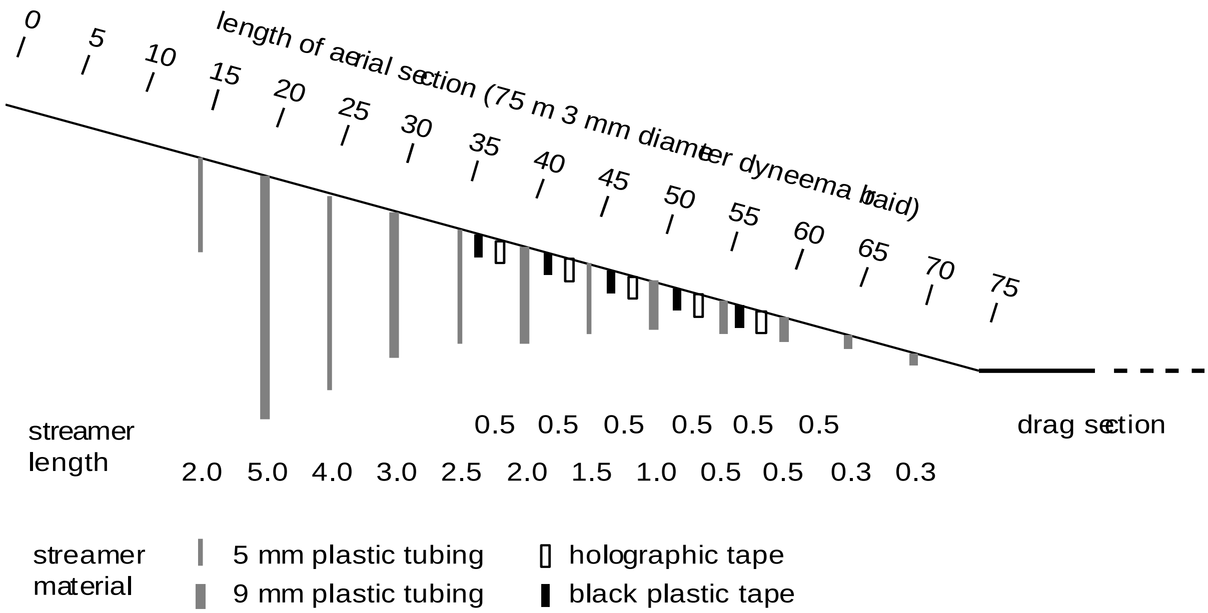


Figure 2: Schematic diagram showing 'standard' aerial section common to all bird-scaring lines. Vertical scale is exaggerated 4 times.

Tubing streamers were attached by two methods: Most were placed alongside the bird-scaring line backbone and tied in place. Tubing was then cut with a taper and the joint taped over with electrical tape (Figure 3). For some pelagic longliners, longer tubing streamers were attached using sister clips held in place by knots in the bird-scaring line backbone. Tubing streamers were attached to a second sister clip to allow removal for storage. Tape streamers were attached by threading through the lay of the rope backbone.

The aerial section was attached to the drag section as smoothly as possible. The thicker (5 or 9 mm) drag sections were tapered and whipped to the 3 mm aerial section along a 150 mm length. This was then wrapped in electrical tape.

Figure 3: Bird-scaring line backbone, streamer materials and streamer attachment.

### 2.2 Drag section

Skippers were given a choice of two drag sections: either 100 m of 9 mm diameter polyester ‘trawl braid’ or 250 m of 5 mm diameter monofilament nylon.

### 2.3 Tori poles

Poles were attached to several vessels without a high point close to the stern of the vessel. Designs were specific to each vessel and were formulated with vessel owners, skippers, and engineers prior to manufacture and installation. Two types of composite pole were produced following discussions with Kilwell Fibretube. Dimensions were constrained by the length of their oven and the mandrel sizes available; 3.9 m long carbon fibre and 5.0 m long fibreglass poles were tested and both were finished with two-pot polyurethane paint for improved UV resistance. Other vessels included in the trial had existing attachment points, and all bird-scaring lines were attached at least 6 m above the sea surface.

### 2.4 Tension release

An adjustable tension release was developed in an iterative manner, during the course of the project. Components were all stainless steel and were either sourced from fastening suppliers or fabricated to suit. The device provided a means for pre-setting the tension at which bird-scaring lines would break away from the high attachment point, in the event of a tangle.

### 2.5 Attachment to vessel

Based on experience at sea and advice from skippers, a method of attachment for bird-scaring lines to tori poles was developed. This ensured that in the event of a tangle with the longline the bird-scaring line broke away from the tori pole and remained attached close to where crew were deploying hooks. A flyer detailing this method was produced and supplied with bird-scaring lines (Figure 4).

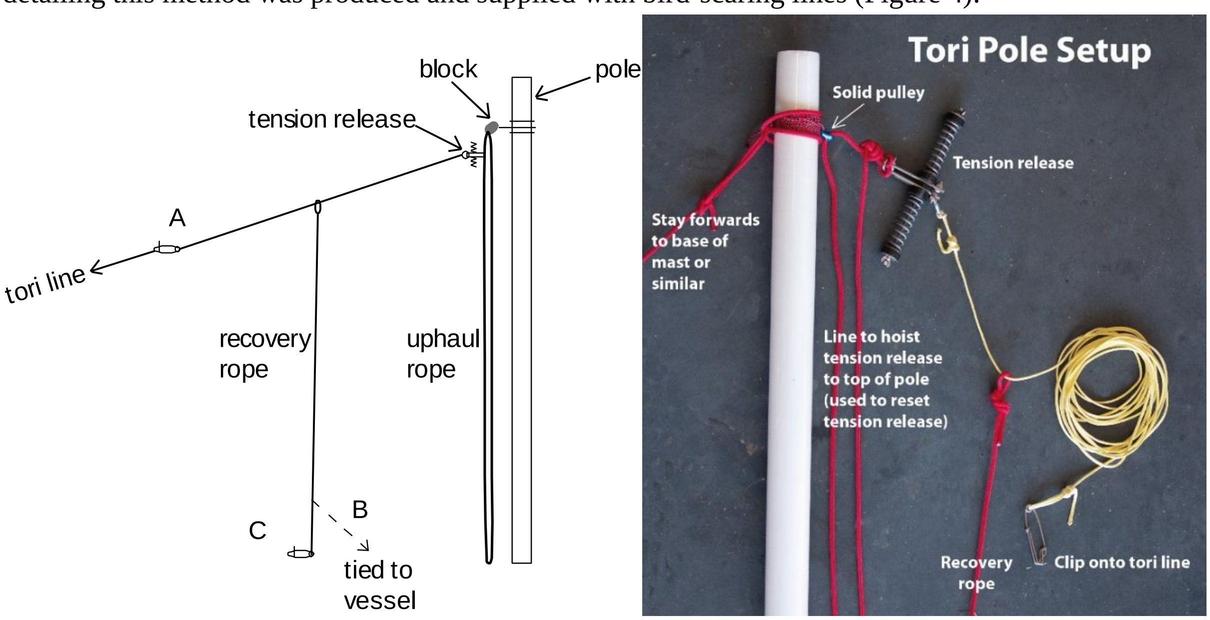


Figure 4: Extract from flyer given to skippers: Once deployed the bird-scaring (tori) line is clipped on at A. If the pre-set tension is exceeded then the line will break away from the tori pole at the tension release, and remain attached to the vessel at B. The bird-scaring line can then be clipped onto the longline using clip C and cut away from the vessel at B.

### 2.6 Modification to suit different vessels

Testing and refinement of bird-scaring lines was in conjunction with skippers, during normal fishing trips. Suggestions for refinements and different configurations were discussed between fishing trips, providing for iterative improvement. One trip on a pelagic longliner was undertaken by the author to set up and refine bird-scaring line designs at sea, and to collect performance data. Sink rate data was collected and processed in line with previous methods (Goad et al. 2010) with time depth recorders (TDRs) placed 50 cm from the hook on pelagic longline branchlines.

Bird-scaring line performance was documented by measuring the aerial extent achieved, and by recording bird behaviour in relation to the bird-scaring line as a proxy measure for bycatch mitigation effectiveness. Bird abundance and foraging behaviour were recorded to examine where birds were active relative to the bird-scaring line.

## 3. Results

A total of 22 vessels were involved in the project and 35 separate bird-scaring lines were produced (Table 2). Skippers were happy to trial new bird-scaring line designs, provide input and modify them to suit their fishing operation. Installations, including poles, are still underway on a further four vessels.

**Table 2:** Summary of bird-scaring lines developed on pelagic longline vessels during the project. Some pole heights were estimated from photographs rather than measured directly. Streamers added to bird-scaring lines were plastic tubing and attached within 20 m of the vessel.

| ID | Aerial extent (m) | Aerial section modifications | Drag section | Pole height (m) | Attachment point |
|---|---|---|---|---|---|
| 1 | 60 | streamers trimmed | mono | 5.5 | stabiliser arm |
| 2 | 75 | none | rope | 6.5 | mast |
| 3 | 75 | none | rope | 6.5 | mast |
| 4 | 75 | none | rope | 7 | 2 pivoting poles |
| 5 | 65 – 80 | none | rope | 5.5-9 | trolling poles |
| 6 | 75 | swivels added | rope | 7 | existing pole |
| 7 | 75 | streamers trimmed | rope | 7.5 | pivoting pole |
| 8 | 75 | none | mono | 6 | trolling poles |
| 9 | 75 | none | mono | 6 | trolling poles |
| 10 | 75 | streamers added | mono | 10 | trolling poles |

### 3.1 Aerial section

A standard aerial section allowed for direct comparison of performance between different vessels and drag sections. Photos and video clips provided a good means to confirm successful deployment of the device, including the length of aerial extent.

Due to vessel pitching motion, associated variations in speed, and swell, the aerial extent varied over short timescales and some momentary sagging occurred. In these instances, the range and average aerial extent under shooting conditions was estimated. Otherwise, the aerial extent achieved at shooting speed in flat water was recorded. Streamer lengths aimed to have them just touching the water in flat conditions. As well as momentary sagging, bird-scaring lines exhibited more movement in poor weather. Varying aerial extent and increased vertical movement of the bird-scaring line appeared to be at least as effective in deterring birds as a more static bird-scaring line in flatter sea conditions. However, comparisons were qualitative only and confounded by birds having greater agility in stronger winds.

There was little observable difference in behaviour between the thicker and thinner tubing streamers. Both hung below the bird-scaring lines in winds up to 25 knots (higher wind speeds were not observed). The thicker streamers were slightly more visible, and the thinner ones showed slightly more movement. Several batches of both tubing sizes were bought and each batch had slightly different colour and stiffness, but no single type was deemed to be better. Providing streamers were not tangled on deployment they tended to remain not-tangled, despite the lack of swivels. The use of plastic sister clips allowed for more movement of tubing streamers. Most skippers elected to leave streamers on the bird-scaring line, even if it was wound onto a reel.

Tape streamers were blown horizontal at wind speeds exceeding around 5 knots and ‘fluttered’ erratically. The holographic tape was noisier but lost its colour relatively quickly, whereas the black plastic was more visible and durable (Figure 5).

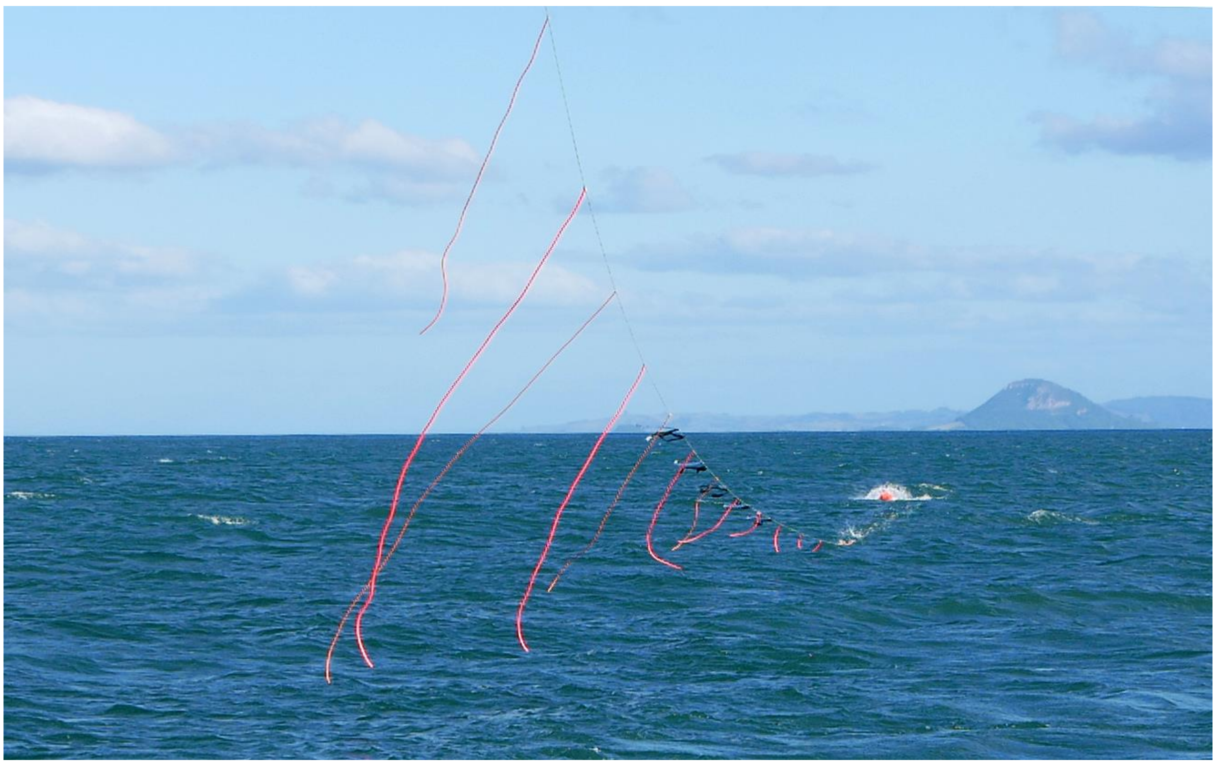

Figure 5: Bird-scaring line under testing showing streamer configuration

### 3.2 Drag section

Some skippers had an initial preference for either a monofilament or rope drag section, and some trialled both options. There was no clear consensus on a preferred option, and different skippers felt more comfortable with different designs. In order to produce similar drag, a longer length of monofilament was required compared to the larger diameter rope. Some skippers favoured a shorter rope drag section as less overall length was deemed beneficial in reducing catch-ups. The rope was also quicker to recover and easier to store as it could be simply flaked into a bin. Other skippers felt the thinner and stiffer monofilament posed less catch-up problems and were happy to put up with storing the longer mono sections, which had to be coiled carefully or wound onto a reel for storage. Both options have advantages but in many cases the need for a purpose built reel and careful recovery dissuaded skippers from selecting a monofilament drag section.

Several skippers shortened the drag sections provided as shorter lengths still provided sufficient drag to achieve a 75 m aerial extent.

One vessel experienced problems with a rope drag section twisting in the water, causing the aerial section to kink or ‘hockle’ and eventually break. Swivels were inserted between the aerial section and drag section and midway along the aerial section and solved the problem.

Skippers all reported better aerial extent and less problems than with other designs however, some catch-ups with the longline occurred with floats and beacons. Advice to skippers to minimise the potential for catch-ups included deploying the bird-scaring line after the first beacon, altering beacon setup to use a string of floats rather than individually attaching multiple floats to the line, and avoiding the use of floats attached to hooks.

### 3.3 Tori poles

Arranging to fit poles to vessels without high attachment points proved time consuming. Coordinating skippers, owners and engineers to visit the vessel to design and fit the poles around a busy fishing schedule was difficult. Engineers were selected by owners or skippers and a different attachment method was designed to suit each vessel. Both pole types were trialled, however in most cases skippers preferred the lighter, stiffer, and larger diameter carbon pole. All poles were supported with a stay forward to a strong point on the vessel. For some installations, a fibreglass pole was mounted inside a carbon pole to gain extra height without compromising on strength. Attachment approaches varied from clamping poles onto the vessels existing structure to designing mounts on CAD systems, laser cutting parts, and offsite fabrication (Figure 6).

On some vessels two separate poles were installed to allow bird-scaring lines to be attached outboard of the vessel on either side. Other skippers preferred a single pivoting pole and some skippers were happier with fixed poles.

When vessels had existing high attachment points including trawl gantries, metal tori poles, masts and albacore trolling poles, these were used.

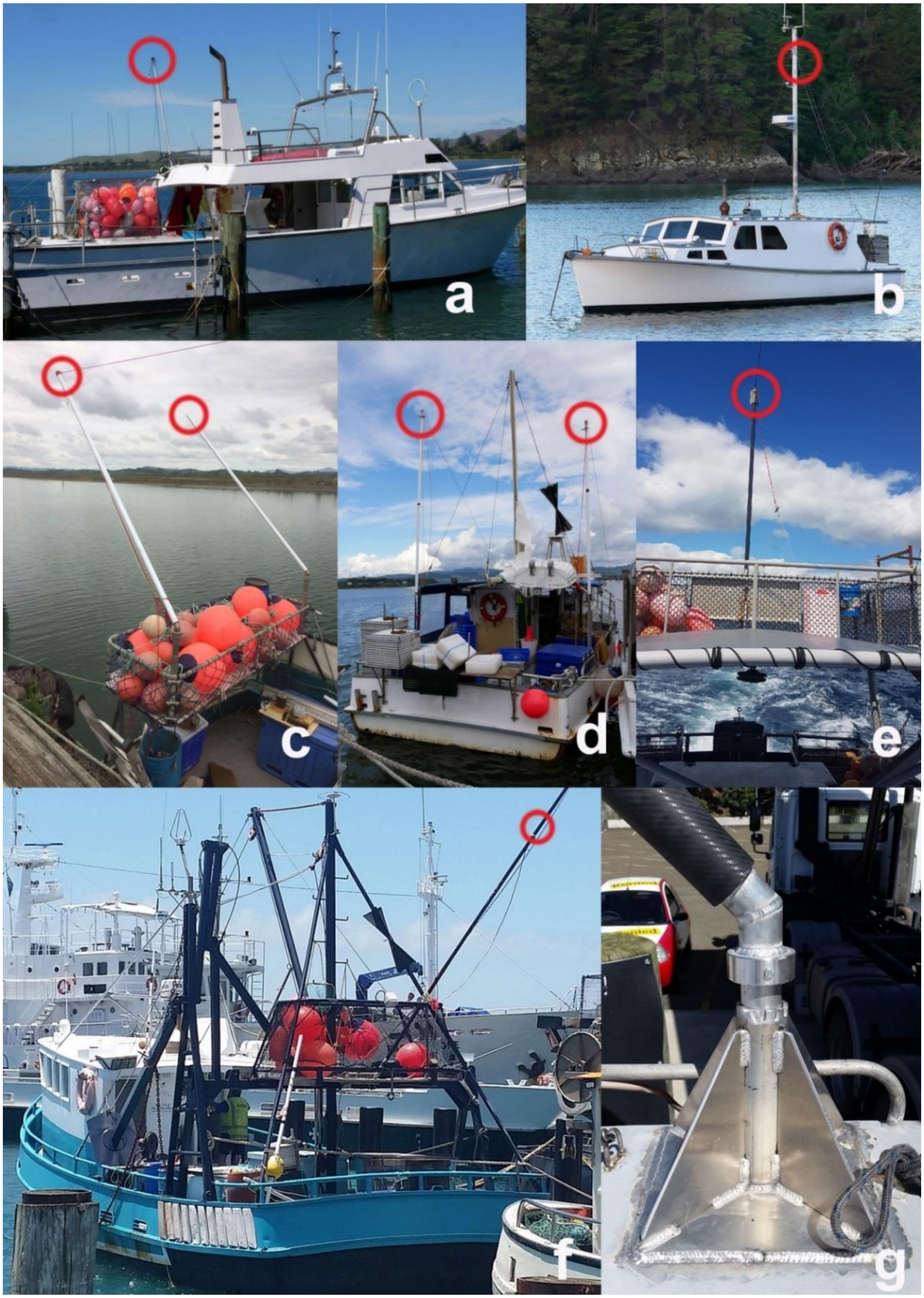


Figure 6: Examples of tori pole attachment to vessels: a: existing tori pole, b: existing mast, c: twin pivoting poles, d: twin fixed poles, e and f: single pivoting pole, g: close up of attachment base. Red circles indicate bird-scaring line attachment points. Note some vessels illustrated are demersal longliners.

### 3.4 Tension release

The tension release (Figure 7) proved capable of reproducible breakaway tensions from 5 to 30 kg. It was employed on most installations to facilitate bird-scaring line recovery during tangles and to protect the tori poles from excessive loads. Some skippers ran bird-scaring lines with greater than 30 kg tension and similarly others preferred a ‘hard wired’ bird-scaring line attached to an existing strong point on the vessel and so elected not to use the tension release.

Figure 7: Tension release developed during the course of the project. The bird-scaring line is attached to the ring and the blue rope to the tori pole. As the wing nuts are tightened more pressure is exerted on the two arms, making it harder to pull the ring out.

### 3.5 Attachment mechanism

Most bird-scaring lines were set up in a similar manner to Figure 4, though some skippers preferred to have the tension release on a length of low stretch rope so that it could be reset more quickly.

In the event of a tangle some skippers will back up on the long line, others preferred to clip the bird-scaring line to the longline and recover it at the haul. Both options have advantages and disadvantages, and the approach taken depended on personal preference and the prevailing conditions at the time of catch-up.

### 3.6 At sea testing

Feedback from skippers on a trip-by-trip basis was particularly useful and allowed for project personnel to make suggestions, benefit from skippers’ knowledge and experience, and share suggestions for improvement.

Skippers of all vessels are currently using the supplied bird-scaring lines. The aerial extent achieved by the designs varied between vessels (Table 2). Running bird-scaring lines slightly downwind of the longline was favoured by some skippers, especially when setting side on to poor weather. This was still observed to be effective in disturbing the flight paths of birds, as they tended to approach the line from downwind. Maximising attachment height and thereby minimising the length of in water sections also contributed to reducing the likelihood of tangles.

During six line sets bird-scaring lines performed well with no tangles occurring and no dead birds returned. Bird abundance was low (less than 10 within 200 m of the vessel), and most hooks were set at night. However, for two sets started before dusk five to ten black petrels were present and were only observed settling on the water behind the aerial section of the bird-scaring line. Poor weather conditions including large swells resulted in considerable changes in aerial extent as waves overtook the vessel. This increased movement of the bird-scaring line, changing the position where it entered the water. Unpredictable movement of the aerial section appeared to help deter birds.

Observer trips covered a further 20 pelagic longline sets with unweighted gear resulting in two dead petrels returned, and 12 pelagic sets with weighted gear and no birds returned dead.

Although bird behaviour counts were not made on pelagic longline vessels due to night setting, Figure 8 summarises the data collected on two small demersal longline vessels. This shows that both the abundance of birds and number of birds placing their heads under water were lower in the count region alongside the aerial portion of the bird-scaring line in comparison to the count region beyond the aerial portion of the bird-scaring line. Whilst any statistical comparison will be complicated by the nature of data collection, the results clearly show that the aerial portion of the bird-scaring lines on both vessels reduced both the number of birds and the number of birds that may be attempting to access baited hooks.

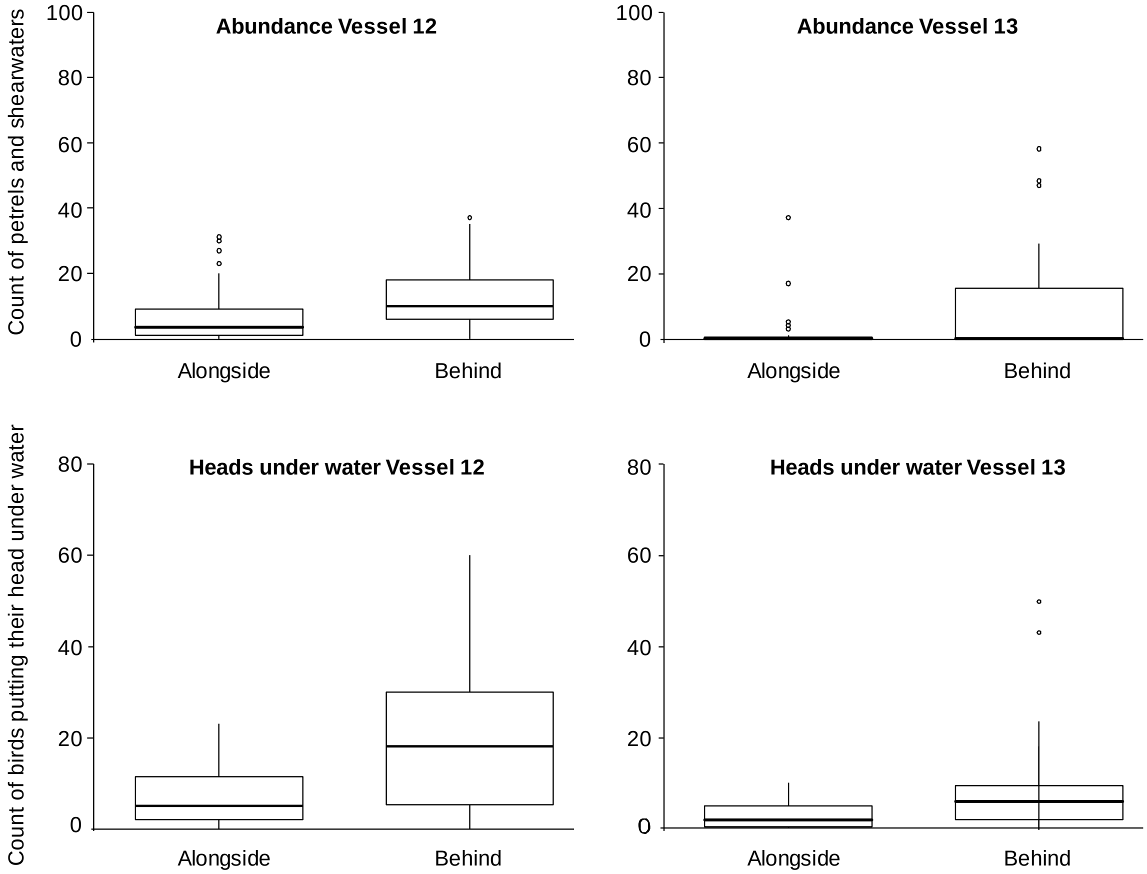


Figure 8: Number of birds (abundance) and counts of birds placing their head under water (heads under water) in relation to bird-scaring line (in the region alongside and behind the aerial extent of the bird-scaring line). Observations were conducted on two demersal longliners, during daylight sets targeting bluenose.

With larger numbers of birds present higher counts were recorded in front of the towed object and, to a lesser extent along the aerial section of the bird-scaring line. However, the bird-scaring line kept most birds out of the area immediately beside the aerial extent. Birds were regularly seen putting their heads under the water, but very few fully submerged dives were observed.

### 3.7 Sink rate data

Sink profiles of the normal gear setups indicate that bird-scaring lines with a 75 m aerial extent provided protection of baited hooks to a depth of 7.5 m on the pelagic vessel (Figure 9). These sink profiles are representative of all hooks on the pelagic vessel.

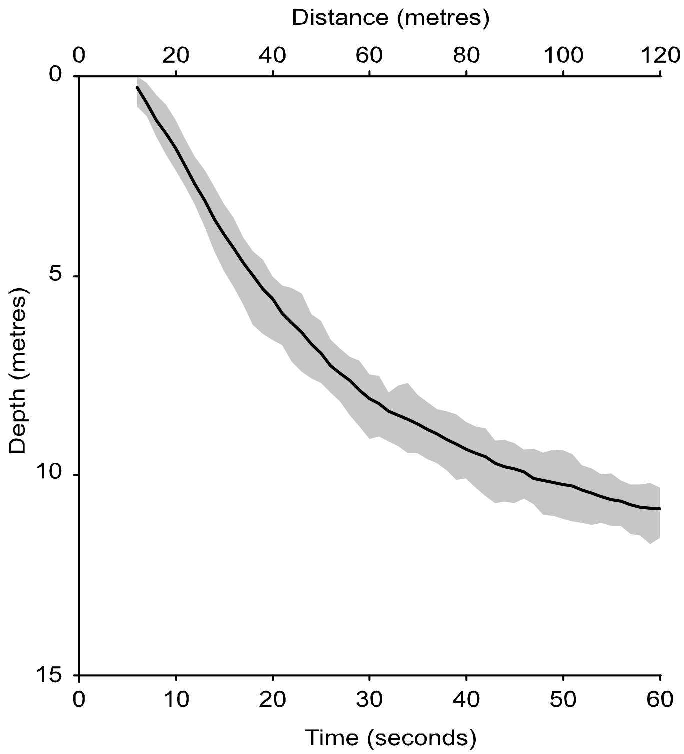


Figure 9: Sink profiles of pelagic gear during sea trials. Time depth recorders (TDRs) were placed at 0.5 m from hook on pelagic branchlines with 38 g weights at 0.5 m from the hook (n=22). Solid lines represent mean sink profiles and shaded areas indicate the interquartile range.

### 3.8 Costing

Total cost of the materials to produce the standard bird-scaring lines supplied was in the order of hundreds of dollars (Table 3).

**Table 3**: Bird-scaring line materials costing, including tension release. Note further costs for rope, clips, blocks etc. for attachment to vessel were variable but in the order of NZ$ 40 - 100 per vessel.

| **Gear type** | **Pelagic** | **Pelagic** |
|---|---|---|
| Aerial section | 75 m | 75 m |
| Drag section | 250 m mono | 100 m rope |
| Bird-scaring cost (NZ$) | 240 | 340 |

Installation and cost of poles varied from NZ$200–5000 and proved hard to predict, largely due to variable engineering costs and solutions.

Throughout the project build time reduced with practice and labour was in the order of half a day to build a bird-scaring line. Time to fit, trial, and modify bird-scaring lines to suit different vessels varied widely from hours to days.

Cost could have been reduced by using cheaper materials but investing in more durable and, for example, UV resistant, materials was thought to provide the most cost-effective solution long term.

## 4. Discussion

Skippers were generally happy to be involved and put time into finding the best solution for their operation. The number of vessels involved grew when several other skippers asked for bird-scaring lines.

### 4.1 Aerial section

The aerial section of bird-scaring lines was kept as lightweight as possible, to minimise sagging, wind resistance, and potential for tangling with the longline. Three millimetres was considered a minimum backbone diameter from a handling perspective, especially when recovering bird-scaring lines by hand. A low stretch material for the aerial section was chosen in order to ensure that it did not store energy and fly back in the event of a tangle and break-off.

Greater tension than was required to hold up the aerial section in the calm conditions replicated ashore was desirable. This helped maintain the aerial extent in poor weather conditions, and reduced the deviation of the bird-scaring line sideways in crosswinds. Typically, tension releases were set at 25 – 30 kg and this held most bird-scaring lines comfortably.

Streamer configuration aimed to strike a balance between having enough streamers to deter birds, but not so many as to produce excessive wind resistance, more tangling points, and thus require impractically long drag sections. Streamers were not placed close to the vessel as birds have not been observed attacking baits immediately behind the vessel. Short streamers were added along the middle of the aerial section, rather than along the whole length. Closer to the boat short streamers would be well above the sea surface, and further from the boat the bird-scaring line backbone acts as a deterrent and short streamers in the water would present an unnecessary tangling risk. Only having short streamers along the middle of the bird-scaring line reduces its wind profile and improves tracking.

Both 5 mm and 9 mm tubing performed well. In the absence of any detectable difference in performance the thicker tubing is recommended, as it was more visible, however the thinner tubing is cheaper.

In poor weather the variation in aerial extent over a short timescale seemed to be just as much a deterrent as a more static bird-scaring line in flatter sea conditions. This was not quantitatively measured and was confounded by birds being more manoeuvrable in stronger winds where there was also more bird-scaring line movement.

Swivels were not used to attach streamers, as they have not been observed to be useful by the author, increase cost, increase danger in the event of a fly-back, and create weak points. If streamers were tangled around the bird-scaring line backbone when deployed, then they tend to stay tangled. Once deployed successfully streamers do not tend to tangle often during set, and swivels have not been observed to reduce tangling. Excluding swivels also made the bird-scaring lines lighter and eliminated potential catch points with the longline. Swivels should be considered as an addition if necessary rather than a pre-requisite, provided non-rotating braided rope is used.

### 4.2 Drag section

Skippers of pelagic vessels preferred smooth drag sections, and consequently no separate towed objects were employed. The choice between longer, smaller diameter, monofilament or shorter, thicker, braided rope was left to the skipper and their personal preference. The rope option was more popular, but both performed well. Skippers tend to judge bird-scaring lines mostly on their personal experience and this often appeared to be the determining factor.

### 4.3 Tori poles

Fitting poles to increase attachment height resulted in increased aerial extent and better control of bird-scaring lines which, in turn, is likely to reduce the frequency of tangles. All setups installed on vessels worked well with little modification necessary. Other than the importance of giving skippers and owners flexibility to design a system to suit their vessel no general conclusions can be drawn. Arriving at the vessel with ideas, photographs and examples of other installations, and two options for composite poles provided a good starting point for productive discussions.

### 4.4 Attachment to vessel

The tension release and attachment method presented here worked well, as did others devised by skippers. The attributes for a successful system included simplicity, ease of use, protecting tori poles from excessive loads, and having a plan in the event of a tangle between the bird-scaring line and the longline. No weak links were incorporated into the bird-scaring line itself for two reasons. Firstly if, for example, the drag section tangles and breaks away then the remaining aerial section sags and is more vulnerable to tangling with fishing gear. Secondly, the breakaway system used maximises the chance of recovering the whole bird-scaring line, which is advantageous from both an economic and a marine pollution perspective.

### 4.5 Performance

Bird-scaring lines were not found to be ‘fit and forget’ for any vessels. All installations required time and effort to tailor to the vessel and the skipper. The author was fortunate in working with skippers who were happy to be involved in this process, discuss their experiences and share solutions.

Aerial extent and lack of catch-ups were the main measures of practical success for bird-scaring lines. All vessels involved in the project now have improved bird-scaring lines using these two measures.

Sea time was useful to modify bird-scaring line setups on vessels and gain insights into performance. The bird-scaring line observation form proved to be a workable measure of bird-scaring line efficacy, albeit more qualitative rather than quantitative. However, both bird abundance and counts of birds putting their heads under water were higher beyond the aerial extent of the bird-scaring line than beside the aerial extent (Figure 8). Although the count area behind the aerial section of the bird-scaring line was larger, diagrams of bird locations indicate that activity was concentrated immediately beyond the aerial extent. Consequently, counts can be considered to approximate bird densities. Those birds counted within the aerial section were recorded either side of the bird-scaring line, indicating that birds were displaced either side of the aerial section as well as beyond it.

Examining efficacy in this manner, using bird behaviour as a proxy for capture risk, relies on observing sets with reasonable bird abundance and enough light to carry out observations. Few sets meet this combination as a matter of course, and so opportunities do not often present themselves. Having protocols and forms on all observed trips increased the chances of collecting valuable data. However, quantitatively teasing out changes in efficacy resulting from minor changes to bird-scaring line configuration is likely to be difficult due to the variation in bird behaviour, and the large amount of data necessary.

Combined with setting speed the sink rate data collected at sea provided some context for aerial extent measurements. For the pelagic vessel examined the 75 m aerial sections afforded protection to around 7.5 m depth (Figure 8). The diving abilities of birds encountered (Bell et al. 2013, Thalman et al. 2009) and the results from bird-scaring line observations indicate that whilst bird-scaring lines reduce foraging activity near baited hooks, they are only part of a successful mitigation strategy. They can be considered as a last line of defence if other operational mitigation measures such as night setting, line weighting, or avoiding areas of overlap have not been successful in eliminating bird interactions with the fishing gear.

## 5. Conclusions

Skippers have been welcoming and keen to develop improvements to their setups, and a workable solution for their fishery. Translating results from field tests conducted under favourable conditions to produce bird-scaring lines useable in the dark, when shooting longlines in poor weather conditions, was challenging. Supportive skippers and crew were invaluable in testing and refining designs, and in some ways the most important measure of success is having skippers happy to use the end product long term.

Whilst the designs and setups presented here are likely to reduce the problems associated with working bird-scaring lines from small vessels, some catch-ups will still happen. Skippers are likely to foresee problems and there is consequently likely to be some reluctance to work bird-scaring lines under certain conditions, especially if birds are not present. Providing a suitable mechanism and plan is in place then hazards and problems associated with catch-ups can be minimised.

Our findings support current ACAP best practice minimum standards (for pelagic vessels <35 m in length) of achieving 75 m aerial extent using long streamers, but with modification to the streamer configuration for vessels in the 12-25 m size category.

## 6. Recommendations

From this study, we recommend that the SC:

- recognise that 75 m of aerial extent of tori lines can be achieved with long streamers for all vessel size classes >12 m in length, in broad alignment with ACAP best practice minimum standards for pelagic vessels <35 m in length and CMM 2015-03 Annex 1, 1b) (specifications for tori line use south of 30° S).

- note that for the smallest of pelagic longline vessels, approx. 20 m in length or smaller, modification to the streamer configurations currently specified in ACAP best practice advice, and in CMM 2015-03 Annex 1 (parts 1 and 2), may be required to allow for operational achievement of 75 m of aerial extent. In particular, long streamers at 5 m intervals reaching the water level over the length of 75 m of aerial extent is feasible, but may require no streamers at 5 and 10 m and a shorter streamer at 15 m to avoid tangling with gear and weighing down the line.

- recognise that sufficient drag to achieve 75 m of aerial extent can be created in numerous ways to best suit the vessel’s operations and minimise tangling with gear, which includes long lengths of monofilament, shorter lengths of braided ropes, or other configurations or devices designed to generate drag.

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