Stocktake of measures for mitigating the incidental capture of seabirds in New Zealand commercial fisheries

Report to Southern Seabird Solutions Trust

Image: J. Molloy

Graham Parker

PARKER CONSERVATION

PARKER CONSERVATION

Stocktake: status of development of measures applicable to New Zealand Commercial Fisheries to mitigate the incidental mortality of seabirds. Report to Southern Seabird Solutions Trust by Parker Conservation, Dunedin

Graham Parker

Author contact: g.parker@parkerconservation.co.nz

Please cite as: Parker, GC 2017. Stocktake of measures for mitigating the incidental capture of seabirds in New Zealand commercial fisheries. Report to Southern Seabird Solutions Trust by Parker Conservation, Dunedin

Introduction

Over 25 species of seabirds are caught as incidental bycatch in a wide range of commercial fisheries in New Zealand, including surface (pelagic) and bottom (demersal) long-line, deep-water and inshore trawl, and set nets (Dragonfly 2016). Due to this a significant amount of effort and resources has gone into developing methods to mitigate the incidental bycatch of seabirds in commercial fisheries in NZ and overseas (Løkkeborg 2011; Bull 2009). This report aims to collate key information about methods developed to mitigate incidental seabird mortality, with a particular focus on the development and testing undertaken for each. This will allow government and stakeholders to plan the type of support each mitigation measure may need and prioritise amongst them where needed. This project also aims to inform fishermen of the status of each of these mitigation measures.

The scope of this report includes mitigation measures (device or fishing practice) that have potential application in New Zealand commercial long-line, trawl or set net fisheries. For completeness, mitigation measures already in use in New Zealand fisheries are included. The mitigation measure may relate to any species of seabird caught in commercial fisheries in New Zealand. The status of mitigation measures discussed range from early prototypes (or practices) through to commercially available mitigation measures. The development and testing of the mitigation measure may be occurring outside New Zealand but have potential application in New Zealand fisheries.

The multi-lateral Agreement for the Conservation of Albatrosses and Petrels (ACAP), of which NZ is a signatory, has provided a set of criteria that defines best practice mitigation to reduce or eliminate the incidental mortality of seabirds in commercial fisheries (given below). This report assesses the extent to which each mitigation measure has been developed and tested against the ACAP criteria.

At the beginning of each fisheries section a table lists the mitigation methods included in the section and the current status of development of each.

The following information will be summarised for each mitigation measure, by fishing method

- Name of mitigation measure
- Current status of development of each measure
    - Early prototype / functionality
    - Limited efficacy testing
    - Broader efficacy testing (may require refinement)
    - Tested comprehensively in most relevant fisheries and gear types
    - Tested comprehensively in all relevant fisheries and gear types
- Current use of each measure (internationally)
    - Not in use / very limited use
    - Used in some fisheries
    - Widespread use
- Brief description of mitigation measure and how it works
- Description of results of development to date (where relevant)
- Description of results of testing to date, reported against the ACAP criteria
- Hurdles to uptake in New Zealand
- Past and current funders and developers (if applicable)
- Development and testing needed to meet ACAP's six criteria:
    i. Effectiveness
    Individual fishing technologies and techniques should be selected from those shown by experimental research to significantly reduce the rate of incidental seabird mortality to the lowest achievable levels.
    ii. Proven specifications and standards

Fishing technologies and techniques, or a combination thereof, shall have clear and proven specifications and minimum performance standards for their deployment and use.

iii. Likely uptake

Fishing technologies and techniques shall be demonstrated to be practical, cost effective and widely available

iv. Effect on target catch

Fishing technologies and techniques should, to the extent practicable, maintain catch rates of target species.

v. Effect on non-target catch

Fishing technologies and techniques should, to the extent practicable not increase the bycatch of other taxa.

vi. Compliance

Minimum performance standards and methods of ensuring compliance should be provided for fishing technologies and techniques, and should be clearly specified in fishery regulations.

- Costs per vessel for installation/uptake (if available)

Surface long-line

In general surface long-line mitigation technologies use one or more of five methods to mitigate the incidental mortality of seabirds.

- Reduce the window of time in which seabirds can access baited hooks using line weighting and/or setting below a depth that birds can access baits.
- Scare birds away from risk areas when lines are set or hauled.
- Reduce attraction for birds by discarding old baits or offal during line setting and hauling
- Make baits 'cryptic' using blue dye or setting at night
- Apply spatial or temporal restrictions to fishing areas

Table 1. Surface long-line mitigation method or device included in this review and current status of development

Mitigation method or device	*Status of development*	*Page*
Tori lines	Tested comprehensively in most relevant fisheries and gear types	9
Night setting	Tested comprehensively in all relevant fisheries and gear types	10
Line weighting	Broader efficacy testing (may require refinement)	12
Double weighting	Broader efficacy testing (may require refinement)	13
Safe Leads	Broader efficacy testing but no longer recommended	15
Lumo Leads	Broader efficacy testing Lumo Leads only (may require refinement), all imitation products untested	17
Smart Tuna Hook	Limited efficacy testing	18
Hook Pod	Broader efficacy testing (may require refinement)	21
Underwater Bait Setter	Early prototype / functionality	23
Bait Caster	Limited efficacy testing	25
Dyed Bait	Limited efficacy testing, qualitative measure of success from fisher reports	26
Water cannons	Limited efficacy testing	27
Acoustic scarers	Limited efficacy testing, qualitative measure of success from fisher reports	28
Bait management	Tested comprehensively in all relevant fisheries and gear types	29
Side setting	Limited efficacy testing	30
Thawed bait	Limited efficacy testing	31
Lunar cycles	No management guidelines	32
Lasers	Limited efficacy testing, qualitative measure of success from fisher reports	32
Artificial bait	Not tested in surface longline fisheries	33

Tori-lines (bird-scaring lines)

Tested comprehensively in most relevant fisheries and gear types

Widespread use

- **Mitigation measure and how it works**

A tori-line, also referred to as bird-scaring lines or bird-scaring streamers, is an aerial line (sometimes referred to the 'back-bone') fixed at the stern and towed behind a vessel, with an object attached at the terminal end that creates drag. Brightly coloured streamers attached to the 'back-bone' of the tori-line move in the wind to deter birds from entering the area where baited hooks are sinking, effectively acting as a 'protective curtain'. To be effective, the tori line streamers must hang above the point where baited hooks are landing in the water, including in cross winds. The design of the tori lines also needs to take into account two factors: the sink rate of baited hooks and the vessel setting speed. The aerial section of the tori-line needs to be long enough to protect baited hooks until they have sunk beyond the depth that diving birds will generally be prepared to dive to retrieve them. This hook sink rate, in combination with setting speed, determines how far behind the boat a tori line needs to deter birds from entering the area. New Zealand vessels can and do slow down to reduce the window of 'hook availability' (D. Goad pers. comm.).

Achieving effective tori-line coverage on small vessels comes with challenges. Most notably, it is difficult to attach the tori line high enough at the stern to provide adequate aerial coverage. (Pierre and Goad 2016) suggest at least 70 m of aerial coverage is needed behind smaller New Zealand vessels.

Evidence to date shows tori-lines can be highly effective at reducing incidental seabird mortality in surface long-line fisheries (Løkkeborg 2011; Bull 2009; Melvin et al. 2014). As a result tori-lines are considered best practice by ACAP when used in conjunction with night-setting and line weighting.

- **Description of results of testing to date**

The benefits of tori-lines in surface long-line fisheries were first described by Brothers (1991) on a Japanese tuna long-liner. That study compared the number of birds caught on lines with and without tori-lines and found that one streamer line reduced the number of baits taken by albatross from 5.8/1000 hooks to 1.7/1000 hooks. Since then numerous studies have shown the efficacy of tori-lines for a range of surface long-line vessel sizes (see ACAP 2014a; Løkkeborg 2011; Bull 2009).

- **Development and testing needed to meet ACAP's criteria**

Tori-lines are already recognised as best practice in surface long-line fisheries by ACAP, when used in conjunction with night setting and branch-line weighting (ACAP 2014a). New Zealand does not currently require longline fishers to follow ACAP best practice guidelines as commercial fishers are currently required to use only two out of the three ACAP best-practice mitigation measures.

Further work needs to be conducted in New Zealand to refine small vessel tori-lines to ensure the mitigation technique is used by all fishers at all times (Pierre and Goad 2016). Challenges refining tori-lines to the individual needs of small vessels are not unique to New Zealand. As a result ACAP are developing a 'tool box' approach for artisanal fishers to use internationally (Mangel et al. 2016) and parts of that 'toolbox' will likely be relevant to smaller and slower setting vessels of the NZ surface long-line fleet.

Effectiveness

Tori-lines have been shown to be highly effective at reducing incidental seabird mortality in surface long-line fisheries internationally (Melvin et al. 2014; Domingo et al. 2011; Løkkeborg 2011; Bull 2009; Yakota et al. 2008; Løkkeborg and Robertson 2002), but lacks testing in New Zealand.

Proven specifications and standards

Tori-line design for surface long-line vessels is well described by ACAP (ACAP 2014a). Further refined guidelines are available for small surface long-line vessels in NZ (Pierre and Goad 2016) and are being developed by ACAP (Mangel et al. 2016).

Likely uptake

Tori-lines are commonly used and are relatively cost-effective, practical and proper materials can now be readily sourced. Non-compliance in NZ is recognised problem however (N. Walker pers. comm.)

Effect on target catch

Tori-lines may increase target catch rates as they reduce seabird attacks on baits so can result in lower bait loss during setting (Lokkeborg 2011).

Effect on non-target catch

Seabird mortality as a result of entanglement with tori-lines has been recorded but is a rare event compared to mortality from taking baited hooks.

Compliance

Clear performance standards for tori-lines are defined by MPI in New Zealand and internationally by ACAP. Methods of ensuring compliance include observers, electronic monitoring (cameras), patrol vessels and patrol-plane fly overs.

- **Hurdles to uptake in New Zealand**

Tori-lines are required by law in surface long-line fisheries in New Zealand; MPI require fishers use tori-lines and either line weighting or night-setting (MPI 2016).

As mentioned, some fishers of small vessels report problems with tori-lines such as safety concerns and particularly fouling with gear. Recent work by Pierre and Goad (2016) provide clear recommendations for small vessel tori-lines designs tailored to individual vessel arrangements, and also highlight areas requiring further investigation. In particular:

- Test the variety of designs under a broader range of fishing and weather conditions
- Test the efficacy of in-water sections in supporting tori line backbones longer than the 70 m backbone trialled in Pierre and Goad (2016)
- Assess whether including swivels or a non-rotating backbone improves performance
- Test if the addition of flashy materials that move unpredictably and create noise improves tori line performance
- Quantify if tori line designs that generate splash are more effective

- **Costs per vessel for installation/uptake (if available)**

NZ $300 – $700

Night-setting

Tested comprehensively in most relevant fisheries and gear types

Widespread use

- **Mitigation measure and how it works**

Most of the seabird species vulnerable to fisheries by-catch are visual feeders so are less active at night. In addition baited hooks may be less visible for those seabird species that do forage at night. For this reason setting long-lines between nautical twilight and nautical dawn reduces baited-hook attack rates by seabirds, and therefore incidental seabird captures. It is important to note that significant bycatch events have been recorded at night as some species feed nocturnally and this can be especially so during the full moon.

- **Description of results of testing to date**

A study using data from 86 longlining vessels operating in Australian waters between April 1992 and March 1995 reported that day sets caught five times as many seabirds as night setting (Klaer & Polacheck 1998). This lead to more testing of night setting as a mitigation measure. Observer data from Japanese long-liners targeting southern Bluefin tuna in New Zealand waters 1989 –1993 reported lower seabird bycatch during night sets compared to day setting (Duckworth 1995). A 1994 – 1997 South Indian Ocean study recorded a similar result; 0.91 birds caught/1,000 hooks for day-set lines vs. 0.17 birds/1,000 hooks for night-set lines (Weimerskirch et al. 2000). Importantly, a Uruguayan study showed that night setting is a less effective mitigation measure if deck lights are on or during full moon (Jiménez et al. 2009).

- **Development and testing needed to meet ACAP's criteria**

Night setting is already recognised as best practice in surface long-line fisheries by ACAP, when used in conjunction with bird scaring lines and branch-line weighting (ACAP 2014a).

Effectiveness

Night setting as a mitigation method has been widely shown to be effective (Jimenez et al. 2009; Klaer and Polacheck 1998; Brothers et al. 1999). ACAP recognise that night setting as a mitigation measure is less effective during full moon periods and when bright deck lighting illuminates the surrounding area.

Proven specifications and standards

'Night' is generally accepted as being half an hour after nautical dusk to half an hour before nautical dawn. Lunar cycles have an influence on the efficacy of night setting (Klaer and Polacheck 1998).

Likely uptake

Night setting is a practical, cost effective and readily achieved mitigation measure for large and small vessels. Longer daylight hours reduce fishing time available at higher latitude during summer months.

Effect on target catch

Reportedly NZ surface long-line fishers prefer to set their lines during daylight hours when they are targeting swordfish so the gear is fishing by dusk. Having gear soaking at dusk is also beneficial to big-eye tuna catch per unit effort (D. Goad pers.com). Research exploring the variables affecting swordfish CPUE, found that CPUE was lower on sets starting after midnight and before mid-afternoon in the NZ EEZ (Murray and Griggs 2003). Portuguese fishers reportedly prefer to set at night when targeting swordfish (A. Wolfaardt pers. comm.).

Effect on non-target catch

Night setting has not been shown to lead to an increase in non-target catch rates.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (VMS, cameras), patrol vessels and patrol-plane fly overs.

- **Hurdles to uptake in New Zealand**

Night setting is already a legal requirement if line weighting is not used by surface long-line vessels in New Zealand. NZ law requires fishers to use two out of three prescribed mitigation measures; tori-lines, line weighting and night-setting (MPI 2016). ACAP recommend the concurrent use of all three measures. Setting at night does not mitigate against incidental seabird mortality at the haul.

- **Costs per vessel for installation/uptake**

There is no direct cost to fishing at night. Indirect cost is primarily less time available to set gear and potentially lower CPUE (catch per unit effort) in swordfish fisheries

Line weighting and weight spacing

Broader efficacy testing (may require refinement)

Some fisheries

- **Mitigation measure and how it works**

Seabirds are at most risk of capture on baited hooks between the time the hooks are deployed behind a vessel and when they sink beyond the diving ranges of seabirds. For surface long-line fisheries, adding weight to the branch lines (snoods) increases the sink rate of baited hooks, thereby reducing the time available for birds to access baited hooks. As described below, the position of the weight in relation to the hook and the size of weight are critical.

- **Description of results of development to date**

Experimental studies from the early 2000s showed clear evidence for line-weighting as a seabird bycatch mitigation measure (Brothers et al. 2001; Brothers et al. 1999). Most of the line weighting development has focused on position of the weight in relation to the hook, size of weight and weight designs to improve safety (see later sections). Anderson and McArdle (2002) compared the sink weight of lead core snoods with monofiliament snoods (both weighted and unweighted) and found that despite the total weight of a lead core branchline being 215 g, compared with 180 g for the lead swivelled branchline, it sank only marginally faster than the unweighted branchline. This would suggest that the total weight of the branchline is not directly related to an increase in hook depth.

- **Description of results of testing to date**

Numerous experimental studies have tested various degrees of line-weighting against standard fishing practices in surface long-line fisheries and have shown line weighting to be effective (Melvin et al. 2010; Boggs 2001). Research in an Australian fishery targeting tuna and swordfish showed baited hooks on fishing gear with a 120 g lead weight 2 m from the hook reduced the time to reach 2 m, 5 m and 8 m depths by 16%, 58% and 70%, respectively, compared with industry standard gear with 60 g at 3.5 m. 40 g leads placed at the baited hooks reduced the time hooks took to reach 2 m, 5 m and 8 m depth by 33%, 28% and 25%, respectively. The reduction in time with a 60 g lead at the hook to these depths was approximately 40% (Robertson et al. 2013). Weighted surface long-lines will not completely eliminate the area behind the vessel where birds can access hooks.

- **Development and testing needed to meet ACAP's criteria**

Line-weighting is already recognised as best practice in surface long-line fisheries by ACAP, when used in conjunction with night setting and tori lines (ACAP 2014a). ACAP recognise that weight closer to the hook results in the fastest sink rates and therefore better mitigates risk. Clear guidelines are provided by ACAP (Barrington et al. 2016c; ACAP 2014a) and the New Zealand Government. Guidelines based on robust testing are, 40 g or greater attached at the hook; or 60 g or greater attached within 1 m of the hook; or 80 g or greater attached within 2 m of the hook (Barrington et al. 2016c). ACAP do not recommend positioning weight farther from the hook. The ACAP Seabird Bycatch Working Group also state that the above recommended weighting regimes provide some protection against non-compliance to the use of bird scaring lines and night setting, due to much faster sink rates (Barrington et al. 2016c).

Effectiveness

Experimental research has shown line-weighting to be an effective technique for reducing incidental seabird captures in surface long-line fisheries (ACAP 2014a).

Proven specifications and standards

Clear minimum performance standards and proven specifications have been defined for surface long-line fisheries (Barrington et al. 2016).

Likely uptake

A few vessels operating in the NZ surface long-line fishery currently use line weighting as standard practice, demonstrating that the necessary materials are cost-effective and widely available.

Effect on target catch

Weighting surface long-line branch-lines did not affect the catch rates of target and non-target fish in studies in Brazil, Uruguay, South Africa and Australia (Gianuca et al., 2013; Jiménez et al., 2013; Melvin et al., 2011, Robertson et al., 2013b).

Effect on non-target catch

No evidence was found that showed line-weighting increases non-target catch (Gianuca et al., 2013; Jiménez et al., 2013).

Compliance

The NZ Ministry for Primary Industries (MPI) consider ensuring compliance for line-weighting would be 'relatively low cost and simple, compared to at-sea or aerial surveillance. Once lead weights are added to the snoods, they become an intrinsic part of the fishing gear. Monitoring could occur by means of port-based inspections of snood lines in gear bins before and after fishing trips' (MPI 2016).

- **Hurdles to uptake in New Zealand**

Snood weighting has been used by a small number of vessels in the NZ surface long-line fleet since 2008 (New Zealand Government 2008). Broader uptake has not occurred because there are concerns of safety due to risk of injury to crew when weights 'fly-back' at speed when lines are broken (e.g. shark bite-offs). Fly-back incidents have been the cause of at least 10 reported injuries and three fatalities internationally between 1994 and 2014 (McCormack and Papworth 2014). Methods to address these safety concerns are discussed in the double weighting, Sliding Leads (formerly Safe Leads) and Glo / Lumo Leads mitigation measures below. In addition, those skippers who routinely use line weighting have onboard procedures and fishing practices that mitigate the risk of "fly-backs" injuring crew. Once these are understood and verified they need to be shared with other skippers in the fleet. The NZ Ministry for Primary Industries released a consultation document to seek feedback from stakeholders on proposed options to strengthen seabird mitigation requirements for commercial surface long-line fishing operations in New Zealand fisheries waters, including line-weighting be used at all times (MPI 2016).

- **Costs per vessel for installation/uptake (if available)**

60 gm weighted swivel NZ $1.05 – 1.20

Lumo-Lead GBP £0.50 per 45 g unit and GBP £0.55 per 60 g unit, not taking shipping costs to NZ into account. Glo-lead AUD $1.40 (untested Chinese replica)

Double weighting

Broader efficacy testing (may require refinement)

Not in use / very limited use

- **Mitigation measure and how it works**

The design is intended to both reduce incidental seabird bycatch and to reduce the potential for injury from weights recoiling during line bite-offs. As with other types of line weighting, the design aims to sink surface long-line hooks beyond the range of seabirds within the aerial extent of a tori line during line setting.

The double-weighting method consists of two leads secured at each end of a 1 to 1.5 m section of wire or wire trace. This weighted section is inserted into a monofilament branchline 2 meters above the hook. The weight nearest the hook is free to slide along the branchline while the second weight is fixed. The 1 to 1.5 meter section of stretch resistant line (wire) further acts to reduce the potential force of a recoil. This double weight system reduces the danger of weight recoil injury in two ways; it spreads the mass of the weights across the wire trace and by including a sliding weight it reduces the speed at which the weight can recoil in the case of bite-offs.

- **Description of results of development to date**

The double-weighting method for surface long-lines was developed by Japanese fisher Kazuhiro Yamazaki (WWF 2011). The concept is designed to be used in conjunction with tori lines and night setting.

- **Description of results of testing to date**

Experiments using the Yamazaki double weight lines in 2010, in conjunction with two bird-scaring lines, yielded results that estimated a 86% reduction in seabird bycatch compared to un-weighted branch lines (Melvin et al. 2010). Furthermore no effect on fish catch rates or injuries to fishermen were recorded while using the Yamazaki double weight system (Melvin et al. 2010).

- **Development and testing needed to meet ACAP's criteria**

ACAP endorse the simultaneous use of double weighting when used in conjunction with tori lines and night fishing as best-practice seabird bycatch mitigation in surface long-line fisheries.

Effectiveness

When used with tori-lines, a double-weighting system reduced seabird bycatch by 86% when compared to sets with no line weighting (Melvin et al. 2010). A double-weight set with two tori-lines that achieved an aerial extent of 100 m behind the vessel resulted in a reduction in birds attacking baits by factor of four, and secondary attacks and incidental seabird mortality by a factor of seven, compared to unweighted branch lines (Melvin et al. 2014). Bird mortalities decreased to zero when weighted gear set with tori-lines was set at night (Melvin et al. 2014).

Proven specifications and standards

Clear metrics for achieving a safe, fast-sinking method of double-weighting are provided in Melvin et al. (2014).

Likely uptake

During research on two Japanese long-liners operating in South Africa the double-weight system was preferred to a single lead weight due to being more compatible with a coiled branch line system and was thought to be safer (Melvin et al. 2014). After the research work by Melvin et al. (2010 and 2014) captains in South Africa implemented line-weighting voluntarily in 2010 (Melvin et al. 2014), but may not be in use as commonly anymore.

Effect on target catch

Mean target fish catch between weighted and unweighted branch lines was very similar; 14.1 fish/1000 hooks on unweighted and 13.2 fish/1000 on weighted hooks (Melvin et al. 2014)

Effect on non-target catch

Melvin et al. (2014) did not record an increase in non-target catch.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras) and vessel inspections in port or at sea.

- **Hurdles to uptake in New Zealand**

In the Melvin et al. (2010) study double-weighted branchlines tangled on themselves three times more often than unweighted branchlines. Further tangle problems arose in subsequent research, but did not impact upon target fish catch rates and Japanese fishers continue to innovate and improve on the double-weight concept to minimize tangles (Melvin et al. 2014).

- **Past and current funders and developers (if applicable)**

World Wildlife Fund

- **Costs per vessel for installation/uptake (if available)**

Approximately NZ $2.00 per hook

Safe Leads (a type of sliding lead)

Broader efficacy testing but no longer recommended

Not in use

- **Mitigation measure and how it works**

Sliding Leads are a commercially produced product available from Fishtek Marine (UK). Instead of attaching lead weighted swivels above the hook, which can present significant safety issues for the crew during bite-offs (see line-weighting), Sliding Leads were developed to provide fishers a safer alternative to weighted swivels. Sliding Leads were previously called Safe Leads but the name was changed to better describe their function.

Sliding Leads consist of two halves of a lead that enclose the line and are held together by two rubber rings (Fig. 1). When bite-offs occur the line stretches 10 – 20% before breaking and the resulting accelerating force on the lead is equivalent to over 100 kg, much more than the 5 kg internal gripping force of the Sliding Lead. Therefore the weight simply slides towards or off the end of the branch line, reducing the recoil force of the stretched line.

- **Description of results of development to date**

The Sliding Lead was developed by Fishtek Marine and Birdlife International. Fishtek Marine are currently only producing Lumo Leads (see below). Sliding Leads could be produced by Fishtek Marine by special order, but Fishtek Marine consider that Lumo Leads have superseded Sliding Leads (H. Thompson, Fishtek Marine pers. comm.).

- **Description of results of testing to date**

Trials on fishing vessels in South Africa illustrated that Sliding Leads dramatically reduce the incidence of fly-backs as a result of bite-offs (Sullivan et al. 2012). The South African research showed 4.2% of fly-backs of Sliding Leads reached the vessel compared to 73.3% of leaded swivel fly-backs hitting the vessel. Because bite-offs are rare events, the authors conducted further research ashore to test the rate of Sliding Leads sliding off the line under varying attachment distances relative to the hook (2.0 – 5.7 m) and four line tensions (20, 60, 80, 120 kg). Sliding Leads placed within 2 m of the hook slid off the line under all four tensions tested. When placed 3 m from the hook the proportion of Sliding Leads that slid off the line was reduced to 80% for the higher two line tensions trialled; 80 and 120 kg. Importantly, high speed photography of fly-backs during the trials ashore showed a statistically significant reduction in the velocity on impact of Sliding Leads compared to leaded swivel and greater than 80% reduction in kinetic energy on impact (Sullivan et al. 2012).

Sliding leads have been trialled in New Zealand. Pierre et al. (2015) reported on trials of Sliding Leads from two vessels in 2013. Fishers reportedly incorporated Sliding Leads into their fishing gear easily. Sink rates for 60-g Sliding leads were faster than normal gear to 7 m depth but below 4 m depth, there was more variation in sink rates amongst Sliding leads (Pierre et al. 2015). For this reason it appears that more needs to be understood about float rope lengths and the proximity of the safe leads to a surface float and how this contributes to variable sink rates.

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Further testing would need to be conducted to illustrate via experimental research that Sliding Leads specifically are able to significantly reduce seabird bycatch. Neither Sullivan et al. (2012) or Pierre et al. (2015) used seabird bycatch rates to evaluate the efficacy of Sliding Leads as a bycatch reduction measure. The New Zealand research showed that hooks using Sliding Leads would still be available to seabirds (Pierre et al. 2015). This is because hooks weighted with Sliding Leads were only 4 – 7 m deep at 75 m astern of the vessel. Sliding Leads do satisfy the ACAP best-practice weight requirements (Barrington et al. 2016) but are recommended in conjunction with tori lines and night setting.

Proven specifications and standards

The work of Sullivan et al. (2012) showed clear and proven specifications for Sliding Leads to achieve safer fishing practices than with weighted swivels. However the research did not address sink rates relative to gear configuration and how this would reduce the access to hooks from seabirds. The scope of the New Zealand Sliding Lead trials also did not address the problem of hooks being at accessible depths (4 – 7 m) beyond the range of bird-scaring lines (Pierre et al. 2015). This is however a problem across all line-weighting in surface long-line fisheries.

Likely uptake

Pierre et al. (2015) reported Sliding Leads were easy to incorporate into fishing gear, but that this must be done well ahead of fishing operations as it took some time due to the detailed nature of the process.

Effect on target catch

Australian research indicates fish catches are unlikely to be affected by Sliding Leads (Robertson et al. 2014)

Effect on non-target catch

There is no evidence that Sliding Leads would increase the bycatch rate of other taxa.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras) and vessel inspections in port or at sea.

- **Hurdles to uptake in New Zealand**

The Ministry for Primary Industries recommended Sliding Leads be used in New Zealand surface long-line fisheries in 2014 (MPI 2014). While Sliding Leads significantly increase safety for crew, Pierre et al. (2015 reported an instance of a Sliding Lead not sliding off the line and as a result the Sliding Lead hit the vessel with significant impact. In addition, Pierre et al. (2015) note that there are still risks to crew when hooks tear out of fish during the haul. Sliding leads have been superseded by Glo / Lumo Leads (see below).

Extra labour needs to be considered in regard to Sliding Leads. Incorporating Sliding leads into fishing gear takes time so must be conducted prior to fishing operations (Pierre et al. 2015).

- **Past and current funders and developers (if applicable)**

Birdlife International and Fishtek Marine.

- **Costs per vessel for installation/uptake (if available)**

No price available as the product is not currently in production, but is avaliable by special order (H. Thompson, Fishtek Marine pers. comm.).

Lumo Leads and Glo leads

Broader efficacy testing (may require refinement) Lumo Leads only, all imitation products untested

Some fisheries

- **Mitigation measure and how it works**

Lumo Leads are a commercially produced product available from Fishtek Marine, the same UK company that developed Sliding Leads, and to achieve the same goal of reducing the risk of dangerous fly-backs that can occur as a result of bite-offs with standard, lead weighted swivels. Marketed in the United Kingdom as Lumo Leads. Three types of lead are available: the original Lumo Lead which glows for 6 hours and, where shark bycatch is an issue, two non-glowing colours, black and natural, all are available in two sizes; 45 g and 60 g (Fig. 1). A collet chuck system is used to lock the Lumo Leads to the line to hold the weight in position, but in the event of a bite-off allow the lead to slide down or off the line.

- **Description of results of development to date**

The Fishtek Marine development of Lumo Leads was an offshoot of Sliding Leads. The locking collar on the Lumo Lead is considered an advancement on the rubber components of the safe lead because it makes attachment easier and the rubber component sometimes failed (H. Thompson, Fishtek Marine pers. comm.).

- **Description of results of testing to date**

Lumo leads have been tested in Brazil, Australia and New Zealand (Claudino dos Santos et al. 2016; Pierre et al. 2015; Robertson 2014). No testing of Glo leads was found.

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Recent research from the Brazilian surface long-line fishery compared 60g Lumo Leads spaced at either 1 m or 3.5 m from the hook to 60g weighted swivels. The Lumo Leads placed 1 m from the hook caught fewer birds than either weight 3.5 m from the hook (Claudino dos Santos et al. 2016). New Zealand research found that Lumo Leads had faster sink rates than weighted normal gear, supporting Lumo Leads as an effective mitigation device (Pierre et al. 2015).

A single Australian distributor markets 'Glo' leads, apparently a direct replica of Lumo Leads. The company states that the product was developed by Queensland fishers in collaboration with an Australian Fisheries Management Authority (AFMA) scientist. Another version of the Lumo Lead is also marketed in New Zealand (by Maui Ocean Pro) under the name Lumo Lock. No information could be found relating to the testing, manufacture, or use of the Lumo Lock. A third company is reportedly developing an imitation of the Lumo Lock (G. Cleary, Maui Ocean Products pers. comm.). Devices that have not been trialled should not be assumed to have the same level of efficacy to reduce incidental bycatch as the original design being imitated.

Proven Specifications and standards

Brazilian, Australian and New Zealand studies (Claudino dos Santos et al. 2016; Pierre et al. 2015; Robertson 2014) provide proven specification and standards.

Likely uptake

Australian tuna fishers reportedly voluntarily changed to Lumo Leads because of operational and safety advantages (Robertson 2014). The Australian Fisheries Management Authority did not respond to requests to substantiate the level of uptake. New Zealand fishers experimentally using Lumo Leads quickly incorporated Lumo Leads into their fishing operation (Pierre et al. 2015).

Effect on target catch

The majority of studies have found no negative effect on catch rates when Lumo Leads were used. For example trials in the Brazilian surface long-line fishery comparing Lumo Leads to 60g weighted swivels found no difference in catch rates of tuna, shark and bill fish between the two leads (Claudino dos Santos et al. 2016). A study in New Zealand showed catch rates of tuna and swordfish was the same when using 40-g Lumo Leads as for standard gear however shark catch was lower than when fishing with normal gear (Pierre et al. 2015). Australian trials have shown that 45g Lumo Leads placed at the hook will not reduce target catch of tuna and tuna like species when compared to traditional line weighting regimes (Robertson et al. 2013).

Effect on non-target catch

Studies to date have not shown an increase in the bycatch of other taxa.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras) and vessel inspections in port or at sea.

- **Hurdles to uptake in New Zealand**

The Ministry for Primary Industries recommended Lumo Leads be used in New Zealand surface long-line fisheries in 2014 (MPI 2014). The ability to change between luminescent and non-luminescent Lumo Leads is only an option if the vessel carries both glow and non-glow version of Lumo Leads.

- **Past and current funders and developers (if applicable)**

Birdlife International and Fishtek Marine.

- **Costs per vessel for installation/uptake (if available)**

AUD $1.40. GBP £0.50 per 45g unit and £0.55 per 60g unit, not taking shipping costs to NZ into account.

Figure 1 . Lumo Leads (Image: Fishtek Marine)

Smart Tuna Hook

Limited efficacy testing

Not in use

- **Mitigation measure and how it works**

The Smart Tuna Hook is designed to prevent seabirds from ingesting baited hooks. A circular, steel shield that is attached to a modified tuna long-line hook (circle or Japanese style) creates a barrier encompassing the hook's point and barb, which prevents seabirds accessing the bait (Fig. 2). The

Smart Hook also adds weight to the branchline, increasing the sink rate of the hook and thus reducing the amount of time the hook is available to birds. A corrodible alloy link dissolves within 15 – 20 minutes after the hook is immersed in salt water, causing the shield to be released. The shield then sinks to the sea floor and corrodes to iron oxide and carbon within 12 months, leaving no toxic residue or problematic pollution. An advantage of the Smart Hook detaching during the soak is that the added weight is no longer present during hauling, addressing safety concerns in relation to bite-offs. After the shield dissolves, the hook is no longer protected during the soak and haul parts of the fishery operation.

- **Description of results of development to date**

Hans Jusseit, a retired fisher and former CEO of the Australian East Coast Tuna Fishery, developed the original concept for the Smart Hook. Jusseit originally considered producing larger hooks that could not be swallowed by seabirds, but then decided upon a protective shield. The Smart Hook is currently being developed under AHI Enterprises Ltd (Australia).

- **Description of results of testing to date**

The Smart Hook was sea tested in 2009 in the Coral Sea, Australia, and found the device was operationally effective and had no negative impact on setting gear (Jusseit 2010). Further, limited pilot testing was conducted in 2008, in Kaikoura, New Zealand. The pilot results showed encouraging results for the Smart Hook as a deterrent to albatrosses (*Diomedea* and *Thallasarche spp.)* and large petrels (*Macronectes spp.)*, species that are well represented in seabird bycatch. Prior to commercial production the need for a larger, experimental trial was identified. In 2014 Barry Baker of Latitude 42 Environmental Consultants Pty Ltd designed and conducted at-sea trials in South Africa for AHI Enterprises. The trials were on two surface long-line vessels with similar configurations and operational procedures, targeting tuna and swordfish off of Cape Town.

- **Development and testing needed to meet ACAP's criteria**

Barrington (2016a) tabled a report recommending that the ACAP Seabird Bycatch Working Group (SBWG) recommend the Smart Hook as a stand-alone best practice seabird bycatch mitigation device in surface long-line fisheries.

Effectiveness

The Smart Hook is only effective as a mitigation method when setting gear as the protective shield is no longer present when the gear is hauled. Experimental research over three fishing trips and 28 long-line sets showed the use of the Smart Tuna Hook led to a reduction in seabird bycatch of 81.8% – 91.4% (Baker and Candy 2014). The research compared the mitigation required by the South African regulators (80 g weighted swivel placed 3.2 m from each hook, and night setting) to the same gear configuration but with the Smart Hook instead of regular hooks. Further research trips testing the Smart Hook in other fisheries would be beneficial.

Proven specifications and standards

The Smart Hook is a simple device and thus has clear and proven specifications and minimum performance standards. For ACAP these are that the device shields the hook until a prescribed depth of 10 m or immersion time of 10 minutes is reached and the device meets current recommended minimum standards for branch line weighting described. ACAP have assessed the device as a stand-alone mitigation method (Barrington 2016a), eliminating the need for measures such as bird scaring lines, line weighting and night setting.

As with other devices, caution should be used if untested imitation products enter the market.

Likely uptake

The Smart Hook is practical and simple for fishers to use. There was some concern that the pin holding the protective shield in place could corrode if splashed on the deck of a vessel, but the shield needs to be fully submerged for at least ten minutes to dissolve. Cost effectiveness and wide availability will depend on uptake by the industry. If the device is mass produced the cost can be lowered significantly (e.g. US $0.50 to US $0.20 per hook). In addition the use of recycled steel stands to lower the price further.

Effect on target catch

Baker and Candy (2014) found no detectable difference between catch rates for setting methods using regulator required mitigation and the Smart Hook for swordfish, yellow-fin tuna, big-eye tuna, southern Bluefin tuna, albacore tuna and other commercially targeted species. Early work suggested the possibility that catch rates may be increased by approximately 10% using the Smart Hook (Jusseit 2010), but this has not yet been shown statistically.

Effect on non-target catch

There is no evidence that the Smart Hook increases the bycatch of other taxa.

Compliance

Minimum performance standards have been proven through experimental trials (Baker and Candy 2014). AHI Enterprises controls the rights to produce the Smart Hook, so can ensure production is standardised to the design that was used in experimental work. To monitor the use of Smart Hooks, the use of a dispensing unit on vessels was investigated but as this would entail extra gear on the vessel deck, the concept has not been taken further. Cameras may be used on vessels to ensure compliance.

- **Past and current funders and developers (if applicable)**

Hans Jusseit funded the design and development of the Smart Hook. Funding for testing was provided by the Agreement on the Conservation of Albatrosses and Petrels, Hans Jusseit, AHI Enterprises and Commercialisation Australia.

- **Hurdles to uptake in New Zealand**

The greatest apparent limitation to the use of the Smart Hook in New Zealand is Maritime New Zealand's interpretation of MARPOL (International Convention for the Prevention of Pollution from Ships). Maritime New Zealand (MNZ) currently maintain that intentionally discarding any material into the sea violates MARPOL (MNZ Rules Part 170). In addition cost, and unless broad-scale uptake occurs, availability, may inhibit uptake. As explained above, greater production volumes and the use of recycled steel will lower the price substantially.

- **Costs per vessel for installation/uptake**

Cost per vessel depends on the number of hooks vessels set each year. Smart Hooks currently retail for US $0.50 per hook shield but as stated above if mass produced the cost can be lowered to US $0.20 per hook, and the use of recycled steel stands to lower the price further.

Figure 2. Smart Tuna Hook (Image: Oceansmart)

Hook pod

Broader efficacy testing (may require refinement)

Not in use / very limited use

- **Mitigation measure and how it works**

The hook pod is a baited hook that is released from a reusable plastic housing once it reaches a prescribed depth (10 – 100 m) (Fig. 3). The Hook Pod also has an LED light that emits flashing or constant light when the hook is released. The Hook Pod is then hauled as per usual, the hook closed back into the housing by hand and the device stored until next used. The pod has been designed to last for 2 – 3 years of normal fishing operations. Once the hook is released from the protective housing during setting, the hook is no longer protected during the soak and haul parts of the fishery operation.

- **Description of results of development to date**

The Hook Pod has been in development since the late 2000s and was first trialled in Tasmania in 2009. The device was refined further and from 2011 – 2015. Hook Pods were trialled on commercial fishing vessels in New Zealand, Australia, Brazil and South Africa (Sullivan et al. *in* Barrington 2016b; Pierre et al. 2015). Information relating to long term use in the commercial environment regarding the reliability of the hook pod opening, rate of breakage, rate of loss and expected life of Hook Pods are not yet available.

- **Description of results of testing to date**

Trials were undertaken in Japan in 2015 and Hook Pods are being tested on another Japanese long-liner in 2016. Results from both of these trials have not yet been publicised. A small New Zealand trial conducted in 2014 saw 272 hook pod deployments over six sets (Pierre et al. 2015). Because Hook Pods cannot be swallowed by seabirds, the sink rate isn't important from a seabird mortality perspective, but from a fishing efficiency perspective, fishers may wish to know the sink rate of their gear is not affected by the hook pod (i.e. no loss of fishing time). In that trial fishers incorporated the Hook Pods into their gear easily, the sink rates of Hook Pods were faster than normal gear for the first 5 – 6 m, but then the functionally shorter snoods, resulting from the attachment of the Hook Pods part way along, decreased sink rates beyond 5 – 6 m when compared to normal gear (Hook Pods ~ 65 seconds from 5.5 m – 10 m depth and normal gear ~ 55 seconds) because the sink rate of the backbone takes effect on Hook Pods earlier than for normal gear (Pierre et al. 2015). Therefore, the sink rate of the backbone itself comes into play earlier than for normal gear with effectively longer snoods.

The 2014 trials lead to further New Zealand trials in 2016, using a "mini" Hook Pod made specifically for NZ surface longline fisheries. Pierre et al. (2015) suggested this may act to reduce the probability that Hook Pods would tangle with other fishing gear. Without the LED light these Hook Pods are 30% smaller and 25% lighter than pods trialled to date (Sullivan 2016). Fishers expressed enthusiasm that catch rates were maintained, devices were durable and for the ease of fitting Hook Pods into their fishing operation.

- **Development and testing needed to meet ACAP's criteria**

Barrington (2016b) tabled a report suggesting that the ACAP Seabird Bycatch Working Group (SBWG) recommend the 'Hook Pod' as a stand-alone best practice seabird bycatch mitigation device in surface long-line fisheries, indicating that the Hook Pod has achieved the six ACAP Seabird Bycatch Mitigation Criteria.

Effectiveness

Trials in Brazil, South Africa and Australia were conducted during 19 fishing trips deploying 62,000 hooks in 127 sets. In total 24 seabirds (0.77 birds per 1000 hooks) were caught using normal line-weighting versus one bird (0.034 birds per 1000 hooks) when Hook Pods were deployed (Sullivan et al. *in* Barrington 2016b).

Proven specifications and standards

Clear specifications and standards are presented in (Sullivan et al. *in* Barrington 2016b).

Likely uptake

Hook Pods are not yet widely available but are expected to be as soon as the machinery for commercial production has been developed (Sullivan et al. *in* Barrington 2016b). Whilst there is a cost to Hook Pods, money is saved on light sticks and other line weighting materials because neither of these is required when using Hook Pods (Sullivan et al. *in* Barrington 2016b). There is an ongoing cost of batteries, but batteries are estimated to cost AUD $0.10 and last for approximately 40 sets.

Effect on target catch

Experimental research found no reduction in catch rates when using the Hook Pod in tuna and swordfish fisheries (Sullivan et al. *in* Barrington 2016b). The 2016 New Zealand study found no significant difference in catch rate or size of target species. The sink rate of Hook Pods was slightly slower than for normal gear after 5.5 m (Hook Pods ~ 65 seconds from 5.5 m – 10 m depth and normal gear ~ 55 seconds) (Pierre et al. 2015).

Effect on non-target catch

Trials in Brazil, South Africa and Australia found no evidence that that Hook Pod increased the bycatch of other taxa. Preliminary results suggest sea turtle bycatch may be reduced when using Hook Pods (Sullivan et al. *in* Barrington 2016b), but no analyses have been provided.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras) and vessel inspections in port or at sea.

- **Hurdles to uptake in New Zealand**

The operational commercial cost per hook is not clear at this point as the life of the Hook Pod under normal fishing conditions is not known. There has been at least one instance of seabirds getting caught in the loop of branchline (N. Walker pers. comm.).

- **Past and current funders and developers (if applicable)**

Birdlife International, Fishtek Marine, Projeto Albatroz

- **Costs per vessel for installation/uptake (if available)**

Standard AUD $17 per hook; 50 g Hook Pods with no LED light AUD $10 per hook. The estimated life of a Hook Pod is two to three years, depending on the amount of fishing time.

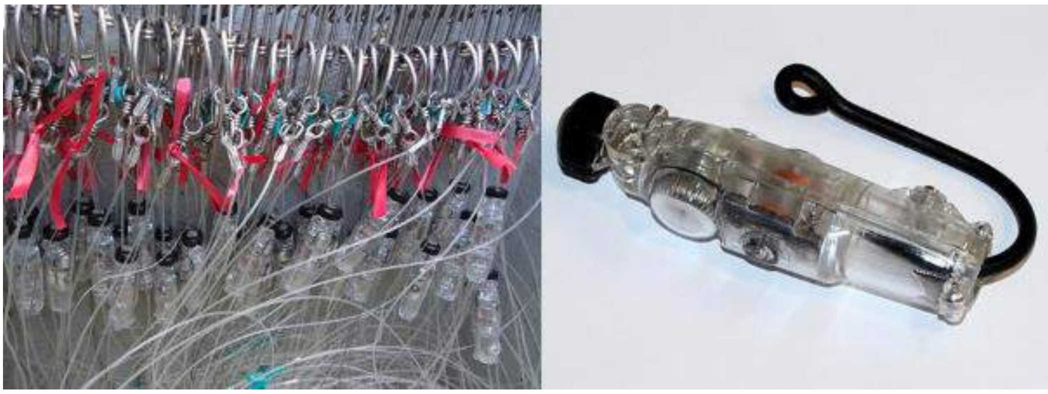


Figure 3. Hookpod (left: RSPB, right: Oliver Yates)

Underwater bait setter

Early prototype / functionality tests

- **Mitigation measure and how it works**

Lines set underwater eliminate the visual cue of available food and reduce the time baited hooks are available to birds, therefore reducing bycatch. The underwater bait setter is a computer controlled, hydraulically-operated device mounted on the stern of long-line vessels. Baited hooks are deployed individually in a steel capsule beneath the average dive depths of albatrosses and petrels (Fig. 4). Once the hook is released from the protective capsule during setting, the hook is no longer protected during the soak and haul parts of the fishery operation.

- **Description of results of development to date**

New Zealand fisher Dave Kellian first pioneered the concept of setting long-line hooks underwater to eliminate seabird bycatch and worked with a local engineer to develop and trial a prototype in 1997–98. The Australian Fisheries Research and Development Corporation and DOC in NZ contributed funding in the late 1990s for trials in New Zealand and Tasmania, overseen by Nigel Brothers from Tasmanian Parks and Wildlife. Solander Seafood provided a vessel and funding for a trial which led to further refinements of the device. More improvements to the capsule were made after trials in 2003 but the device still did not function one hundred percent effectively. Graham Robertson from the Australian Antarctic Division became involved in the mid-2000s and with major funding from the Packard Foundation and International Association of Antarctic Tourism Operators (IAATO) worked with Amerro Engineering to remedy the few remaining problems.

- **Description of results of testing to date**

Experimental work conducted on the underwater setter have shown that the device is practical for fishers on a number of important points. These are (1) the cycle times of the hook from release to recovery are practical for most fishery operations, (2) bait retention is not negatively affected and (3) the device is safe to use in a range of fishing conditions. Cycle times varied depending on vessel speed and depth. The deeper the target depth for hooks to be released from the capsule the longer the cycle time. Average cycle times were 7.4 – 15.2 seconds for vessel speeds of 6 – 9 knots setting hooks at a mean maximum depth of 5.4 – 9.7 metres (Robertson et al. 2015).

The device has also been tested using time depth recorders (TDRs) and the results show the device to be effective at releasing baits at depths that eliminates the visual cue of bait to diving petrels and albatrosses (6 – 10 m for the most commonly caught species).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

The Smart Hook is only effective as a mitigation method when setting gear, so won't mitigate soak and haul captures. The underwater bait setter has not been experimentally compared to current best-practice mitigation for surface long-line fishing (night setting, tori-lines and line weighting) or to fishing with no mitigation with the exception of a limited trial in Uruguay in 2010 and 2012.

Research using two prototypes in Uruguay in 2010 and 2012 involved alternating from normal hand setting to using the underwater bait setter. The work was not completed because the fishery was closed early that season, and due to the cost of conducting at sea trials no further work has been conducted there. Observations showed constant attack rates occurred until changing to the underwater setter, when seabird attendance and hook attack rates were eliminated because the baited hooks were no longer visible. Two birds were caught at 6 m deep in 2010 and two further at 10 m deep in 2012. Bird attacks on bait hooks were not apparent during setting so it is possible that these seabird captures occurred during the soak, when a fish brought gear to the surface (G. Robertson pers. comm.).

Further testing of the underwater bait setter is hoped to begin in NZ in the near future.

Proven specifications and standards

The underwater setter has clear performance specifications and minimum performance standards. Most important is the deployment of hooks below a depth where most seabirds are able to dive too and with an associated sink rate that further reduces the probability birds can access baits.

Likely uptake

The underwater bait setter is relatively easy to install on vessels, taking three people and a forklift about 4 – 5 hours. The design tested to date is a self-contained unit, which includes having its own power via a three-phase motor and a 50 litre tank of hydraulic oil. If the device can instead be powered from a vessel's existing hydraulic system, the unit will be much lighter so installation and removal would be easier.

The underwater bait setter has a high initial cost, at approximately AUD $30,000. But if hydraulic oil is filtered properly, the units are estimated to last for 12 years. The spectra rope used to recover the steel capsule needs to be replaced annually. Other ongoing maintenance requirements are as yet unknown.

The underwater setter is not currently available commercially, but if it is adopted by fishing industry then Amerro Engineering will mass produce the device for broad distribution.

Effect on target catch

Results from trials in Australia and Uruguay found no evidence that catch rates of target fish is reduced when using the underwater setter (G. Robertson pers. comm.).

Effect on non-target catch

There is no evidence that using the underwater setter could result in an in increase in bycatch of other taxa.

Compliance

Methods of ensuring compliance include observers or electronic monitoring (cameras). In addition the underwater setter has a data logging function so can record the number and location of all hooks deployed.

- **Hurdles to uptake in New Zealand**

The system is still in the prototype stage and has been for many years. The cost of the Underwater Setter equates to a significant upfront expense and potentially significant maintenance costs.

- **Past and current funders and developers (if applicable)**

The Underwater Bait Setter has been funded by DOC, Amerro Engineering, David and Lucile Packard Foundation (USA), Quark Expeditions, Peregrine Adventures, Commercialisation Australia Pty Ltd, Australian Fisheries Research and Development Corporation and the World Wide Fund for Nature.

- **Costs per vessel for installation/uptake (if available)**

Currently estimated as AUD $30,000, but if the Underwater Setter is mass produced the cost will be reduced.

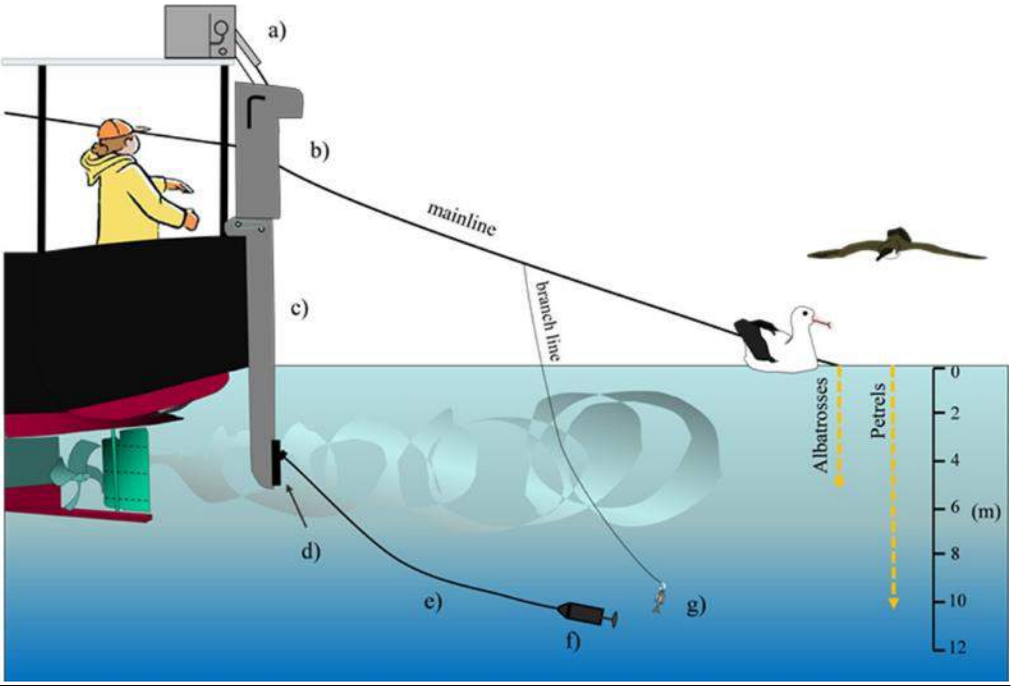


Figure 4. Underwater Setter. (a); head section of the track assembly (b); the track attached to vessel transom (c); capsule docking cart (d); Spectra rope connecting the capsule to the recovery motor winch (e); capsule with bait door fully extended (f) and baited hook following release from the capsule (g). Not shown is the systems control unit which is located in the wheel house and operated by the skipper. Dive depths of the main seabird groups are indicated at right. The curved shapes above the capsule depict aerated water thrust from the propeller (Image: Robertson et al. 2015).

Bait caster

Limited efficacy testing

Not in use (as a seabird bycatch mitigation measure)

- **Mitigation measure and how it works**

Bait casting machines deploy baited hooks during surface long-line fishing, thus saving the requirement of individual hooks needing to be cast by hand. Bait casting machines offer numerous advantages to fishers by reducing tangles in branchlines and reducing bait loss. The potential benefits to seabirds can be gained by the device allowing fishers to accurately place baited hooks below tori lines.

- **Description of results of development to date**

Bait casting machines, particularly the original Gyrocast Pty Ltd machine, showed promise as a mitigation device as using them enabled baited hooks to be placed beneath tori- lines, even in windy conditions.

- **Description of results of testing to date**

Early trials of Gyrocast Pty Ltd bait casters showed that bait loss to seabirds was lower if the machines reliably placed baited hooks beneath tori-lines (Brothers et al. 1999). Gyrocast Pty Ltd no longer manufacture bait casting machines. The models marketed currently do not have variable distance and direction of casting and are designed solely to improve fishing operations.

- **Hurdles to uptake in New Zealand**

Lack of evidence that bait casting machines are an effective mitigation device. Bait casters are not practical with the short snood length used in New Zealand (D. Goad pers. com.).

- **Development and testing needed to meet ACAP's criteria**

ACAP currently maintain that commercially produced bait casting machines need further development, followed by trialling, to be considered as a mitigation measure. Specifically, bait casting machines need to be capable of controlling the distance that baited hooks are cast.

- **Costs per vessel for installation/uptake (if available)**

Not applicable.

Dyed bait

Limited efficacy testing, qualitative measure of success from fisher reports

Some fisheries

- **Mitigation measure and how it works**

The logic behind dyeing bait (normally blue) is that the majority of seabirds are visual predators so birds will be less likely to take bait if it is difficult to see against the water.

- **Description of results of development to date**

Reports of fishers dyeing bait blue in the 1970s were reportedly to increase catch rates of target fish (ACAP 2014). More recent research has focused on the efficacy of dyed bait for mitigating incidental seabird mortality.

- **Description of results of testing to date**

Robust research in Hawaii found that dyeing squid bait blue reduced attacks during setting by black-footed (*Phoebastria nigripes)* and Laysan (*P. immutabilis)* albatrosses by 95% and 94% respectively, compared to lines set with un-dyed baits (Boggs 2001). In a second, Australian study, a 68% reduction in seabird interactions with blue-dyed squid was recorded compared to non-dyed squid (Cocking et al. 2008). The authors of both studies concluded that the use of blue-dyed squid bait could decrease seabird bycatch in surface long-line fisheries.

Importantly Cocking et al (2008) showed that blue-dyed fish was much less effective than blue-dyed squid. Approximately 48% of all blue-dyed fish baits presented in the first two days of trials received strikes from seabirds but this increased to 90% over the last three days, suggesting increased awareness of the dyed fish by seabirds.

Japan conducted research on the effect of blue-dyed bait to reduce the seabird bycatch in the southern blue fin tuna fishery off South Africa (Minami and Kiyota 2006). The authors reported a reduction in seabird catch rates of 75%. The research also found no evidence that tuna catch rates were significantly affected by the use of blue-dyed bait. The statistical strength of the Japanese research was questionable (Minami and Kiyota 2006).

The Western and Central Pacific Fisheries Commission state that blue-dyed bait may be used as a method to reduce incidental seabird bycatch, but it must be fully thawed when dyed. The Commission plans to distribute a standardized colour placard and all bait must be dyed to the shade shown in the placard (WCPFC 2016).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP (2014b) state that more experimental research is required to illustrate the efficacy of dyed bait for specific bait types, target fish and seabird species.

Proven specifications and standards

The specific type, concentration and target colour for all dyes used would need to be established for each fishery. These would then need to be tested against different bait types, fisheries and seabird species.

Likely uptake

Techniques for dyeing bait would need to be refined, or perhaps even better would be commercially available pre-dyed bait for use by fishers. At US $8 per 1000 hooks the price is not insignificant. Bulk purchasing of dyes, or commercially available dyed baits, may lower this figure significantly. Food grade dyes should be widely available.

Effect on target catch

Broader research needs to be conducted to ensure that blue-dyed bait does not reduce catch rates.

Effect on non-target catch

To date there is no evidence that blue dyed bait increases the bycatch of other taxa.

Compliance

Observers, cameras or port inspections would be required to ensure fishers are using dyed bait if it was mandatory.

- **Hurdles to uptake in New Zealand**

Bait needs to be completely thawed for it to absorb dye. Thawed bait may increase bait loss. Dyeing bait is messy and laborious. Birds may become habituated to dyed bait.

- **Past and current funders and developers (if applicable)**

Australian Natural Heritage Trust of the Department of Environment and Heritage

- **Costs per vessel for installation/uptake (if available)**

The Hawaiian study estimated the cost of dyeing bait as approximately US $8 per 1000 hooks (Boggs 2001).

Water cannons

Limited efficacy testing

Not in use

- **Mitigation measure and how it works**

Discharging water at high pressure from water cannons across the area hooks are available during gear setting, or during hauling, could prevent or reduce seabirds from entering the area, thereby reducing incidental bycatch.

- **Description of results of development to date**

This method has not been widely developed in surface long-line fishing. This is largely due to limited testing showing the method is not likely to effectively protect the area birds are at risk to incidental capture on hooks.

- **Description of results of testing to date**

Japanese researcher's trialled high-pressure hoses using a 30 kw pump and various nozzle tips, flow stabilisers, angles of flow direction and adding ice crystals to the water to increase the distance reached (Kiyota et al. 2001). Whilst seabirds avoided the water jet and did not try to fly under the water curtain produced, the water jet was hampered by cross winds. The resulting system had a maximum distance coverage of 60 m, and this was much less in cross winds. The authors concluded that the system was not viable as a stand-alone mitigation method, but may work in conjunction with other mitigation devices. In addition to insufficient distance achieved, strong winds can cause water from cannons to be blown back onto deck, saturating and significantly reducing the comfort of crew (Brothers et al. 1999).

- **Development and testing needed to meet ACAP's criteria**

ACAP state that the evidence to date is insufficient for water cannons to be considered a viable method of mitigating incidental seabird bycatch in surface long-line fisheries. Therefore further testing would be needed to establish if the method is viable. However it seems unlikely that sufficient distance could be achieved to provide adequate coverage of the full extent of the area birds are susceptible to incidental bycatch.

- **Hurdles to uptake in New Zealand**

Insufficient evidence to support the efficacy of the method, cost of installation is usually high (Wiedenfeld 2016), presents problems to crew due to wind blowing water back onto the vessels working area (Brothers et al. 1999), crew often have to actively manage the direction of the water jet (Wiedenfeld 2016).

Acoustic scarers

Limited efficacy testing, qualitative measure of success from fisher reports

Used in some fisheries

- **Mitigation measure and how it works**

Use of acoustic devices to produce loud noises to scare seabirds away from boats and prevent them from entering the setting or hauling area.

- **Description of results of development to date**

A commercially available device, Seabird Saver produced by Dutch company SaveWave, uses acoustic scaring technology alongside laser deterrents or as a stand-alone method. Japanese vessels chartered by Solander fisheries (J. Molloy pers. comm.) and NZ toothfish vessels (R. Wells pers. comm.) reportedly use gas cannons, designed for use in orchards, on board to scare birds away.

- **Description of results of testing to date**

A study from the South Georgia bottom long-line fishery found no evidence that long-lines set with an acoustic scaring device, emitting periodic bursts of compressed gas, caught fewer seabirds than lines set without an acoustic scaring device (Ashford et al. 1995). Clear changes in seabird behaviour were recorded in the study when the acoustic scaring device was first used, but birds quickly became desensitised to the noise. In a review of seabird bycatch Wiedenfeld (2016) also states that seabirds become habituated to acoustic scaring devices.

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Unproven. Extensive testing across fisheries and seabird species would need to be conducted to fulfil ACAPs requirement of clear evidence from experimental research.

- **Hurdles to uptake in New Zealand**

Insufficient evidence to support the efficacy of the method, cost of installation possibly high, may present problems to crew due to loud noise reducing communication clarity on the work deck, possible health and safety hazard if sufficiently loud.

- **Past and current funders and developers (if applicable)**

World Wildlife Fund.

- **Costs per vessel for installation/uptake (if available)**

Cost varies depending on the system selected.

Bait management

Tested comprehensively in all relevant fisheries and gear types

Widespread use

- **Mitigation measure and how it works**

Seabirds are attracted to fishing vessels to forage on fish waste and non-commercial species discarded by the vessel. Removing this source of food reduces the number of birds attending the vessel, thereby reducing the number of birds caught as bycatch.

- **Description of results of development to date**

Numerous studies have shown the abundance of seabirds attending a vessel is greatly affected by the presence of fish waste in the water around the vessel. Eliminating or reducing fish waste discharge is therefore an obvious way to mitigate incidental seabird bycatch.

- **Description of results of testing to date**

Significantly more birds follow fishing boats when releasing offal and this may create both short and long-term associations between fishing boats and food (Weimerskirch et al 2000).

- **Development and testing needed to meet ACAP's criteria**

ACAP (2014) currently recognise bait and discard management as a supplementary measure that cannot be used in isolation. ACAP recommend that no discharge of used baits should occur during setting and that used baits should be retained until hauling is complete and all hooks should be removed from discarded baits (ACAP 2014). If used baits are discharged during hauling this should be on the opposite side of the vessel to where hauling takes place to encourage birds away from the area baited hooks are available.

- **Hurdles to uptake in New Zealand**

Bait management is easily achieved on surface long-liners operating in NZ.

- **Past and current funders and developers (if applicable)**

Not applicable.

- **Costs per vessel for installation/uptake (if available)**

No significant costs to managing discarded baits in surface long-line fisheries.

Side setting

Limited efficacy testing (in the Southern Hemisphere)

Some fisheries (but not in New Zealand)

- **Mitigation measure and how it works**

By setting lines at the side of the vessel baited hooks enter the water and begin sinking before passing the stern. Depending on the distance in front of the stern lines are set during side-setting, hooks may sink to a greater depth by the time hooks become available to foraging seabirds behind the vessel.

- **Description of results of development to date**

Developed and mostly tested in Hawaii (and sometimes referred to as the Hawaiian method) in the presence of surface foraging seabirds (Gilman et al. 2007). Not directly tested in the Southern Hemisphere where diving seabirds (petrels and shearwaters) commonly attend vessels, and may contribute to secondary hooking by diving and bringing hooks to the surface where non-diving seabird species can ingest them.

- **Description of results of testing to date**

Trials conducted in Hawaii tested side-setting combined with a tori-line. Weighted swivels weighing 45 – 60 g, located 0.5 m from hooks showed side-setting was more effective at reducing seabird bycatch than underwater setting-chutes and blue-dyed bait (Yokota and Kiyota 2006). More recent Hawaiian research showed that side-setting resulted in a statistically significant lower bycatch rate of surface-foraging north Pacific albatross species than stern-setting (Gilman et al. 2016).

- **Development and testing needed to meet ACAP's criteria**

ACAP currently maintain that side-setting has not been sufficiently tested in the Southern Hemisphere, so is not recommended as a bycatch mitigation measure there. ACAP further state that there is an urgent need for research, particularly for the efficacy of side-setting, when combined with line-weighting and a bird-curtain, against assemblages of Southern Hemisphere diving seabirds. ACAP also state that a clear definition of side-setting is currently lacking. In Hawaii side-setting is defined as a minimum of only 1 m from the stern, which whilst working well in the presence of surface-foraging seabirds, such a short distance will likely reduce effectiveness in the Southern Hemisphere (ACAP 2014a).

- **Hurdles to uptake in New Zealand**

The benefits are perhaps limited to larger vessels where the side-setting position is sufficiently forward of the stern to allow sufficient sinking before the baited hooks pass the stern. There is a financial cost to converting a vessel to side-setting capability and potential for gear fouling on propeller(s). There is also increased crew exposure to swells when clipping branch-lines and side-setting.

- **Past and current funders and developers (if applicable)**

Not applicable.

- **Costs per vessel for installation/uptake (if available)**

Whilst a one-off cost, the expense of switching from stern-setting to side-setting will vary among vessels.

Thawed bait

Limited efficacy testing

Not in use

- **Mitigation measure and how it works**

The buoyancy of baits may vary depending on its state, frozen or thawed. Less buoyant baits sink faster, so are available to birds for shorter periods of time.

- **Description of results of development to date**

Experimental work in the 1990s, and analysis of observer data, suggested that thawed baits sink faster than frozen bait (Brothers et al. 1995).

- **Description of results of testing**

Studies testing the effectiveness of thawed and frozen bait produced conflicting results. Brothers et al. (1995) tested sink rates of frozen versus thawed bait in a seawater tank. Thawed baits sank significantly faster than frozen bait, but the sink rate was affected by the state of the swim bladder in fish baits (Brothers et al. 1995), and the bait size and species. In another study, data from a total of 141 line sets on 86 longlining vessels operating around Tasmania, Australia, between April 1992 and March 1995, showed sets that used partially or completely thawed bait had significantly lower bycatch rates, compared to sets using unthawed bait (Klaer & Polacheck 1998). However when sink rates were scientifically tested the thaw status of bait had a negligible effect on the sink rate so would have no effect on seabird bycatch rates (Robertson et al 2010b).

- **Development and testing needed to meet ACAP's criteria**

ACAP (2014a) include bait thaw status in a list of mitigation technologies that are not recommended. This is because the thaw status of baits has no effect on the sink rate of baited hooks set on weighted lines (Robertson et al. 2010b).

- **Hurdles to uptake in New Zealand**

Thawed bait is in use throughout New Zealand, although time can be a limitation to using thawed bait, as when fishers want to set gear earlier than planned the bait may not have thawed completely (D. Goad pers. comm). Lack of evidence of the efficacy across different bait types (Robertson et al 2010a). Thawed baits detach from hooks more readily (Brothers et al. 1995). Requires a specific area on the vessel for thawing baits.

Lunar cycles

No management guidelines

Not in use

- **Mitigation measure and how it works**

Moon phase affects night light levels, which in turn may influence the ability of nocturnal foraging seabirds to detect and locate baited hooks when scavenging around fishing vessels.

- **Description of results of development to date**

An analysis of seabird bycatch data on Japanese longline vessels fishing in the New Zealand EEZ 1989 to 1993 found the moon phase had a substantial impact on seabird bycatch rate for sets made at night. The rate at which seabirds were caught at night increased with increasing moon light and few birds were caught at night when the moon was less than half full (Duckworth 1995).

More birds were caught during the full and first quarter moon than in the new and last quarter moon in a Uruguayan study investigating night setting (Jimenez et al. 2009). In an Australian study bright, moonlit conditions increased the probability seabirds were caught at night 3.6 times (Brothers et al. 1999b). Furthermore night sets during the new moon had 82% lower probability of catching seabirds versus sets at the full moon (Klaer and Polacheck 1998). Conversely no evidence was found for an effect of the lunar cycle on seabird bycatch in the Hawaiian long-line tuna fishery (Gilman et al. 2016). No relation between the moon phase and captures of White-chinned petrels, was found in the Argentine bottom long-line fishery (Goméz-Laich and Favero 2007).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP recognise that night-setting as a mitigation measure is less effective during full moon periods. New Zealand data from 1989 – 1993 revealed seabird bycatch increased with increasing moon light, and few birds were caught at night when the moon was less than half full (Duckworth 1995).

- **Hurdles to uptake in New Zealand**

There is currently a lack of evidence- based guidelines for managing incidental seabird bycatch during full moon periods. Fishers could simply be prevented from fishing during full moon periods, but as cloud cover has an effect on lunar brightness a blanket ban may be unneccesarily restrictive. Reduces the amount of time available for fishing.

Lasers

Limited efficacy testing, qualitative measure of success from fisher reports

Used in some fisheries

- **Mitigation measure and how it works**

A laser beam projected into the area where seabirds are at risk of incidental capture may deter seabirds from entering the area.

- **Description of results of development to date**

A commercially produced device named the SeaBird Saver is a laser deterrent device with an optional acoustic bird scaring device included. Trials using a commercially produced and a prototype laser have been trialled in trawl fisheries in Alaska (Melvin et al. 2016).

- **Description of results of testing to date**

Trials in trawl fisheries in Alaska compared a commercially available laser to a prototype (Melvin et al. 2016). Both lasers emitted a beam at 532 nm (green) with optical power output measured at 1.26 and 1.01 W, respectively, categorising both devices as class-4 lasers. The Nominal Optical Hazard Distance for each was 102 m and 192 m, respectively. The devices were not effective during daylight, but showed varying levels of effectiveness at night for seabirds. The lasers were less effective at deterring Northern fulmars compared to gulls. The authors concluded that laser beam detection by birds may be difficult to achieve at high light levels (Melvin et al. 2016). The Australian Fisheries Management Authority recently undertook trials of lasers in a bottom long-lining fishery (R. Wells pers. comm.), but no results are currently available.

SaveWave, the company that developed the commercially produced SeaBird Saver, states that the system is being used in Norway, USA, Australia and Chile (SaveWave 2015) and is effective during dawn, dusk, cloudy, foggy and rainy conditions (van Dam et al. 2014). The device appears to only have been trialled during three long-line sets fishing in Iceland (SaveWave 2014), and the work was not peer-reviewed. Seabirds were reported to follow the vessel at greater distances astern when the device was in use, compared to when it was not used (van Dam et al. 2014). A New Zealand fishing industry newsletter, Bycatch Bylines, reported that additional testing was under consideration, including on an Australian long-line vessel (Pierre 2014). If this testing has occurred it has not yet been reported.

US researchers are planning a study of a specific brand of laser (not provided) by exposing invasive species to the laser and measuring morphological damage as well as conducting behavioural assays to detect changes in foraging ability, visual acuity and using albatross eye samples to extrapolate these results for albatross vision (A. Blumenthal pers. comm.).

- **Development and testing needed to meet ACAP's criteria**

Importantly, an assessment on the potential impact of lasers on seabirds has not been conducted.

No trials have been conducted to test lasers as a mitigation device in surface longline fisheries. Insufficient experimental research has been conducted in other fisheries to show the SeaBird Saver has a statistically significant effect on reducing incidental seabird bycatch, in particular there is a lack of efficacy during daylight (Melvin et al. 2016; van Dam et. al. 2014). Australian researchers are currently reviewing the use of lasers, particularly the potential for negative impacts upon seabirds (J. Barrington pers. comm.) and this is expected to be available mid-2017.

- **Hurdles to uptake in New Zealand**

Lack of evidence the system works, lack of testing on whether seabirds become desensitised to lasers over time, significant potential for lasers to injure seabirds, commercial models are potentially expensive.

- **Past and current funders and developers (if applicable)**

SaveWave.

- **Costs per vessel for installation/uptake (if available)**

Awaiting information from the manufacturer, but a Mustad model reportedly costs over NZ $30,000

Artificial bait

Not tested in surface longline fisheries

Not in use

- **Mitigation measure and how it works**

Artificial baits have been experimented with in surface long-line fisheries for a number of reasons. These include cost efficiencies, reductions in the use of bait material that would otherwise be fit for human consumption, eliminating the need to freeze bait, ensuring a steady supply of bait, reductions in bycatch of non-target fish and potential reduction or elimination of the incidental mortality of seabirds, sea turtles, sharks and marine mammals (Løkkeborg et al. 2014).

- **Description of results of development to date**

In a summary of the development of artificial baits Løkkeborg et al. (2014) states that artificial baits have been either natural or synthetic based and to date have not been successful from a fisheries perspective. The Norwegian fishing industry was reportedly developing artificial baits for fishing in 2014 but to date no evidence that they will help reduce seabird mortality has been reported (Løkkeborg et al. 2014).

- **Description of results of testing to date**

None in surface long-line fisheries.

- **Development and testing needed to meet ACAP's criteria**

No direct experimental research has been conducted that shows artificial baits reduce incidental seabird bycatch whilst maintaining target fish catches.

- **Hurdles to uptake in New Zealand**

Lack of evidence for the efficacy of artificial baits as a substitute for natural bait or as a method to mitigate incidental seabird mortality.

- **Costs per vessel for installation/uptake (if available)**

There are no commercially available products tested for use in NZ surface long-line fisheries.

Bottom long-line

In general bottom long-line mitigation technologies use a combination of six methods to mitigate the incidental mortality of seabirds.

- Reduce the window of time in which seabirds can access baited hooks
- Set lines beneath the surface
- Scare birds away from dangerous areas when lines are set or hauled
- Set fishing gear at night
- Don't attract birds by discarding old baits or offal during line setting and hauling
- Apply spatial or temporal restrictions to fishing areas

Table 2. Bottom long-line mitigation method or device included in this review and current status of development

Mitigation method or device	*Status of development*	*Page*
Tori lines	Tested comprehensively in most relevant fisheries and gear types	36
Line weighting and weight spacing	Tested comprehensively in many relevant fisheries and gear types	37
Integrated line weighting	Tested comprehensively in many relevant fisheries and gear types	39
Brickle Curtain	Tested comprehensively in many relevant fisheries and gear types	41
Kellian line setter	Early /prototype / funcionality	42
Line tension	Limited efficacy testing	44
Underwater setting funnel	Limited efficacy testing	46
Offal management	Tested comprehensively in most relevant fisheries and gear types	47
Moon pool	No longer used in NZ	48
Fish oil	Limited efficacy testing	49

Table 3. Measures also applying to bottom long-line fisheries that are described in the surface long-line section. The 'Status of development' provided below relates to the method or device's use in bottom long-line fisheries.

Mitigation method or device	*Status of development*	*Page*
Tori lines	Tested comprehensively in most relevant fisheries and gear types	9
Night setting	Tested comprehensively in most relevant fisheries and gear types	10
Water cannon	Limited efficacy testing	27
Acoustic scarers	Limited efficacy testing, qualitative measure of success from fisher reports	28
Side setting	Limited efficacy testing	30
Lunar cycles	Limited efficacy testing, qualitative measure of success from fisher reports	32
Lasers	In use overseas and in NZ, qualitative measure of success from fisher reports	32

Tori-lines

Tested comprehensively in most relevant fisheries and gear types

Widespread use

- **Mitigation measure and how it works**

A tori-line is an aerial line fixed to the stern of a vessel with an item secured at the terminal end that creates drag. Brightly coloured streamers attached to the tori-line move in the wind to deter birds from entering the area where baited hooks are sinking, effectively acting as a 'protective curtain'. This reduces the rate of seabirds attacking baited hooks, and subsequent incidental seabird mortalities.

- **Description of results of development to date**

Tori-lines have been trialled and then incorporated into many bottom long-line fisheries worldwide for more than fifteen years.

- **Description of results of testing to date**

Tori-lines have been tested and shown to be effective in both the northern and southern hemisphere. The most important performance standards of tori-lines are the aerial coverage and the location of the tori-line in relation to the position the hooks enter the water (ACAP 2014e).

Single tori-lines have been shown to be less effective than paired tori-lines, especially in strong crosswinds (Agnew et al. 2000; Brother et al. 1999; Løkkeborg 1998) as a single tori-line only works when it is positioned above sinking hooks. Paired streamer lines 'box off' the area baits are sinking so are more effective. Whilst a single tori-line was effective in the Alaskan bottom long-line fishery, paired tori-lines reduced seabird bycatch further, by 88 – 100% (Melvin et al. 2001). Further trials comparing single and paired streamer lines have shown that paired lines perform consistently better than a single line (Melvin et al. 2004; Reid et al. 2004).

Nevertheless a single tori-line can still dramatically reduce incidental seabird bycatch. For example in the Northeast Atlantic seabird bycatch was reduced by 99% when using a single tori-line (Løkkeborg 2003). In the Antarctic toothfish fishery at South Georgia vessels not using tori-lines caught three times as many seabirds as vessels using single tori-lines (Moreno et al. 1996). Trials in the NZ ling fishery reported that a single tori-line excluded all seabirds except Cape petrels from the sinking long-line (Smith 2001).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Paired tori-lines are currently the ACAP recommended best-practice, when used in conjunction with line-weighting and night-setting.

Proven specifications and standards

The CCAMLR design is recommended as best practice by ACAP (2014e). For small vessel bottom long-liners in NZ Pierre and Goad (2016) provide detailed specifications.

Likely uptake

Single tori-lines are required on all vessels over 7 m length overall (LOA) in bottom long-line fisheries operating in NZ (MPI 2013). A second tori-line is not required but is voluntarily used on some bottom long-line vessels > 20 m LOA (MPI 2013). Paired tori-lines are more susceptible to tangling and paired, 150 m long tori-lines require multiple people, or winches, to retrieve (ACAP 2014e).

Effect on target catch

No effect of tori-lines on target catch has been identified.

Effect on non-target catch

Seabirds becoming entangled in tori-lines has been reported (Otley et al. 2007), but ACAP (2014e) state that the number of birds potentially injured or killed by tori-line entanglement is a fraction of the number of birds that are killed on baited hooks.

Compliance

Methods of ensuring compliance include post inspection, observers, electronic monitoring (cameras), patrol vessels and patrol-plane fly overs.

- **Hurdles to uptake in New Zealand**

The same issues discussed under surface longline such as fouling with fishing gear and breakages exist for bottom longliners. Slow setting speed poses challenges to some small bottom long-line vessels as trying to achieve increased setting speeds to deploy tori-lines properly reduces the hook sink rate (Pierre and Goad 2017).

- **Costs per vessel for installation/uptake (if available)**

Tori-line costs in NZ for bottom long-line vessels vary. Approximately NZ $500 per annum (R. Wells pers. comm.). If a vessel has to install a pole to attain greater aerial height the cost increases. Pierre and Goad (2016) costed an effective pole type at NZ $500, with savings if multiple poles are purchased.

Line weighting and weight spacing

Tested comprehensively in many relevant fisheries and gear types

Widespread use

- **Mitigation measure and how it works**

External weights can be added to bottom long-lines to position the fishing gear on or near the sea floor for target catch (Fig. 5). Adding weight to lines also increases the sink-rate of baited hooks, and thereby reduces the possibility of incidental seabird bycatch. Hooks on bottom long-line gear are spaced approximately 1.5 m – 4 m apart (depending on vessel type and fishery) and are located at the end of 0.3 – 0.5 m snoods, correct line weighting and weight spacing must be used with tori-lines, as tori-lines create a protected area where the weighted hook achieves a depth of 10 m or greater before being exposed to seabirds.

Figure 5. External weights being set (Image: Bruce Foster)

- **Description of results of development to date**

Studies in a range of bottom long-line fisheries have clearly shown that the use of a proven line-weighting regime can achieve hook sink rates that greatly reduce the probability of incidental seabird mortality (Løkkeborg 2011; Bull 2007). Line weighting should enable the baited hook to sink beyond

10 m depth within the area astern the vessel protected by tori-lines (Robertson et al. 2006) as 10 m is the average maximum diving depth of commonly bycaught species such as white-chinned petrels.

- **Description of results of testing to date**

Line-weighting in bottom long-line fisheries has been tested in both the northern and southern hemispheres (Løkkeborg 2011; Bull 2007). All studies trialling line weighting have recorded significant reductions in incidental seabird mortality (Løkkeborg 2011).

For the mitigation of incidental seabird mortality line weighting should enable the baited hook to sink beyond 10 m depth within the area astern that is protected by tori-lines (Løkkeborg 2011; Robertson 2000). Robertson (2000) showed that sink rates increased when the spacing between line weighting increased. Line weighting trials in Sough Georgia's Patagonian toothfish fishery found that doubling the weight resulted in significantly less incidental seabird mortality, but no further reduction in mortality was recorded when the weight was tripled (Agnew et al. 2000).

In the northern New Zealand inshore bottom long-line fleet, line-weighting, and the corresponding sink rates, varied greatly between vessels, and variation also existed between longlines used on the same vessel. In addition floats were used on most vessels, and these acted to reduce the mean sink rates when deployed without extra weights to compensate for the buoyancy of the floats (Pierre et al. 2013).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP (2014e) best practice recommends line weighting is combined with tori-lines, and night setting when possible, to mitigate incidental seabird mortality in bottom longline fisheries.

To reduce incidental seabird mortality in northern New Zealand bottom long-line fisheries Pierre et al. (2013) recommended improving the current system by placing weights closer together, increasing and standardising weight masses, sinking hooks closer to the boat, using longer float ropes and setting gear at slower vessel speeds.

Proven specifications and standards

Due to the wide range of size classes of bottom longline vessels, and the range of fishing gear used. Rather, a specification relating to depth of the hook at the end of the aeiral section of the tori line would be more meaningful.

Likely uptake

Line weighting is in use to varying degrees in bottom longline fisheries in New Zealand but is not mandatory in bottom long-line fisheries. Rather, line weighting *or* night-setting is required (MPI 2013). In some fisheries problems have been identified with the amount and placement of weight not achieving sink rates required to mitigate incidental seabird mortality (Pierre et al. 2003).

Effect on target catch

Line-weighting may improve target catch as weights can increase the speed at which hooks reach the fishing depth (Løkkeborg 2011) and thus help maintain the hooks in the fishing position for longer (Melvin et al. 2001).

Effect on non-target catch

No evidence of an effect of weights on non-target catch was found.

Compliance

Methods of ensuring compliance include observers and electronic monitoring (cameras and gear inspections.

- **Hurdles to uptake in New Zealand**

Adding weights to lines during setting and removing during hauling is also labour intensive (Løkkeborg 2011). Cost of weights, the effect of weight when trying to float gear to reduced fouling, bait loss to bottom feeders, laborious to shift around a vessel. Line weighting regimes may require vessel specific tests (e.g. using the bottle test) to find out the optimum spacing and weights. Safety is a concern both when adding external weights to long-lines and when moving weights around a vessels deck (ACAP 2014e).

- **Costs per vessel for installation/uptake (if available)**

Cost varies depending on gear configuration used.

Integrated line weighting

Tested comprehensively in many relevant fisheries and gear types

Used in some fisheries (Autoline)

- **Mitigation measure and how it works**

Integrated weighted lines incorporate lead beads into the mainline, frequently at a weight of 50 g per metre of mainline (Fig. 6). The lead beads aim to create a more consistent sink rate than external weights. Integrated weighted lines negate the requirement of adding weight to lines at setting and removing the weights at hauling.

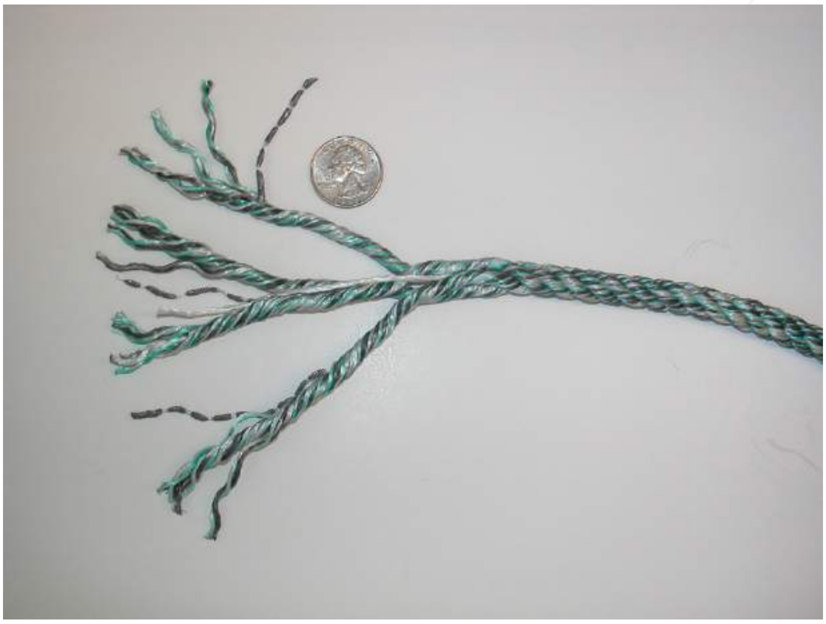


Figure 6. Integrated weighted line (Image: Janice Molloy)

- **Description of results of development to date**

In 2000 CCAMLR were the first regional fisheries management authority to require long-liners to weight lines to ensure sink rates of 0.3 metre per second to 10 m depth to minimise incidental seabird mortality. For autoline vessels the attachment and removal of external weights each time lines are set and hauled requires additional labour and can be dangerous in poor sea conditions (Robertson et al. 2006). In addition the sink rates of lines set with external weights are not even; the lines loft in between weights, especially due to propeller turbulence, slowing sink rates in that part of the longline (Robertson et al. 2006). An alternative method is to use longlines with integrated weight. Graham Robertson and Ed Melvin trialled integrated weight lines after New Zealand fisheries manager

Malcolm NcNeill engaged Norway fisheries gear manufacturer Fiskevegns to trial potential solutions (SSST 2016)

- **Description of results of testing to date**

Integrated weighted long-line has been shown to be effective in reducing seabird bycatch by increasing the sink rate and achieving a linear sink profile (Robertson et al. 2006). Integrated weighted lines trialled in the NZ ling bottom long-line fishery reduced seabird bycatch by 94 – 99% for white-chinned petrels and 61% for sooty shearwaters (Robertson et al. 2006). The New Zealand trials found the sink rate of integrated weighted lines were similar to unweighted lines with 6 kg external weights spaced 42 m apart (Robertson et al. 2006). In Alaskan bottom long-line fisheries integrated weighted lines reduced the distance astern that birds have access to sinking baits by near half compared to un-weighted lines (Dietrich et al. 2008).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Line weighting, used in conjunction with tori-lines, offal management and night setting is recommended best practice in bottom long-line fisheries (ACAP 2014e). ACAP consider integrated weight long-lines best practice for autoline vessels (ACAP 2014e).

Proven specifications and standards

ACAP (2104e) recommend integrated weighted lines with a minimum 50 g lead beading per metre.

Likely uptake

Integrated line weighting is in use in New Zealand bottom longline fisheries, but presently only two auto-liners are using it. Integrated weight long-lines were easier to handle compared to un-weighted lines (Dietrich et al. 2008).

Effect on target catch

Target catch has not been shown to decrease when using integrated line weighting (ACAP 2014e; Dietrich et al. 2008; Robertson et al. 2006). Possible bait lots to bottom feeding species (R. Wells pers. comm.).

Effect on non-target catch

Integrated-weight lines may lead to a greater catch of unwanted fish, shark and ray species (ACAP 2014e) because more long-line is on the seafloor. Petersen (2008) suggested that the solution to that problem may be to attach a weight and float on a 10 m line at the point of the snood attachment. Non-target catch did not increase when using integrated line weighting in Alaskan or New Zealand trials (Dietrich et al. 2008; Robertson et al. 2006).

Compliance

Port inspections adequate for ensuring integrated weight line is used.

- **Hurdles to uptake in New Zealand**

Two bottom longline vessels in New Zealand currently use integrated weight lines. Some 9.2mm IW line has been used in NZ in the past but is not currently W. Beauchamp pers. com.). Vessels in the NZ fleet use 7mm backbone and IW line is not manufactured in this diameter as reportedly adding lead strands reduces the strength of 7.2mm (W. Beauchamp pers. com.).

- **Past and current funders and developers (if applicable)**

Fiskevegn's, New Zealand Ministry of Fisheries (now Ministry for Primary Industries), Australian Fisheries Management Authority.

- **Costs per vessel for installation/uptake (if available)**

Depends on gear configuration. Robertson et al. (2006) reported that the cost of 50 g per m lead integrated weighted line was 14–23% higher than unweighted line but if demand increased prices may lower. Some gear on autoliners may have to be modified to handle the extra weight, and as the lead core in integrated weighted lines is 10% weaker than unweighted line, increased gear loss could add to the cost (Robertson et al. 2006).

Brickle curtain

Tested comprehensively in many relevant fisheries and gear types

Widespread use (internationally)

- **Mitigation measure and how it works**

The Brickle Curtain is a frame extending over the hauling area with bird scaring streamers attached (Fig. 7). The streamers form a protective curtain around the hatch where longlines are hauled. Also often used are a line of purse seine buoys placed on the water surface to further exclude seabirds from the hauling area.

Figure 7. Brickle curtain. (Image: Australian Fisheries Management Authority)

- **Description of results of development to date**

Developed by Paul Brickle and first trialled in the Falkland Islands / Malvinas toothfish fishery in 2003 (Snell 2008).

- **Description of results of testing to date**

Snell (2008) reported a 97% reduction in seabird interactions with fishing gear in the Falkland Islands / Malvinas toothfish fishery when a Brickle curtain was used. A 2005 – 2008 study on longline vessels near South Georgia, South Atlantic, found that significantly more birds were caught during longline hauling operations when Brickle Curtains were used compared to a single boom exclusion device (Reid et al. 2010).

Some seabirds in the Falkland Islands became desensitised to the Brickle curtain, notably black-browed albatrosses and Cape petrels (Sullivan 2004).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP recognise that the appropriate use of a Brickle Curtain, when used in conjunction with thorough offal management, can greatly reduce the number of birds hooked during hauling. The

Brickle Curtain is considered the most effective method to prevent swimming or flying birds entering the area around the hauling bay where hooks are available (ACAP 2014e). The efficacy of the Brickle Curtain in specific fisheries should be monitored to test for habituation by seabirds over time.

Proven specifications and standards

ACAP don't recognise an exact design, but rather the goal of achieving the objective of deterring birds from flying or swimming into the area where hooks are being hauled (ACAP 2014e). Snell (2008) provides clear metrics necessary for achieving mitigation requirements.

Likely uptake

Brickle curtains are relatively simple and inexpensive to construct and install. Their scale and design would need to be tailored for the vessel size.

Effect on target catch

No effect of the Brickle Curtain on target catch has been reported.

Effect on non-target catch

No effect of the Brickle Curtain on non-target catch has been reported

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras) and gear inspections.

- **Hurdles to uptake in New Zealand**

In heavy weather, the vertically hanging streamers, often weighted at the bottom, can flick up and interfere with fishermen working at the hauling hatch. Some seabirds in the Falkland Islands became desensitised to the Brickle curtain, notably black-browed albatrosses and Cape petrels (Sullivan 2004).

- **Past and current funders and developers (if applicable)**

Falkland Island Fisheries Department, Falklands Conservation, Birdlife International.

- **Costs per vessel for installation/uptake (if available)**

No current price was obtained.

Kellian line setter

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

The Kellian Line Setter is an underwater setting device. Lines set underwater eliminate the visual cue to seabirds of available food and reduce the time baited hooks are available to birds, therefore reducing incidental seabird bycatch.

- **Description of results of development to date**

Concept and initial development by Dave Kellian, a New Zealand fisherman, with input from the Southern Seabirds Solution Trust. Since then development has been carried out by Barry Baker, Dave Goad and Brian Kiddie under contract to DOC.

- **Description of results of testing to date**

The device has gone through seven iterations of refinement based on at-sea and flume-tank trials (Baker et al. 2016). Initially the device was designed to run the mainline under a nylon roller towed at depth behind the vessel. The original design had problems with fouling that were identified in 2011 trials. A second model (Fig. 8, prototype 2) was developed in 2014, but this rolled over and did not maintain depth. Further changes were made to arrive at the most recent device that no longer uses rollers and instead guides the line via a fork type design towed behind the vessel on a cable (Fig. 8, prototype 4.4) (Baker et al. 2016).

The most recent, simpler design, which has less drag, is more stable than previous prototypes and can run from the port or starboard side, produced encouraging gear setting results in relation to mitigating incidental seabird mortality (Baker et al. 2016).

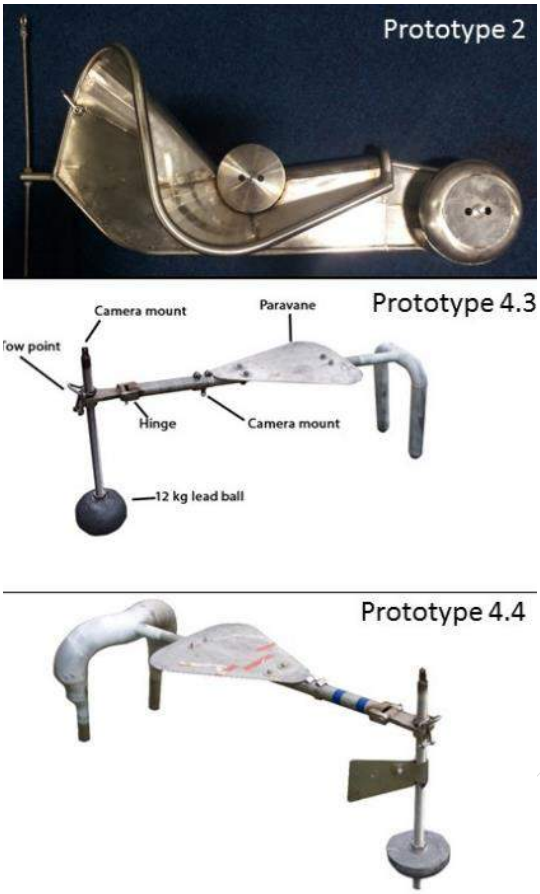


Figure 8. An example of Kellian line setter prototypes. Prototype 4.4 is the most recent version (Image: Baker et al. 2016).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP (2014e) do not currently recommend the use of underwater setters in bottom long-line fisheries. The latest iteration of the Kellian Line Setter 4.4, needs to undergo trials under full fishing conditions (Baker et al. 2016). In particular the device requires further trialling to determine the optimal setting depths for both function and mitigation purposes. Currently the Kellian line setter functions well setting at 4 – 7 m but any deeper can increase pilchard bait loss, depending on the hooking position of the bait (Baker et al. 2016).

Proven specifications and standards

The Kellian Line Setter is still in the development stage. Whilst results from the most recent prototype trialled (4.4) are encouraging, Baker et al. (2016) provide a summary of further refinements and trials required.

Likely uptake

The simpler design of the most recent Kellian line setter made manufacturing and alterations easier and cheaper.

Effect on target catch

Setting deeper than 4-7 m causes bait loss of pilchards hooked through the muscle. The authors note that hooking pilchard bait through the backbone is common practice and should reduce bait loss.

Effect on non-target catch

Trials of the Kellian line setter to date have not recorded an increase in non-target bycatch.

Compliance

Methods of ensuring compliance include observers and electronic monitoring (cameras) and portside checks.

- **Hurdles to uptake in New Zealand**

Currently there is a lack of evidence for the efficacy and practicality of the device both for fishing and mitigating incidental seabird mortality.

- **Past and current funders and developers (if applicable)**

The Kellian line setter was developed by Dave Kellian. The FV Kotuku assisted in trials, Southern Seabirds Solutions Trust Mentor Programme's Technical Advisory Group provided advice on the initial prototype and how to progress further development of the device. The New Zealand Department of Conservation's (DOC) Conservation Services Programme (CSP) provided significant funding.

- **Costs per vessel for installation/uptake (if available)**

The Kellian line setter is not yet past the prototype stage, but the simpler design of the most recent iteration made manufacturing and alterations easier and cheaper.

Line tension

Limited efficacy testing

Not in use (as a seabird bycatch mitigation measure)

- **Mitigation measure and how it works**

Setting speed affects line tension; lines set with less tension sink faster than lines set tight (ACAP 2014e). Also the pitching of a vessel increases tension in the line and can bring hooks back to the surface (ACAP 2014g).

Hydraulically controlled line shooters are designed to remove tension from the mainline by deploying the mainline faster then the vessel speed. The mainline then enters the water under less tension, and at the stern rather than tens of metres astern.

- **Description of results of development to date**

Very little formal testing of line tension and setting speed on hook sink rates in bottom long-line fisheries have been conducted. Pierre et al. (2013) recorded drum tension and vessel speed, along with many other variables, when assessing the mitigation of incidental seabird mortality in the northern New Zealand inshore bottom long-line fishery. Advertising for the Mustad company Autoline LineSetter™ states that the device sets a slack line and as this will sink faster incidental seabird bycatch will be reduced. In a trial on an auto-line vessel targeting toothfish in the French subantarctic island groups, Crozet and Kerguelen found sink rates of integrated weighted line were identical for lines set both with and without a line setter (Robertson 2008).

- **Description of results of testing to date**

Pierre et al. (2013) reported that a decrease in setting speed on northern New Zealand inshore long-line vessels resulted in a reduction in line tension, and this enabled fishing gear to sink closer to the vessel.). A Norwegian study reported that slacker lines, as a result of setting with a line shooter, reached 3m depth 15% faster than lines set tighter without a line setter (Løkkeborg and Robertson 2002).

Lines set with a Mustad line shooter alone caught more birds than lines set with a line shooter and the protection of a bird scaring line (Løkkeborg and Robertson 2002). Less birds were caught with the line-shooter than with no mitigation equipment, but the result was not statistically significant. The study reported that slacker lines, as a result of setting with a line shooter, reached 3m depth 15% faster than lines set without a line setter (Løkkeborg and Robertson 2002). The authors concluded that line shooters thus may reduce Northern fulmar bycatch, but not as a stand-alone measure. The use of a Mustad line shooter resulted in an increase in seabird bycatch in two demersal fisheries in Alaska, USA (Melvin et al. 2001).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAPs current position is that there is no experimental evidence that line shooters reduce seabird bycatch in bottom longline fisheries (ACAP 2014e). Results from two experimental research projects have provided evidence that line-shooters are not an effective measure to reduce seabird bycatch (Løkkeborg 2003; Løkkeborg and Robertson 2002).

Proven specifications and standards

Guidelines across bottom long-line fisheries do not exist (ACAP 2010). Further trials may be useful in some fisheries to measure whether a line tension can help hooks sink to a depth of 10 m with the area astern protected by tori-lines.

Likely uptake

Slowing the vessel speed, which is one method of reducing line tension, would result in a longer setting duration.

Unlikely uptake of line-shooters due to lack of evidence they can reduce incidental seabird mortality in bottom long-line fisheries.

Effect on target catch

No effect of reducing drum-tension during setting on target catch has been identified, but very few studies have been conducted.

No effect of line-shooters on target catch has been identified.

Effect on non-target catch

No effect of reducing line tension during setting on non-target catch has been identified, but very few studies have been conducted.

Compliance

Methods of ensuring compliance include observers and electronic monitoring (cameras).

- **Hurdles to uptake in New Zealand**

Lack of evidence that line tension reduces incidental seabird mortality. Very slack lines will loft between weights and reduce the sink rate of hooks midway between weights (D. Goad pers. com.)

- **Costs per vessel for installation/uptake (if available)**

Depends on whether a line shooter is purchased, or other fishing practices (such as slowing the vessel) are used.

Mustad underwater setting funnel

Limited efficacy testing

Not in use

- **Mitigation measure and how it works**

Lines set underwater eliminate the visual cue of available food and reduce the time baited hooks are near the surface and available to birds, therefore reducing bycatch.

- **Description of results of development to date**

The Mustad Company of Norway developed and marketed a stern mounted tube designed to set demersal long-lines at 1 – 2 m below the sea surface (Brothers et al. 1999). The product is no longer listed on the Mustad website, so may no longer be available. A New Zealand autoliner fitted with a Mustad setting funnel experienced stress on the stern and the device was subsequently removed (J. Molloy pers.comm.).

- **Description of results of testing to date**

Underwater bait setters have been trialled in USA (Alaska), Norway and South Africa.

South African trials used a Mustad underwater setter on slightly more than half of 1714 bottom long-line sets over a two year period (Ryan and Watkins 2002). Tori-lines are a requirement for vessels fishing in the Prince Edward Islands so were used in conjunction with the Mustad underwater setter. When fishing with tori-lines the seabird bycatch rate was three times lower when the funnel was used during day and night setting (Ryan and Watkins 2002). A small Norwegian trial using the Mustad underwater setter found when the underwater setter was used seabird bycatch decreased to less than third of bycatch when fishing without using the device (Løkkeborg 1998).

Despite these encouraging results, Ryan and Watkins's (2002) and Løkkeborg (1998) noted that the funnel frequently lifted out of the water, particularly in high seas as vessels pitched, a common phenomenon in southern ocean bottom long-line fisheries. The scientists also noted that the depth that the underwater setter could achieve was also affected by the vessels waterline, which changed as fuel was used and the weight of stored catch accumulated. Ryan and Watkins (2002) also doubt the possibility of underwater setting completely preventing incidental seabird mortality in the southern hemisphere because some seabirds species dive to at least 10 m, and this depth is not considered to be achievable with a tube-type underwater setter mounted on the stern. Night setting captures of albatrosses are rare in the Prince Edward Islands fishery, so the occurrence of a small number of daytime captures of albatrosses whilst using the underwater setter was cited as grounds for monitoring of any day time fishing using underwater funnels (Ryan and Watkins 2002).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP (2014e) do not currently recommend the use of underwater setters in bottom long-line fisheries. There is a need to trial the current Mustad design with an increased setting depth, particularly during rough seas (ACAP 2014e). Underwater setters also need to be tested with integrated weight and establish the ideal combination of the underwater setter together with other mitigation measures (bird scaring lines and weighted lines).

Proven specifications and standards

No proven specifications and standards have been established for southern hemisphere seabirds.

Likely uptake

Underwater setting devices may allow daylight fishing, a significant benefit, especially at higher latitudes during summer months when days are long (Ryan and Watkins 2002).

Effect on target catch

Underwater setting funnels may increase bait loss which could result in reduced catch rates (Løkkeborg, 1998). A South African vessel trialling a Mustad underwater setter did not record a decrease in target catch especially because allowing setting during the day and night improved their catch rate per day (Ryan and Watkins 2002).

Effect on non-target catch

No effect of underwater setter devices on non-target catch has been identified.

Compliance

Methods of ensuring compliance include observers and electronic monitoring (cameras).

- **Hurdles to uptake in New Zealand**

Lack of proven efficacy at setting long-line hooks at depths sufficient to mitigate the incidental mortality of New Zealand seabirds that are proficient divers. Ryan and Watkins's (2002) and Løkkeborg (1998) noted that the funnel frequently lifted out of the water, particularly in high seas as vessels pitched so hooks were deployed at the surface.

- **Past and current funders and developers (if applicable)**

Mustad

- **Costs per vessel for installation/uptake (if available)**

Mustad underwater setter's are not currently advertised by Mustad.

Offal management & strategic offal management

Tested comprehensively in most relevant fisheries and gear types

Widespread use

- **Mitigation measure and how it works**

Seabirds are attracted to vessels when offal is discharged. If offal is not discharged, less seabirds will attend vessels and thus the probability of capturing seabirds during setting or hauling will be reduced.

On autoliners a 'loose bait trail' is created during the set by unhooked baits and off cuts from the baiting machine, this attracts seabirds so must be managed to reduce the attractiveness for seabirds to follow a vessel (Smith 2001).

Strategic offal management is using offal discharge as a diversion, attracting birds to the offal rather than the setting or hauling hooks.

- **Description of results of development to date**

Reducing or eliminating the discharge of waste results in a clear reduction in the number of seabirds attending all types of fishing vessels (Løkkeborg 2011; Bull 2007). Strategic offal management has been tested in the Kerguelen Islands (Weimerskirsch et al. 2000; Cherel et al. 1996).

- **Description of results of testing to date**

More birds attend vessels discharging offal and if offal is discharged concurrently and in the same area as setting or hauling long-lines the probability of incidental seabird mortality increases (Weimerskirch et al. 2000). Strategic offal management was shown to reduce incidental seabird bycatch in bottom long-line fisheries around the Kerguelen Islands (1996).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP best practice is for offal management to be used in combination with bird scaring lines, line-weighting and night setting (ACAP 2014e).

ACAP (2014e) do not recommend the strategic management of offal discharge as a primary mitigation measure. Strategic offal discharge is only plausible on vessels with a short amount of setting or hauling time. This is because if the offal discharging ceases prior to setting or hauling, the seabirds that congregated to forage on the offal will shift their attention to the baited fishing gear (ACAP 2014e).

Proven specifications and standards

ACAP best practice is ideally for all offal to be retained onboard, and if that is not possible no discarding of waste should occur while setting lines (ACAP 2014e).

The strategic management of offal to create a diversion from the area baited hooks may be available to seabirds is not recommended (ACAP 2014e).

Likely uptake

Offal management is required during setting on bottom long-line vessels operating in New Zealand. Some long-line vessels in New Zealand discharge offal during hauling (Pierre et al. 2008).

Effect on target catch

No effect of offal management on target catch has been reported.

Effect on non-target catch

No effect of offal management on non-target catch has been reported.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras) and vessel inspections.

- **Hurdles to uptake in New Zealand**

Retaining all offal while setting or hauling is most practical on vessels where setting gear can be completed relatively quickly.

Moon pool

No longer in use in New Zealand

Not in use (as a seabird bycatch mitigation measure)

- **Mitigation measure and how it works**

A moon pool is a well in a vessel's hull through which the longline is hauled. Moon pools also confer the advantage of hauling long-lines in the absence of seabirds.

- **Description of results of development to date**

Little information could be found directly citing the use and testing of moon pools to reduce or eliminate incidental seabird bycatch. An Australian Fisheries Management Authority report on the impact of longline fishing around Australian subantarctic Macquarie Island stated that a vessel had a moon pool, so did not need to use a Brickle Curtain to mitigate seabird bycatch at hauling (Australian Government 2010). The remainder of available information cites that moon pools have been developed for economic reasons relating to fish catch and vessel safety. For example Icelandic shipbuilding company Skipasyn have developed moon-pool hauling wells for a reduction in fish bruising during the haul. Likewise Norwegian ship builders Fiskerstrand Verft and Carisma state that they build vessels with moon pools to reduce fish loss, but also to improve crew safety and allow fishing to continue during inclement weather. Norwegian designer Skipsteknisk have also worked with United States and Vietmanese vessel manufacturers to build vessels with moon pools for the same reasons as those stated above, to fish in Alaska and South Indian Ocean waters. Whilst the latter were designed to fish around the Crozet and Kerguelen Island groups, areas of high seabird abundance and diversity, no information concerning moon pools and seabird bycatch could be found.

ACAP state that very few vessels have moon pools, and many of the few vessels that do have them do not always use them.

- **Description of results of testing to date**

No testing specific to mitigating incidental seabird bycatch was found.

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

No testing specific to mitigating incidental seabird bycatch was found. The available information, predominantly from Scandinavian fish builders, suggest moon pools are used only during the haul. If this is the case seabirds would still be susceptible to incidental bycatch during setting.

- **Hurdles to uptake in New Zealand**

Moon pools are an option only on newly built vessels, so for economic reasons are likely to be slow to uptake, if at all. No detailed studies illustrating the efficacy of moon pools to reduce seabird bycatch during the haul.

- **Past and current funders and developers (if applicable)**

No funders have directly supported research focused on moon pools to reduce seabird bycatch.

- **Costs per vessel for installation/uptake (if available)**

Available only on newly built vessels, so for this reason a cost per vessel uptake is not obtainable.

Fish oil

Limited efficacy testing

Not in use

- **Mitigation measure and how it works**

Seabirds have been observed to avoid water with an oil slick at the surface, so dripping fish or shark liver oil from a vessels stern is a possible method to reduce seabirds attending a vessel, and thus reduce incidental bycatch.

- **Description of results of development to date**

Two studies, both conducted in New Zealand, tested the efficacy of shark oil as a deterrent to seabirds attending fishing vessels. A United States researcher also trialled fish oil behind a trawler in Alaska in a one off experiment, and found that shearwaters departed the area completely (Melvin et al. 2004).

- **Description of results of testing to date**

The first study, conducted in the Hauraki Gulf included at risk seabird species such as the flesh-footed and Buller's shearwaters, and black petrels. The study recorded less seabird dives for pilchard baits behind a long-line vessel (< 5 birds/min) when small quantities of shark liver oil were dripped onto the water aft of the vessel compared with vegetable oil (> 30 birds/min) or sea water (20 – 40 birds/min) (Pierre & Norden 2006). The second study was conducted in Kaikoura where the seabird assemblage includes great and lesser albatrosses, and petrels. Neither of two types of shark oil had any significant effect on the number of these seabird species attending the vessel, compared with the control of seawater (Norden & Pierre 2007). Melvin et al. (2004) recorded anecdotal observations of pollock oil deterring birds from foraging behind Alaskan trawl vessels. The limited results suggested that the presence of pollock oil appeared to discourage birds from entering the area of discarded fish waste (Melvin et. al. 2004).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP currently state that there is insufficient evidence for the use of fish oil as a seabird bycatch mitigation measure (ACAP 2015a)

Proven specifications and standards

Insufficient testing has been conducted to refine specifications and performance standards.

Likely uptake

Shark oil has not been shown to be practical in many sea condition. Marine pollution regulations (e.g. Marpol) prevent the discarding of oil at sea.

Effect on target catch

No evidence was found in the small number of studies conducted indicating that catch rates were negatively affected when using shark or fish oil.

Effect on non-target catch

No evidence was found in the small number of studies conducted indicating an increase, or potential increase in the bycatch of other taxa. However the use of shark oil as a mitigation method could possibly encourage sharks to be targeted purely for oil extraction.

Compliance

Minimum performance standards have not been developed and methods of ensuring compliance would be through observers or electronic surveillance such as cameras.

- **Hurdles to uptake in New Zealand**

Whilst fish oil has been shown to be effective in northern New Zealand (Pierre & Norden 2006), legal limitations to discharging oil at sea by Maritime NZ, the potential for negative impact of oil on seabird feathers and the possibility of seabirds becoming habituated to fish or shark oil prevents uptake. Also important to consider is the availability, affordability and ethical concerns regarding fish and shark oil, and inadequate proof of efficacy as a mitigation measure for albatrosses and giant petrels species (Norden and Pierre 2007).

- **Past and current funders and developers (if applicable)**

Washington SeaGrant Program, New Zealand Department of Conservation through the Conservation Services Programme, SeaWorld and Busch Gardens Conservation Fund, International Association of Antarctic Tourist Operators.

- **Costs per vessel for installation/uptake (if available)**

Depends on the type and quantity of oil used. Imported Chilean hoki oil is the cheapest fish oil available in NZ.

Trawl

Trawl mitigation devices and methods focus on preventing seabirds from being struck by the warp-cable or becoming caught within or entangledon the net (Table 3). Methods to achieve this include:

- Scaring birds away from the area they are vulnerable to warp-strike
- Manage offal discharge and discards so seabirds do not attend vessels
- Reduce the amount of time the net is on the surface
- Reduce seabird attraction to the net by removing potential food (net-cleaning)

Table 3. Trawl mitigation method or device included in this review and current status of development

Mitigation method or device	***Status of development***	***Page***
Tori lines	Tested comprehensively in most relevant fisheries	51
Bafflers	Broader efficacy testing (may require refinement), qualitative measure of success from fisher reports	53
Warp-scarers	Limited efficacy testing	56
Cones	Limited efficacy testing, qualitative measure of success from some fisher reports	58
Warp deflector	Limited efficacy testing, qualitative measure of success from some fisher reports	60
Offal management	Broader efficacy testing (may require refinement)	63
Net cleaning	Limited efficacy testing	64
Net binding	not in use in NZ, but guidelines exist for some companies, e.g. DWG	65
Net weighting	not in use in NZ	67
Net restrictor	in use in NZ (scampi fishery)	68

Tori-lines

Tested comprehensively in most relevant fisheries

Widespread use

- **Mitigation measure and how it works**

When foraging on fish waste discarded behind a working trawl vessel, seabirds can become entangled on, or struck by, the warp cables used to tow the trawl net. This can lead to drowning or fatal injury. Tori-lines on trawl vessels are designed to prevent birds from entering the area astern of the vessel where they are at risk of 'warp strike'. Fixed to the stern and towed running parallel to the outside of each warp cables, tori-lines essentially form a protective curtain to stop birds entering the area they are at risk of warp strike (Fig. 9).

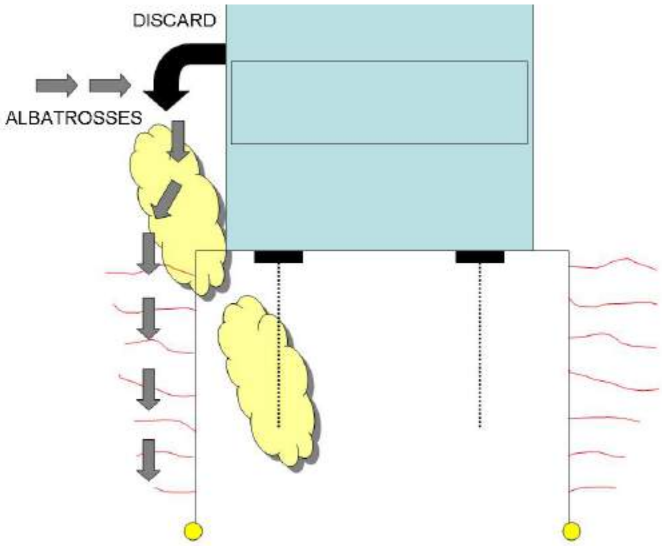


Figure 9. Schematic of tori-lines towed behind a fishing vessel forming a protective curtain for the warp cable (dotted lines) by deterring seabirds from entering the warp-water interface area. The two clouds represent offal and discards leaving the vessel and drifting into the warp / water interface. Tori-line depicted as the mainline (black), streamers (red) and tow device (yellow net floats).

- **Description of results of development to date**

Whilst developed for long-line fisheries, tori-lines were first trialled as a method to reduce incidental seabird mortality by warp-strike (principally of black browed albatross) on a 66 m LOA demersal factory-freezer trawler in the Falkland Islands / Malvinas in the early 2000s (Sullivan et al. 2006a). Since then further research trials have been conducted in New Zealand on eleven factory-freezer trawler vessels > 28 m LOA (Middleton and Abraham 2007), in the United States on two factory-freezer trawlers of 84 m and 102 m LOA (Melvin et al. 2011) and in South Africa on 19 wet-fish trawl vessels (Maree et al. 2014) with an average length of 45 m LOA (SADSTIA 2016).

- **Description of results of testing to date**

Testing in the Falkland Islands / Malvinas (Sullivan et al. 2006a) showed tori-lines to be significantly more effective at reducing incidental seabird mortality than no mitigation, and tori-lines performed better than bird bafflers or warp scarers (both described below). Further trials in New Zealand determined that tori-lines reduced warp-strikes by 80 – 95% (Middleton and Abraham 2007). Tori-line trials on factory freezer trawlers in Alaska reduced warp-strike by more than 90% (Melvin et al. 2011). The use of tori-lines on trawl vessels in South Africa resulted in an estimated reduction of incidental seabird mortality between 73–95% (Maree et al. 2014). Nine percent of incidental seabird mortality in the Falkland Islands in 2016 was attributed to tori-line entanglement (Kuepfer et al. 2016).

The use of off-set towing devices instead of, or in addition to a trawl float or buoy at the terminal end of a tori-line, have been trialled in South Africa, South America and the Falklands / Malvinas (Maree et al. 2010; Tamini et al. 2010; Parker 2012). The initial results were promising in as far as reducing warp and tori-line tangles due to tori-lines deviating in the wind. The 'Tamini Tabla' is a refined version of an off-set tow device developed by Leo Tamini and Birdlife in Argentina (Tamini 2012). Tamini first developed a metal prototype that was refined to a plastic mould, of which the latest iteration was scheduled for sea trials in 2012 (Pierre 2012). Both South African and South American trials assumedly showed low efficacy as the devices have not been incorporated into recommended best-practice (ACAP 2016d). Off-set towing devices were trialled in the Falkland Islands/ Malvinas trawl fishery in July of 2012 to investigate whether these devices could reduce tori-line deviation and thus seabird contacts with the warp cable. However the prototypes trialled were relatively crude and did not perform well (Parker 2013).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Tori-lines have been shown by experimental research to reduce the rate of incidental seabird mortality in South Africa, Alaska, USA, New Zealand and the Falkland Islands / Malvinas (Maree et al. 2014; Abraham et al. 2008; Middleton and Abraham 2006; Sullivan et al. 2006). ACAP recognise tori-lines as best-practice mitigation on trawl vessels (ACAP 2016d).

Proven specifications and standards

Clear specifications (based on Falkland trials) for New Zealand trawl vessels > 28 m are available from MPI (2015).

Likely uptake

Tori-lines are required on New Zealand trawl vessels greater than 28 m LOA since 2007 (MPI 2015). There are currently no requirements to mitigate the incidental mortality of seabirds in any form on inshore (< 28 m LOA) trawlers.

Effect on target catch

No effect of tori-lines on target catch has been identified.

Effect on non-target catch

New Zealand tori-line trials reported that at least a proportion of seabird interactions with tori lines risked injuring or killing seabirds (Middleton and Abraham 2007). Nine percent of incidental seabird mortality in the Falkland Islands in 2016 was attributed to tori-line entanglement (Kuepfer et al. 2016). Mitigation device captures are still regularly if not frequently reported from NZ trawlers (Dragonfly 2017).

Compliance

Clear performance standards for tori-lines on large trawl vessels are defined by ACAP (2016d), MPI (2015), DOC (2011) and Pierre et al. (2010). Methods of ensuring compliance include observers, electronic monitoring (cameras), patrol vessels and patrol-plane fly overs.

- **Hurdles to uptake in New Zealand**

Tori-lines are currently one of three options to mitigate incidental seabird mortality on warps on New Zealand trawl vessels over 28 m LOA.

- **Past and current funders and developers (if applicable)**

Falklands Conservation, International Association of Antarctic Tour Operators (IAATO), Falkland Islands Fisheries Department, New Zealand Department of Conservation, Deepwater Group (DWG)

- **Costs per vessel for installation/uptake (if available)**

A standard tori-line set on a factory freezer trawler costs approximately NZ $500

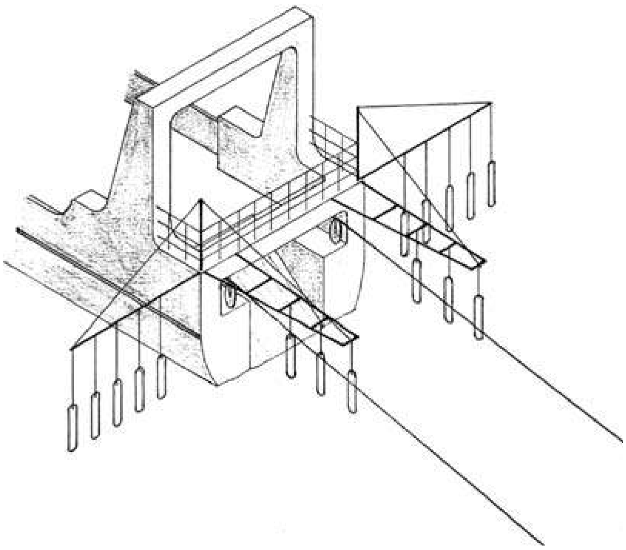
Bafflers / boom systems

Broader efficacy testing (may require refinement), qualitative measure of success from fisher reports

Some fisheries

- **Mitigation measure and how it works**

Like tori-lines, bafflers and boom systems on trawl vessels are designed to prevent birds from entering the area both alongside and astern of the vessel where they are at risk of mortality or injury from 'warp strike'. First developed in New Zealand by Keith Brady (the Brady Baffler), there are a variety of baffler designs (Fig. 10, 11) (Sullivan et al. 2006b; Prendeville 2007; Parker et al. 2013; Cleal and Pierre 2016). Generally bird bafflers consist of two booms extending aft, straight or angled, from each side of the stern of a trawler, and two smaller arms extending to the side of a vessel (Fig. 10, 11). 'Droppers', consisting of ropes with cones attached, bird-scaring streamers or other materials are attached to the booms and the movement of these serve the same purpose as streamers on tori-lines; to deter birds from entering the area they are at risk of warp strike.



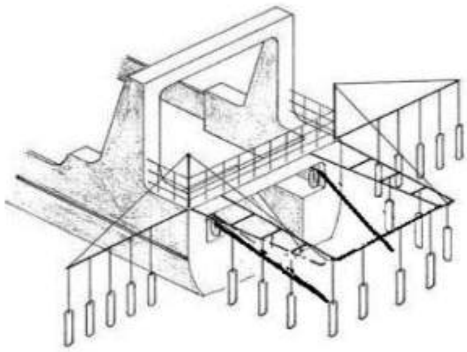


Figure 10. **Left**: Brady Baffler depicted on a trawl vessel in the Falkland Islands. Note the warp-water interface is a significant distance from the furthest reaching 'dropper' (Image: Sullivan et al. 2006b). **Right**: Burka Baffler, an iteration of the Brady Baffler, modified to 'box in' the warp cables. The warp cables are depicted by the dark black lines (Image: Prendeville 2007).

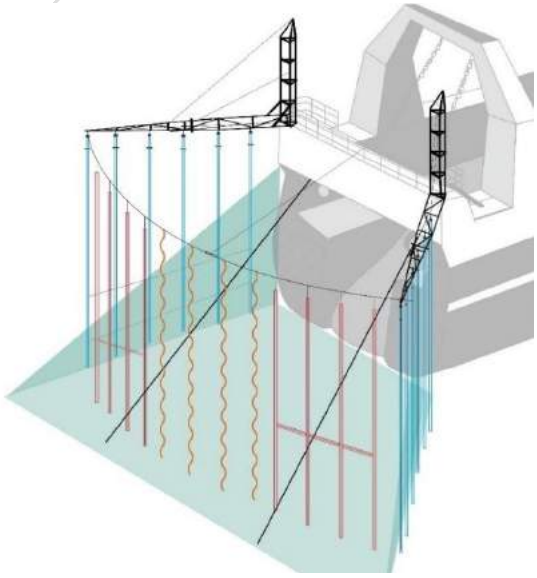


Figure 11. **Left**: Boom system installed on a vessel in the Falkland Islands / Malvinas. These 12 m booms were not long enough to protect the warp-water interface in the Falkland Islands / Malvinas trawl fishery (Image: Parker et al. 2013). **Right**: Schematic of a boom system on a vessel in New Zealand. Note the warp-water interface sits outside the bird-scaring lines and droppers (Image: Cleal and Pierre 2016)

- **Description of results of development to date**

The Brady Baffler was first trialled and used under normal fishing conditions in New Zealand on eleven factory-freezer trawler vessels > 28 m LOA (Middleton and Abraham 2007). The same device was trialled in the Falkland Islands / Malvinas on a 66 m LOA factory-freezer trawler, and since then a further variation on a baffler / boom type system, designed in an attempt to protect the warp-water interface, have been trialled in the Falkland Islands / Malvinas (Parker et al. 2013) on factory freezer trawlers > 55 m LOA. Trials testing the efficacy of 6.3 m and 7.6 m booms with streamers attached were conducted in Alaska trawl fisheries (Melville et al. 2010) on two vessels 84 m and 102 m LOA. Recent New Zealand research on a 60 m LOA vessel (Cleal and Pierre 2016) focused on attempting to fully encircle warp cables by streamer lines to deter birds from entering the area. This was reported to have been achieved on a 64 m trawler in New Zealand (Prendeville 2007), but the efficacy has not been formally trialled and the warp-water interface was close to the stern in that vessel due to the depths fished, making coverage of the area significantly easier. Baffler trials in the Falklands / Malvinas continues, with a modified baffler, further lengthened and angled outwards from that of Parker et al. (2013), arriving in the Falkland Islands September 2016 and currently undergoing trials on vessels > 50 m LOA there (J. Pompert pers. comm).

- **Description of results of testing to date**

Bull (2007) stated that observer data from 2002 – 2005 New Zealand squid trawling showed early, non-standardised Bird Bafflers did not significantly reduce incidental seabird mortality. Trials in the Falkland Islands comparing bird bafflers to tori-lines and 'warp-scarers' (see below) found that bird bafflers were the least effective mitigation measure, but were still more effective than no mitgation (Sullivan et al. 2006b). New Zealand research showed that bird bafflers resulted in a statistically significant, 35 – 90% reduction in the number of warp strikes by large seabirds (*Diomedea, Thallasarche* and *Macronectes* spp.) (Middleton and Abraham 2007). Whilst the bird bafflers were also effective at reducing the number of warp strikes by small seabirds, the result was not statistically significant (Middleton and Abraham 2007).

Trials of a boom system in Alaska determined the device failed to reduce seabird warp strikes, but the authors considered the device could be improved (Melville et al. 2010). A baffler / boom system trialled in the Falkland Islands trawl fishery was not long enough to cover the warp water interface, and did not cover the warp zone when warps were deviating (e.g. when turning; in strong currents)(Parker et al. 2013). The device was trialled on two further vessels in the Falkland Islands / Malvinas, but was not long enough in both cases (J. Pompert pers. comm). A modified boom system, further lengthened and angled outwards, arrived in the Falkland Islands in September 2016 and is currently undergoing trial there (J. Pompert pers. comm). Three refined boom systems have recently been trialled in New Zealand (Cleal and Pierre 2016). Observers reported that the third prototype trialled functioned better than other bafflers in use in New Zealand, but all three bafflers were not long enough to cover the warp-water interface so seabirds were still vulnerable to mortality by warp strike (Cleal and Pierre 2016). ACAP state that bafflers and boom systems have 'limited capacity to reduce seabird bycatch on most vessels (ACAP 2016d), and this is supported by the Falklands / Malvinas trials (Sullivan et al. 2006) and New Zealand designs trialled in the past three years (Pierre and Cleal 2016). The height of the trawl warp-block affects where warp cables enter the water as does fishing depth and as such further trials to validate the efficacy of bafflers in specific fisheries are needed. For example in some NZ deep water trawl fisheries the warps enter the water close to the stern so are effectively surrounded by bafflers (R. Wells pers. comm.).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP state that there is not currently enough evidence to support the use of bafflers / boom systems to mitigate incidental seabird mortality in trawl fisheries (ACAP 2016d). The Australian Fisheries Management Authority recently allowed bafflers to be used in their Southern and Eastern Scalefish and Shark Fishery Commonwealth Trawl Sector (AFMA 2017). The research basis for the introduction of bafflers in the Australian trawl fisheries is unclear. The NZ Deep Water Group (DWG) require all DWG trawlers to have both a baffler and tori-lines.

Proven specifications and standards

Anecdotal NZ evidence suggest bafflers work, although not in all conditions (R.Wells pers.com.) but proven specifications and standards have not yet been achieved.

Likely uptake

Bafflers have been in use in New Zealand for more than ten years and are currently one of three options for mitigating incidental seabird mortality on warp cables (New Zealand Government 2010). Whilst trials to date have shown tori-lines to be significantly more effective than bafflers, and cheaper, bafflers are preferred because tori-lines deviate in cross winds or during vessel turns and leave warps unprotected from bird strike. In addition, tori-lines can tangle with warp-cables and this can result in lost fishing time due to efforts spent untangling the tori-lines from warps and risking crew injury as they must lean out past the stern rail to access tangles.

Effect on target catch

No effect of bafflers on target catch has been identified.

Effect on non-target catch

No effect of bafflers on non-target catch has been identified. Because the bird scaring materials used on bafflers is not resting on the surface, there is a lower probability of seabirds becoming entangled than for mitigation devices that interact with the water surface, although occasional collisions occur.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras), patrol vessels and patrol-plane fly overs.

- **Hurdles to uptake in New Zealand**

Bafflers are used widely in New Zealand but a lack of proven consistent efficacy of preventing incidental seabird mortality as a result of warp-strike, despite multiple designs trialled, could be a barrier for future use. The substantial cost of bafflers and vessel modifications required for fitting the devices. Overly long bafflers risk being torn of when a vessel rolls.

- **Past and current funders and developers (if applicable)**

Keith Brady, Falklands Conservation, International Association of Antarctic Tour Operators (IAATO), Falkland Islands Fisheries Department, New Zealand Department of Conservation, Deepwater Group Ltd

- **Costs per vessel for installation/uptake (if available)**

Depends entirely on the vessel size, number of booms, the reach required and if the booms are able to be deployed and retrieved. NZ $40,000 plus vessel strengthening for a 65 m LOA factory trawler (Cleal and Pierre 2016), US $4800 (Sullivan et al. 2006).

Warp scarer

Limited efficacy testing

Not in use

- **Mitigation measure and how it works**

Warp-scarers are designed to be attached directly to the warp cable. Streamers or reflective tape are attached to the warp deflector and these act to deter seabirds from entering the area beneath the warp, and thus reduce or eliminate incidental seabird mortality. Warp-scarers / deflectors generally consist of a series of clips (Fig. 12) (Middleton and Abraham 2007) or rings and rollers (Fig. 12) (Sullivan et al. 2006) connected with netting and rope, and reflective tape or streamers hanging from each ring to the sea surface. The warp-scarer cannot be left on the warp cable throughout fishing, so is deployed after shooting the net, and retrieved prior to hauling. During trawling it is held in position by two 'lazy lines' attached to the stern.

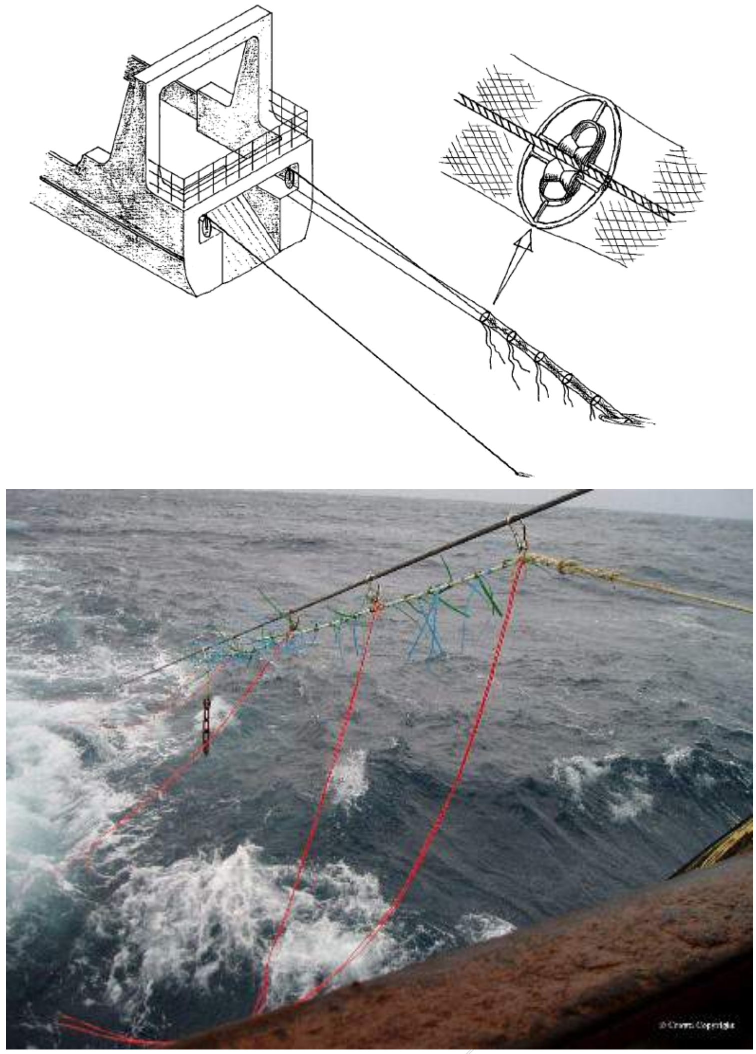


Figure 12. **Top**: Warp-scarer trialled in the Falkland Islands / Malvinas (Sullivan et al. 2006). **Bottom**: Warp-scarer trialled in New Zealand (Image: Middleton and Abraham 2007).

- **Description of results of development to date**

Warp-scarers were first trialled in the Falkland Islands / Malvinas, and subsequently in New Zealand (Sullivan et al. 2006b; Middleton and Abraham 2007).

- **Description of results of testing to date**

Trials of a warp-scarer on a 66 m LOA vessel in the Falklands / Malvinas found significantly more total and heavy contacts between seabirds and warp cables when using a warp-scarer, compared to tori-lines (Sullivan et al. 2006b). Concern for crew safety was also expressed when deploying and retrieving the warp-scarer, and as it was difficult to manage, the device was considered impractical for commercial use (Sullivan et al. 2006b). A New Zealand trial on vessels all greater than 28 m LOA found that a warp-scarer was reliably effective at preventing warp strikes for smaller birds, but less consistently reliable for large seabirds (Middleton et al. 2007). In addition, the warp-water interface was not protected by the warp-scarer in the New Zealand trials because insufficient weight prevented the device staying in place and adding more weight resulted in the device tangling with the warp cable (Middleton et al. 2007). Australian trials of a warp-scarer (Pierre et al. 2014) found the device not effective in reducing seabird contacts made with warp cables. Although the number of birds attending the vessel had an effect on the efficacy of the warp-scarer. For example when fewer birds were foraging at the vessel the warp-scarer did not reduce seabird interactions with the warp. But when foraging competition was aggressive between smaller albatrosses, warp-scarers reduced light interactions with the warp but did not reduce heavy interactions where warp-strike pushed birds beneath the water surface (Pierre et al. 2014).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Warp-scarers have not been shown to significantly reduce incidental seabird mortality (Sullivan et al. 2006b), so are not recommended by ACAP (ACAP 2016d). No NZ deep water trawlers use scarers despite MPI rules allowing for them, mostly for the reasons noted above.

Proven specifications and standards

No clear specifications for a warp scaring device that significantly reduces incidental seabird mortality have been reported.

Likely uptake

Warp-scarers cannot pass through warp-blocks, so have to be attached to the warp cable aft of the warp-blocks (Sullivan et al. 2006b). This puts vessel crew in an exposed position, making deploying and retrieving warp deflectors dangerous during inclement weather (Sullivan et al. 2006; Middleton and Abraham 2007). Many trawlers have an auto trawl function that acts to constantly adjust the warps and this adds to the risk of the warp-scarer tangling with the warp.

Effect on target catch

No effect of warp-scarers on target catch has been identified.

Effect on non-target catch

No effect of warp-scarers on non-target catch has been identified.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras), patrol vessels and patrol-plane fly overs.

- **Hurdles to uptake in New Zealand**

Warp scarers are currently one of three options for mitigating incidental seabird mortality on warp cables (New Zealand Government 2010). Safety concerns when deploying and retrieving warp-scarers (Sullivan et al. 2006; Middleton and Abraham 2007) and the lack of proven efficacy result in bafflers and tori-lines being used (MPI 2015).

- **Past and current funders and developers (if applicable)**

Falklands Conservation, International Association of Antarctic Tour Operators (IAATO), Falkland Islands Fisheries Department, New Zealand Department of Conservation, Deepwater Group Ltd

- **Costs per vessel for installation/uptake (if available)**

US $800 in 2006 (Sullivan et al. 2006b).

Cones

Limited efficacy testing, qualitative measure of success from some fisher reports

Some fisheries (NZ inshore trawl)

- **Mitigation measure and how it works**

The cone mitigation device consists of a cone, or a tapered cylindrical object that is attached, usually via a hinge, to the warp cable and stays at the warp-water interface (Fig 13). The cone device is designed to prevent birds from becoming entangled and drowned on warp cables.

Figure 13. **Top**: Cone deployed on in-shore trawl warp cable to prevent seabird strike on the warp cables at the warp-water interface (Image: J. Molloy). **Bottom**: The Seabird Control Unit Device (SCUD) (Guild 2007)

- **Description of results of development to date**

Cones have been trialled in Argentina (Gonzalez-Zevallos 2007) and are currently used by an unknown number of vessels in New Zealand inshore trawl fisheries. Rick Guild trialled a Seabird Control Unit Device (SCUD) (Fig. 13) on a trawler in New Zealand (Guild 2007). The SCUD was designed to freely float, ride up and down the warp at setting and trawling speeds and not require tethering. No further reporting on the efficacy of the SCUD is available.

- **Description of results of testing to date**

Argentina trialled, on a small scale, road cones attached to warp cables on three approximately 24 m LOA fresh fish trawlers (Gonzalez-Zevallos et al. 2007). Development and testing needed to meet ACAP's criteria

Effectiveness

Argentinian trials resulted in an 89% reduction in warp contact rates (Gonzalez-Zevallos et al. 2007), although the sample size in the study was small.

Proven specifications and standards

ACAP consider there to be insufficient evidence to support the use of cones (ACAP 2016d). Gonzalez-Zevallos et al. (2007) provide detailed information on the device that proved effective on Argentine trawl vessels with an average LOA of 24 m, but this is the only formal trial reported.

Likely uptake

Cones are already in use in New Zealand inshore trawl fisheries, but it is unclear what proportion of vessels are using the devices or if the devices are effective at reducing or eliminating incidental seabird mortality on trawl warp cables in those fisheries.

Effect on target catch

No effect of cones on target catch has been identified.

Effect on non-target catch

No effect of cones on non-target catch has been identified. But deploying anything onto the water's surface where seabirds can interact with it presents the potential of capturing or entangling seabirds, possibly leading to injury or death.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras) and gear inspections at sea.

- **Hurdles to uptake in New Zealand**

Cones are used to an unknown extent in inshore trawl fisheries, but testing is needed to prove efficacy in a range of vessels and fisheries.

Past and current funders and developers (if applicable)

NZ inshore trawl fishers, WWF, Centro Nacional Patagónico, Wildlife Conservation Society

- **Costs per vessel for installation/uptake (if available)**

Costs dependent on material used to construct cones. Cones papproximately NZ $ 35

Warp deflectors

Limited efficacy testing, qualitative measure of success from some fisher reports

Used in some fisheries

- **Mitigation measure and how it works**

Warp-deflectors or 'pinkie buoys' trialled in Australian demersal trawl fisheries consisted of a 600 diameter mm buoy clipped to the warp cable and secured to the vessel by a line and positioned within 400 mm of the water surface (Fig. 14). Informal trials were conducted in the Falkland Islands, but with buoys of 400 mm diameter (Parker 2012). In some use in NZ coastal trawl fisheries. Highly visible so good in that regard for others to see in use. Often deployed on one warp, the fish waste side of vessel

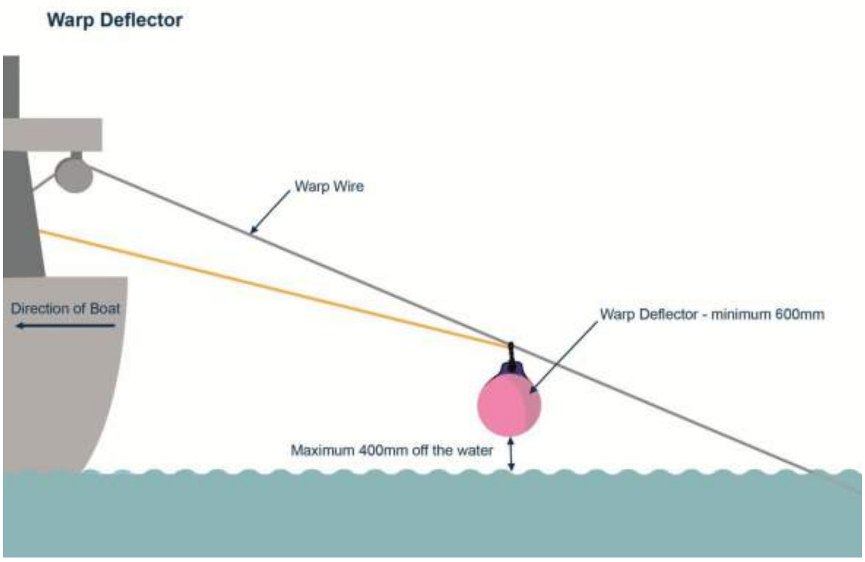


Figure 14. Warp-deflector, or "pinkie', used in the Australian South East Trawl and Great Australian Bight Trawl sectors of the Southern and Eastern Scalefish and Shark Fishery (SESSF) (Image: Pierre et al. 2014)

- **Description of results of development to date**

Warp-deflectors were trialled during 49 trawls on nine Australian demersal trawl vessels 17.9 – 26 m LOA. Informal trials were conducted in the Falkland Islands, but with buoys of 400 mm diameter (Parker 2012).

- **Description of results of testing to date**

Warp deflectors reduced heavy contact with warp cables by 75 percent, depending on how birds were feeding. During both relaxed and more aggressive seabird feeding warp deflectors reduced heavy contacts between small albatrosses and trawl warps. (Pierre et al. 2014). Warp-deflectors were not effective at reducing light contacts during relaxed feeding, but were during aggressive feeding (Pierre et al. 2014). Warp-deflectors informally trialled in the Falkland Islands failed to remain in place at or near to the warp-water interface, tangled with warps and did not deter birds from the area (Parker 2014).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

The warp-deflector has been shown by experimental research to significantly reduce seabird interactions with the warp cable. Until recently warp-deflectors were the legal requirement in the Australian Fisheries Management Authority Southeast Trawl fishery, but fishers are now able to use bafflers (AFMA 2017). Further trials are needed to test the efficacy of this device on a range of vessels and in different fisheries. Informal trials in the Falklands Islands showed the buoy failed to provide consistent warp protection due to swell effects.

Proven specifications and standards

Pierre et al. (2014) used a 600 mm diameter buoy that was 820 mm in length, from the bottom of the buoy to the centre of the top eye hole.

Likely uptake

Further testing needed to prove efficacy in a range of vessels and fisheries.

Effect on target catch

No effect of warp-deflectors on target catch has been identified

Effect on non-target catch

No effect of warp-deflectors on non-target catch has been identified.

Compliance

Methods of ensuring compliance include observers, electronic monitoring (cameras) and gear inspections at sea.

- **Hurdles to uptake in New Zealand**

Lack of proven efficacy in New Zealand conditions. Quite expensive.

- **Past and current funders and developers (if applicable)**

Australian Fisheries Management Authority

- **Costs per vessel for installation/uptake (if available)**

For each warp the cost is associated with a single 600 mm diameter x 820 mm buoy, a clip and line. There is some loss.

Offal management – batch discarding, mincing, mealing, full retention

Broader efficacy testing (may require refinement)

Widespread use

- **Mitigation measure and how it works**

Seabirds are at risk of mortality on trawl warp cables because they are attracted to fishing vessels in largely due to the foraging opportunities provided by the discharge of fish waste material (offal, heads, tails and non-commercial catch species) (ACAP 2016d).

- **Description of results of development to date**

Observations in the Falkland Islands (Sullivan et al. 2006a), South Africa (Watkins et al. 2008), Argentina (Favero et al. 2010) and New Zealand (Pierre et al. 2012a) showed that the number of seabirds attending trawl vessels when discarding was not occurring was a fraction of those attending vessels that were discarding, and thus little to no incidental seabird mortality occurred when vessels did not discard fish waste.

- **Description of results of testing to date**

Trials of mincing all fish waste and discards showed a clear reduction in the number of large albatrosses attending trawlers > 28 m in New Zealand, but did not have a significant effect on other seabirds (Abraham et al. 2009; Abraham 2010). Further New Zealand trials on vessels > 28 m comparing two types of fish waste processing to the status quo of discharging unprocessed discard continuously reported that less birds attended the vessel for the two discard processing methods (hashed and hashed + cutter pump) than when discards were not processed (Pierre et al. 2012a). The authors concluded that whilst processing fish waste reduced seabird attendance at the vessel, the ultimate solution to preventing incidental seabird bycatch mortality on trawl warp cables was to not discard at all, or less frequently, as vessel attendance was negligible when not discarding (Pierre et al. 2012a). New Zealand trials were conducted using storage tanks for discard material and discharging waste intermittently; every 30 minutes, or two, four or eight hours (Pierre et al. 2010). The trial found that intervals of four hours significantly reduced the number of large seabirds attending the vessel and eight hour intervals significantly decreased the number of small birds.

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP recognise that the presence of offal and discards is the most important factor attracting seabirds to trawl vessels and as such managing offal discharge and discards while fishing gear is deployed has been shown to reduce seabird attendance (ACAP 2016). Mealing or retaining all waste essentially eliminates incidental seabird mortality at trawl warps (ACAP 2016), but will not eliminate net captures. When all waste cannot be retained on the vessel, discharging waste in batches has been shown to significantly reduce the number of seabirds attending trawl vessels, and thus dramatically reduce the risk of incidental mortality on trawl warp cables (Pierre et al. 2010; Kuepfler et al. 2016).

Mincing has also been shown to reduce the number of seabirds attending trawl vessels (ACAP 2016d).

Proven specifications and standards

ACAP (2016d) recommend holding discard for at least two hours but preferably more than four hours and this is supported by trials from New Zealand which showed clear differences in the number of seabirds attending vessels relative to the amount of time between discard batches (Pierre et al. 2010).

Likely uptake

Offal management is a requirement of some fishing companies in the trawl fleet in New Zealand, but practices vary between fisheries and vessels and it is not a government requirement.

Effect on target catch

No effect of batch discarding on target catch has been identified.

Effect on non-target catch

No effect of batch discarding on non-target catch has been identified.

Compliance

Clear performance standards for batch-discarding are defined by ACAP (2016d) and Pierre et al. (2010). Methods of ensuring compliance include observers, electronic monitoring (cameras), Hurdles to uptake in New Zealand

If not mealing all waste, a requirement of Vessel Management Plans (VMPS) on large Deep Water Group trawlers (> 28 m LOA) in New Zealand is to either batch discard with minimum 30 minute intervals or mince all discard (DWG 2009), and with no discharge of fish waste within 40 mins of hauling and shooting

- **Costs per vessel for installation/uptake (if available)**

The cost of installing tanks capable of holding sufficient waste to batch discard at least every 30 minutes varies, but is a significant one-off cost and requires constant management within the factory and between the factory and wheelhouse.

Net cleaning

Limited efficacy testing

Some fisheries

- **Mitigation measure and how it works**

Seabirds are attracted to trawl nets on the sea surface because fish or squid stuck in the net webbing present a foraging opportunity. However the larger mesh size of some trawl nets, particularly pelagic (120 – 800 mm (ACAP 2016d) can capture seabirds, or birds can dive into the net entrance, and be drowned when the net sinks (shooting) or killed or injured when the net is hauled aboard the vessel. Smaller mesh on the lengthener and cod-end of some trawl nets is also capable of capturing seabirds (R. Wells pers. comm.).

- **Description of results of development to date**

Net cleaning as an effective mitigation measure has not been quantified (ACAP 2016d) so is supported by observation only (Hooper et al. 2003).

- **Description of results of testing to date**

Net cleaning has not been formally tested, but anecdotal observations suggest fewer seabirds attend a cleaned net compared to one with food items remaining.

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP best practice (ACAP 2016d) is for net cleaning to be used in conjunction with net binding and net weighting.

Nets should be cleaned after every shot to remove fish and other potential seabird food items to discourage seabird foraging on the net during net shooting (ACAP 2016d). In addition ACAP recommend good maintenance of winches and efficient deck procedures to reduce the amount of time the net is on the water surface during hauling. For pelagic trawl gear, ACAP recommend net binding large meshes (120–800 mm) in the wings and a minimum of 400-kg weight incorporated into the net belly prior to shooting (see net binding and net weighting).

Proven specifications and standards

No specifications or standards based on trials showing the efficacy of net cleaning have been documented. However the recommendations are to simply remove all potential seabird food items from the net (ACAP 2016d).

Likely uptake

Net cleaning is not currently required by the NZ Government. The Deepwater Group Vessel Management Plans require the removal of all 'fish stickers' prior to shooting the net (DWG 2009).

Effect on target catch

No effect of net cleaning on target catch has been reported. Lost fishing opportunities as a result of time spent cleaning the net may affect target catch rates.

Effect on non-target catch

No effect of net cleaning on non-target catch has been reported. Reducing the foraging opportunities at nets by cleaning may reduce the capture of species other than seabirds (e.g. marine mammals).

Compliance

Methods of ensuring compliance include observers and electronic monitoring (cameras).

- **Hurdles to uptake in New Zealand**

Net cleaning is not currently required by the NZ Government. It is labour intensive and potentially dangerous in heavy weather as extends time crew are required on deck

- **Costs per vessel for installation/uptake (if available)**

The cost of net cleaning is the amount of time it takes crew to clean the net.

Net binding

Limited efficacy testing

Not in use (in NZ, but guidelines exist for some companies, e.g. DWG)

- **Mitigation measure and how it works**

Net binding reduces the amount of time seabirds can interact with the net when it is on the sea surface during shooting. The bindings prevent the net webbing from opening at the surface and potentially entangling, and consequently drowning, seabirds.

- **Description of results of development to date**

First trialled in the South Georgia icefish trawl fishery (Sullivan et al. 2004). Three types of net binding have undergone limited trials on two classes of New Zealand trawl fisheries vessels; a factory-freezer trawler 106 m LOA (7 stations trialled) and a fresh fish trawler 42 m LOA (5 stations trialled) Cleal et al 2009.

- **Description of results of testing to date**

Found to be an effective mitigation measure in CCAMLR icefish trawl fishery (Sullivan 2010 submitted *in* ACAP 2016d). A trial in South Georgia with a small amount of replication found that some of the bindings broke before the net sank, indicating that stronger binding material may need to be used (Bull 2007; Sullivan et al. 2004). Limited New Zealand trials found that net binding could be easily applied to a large factory-freezer pelagic trawl net and to a smaller fresh fish trawler (Cleal et al. 2009). In that trial of 13 trawls with net binding no incidental seabird mortality occurred (Cleal et al. 2009).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

For pelagic trawl gear, ACAP best practice recommends net binding large meshes (120–800 mm) in the wings prior to shooting.

Proven specifications and standards

ACAP recommend combining net binding in pelagic trawl fisheries with net cleaning and net weighting to minimise the attractiveness of the net to foraging seabirds and the amount of time the net is on the surface (Sullivan et al. 2010 submitted *in* ACAP 2016d). Specific net binding guidelines are provided in ACAP (2016d).

Likely uptake

Cleal et al. (2009) reported that net binding was quick and safe on two different types of trawl vessels in New Zealand. However the ease of applying net-binding to the full range of trawl vessels in New Zealand was scored from 1 – 5 (easy to difficult) (Cleal et al. 2009). The vessels most suited to applying net-binding were very large trawlers, only using midwater gear and with full-time deck crew. In addition the authors commented that as the attendance of seabirds during shooting is very low, net binding is not necessary in New Zealand pelagic trawl fisheries. However the authors' state that net-binding trials would be useful in bottom trawls fisheries with large numbers of seabirds in attendance, such as squid fisheries (Cleal et al. 2009).

Effect on target catch

During a New Zealand net-binding trial bindings in one of five trial trawls did not break once the trawl doors spread apart and as such the net did not open and could not catch fish (Cleal et al. 2009).

Effect on non-target catch

No effect of net-binding on non-target catch has been reported.

Compliance

Methods of ensuring compliance include observers and electronic monitoring (cameras).

- **Hurdles to uptake in New Zealand**

Cleal et al. (2009) consider that net-binding trials would be useful in bottom trawls fisheries with large numbers of seabirds in attendance, such as squid fisheries (Cleal et al. 2009). Net binding is reasonably complicated and if not applied correctly there is a risk the net will not open and fish correctly (Cleal et al. 2009). Net binding bottom trawls with very long or very heavy ground ropes (squid and hoki trawls respectively for instance) has not been attempted but it is unclear if seabird captures occur during the net shooting (R. Wells pers. comm.).

- **Past and current funders and developers**

Government of South Georgia and the South Sandwich Islands, Sealord, Deepwater Group Ltd, Department of Conservation

- **Costs per vessel for installation/uptake (if available)**

Inexpensive as all that is required is mussel lashing material used in the aquaculture industry.

Net weighting

Limited efficacy testing

Not in use in New Zealand

- **Mitigation measure and how it works**

Net weighting on or near the cod end has been shown to increase the angle of net ascent during hauling operations, thereby reducing the amount of time the net is on the water's surface (ACAP 2016d; Hooper et al. 2003).

- **Description of results of development to date**

ACAP recommend combining net weighting with net binding and net cleaning to minimise the time the net is on the surface during both setting and hauling (Sullivan 2010 submitted in ACAP 2016d).

- **Description of results of testing to date**

The only very limited trials to date have been conducted in CCAMLR trawl fisheries (Sullivan et al. 2010 submitted in ACAP 2016d).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP state that there is a requirement to develop minimum standards for the amount and placement of weight (cod end, wings, footrope, mouth, belly) based on limited work done to date in CCAMLAR (ACAP 2016d).

Proven specifications and standards

ACAP state that no minimum standards or recommendations have been established (ACAP 2016d). Best-practices including retrieving the net as quickly as possible and maintaining good deck practices to minimise the time that the net is on the water's surface have been effective at reducing seabird net-entanglements during hauling in South Atlantic trawl fisheries (Hooper et al. 2003; Sullivan 2010 submitted in ACAP 2016d).

Likely uptake

The efficacy of net weighting is untested in NZ so it is not possible to predict likely uptake.

Effect on target catch

No effect of net-weighting on target catch has been reported.

Effect on non-target catch

No effect of net-weighting on non-target catch has been reported.

Compliance

Methods of ensuring compliance include observers and electronic monitoring (cameras).

- **Hurdles to uptake in New Zealand**

Lack of proven efficacy. Not practicable in NZ mid-water trawl fishers that record incidental seabird mortality as fishing gear is frequently in contact with the bottom and therefore would be subject to excessive wear if weighted (R. Wells pers. comm.).

- **Costs per vessel for installation/uptake (if available)**

Undetermined.

Net restrictor

Limited efficacy testing

In use in NZ (scampi fishery)

- **Mitigation measure and how it works**

Net restrictors prevent the mouth of the net from opening widely during shooting and hauling. It is particularly suited to certain gear arrangements notably triple rig trawls. When av triple rig is hauled and emptied, the two outside nets mouths close up but the centre net remains agape as it is spread across the width of the vessel's transom and remains so until shot again as scampi trawls are not hauled on deck for emptying. Due to this the DWG fleet are moving to a double rig system instead (R. Wells pers. comm.).

- **Description of results of development to date**

Tested in the New Zealand scampi fishery (Pierre et al. 2011). Nets in that fishery are characterised by multiple adjacent nets that can be at or close to the surface for extended periods during hauling and emptying, resulting in high seabird interactions and incidental mortalities.

- **Description of results of testing to date**

Limited results from cameras deployed in nets with net-restrictors in place identified the net restrictor as a potential mitigation device in the New Zealand scampi trawl fishery, where multiple (triple) nets are deployed adjacently (Pierre et al 2013).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

ACAP (2016d) state that there is insufficient support for the efficacy of net-restrictors as at-sea testing is required to determine if captures in the centre net are reduced.

Proven specifications and standards

Pierre et al. (2013) provide detailed information on the experimental net-restrictor used in preliminary trials.

Likely uptake

Net-restricting materials are easily sourced and are not expensive. Most scampi vessels with triple rig have the restrictor fitted at all times and all are required by DWG procedures to fit one if seabird risk manifests itself in the form of net captures

Effect on target catch

Not formally tested.

Effect on non-target catch

Not formally tested.

Compliance

Methods of ensuring compliance include observers and electronic monitoring (cameras).

- **Hurdles to uptake in New Zealand**

Pierre et al. (2013) recommended that instead of experimental trials of a net restrictor data collection by observers on scampi vessels that are using restrictors in the centre net of triple-rig gear would enable bycatch rates before and after net restrictors were deployed to be compared quantitatively.

- **Costs per vessel for installation/uptake (if available)**

Negligble.

Setnet (gill net)

The following fishing gear is classed as gill nets or entangling nets, following the International Standard Statistical Classification of Fishing Gear (Nedelec and Prado 1990): set gillnets (anchored), driftnets, encircling gillnets, fixed gillnets (on stakes; not legal in NZ), trammel nets, and combined gillnets-trammel nets.

There has been little concerted effort worldwide to reduce seabird bycatch in set net fisheries despite the fact bycatch is very significant especially in areas such as the Baltic, Iceland and NW USA (Zydelis et al 2013). At present there is no universal solution to setnet seabird bycatch, partly because set net fisheries are often small-scale fisheries using a large range of gear types (Wiedenfeld et al. 2015). It also reflects a modest investment globally in seabird mitigation in gillnet fisheries compared to other fisheries (Gilman et al. 2010; Żydelis et al. 2013).

Research points to several areas where mitigation technologies are promising, but most need substantial development. Methods to increase net visibility (e.g., Melvin et al. 1999; Crawford et al. 2016) show most promise to reduce incidental mortality of seabirds in set net fisheries.

Table 4. Setnet mitigation method or device included in this review and current status of development

Mitigation method or device	*Status of development*	*Page*
Net-visibility: high-contrast panels	Early prototype / functionality	70
2Net visibility: White / coloured nets	Early prototype / functionality	72
Net visibility: Barium sulphate	Early prototype / functionality	73
Net visibility: Moving/reflective objects on net	Early prototype / functionality	76
Net visibility: Illumination	Early prototype / functionality	77
Net visibility: Multistrand mesh	Limited efficacy testing, not recommended	79
Time of setting	Broader efficacy testing (may require refinement)	80
Net specs: Smaller mesh size	Early prototype / functionality	81
Net specs: Setting depth (sub-surface)	Early prototype / functionality	82
Net specs: Upright taut nets	Limited efficacy testing, not recommended	84
Net specs: Hanging ratio	Early prototype / functionality	86
Net specs: Net height	Early prototype / functionality	87
Acoustic deterrents: Pingers	Early prototype / functionality	88
Acoustic harassment devices (AHDs)	Limited efficacy testing, not recommended	90
Above-water scarers	Early prototype / functionality	90

Net-visibility: high-contrast panels

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

Panels with a repeated pattern in high-contrast black and white are fixed to nets (Fig. 15). To be visible across a range of underwater light conditions, patterns use contrast and dimensions to maximise visibility at low light levels (Martin and Crawford 2015).

- **Description of results of development to date**

High-visibility panels were developed based on research on what vertebrate eyes see underwater, which suggested that a pattern of high contrast and low spatial frequency is needed (Martin and Crawford 2015). Panels are black and white since colour vision is lost at low light levels (Martin and Crawford 2015). For a panel to be visible at 2m (low light levels), a striped grating pattern needs 6cm stripe width, and a checkerboard grid should have 6cm squares (Martin and Crawford 2015). Panels would need to be 60 cm x 60 cm overall. To be visible at 4m, stripes or squares would need 12cm width and panels 120 x 120cm overall (Martin and Crawford 2015). Panels are fixed to the net in a regular 4 m grid (Martin and Crawford 2015).

Solid panels that prevent water flow-through could cause net lofting, impacting net function (Martin and Crawford 2015; Wiedenfeld et al. 2015). Striped mesh is unlikely to be as visible since contrast is not as high (Martin *in* Wiedenfeld et al. 2015), but potential solutions include cutting slits or 2cm holes into the black parts of the panel, cutting the panel into strips, and attaching panels only on the top and on either side of the net to allow water movement through the net (Martin and Crawford 2015; Wiedenfeld et al. 2015). Panels with strips to allow water flow-through were developed by the Birdlife International Seabird Task Force to test in Lithuanian and Portuguese fishery (Fig. 15).

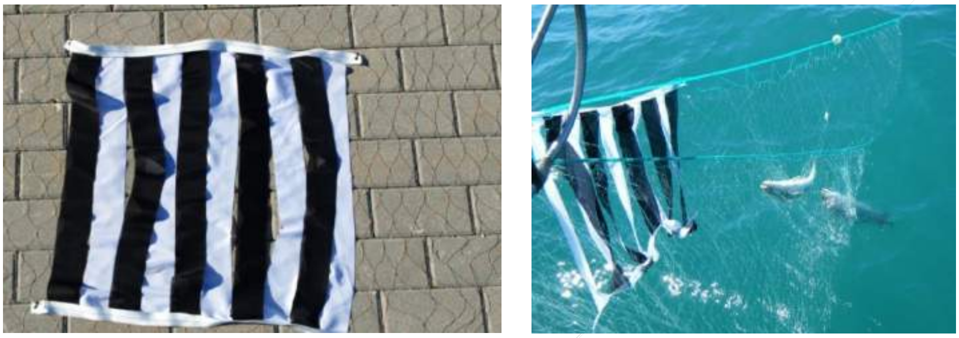


Figure 15. Drag-reducing contrast net panel in a grating pattern (**left**) attached to the fishing net (**right**). (Images: Julius Morkunas, Seabird Task Force, from Crawford et al. (2016) and SPEA from seabirdbycatch.com)

- **Description of results of testing to date**

Preliminary testing of net panels is taking place in Chile, Lithuania and Portugal (Crawford et al. 2016; Gutiérrez and Santos 2016). Pilot tests are promising but need analysis and extension into full-scale testing.

Testing planned: The Albatross Task Force in Chile had prototypes made and were about to start testing high-visibility panels in 2015, mostly for mitigating penguin and shearwater bycatch (Wiedenfeld et al. 2015). Trials were planned for surface- and demersal-set net fisheries in summer and winter. Panels with 60 cm x 60 cm black-and-white checkerboard grid were to be fixed centrally in the net (test fishery nets 4 m high) and spaced 4 m apart. Testing would also include panels modified to minimise net lofting, although these test fisheries do not set in waters with strong currents (ATF *in* Wiedenfeld et al. 2015). BirdLife's Seabird Task Force programme in Portugal planned to extend gear tests into fisheries trials in September 2016 for mitigating shearwater, razorbill and murre bycatch (Gutiérrez and Santos 2016). Testing of net panels partly to address auk / alcid bycatch is also proposed for the UK bass driftnet fishery, led by the Sea Mammal Research Unit (SMRU) in Scotland (Wiedenfeld et al. 2015).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

No data yet; experimental research planned or underway

Proven specifications and standards

None

Likely uptake

Cheap to construct and easy to deploy (Martin and Crawford 2015; Gutiérrez and Santos 2016). Concern about the potential for solid panels to cause net lofting, reducing fishing ability of nets, is being addressed in tests in active fisheries.

Effect on target catch

Not yet tested

Effect on non-target catch

Not yet tested

Compliance

Panels are attached to nets so gear use could be checked in port. Compliance could be monitored via fisheries observers and electronic monitoring systems (cameras).

- **Hurdles to uptake in New Zealand**

If solid net panels cause net lofting and affect fishing performance, uptake would be affected.

- **Past and current funders and developers (if applicable)**

Concept development by G. Martin via BirdLife Partner in the UK Royal Society for the Protection of Birds, with funding from the David and Lucile Packard Foundation. Albatross Task Force Chile, and Sea Mammal Research Unit (SMRU) in St. Andrews, Scotland.

- **Costs per vessel for installation/uptake (if available)**

Dependent on panel materials, but of relatively low cost

Net visibility: White / coloured nets

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

Nets are modified to make them less transparent and more visible to seabirds by including white or coloured sections, or by colouring the entire monofilament net. The more-visible material replaces upper meshes (Melvin 1995; Melvin et al. 1999), is woven or painted into the net as coloured stripes, or the whole net is made with opaque coloured monofilament (Wiedenfeld et al. 2015).

- **Description of results of development to date**

White-top nets: netting made of white twine (no. 18 or 24, ~ 4x monofilament diameter) replaced the upper 10% and 25% of nets, developed in the salmon drift gillnet fishery in Puget Sound USA (Melvin 1995; Melvin et al. 1999). Nets with white top meshes were also tested in a bottom-set gillnet fishery in the Lithuanian Baltic Sea (Crawford 2015).

Net striping: nets in stripes of white and green monofilament, or with vertical stripes of different net materials, have been proposed (Wiedenfeld et al. 2015). Neither idea appears to have been trialled. Nets painted with stripes have been tested by the Japanese government in their EEZ. In 2015, trials were still ongoing (Mayumi Sato in Wiedenfeld et al. 2015). Stripes would need to be at most 0.5 m apart for animals to see them and not be caught in the between-strip gaps (G. Martin in Wiedenfeld et al. 2015).

Single-colour nets: Opaque blue nets had reduced seabird bycatch (Trippel et al. 2003), but could also have been from increased net stiffness (nets barium sulphate treated). The German Institut für Fischereitechnik developed high-visibility coloured nets (Mentjes and Gabriel 1999). Hanamseth et al.

(submitted) compared the visibility of green, orange and standard clear monofilament with a no-mesh control, using captive little penguins *Eudyptula minor*. Orange was more visible to penguins than green or clear monofilament, and might be useful for near-surface nets (Hanamseth et al. submitted). Entirely white or green monofilament nets have also been proposed (Wiedenfeld et al. 2015). Importantly, net colour will not be useful for nets set at night or at depth, since colour vision is not possible in low light and is effected by absorption of light rays spectrum by depth so different colors fade at different depths. The colours visible to seabird species caught as bycatch are unknown (Martin and Crawford 2015).

Glow nets and glow ropes have been proposed to increase net visibility to marine mammals and turtles, made by adding strontium aluminate $SrAlO_4$ to the rope / monofilament during manufacture (Werner et al. 2006; Wang et al. 2010). Glow ropes and nets glow brightly for up to 48 hours after being laid out in the sun to activate, but glow was not robust to repeated setting and hauling (Werner et al. 2006; Wiedenfeld et al. 2015). Glow nets would only be useful at night or at depth.

- **Description of results of testing to date**

White-top nets: highly visible white twine sections replacing the upper 10% and 25% of 18.3 m nets were compared to standard monofilament gillnets in the salmon driftnet fishery in Puget Sound, USA (Melvin 1995; Melvin et al. 1999). Common murre bycatch was reduced in both 10% and 25%-white nets (45% and 40% bycatch reduction compared to control net). Rhinoceros auklet bycatch was also reduced (by 42%) but only in the 25%-white nets (Melvin et al. 1999). White-top nets were also trialled in a bottom-set cod gillnet fishery (Baltic Sea off Lithuania, 4m gillnets) (Crawford 2015). The pilot study did not see a reduction in bird captures compared to standard nets, but more trials are needed before the effect can be confirmed (Crawford 2015). The lack of light at the setting depth may explain the result (Crawford 2015). Further white-top net trials will take place in Puget Sound over 2017/2018 to confirm that target catch is maintained, and test nets with fewer white meshes (top 5% white) (Wiedenfeld et al. 2015).

Net striping: Nets painted with stripes have been tested by the Japanese government in their EEZ. In 2015, the net-striping trials had not found any effect on bycatch rate, but trials were still ongoing (Mayumi Sato in Wiedenfeld et al. 2015). Vertical stripes of different net materials, or of white and green monofilament, do not seem to have been tested. In 2015 there was discussion that striped nets would be tested in Newfoundland, Canada (Wiedenfeld et al. 2015). Nets would be striped with twine or monofilament of a different colour woven in, and trialled in a bottom-set cod fishery (Wiedenfeld et al. 2015).

Single-colour nets: high-visibility coloured monofilament nets were trialled in a German cod set-net fishery, but a pilot study showed no effect on sea-duck bycatch but reduced cod catch by ~ 20% (Mentjes and Gabriel 1999). Although Trippel et al. (2003) trialled blue nets, nets were also stiffer than normal, having been treated with barium sulphate. Teams testing gear in a Newfoundland bottom-set cod fishery are also planning to test white monofilament nets to try and reduce gannet, alcid and shearwater bycatch (Wiedenfeld et al. 2015).

When light levels are poor, coloured nets are less effective: in a bottom-set cod gillnet fishery, white meshes in the upper 10% and 25% appear to have no effect on bird captures (Crawford 2015). Light is needed for white or coloured nets to be seen, so white/colour is unlikely to help species diving at night or in deep water (Trippel et al. 2003; Žydelis et al. 2013; Martin and Crawford 2015).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

White top meshes: In a coastal driftnet fishery, seabird bycatch was reduced in nets with white twine replacing the upper 10% and 25% of meshes (Melvin et al. 1999), but the effect depended on species: common murre bycatch was lower in both 10% and 25%-modified nets, but rhinoceros auklet bycatch was reduced only in the 50%-modified nets (Melvin et al. 1999).

Net striping and net colour: There is no evidence that net striping reduces seabird bycatch rates (Mayumi Sato in Wiedenfeld et al. 2015). It is inconclusive whether colouring the whole net is effective; sea-duck catch did not appear to be reduced by coloured nets, but that pilot study was not extended (Mentjes and Gabriel 1999).

Using colour as a visual cue is unlikely to be effective in demersal nets below the photic zone (Crawford 2015) or at night, since colour is not seen in poor levels (Martin and Crawford 2015). But may be useful in shallow set net fisheries.

Proven specifications and standards

Specifications and performance standards available for white-top nets in a driftnet fishery. No proven specifications or standards for net striping or coloured nets.

Likely uptake

Easy to deploy and no extra time on deck as modifications integral to gear.

Effect on target catch

White-top nets: Upper 10%-white nets maintained fishing efficiency for sockeye salmon, but 25%-white nets reduced sockeye catch rates by more than 50% (Melvin et al. 1999). Effects on target catch in this fishery will be tested further in summer 2017/18 (Wiedenfeld et al. 2015).

Single-colour nets: Inconclusive, but catch may be reduced; a pilot study of high-visibility coloured set nets suggested cod catch reductions of ~ 20%, but was unconfirmed (Mentjes and Gabriel 1999).

Effect on non-target catch

Coloured nets are unlikely to reduce pinniped bycatch since their vision seems to be monochromatic (Hanke et al. 2008).

Compliance

Modifications are integral to the net so compliance can be checked in port.

- **Hurdles to uptake in New Zealand**

Potential reductions in target catch in 25%-white top nets (Melvin et al. 1999). .

- **Past and current funders and developers (if applicable)**

US Washington Sea Grant program (Melvin), with the Puget Sound Gillnetter's Association and the Washington Department of Fish and Wildlife. Funders included National Ocean and Atmospheric Administration (NOAA) and National Marine Fisheries Service. Germany: Institut für Fischereitechnik of the state fisheries research organisation Bundesforschungsanstalt fur Fischerei. Lithuania: Lithuanian Ornithological Society, supported by the BirdLife Marine Program. Canada: collaboration between Memorial University of Newfoundland, Canadian Wildlife Service, Canadian Department of Fisheries and Oceans, US Fish and Wildlife Service, Bird Studies Canada, and the fishermen's union.

- **Costs per vessel for installation/uptake (if available)**

No costing available yet.

Net visibility: Barium sulphate

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

Barium sulphate treated nets, dyed blue, are less transparent and stiffer than monofilament nylon nets (Trippel et al. 2003). This could make them more visible and less entangling for seabirds.

- **Description of results of development to date**

Nets with better sound reflectiveness were developed around 1999 to target marine mammal bycatch (King and Holy 2003). Monofilament nets containing barium sulphate ($BaSO_4$ 3% by volume) were dyed opaque pale blue and tested in a demersal gillnet fishery off New Brunswick, east Canada (Trippel et al. 2003).

- **Description of results of testing to date**

In demersal nets set at 100m, great shearwater bycatch was significantly lower in barium sulphate-treated blue nets (0.06 birds/net, 185 nets) compared to standard 0.6 mm monofilament gillnets (0.26 birds/net, 364 nets) (Trippel et al. 2003). Most birds were caught near the surface during setting (Trippel et al. 2003). There was no significant decrease in catches of the four commercial fish species. Testing was not designed for seabirds, so did not show whether net visibility (opaque blue) or net stiffness decreased seabird catches.

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Opaque pale blue barium-treated nets significantly reduced great shearwater bycatch compared to control nets (Trippel et al. 2003). There was no test of which feature decreased seabird catches: net stiffness or net visibility.

Proven specifications and standards

Clear specifications for including barium sulphate in monofilament for nets and for net use.

Likely uptake

The barium sulphate filler made nets stiffer (Trippel et al. 2003), with potential for net handling problems. Chemically enhancing nets is also expensive, which may reduce uptake (Waugh et al. 2011).

Effect on target catch

There was no difference in catches of commercial fish species between barium sulphate gillnets and the control (Trippel et al. 2003).

Effect on non-target catch

Harbour porpoise bycatch was also significantly reduced in barium-sulphate treated blue nets (Trippel et al. 2003).

Compliance

Modification integral to the net so could be checked in port.

- **Hurdles to uptake in New Zealand**

Net stiffness and the high cost of chemical treatment.

- **Past and current funders and developers (if applicable)**

Developed by collaboration between Fisheries and Oceans Canada, Atlantic Gillnet Supply (Maine USA), the US National Marine Fisheries Service, and the University of New Brunswick. Funding from the U.S. National Marine Fisheries Service and Fisheries and Oceans Canada.

- **Costs per vessel for installation/uptake (if available)**

The nets are more expensive, but are 30 % more durable than regular nets.

Net visibility: Moving/reflective objects on net

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

Attaching moving and/or reflective materials to nets increases visibility to seabirds and marine mammals.

- **Description of results of development to date**

Highly-reflective CDs attached to nets were developed to deter seabirds in the Japanese right-eye flounder fishery (Wiedenfeld et al. 2015). Objects that can move in the current include small corks on the net (Waugh et al. 2011), shapes of predators (Wang et al. 2010) and streamers. Streamer ideas include short square 'mesh streamers' (same length and width as mesh), and long narrow 'ribbon streamers' (Wiedenfeld et al. 2015). Ribbon streamers would move more and be more visible than mesh streamers, but are also expected to tangle more (Wiedenfeld et al. 2015).

- **Description of results of testing to date**

Nets hung with reflective CDs were trialled in the Japanese right-eye flounder fishery to deter seabirds, but the effectiveness was 'doubtful', 'unclear', and 'somewhat promising' (Wiedenfeld et al. 2015). Studies need translating from Japanese (Wiedenfeld et al. 2015). Nets hung with cut-out shapes of predators have not been tested for seabirds, but shark shapes significantly reduced non-target turtle catch as well as target catch in Mexican surface- and bottom-set fisheries (Wang et al. 2010). No testing of streamers to date. Testing should consider factors including the size and spacing of streamer areas and streamer colour/reflectiveness (Wiedenfeld et al. 2015).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Inconclusive effectiveness of CD-reflective nets at deterring seabirds. No testing of predator shapes or net streamers.

Proven specifications and standards

None

Likely uptake

Nets hung with reflecting CDs on is very inexpensive, but CDs became tangled in nets during setting and hauling (Wiedenfeld et al. 2015).

Effect on target and non-target catch

Unclear. Predator shapes reduced target catch significantly, but also reduced non-target turtle bycatch (Wang et al. 2010).

Compliance

Predator shapes attached to net during deployment, so electronic monitoring and/or observers required. Streamers: Modification integral to net so could be checked in port.

- **Hurdles to uptake in New Zealand**

Impacts on target catch suggest fishers unlikely to adopt predator shapes. Tangling of CD-hung nets would affect fisher uptake.

- **Past and current funders and developers (if applicable)**

Predator shapes were developed by the US National Ocean and Atmospheric Administration Pacific Islands Fisheries Science Center, University of Hawaii and Ocean Discovery Institute

- **Costs per vessel for installation/uptake (if available)**

Likely to be low

Net visibility: illumination

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

Using coloured lights attached to the float lines to illuminate the net, bycatch species can see and avoid the net (Fig. 16, 17).

Figure 16. LED light sticks (left side) and chemical light sticks (right). (Image: J. Wang, from NMFS 2013)

- **Description of results of development to date**

LED light sticks development initially focused on attracting target fish species (Patrick and Poulton 2007) and then on reducing sea turtle bycatch (Wang et al. 2010). Colour and light levels are chosen according to species (Patrick and Poulton 2007; Wiedenfeld et al. 2015), but little is known about what colours seabirds can see (Martin and Crawford 2015). Lights developed for longlines are used, but a light is being developed for gillnet use (Wiedenfeld et al. 2015). Lights can be used to 300 – 400m (Wiedenfeld et al. 2015) and are 'very robust' with an expected 3-year life span (Mangel 2015). LED lightsticks in turtle trials use AA batteries which lasted about a month before battery replacement needed (Wang et al. 2010), but lights can be solar-powered or have a remote power supply (Patrick and Poulton 2007). Chemical lightsicks (glowsticks) are simpler and cheaper than LED light but are not reusable, and limited to fisheries with short soak-times since light intensity declines after only a few hours (Patrick and Poulton 2007). UV LED lightsticks have been trialled (Milliken and Wang 2013; Mangel 2015), but are unlikely to be useful for seabirds since UV-vision has not been found in any amphibious bird species (Martin and Crawford 2015).

Lights are unlikely to help reduce seabird bycatch in daytime, surface-set nets. In low light levels, bright lightsticks may reduce seabirds' ability to see the net by disrupting dark-adapted vision (Martin and Crawford 2015). This is important since even during daylight, many diving seabirds forage at low light levels with permanently dark-adapted vision (Martin and Crawford 2015).

- **Description of results of testing to date**

Net lights can significantly reduce sea turtle and seabird bycatch without affecting target catch rates (Wang et al. 2010; Milliken and Wang 2013; Mangel et al. 2014), but ambient light affects how well they work (Milliken and Wang 2013).

In Peru, green LED lightsticks (model CM-1, Centro Power Light) every 10m along the demersal set net headline significantly reduced catches of cormorants (84% less than unlit control nets, 114 paired trials) (Mangel et al. 2014). Green LEDs also decreased turtle and Pacific seahorse captures, while target catch remained the same (Mangel et al. 2014). Similarly, green LED lightsticks every 10m and chemical lightsticks every 5m did not affect target catch rates or values in night trials in Mexican coastal fisheries, but decreased turtle bycatch by 40% (LED) and 59% (chemical) (Wang et al. 2010). At night, net lights could be more effective than during day sets, but also significantly decrease target catch (Milliken and Wang 2013). That pilot study (focused on turtle catch) was not conclusive and needs extending.

Figure 17. Longline lights on a gillnet headline, Peru. (Image: Jeff Mangel, from Crawford et al. 2016).

Upcoming work: New work discussed in early 2015 was to test LED lights in Ecuador, Canada, UK, Germany, Latvia, Poland and the mid-Atlantic (Wiedenfeld et al. 2015; Crawford et al. 2016). LED light trials would continue in bottom-set gillnet fisheries in Peru and expand into Ecuador in 2015 (ProDelphinus, in Wiedenfeld et al. 2015). In Canada, LED lights would be tested in Newfoundland bottom-set cod and surface-set herring fisheries. LED lights were to be tested in UK inshore monkfish bottom-set fisheries, and possibly in the mid-Atlantic monkfish fishery led by US National Marine Fisheries Service. Groups interested in testing LED lights in German and Latvian bottom-set cod fisheries were Naturschutzbund Deutschland in Germany and the Latvian Latvijas Ornitologijas Biedriba (Wiedenfeld et al. 2015).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Green LED lightsticks significantly reduced catch rates of cormorants (84% reduction) in a Peruvian demersal set net fishery (Mangel et al. 2014).

Proven specifications and standards

For seabirds, green LED lightsticks attached every 10m along the headline of demersal set nets.

Likely uptake

May not work with a net hauler. May be costly to implement in larger operations since cost of illumination relatively high and placing lights on float lines takes time (Wang et al. 2010; NMFS 2013; Mangel et al. 2014).

Effect on target catch

Target species catch was the same in lit and unlit nets in guitarfish demersal set nets in Peru (Mangel et al. 2014). Nets lit to deter turtles either increase or do not change target catches, depending on target species (Wang et al. 2010; Milliken and Wang 2013). Importantly, net lights used at night can decrease target catches of some species (Milliken and Wang 2013).

Effect on non-target catch

Green LED lights also reduced non-target catch of green turtles and Pacific seahorses in Peru (Mangel et al. 2014).

Compliance

Would require electronic monitoring and observer presence on board.

- **Hurdles to uptake in New Zealand**

Implementation cost in larger operations could affect the commercial viability of lights (NMFS 2013). Potential loss of catch ((Milliken and Wang 2013).

- **Past and current funders and developers (if applicable)**

Testing and development to date has been by the US National Marine Fisheries Service's (NMFS) Northeast and Pacific Islands Fisheries Science Centers, and by ProDelphinus (Peru with further testing proposed in Ecuador) with funding from the Darwin Initiative.

Further testing and development which was proposed in 2015 (Wiedenfeld et al. 2015) to be led by the following countries and organisations. Canada: Memorial University of Newfoundland, Canadian Wildlife Service, Canadian Department of Fisheries and Oceans, US Fish and Wildlife Service, Bird Studies Canada, and the fishermen's union Fish, Food and Allied Workers. England: Sea Mammal Research Unit (SMRU) in St. Andrews Scotland, and Cornish Fish Producers' Organization. Germany: Naturschutzbund Deutschland (NABU; BirdLife Partner in Germany), supported by Bundesamt für Naturschutz (the state nature conservation authority). Latvia: BirdLife Partner Latvijas Ornitologijas Biedriba

- **Costs per vessel for installation/uptake (if available)**

Each LED lightstick costs USD$8 – $9 (Korean manufacture) or $4 – $6 (Chinese), compared to $0.10 – 1.00 for disposable chemical light sticks (Wang et al. 2010; Wiedenfeld et al. 2015). Lights are attached to the headline every 5 – 10m. AA batteries need replacing after a month, or chemical lightsticks replaced after 24 hrs. Net lighting was estimated to cost between USD$19,000 to $33,000 per year in one demersal set net test fishery, but could be amortised over the 3-year life of the gear since light sticks are 'very robust'. The cost of lights is decreasing, and shallow-fishing LEDs are cheaper than those developed for long-line fishing (Cost estimates from Milliken and Wang 2013; Mangel 2015; Wiedenfeld et al. 2015).

Net visibility: Multistrand mesh

Limited efficacy testing, not recommended

Not in use

- **Mitigation measure and how it works**

By increasing the diameter of the net material, nets are more visible.

- **Description of results of development to date**

Although most materials thicker than monofilament nylon have fallen out of favour, being worse at catching fish (e.g. hemp nets, Wiedenfeld et al. 2015), changes to monofilament thickness were tested. Test nets with panels of multi-monofilament (3 twisted monofilament strands) were developed and compared with standard monofilament nets (~ 0.5 mm diameter) (Melvin 1995).

- **Description of results of testing to date**

In a pilot study, multifilament nets caught the same number of seabirds as control monofilament nets and entangled a seal, but caught fewer target catch (Melvin 1995).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Multifilament nets are not a viable alternative to reduce seabird catch in monofilament nets (Melvin 1995).

- **Past and current funders and developers (if applicable)**

US Washington Sea Grant program, University of Washington (Melvin), with funding from National Ocean and Atmospheric Administration (NOAA) and support from the Puget Sound Gillnetter's Association.

Time of setting

Broader efficacy testing overseas (may require refinement)

Not in use

- **Mitigation measure and how it works**

Nets are set at times of day when bycatch species are least abundant to minimise the risk of encounters with fishing gear.

- **Description of results of development to date**

The method was developed following observations that seabirds can be more abundant at some times of day than at others. Development by Melvin et al. (1999).

- **Description of results of testing to date**

Avoiding fishing at dawn and dusk significantly reduced auklet and murre entanglements in a salmon driftnet fishery (Melvin et al. 1999), but not duck entanglements in a cod setnet fishery (Mentjes and Gabriel 1999). Both seabird and target fish species captures were highest at dawn in salmon driftnets (Puget Sound USA, Melvin et al. 1999). Avoiding fishing around sunrise reduced target species catch rates by 5% but also significantly decreased murre and auklet entanglements (Melvin et al. 1999). Trials in a German cod set-net fishery found that restricting fishing to just one of the dawn or dusk periods had no effect on duck captures, but significantly reduced target fish captures (Mentjes and Gabriel 1999).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Effectiveness species-dependent: auklet bycatch was reduced significantly by avoiding dawn fishing (60% reduction), but not to the same extent for common murre (30% reduction) since murres were also caught at dusk (Melvin et al. 1999). Duck bycatch was not significantly changed by avoiding dawn or dusk fishing (Mentjes and Gabriel 1999).

Proven specifications and standards

Time of day clearly defined relative to nautical dawn and dusk.

Likely uptake

Following the study in Puget Sound, fishing hours changed to avoid dawn and dusk (when the greatest number of seabirds were present), despite the anticipated reduction in target catch (Moore in Wiedenfeld et al. 2015).

Effect on target catch

Target species catch was reduced by 5% by fishing during the day compared to fishing around sunrise (Melvin et al. 1999).

Effect on non-target catch

Not documented

Compliance

Electronic monitoring and/or fisheries observers would be required.

- **Hurdles to uptake in New Zealand**

Requires detailed knowledge of abundance changes over the course of a day, and will differ for every seabird and target fish species combination. Abundance patterns will also vary over time (e.g. different between seasons, years; Melvin et al. 1999; Dagys and Žydelis 2002) so annual monitoring needed. Potential loss of catch.

- **Past and current funders and developers (if applicable)**

Developed by the US Washington Sea Grant program with Puget Sound Gillnetters' Association and the Washington Department of Fish and Wildlife. Funding from the National Marine Fisheries Service and the National Oceanic and Atmospheric Administration.

- **Costs per vessel for installation/uptake (if available)**

n/a

Net specs: Smaller mesh size

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

Decreasing mesh size is thought to reduce the risk of seabirds becoming entangled in nets.

- **Description of results of development to date**

Bird captures are linked to mesh sizes (Northridge et al. 2016): observer data and fisher reports suggest that bird captures are lower in smaller meshes (finer than 35 mm; Stempniewicz 1994), and that increasing mesh sizes from 25 to 60 mm increases bird capture rates dramatically (Dagys and Žydelis 2002), but not in all cases (Bellebaum et al. 2013). Fisheries tests of mesh size to reduce sea duck bycatch were developed by the Institut für Fischereitechnik in Germany.

- **Description of results of testing to date**

In a German set-net cod fishery, sea-duck catch was not affected by changing mesh sizes from 55 to 80 mm, compared to the typical 60 mm in this fishery (Mentjes and Gabriel 1999).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Captures of some bird species were not predictably improved by reducing mesh sizes (sea ducks, Mentjes and Gabriel 1999), but there has been no experimental research to see if this holds for other birds.

Net specs: Setting depth (sub-surface)

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

Fishing gear is lowered in the water column to put nets out of reach of seabirds (Fig. 18). Surface-set nets are submerged below the surface (sub-surface or dropped-headline nets), beyond the reach of surface-lunging species like albatrosses.

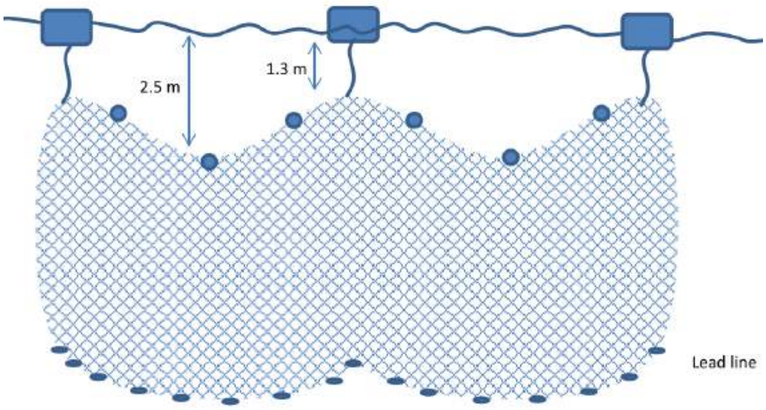


Figure 18. Subsurface net panel showing extra leadline weights used to pull the headline below the surface. (Image: Mangel et al. 2014).

- **Description of results of development to date**

Development was based on observations that in some groups of seabirds, most bycatch occurs within 5 m of the surface (alcids, shearwaters, albatrosses; Hayase and Yatsu 1993; Melvin et al. 1999; Mangel et al. 2014). Unlikely to be useful for diving seabirds. The Fisheries Agency of Japan developed sub-surface nets by increasing the length of the hanging lines between surface floats and midline (Hayase and Yatsu 1993). Similarly, Mangel et al. (2014) modified surface driftnets to float 1.3 – 2.5 m below the surface using extra weights on the leadline.

Importantly, sub-surface and deeper bottom-set nets can still entangle birds during setting and hauling (Løkkeborg 2008).

- **Description of results of testing to date**

Hayase and Yatsu (1993) compared nets submerged 2 m below the surface with surface nets in Japanese high-seas drift gillnet fisheries. Seabird entanglements (mostly sooty and short-tailed shearwaters) were significantly lower in sub-surface nets (27% reduction), but target catch was reduced by 64% and 49% (squid and Pacific pomfret; Hayase and Yatsu 1993). Hanging lines 1m apart tangled with the net during setting, but tangling was reduced and net handling improved when hanging lines were 5m apart (Hayase and Yatsu 1993). In Peru, ProDelphinus tested sub-surface nets in driftnet fishery. Too few seabirds were caught to determine an effect, but subsurface nets caught significantly less of the target catch (73% reduction in sharks and 80% in rays; Mangel et al. 2014). Experiments continued into 2015, adjusting net weighting and tension to improve operation of sub-surface nets (Mangel et al. 2014; Wiedenfeld et al. 2015).

Planned testing: Trials for 2017/2018 were discusssed in 2015 which would test the ability of a drop line (among other gear modifications) to reduce seabird bycatch in North Pacific salmon driftnet fisheries (Wiedenfeld et al. 2015). Longer-term plans included testing whether sunken headlines would reduce seabird bycatch in UK bass driftnet fisheries (Wiedenfeld et al. 2015).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Shearwater entanglements were significantly reduced in 2 m-submerged nets (Hayase and Yatsu 1993). Initial trials in Peru did not encounter enough seabirds to test if seabird bycatch is affected (Mangel et al. 2014). Importantly, setting depth does not stop the potential for birds to get entangled during setting or hauling (Løkkeborg 2008).

Proven specifications and standards

None.

Likely uptake

Unlikely if changing the position of the net in the water column affects target species catch (Wiedenfeld et al. 2015). Tangling of hanging lines with netting would also reduce fisher uptake, but line spacing can address that (Hayase and Yatsu 1993).

Effect on target catch

In high seas driftnets, target species catch was reduced by 64% and 49% (squid and Pacific pomfret, Hayase and Yatsu 1993). Subsurface nets caught significantly less target sharks and rays (Mangel et al. 2014).

Effect on non-target catch

Bycatch rates of other species (seals, small cetaceans, turtles) were not significantly different in sub-surface submerged drift nets (Hayase and Yatsu 1993). Although subsurface nets had much lower turtle catch rates, the effect was not significant because of variation between vessels (Hayase and Yatsu 1993). Mangel et al. (2014) saw fewer cetacean captures (non-significant change).

Compliance

Nets with longer hanging lines need to be prepared in advance of setting, so compliance could be checked in port.

- **Hurdles to uptake in New Zealand**

Target catches of squid, finfish, sharks and rays declined significantly (Hayase and Yatsu 1993; Mangel et al. 2014). Less likely to be used if hanging lines cause tangles and affect gear handling (Hayase and Yatsu 1993).

- **Past and current funders and developers (if applicable)**

High seas experiments: Japanese Fisheries Agency. ProDelphinus (Peru) with support from the American Bird Conservancy and the Darwin Initiative. Planned testing in North Pacific salmon fisheries will involve US National Ocean and Atmospheric Administration, Department of Fisheries and Oceans (Canada), the Pacific Salmon Commission, Washington Department of Fish and Wildlife (US), and tribal fishing governments. In England testing would led by the Sea Mammal Research Unit (SMRU), Scotland, with local Producers' union.

- **Costs per vessel for installation/uptake (if available)**

Not available

Net specs: upright taut nets (low-profile or stand-up nets)

Limited efficacy testing, not recommended

Not in use

- **Mitigation measure and how it works**

Maintaining a net vertical in the water, with sufficient net tension so that it does not loft when full of fish, should minimise how much net is horizontal and available to capture birds (Fig. 19) (Montevecci in Wiedenfeld et al. 2015).

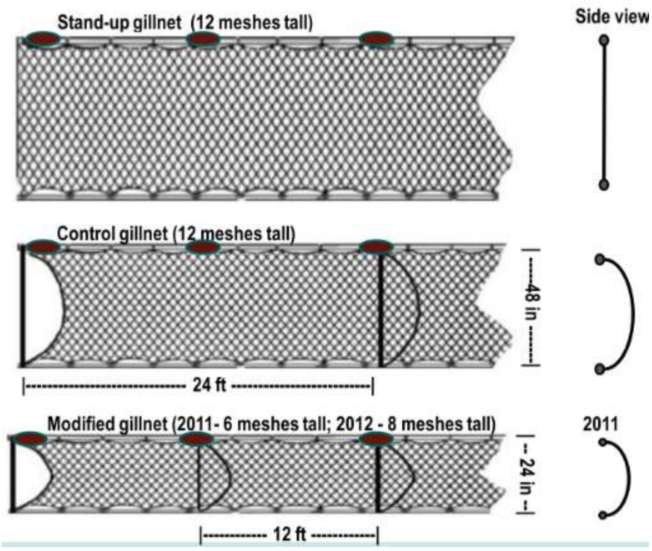


Figure 19. Standup gillnet compared to standard net with tiedowns. (Image: Wark et al. 2013).

- **Description of results of development to date**

Bird captures were observed to be higher in nets set loose/unstrained (e.g. flatfish nets in southern Baltic), and when nets had been loosened by storms (Stempniewicz 1994). Upright, taut nets as a way to reduce seabird bycatch is an idea being developed in Newfoundland, Canada, but have not been tested. Upright stand-up nets (without tiedowns) have been developed to reduce sea turtle and sturgeon bycatch.

- **Description of results of testing to date**

Experimental trials of upright taut nets for reducing seabird bycatch have not yet been initiated (Fig. 20). Planned testing of double-weighted lead lines to decrease lofting and minimise seabird bycatch was discussed in 2015 (Wiedenfeld et al. 2015). This focused particularly on northern gannet bycatch in the surface-set herring fishery off Newfoundland, Canada.

Stand-up gear without tiedowns have had mixed results for other bycatch species (NMFS 2013). Low-profile nets without tiedowns significantly reduced turtle bycatch in a bottom-set flounder fishery in North Carolina, USA (Price and von Salisbury in Gilman et al. 2010), but standup nets without tiedowns had higher turtle and dolphin capture rates in New Jersey monkfish fisheries (Armstrong et al. 2013; Wark et al. 2013). In both fisheries' trials, target species catch was significantly lower in stand-up nets relative to control nets (with tiedowns).

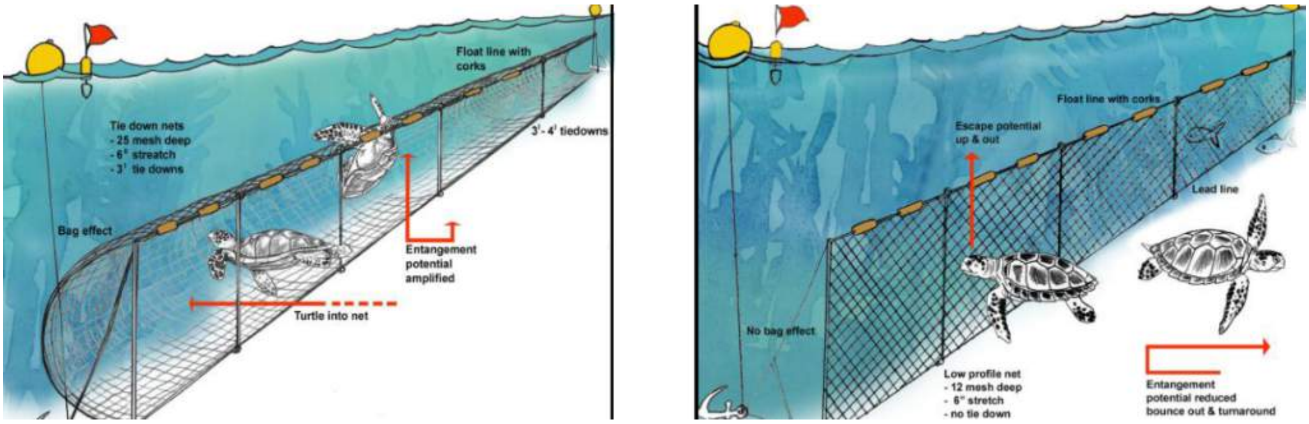


Figure 20. Standard net with tie-downs (left) compared to low-profile standup net (right). (Image modified from original drawings in Gilman et al. (2010) by Jeff Gearhart).

In 2015, plans to continue work on low-profile stand-up nets for sea turtles in the Mid-Atlantic monkfish fishery were discussed. Testing would continue work led by US National Marine Fisheries Service's Northeast and Pacific Islands Fisheries Science Centers (Henry Milliken) and research partners (Wiedenfeld et al. 2015).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

No documented trials for seabirds

Proven specifications and standards

None for seabirds

Likely uptake

Effectiveness for seabirds unproven, target species captures decrease and non-target species captures may increase.

Effect on target catch

Flounder and monkfish captures were both lower in stand-up nets than in nets with tie-downs (Gilman et al. 2010; Wark et al. 2013).

Effect on non-target catch

Mixed results for sea turtles: stand-up nets might reduce or increase sea turtle bycatch relative to nets with tie-downs (Gilman et al. 2010; Armstrong et al. 2013; Wark et al. 2013). Dolphin catch rates were higher in stand-up nets than nets that use tie-downs (Murray 2012; Wark et al. 2013).

Compliance

Double-weighted nets could be checked in port.

- **Hurdles to uptake in New Zealand**

Unlikely to be used if target species captures affected and risk to other non-target species also increases.

- **Past and current funders and developers (if applicable)**

Turtle and sturgeon work developed by the US Delaware State University, Mid Atlantic Fishery Management Council, AIS Inc. and National Ocean and Atmospheric Administration, among others.

Newfoundland team proposing seabird testing includes Memorial University of Newfoundland, Canadian Wildlife Service, Canadian Department of Fisheries and Oceans, US Fish and Wildlife Service, Bird Studies Canada, and the Fish, Food and Allied Workers (the fishermen's union).

- **Costs per vessel for installation/uptake (if available)**

n/a

Net specs: Hanging ratio

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

The hanging ratio describes the shape of meshes once a net is hung along a headrope, and affects net slackness (Fig. 21). Hanging ratio, or the ratio of headrope length to the net length, affects the shape of meshes as illustrated below (Fig. 21). Hanging ratio affects the likelihood of entanglement across diverse species, so is expected to affect seabird entanglement as well.

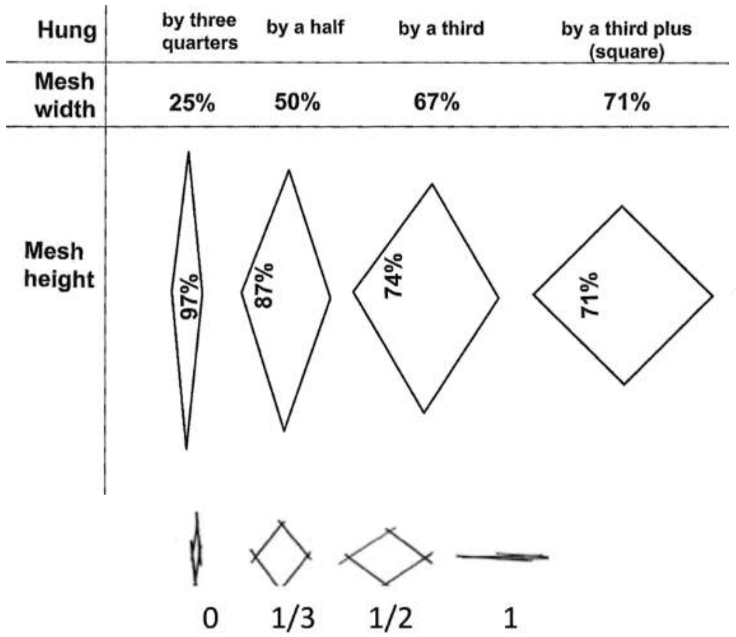


Figure 21. Hanging ratio is the ratio of headrope length to net length, affecting mesh width and height. (Images modified from: He 2006; Schnaittacher and Milliken 2012).

- **Description of results of development to date**

Hang ratio affects fish species entanglement rates and target specificity (He 2006), and the effects of hang ratio on marine mammal and turtle bycatch have been widely studied (e.g. Murray 2012; Schnaittacher and Milliken 2012). The idea that hang ratio could affect seabird entanglement was developed by the Institut für Fischereitechnik in Germany.

- **Description of results of testing to date**

In the German cod set-net fishery, nets with a hang ratio of 0.33 and 0.4 were compared with controls (hang ratio 0.5; Mentjes and Gabriel 1999). There was no significant change in sea duck capture rates. Cod and winter skate captures were greater in gear hung on the 0.33 than on the 0.50 (Mentjes and Gabriel 1999; Schnaittacher and Milliken 2012). Marine mammal captures are not significantly decreased by changing the hanging ratio, although the number of marine mammals caught was fewer in gear hung on the 0.33 (Schnaittacher and Milliken 2012).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Changing hanging ratio does not predictably improve sea duck bycatch (Mentjes and Gabriel 1999), but it is unknown whether this is true for other seabirds.

Proven specifications and standards

None

Likely uptake

Unlikely without positive trials for other seabird groups

Effect on target catch

Softer hang ratios (0.33 rather than 0.5) either did not change or increased target catch of cod, skate, monkfish and flounder (Mentjes and Gabriel 1999; Schnaittacher and Milliken 2012).

Effect on non-target catch

Turtle bycatch was lower in nets on the 0.33 than on 0.50 (Murray 2012) but this has not been tested in fisheries trials. Fewer marine mammals were caught in nets hung on the 0.33 than on the 0.50, but the effect was not statistically significant (Schnaittacher and Milliken 2012).

Compliance

Hanging ratio is integral to nets so can be checked in port.

- **Hurdles to uptake in New Zealand**

No information on effectiveness for other groups of birds.

Likely to effect catch rates

- **Past and current funders and developers (if applicable)**

For seabirds - Institut für Fischereitechnik of the German state fisheries research organisation Bundesforschungsanstalt fur Fischerei.

- **Costs per vessel for installation/uptake (if available)**

None.

Net specs: Net height

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

By limiting the height of a net (measured in number of meshes in depth, eg. 8 meshes deep), less net is available for non-target species to get caught in.

- **Description of results of development to date**

Net height changes have been ongoing in fisheries around the world to improve target catch and reduce non-target catch (e.g. He 2006; Wark et al. 2013). Although Northridge et al. (2016) suggest that net height is linked to seabird bycatch, there has been little testing.

- **Description of results of testing to date**

To see whether bird bycatch was reduced by changing net height in a German cod setnet fishery, Mentjes and Gabriel (1999) ran trials comparing nets 12 and 30 meshes deep with 20 meshes deep controls. There was no predictable effect on captures of sea ducks, but shorter nets significantly reduced cod captures (Mentjes and Gabriel 1999). For other non-target species like porpoise, sturgeon and turtles, there has been extensive testing of the effect net height (He 2006; NMFS 2013; Wark et al. 2013).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

No effect for sea ducks (Mentjes and Gabriel 1999), but unclear whether this would also be true for other seabirds.

Proven specifications and standards

None

Likely uptake

Unlikely until a positive effect seen.

Effect on target catch

Significant reductions in cod catch seen when net height was reduced (Mentjes and Gabriel 1999).

Effect on non-target catch

Net height influenced bycatch of turtles, porpoises and sturgeon, with less net height resulting in less captures (He 2006; Gilman et al. 2010; Wark et al. 2013).

Compliance

Net height is integral to the gear and could be checked in port. New Zealand already has mandated net height restrictions so compliance assessment processes exist.

- **Hurdles to uptake in New Zealand**

In theory, no new hurdles to uptake since New Zealand already has mandated net height restrictions. May reduce target catch.

- **Past and current funders and developers (if applicable)**

For seabirds - Institut für Fischereitechnik of the German state fisheries research organisation Bundesforschungsanstalt fur Fischerei.

Acoustic deterrents: Pingers

Early prototype / functionality (in common and widespread use for marine mammals).

Not in use

- **Mitigation measure and how it works**

Pingers are small underwater devices that emit high-frequency sound pulses, which are attached along nets to alert an animal to the presence of a net (Fig. 22).

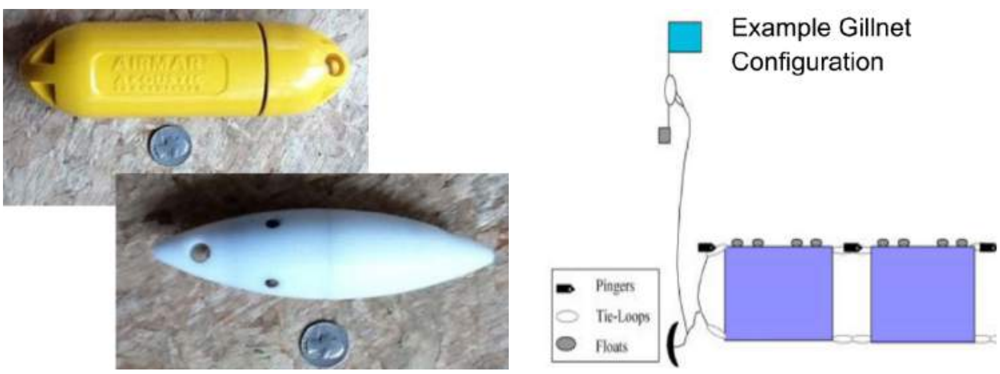


Figure 22. Acoustic pingers (**left**) attached to tie-loops of gillnets (**right**). (Images: NMFS 2013).

- **Description of results of development to date**

Pingers have been under development for marine mammal bycatch reduction since the 1970s (Guzzwell et al. 1994). To target seabirds, pinger sound output intensity was reduced from 10-70 kHz for marine mammals to ~1.5 kHz (Melvin et al. 1999), but this was based on generic bird hearing since hearing has not been studied in any of the bycatch bird groups (Melvin et al. 1999; Martin and Crawford 2015). Pingers may be of limited real use in seabirds since even in the air, most birds are poor at detecting a sound's source (Martin and Crawford 2015). Since so little is known about bird hearing (Melvin et al. 1999; Wiedenfeld et al. 2015), a study on what frequencies seabirds can hear underwater was planned to help develop pingers for seabird mitigation (Bill Montevecci *in* Wiedenfeld et al. 2015).

Research and development costs for pingers targeting new species are substantial (as much as US $500/unit, John Wang in Wiedenfeld et al. 2015). Pinger development has focused on improvements to battery life to reduce servicing/maintenance costs, and on variable-interval pingers to reduce habituation (Waugh et al. 2011; Wiedenfeld et al. 2015). Both are relevant to seabird pingers, since there seabirds are as likely to habituate to long-term pinger use as other animals.

- **Description of results of testing to date**

Monofilament nets with pingers were trialled in a salmon drift gillnet fishery in Puget Sound, USA (Melvin et al. 1999). Pingers were attached to the corkline every 50 m and emitted a 1.5 kHz (±1 kHz) signal every 4 s at 35–40 dB above background noise level (Melvin et al. 1999). Pingers reduced common murre bycatch rates by 50% compared to monofilament net, but did not reduce rhinoceros auklet entanglement. Fishing catch rate was not compromised, but pinger nets attracted significantly more seals (Melvin et al. 1999).

Pingers for marine mammals and turtles are tuned to other frequencies, but a number of observations are relevant to seabirds. The rate of seabird take was three times higher when marine mammal pingers were used in salmon fisheries in Kodiak Island, Alaska, compared to hauls without pingers (Manly 2007).

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Pinger effectiveness for seabirds is inconclusive. Pingers were effective at reducing common murre bycatch, but not of rhinoceros auklet (Melvin et al. 1999). 'Seabird' pingers significantly increased seal presence (Melvin et al. 1999). Pingers of other frequencies can increase seabird bycatch rates (Manly 2007).

Proven specifications and standards

Unproven. The sound frequency used to target seabirds needs to be refined based on what bycatch species can actually hear underwater.

Likely uptake

Pingers are widely used to target marine mammals so may be familiar to fishers. On the other hand, they are costly to buy and maintain, and can interfere with net operations like setting/hauling (Waugh et al. 2011). Concern that seabird pingers could attract net predators would also affect uptake.

Effect on target catch

Did not compromise fishing efficiency (Melvin et al. 1999).

Effect on non-target catch

Unclear whether pingers tuned to deter seabirds affect bycatch of other animals. At other frequencies, pingers are effective at reducing bycatch for some marine mammal and turtle species but not others.

Compliance

Non-compliance has been difficult to identify with pingers targeting cetaceans (Wiedenfeld et al. 2015). Electronic monitoring or on-board observers would be required.

- **Hurdles to uptake in New Zealand**

Pingers are costly compared to other mitigation methods, need regular servicing, and can interfere with net operations (Waugh et al. 2011). Concern about net predators learning to locate on pingers would also affect uptake by fishermen.

- **Past and current funders and developers (if applicable)**

Seabird pingers were developed by the US Washington Sea Grant program with technical support from the Dukane Corporation and funding from the US National Marine Fisheries Service and the National Oceanic and Atmospheric Administration.

- **Costs per vessel for installation/uptake (if available)**

Pingers cost ~ GBP £40 – 50 each, and batteries last 2 – 4 years, depending on model (SFIA 2005). For some models the battery can be replaced (~ £4) while others require unit replacement. Estimates of the running costs for four years in Cornish set net fisheries in the UK were £21 – 67,000, including annual replacement costs (~ 10 – 14% replacement per year) (SFIA 2005).

Acoustic harassment devices (AHDs)

Limited efficacy testing, not recommended

Not in use

- **Mitigation measure and how it works**

Acoustic harassment devices (AHDs) emit underwater sounds of such high intensity (at least 200 dB re 1 μPa @ 1m) that they cause pain and/or alarm in some species.

- **Description of results of development to date**

AHDs were developed primarily in aquaculture operations (Werner et al. 2006) to deter marine mammals, and are untested for diving seabirds.

- **Description of results of testing to date**

This approach has had variable success, reviewed in (Werner et al. 2006). AHDs may be harmful since they may exclude some animals from important habitat, and risk damaging an animal's hearing (Werner et al. 2006)

- **Development and testing needed to meet ACAP's criteria**

Effectiveness

Unknown for seabirds.

Above-water bird scarers

Early prototype / functionality

Not in use

- **Mitigation measure and how it works**

Streamers or bird scarers set above surface-set nets, or above nets set in shallow water, might deter birds from the net. Bird scarers could be attached to the buoys (Klinge and Grimm 2002) or strung along a line suspended on poles, with poles placed on buoys at the net ends (Wiedenfeld et al. 2015).

- **Description of results of development to date**

Streamers held up by poles on buoys have been discussed but not developed as too hard to deploy and maintain (Wiedenfeld et al. 2015). Bird-scarers were developed to attach to buoys (Klinge and Grimm 2002).

- **Description of results of testing to date**

Bird-scarers attached to buoys were tested (e.g. Klinge and Grimm 2002), but reports need translation from Dutch.

Acknowledgements

Expert advice was generously provided by the following people; Suze Baird, Barry Baker, Peter Hardstaff, Mike Gerner, Dave Goad, Janice Molloy, Joost Pompert, Johanna Pierre, Kris Ramm, Graeme Robertson, Daryl Smith, Nathan Walker, Richard Wells, Anton Wolfaardt and Oil Yates. Sonja Austin, Dave Goad, Janice Molloy and Richard Wells reviewed and greatly improved this report.

References

Abraham ER, Middleton DAJ, Waugh SM, Pierre JP, Walker A 2008. A fleet scale experimental comparison of devices used for reducing the incidental capture of seabirds on trawl warps. New Zealand Journal of Marine and Freshwater Research.

Abraham ER, Pierre JP, Middelton DAJ, Cleal J, Walker NA, Waugh SM 2009. Effectiveness of fish waste management strategies in reducing seabird attendance at a trawl vessel. Fisheries Research 95:210–219

ACAP 2010. Report of the Third Meeting of the Seabird Bycatch Working Group. Mar del Plata, Argentina

ACAP 2014a. ACAP Summary advice for reducing impact of pelagic long-lines on seabirds.

ACAP 2014b. Bycatch Mitigation Fact Sheet 10; Pelagic Longline: Blue-dyed bait. ACAP, Hobart.

ACAP 2014d. Bycatch Mitigation Fact Sheet 13, Trawl Fisheries: Warp Strike.

ACAP 2014e. Review of seabird bycatch mitigation measures for demersal longline fisheries. ACAP Sixth Meeting of the Seabird Bycatch Working Group, Punte del Este, Uruguay

ACAP 2014f. ACAP Bycatch Fact Sheet 3. Demersal Longline: Integrated weight longlines. http://www.birdlife.org/sites/default/files/attachments/ENG%20FS_3%20Demersal%20LL%20Integrated%20weight%20LL_SEPT14_w.pdf. Accessed November 1, 2016

ACAP 2014g. ACAP Bycatch Fact Sheet 2. Demersal Longline: Integrated weight longlines. http://seabirdbycatch.washington.edu/wp-content/uploads/FS_02_v1_Demersal_LL_Line_weight_external.pdf Accessed November 1, 2016

AFMA 2017. Bird Baffler. Australian Fisheries Management Authority, http://www.afma.gov.au/portfolio-item/bird-baffler/. Accessed February, 2017

Agnew DJ, Black AD, Croxall JP, Parkes GB 2000. Experimental evaluation of the effectiveness of weighting regimes in reducing seabird by-catch in the longline toothfish fishery around South Georgia. CCAMLR Science 7: 119–131

Anderson S, McArdle B (2002) Sink rate of baited hooks during deployment of a pelagic longline from a New Zealand fishing vessel. New Zealand Journal of Marine and Freshwater Research: 185–195

Armstrong JL, Brown LM, Fox DA, Milliken H 2013. Gillnet configurations and their impact on Atlantic sturgeon and marine mammal bycatch in the New Jersey monkfish fishery. In: NMFS (ed) Workshop on sea turtle and Atlantic sturgeon bycatch reduction in gillnet fisheries. Jan 22–23, 2013. National Marine Fisheries Service and Atlantic States Marine Fisheries Commission

Ashford JR, Croxall JP, Rubilar PS, Moreno CA 1995. Seabird interactions with longlining operations for *Dissostichus eleginoides* around South Georgia, April to May 1994. CCAMLR Science, 2, 111–121

Baker GB, Candy SG 2014. Proof of concept experiment to demonstrate the efficacy of the 'Smart Tuna Hook'. Report prepared for AHI Enterprises by Latitude 42 Consultants. Kettering, Tasmania.

Baker GB, Goad D, Kiddie B, Frost R 2016. Kellian Line Setter Sea Trials Refinement of design and subsequent developments. Draft Final Report prepared for the Department of Conservation Contract 4529 by Latitude 42 Consultants. Kettering, Tasmania

Barrington JHS 2016a. 'Smart Tuna Hook' as best practice seabird bycatch mitigation in pelagic long-line fisheries. Seventh Meeting of the Seabird Bycatch Working Group, ACAP, La Serena, Chile.

Barrington JHS 2016b. 'Hook Pod' as best practice seabird bycatch mitigation in pelagic long-line fisheries. Seventh Meeting of the Seabird Bycatch Working Group, ACAP, La Serena, Chile.

Barrington JHS, Robertson G, Candy SG 2016c. Categorising branch line weighting for pelagic long-line fishing according to sink rates Jonathon HS. Seventh Meeting of the Seabird Bycatch Working Group, ACAP, La Serena, Chile.

Bellebaum J, Schirmeister B, Sonntag N, Garthe S 2013. Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast. Aquatic Conservation: Marine and Freshwater Ecosystems 23: 210–221

Boggs C H 2001. Deterring albatrosses from contacting baits during swordfish long-line sets. Pages 79 – 94. Alaska Sea Grant, Fairbanks.

Brothers N 1991. Albatross mortality and associated bait loss in the Japanese long-line fishery in the Southern Ocean. Biological Conservation, 55, 255–268

Brothers NP, Cooper J and Løkkeborg S 1999a. The incidental catch of seabirds by long-line fisheries: worldwide review and technical guidelines for mitigations. FAO Fisheries Circular No. 937. Food and Agriculture Organisation of the United Nations.

Brothers N, Gales R, Reid T 1999b. The influence of environmental variables and mitigation measures on seabird catch rates in the Japanese tuna long-line fishery within the Australian Fishing Zone, 1991–1995. Biological Conservation 88: 85–101

Brothers N, Gales R, Reid T 2001. The effects of line weighting on the sink rate of tuna long-line hooks, and its potential for minimising seabird mortalities. Unpublished conference report CCSBT-ERS/0111/53. 23p

Bull LS 2007. Reducing seabird bycatch in longline, trawl and gillnet fisheries. Fish and Fisheries 8: 31–56

Bull LS 2007. A review of methodologies for mitigating incidental bycatch of seabirds in New Zealand fisheries. DOC Research and Development Series 263. Department of Conservation, Wellington

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

CCAMLR 2011. CONSERVATION MEASURE 29/XV1,2 Minimisation of the Incidental Mortality of Seabirds in the Course of Longline Fishing or Longline Fishing Research in the Convention Area. https://www.ccamlr.org/sites/drupal.ccamlr.org/files//29-xv.pdf. Accessed November 26, 2016

Cherel Y, Weimerskirch H, Duhamel G 1996. Interactions between longline vessels and seabirds in Kerguelen waters and a method to reduce seabird mortality. Biological Conservation 75: 63–70

Claudino dos Santos R, Silva-Costa A, Sant'Ana R, Gianuca D, Yates O, Marques O, Neves T 2016. Comparative trails of Lumo Leads and traditional line weighting in the Brazilian pelagic long-line fishery. Seventh Meeting of the Seabird Bycatch Working Group, ACAP, La Serena, Chile.

Cleal J, Pierre JP 2016. Development of bird baffler designs for offshore trawl vessels. Conservation Services Programme Project MIT2013/05 Final Report. Report from Clement and JPEC to the Department of Conservation, Conservation Services Programme, Wellington.

Cleal J, Clement G, Wells R 2009. Mitigating Seabird Interactions with Trawl Nets. Report Commissioned by Department Of Conservation Project Mit 2006/02 February 2009. Clement and Associates, Nelson.

Cocking LJ, Double MC, Milburn PJ, Brando VE 2008. Seabird bycatch mitigation and blue dyed bait: A spectral and experimental assessment. Biological Conservation 141:1354–1364

Crawford R 2015. Preliminary results from bycatch mitigation testing in Lithuanian gillnets. In: Wiedenfeld DA, Crawford R, Pott CM (eds) Results of a workshop on reduction of bycatch of seabirds, sea turtles, and sea mammals in gillnets. National Conservation Training Center Shepherdstown, West Virginia, USA, 21–23 January 2015. American Bird Conservancy & BirdLife International

Crawford R, Mangel J, Morgan K 2016. Gillnet bycatch of ACAP species and ongoing mitigation development. ACAP SBWG7 Inf 09. ACAP, Hobart

Dagys M, Žydelis R 2002. Bird bycatch in fishing nets in Lithuanian coastal waters in wintering season 2001–2002. Acta Zoologica Lituanica 12: 276–282

Dietrich KS, Melvin ES, Conquest L 2008. Integrated weight longlines with paired streamer lines – Best practice to prevent seabird bycatch in demersal longline fisheries. Biological Conservation 7: 1793–1805

DOC 2011. DOC/ CSP Funding Project Review of Mandatory Seabird Scaring Devices MIT 2011-07. http://clementgroup.co.nz/Docs/TORI%20Final4.pdf. Accessed 29 October, 2016.

Domingo A, Jiménez S, Abreu M, Forselledo R, Pons M 2011. Effectiveness of tori-line use to reduce seabird bycatch in the Uruguayan pelagic long-line fleet. Sixth Meeting of ACAP Advisory Committee. Guayaquil, Ecuador, 29 August – 2 September 2011.

Dragonfly 2016. Protected Species Bycatch https://data.dragonfly.co.nz/psc/v20150002/birds/trawl/all-vessels/eez/2013-14/. Accessed October 26, 2016.

Duckworth K 1995. Analysis of factors which influence seabird bycatch in the Japanese southern Bluefin long-line fishery in New Zealand waters, 1989–1993. New Zealand Fisheries Assessment Research Document 95/26. 62 p.

DWG 2009. Vessel Management Plan (VMP) Deepwater Factory Trawler over 28 m. Deepwater Group, Nelson.

Favero M, Blanco G, Garcia G, Copello S 2010. Seabird mortality associated with ice trawlers in the Patagonian shelf: effect of discards on the occurrence of interactions with fishing gear. Animal Conservation 14: 131–139

Gianuca D, Peppes FV, César JH, Sant'Ana R, Neves T 2013. Do leaded swivels close to hooks affect the catch rate of target species in pelagic long-line? A preliminary study of southern Brazilian fleet. Agreement on the Conservation of Albatrosses and Petrels, Fifth Meeting of the Seabird Bycatch Working Group. La Rochelle, France, 1–3 May 2013, SBWG5 Doc 33.

Gilman E, Brothers N, Kobayashi DR 2007. Comparison of 3 seabird bycatch avoidance methods in Hawaii-based pelagic long-line fisheries. Fish Sci 73:208–210

Gilman E, Gearhart J, Price B, Eckert S, Milliken H, Wang J, Swimmer Y, Shiode D, Abe O, Hoyt Peckham S, Chaloupka M, Hall M, Mangel J, Alfaro-Shigueto J, Dalzell P, Ishizaki A 2010. Mitigating sea turtle by-catch in coastal passive net fisheries. Fish and Fisheries 11: 57–88

Gilman E, Chaloupka M, Peschon J, Ellgen S 2016. Risk Factors for Seabird Bycatch in a Pelagic Longline Tuna Fishery. PLoS ONE 11(5): e0155477. doi:10.1371/journal.pone.0155477

Goad D 2011. Trialling the 'Kellian Device'. Setting bottom longlines underwater. Unpublished report from Vita Maris to New Zealand Department of Conservation. Vita Maris, Papamoa, New Zealand

Gonzalez-Zevallos D, Yorio P, Caille G 2007. Seabird mortality at trawler warp cables and a proposed mitigation measure: a case study in Golfo San Jorge, Patagonia, Argentina. Biological Conservation 136:108–116

Guild R 2007. The SCUD (Seabird Control Unit Device). Albert Times 14: 1

Guitérrez I, Santos A 2016. First measures to reduce seabird bycatch in Portugal. BirdLife International. https://seabirdbycatch.com/2016/05/26/first-measures-to-reduce-seabird-bycatch-in-portugal/#more-987. Accessed November 2016.

Guzzwell J, Lien J, Guigne JY 1994. Acoustic net alarm. Filed March 1993. Google Patents. https://www.google.com/patents/CA2091043A1?cl=en&dq=gill+net+pingers&hl=en&sa=X&ved=0ahUKEwjj_a60trPQAhXEUZQKHbqlCcMQ6AEISDAG. Accessed 19 November 2016.

Hanamseth R, Baker GB, Sherwin S, Hindell M, Lea M (submitted) Assessing the importance of net colour as a seabird bycatch mitigation measure in gillnet fishing. submitted

Hanke FD, Kröger RHH, Siebert U, Dehnhardt G 2008. Multifocal lenses in a monochromat: the harbour seal. The Journal of Experimental Biology 211: 3315–3322

Hayase S, Yatsu A 1993. Preliminary report of a squid sub-surface driftnet experiment in the North Pacific during 1991. North Pacific Commission Bulletin 53(III). International North Pacific Fisheries Commission, Tokyo

He P 2006. Gillnets: Gear design, fishing performance and conservation challenges. Marine Technology Society journal 40: 12–19

Hooper J, Agnew D, Everson I 2003. Incidental mortality of birds on trawl vessels fishing for icefish in Subarea 48.3. WG-FSA-03/79, SC-CAMLR XXII, Hobart, Australia.

Jiménez S, Domingo A, Brazeiro A 2009. Seabird bycatch in the Southwest Atlantic: interaction with the Uruguayan pelagic longline fishery. Polar Biology 32:187–196

Jiménez S., Domingo A., Abreu M., Forselledo R., and Pons M. 2013. Effect of reduced distance between the hook and weight in pelagic long-line branchlines on seabird attack and bycatch rates and on the catch of target species. Agreement on the Conservation of Albatrosses and Petrels, Fifth Meeting of the Seabird Bycatch Working Group. La Rochelle, France, 1–3 May 2013, SBWG5 Doc 49.

Jusseit H. 2010. Testing seabird & turtle mitigation efficacy of the Smart Hook system in tuna long-line fisheries - Phase 1. AFMA Fisheries research 2008/805. http://www.inhalesuite2.com/uploads/62/documents/Smart%20Hook%20Project%20FInal%20Report.pdf. Accessed 29 November 2014.

King DP, Holy NL 2003. Acoustically visible fishing net. Filed March 1999. Google Patents. https://www.google.com/patents/US6543177?dq=gill+net+pingers&hl=en&sa=X&ved=0ahUKEwjj_a60trPQAhXEUZQKHbqlCcMQ6AEIJTAB. Accessed19 Nov 2016.

Kiyota M, Minami H, Takahashi M 2001. Development and tests of water jet devices to avoid incidental take of seabirds in tuna long-line fishery. CCSBT ERS-0111-63.

Klaer N, Polacheck T 1998. The influence of environmental factors and mitigation measures on by-catch rates of seabirds by Japanese long-line fishing vessels in the Australian region. Emu, 98, 305–316

Klinge M, Grimm MP 2002. Voor vogels en vissen. Bepaling van de omvang van de vogelsterfte in de staande nettenvisserij in 2002–2003, uitvoering van experimenten met alternatieve visserijtechnieken en evaluatie van maatregelen voor het seizoen 2003–2004. (In Dutch). Witteveen+Bos, Deventer, Netherlands

Løkkeborg S, 1998. Seabird by-catch and bait loss in long-lining using different setting methods. ICES Journal of Marine Science 54: 145–149

Løkkeborg S, Robertson G 2002. Seabird and long-line interactions: effectiveness of a bird-scaring streamer line and line shooter on the incidental capture of northern fulmars *Fulmarius glacialis*. Biological Conservation 106: 359–364

Løkkeborg S 2003. Review and evaluation of three mitigation measures-bird scaring line, underwater setting and line shooter-to reduce seabird bycatch in the northern Atlantic longline fishery. Fisheries Research 60: 11–16

Løkkeborg S 2008. Review and assessment of mitigation measures to reduce incidental catch of seabirds in longline, trawl and gillnet fisheries. FAO Fisheries and Aquaculture Circular. No. 1040. FAO, Rome

Løkkeborg S 2011. Best practices to mitigate seabird bycatch in long-line, trawl and gillnet fisheries - efficiency and practical applicability. Marine Ecology Progress Series 435: 285–303

Løkkeborg S, Siikavuopio SI, Humborstad OB, Utne-Palm AC, Ferter K 2014. Towards more efficient long-line fisheries: fish feeding behaviour, bait characteristics and development of alternative baits. Reviews in Fish Biology and Fisheries 24: 985–1003.

Mangel JC .2015. Bycatch mitigation research. In: Wiedenfeld DA, Crawford R, Pott CM (eds) Results of a workshop on reduction of bycatch of seabirds, sea turtles, and sea mammals in gillnets. National Conservation Training Center Shepherdstown, West Virginia, USA, 21–23 January 2015 American Bird Conservancy & BirdLife International

Mangel JC, Alfaro-Shigueto J, Wang J, Swimmer Y, Wallace G 2014. Tests of visual cues and sub-surface nets as bycatch mitigation measures in small-scale gillnet fisheries in Peru. ACAP SBWG6 Doc 16. ACAP, Hobart

Mangel JC, Alfaro-Shigueto J, Azocar J, Debski I 2016. 'Toolbox' template for mitigation advice in artisanal and small-scale fisheries. Seventh Meeting of the Seabird Bycatch Working Group, ACAP, La Serena, Chile.

Manly BFJ 2007. Incidental take and interactions of marine mammals and birds in the Kodiak Island salmon set gillnet fishery, 2002 and 2005. Final Report to NMFS Alaska Region. https://alaskafisheries.noaa.gov/sites/default/files/kodiakreport02_05.pdf. Western EcoSystems Technology, Cheyenne, USA

Maree BA, Wanless RM, Fairweather TP, Sullivan BJ, Yates O 2014. Significant reductions in mortality of threatened seabirds in a South African trawl fishery. Animal Conservation 17: 520–529.

Maree B, Mansfield L, Wanless R, Goren M 2010. South Africa. *In* BirdLife Global Seabird Programme 2010. Albatross Task Force Annual Report 2009. Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire, UK pp. 48–51.

Martin GR, Crawford R 2015. Reducing bycatch in gillnets: A sensory ecology perspective. Global Ecology and Conservation 3: 28–50

McCormack E, Papworth W 2016. Review of evidence of injuries sustained by fishers in the course of using weighted lines in pelagic long-line fisheries. ACAP Sixth Meeting of the Seabird Bycatch Working Group, Punte del Este, Uruguay, 10–12 September 2014.

Melvin EF 1995. Reduction of seabird entanglements in salmon drift gillnets through gear modification. WSG AS 95-01. Washington Sea Grant Program, University of Washington, Seattle

Melvin EF, Parrish JK, Conquest LL 1999. Novel tools to reduce seabird bycatch in coastal gillnet fisheries. Conservation Biology 13: 1386–1397

Melvin EF, Parrish JK, Dietrich KS, Hamel OS 2001. Solutions to seabird bycatch in Alaska's demersal longline fisheries. Washington Sea Grant Program

Melvin EF, Dietrich KS, Thomas T 2004. Pilot tests of techniques to mitigate seabird interactions with catcher processor vessels in the Bering Sea Pollock trawl fishery. University of Washington report to the Washington SeaGrant Program.

Melvin EF, Sullivan B, Robertson G, Wienecke B 2004. A review of the effectiveness of streamer lines as a seabird bycatch mitigation technique in longline fisheries and CCAMLR streamer line requirements. CCAMLR Science 11: 189–201

Melvin E, Guy T, Sato N 2010. Preliminary report of 2010 weighted branch line trials in the Tuna Joint Venture Fishery in the South African EEZ. 4th Meeting of the Seabird Bycatch Working Group. Agreement on the Conservation of Albatrosses and Petrels, SBWG-4 Doc 07.

Melvin EF, Dietrich KS, Fitzgerald S, Cardoso T 2011. Reducing seabird strikes with trawl cables in the pollock catcher-processor fleet in the eastern Bering Sea. Polar Biology 34:215–226

Melvin, E. F., Guy, T. J. and Reid, L. B. 2014. Best practice seabird bycatch mitigation for pelagic long-line fisheries targeting tuna and related species. Fisheries Research 149: 5–18.

Mentjes T, Gabriel O 1999. Fangtechnische Möglichkeiten zur Reduzierung des Beifangs von Meeresenten in der Dorschfischerei mit stationären Fanggeräten. (In German with English summary: Technical possibilities to reduce duck bycatches in winter cod fishery with static gear). Informationen für die Fischwirtschaft aus der Fischereiforschung 46: 36–41

Milliken H, Wang J 2013. Overview of bycatch reduction research for sea turtles. NOAA Northeast and Pacific Islands Fisheries Science Centers. In: NMFS (ed) Workshop on sea turtle and Atlantic sturgeon bycatch reduction in gillnet fisheries. Jan 22–23, 2013. National Marine Fisheries Service and Atlantic States Marine Fisheries Commission

Minami H and Kiyota M 2006. Influence of blue-dyed bait on catch rates of seabirds and tuna species in the experimental operations of the Japanese southern bluefin tuna long-line. *In* Commission for the Conservation of Southern Bluefin Tuna. Report of the Sixth Meeting of the Ecologically Related Species Working Group. 20–23 February 2006 Kaohsiung, Taiwan.

Ministry for Primary Industries (MPI) 2013. National Plan of Action to reduce the incidental catch of seabirds in New Zealand Fisheries. ISBN No: 978-0-478-40532-3 (online) ISBN No: 978-0-478-40533-0 (print), Wellington, New Zealand

Ministry for Primary Industries New Zealand 2014. Fisheries (Seabird Mitigation Measures—Surface Long-lines) Circular 2014.

MPI 2015. Requirements for Correct Use of Seabird Mitigation Devices. Compliance Fact Sheet 6. Ministry for Primary Industries, Wellington.

Ministry for Primary Industries New Zealand 2016. Mitigation Measures to Reduce Incidental Seabird Capture in Commercial Surface Long-line Fisheries Consultation Document. MPI Discussion Paper No: 2016/26. Wellington.

Moreno CA, Rubilar PS, Marschoff E, Benzaquen E 1996. Factors affecting the incidental mortality of seabirds in the Dissostichus eleginoides fishery in the south-west Atlantic (Subarea 48.3, 1995 season). CCAMLR Science 3: 79–91

Murray KT 2012. Sea turtle bycatch in sink gillnet gear: observations and analyses from 1995–2011. *In*: NMFS Workshop on sea turtle and Atlantic sturgeon bycatch reduction in gillnet fisheries. Jan 22–23, 2013. National Marine Fisheries Service and Atlantic States Marine Fisheries Commission

Nedelec C, Prado J 1990. Definition and classification of fishing gear categories. FAO Fisheries Technical Paper, No. 222, Revision 1. Food and Agriculture Organisation

New Zealand Government 2008. Fisheries (Seabird Sustainability Measures—Surface Long-lines) Notice 2008 (No. F429). New Zealand Gazette 21 February 2008, No. 31. New Zealand Government, Wellington.

New Zealand Government 2010. Seabird Scaring Devices Circular 2010 (No. F517). New Zealand Gazette 29, New Zealand Government, Wellington.

NMFS 2013. Workshop on sea turtle and Atlantic sturgeon bycatch reduction in gillnet fisheries. Jan 22–23, 2013. National Marine Fisheries Service and Atlantic States Marine Fisheries Commission

Norden WS, Pierre JP 2007. Exploiting sensory ecology to reduce seabird by-catch. Emu, 107, 38–43

Northridge S, Coram A, Kingston A, Crawford R 2016. Disentangling the causes of protected-species bycatch in gillnet fisheries. Conservation Biology Doi:10.1111/cobi.12741

Otley H 2005. Seabird mortality associated with Patagonian toothfish longliners in Falkland Island waters during 2002/03 & 2003/04. Falkland Islands Fisheries Department, Stanley, Falkland Islands

Parker GC 2013.Observer Report 939, Manuel Angel Nores. Falkland Islands Government, Stanley.

Parker GC 2013.Observer Report 928, Argos Vigo. Falkland Islands Government, Stanley.

Parker G, Pompert J, Brickle P 2013. Early results from trials of a novel system for mitigating incidental seabird mortality in trawl fisheries. Fifth Meeting of the Seabird Bycatch Working Group. Agreement on the Conservation of Albatrosses and Petrels (ACAP), Hobart

Parker GC 2013. An assessment of seabird bycatch in Falkland Island trawl fisheries: July 2011 to June 2012. Falkland Islands Government, Stanley.

Patrick PH, Poulton S 2007. Fish attracting or repelling device comprising diode array, May 8 2000. Google Patents. https://www.google.com/patents/CA2307728C?dq=gill+net+lights&cl=en. Accessed 19 November 2016.

Petersen SL, Honig MB, Ryan PG, Underhill LG 2008. Line sink rates and implications for seabirds, target and non-target fish species in the south African demersal longline fishery. *In* Petersen SL, Nel DC, Ryan PG, Underhill LG (eds). Understanding and Mitigating Vulnerable Bycatch in southern African Trawl and Longline Fisheries. WWF South Africa Report Series - 2008/Marine/002.

Petersen SL 2008. Understanding and mitigating vulnerable bycatch in longline and trawl fisheries off southern Africa. Unpublished PhD thesis, University of Cape Town, Cape Town, South Africa

Pierre JP, Norden WS 2006. Reducing seabird bycatch in longline fisheries using a natural olfactory deterrent. Biological Conservation 130:406–415

Pierre JP, Abraham ER, Middleton DAJ, Cleal J, Bird R, Walker NA, Waugh SM 2010. Reducing interactions between seabirds and trawl fisheries: responses to foraging patches provided by fish waste batches. Biological Conservation 143: 2779–2788.

Pierre JP 2012. The 'Tamini tabla'. Bycatch Bylines 2, November 2012

Pierre JP, Abraham ER, Cleal J, Middleton DAJ 2012a. Reducing effects of trawl fishing on seabirds by limiting foraging opportunities provided by fishery waste. Emu-Austral Ornithology 112: 244–254.

Pierre JP, Abraham ER, Cleal J, Middleton DAJ 2012b. Controlling trawler waste discharge to reduce seabird mortality. Fisheries Research 131–133: 30–38.

Pierre JP, Cleal FV, Thompson FN, Butler H, Abraham ER 2013. Seabird mitigation in New Zealand's scampi trawl fishery. Research report for the Department of Conservation, Wellington, New Zealand.

Pierre JP, Goad DW, Thompson FN, Abraham ER 2013. Reducing seabird bycatch in bottom-longline fisheries. Final Research Report for Department of Conservation projects MIT2011-03 and MIT2012-01 (Unpublished report held by Department of Conservation, Wellington). 59 pages

Pierre J, Gerner M, Penrose L 2014. Assessing the Effectiveness of Seabird Mitigation Devices in the Trawl Sectors of the Southern and Eastern Scalefish and Shark Fishery in Australia. http://www.afma.gov.au/wp-content/uploads/2014/12/Seabird-Mitigation-Assessment-Report.pdf. Accessed October 24, 2016

Pierre JP, Thompson FN, Cleal J 2014. Seabird interactions with the deepwater bottom-longline fleet, 33 pages. MIT2013-03 – Characterisation of smaller vessel deepwater bottom-longline operations in relation to risk factors for seabird capture

Pierre JP, Goad DW, Abraham, ER 2015. Novel approaches to line-weighting in New Zealand's inshore surface-longline fishery, 41 pages. Final Report prepared for the Department of Conservation: Conservation Services Programme project MIT2012-04.

Pierre JP, Goad DW 2016. Improving tori line performance in small-vessel longline fisheries. Report prepared by JPEC Ltd and Vita Maris for the New Zealand Department of Conservation, Wellington. 34p.

Prendeville M 2007. Don't be warped – trawl for fish, not birds. Albert Times 19: 1–2

Reid TA, Sullivan BJ, Pompert J, Enticott JW, Black AD 2004. Seabird mortality associated with Patagonian Toothfish (*Dissostichus eleginoides*) long-liners in Falkland Islands waters. Emu 104: 317–325

Reid E, Sullivan B, Clarke J 2010. Mitigation of seabird captures during hauling in CCAMLR longline fisheries. CCAMLR Science, 17, 155–162

Robertson G 2000. Effect of line sink rate on albatross mortality in the Patagonian toothfish longline fishery. CCAMLR Science 7: 133–150

Robertson G, McNeill M, Smith N, Wienecke B, Candy S, Olivier F 2006. Fast sinking (integrated weight) longlines reduce the mortality of white-chinned petrels (*Procellaria aequinoctialis*) and sooty shearwaters (*Puffinus griseus*) in demersal longline fisheries. Biological Conservation 132: 458–471

Robertson G, Moreno CA, Crujeiras J, Wienecke B, Gandini PA, McPherson G, Seco Pon JP 2008. An experimental assessment of factors affecting the sink rates of Spanish-rig longlines to minimize impacts on seabirds. Aquatic Conservation: Marine and Freshwater Ecosystems 17: 102–121

Robertson G, Candy SG, Wienecke B 2010a. Effect of line shooter and mainline tension on the sink rates of pelagic long-lines and implications for seabird interactions. Western and Central Pacific Fisheries Commission 6th regular session, WCPFC-SC6-2010/EB-WP-0 7. pp 21

Robertson G, Candy SG, Wienecke B, Lawton K 2010b. Experimental determinations of factors affecting the sink rates of baited hooks to minimize seabird mortality in pelagic long-line fisheries. Aquatic Conservation: Marine and Freshwater Ecosystems 20: 632–643

Robertson, G. 2013. Improving ACAP's advice on best practice line weighting for coastal State pelagic long-line fisheries. ACAP Fifth Meeting of the Seabird Bycatch Working Group, La Rochelle, France, 1–3 May 2013.

Robertson G, Candy SG, Hall S 2013. New branch line weighting regimes to reduce the risk of seabird mortality in pelagic long-line fisheries without affecting fish catch. Aquatic Conservation: Marine and Freshwater Ecosystems. 23: 885–900.

Robertson G, Ashworth P, Ashworth P, Carlyle I, Candy S 2015. The development and operational testing of an underwater bait setting system to prevent the mortality of albatrosses and petrels in pelagic long-line fisheries. Open Journal of Marine Science 5, 1–12.

Ryan PG, Watkins BP 2002. Reducing incidental mortality of seabirds with an underwater longline setting funnel. Biological Conservation 104: 127–131

SADSTIA 2016. South African Deep Sea Trawl Industry Association. http://www.sadstia.co.za/the-fishery/the-cape-hakes/the-hake-fisheries/deep-sea-trawl. Accessed October 29, 2016.

Savewave 2015. Rotating Seabird Saver information pack 2015. file:///C:/Users/Graham/Documents/Work/SSST%20mitigation%20stocktake/Savewave%20laser%20RSBS-Information-Pack-2015.pdf

SaveWave 2014. SeaBird Saver offshore trial report, West Iceland. *In* E. Schrijver (Ed.) SaveWave 15 p

Schnaittacher G, Milliken H 2012. The effects of hanging ratio on the catch of harbor porpoise and targeted finfish species. In: NMFS (ed) Workshop on sea turtle and Atlantic sturgeon bycatch reduction in gillnet fisheries. Jan 22–23, 2013. National Marine Fisheries Service and Atlantic States Marine Fisheries Commission

Seco Pon, JP, Gandini PA, Favero M 2007. Effect of longline configuration on seabird mortality in the Argentine semi-pelagic kingclip *Genypterus blacodes* fishery. Fisheries Research 85: 101–105

SFIA 2005. Trial of acoustic deterrents ('porpoise pingers') for prevention of porpoise (*Phocoena phocoena*) bycatch. FIFG FEP 686A. Seafish Technology Implementation Department. Sea Fish Industry Authority, Hull

Smith NWM 2001. Longline sink rates of an autoline vessel, and notes on seabird interactions. *Science for Conservation 183*. Department of Conservation, Wellington, New Zealand. 32 p.

Snell K 2008. Brickle Curtain Report: Quantifying the Effectiveness of the Brickle Curtain at Mitigating Against Secondary Hooking. Falkland Island Fisheries Department, Stanley, Falkland Islands.

Stempniewicz L 1994. Marine birds drowning in fishing nets in the Gulf of Gdansk (southern Baltic): numbers, species composition, age and sex structure Ornis Svecica 4: 123–132

Southern Seabirds Solution Trust 2016. Case Study 2 – Integrated weighted line. http://www.southernseabirds.org/about-us/projects/mitigation-development-pathway/case-studies/integrated-weighted-line/ Accessed December 8, 2016

Sullivan BJ 2004. Falkland Islands FAO National Plan of Action for reducing incidental catch of seabirds in commercial fisheries. Falklands Conservation, Stanley, Falkland Islands

Sullivan BJ, Liddle GM, Munro GM 2004. Mitigation trials to reduce seabird mortality in pelagic trawl fisheries (Subarea 48.3). WG-FSA-04/80. CCAMLR, Hobart

Sullivan BJ, Reid TA, Bugoni L 2006a. Seabird mortality on factory trawlers in the Falkland Islands and beyond. Biological Conservation 131, 495–504

Sullivan BJ, Brickle P, Reid TA, Bone DG, Middleton DAJ 2006b. Mitigation of seabird mortality on factory trawlers: trials of three devices to reduce warp cable strikes. Polar Biology 29: 745–753.

Sullivan BJ, Kibel P, Robertson G, Kibel, B, Goren M, Candy SG, Wienecke B 2012. Safe leads for safe heads: safer line weights for pelagic long-line fisheries. Fisheries Research 134–136: 125–132.

Sullivan BJ 2016. Hook Pod Update to the Department of Conservation Conservation Services Programme Technical Working Group, June 16 2016.

Tamini L 2012. Latest update on the Tamini Tabla. http://www.rspb.org.uk/community/getinvolved/b/albatross/archive/2012/10/12/latest-update-on-the-tamini-tabla.aspx Accessed November 9, 2016

Tamini L, Chavez L, Rabuffetti F 2010. *In* BirdLife Global Seabird Programme (2010). Albatross Task Force Annual Report 2009. Argentina. Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire, UK pp. 42–47.

Trippel EA, Holy NL, Palka DL, Shepherd TD, Melvin GD, Terhune JM 2003. Nylon barium sulphate gillnet reduces porpoise and seabird mortality. Marine Mammal Science 19: 240–243

van Dam W, Schrijver E, Sorensen B 2014. SeaBird Saver: an innovative laser technology to reduce seabird bycatch in commercial fisheries. ACAP Sixth Meeting of the Seabird Bycatch Working Group, Punte del Este, Uruguay, 10–12 September 2014.

Wang JH, Fisler S, Swimmer Y 2010. Developing visual deterrents to reduce sea turtle bycatch in gill net fisheries. Marine Ecology Progress Series 408: 241–250

Wark K, Fox D, Milliken H, Armstrong J 2013. Overview of bycatch reduction research for sturgeon, or similar fish morphologies. *In*: NMFS Workshop on sea turtle and Atlantic sturgeon bycatch reduction in gillnet fisheries. Jan 22–23, 2013. National Marine Fisheries Service and Atlantic States Marine Fisheries Commission

Watkins BP, Petersen SL, Ryan PG 2008. Interactions between seabirds and deep-water hake trawl gear: an assessment of impacts in South African waters. Animal Conservation 11: 247–254.

Waugh SM, Filippi DP, Blyth R, Filippi PF 2011. Assessment of bycatch in gillnet fisheries. Report for the Convention on Migratory Species. UNEP/CMS/Inf.10.30. Sextant Technologies, Wellington

Weimerskirch H, Candeville D, Duhamel G 2000. Factors affecting the number and mortality of seabirds attending trawlers and long-liners in the Kerguelen area. Polar Biology 23: 236–249

Werner T, Kraus S, Read A, Zollett E 2006. Fishing techniques to reduce the bycatch of threatened marine animals. Marine Technology Society Journal 40: 50–68

Western Central Pacific Fisheries Commission 2016. Conservation and Management Measures (CMMs) and Resolutions of the Western Central Pacific Fisheries Commission (WCPFC) - Compiled 7 Aug 2016 http://www.wcpfc.int/system/files/booklets/31/CMM%20and%20Resolutions.pdf

Wiedenfeld DA, Crawford R, Pott CM 2015. Results of a workshop on reduction of bycatch of seabirds, sea turtles, and sea mammals in gillnets. National Conservation Training Center Shepherdstown, West Virginia, USA, 21–23 January 2015. American Bird Conservancy & BirdLife International

Wiedenfeld DA 2016. Seabird bycatch solutions for fishery sustainability. American Bird Conservancy.

Wienecke B, Robertson G 2002. Seabird and seal—fisheries interactions in the Australian Patagonian toothfish *Dissostichus eleginoides* trawl fishery. Fisheries Research 54: 253–265

WWF 2011. Yamazaki Double-Weight Branchline Factsheet. http://www.wwf.or.jp/activities/upfiles/WINNER_TUNA-Prizes-Double-Branchline-Fact.pdf

Yokota K, Kiyota M 2006. Preliminary report of side-setting experiments in a large sized long-line vessel. Report to the Scientific Committee Second Regular Session, Western and Central Pacific Fisheries Commission, WCPFC-SC2-2006/EB WP-15, Manila, Philippines

Žydelis R, Small C, French G 2013. The incidental catch of seabirds in gillnet fisheries: A global review. Biological Conservation 162: 76–88