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Developing tori lines for New Zealand's small-vessel longline fisheries

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SUMMARY

Tori lines are a well-tested seabird bycatch reduction device with proven efficacy in longline fisheries. However, because they were originally designed for larger vessel fisheries, the application of tori lines to small-vessel longline fisheries can be challenging. This report documents a New Zealand project developing tori lines specifically optimised for safe and effective use on small longline vessels. We worked with the operators of four vessels less than 28 m in overall length to develop and test tori lines and to document tori line performance. Setting speed when fishing and vessel design characteristics (specifically in terms of tori line attachment options) were used to categorise small-vessel fishing fleets for the application of tori line designs. In addition, different tori line designs were required for bottom and surface longliners based on the latter setting gear that remains in proximity of the surface for significantly greater distances astern (thereby increasing the risk of fishing gear tangling with the tori line rig). New construction materials were tested during the project, including deployment poles, streamer materials and terminal sections used for the creation of drag. Further, weak links were designed and incorporated into tori line designs for safety, should tangling with the fishing gear occur. Tori line performance was characterised primarily in terms of the aerial extent each design achieved, streamer behaviour, tracking efficacy, and the amount of water disturbance created at the end of the line. Designs were categorised with reference to a specific deployment height, drag section design, and streamer configuration. The best performing designs emerging from the project are described in this report. While the design and construction of tori lines were the foci of this project, next steps include assessing the performance of the new tori line designs in deterring seabirds from the setting area astern small longline vessels.

Elaboración de las líneas espantapájaros para las pesquerías neozelandesas de palangreros pequeños

RESUMEN

Las líneas espantapájaros son dispositivos de reducción de la captura secundaria de aves marinas ampliamente probados que cuentan con una eficacia demostrada en las pesquerías de palangre. Sin embargo, como las líneas espantapájaros fueron originalmente diseñadas para pesquerías de barcos más grandes, su aplicación en pesquerías de palangreros pequeños puede resultar un desafío. El presente informe documenta un proyecto de Nueva Zelanda para elaborar líneas espantapájaros específicamente optimizadas para su uso eficaz y seguro en palangreros pequeños. Trabajamos con los operadores de cuatro barcos de menos de 28 m de eslora total a fin de elaborar y probar las líneas espantapájaros y de documentar el rendimiento de este dispositivo. Se utilizaron la velocidad de calado alcanzada durante la pesca y las características del diseño del barco (en particular con relación a las opciones de sujeción de las líneas espantapájaros) a los efectos de categorizar las flotas de pesqueros pequeños para la aplicación de los diseños de las líneas espantapájaros. Además, se necesitaron diferentes diseños de líneas espantapájaros para palangreros tanto de superficie como de fondo a partir de los artes de calado del último que permanecen próximos a la superficie para las distancias a popa significativamente mayores (lo que aumenta el riesgo de que los artes de pesca se enreden en el aparejo de la línea espantapájaros). Durante la puesta en marcha del proyecto, se probaron nuevos materiales de construcción, incluidos mástiles de despliegue, materiales de las cuerdas y secciones terminales utilizadas para la creación de arrastre. Además, se diseñaron enlaces lábiles que fueron incorporados a los diseños de las líneas espantapájaros por seguridad, para los casos en que se produzcan enredos con los artes de pesca. El rendimiento de las líneas espantapájaros se caracterizó principalmente por el grado de extensión aérea que se alcanzó con cada diseño, por el comportamiento de las cuerdas, por la eficacia en materia de seguimiento y por la cantidad de alteración del agua generada al final de la línea. Los diseños se categorizaron con relación a una altura de despliegue, una configuración de cuerdas y un diseño de sección de arrastre específicos. En este informe, se describen los diseños surgidos del proyecto que tuvieron un mejor rendimiento. Si bien los ejes del presente proyecto fueron el diseño y la fabricación de las redes espantapájaros, los pasos siguientes incluyen evaluar el rendimiento de los nuevos diseños de líneas espantapájaros a la hora de ahuyentar aves marinas del área de calado a popa en los palangreros pequeños.

Développement de lignes de banderoles pour les petits palangriers de Nouvelle-Zélande

RÉSUMÉ

Les lignes de banderoles sont une méthode d'atténuation des captures accessoires d'oiseaux marins largement testée et ayant fait ses preuves sur les palangriers. Toutefois, comme elles ont été initialement conçues pour des navires plus gros, l'utilisation de lignes de banderoles sur de petits palangriers peut s'avérer difficile. Le présent rapport fait état d'un projet néo-zélandais visant à développer des lignes de banderoles spécialement optimisées pour une utilisation sûre et efficace sur les petits palangriers. Nous avons collaboré avec les exploitants de quatre navires d'une longueur totale de moins de 28 mètres afin de concevoir et de tester des lignes de banderoles et de rendre compte de leurs performances. La catégorie des petits navires de pêche a été définie en fonction de la vitesse de prise et des caractéristiques des navires (notamment en termes de possibilités de fixation des lignes de banderoles) et a permis de définir la conception des lignes. Par ailleurs, différents types de lignes ont dû être créés pour les palangriers de fond et les palangriers de surface, car les engins de pêche de ces derniers restent proches de la surface pour conserver une large distance à l'arrière (augmentant ainsi le risque d'emmêler les engins de pêche dans les lignes de banderoles). De nouveaux matériaux de fabrication ont été testés au cours du projet, notamment pour les poteaux de déploiement, les banderoles et les segments terminaux utilisés pour la création d'une trainée. De plus, des jonctions plus faibles ont été conçues et intégrées aux lignes de banderoles, dans l'éventualité où ces dernières se prendraient dans les engins de pêche. La performance des lignes de banderoles a été déterminée principalement en fonction de l'ampleur aérienne de chaque type de ligne, de la réaction des banderoles, de leur efficacité de suivi et de la perturbation créée à la surface de l'eau en bout de ligne. Les différents types de lignes ont été classés selon leur hauteur de déploiement, la conception de leur trainée et la configuration des banderoles. Les conceptions ayant révélé les meilleures performances au cours du projet sont décrites dans le présent rapport. Bien que ce projet avait pour but de se concentrer sur la conception et la fabrication des lignes de banderoles, il s'attachera à l'avenir à évaluer la capacité de ces nouvelles lignes à dissuader les oiseaux marins de s'approcher des filets situés à l'arrière des petits palangriers.

1. INTRODUCTION

Amongst New Zealand fisheries, small vessel longline fisheries have been identified as presenting particularly high risks to some seabird populations due to incidental captures, and associated uncertainties in capture estimation (Richard and Abraham 2013). A suite of tested and effective mitigation strategies provides a strong foundation for the deployment of bycatch reduction measures on small longline vessels (e.g., Bull 2007, Løkkeborg 2011). However, variation amongst vessels (e.g., in vessel design) and in the characteristics of fishing operations (e.g., setting speed), is such that to ensure efficacy, mitigation measures must be tailored to individual vessels and gear deployed. In recent years, mitigation strategies used on smaller longline vessels (< 28 m in overall length) have been characterised and refined (Goad et al. 2010, Goad 2011, Pierre et al. 2013, Pierre et al. 2014a, 2014b). These studies show that the efficacy and safety of mitigation strategies may often be improved through amending the particular design and implementation of measures used, including on a vessel by vessel basis.

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, 2009). Despite the efficacy of this mitigation measure, ongoing controversy around the costs and benefits of tori line usage exists in some New Zealand fisheries, particularly amongst the operators of smaller vessels. Both crew safety and the efficacy of tori lines in reducing seabird interactions with fishing gear are cited as concerns amongst operators (e.g., Goad et al. 2010, Goad 2011; J. Cleal and D.G. Goad, pers. comm.).

To contribute to the resolution of these issues, this project explores tori line design and implementation for smaller-vessel longline fisheries. The overall objective of the project is to develop improved tori lines which are specifically optimised for safe and effective use on small longline vessels (CSP 2014).

The outputs of the project will include (CSP 2014):

1. The design and construction of one or more tori line designs,
2. Documentation of the design, testing methodology and results in terms of mitigation effectiveness, crew safety, resilience to weather and ease of use, and,
3. A resource factsheet on optimal designs.

Both demersal and pelagic longliners are in-scope for this project. The vessels to be included are those < 28 m in overall length from which hand-baited gear is set manually and, for demersal longliners, some day-setting occurs.

2. METHODS

This project commenced with a planning workshop, which was followed by testing of tori line components on land. Subsequently, a series of at-sea trials was initiated. At-sea work is still underway, with project completion planned for mid-2016.

2.1. Workshop

The project commenced with a workshop to:

1. Identify potential issues relating to the use of tori lines on smaller longline vessels, in terms of tori line performance, barriers to implementation, and safety,
2. Pull together ideas on effective construction and design for small-vessel tori lines that are considered likely to address these issues, and,
3. Identify next steps, including an at-sea programme, to develop an effective tori line design for smaller-vessel bottom longline fisheries.

The workshop group concluded that the most challenging element of tori line design, and also the most critical to ensuring tori line efficacy, was the attachment of the tori line to the vessel. The attachment determines the height from which the tori line is deployed. It also affects the practicality of the tori line from an operational perspective (i.e., the ease with which the tori line is deployed and retrieved). Therefore, if a structurally robust and operationally practical attachment method cannot be achieved, tori lines are unlikely to be used. Further, if the attachment does not elevate the tori line sufficiently, the efficacy of the tori line will be compromised.

On reviewing vessel characteristics and operational factors relating to tori line performance, setting speed and the physical structure of vessels were identified as most important. Past work on smaller inshore vessels highlighted wide ranges in setting speed across target species and vessel lengths. For example, setting speeds of 2.2 – 5 knots have been documented on vessels targeting snapper, 1.8 – 5.1 knots on vessels targeting bluenose and 2.6 – 4.1 knots on vessels targeting ling (Goad et al. 2010, Goad 2011, Pierre et al. 2013). Therefore, target species was not especially useful to characterise vessels for further work. Instead, developing tori lines that work at a range of setting speeds, irrespective of target, is appropriate.

Further, a perusal of the physical characteristics of vessels demonstrated that amongst inshore bottom longliners, there are essentially four broad structural categories of vessels for which tori lines must be tailored. Key vessel characteristics relate to the options for attaching and elevating tori lines. Categories of bottom longline vessels identified for further work were:

1. Very small vessels (i.e., around 8 m or less in length) with a wheelhouse but no other significant superstructure: These vessels will be the most challenging in terms of tori line development, given their low height above water and minimal options for tori line attachment (Figure 1).
2. Vessels around 9 – 12 m in length with some metalwork above the deck: This category comprises the majority of small bottom longline vessels. The shelter deck may have a hard (fibreglass or metal) or soft (canvas) roof (Figure 2). The structural supports for the shelter deck provide opportunities for robust tori line attachment, e.g., through bolting davits from which tori lines are deployed onto metal struts.

3. Vessels around 12 – 15 m in length that were formerly trawlers but have been converted for longlining: These vessels are the most straightforward to deploy tori lines from. This is because they have some residual gantry metalwork in place, which is robust and can be used to elevate and support tori lines (Figure 3).
4. Vessels that are 15 – 20 m in length and fish using both the bottom and surface longline methods: These vessels have metalwork around the stern that can be used to attach and elevate tori lines (Figure 4). The deck layout at the stern may differ significantly between vessels, but all offer a number of potential options for tori line attachment.

Figure 1. A small bottom longline vessel that is low to the water and has minimal deck structure at the stern for the robust attachment and effective elevation of a tori line. Photo: D. Goad.

Figure 2. An example of a “typical” small bottom longline vessel, i.e., vessels 12-15 m in length with a shelter deck and some metalwork close to the stern. Photo: D. Goad.

Figure 3. A former trawler that has been converted for inshore bottom longlining. The residual gantry metalwork in place provides many options for the attachment of tori lines. Photo: D. Goad.

Figure 4. A vessel that fishes using both the bottom and surface longline methods, with metal shelter deck supports and a float cage near the stern. Photo: D. Goad.

With the vessel groupings in mind, the project team moved on to identifying tori line designs that could be implemented on each of the four identified vessel types. This process comprised both on-land and at-sea testing.

2.2 On-land testing

On land, our objective was to investigate the performance of the aerial sections of tori lines at a range of deployment heights and using different construction materials and designs. We used three deployment heights (5 m, 7 m and 9 m, achieved by using interlocked fibreglass poles in 3-m sections), three backbone materials (3 mm diameter Dyneema rope, 3 mm monofilament nylon, 3.1 mm Ashaway albacore braid), two streamer configurations of equal weight (single streamers of Kraton or double 10 mm trawl braid streamers every 2.5 m and every 5 m), and examined the effects of adding variable numbers of shark clips (often used to attach streamers) to the tori line backbone (Table 1). Fibreglass poles were chosen due to their strength and lightweight characteristics. A 42 mm external diameter pole was chosen for the testing. This had a wall thickness of 2.5 mm. The base of the pole was held inside a 1 m steel tube, with 500mm of the pole inserted into the tube. When testing deployment heights of 7 m and 9 m, a rope loop was added to provide extra support for the pole. This was tied loosely to a support strut behind the tori pole at approximately 5 m height.

With each different tori line design and deployment configuration, we used a set of Salter spring scales to record the drag required to maintain the aerial extent of the test tori line at 40 m, and thereafter at 10 m intervals up to 80 m. We also tested the drag that the support poles and a standard 4.7 m game fishing outrigger pole (which had a lighter wall thickness and tapered from 45 to 22 mm outside diameter) could sustain before bending to close to breaking point.

Table 1. Preliminary testing conducted to determine the drag required to achieve aerial extents of 40 m, 50 m, 60 m, 70 m, and 80 m, given a range of tori line designs and construction materials.

Deployment height	Backbone material	Streamer configuration
5 m	Dyneema (3 mm)	Every 5.0 m
	Monofilament (3 mm)	Every 5.0 m
	Ashaway albacore braid (3.1 mm)	Every 5.0 m
7 m	Dyneema (3 mm)	Every 5.0 m
	Monofilament (3 mm)	Every 5.0 m
	Ashaway albacore braid (3.1 mm)	Every 5.0 m
9 m	Dyneema (3 mm)	Every 5.0 m
	Monofilament (3 mm)	Every 5.0 m
	Ashaway albacore braid (3.1 mm)	Every 5.0 m
Additional designs tested:		
7 m	Dyneema (3 mm)	Every 2.5
		Every 5 m + 10 shark clips
		Every 2.5 m + 10 shark clips
		Every 2.5 m + 17 shark clips

2.3 At-sea trials

2.3.1. Drag testing

Having completed on-land testing, the in-water elements of the tori line (the ‘drag section’) were explored in calm sea conditions (Table 2). The focus of this testing was on the drag produced in-water by a range of materials and designs. Therefore, deployment height was removed as a factor during this testing. The trial drag sections were deployed from the vessel attached to a rope. The drag sections were immersed entirely, and the separate rope was maintained in the air and towed from approximately 1.5 m above the vessel stern. This provided consistency for comparing the drag achieved by the different designs tested. Drag was measured at the vessel, using either of two sets of spring scales at the vessel end of the rope attached to the trial drag section. Drag at 2.6 knots, 4.2 knots, and 6.5 knots was recorded; these speeds reflect the range of setting speeds of longline vessels, and were chosen to be easily reproduced at sea using the engine revolutions as a guide.

Dimensions and images of materials used for drag testing are shown in Table 3. Drag objects included some that generated splash in the water, as well as objects that did not. While not empirically tested, the disturbance of the water surface is considered by some practitioners to be an effective method for distracting seabirds away from risk areas. All materials used in drag testing are commercially available except the flutterboard. This device was created by Brian Kiddie, a fisher based in Tauranga, New Zealand, for use as a bird deterrent astern his own bottom longline vessel.

Table 2. Preliminary testing conducted to determine the drag delivered by different materials that could comprise the in-water section of a tori line.

Design #	Rope	Road cone	Gillnet floats	Funnels	Flutterboard	Configuration
1	50 m					
2	50 m	1 large				Rope with cone at terminal end
3	50 m	1 small				
4	2 x 25 m	3 small				1 cone – 25 m rope – 1 cone – 25 m rope – 1 cone
5	2 x 25 m		10 small			25 m rope then second 25 m length with floats 2.5 m apart
6	50 m		20 small			Rope with floats evenly spaced
7	2 x 25 m		10 small			25 m rope then second 25 m length with floats 2.5 m apart
8	50 m		20 large			Rope with floats evenly spaced
9	2 x 25 m			10 small		25 m rope then second 25 m length with funnels 2.5 m apart
10	2 x 25 m			10 medium		
11	2 x 25 m			10 large		
12	2 x 25 m			10 small, 10 large		25 m rope with 10 small funnels 2.5 m apart, then 25 m rope with 10 large funnels 2.5 m apart
13	2 x 25 m				3 small	1 flutter board – 25 m rope – 1 flutterboard – 25 m rope – 1 flutterboard
14	50 m				1 small	Rope with flutterboard at terminal end
15	25 m			10 small		Rope with funnels together at terminal end
16	2 x 25 m	2 small 1 large	30 small			1 small cone – 25 m rope with 10 small equally spaced floats – 1 small cone – 25 m rope with 10 small equally spaced floats – 1 large cone

Table 3. Construction materials used during in-water drag testing conducted in coastal waters.

Material	Cost (each or per m, NZD)	Dimensions	Image
Rope	$0.46	Trawl braid (10 mm)	
Small road cone	$21	300 mm long, 210 x 210 mm base	
Large road cone	$34	440 mm long, 280 x 280 mm base	
Small gillnet floats	$1	80 mm long, 50 mm maximum diameter	
Large gillnet floats	$1.40	92 mm long, 59 mm maximum diameter	
Small funnel	$3	105 mm long, 75 mm maximum diameter	
Medium funnel	$3	140 mm long, 96 maximum diameter	
Large funnel	$3	150 mm long, 115 maximum diameter	
Small flutterboard	$60	670 mm long, 200 m wide, 40 mm deep	

2.3.2. Tori line designs for small longline vessels

A series of at-sea tests is now underway to refine the designs of tori lines for smaller longline fishing vessels. Testing will be conducted on three vessels, at speeds of 2 – 7 knots. For each test, the drag of the in-water section of each the tori line will be determined for three target speeds, then the aerial extent of the tori line will also be recorded. Where weather permits, tracking of tori lines in wind is also of interest.

Detailed methods will be documented in final project reporting.

3. RESULTS

3.1 On-land testing

3.1.1 Deployment height

The drag required to achieve tori line aerial extent decreased with increasing deployment height (Figure 5). Across all treatments tested, the maximum drag required to deliver 80 m of aerial extent was 16.5 kg, for a monofilament backbone.

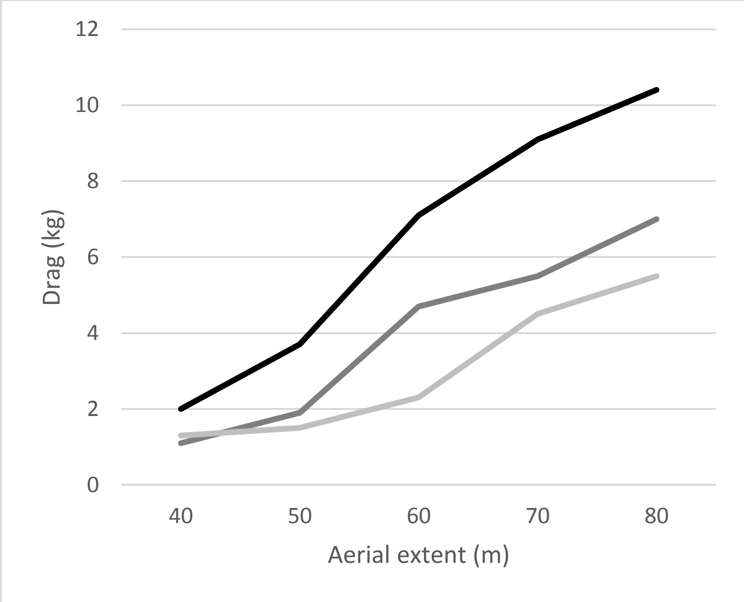

Figure 5. Drag required to achieve tori line aerial extents of 40 m – 80 m at deployment heights of 5 m (black), 7 m (dark grey) and 9 m (light grey), when 3 mm Dyneema backbone was used with streamers placed every 5 m along the line.

The fibreglass poles used to suspend tori lines tested flexed as increasing drag was applied to achieve increasing aerial extents (Figure 6). The rope loop used to support the tori pole at the 7 m and 9 m deployment heights was effective. That is, when the pole flexed, it did so above this loop. Poles effectively sustained the drag required to deliver aerial extents of 80 m. One pole broke when 30 kg of drag was applied to it. This is almost twice the maximum drag required to achieve an 80 m aerial extent for any of the designs tested.

Following this part of the project work, we revisited the pole design with the manufacturer and developed a stronger more rigid pole (with thicker walls) for at-sea testing.

Figure 6. A tori pole under 20 kg of drag - more than was ever required to achieve an aerial extent of 80 m during the on-land trials.

Tori poles were more difficult to handle when tori lines were attached at 9 m high, and also required support to ameliorate the flexing that occurred as increasing drag was applied. Therefore, we concluded that focusing on a deployment height of 7 m deck was most appropriate where:

- the tori pole is to be attached at deck level and there is an opportunity to add support for it, and,
- the pole is to be attached at or close to the vessel stern.

Using our previously identified functional groupings of bottom longline vessels (Figures 1-4), 7 m would be the preferred deployment height for groups 2, 3 or 4.

Where the tori pole cannot be attached at the stern or further forward on the vessel, the lack of support available for tori poles limits the possibilities for achieving a deployment height of 7 m above the stern. Therefore, we consider that tori line designs delivering deployment heights of 5 m are more achievable for these vessels. This situation encompasses vessel group 1. These tori lines will require more drag to achieve a target aerial extent than tori lines deployed from 7 m.

Note that these deployment heights refer to the height above the deck. The vertical distance from the sea surface to the vessel deck will increase the actual tori line height further. For small longline vessels, the difference between deployment height above deck and height above sea level is likely to be around 1-1.5 m.

3.1.2 Backbone material

Of the three materials tested, monofilament sagged and stretched the most, and therefore also required the largest drag weights to achieve aerial extents of 40 m – 80 m (Figure 7). From an operational perspective, this sagging will result in the tori line providing less consistent protection over the mainline in less favourable weather conditions. Further, the increased stretch has safety implications in that if the tori line broke, the energy held by the monofilament would exacerbate the potential for fly-back towards the vessel.

The performance of Ashaway albacore braid and Dyneema was more similar. However, Ashaway stretched more than Dyneema. Dyneema is also an extremely durable material, which is expected to have benefits in terms of tori line durability. Therefore, for bottom longline vessels, our preference was to carry the Dyneema backbone forward into at-sea testing.

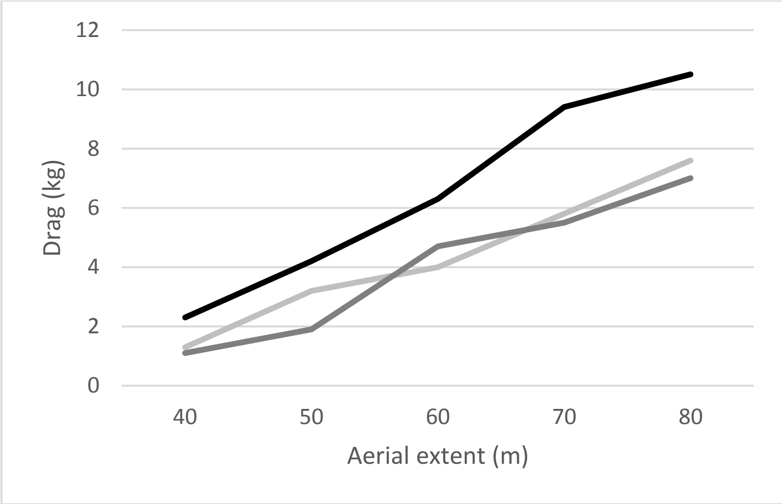

Figure 7. Drag required to achieve tori line aerial extents of 40 m – 80 m using three different backbone materials: monofilament (black), Dyneema (dark grey), Ashaway albacore braid (light grey) at a deployment height of 7 m.

3.1.3 Streamer configuration

Streamers add significant weight to the tori line backbone. This in turn increases the drag required to maintain aerial extent and minimise sagging. While more frequently spaced streamers may increase the efficacy of tori lines as a seabird deterrent, the streamers will also increase the weight of the line (and therefore require more drag to be added to maintain aerial extent). We used streamers of equivalent weight to single 9 mm Kraton® tubing in these trials, and note the effects of placing streamers at 2.5 m spacings compared to 5 m spacings (Figure 8).

In terms of the additional drag required, the effects of adding streamers to tori line backbones was much greater than when shark clips were added (Figure 8). Both Dyneema and Ashaway albacore braid are non-twist materials, reducing or eliminating some of the benefits of attaching streamers to the tori line backbone using shark clips. However, where skippers and crew find shark clips convenient for attaching streamers, this is not problematic in that the weight these add to the tori line designs tested had little effect on drag requirements.

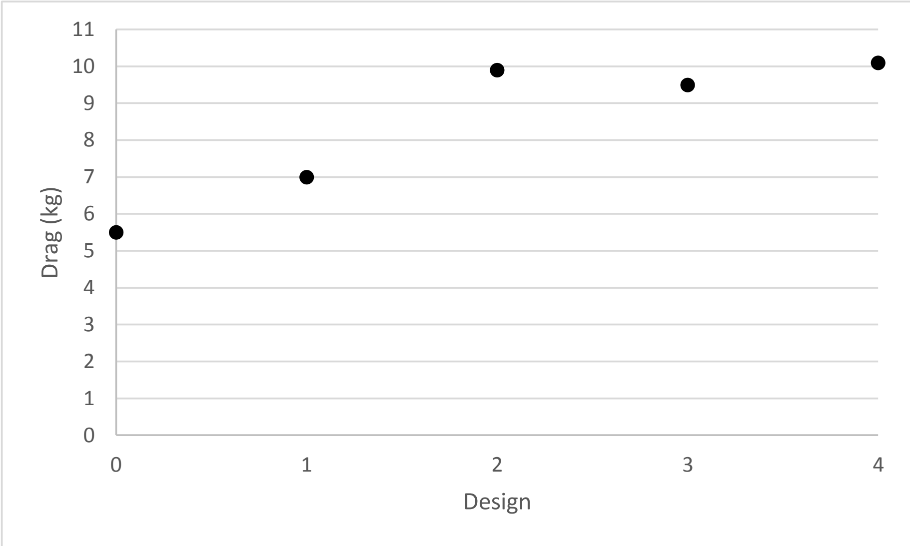

Figure 8. Drag required to provide 70 m aerial extent for a tori line with a 3 mm Dyneema backbone deployed at 7 m high, with different combinations of streamers and shark clips attached. Design 0: streamers at 5 m intervals; 1: streamers at 5 m intervals and 10 shark clips attached; 2: streamers at 2.5 m intervals with no shark clips; 3: streamers at 2.5 m with 10 shark clips; 4: streamers at 2.5 m with 17 shark clips.

3.2 At-sea trials

3.1.1. Preliminary drag testing

Drag delivered across the 16 configurations of in-water sections varied from approximately 1 kg to a maximum of 20 kg. Predictably, increasing vessel speed increased the drag provided by each design of in-water section tested (Figure 9). Funnels provided the most splash, with splashing decreasing commensurately with tow speed. Large funnels provided less consistent drag than smaller funnels, as they tended to skip over the water.

The drag produced by most of the in-water sections tested was substantially less than the drag required in the on-land tests to achieve aerial extents of 80 m, particularly at slower speeds. Therefore, for further at-sea trials, we have focused on in-water sections designed to produce significantly more drag.

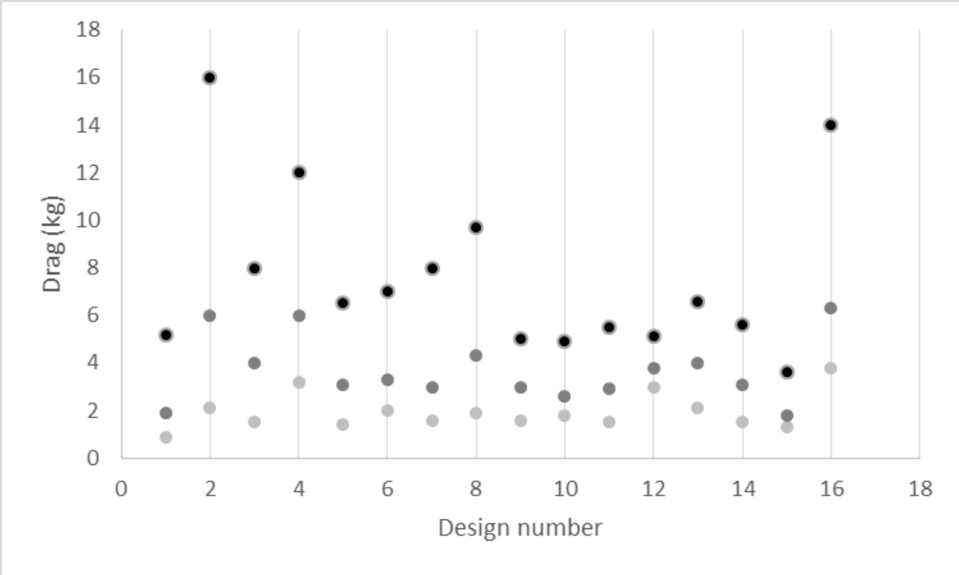

Figure 9. Drag generated from an in-water section of rope with various objects attached, at approximately 2.6 knots (light grey), 4.2 knots (dark grey dots) and 6.5 knots (black dots). Configurations of the in-water section are described in Table 2.

3.1.2. Tori line designs for small longline vessels

To balance tori line weight and seabird protection, we initiated at-sea trials with single streamers spaced at 3.5 m intervals, and used narrower streamers than in these preliminary trials (6-mm diameter compared to 9 mm diameter). Narrower streamers have the added benefit of reducing tori line windage, and therefore facilitating more effective tracking of the mainline by the tori line.

At-sea testing of tori line designs for small longline vessels is still underway. To date, trial designs have been developed that produce aerial extents of around 55 – 60 m at 3.5 knots, 70 m at 5 knots, and up to 90 m at 7 knots, from deployment heights of 7 m above the sea surface. The amount of splash generated varies with different in-water sections, as expected.

For both demersal and pelagic longliners, mitigating the likelihood of gear getting caught in tori line streamers and/or backbones by using a spacing section of monofilament is under further investigation. This concept was well-received by skippers and crew as it provides more distance astern for gear to sink below the sea surface. In addition, the monofilament section contributes some drag to the tori line design.

Design components that we consider safe and practical for deployment on small longline vessels include the following:

5. Backbone: The 3 mm Dyneema backbone performs well. This material floats on water, does not twist, does not stretch, and comes in a variety of colours. Tubular streamers, such as of narrow-diameter Kraton® or Kraton®-like materials can also be threaded over the backbone to increase its visibility, if needed.
6. Streamers: Single streamers spaced at 3.5 m intervals and made of bright orange Kraton®-like material have worked well during testing conducted to date. These are lighter in weight than larger-diameter streamers and also provide less windage given their relatively narrow diameter. However, their stiffness means that tangling has not (yet) been an issue. Spacing single

streamers at 3.5 m rather than double streamers at 5 m optimises tori line weight, streamer coverage and some level of redundancy should a streamer be lost or damaged. To reduce the likelihood of gear hooking up on streamers during setting, the first 3 streamers in our test tori lines are slightly shorter (ending above the sea surface) whereas subsequent streamers went right to the sea surface. Incorporating short 'flashy' streamer components that move around unpredictably and create rustling noises is planned for future work. Some fishers consider that these design components add significantly the tori line's deterrent effect.

7. Mounting pole: Progressing from the findings of our initial on-land tests, the second (stronger) pole design supported drag of up to 26 kg without bending. (This is the maximum drag produced to date during at-sea testing). This pole is expected to be well-suited to small vessel deployments. It can be relatively easily attached (e.g. to uprights of vessel railings using large-diameter hose clamps and solid pipes). A rope support can also be attached high up on the pole back to the vessel, if desired. Production costs of this unit are to be determined and will be included in final reporting. However, its durability means that purchase price should be effectively offset by the lifespan of the pole.
8. Weak link: Incorporating one or two weak links (i) between the in-water drag section of the tori line and the aerial section, and (ii) at the mounting pole where the backbone attaches, is recommended. This is for safety as when a tangle occurs between the tori line and the gear, the weak link will give way but the tori line will not be lost. During this project, we have considered several kinds of weak links. At its simplest, a weak link could comprise a loop of rope with a lower breaking strain than the Dyneema backbone and drag section, and the longline backbone.
9. Storage: Two options for storage have been identified. Often tori lines in use on vessels are stored in large drums or on reels. Either storage approach is simple and works well, keeping the tori line out of the way and facilitating deployment and retrieval. The drum option is also extremely economical.

Work remaining on this project will focus on refining the in-water or drag sections, as below.

Detailed results including recommended designs will be reported in full once work is complete.

4. NEXT STEPS

To date in this project, we have identified tori line designs that produce satisfactory aerial extent at vessel speeds of 5 knots and above. We are conducting further work focusing on slower setting speeds, for which creating drag sufficient to maintain aerial extent is more challenging.

Final reporting will include recommended designs for small-vessel longliners setting across the range of speeds from 2 knots to 7 knots, and will also include costings required to construct these designs.

Next steps from there involve testing the efficacy of the new designs in deterring seabirds from attending small longline vessels.

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