# Warp strike mitigation devices in use on trawlers $\geq$ 28 m in length operating in New Zealand fisheries

## Draft Final Report: At-sea trials and analysis

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John Cleal, F.V. Management Services Ltd, P.O. Box 1279, Nelson, New Zealand, john.fvms@xtra.co.nz

Johanna P. Pierre, JPEC Ltd, P.O. Box 35122, Lower Hutt, New Zealand 5041, johanna@jpec.co.nz

George Clement, Clement and Associates Ltd, P.O. Box 1460, Nelson, New Zealand,

clement@fishinfo.co.nz


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## Abstract

The use of devices that aim to reduce seabird strikes on trawl warps has been required on New Zealand trawlers $\geq$ 28 m in overall length since April 2006. Seabirds may strike, or be struck by trawl warps while feeding opportunistically astern trawl vessels. These strikes can cause injury or death. We examined two of the three legally-specified seabird scaring devices - paired streamer lines and bird bafflers - with the aim of improving their design, construction, durability, and ultimately performance and efficacy at sea. For bafflers, we also sought to use existing data to compare the efficacy of 2- and 4-boom designs. At-sea trials of streamer line materials were conducted on a deepwater trawler 105 m in length, using midwater gear. These trials produced clear recommendations on streamer line materials and construction. Of the four tested, the best-performing streamer material was Kraton. The optimal configuration for streamers involved direct attachment (i.e., interweaving streamers into the backbone and not using clips or swivels) at 3 m intervals along the backbone of the streamer line. The best-performing terminal object of the five tested was a trawl float 360 mm diameter and 9.1 kg in weight. This could be replaced by a 6.5 kg trawl float of the same diameter on vessels with lower block height. Deploying a terminal object of 1.2 kg for every 1 m of vessel block height is recommended. Amongst the 30 – 60 m lengths tested, a backbone of 30 m almost always performed best. Deploying 5 m of backbone for every 1 m of vessel block height is recommended. These recommended design specifications have been captured in a fact sheet, and promulgated amongst the deepwater trawl fleet. For bafflers, a step analysis showed that processing waste discharge is consistently more important in determining the prevalence of trawl warp strikes than whether these devices comprised two or four booms. However, the data available were insufficient to support more in-depth modelling. Drawing on the design, construction and performance features of bafflers currently deployed in the fleet, an improved baffler design is proposed. Further work

comparing the performance of bafflers of different designs quantitatively is also recommended.

**Key words**

Streamer lines, bird baffler, trawl fisheries, mitigation, seabird scaring devices

## Introduction

From April 2006, the use of devices aimed at reducing the incidental capture of seabirds has been required in New Zealand fisheries waters, for trawl vessels $\geq$ 28 m in overall length (New Zealand Gazette No. 33, 6 April 2006). The devices required are intended to reduce seabird deaths caused by warp strikes, which occur in trawl fisheries worldwide (Bull 2007). The 2006 Gazette notice required the use of one of three devices by such vessels: paired streamer lines, a bird baffler, or a warp deflector. In March 2010, the Gazette notice was updated on points of clarification (New Zealand Gazette No. 29, 11 March 2010, Appendix 1), and the requirement to use one of these three devices was maintained.

The gazetted specifications for the required devices are somewhat flexible in New Zealand, and convey minimum standards. Within these standards, operators are able to select the materials to be used and make design variations for each device type. This provides scope for innovation. In addition, the flexibility in specifications allows for operators to customise devices to best fit vessels, which is important due to the diversity of vessel sizes, classes, and characteristics (e.g., variable block heights) across the deepwater trawl fleet. However, this approach also introduces the possibility of variable efficacy amongst devices, as well as differences in quality, practicality, durability, and cost effectiveness.

The two devices used by most trawlers $\geq$ 28 m that are operating in New Zealand waters are streamer lines and bird bafflers. Streamer lines are demonstrably more effective than 4-boom bafflers at reducing seabird strikes on trawl warps (Middleton & Abraham 2007, Bull 2007, 2009). However, their performance can be compromised in bad weather conditions due to the lines blowing away from the trawl warp and consequently leaving it exposed to seabirds. Other issues affecting the usage and performance of streamer lines include the ease of deploying and retrieving the lines, fading colours of streamer materials, tangling, and structural failure of the materials currently in use. In contrast, bafflers may be more durable than streamer lines in common usage. Bafflers are also preferred by crews due to their ‘set-and-forget’ nature.

While experimental testing has compared the efficacy of the streamer lines and 4-boom bafflers in two locations (New Zealand and the Falkland Islands), the efficacy of 2-boom bafflers is unknown. Further, for 2- and 4-boom arrangements, legal specifications can be met while affording minimal, if any, protection to trawl warps. The efficacy of the ‘Burka baffler’ is also unknown (Bull 2009). This design meets the legal requirements for bafflers while providing better coverage of trawl warps than other designs currently in use.

Initial work for this project (described in Cleal and Pierre 2012) included a workshop with industry and an examination of the materials and designs of gazetted mitigation devices in the deepwater trawl fleet ($\geq$ 28 m). Recommendations emerging from this work were, for paired streamer lines (PSLs):

- Investigate deployment and retrieval systems that improve on manual techniques currently employed,
- Investigate alternative streamer materials to increase durability and colour-fastness, and reduce tangling, and
- Trial alternative terminal objects to improve the aerial extent and tracking of PSLs over trawl warps.

Recommendations for further work on bafflers included the following:

- Using information collected to date by observers, compare warp strike rates on 2- and 4-boom bafflers,
- If sufficient information is available, compare warp strike rates during deployment of the Burka baffler, compared to a regular 4-boom baffler, and

- Trial webbing and dropper materials that may reduce tangling and damage on contact with the trawl warps.

This report focuses on work undertaken to address these recommendations. We describe at-sea testing undertaken to improve the performance of streamer (also known as tori) lines, including trials of a variety of construction materials, and dimensions and configurations of streamer line components. We also utilise the data available to investigate the efficacy of 2- versus 4-boom bird bafflers used in New Zealand trawl fisheries. Finally, we make recommendations for improvements in baffler design and construction, as well as for the quantitative assessment of the performance of bafflers of various configurations, to ascertain their efficacy in reducing seabird strikes on trawl warps.

## Methods

### Streamer lines

*Deployment and retrieval systems*

Current deployment operations were reviewed on vessels currently using streamer lines, with a focus on where these are the primary mitigation device in place. Key performance attributes required from deployment systems were identified, including a less labour-intensive approach. Searches for products meeting the necessary requirements were undertaken, for example, using internet sources and through discussions with fishing and farming gear suppliers.

*At-sea trials of streamer materials*

A series of at-sea trials testing streamer lines of different configurations was executed from 2 – 15 August 2012, on a trawler 105 m in length operating in the hoki (*Macruronus novaezelandiae*) fishery. Bafflers were also in place on the experimental vessel at all times, to ensure compliance with legal requirements for the deployment of seabird scaring devices (see above, Appendix 1). This vessel fishes using midwater gear in both midwater and bottom fisheries. The headline length and ground rope length of the net are 128 m and 116 m, respectively. The fishing circumference is 728 m and the headline height of the net mouth is approximately 75 m. Fishing effort occurs in relatively shallower waters. This means that the warp angle is also relatively shallow and the amount of exposed warp is longer than for vessels bottom fishing in deep water. Streamer line configurations for testing were identified prior to going to sea. An experienced observer executed trials and recorded his observations on a form (Appendix 2), as well as using still photos and video. Observations were largely qualitative in nature, and were based on comparisons of pairs of streamer lines astern the experimental vessel. (Thus, the efficacy of streamer lines in reducing seabird strikes on trawl warps was not quantified *per se*). Trials involved affixing an 'experimental' streamer line to the starboard stern quarter and a 'control' streamer line to the port stern quarter. Initially, the control streamer line was the vessel's own line, similar to streamer lines used on deepwater trawlers operating in New Zealand waters, with PVC streamers 4.5 m apart and with a pink windy buoy as the terminal object. After all experimental lines had been compared against the vessel's own line, pairs of 'experimental' streamer lines were compared with each other. This included switching lines between the port and starboard quarters, to facilitate comparisons of lines in potential cross winds. Table 1 describes the streamer lines tested and the pairs of experimental and control lines deployed. Both port and starboard lines were deployed from the same height and position above and outside the warps for each trial. Each line was fitted 2.5 m outside the port side and 1 m above the trawl block (and over the trawl warp). The block height on the vessel serving as the experimental platform was 7.5 m above the sea surface.

The effects of three components of streamer lines (streamers, terminal objects, and backbones) on line performance were compared between lines of differing construction. The materials tested were as follows:

*Streamers:*

Streamers were placed at intervals of 3 m or 5 m on streamer line backbones. Four streamer materials were included in the trials.

1. **Luminous tubing (Figure 1a)**: This tubing is the material most often used to construct trawler tori lines currently. Its original application is to protect nylon traces on longlines from abrasion and being bitten by fish. The luminosity is thought to attract fish at depth. The material is soft, pliable, lightweight, and very thin. It measures 4.2 mm outside diameter and 2.5 mm inside diameter. The initially brightly-coloured material fades to light grey within approximately one to two weeks of being deployed on a streamer line (Figure 2).
2. **Kraton (Figure 1b):** Kraton is the trade name given to a number of high performance elastomers manufactured by Kraton Polymers and used as synthetic replacements for rubber. Kraton polymers offer many of the properties of natural rubber, such as flexibility and high traction, but with increased resistance to heat, weathering, and chemicals. When UV-treated, Kraton is reported by the manufacturer to hold its colour for many years. This material is currently used for streamers on streamer lines that are used in the United States (including Alaska) by deepwater fishing vessels. It is bright blaze orange in colour. The material used in these trials was 10 mm in outside diameter and 7 mm inside diameter. (Kraton was imported from Oregon for these trials).

3. **Thermoplastic Polyurethane (TPU) (Figure 1c):** TPU is extremely flexible tubing with good resistance to chemicals, abrasion and ageing. TPU is widely used in instrument controls, such as pressure gauges. The material is a harder (and therefore less flexible) plastic compared to rubber and Kraton. It is red, 8 mm in outside diameter and 5 mm in inside diameter. Thermoplastic was difficult to source locally. TPU is the same material as recommended for PSL streamers in the Falkland Islands. There, a brand called 'Mazzerpur' has been recommended, but this proved to be difficult to source.
4. **Polyvinyl Chloride (PVC) (Figure 1d):** PVC is often used in construction because it is cheaper and stronger than more traditional alternatives such as copper or ductile iron and it can be made softer and more flexible by the addition of plasticizers (e.g. phthalates). In this form it is used in a wide range of materials such as clothing and upholstery, electrical cable insulation, inflatable products and many applications in which it replaces rubber. This material is available in New Zealand, is sold as streamer material, and is used by some longliners. It is red or yellow in colour and has an outside diameter of 7.5 mm and an inside diameter of 3.5 mm.

*Terminal objects:*

Five types of terminal objects were investigated.

1. **Windy buoy** or 'pinkie' covered by a mesh sock (Figure 3a): These buoys are readily commercially available. The pinkie weighs 5.2 kg, and is soft plastic.
2. **200 mm-diameter trawl float** (Figure 3b): These floats are hard plastic with a hole through the centre and weigh 2.0 kg. Either two or three 200 mm floats were used, joined in series on 5 m of rope. The weight of three 200 mm floats and the rope was 5.3 kg.

3. **360 mm-diameter trawl float** (Figure 3c): This is a hard plastic double lug deep sea trawl float intended for use to depths of 1,200 m. This float weighs 9.1 kg, is green in colour, and was covered by a mesh sock.
4. **Mooring Rope** (Figure 3d): Two configurations of mooring rope were tested. One configuration involved a 10 m length of mooring rope that weighed 9.6 kg. The second configuration required two 10 m lengths of mooring rope, which weighed 19 kg.
5. **Road cone** (Figure 3e): A 200 mm trawl float was inserted inside a road cone, and this terminal object weighed 5.3 kg.

*Backbones:*

Four backbone lengths were investigated. These were 30 m, 40 m, 50 m and 60 m. The 30 m, 40 m and 60 m backbones were yellow in colour, while the 50 m backbone (the 'control' line) was blue-green. All backbones were Danline of 9 mm diameter and had clamps with swivel clips fitted at set intervals.

Table 1. Streamer line trials conducted. The components of lines are listed in consistent order: streamer material, distance between streamers, length of backbone, type of terminal object. Trials were conducted for one trawl tow, except for those marked *, which were implemented over 2 – 3 days.

| Trial number | Experimental line Starboard stern quarter | Control line Port stern quarter |
|---|---|---|
| 1 | Kraton streamers 3 m apart, 40 m backbone, 360 mm trawl float | Vessel's own |
| 2 | Kraton streamers 5 m apart, 40 m backbone, 10 m mooring line | Vessel's own |
| 3 | Thermoplastic streamers 3 m apart, 40 m backbone, pink windy buoy | Vessel's own |
| 4 | Thermoplastic streamers 3 m apart, 40 m backbone, 2 x 200 mm floats | Vessel's own |
| 5 | PVC streamers 5 m apart, 40 m backbone, 1 x 10 m mooring line | Vessel's own |
| 6 | PVC streamers 5 m apart, 40 m backbone, 2 x 10 m mooring line | Vessel's own |
| 7 | PVC streamers 5 m apart, 40 m backbone, 3 x 200 mm trawl floats | Vessel's own |
| 8 | PVC streamers 3 m apart, 30 m backbone, 360 mm trawl float | Vessel's own |
| 9 | Kraton streamers 5 m apart, 30 m backbone, 360 mm trawl float | PVC streamers 5 m apart, 60 m backbone, 360 mm trawl float |
| 10 | PVC streamers 5 m apart, 30 m backbone, 2 x 10 m mooring line | Kraton streamers 3 m apart, 60 m backbone, 360 mm trawl float |
| 11 | Thermoplastic streamers 3 m apart, 40 m backbone, 360 mm trawl float | Kraton streamers 3 m apart, 40 m backbone, 2 x 10 m mooring rope |
| 12 | Kraton streamers 3 m apart, 40 m backbone, road cone with float inside | Thermoplastic streamers 3 m apart, 40 m backbone, 360 mm trawl float |
| 13* | Kraton streamers 3 m apart, 40 m backbone, 360 mm trawl float | Thermoplastic streamers 3 m apart, 40 m backbone, 360 mm trawl float |
| 14* | Kraton streamers 3 m apart, 30 m backbone, 360 mm trawl float | Kraton streamers 3 m apart, 30 m backbone, 360 mm trawl float |
| 15 | Vessel's own | Kraton streamers 3 m apart, |

| | | |
|---|---|---|
| | | 30 m backbone, 360 mm trawl float |
| 16* | PVC streamers 3 m apart,<br>30 m backbone, 360 mm trawl float | Kraton streamers 3 m apart,<br>30 m backbone, 360 mm trawl float |

(a) (b)

(c) (d)

Figure 1. Streamer materials tested at sea: (a) luminous tubing, (b) Kraton, (c) thermoplastic, and (d) PVC. The backbones of the streamer lines are also shown.

Figure 2. The luminous tubing typically used in streamer lines currently deployed on trawlers ≥ 28 m operating in New Zealand waters. Figure 1(a) shows this material when new. Here, the material is shown after 10 days at sea, highlighting the extent of fading that occurs in relatively short timeframes.


(a) (b)


(c) (d)

(e)

Figure 3. Terminal objects tested at sea: (a) Mesh-covered windy buoy or ‘pinkie’, (b) 200 mm-diameter trawl floats, (c) mesh-covered 360 mm-diameter trawl float, (d) mooring rope, and, (e) road cone with internal float.

The observer monitored streamer line performance, assessing a range of characteristics of the experimental lines compared to the control lines, as described in Table 2.

Table 2. Characteristics of streamer lines assessed at sea by the observer. (Those marked * are the focus of this report). Assessments were made visually, initially relative to the control, and then in comparison with other lines tested over time.

| Component | Characteristics assessed |
| --- | --- |
| Streamer line set-up and overall performance | Attachment height (above the sea surface, and above the trawl block sheath) |
| | Distance from the outside edge of the trawl block to the streamer line |
| | Distance from the vessel stern to the first streamer |
| | Distance from vessel stern to where warp enters water |
| | Aerial extent* |
| Streamer materials* | Tangling |
| | Visibility |
| | Breakages |
| Streamer intervals* | 'Curtain' effect generated by streamers that excluded seabirds |
| Terminal objects* | Drag produced |
| | Ease of deployment and retrieval |
| | Efficacy of warp-tracking |
| | Consistency of movement through water |
| Backbone* | Extent of warp coverage achieved |

The observer also recorded weather conditions (wind direction relative to vessel and sea state) during the trials (Appendix 2).

**Bird bafflers**

<u>*Data analysis*</u>

Government fisheries observers have made warp strike observations from trawlers operating in New Zealand fisheries since 2001 and in a structured way since 2004-05. From 2007 onwards, observers also recorded the characteristics of mitigation devices, including the number of booms vessel bafflers comprised.

The Ministry for Primary Industries provided data on seabird warp strikes occurring in the presence of bafflers from the Central Observer Database (COD). We compared the rates of warp strikes between 2- and 4-boom bafflers, and between 4-boom bafflers and the Burka baffler, where these data allowed. When observer data were available, we used those data to identify vessels carrying 2- or 4-boom bafflers. For observation periods conducted prior to 2007, we assigned vessels either 2- or 4-boom bafflers using industry records. When both industry records and observer data were available, these two data sources were consistent with respect to the numbers of baffler booms present on vessels.

Seabirds were categorised as 'large' or 'small' in warp strike observations. Large birds were albatrosses (*Thalassarche* spp., *Diomedea* spp.) and giant petrels (*Macronectes* spp.). Small birds were all other seabirds. We included covariates that may affect warp strikes in analyses. Covariates included seabird abundance astern vessels (categorised as 'large' or 'small' seabirds, in the air or on the water, in a 40 m x 40 m area centred on the point at which the warp entered the water, and recorded as a range or a number), weather conditions (wind speed and direction, swell height and direction), year, whether discharge was present astern (any combination of minced material, offal, discards, and sump discharge), and the rate at which discharge was appearing astern (no discharge, negligible, intermittent, continuous). (For more information on the warp strike sampling protocol used by observers, see Abraham (2010)).

<u>*Baffler designs and materials*</u>

To improve the designs of bafflers in place, bafflers in use on trawlers were examined and materials of construction investigated (Cleal and Pierre 2012). Further, key elements of the

Burka baffler were identified that are expected to more effectively restrict seabird access to danger areas near the trawl warps. This included consideration of problems with materials used in bafflers currently (e.g., droppers tangling with trawl warps, Cleal and Pierre 2012). A new design was developed and drafted for deployment at sea, that incorporated design elements and materials that capture best practice for bafflers (recognising that the relative efficacy of bafflers other than 4-boom versions is unknown).

## Results

### Streamer lines

*Deployment and retrieval systems*

Currently, the best-performing deployment and retrieval systems for streamer lines are found on vessels using these devices often, including as their primary mitigation device (e.g. Korean-owned trawlers). On Korean vessels using streamer lines, a pole or boom and a lazy line allow ready deployment of the device from the trawl deck (Figure 4). The backbone of the streamer line and the streamers pass through pulleys on the boom during deployment and retrieval. Crew unclip the lazy line from the trawl deck, which releases the terminal object and allows this to be deployed over the side of the vessel. Deploying lines using a boom also allows the streamer line to settle further outboard of the hull and therefore outside the trawl warps on each side of the vessel.

Figure 4. System used to deploy streamer lines on Korean-operated trawl vessels. The buoy is released with a lazy line, drops to the water surface, and pulls the streamer line out as it trails onto the water surface.

Alternative storage systems involve keeping the streamer lines in plastic drums located close to the point of deployment (e.g., the aft gantry), tying the line between two posts on the vessel's railing, or using a hose reel at the vessel stern which allows ready retrieval of the line but requires attention to prevent streamers tangling on deployment, which occurs following attachment of the terminal object (Figure 5).

(a) (b)

Figure 5(a, b). Storage of a streamer line on a hose reel.

Bridle systems are also used on a small number of vessels from which bafflers and streamer lines are regularly deployed. The terminal object is stored on the trawl deck, while the backbone is fixed to the gantry. The terminal object is deployed from the trawl deck and the line deploys as the object pulls astern. For retrieval, the line is pulled from the bridle end and stored again.

We were unable to identify an off-the-shelf, cost-effective approach to make streamer line deployment less manually-intensive and more automated.

*At-sea trials of streamer materials*

At-sea trials were completed successfully and identified clear improvements in materials and streamer line designs. Conditions during the trials were variable with winds ranging from 8 – 20 knots and calm to moderate seas with up to 3 m swells. No severe conditions were encountered. The relative performance of streamer line components is summarised in Figure 6.

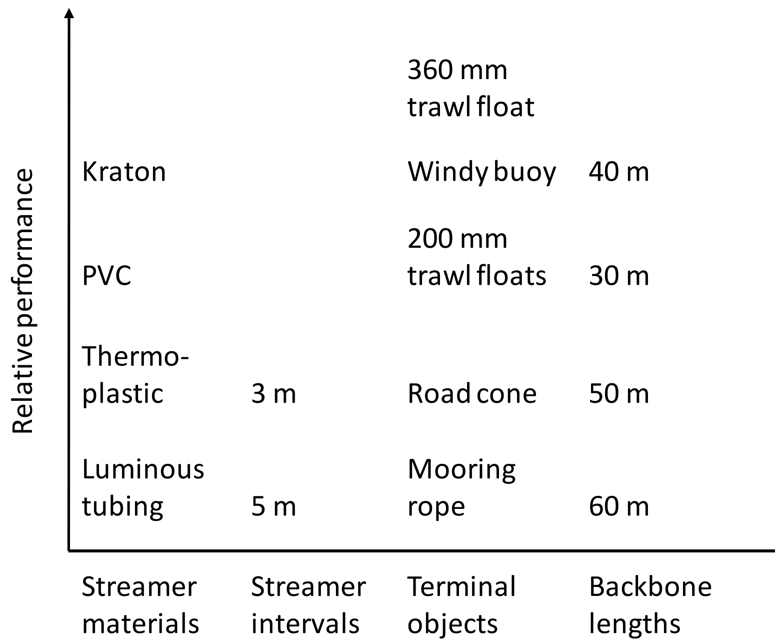



Figure 6. Relative performance of streamer line components tested at sea. Performance was assessed based on characteristics described in Table 2.

Of the streamer materials tested, Kraton performed best. Streamers hung well, did not become entangled in trawl warps, and did not break. The observer noted that having 0.5 m of the streamers' length lying in the water reduced the amount that lines drifted and therefore protected trawl warps even more effectively. However, this also increased drag. Streamers provided more effective screening for trawl warps at 3 m spacings and the most effective terminal object was the 360 mm trawl float. In almost all trials, a 30 m backbone was sufficient and this performed better than longer backbones. However, there was one situation for which 30 m was inadequate. In this case, the vessel was fishing in pronounced swells and at shallow depths which led to a low warp angle. For this vessel, 40 m appeared to be the optimal backbone length. When backbones were longer, increased drag led to aerial extent being compromised when the drag weight of the terminal object was inadequate. Risk of tangling also increased when streamers could wind around the backbone as the streamer line was towed.

More detailed observations of materials tested follow:

*Streamers*

**Luminous tubing**: The luminous tubing was very sensitive to wind, given its lightness and flexibility, and often blew at an angle off the trawl warps instead of hanging down and protecting them. When the tubing did make contact with the warps, it often broke. It was also significantly less visible, compared to the other streamer materials tested. Streamers did not track the warp well. Overall, luminous tubing was the material least likely to be effective in reducing seabird interactions over time.

**Kraton**: Kraton tangled less than the luminous tubing and hung well from the backbone. When the Kraton streamers made contact with the trawl warp, they tended to fall off the warp rather than wrap around it. Its pliability meant that Kraton could easily be threaded through the backbone of the streamer line, eliminating the need for swivels, clips and ties to secure streamers. At night, Kraton glowed in the vessel's stern lights which the other materials tested did not. This heightened visibility is expected to increase the efficacy of the streamers in reducing warp strikes.

**Thermoplastic:** Streamers made of Thermoplastic were stiffer than those of Kraton and luminous tubing. They tangled more on deck, tended to retain some coiling in their form on deployment, and were consequently more difficult to handle. Thermoplastic was lighter than PVC but heavier than the other materials tested.

**PVC:** Streamers made of PVC were yellow in colour. These were stiffer than streamers of Kraton and luminous tubing. Stiffness increased at colder temperatures, which could make these streamers prone to breakage if brittle. They also tangled more on deck than these other materials, and were consequently more difficult to handle. PVC was the heaviest streamer material trialled.

*Terminal objects*

**Windy buoy or 'pinkie' covered by a mesh sock**: The windy buoy was very buoyant, which made it vulnerable to being blown off course by wind. It did not track warps effectively in wind. In addition, it did not provide sufficient drag for heavier streamer line configurations. However, it was easy to handle, deploy, and retrieve.

**Trawl floats**: The single 360 mm trawl float performed best of the float arrangements tested. However, it was noticeably more difficult to retrieve at higher vessel speeds (e.g., 4.8 – 5.2 knots compared to 4.0 – 4.3 knots).

**200 mm-diameter twin floats**: The smaller 200 mm diameter floats did not provide enough drag to maintain the tautness of the streamer line. They were also more difficult to handle compared to one larger float.

**Mooring Rope:** The mooring rope provided less drag in the water than the 360 mm trawl float, although it was also considerably heavier. When two lengths were used, the 19 kg weight made retrieval difficult. It did not deliver adequate aerial extent; streamer lines sagged.

**Road cone:** The performance of the road cone was not better than the trawl floats. Further, it is likely less durable over time. In these trials, the cone became laterally flattened. It also tended to bounce across the water rather than move at a consistent pace.

*Backbones*

In general, greater and more consistent aerial extents, and more effective tracking of trawl warps, were achieved by shorter streamer line backbones. The 30 m backbone performed best in most trials on this vessel, which is one of the largest in the deepwater trawl fleet. However, at shallower depths trawled during one tow of the trials, a 30 m backbone was inadequate.

The shallow towing depth caused trawl warps to be exposed more than they had been in other tows, due to a shallower warp angle and swells. In swells, the trawl float at the end of the 30 m backbone crossed under the trawl warp on one occasion, rendering the streamer line ineffective.

Given that trials showed that the 50- and 60 m long backbones did not track the warps as effectively and also tended to whip up and down, backbone length of 40 m appears optimal for this vessel (Figure 6, 7). However, the appropriateness of different backbone lengths will vary with the height of the trawl blocks on vessels and the warp angle resulting from the depth at which the net is towed.

Figure 7. Streamer line with 30 m backbone, Kraton streamers at 3 m intervals, and a mesh-covered 360 mm-diameter trawl float as the terminal object. The starboard trawl warp is also visible (and the port warp crosses the photo in the upper right corner).

## Bird bafflers

### *Data analysis*

Ministry for Primary Industries data included 230 observation periods monitoring warp strikes on trawl warps on vessels equipped with 2-boom bafflers. There were 809 observation periods conducted on vessels carrying 4-boom bafflers. No warp strike data were available for Burka bafflers. Exploratory modelling was unsuccessful given the limited dataset. However, data were sufficient to support a step analysis. This was conducted using a poisson model and a log link function (Akaike 1974, Venables and Ripley 2002).

The abundance of large (albatrosses and petrels) and small (all other seabirds) birds astern of the vessel, the discharge types and rates, fishing year, and wind speed were all more important than the number of baffler booms, in accounting for variations in large seabird strikes on trawl warps (Table 3). For warp strikes by small seabirds, the abundance of small birds, discharge type and rate, and fishing year were all more important than the number of baffler booms (Table 3).

Table 3. Results of the step analysis investigating the influence of the number of baffler booms, and other covariates, on seabird strikes on trawl warps. (See text for information on warp strike data collection protocols and covariates).

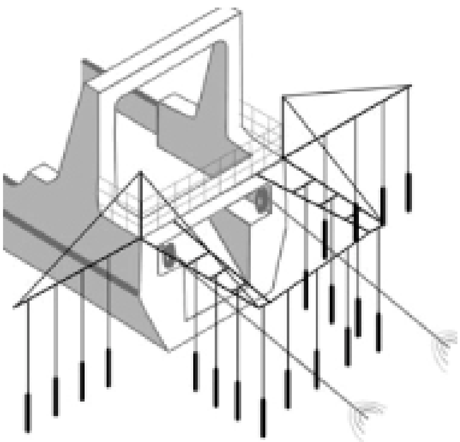
| Large seabird strikes | Df | Deviance | Residual Df | Residual Deviance |
|---|---|---|---|---|
| | | | 791 | 5230.5 |
| Large seabird abundance (range) | 3 | 1936.77 | 788 | 3293.7 |
| Discharge rate | 1 | 653.27 | 787 | 2640.4 |
| Fishing year | 3 | 495.01 | 784 | 2145.4 |
| Discharge types present | 3 | 89.45 | 781 | 2056.0 |
| Large bird abundance (number) | 1 | 82.40 | 780 | 1973.6 |
| Windspeed | 1 | 9.82 | 779 | 1963.8 |
| Small seabird abundance (range) | 3 | 11.57 | 776 | 1952.2 |
| Number of booms | 1 | 3.86 | 775 | 1948.3 |

| Small seabird strikes | Df | Deviance | Residual Df | Residual Deviance |
|---|---|---|---|---|
| | | | 791 | 8403.8 |
| Small seabird abundance (range) | 3 | 1277.49 | 788 | 7126.3 |
| Fishing year | 3 | 857.12 | 785 | 6269.2 |
| Discharge rate | 1 | 488.19 | 784 | 5781.0 |
| Small seabird abundance (number) | 1 | 371.21 | 783 | 5409.8 |
| Discharge types present | 3 | 187.82 | 780 | 5222.0 |
| Number of booms | 1 | 195.13 | 779 | 5026.9 |

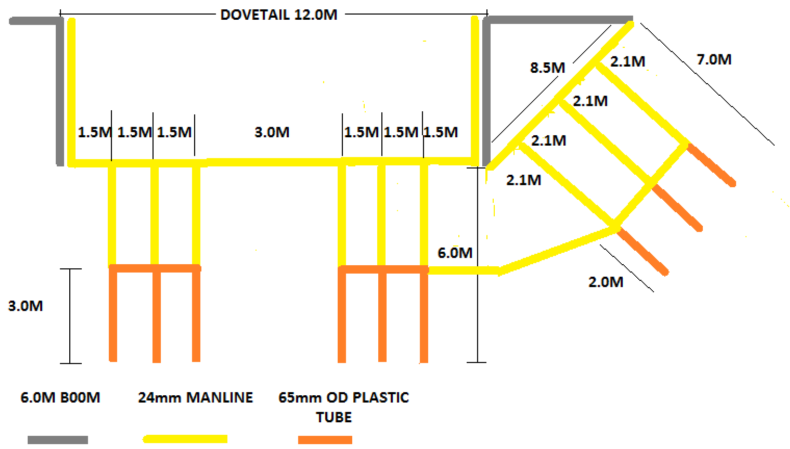
| | | | | |
|---|---|---|---|---|
| Wind speed | 1 | 65.67 | 778 | 4961.2 |
| Large seabird abundance (range) | 3 | 48.15 | 775 | 4913.1 |
| Large seabird abundance (number) | 1 | 45.58 | 774 | 4867.5 |
| Fishery | 2 | 55.76 | 772 | 4811.7 |

*Baffler designs and materials*

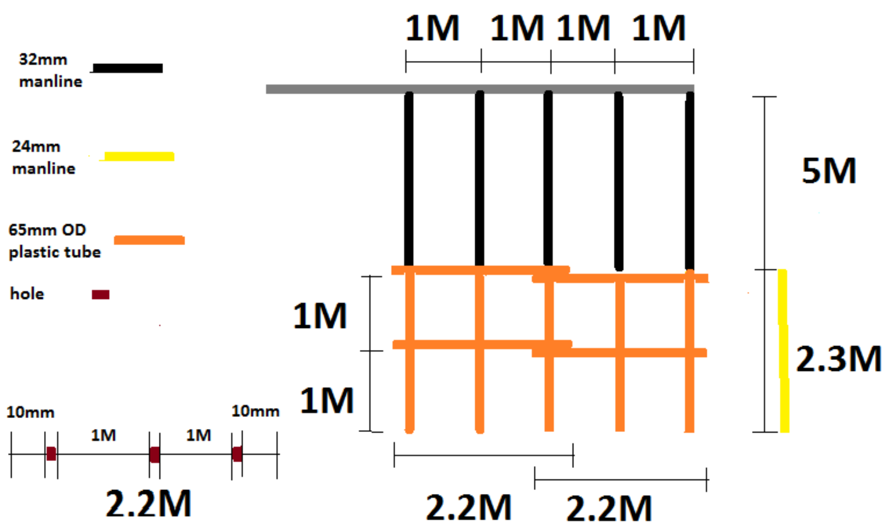
Key features of the Burka design that may increase its efficacy relative to other bafflers include the position of booms and the 'curtain' aft of and parallel to the vessel stern (Figure 8). This arrangement protects more of the trawl warps than any other baffler. Materials such as hard plastic pipe droppers and ropes covered in plastic tubing are expected to restrict seabird access to the trawl warps, to reduce the likelihood of tangles within the baffler and on trawl warps, and to reduce wear and tear over time (Figure 9). On the Burka, lazy lines are often used to connect the droppers to the vessel, reducing dropper movement and tangling. A streamer line is deployed through the Burka, to further reduce the risk of seabird warp strikes.



(a)




(b)




(c)

Figure 8. (a) Schematic of the prototype 'Burka' baffler (Source: www.fishinfo.co.nz/Newsletters/19_Sep07.pdf), and (b, c) the design now used. (b) shows the stern and boom array deployed from the starboard stern quarter corner. (c) shows the side boom design.

(a) (b)

(c) (d)

Figure 9. Parts of the Burka in operation at sea. Note the curtain of droppers diagonally connecting the side and stern booms, and the lazy line, visible in (a), and the trawl warp visible in (b). The structure of pipes and ropes is shown in figures (c) and (d). Use of pipes is expected to reduce tangling.

These design components have been incorporated into a recommended specification for a new baffler design (Appendix 3). The estimated cost of deploying this design is ~$12,000 - $18,000, making it less expensive than a full Burka baffler (costing up to $30,000). At-sea trials are necessary to assess the practicality and efficacy of this design (Appendix 4).

## Conclusions and Recommendations

### Streamer lines

The series of trials described above showed that the line that provided the best screening from the trawl warps, aerial extension, and ease of deployment on this vessel was made with Kraton streamers at 3 m spacing on a 40 m long backbone line, with a 360 mm-diameter trawl float as the terminal object. Removing swivels and clips and interweaving streamers directly into the backbone reduced streamer breakages while maintaining the same performance in terms of the ‘curtain’ effect created. Using single-stranded streamers instead of streamers with two strands would reduce the weight of the line overall, allowing for increased aerial extent, reducing the drag weight needed, and facilitating retrieval. Single-stranded streamers could also be placed more frequently along the backbone than double streamers, providing better screening while still reducing the overall weight of the line. However, paired streamers will still provide warp screening if one streamer breaks during towing. Backbones of 30 m in length were almost always adequate in the trials described here. However, the combination of swells and low warp angle rendered a 40 m backbone more appropriate for a broader range of conditions. The most appropriate backbone length will also be influenced by attachment height and vessel block height. On the vessel used in these trials, streamer lines are attached at a height of 7.5 m above the water surface, due to the height of the trawl blocks (which are amongst the highest in the deepwater fleet). When the attachment point is closer to the water surface, shorter backbones would be expected to work well. Creating a shorter backbone to which additional sections could be added may be an optimally flexible solution.

The 360 mm-diameter, 9.1 kg trawl float (coloured green) delivered the best performance of the terminal objects tested at sea. The colour of trawl floats often reflects depth rating, which is delivered through varying the thickness of plastic that the float is constructed from (and consequently the weight of the float). As noted above, this vessel is one of the largest operating in the deepwater trawl fleet, at 105 m in overall length. On smaller to medium-sized vessels (e.g., 28 – 70 m in overall length), shorter backbones will require less drag to maintain the aerial extent of streamer lines. For these vessels, trawl floats of 360 mm but weighing 6.5 kg (coloured orange) are expected to suffice as terminal objects. While untested, the performance of 360 mm trawl floats may potentially be improved by adding half a cone ahead of the float, to deflect any birds that become caught up in the backbone as the float tows through the water. Finally, while the trawl float performed best of the terminal objects tested, the performance of the windy buoy may be improved by increasing the drag weight. This could be achieved through filling the buoy with 3 – 6 litres of water.

As noted above, no severe weather conditions were encountered during the at-sea trials. Wind and swell can affect the performance of streamer lines significantly. The performance of the optimal streamer line identified here should be confirmed in rough weather. In addition, streamer line performance could be compared quantitatively on an outcome basis, i.e., numbers of seabird strikes on trawl warps.

The results of our trials provide the following guidelines for constructing a well-performing streamer line for vessels $\geq$ 28 m in overall length.

- Streamer intervals: Use double Kraton streamers threaded through the backbone ropeat 3 m intervals. (Swivels or clips are not necessary).
- Backbone length: For every 1 m of trawl block height (i.e., block height over the water), deploy 5 m of backbone.
- Backbone diameter: Use Danline rope of 8 – 9 mm diameter for the streamer line backbone. Note that 8 mm is the minimum diameter legally required.
- Terminal object: Use 1.2 kg of drag weight per metre of trawl block height.

These recommendations were summarised in a fact sheet distributed amongst the deepwater trawl fleet (Appendix 5).

As reported elsewhere (Cleal and Pierre 2012), vessels typically use bafflers as the primary device deployed to meet legal requirements for seabird scaring devices. However, most also carry streamer lines for deployment during periods when the risk of seabird strikes on trawl warps is higher. An improved approach that will reduce the reliance of deployment and retrieval on manual systems is yet to be identified for streamer lines. Some vessels have developed their own systems which work within their operations. However, some issues remain (e.g., tangling on deployment when streamer lines are stored on reels). Using the streamers of larger diameter and greater length, as recommended in this project to improve streamer line performance, will necessitate the amendment of storage systems currently in place to ensure efficiency and to minimise tangling. However, this is not expected to be onerous.

Considerations of cost-effectiveness for a deployment and retrieval system for streamer lines should be tempered by the relatively low cost of paired streamer lines themselves (~$250) compared to bafflers (~$5,000 - $30,000 depending on design and quality of materials).

However, the fact that bafflers are the primary gazetted device in use on most trawlers $\geq$ 28 m emphasises that cost is not the most important factor guiding device choice.

**Bird bafflers**

Currently, the lack of knowledge on the efficacy of baffler designs other than the 4-boom version is problematic, especially given the legal status (implemented using the gazette notice) of various designs of this device. Exploratory analysis of existing data showed that the number of booms was less important than seabird abundance, year, and discharge in determining seabird strikes on trawl warps. While the efficacy of bafflers other than 4-boom constructions remains unknown, we recommend that new bafflers fitted follow an improved design specification which provides more effective screening of the trawl warps than current designs. If the baffler is to maintain legal currency, we also recommend a dedicated at-sea data collection programme to ascertain the efficacy of 2- and 4-boom and Burka-style bafflers (including the new design developed; see Appendices 3, 4).

Currently, the baffler is the primary device intended to reduce seabird interactions with trawl warps that is in place on trawlers $\geq$ 28 m (Cleal and Pierre, 2012). Most also carry streamer lines for deployment when the risk of seabird strikes on trawl warps is heightened. While further investigation is required to ascertain the efficacy of a range of baffler designs (Appendix 4), the findings of this project include ways to improve the performance and practicality of both these devices.

## Acknowledgements

The authors thank P. Fullerton for conducting and recording the trials, Sealord Group Ltd for providing vessel access, and F. Thompson (Dragonfly Science) for conducting step analyses on the baffler data. We are grateful to the Ministry for Primary Industries for making available warp strike data collected by government fisheries observers. This project was funded by the Department of Conservation's Conservation Services Programme (www.doc.govt.nz/csp) project MIT2011-07, principally through a levy on the quota holders of relevant commercial fish stocks.

## References

Abraham, E.R. 2010. Warp strike in New Zealand trawl fisheries, 2004–05 to 2008–09. New Zealand Aquatic Environment and Biodiversity Report No. 60, Ministry of Fisheries, Wellington.

Akaike, H. 1974: A new look at the statistical model identification. *IEEE Transactions on Automatic Control* 19: 716–723.

Bull, L.S. 2007: Reducing seabird bycatch in longline, trawl and gillnet fisheries. *Fish and Fisheries 8*: 31-56.

Bull, L.S. 2009: New mitigation measures reducing seabird by-catch in trawl fisheries. *Fish and Fisheries 10*: 408–427.

Cleal, J.; Pierre, J.P. 2012: Seabird scaring devices in use on trawlers > 28 m in length operating in New Zealand fisheries: Report on Marine Conservation Services Project MIT2011/07. Unpublished report for the Conservation Services Programme, Department of Conservation.

Middleton, D.A.J.; Abraham, E.R. 2007: The efficacy of warp strike mitigation devices: Trials in the 2006 squid fishery. Final Research Report: IPA2006/02. Unpublished report held by Ministry of Fisheries, Wellington. Available from: http://fs.fish.govt.nz/Page.aspx?pk=113&dk=22910.

Sullivan, B.J.; Brickle, P.; Reid, T.A.; Bone, D.G.; Middleton, D.A.J. 2006: Mitigation of seabird mortality on factory trawlers: trials of three devices to reduce warp cable strike. *Polar Biology 29*: 745-753.

Venables, W.N.; Ripley, B.D. 2002. Modern applied statistics with S (Fourth ed.). Springer, New York.

**Appendix 1.** Legal requirements for streamer lines and bird bafflers deployed on trawlers $\geq$ 28 m in overall length operating in New Zealand waters (New Zealand Gazette No. 29, 11 March 2010).

**SEE SEPARATE DOCUMENT POSTED TOGETHER WITH THIS REPORT**

**Appendix 2.** Form used by the at-sea observer to record information describing streamer line performance.

## MIT2011/07: Streamer line at-sea trials

| | |
|---|---|
| **Date:** | |
| **Trip #:** | |
| **Tow #:** | |
| **Trial # (see Trial Schedule):** | |

**If new combination (i.e. Trial 17 onwards), please list design & materials:**

| |
|---|
| |

**Weather during observation period (circle):**
**Beaufort scale:** 1-3 3-6 6-9

**Wind direction, relative to vessel and tori lines:**
**(Draw diagram)**

**Attachment information (experimental line):**

1. **Estimated height from the tori line attachment point to the water surface (m)**

2. **Estimated height from the vessel trawl block sheath to the attachment point (2 m or more)**

3. **Estimated distance from the outside edge of the trawl block to the port & starboard outside edge, in line with the attachment point (must be 1 m to 3 m)**

4. **Estimated the distance from the vessel stern to the first streamer (m)**

5. **Estimated aerial extent of the tori line backbone in total, and behind the point where the warp enters the water (m)**

Total aerial extent: Aerial extent beyond warp:

6. **Estimated distance from the vessel stern to the point at which the warp enters the water (m)**

**Streamer line observations:**

**7. How well did the experimental streamer line track the trawl warp during towing? Please circle, and draw the normal and experimental streamer lines**

Tracked warp well

Blew off course

Moved off course without wind

Comments:

**8. How did the terminal object affect the aerial extent of the experimental streamer line?**

Line sagged more than the control line

Line more taut than the control line

No difference from control line

Comments:

**9. Did the experimental streamers tangle during the trial?**

Yes Sometimes No

**10. If tangling occurred, was it more or less than the streamers on the control line?**

More Same Less

**11. Did the experimental streamers break?**

All Some None

**12. If yes, was this because they contacted the:**

Warp Tori line backbone Other (please comment)

**13. If all or some streamers broke, was this more or less than the control tori line's streamers?**

More Less Same

**14. Did the experimental streamers hang well, from the backbone to the water surface?**

Yes Sometimes No

**15. Did the experimental streamers move around (off line) in the wind easily?**

Yes Sometimes No

**16. Does the aerial extent ensure the experimental tori line and streamers cover the warp well?**

Yes Sometimes No

Same as control Worse than control Better than control

**17. How did birds react to the experimental line? (Please circle and comment)**

Same as the control streamer line

Different to the control streamer line

| Comments: |
|---|
| |

**18. Is the experimental tori line backbone providing aerial coverage beyond where the warp enters the water?**

Yes No

Better than the control Worse than the control Same as the control

**19. Was the warp ever exposed during this observation period, on the starboard (i.e. experimental) side?**

Yes No

Why? (Please comment):

| |
|---|
| |

**20. If the vessel turned during this observation period, how far outside the protection of the tori line did the warp travel (m)?**

**21. Did the crew have any comments on the experimental line used on this tow (e.g. ease of deployment, drag on retrieval, their impressions of efficacy, or anything else)**

| Comments: |
|---|
| |

**22. Is there anything else we should know about the performance of this streamer line, compared to the normal control line or others you have tried this trip?**

| |
|---|
| |

**Please record identifiers of photos and videos taken during the trials, so we can link them to the experimental tori lines.**

**Photos taken:**

| ID number: | Time: | What photo shows: |
|---|---|---|
| | | |

**Videos taken:**

| ID number: | Time: | What video shows: |
|---|---|---|
| | | |

**Appendix 3.** Recommended specifications for a new baffler design that incorporates key features of the Burka baffler, which may increase efficacy relative to other bafflers.

**SEE SEPARATE DOCUMENT POSTED TOGETHER WITH THIS REPORT**

**Appendix 4.** Recommendations for baffler development and assessment of device efficacy.

## Objective

To determine the efficacy of bird bafflers of selected designs in use in New Zealand trawl fisheries on vessels $\geq$ 28 m in overall length.

## Background

- Since April 2006, the use of devices aimed at reducing the incidental capture of seabirds has been required in New Zealand fisheries waters, for trawl vessels $\geq$ 28 m in overall length.
- The gazetted specifications for the required devices are somewhat flexible and introduce the possibility of variable efficacy amongst devices of different designs.
- The efficacy of 4-boom bafflers has been investigated. However, the efficacy of 2-boom bafflers and other designs, such as the Burka, in reducing seabird strikes on trawl warps is unknown.
- The worst case scenario given this lack of knowledge is that vessel operators in New Zealand may be deploying devices (at sometimes considerable expense) that do not deliver mitigation benefit in terms of reducing seabird strikes on trawl warps.

## Approach

- Support selected vessels to build bafflers of the newly developed design (see Appendix 3) for testing.
- Use existing observer coverage to examine the efficacy and performance of different baffler designs (2 boom, 4 boom, and the newly proposed design) via a range of metrics:
    - Amount of unprotected warp exposed during towing
    - Seabird abundance inside, versus outside, the warp danger zone
    - Costs associated with construction, deployment and maintenance
- Analyse data using robust statistical methods that manage ‘messy’ datasets well.

## Outcomes

- The efficacy of different baffler designs will be established.
- Recommendations will be developed on optimal designs for bafflers, given both performance and cost considerations.
- Mitigation strategies will be identified that are known to reduce seabird warp strikes, and consequent bycatch risk.

## Next steps

- The baffler design described in Appendix 3 is currently being deployed on a deepwater trawler. This will allow any design flaws to be resolved prior to deploying this design on other vessels and before any additional work (i.e., that recommended above) is undertaken.

**Appendix 5.** Fact sheet distributed among the deepwater trawl fleet that captures design recommendations for a well-performing streamer line.

**SEE SEPARATE DOCUMENT POSTED TOGETHER WITH THIS REPORT**