Tori line designs for small longline vessels

Final Report

D. Goad, May 2017

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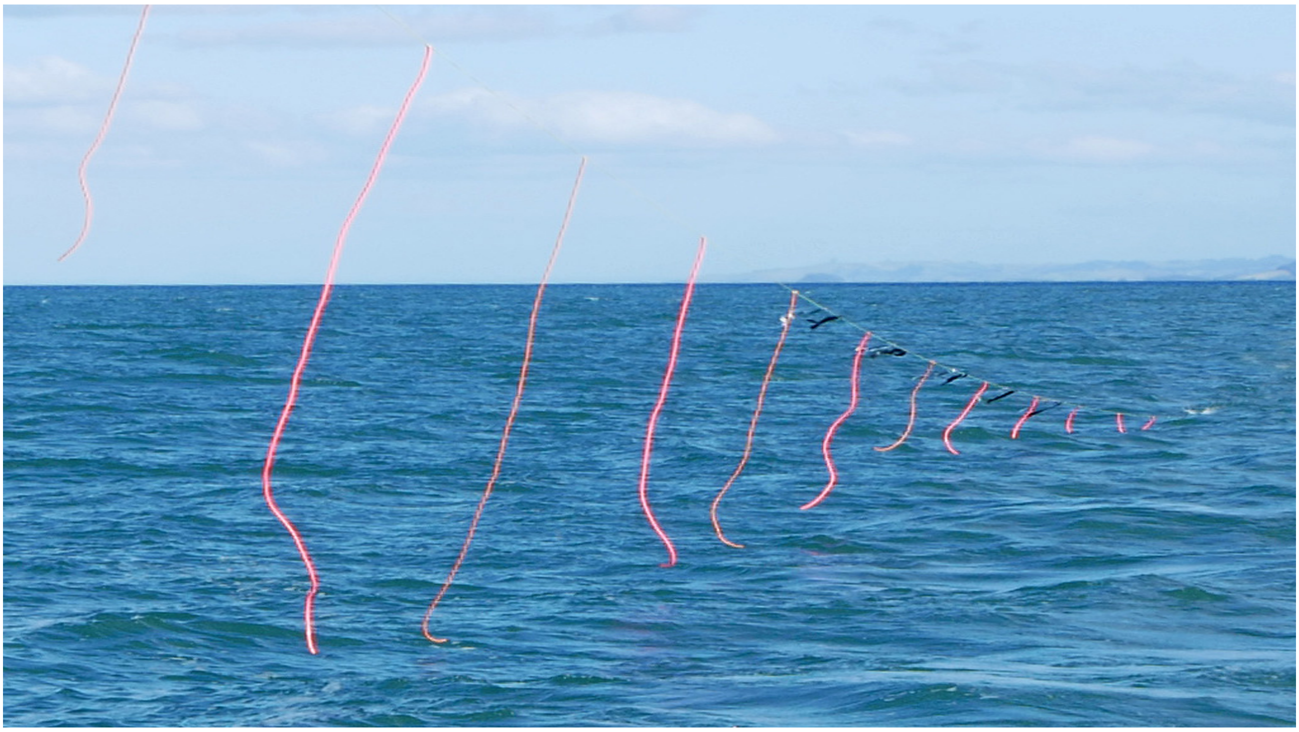

Introduction

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 (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 surface longline vessels less than 35 m in length, best practice has been recognised as a single tori line with an aerial extent of 75 m or more, attached so the tori 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 2016a).

Tori line regulations in New Zealand for surface longline vessels under 35 m include an attachment height of at least 6 m, an aerial extent of 75 m, and streamers reaching the surface of the water every 5 m for the first 55 m. Streamers of a minimum length of 1 m should also be attached along the whole aerial extent (75 m). Streamers must be attached by swivels.

For demersal longline vessels ACAP advice is not split by vessel size and includes an attachment height of 7 m, a total length of 150 m and streamers reaching the sea surface every 5 m. A suitable towed device should be used to provide drag, maximise aerial extent and maintain the line directly behind the vessel during crosswinds (ACAP 2016b).

New Zealand regulations for demersal longline vessels less than 20 m include an aerial extent of 50 m, an attachment height of 5 m, and streamers reaching the sea surface every 5 m along the aerial extent.

While some New Zealand operators of small longline vessels successfully deploy tori lines on a regular basis, others report concerns about the safety of tori lines or do not consider that current best practice specifications are operationally feasible. Observer reports and discussions with fishers (e.g. Pierre 2016, Goad 2017) 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.

Sink rates during normal fishing operations for demersal and pelagic longliners have shown considerable variability both between and within sets, and between vessels (e.g. Goad et al. 2010, Pierre et al. 2013).

Well-weighted gear and appropriate setting speed have reduced the window of availability of baited hooks behind the vessel. However tori lines still need to provide protection for hooks to a considerable distance astern, especially given the overlap between line fisheries and diving birds such as flesh-footed shearwaters (*Puffinus carneipes*) and black and Westland petrels (*Procellaria parkinsoni* and *P. westlandica*).

Pierre & Goad (2016) conducted trials 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 fishing conditions, aiming to address the concerns raised by fishers.

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 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.

New Zealand small vessel demersal longline fleet

The demersal longline fleet shows more variation in gear type and this has been reported in detail elsewhere (e.g. Goad et al. 2010, Pierre et al. 2013). Vessels over 20 m tend to target mostly ling (*Genypterus blacodes*) and fish with hand-baited hooks or the Mustad inshore autoline system. These vessels are generally over 20 m and operate outside of Fisheries Management Area 1 (East Cape to North Cape) and have lower overlap with flesh-footed shearwaters and black petrels.

Within the Area 1 fishery all demersal longliners are under 20 m and set hand-baited hooks, individually clipped onto a monofilament longline. Baits employed include; barracouta, (*Thyrsites atun*), kahawai (*Arripis trutta*), octopus, (*Octopus maorum*), pilchard, (*Sardinops sagax*), sanma *(Cololabis sair), and* squid (*Teuthida spp.)*. The fleet can be split into two groups based on gear type:

'Snapper' *(Pagrus auratus)* vessels typically fish up to 6000 hooks a day, employing 16-18 R 'Tainawa' hooks on a 60 cm snood, clipped onto a 1.2 - 2.5 mm backbone at intervals of 2.4 – 4 m. Setting speeds are generally in the 4 – 7 knot range. Catch is mostly snapper but vessels will also target granddaddy hapuku (*Scorpaena cardinalis*), gurnard (*Chelidonichthys kumu*), hapuku (*Polyprion oxygeneios)*, kahawai, red snapper (*Centroberyx affinis*), and tarakihi (*Nemadactylus macropterus*). Depths fished are generally less than 200 m, and trip lengths are 1-4 days.

'Bluenose' (*Hyperoglyphe antarctica*) vessels typically work up to 4000 hooks a day and use Mustad 'Ezibaiter' or 10-12/0 circle hooks on a 40 cm 1.8 mm diameter snood clipped onto a 5–6 mm diameter backbone. Snood monofilament is often protected by fluorescent tubing. Setting speeds are generally less than 3.5 knots. Target species also include alfonsino *(Beryx splendens, B. decadactylus*), bass (*Polyprion americanus),* hapuku, and ling. Depths fished are generally greater than 200 m, and trip lengths are in the order of 7 days.

Objective

The aim of this project was to produce and test tori lines based on recommendations from Pierre & Goad (2016) that could be routinely deployed under a range of commercial fishing conditions at-sea and were effective in reducing bird interactions with baited hooks.

Methods

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

Tori line designs were based on results from (Pierre and Goad 2016), experience at sea, and information from discussions with skippers and crew. Tori 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.

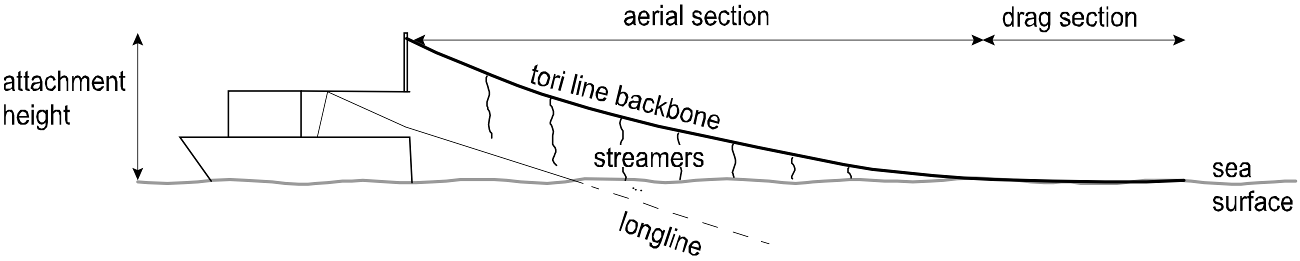

Figure 1: Tori line components.

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

Table 1: Materials used to construct standard tori 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

Aerial section

A standard aerial section was produced for all tori 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 tori 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 tori line additional alternate black and holographic tape streamers were added between the tubing streamers.

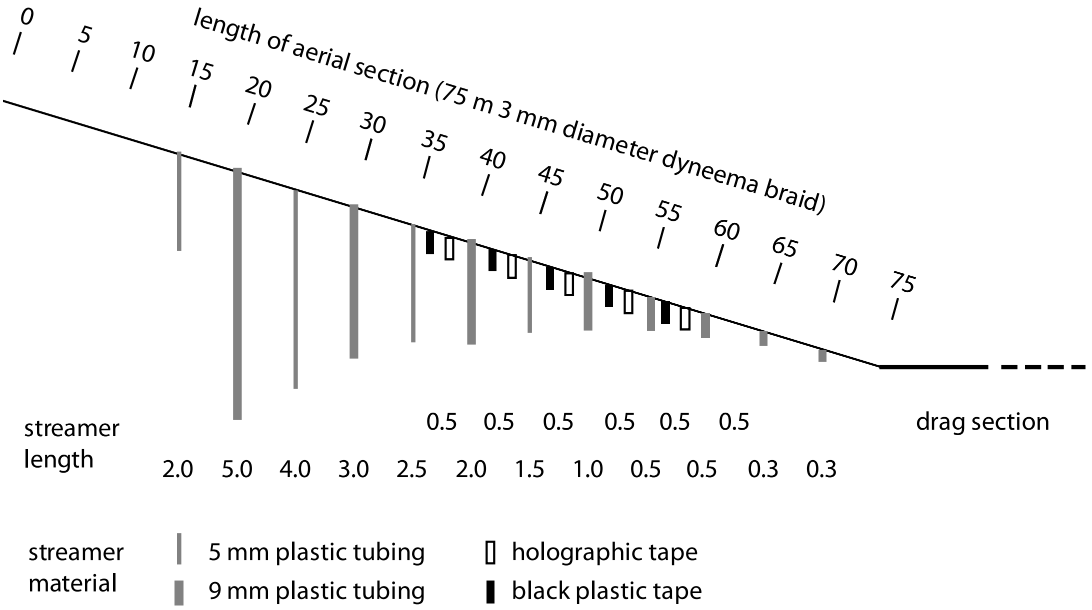

Figure 2: Schematic diagram showing 'standard' aerial section common to all tori lines. Vertical scale is exaggerated 4 times.

Tubing streamers were attached by two methods: Most were placed alongside the tori 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 tori 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: Tori line backbone, streamer types and streamer attachment.

Drag section - pelagic longliners

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.

Drag section - demersal longliners

Drag sections for snapper liners comprised either a 30 or 40 m length of 9 mm polyester 'trawl braid', with a series of gillnet floats and plastic cones threaded onto the line at 1 m intervals. Floats and cones were used in a 4:1 ratio. A separate terminal towed object comprised either a road cone or flapper board (Figure 4).

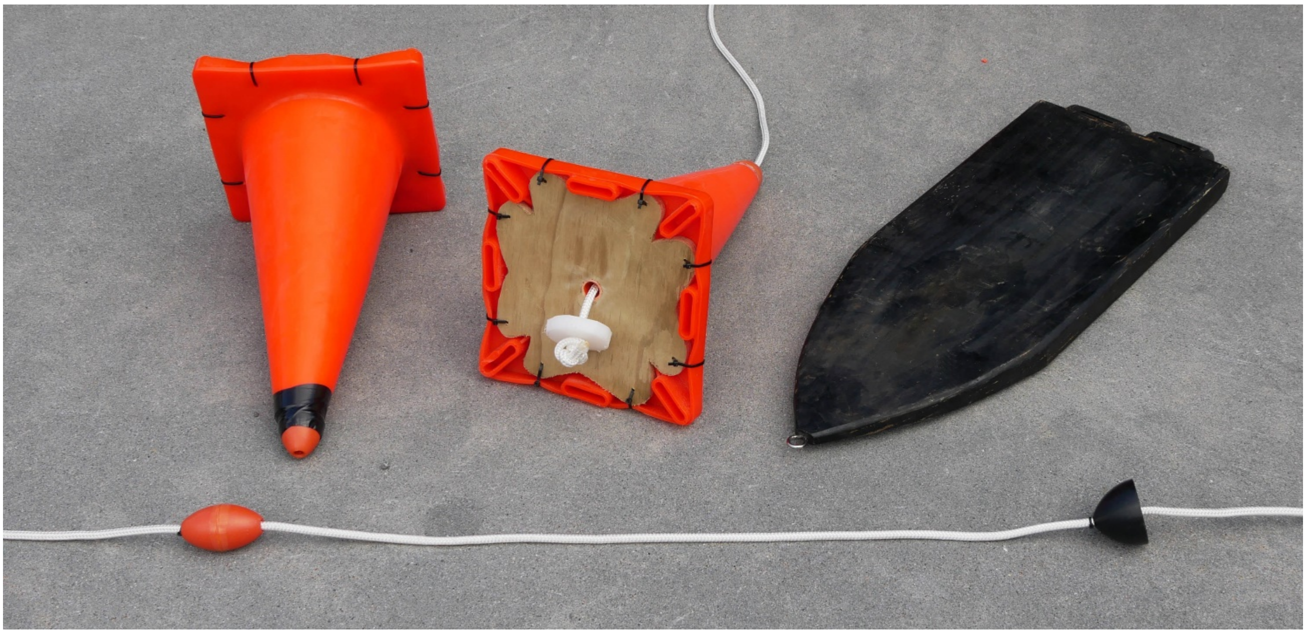

Figure 4: Drag section components for demersal longliners.

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 tori lines were attached at least 6 m above the sea surface.

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 tori lines would break away from the high attachment point, in the event of a tangle.

Attachment to vessel.

Based on experience at sea and advice from skippers, a method of attachment for tori lines to tori poles was developed. This ensured that in the event of a tangle with the longline the tori 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 tori lines (Figure 5)

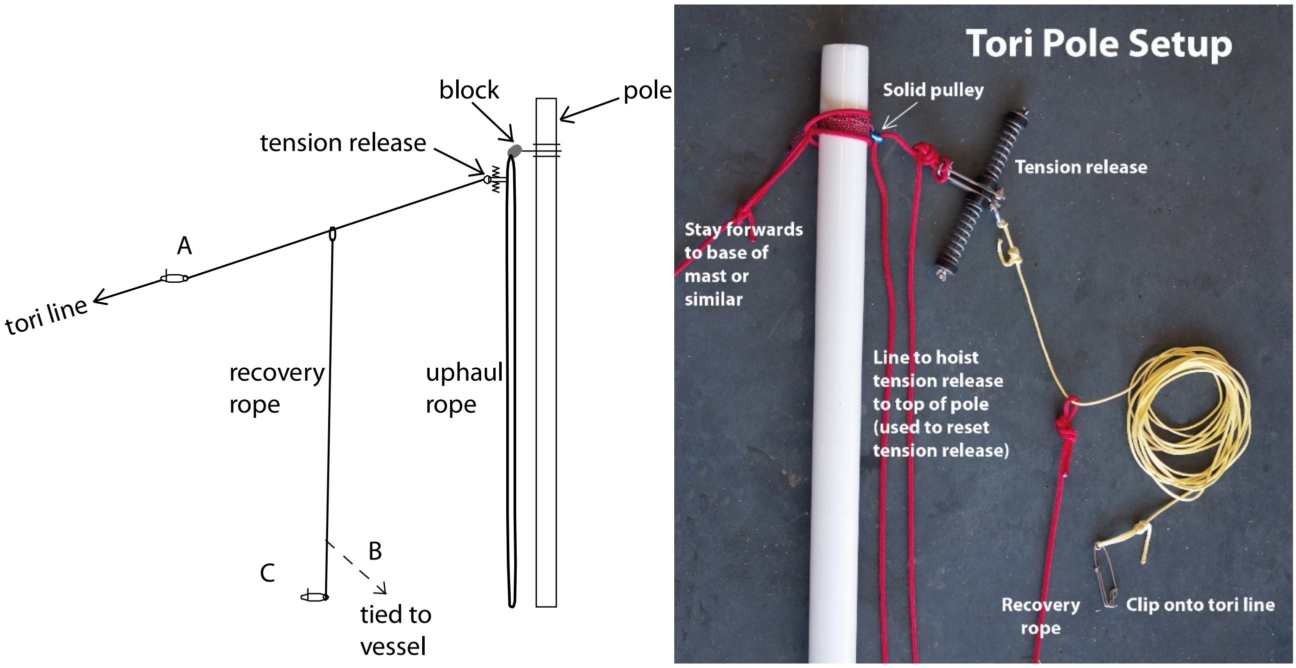

Figure 5: Extract from flyer given to skippers: Once deployed the tori line is clipped on at A. If the pre-set tension is exceeded then the line will break away from the tori pole at the tension release, and remain attached to the vessel at B. The tori line can then be clipped onto the longline using clip C and cut away from the vessel at B.

Modification to suit different vessels

Testing and refinement of tori 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. Three trips were undertaken by the author to set up and refine tori line designs at sea, and to collect performance data. These trips were aboard a pelagic longline vessel and two snapper vessels. Sink rate data was collected and processed in line with previous methods (Goad et al. 2010) with time depth recorders (TDRs) placed on demersal longlines midway between weights and 50 cm from the hook on pelagic longline branchlines.

Tori line performance was documented by measuring the aerial extent achieved, and by recording bird behaviour in relation to the tori 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 tori line (Appendix 1). For the demersal fleet, this protocol was also conducted as part of government observer trips.

Results

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

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, tori lines exhibited more movement in poor weather. Varying aerial extent and increased vertical movement of the tori line appeared to be at least as effective in deterring birds as a more static tori line in flatter sea conditions. However, comparisons were qualitative only and confounded by birds having greater agility in stronger winds.

Table 2: Summary of tori lines developed during the project. Vessel type key: PEL = pelagic longline, BNS = demersal line targeting bluenose and SNA = demersal longline targeting snapper. Some pole heights were estimated from photographs rather than measured directly. Streamers added to tori lines were plastic tubing and attached within 20 m of the vessel.

ID	Vessel Type	Aerial extent (m)	Aerial section modifications	Drag section	Pole height (m)	Attachment point
1	PEL	60	streamers trimmed	mono	5.5	stabiliser arm
2	PEL	75	none	rope	6.5	mast
3	PEL	75	none	rope	6.5	mast
4	PEL	75	none	rope	7	2 pivoting poles
5	PEL	65 – 80	none	rope	5.5-9	trolling poles
6	PEL	75	swivels added	rope	7	existing pole
7	PEL	75	streamers trimmed	rope	7.5	pivoting pole
8	PEL	75	none	mono	6	trolling poles
9	PEL	75	none	mono	6	trolling poles
10	PEL	75	streamers added	mono	10	trolling poles
11	BNS	20	shortened	none	6	2 pivoting poles
12	BNS	50	none	100 m rope and cone	8.5	1 fixed pole
13	BNS	50 - 60	none	100 m rope and buoy	7.5	1 pivoting pole
14	SNA	75	none	40 m, cone	6.5	2 fixed poles
15	SNA	75	none	40 m, cone / board	6	1 fixed pole
16	SNA	75	none	40 m, cone	6.5	existing poles
17	SNA	50	shorter, streamers added	30 m rope, floats, cone	5	existing pole
18	SNA	50	shorter, streamers added	30 m rope, floats, cone	5	mast
19	SNA	50	shorter, streamers added	30 m rope, floats, cone	5.5	mast
20	SNA	75	none	40 m, cone / board	6.5	mast
21	SNA	75	none	40 m, cone	6	mast
22	SNA	75	none	40 m, cone / board	6	pivoting pole
23	SNA	75	none	40 m, cone	6	mast

For three smaller snapper vessels shooting at 5 knots or less the aerial section was shortened to 50 m, with streamers starting closer to the vessel. Based on skippers experience and fishing to date this still represented an increase in aerial extent over previous designs and 50 m aerial extent was achieved on these vessels.

Other snapper vessels achieved the full 75 m aerial extent without modification.

On two of the three bluenose boats a thicker braided polyester cord was used for the aerial section so that tori lines could be recovered mechanically, through a hydraulic rope hauler. This rapid recovery helped reduce catch-ups at the end of the set.

There was little observable difference in behaviour between the thicker and thinner tubing streamers. Both hung below the tori 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 tori 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 6).

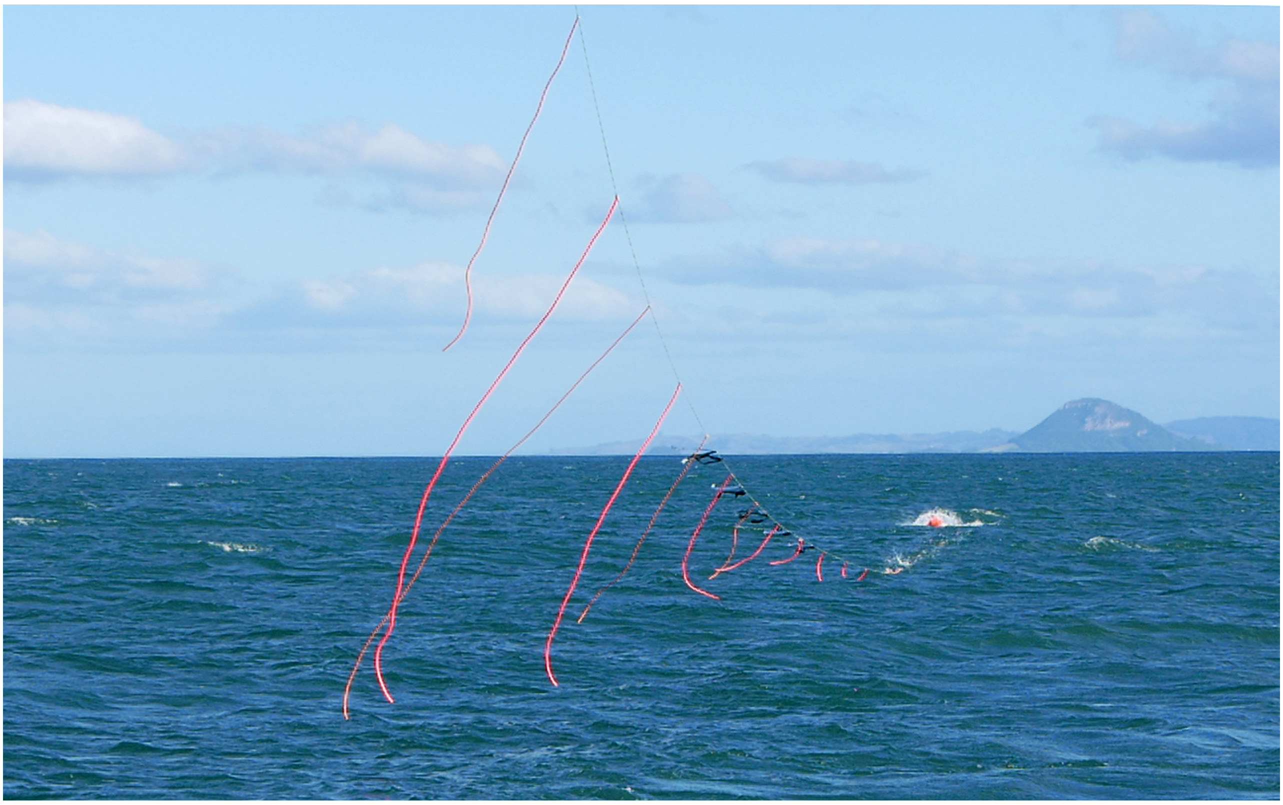

Figure 6: Tori line under testing showing streamer configuration

Drag section - pelagic longliners

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 tori 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.

Drag section - snapper longliners

Snapper vessels required very little modification to the drag section. For the three vessels with 50 m aerial sections a 30 m drag section was employed. Otherwise, a 40 m drag section was used. Compared to flapper boards, road cones produced more drag, more splash, and more movement in the aerial section as the cone bit into or skipped over waves. Filling road cones with expanding foam, reinforcing the base with plywood, and attaching a half gillnet float to the top minimised the chances for catch-ups, and helped maintain the shape of the cone. Most skippers preferred the road cone although one chose a flapper board instead, and some kept both a cone and board. Gillnet floats and solid plastic cones along the length of the drag section made it more visible and created splash, particularly the plastic cones.

Drag section - bluenose longliners

Creating sufficient drag was problematic at the slower setting speeds of the three bluenose vessels.

Various combinations of towed objects were trialled including; three different size road cones, 40 mm diameter polypropylene eight strand rope, flapper boards, and windy buoys. Different combinations and multiples of drag objects were tested along 50 or 100 m lengths of 9 mm diameter 'trawl braid'. Drag sections were improved in an iterative manner aiming to achieve at least the minimum legislated aerial extent with least problems. Catch-ups occurred more frequently than with other vessel types, and the tension release was tested repeatedly and found to work well.

Two vessels settled on an attachment height of at least 7 m, a drag section of 100 m of 9 mm diameter trawl braid, and a single towed object of either a road cone or an A3 polyform buoy. Both of these vessels modified their setting procedure to accommodate deploying a tori line after the first floats, but before hooks were clipped on.

Another bluenose vessel tried a series of drag options over a couple of months fishing. None proved to be suitable or sufficiently catch-up-free, or fit in with the skippers style of fishing which includes setting multiple short lines per day, precisely fishing foul ground, exclusively setting at night, and working in areas with strong currents. The vessel ended up working a short 20 m tori line, without a separate drag section and a 150 mm diameter hard float as a towed object. This was able to be deployed and retrieved sufficiently quickly to avoid tangles with the end floats and so was considered workable long term.

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 7).

On some vessels two separate poles were installed to allow tori 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.

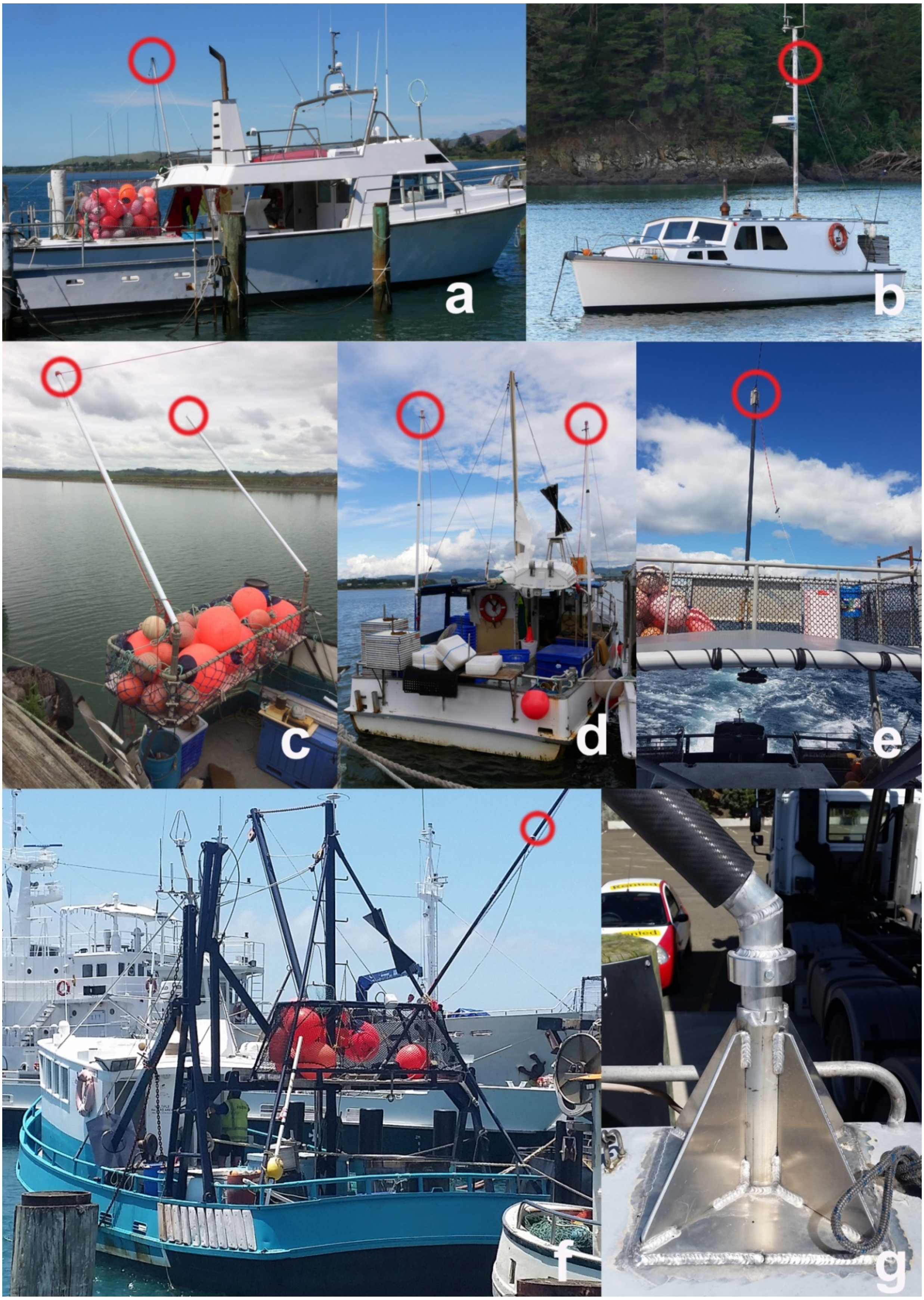

Figure 7: Examples of tori pole attachment to vessels: a: existing tori pole, b: existing mast, c: twin pivoting poles, d: twin fixed poles, e and f: single pivoting pole, g: close up of attachment base. Red circles indicate tori line attachment points.

Tension release

The tension release (Figure 8) proved capable of reproducible breakaway tensions from 5 to 30 kg. It was employed on most installations to facilitate tori line recovery during tangles and to protect the tori poles from excessive loads. Some skippers ran tori lines with greater than 30 kg tension and similarly others preferred a 'hard wired' tori line attached to an existing strong point on the vessel and so elected not to use the tension release.

Figure 8: Tension release developed during the course of the project. The tori 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.

Attachment mechanism

Most tori lines were set up in a similar manner to Figure 5, 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 tori 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.

At sea testing

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

Skippers of all vessels are currently using the supplied tori lines. The aerial extent achieved by the designs varied between vessels (Table 2). Running tori 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 eight line sets tori 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 on the pelagic longliner five to ten black petrels were present and were only observed settling on the water behind the aerial section of the tori line. Poor weather conditions including large swells resulted in considerable changes in aerial extent as waves overtook the vessel. This increased movement of the tori 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. Forty-four bluenose sets on two vessels were observed with no birds returned dead.

When bluenose fishing a total of 85 five minute observations were recorded during daylight setting, with shearwater and petrel abundance averaging 26 (with a maximum of 60) individuals present within 200 m.

Figure 9 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 tori line in comparison to the count region beyond the aerial portion of the tori line. Whilst any statistical comparison will be complicated by the nature of data collection, the results clearly show that the aerial portion of the tori lines on both vessels reduced both the number of birds and the number of birds that may be attempting to access baited hooks.

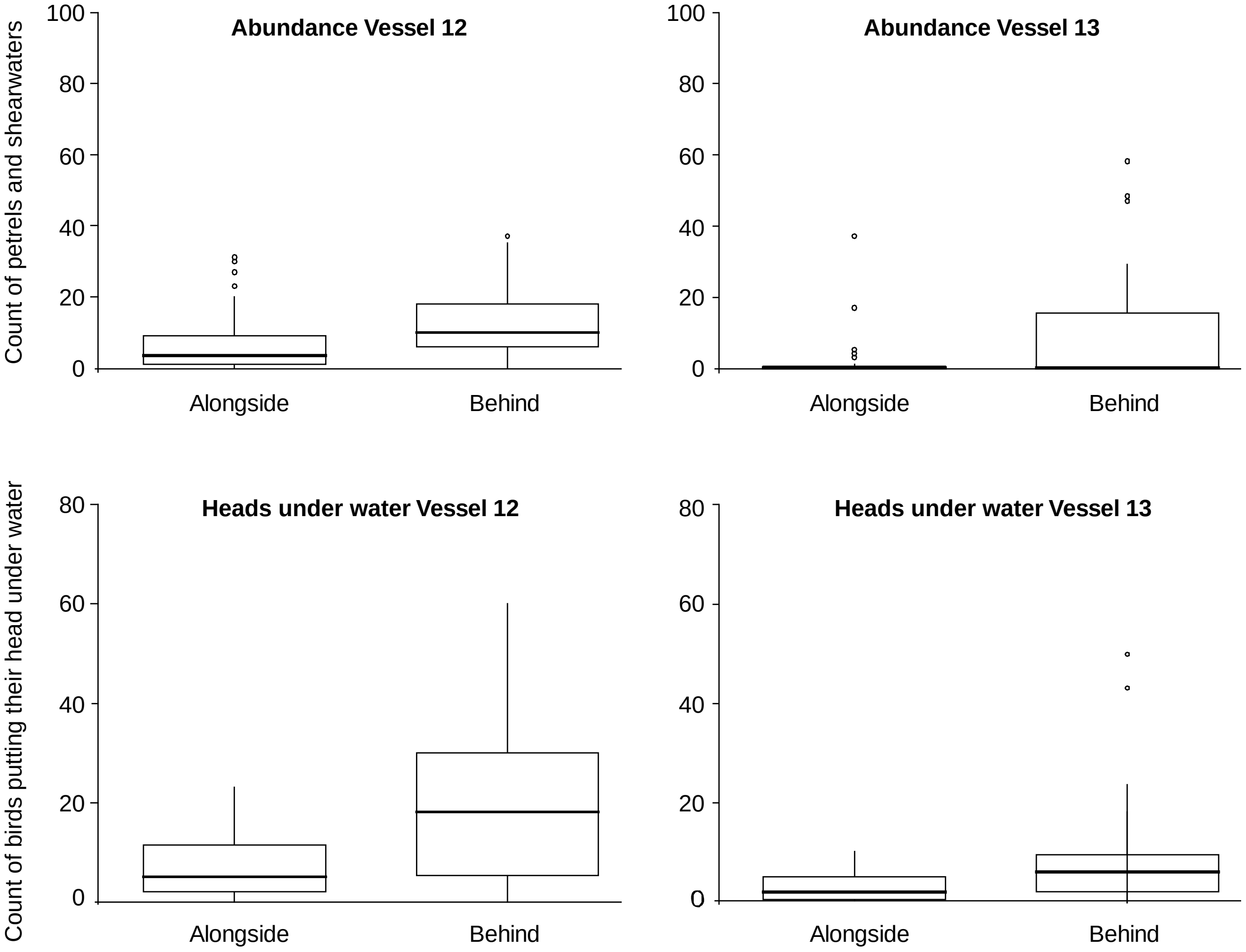

Figure 9: Number of birds (abundance) and counts of birds placing their head under water (heads under water) in relation to tori line (in the region alongside and behind the aerial extent of the tori line). Observations were conducted on two demersal longliners, during daylight sets targeting bluenose.

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 tori line. However, the tori 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.

Sink rate data

Sink profiles of the normal gear setups indicate that tori lines with a 75 m aerial extent provided protection of baited hooks to a depth of 7.5 m on the pelagic vessel and 5.5 m on the snapper vessel (Figure 10). These sink profiles are representative of all hooks on the pelagic vessel. However, on the demersal gear the sink profiles represent only the slowest sinking hooks. Weighting regimes used were typical of normal practice, however the demersal vessel will reduce weight spacing in instances of heightened risk, for example when setting in daylight.

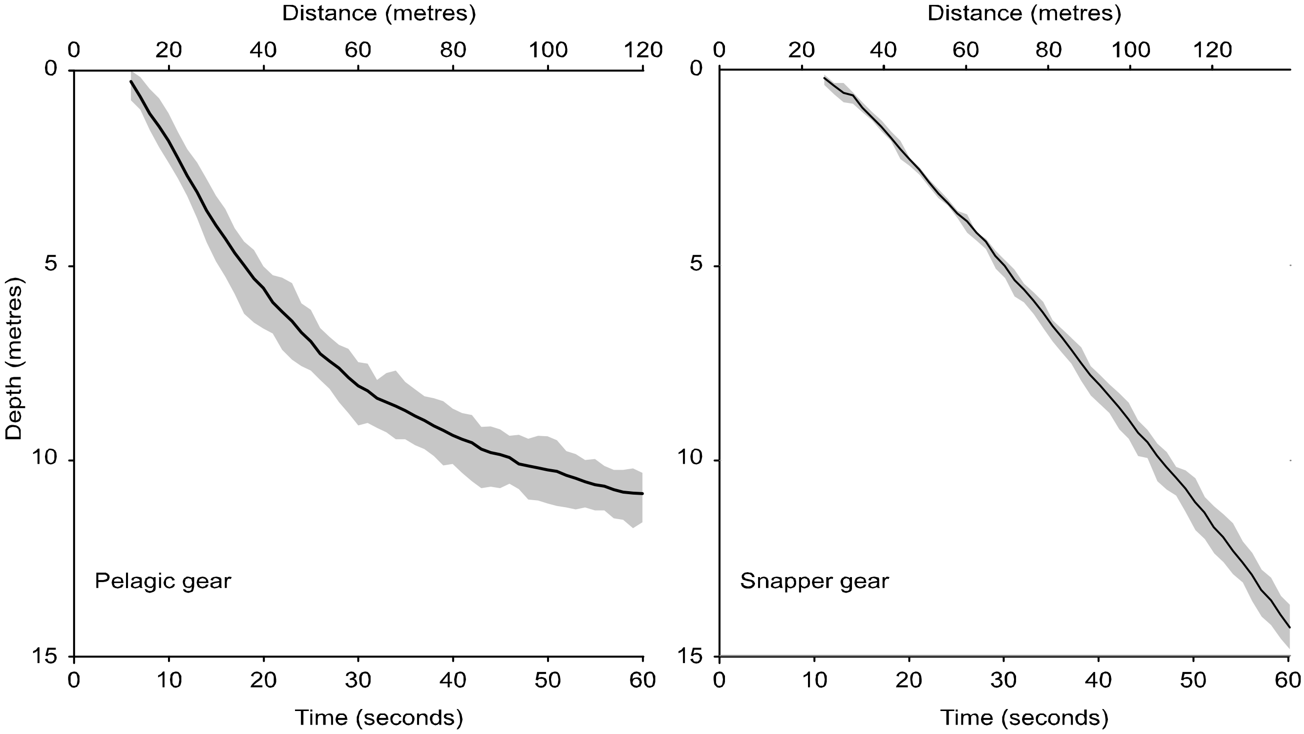

Figure 10: Sink profiles of pelagic and demersal gear during sea trials. Time depth recorders (TDRs) were placed at 0.5 m from hook on pelagic branchlines with 38 g weights at 0.5 m from the hook (n=22) . TDRs on demersal gear were placed midway between 3.75 kg steel weights, spaced at 96 m intervals (n=8). Solid lines represent mean sink profiles and shaded areas indicate the interquartile range.

Costing

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

Table 3: Tori 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	Snapper	Snapper	Bluenose	Bluenose	Pelagic	Pelagic
Aerial section	75 m	50 m	75 m	75 m	75 m	75 m
Drag section	40 m	40 m	100 m + cone	100 m + buoy	250 m mono	100 m rope
Tori cost (NZ$)	360	300	375	420	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 tori line. Time to fit, trial, and modify tori 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.

Discussion

Skippers were generally happy to be involved and put time into finding the best solution for their operation. The prosecution of a fisher last year and DOC meeting all costs helped with participation. The number of vessels involved grew when several other skippers asked for tori lines.

Aerial section

The aerial section of tori 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 tori 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 tori line sideways in crosswinds. Typically, tension releases were set at 25 – 30 kg and this held most tori 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 tori 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 tori 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.

Although 50 m aerial extent was achieved behind bluenose vessels the full length 75 m sections were used because in poor weather aerial extent was, at times up to 75 m. In poor weather the variation in aerial extent over a short timescale seemed to be just as much a deterrent as a more static tori 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 tori 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 tori 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 tori 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.

Drag sections

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 tori lines mostly on their personal experience and this often appeared to be the determining factor.

Snapper vessels all found the use of floats along the drag section practical and road cones were preferred as a towed object by most skippers.

Buoyancy of the tori line was a concern for bluenose skippers. The combination of short longlines and deep water meant that a tori line left tangled around the longline had the potential to stop a large proportion of hooks reaching fishing depth. Attaching large weights following a tangle alleviated this problem to some extent but this brings its own set of problems and compromises, especially when fishing particularly rough ground.

A combination of high attachment points, long drag sections, a single towed object, and altered setting practices proved tori lines practical on two bluenose vessels. One other vessel, and two others which fish in a similar manner (Goad 2017), were reluctant to work full-length tori lines. Given the claimed, and observed, low capture rates on these vessels resulting from other mitigation, a vessel by vessel approach to developing appropriate suites of mitigation, rather than fleet-wide standards, may be appropriate.

Tori Poles

Fitting poles to increase attachment height resulted in increased aerial extent and better control of tori 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.

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 tori line and the longline. No weak links were incorporated into the tori 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 tori line, which is advantageous from both an economic and a marine pollution perspective.

Performance

Tori 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 tori lines. All vessels involved in the project now have improved tori lines using these two measures.

Sea time was useful to modify tori line setups on vessels and gain insights into performance. The tori line observation form proved to be a workable measure of tori 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 tori line than beside the aerial extent (Figure 9). Although the count area behind the aerial section of the tori line was larger, diagrams of bird locations indicate that activity was concentrated immediately beyond the aerial extent. Consequently, counts can be considered to approximate birds densities. Those birds counted within the aerial section were recorded either side of the tori 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 tori 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. In the two vessels examined the 75 m aerial sections afforded protection to around 7.5 m depth for the pelagic gear and 5.5 m for the demersal gear (Figure 9). The diving abilities of birds encountered (e.g. Bell et al., 2013, Thalman et al., 2009) and the results from tori line observations indicate that whilst tori 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, avoiding areas of overlap, dyeing bait etc. have not been successful.

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 tori 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 tori 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 tori 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.

The style in which some bluenose vessels fish makes fitting a long tori line into the setting process difficult and likely to cause problems on a regular basis. It is important to note that these vessels have a very low observed capture rate, largely due to the combination of gear setup, line weighting, setting speed and night setting.

There has been an increased focus on the design, efficacy, and use of tori lines on longline vessels over the course of the project. The author is confident that the designs reported have produced improved tori lines behind longliners, but there is undoubtedly potential for further refinements and improvements following feedback from skippers, after extended periods of use.

Recommendations

Regulations

Change regulations to incorporate the lessons learnt from this work to make them more achievable and more relevant to the fleets discussed. At present, they are strictly specified without due consideration of practical feasibility.

Pelagic longliners

Achieving a 75 m aerial extent and streamer configuration similar to that tested is feasible as a minimum standard. This avoids problems associated with long streamers tangling with the longline close to the boat, and one-metre streamers dragging in the water further from the boat.

Specifications or guidance should incorporate as much flexibility as possible for the drag section of the tori line. How drag is generated is not important and skippers are more likely to use something they can modify as much as possible. Some may prefer shorter drag sections with a towed object whilst others may prefer longer less catchy options such as those presented here.

Snapper longliners

The current regulations are achievable and suitable as a minimum standard, although removing the need for streamers touching the water within 20 m of the vessel will reduce the potential for tangling.

Achieving an increased aerial extent of 75 m for those larger vessels shooting faster and with less regular weighting is feasible.

Bluenose longliners

The current regulations are achievable in most cases and suitable as a minimum standard, although removing the need for streamers touching the water within 20 m of the vessel will reduce the potential for tangling.

In some cases meeting the current regulations proved problematic. A vessel-by-vessel approach to developing appropriate mitigation suites may be appropriate, providing they can show acceptably low capture rates. This is particularly timely given the roll out of cameras to monitor capture rates.

Compliance

In order to check compliance with regulations port inspections to verify the presence of a tori line should be backed up with inspections at sea to verify that tori lines are deployed appropriately and meeting specified standards.

Further work

Supply complete tori line setups and poles, as required, to all small longliners. Follow up with skippers to provide help and support with installation, testing, and modification to maximise performance.

Promote tori lines as part of a suite of mitigation measures necessary to reduce captures rather than a 'tick box' regulatory approach. This empowers fishers to consider all aspects of the fishing operation with respect to minimising captures.

Try a longer aerial section on surface liners.

Continue to monitor tori line use and performance with tori line observations on government observer trips. Given the propensity for night setting, data collection opportunities will be rare. However, with more pelagic vessels working weighted gear and setting early for swordfish, some useful data will be collected, especially in areas of overlap with black petrels in the summer bigeye and swordfish fishery.

Continue to gather feedback from skippers to improve tori line designs.

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