SCIENTIFIC COMMITTEE
FIFTH REGULAR SESSION

10-21 August 2009
Port Vila, Vanuatu

Seabird bycatch mitigation measures

WCPFC-SC5-2009/EB-WP-03

BirdLife International, Global Seabird Programme[1]

[1] BirdLife International, UK

Abstract:

BirdLife International has worked with the community of researchers on seabird bycatch mitigation, and following the 2008 FAO recommendations on best-practice management for reducing incidental mortalities of seabirds in fisheries, has produced this series of 14 Seabird Bycatch Mitigation Factsheets. Seven of these are focussed on pelagic longline fisheries, and together they describe the range of potential mitigation measures available to reduce seabird bycatch in longline and trawl fisheries. The sheets assess the effectiveness of each measure, highlight their limitations and strengths, and make best practice recommendations for their effective adoption. They are designed to help decision-makers choose the most appropriate measures for their longline and trawl fisheries.

Fisheries bycatch is the single greatest threat facing many seabird populations. Albatrosses, in particular, are under extreme pressure with 18 of the 22 species threatened with extinction.

To date no single mitigation measure has proven successful at eliminating seabird bycatch in all situations. In most cases, it is necessary to use a number of mitigation measures in combination to minimise seabird bycatch. Each fishery has different operational characteristics and interacts with a specific assemblage of seabirds, which may require specific considerations. For this reason, having available specifications and detailed information about effective mitigation measures is vital for fisheries managers; including Regional Fishery Management Organisations.

The sheets are available in PDF and hard copy; and will be translated into the main languages of fishing nations. Due to the careful review and research that has supported the development of these Fact Sheets, they represent a benchmark in defining mitigation requirements, and should be used by WCPFC to revise its requirements for effective mitigation measures.

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Bycatch Mitigation

Practical information on seabird bycatch mitigation measures

Introduction: Seabird bycatch mitigation measures

This series of 14 Seabird Bycatch Mitigation Fact-sheets describes the range of potential mitigation measures available to reduce seabird bycatch in longline and trawl fisheries. The sheets assess the effectiveness of each measure, highlight their limitations and strengths, and make best practice recommendations for their effective adoption. They are designed to help decision-makers choose the most appropriate measures for their longline and trawl fisheries.

The threat to seabirds

Seabirds are characterised as being late to mature and slow to reproduce; many albatrosses do not breed before they are ten years old and thereafter a maximum of a single egg is produced each year, with many species only breeding every other year. To compensate for this seabirds are very long-lived, with natural adult mortality typically very low. These traits make any considerable increase in human-induced adult mortality potentially damaging for population viability, as even small increases in mortality can result in population declines.

Fisheries bycatch is the single greatest threat facing many seabird populations. Albatrosses, in particular, are under extreme pressure with 18 of the 22 species threatened with extinction (BirdLife International, 2008). Seabird bycatch is unnecessary and preventable. In fact, it not only has disastrous consequences for the birds but also renders fishing operations less efficient. Fortunately, there are simple and effective solutions that can prevent seabird bycatch in longline and trawl fisheries.

Seabird bycatch in longline fisheries

Seabirds are most vulnerable to mortality on longline hooks during the short period between hooks leaving the vessel and sinking beyond the diving range of foraging seabirds. Mitigation measures are designed to prevent contact between seabirds and hooks during this critical period. The period during which bait are available to birds is determined by the sink rate of the line, the diving ability of the bird species present and the use, or not, of seabird deterrents. Seabirds can also be hooked and potentially injured during line hauling.

Seabird bycatch in trawl fisheries

Over recent years, mortality of albatrosses and petrels in trawl fisheries has been identified as a major threat. The causes of mortality in trawl fisheries are varied and depend on the nature of the fishery (pelagic or demersal) and the species targeted. However, it may be categorised into two broad types: cable-related mortality, including collisions with netsonde cables, warp cables and paravanes; and net-related mortality, which includes all deaths caused by net entanglement.

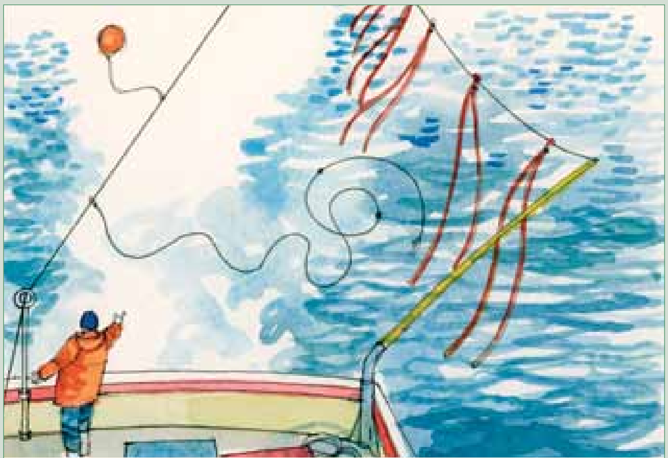

Figure 1. Streamer lines are an example of a cheap seabird bycatch mitigation measure, which can be used in combination with other measures to great effect.

Mitigation measures

There are several simple, inexpensive yet effective mitigation measures available that, when used conscientiously, can reduce the number of seabirds killed in longline and trawl fisheries. A mitigation measure can be defined as a modification to gear design or fishing operation that reduces the likelihood of catching seabirds.

Mitigation measures tested in trawl fisheries are either based on the principle of deterring birds from coming into contact with the warp, paravane or netsonde cables, which are the parts of the trawl that cause the majority of seabird deaths, or reducing the attractiveness of the vessel by managing the discharge of offal/factory waste (Løkkeborg, 2008).

Mitigation measures for longline fishing have been classified somewhat differently, but are typically divided into four main categories:

1. Avoid fishing in areas and at times when seabird interactions are most likely and intense (night setting, area and seasonal closures).
2. Limit bird access to baited hooks (underwater setting funnel, weighted lines, thawed bait, line shooter, bait-casting machines, side-setting).
3. Deter birds from taking baited hooks (streamer (bird-scaring) lines, acoustic deterrents, water cannon).
4. Reduce the attractiveness or visibility of the baited hooks (dumping of offal, artificial baits, blue-dyed bait) (Løkkeborg, 2008).

To date no single mitigation measure has proven successful at eliminating seabird bycatch in all situations. In most cases, it is necessary to use a number of mitigation measures in combination to minimise seabird bycatch. Each fishery has different operational characteristics and interacts with a specific assemblage of seabirds, which may require specific considerations.

Mitigating bycatch in longline fisheries

Sink rate

A range of operational (e.g. line weighting regime, vessel speed, crew awareness) and environmental (e.g. sea state) factors determine longline sink rate. An appropriate line-weighting regime is the key to achieving a desired sink rate. In addition to the sink rate, the setting speed of a vessel has a direct effect on the distance behind a vessel that bait are accessible to birds, the faster the setting speed, the further behind the boat the baits are available, and the less likely they are to be covered by the protection of streamer lines.

Seabird diving capabilities

The 'safe' depth, below which seabirds are not vulnerable to becoming caught, is a function of the foraging bird's diving proficiency. Albatross diving ability ranges from zero (wandering albatross) to about 12 m (light-mantled albatross), most small albatross species (mollymawks) fall somewhere in between. Of other species regularly caught on longlines, northern fulmars are restricted to surface waters, white-chinned petrels dive to depths of 13 m while sooty shearwaters have been recorded diving to 67 m. The deeper diving species are not only caught themselves but can cause 'secondary mortality', whereby they retrieve baited hooks from depth making them available to less proficient divers, like albatrosses. This is particularly prevalent in pelagic longline fisheries.

Mitigating bycatch in trawl fisheries

The key to cable related mortality is managing the discharge of offal and discards, although such measures can require vessel re-fits and so are often seen as a long-term, albeit extremely effective, option. There are a range of interim and highly effective measures (e.g. streamer lines) currently available. The adoption of mitigation measures during the shot can also largely eliminate net-related entanglement of seabirds, but during haul, the problem is more difficult to mitigate.

The next step

Once a bycatch problem has been identified and appropriate solutions (mitigation measures) identified the challenge is to ensure mitigation measures are adopted. The presence of skilled observers who can provide assistance and advice is a key step toward the effective use of mitigation measures.

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BirdLife International (2008) http://www.birdlife.org/datazone/species/index.html
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. Rome, FAO. pp. 24.

Fact-sheets available include:

Fact-sheet number	Target fisheries	Mitigation measures
1	Demersal longline	Streamer lines
2	Demersal longline	Line weighting – external weights
3	Demersal longline	Integrated weight longlines
4	Demersal longline	Line weighting – Chilean system
5	Demersal and pelagic longline	Night-setting
6	Demersal longline	Underwater setting chute
7	Pelagic longline	Streamer lines
8	Pelagic longline	Line weighting
9	Pelagic longline	Side-setting
10	Pelagic longline	Blue-dyed bait (squid)
11	Pelagic longline	Bait caster and line shooter
12	Demersal and pelagic longline	Haul mitigation
13	Trawl	Warp strike
14	Trawl	Net entanglement

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Bycatch Mitigation FACT-SHEET 5

Practical information on seabird bycatch mitigation measures

Demersal and Pelagic Longline: Night-setting

Night-setting is one of the few mitigation measures that is equally applicable to both demersal and pelagic longline fisheries.

What is night-setting?

Night-setting requires no modification of the fishing gear. It simply requires setting to be started and finished during the hours of darkness, between nautical dusk and dawn.

Setting at night avoids periods when most seabirds are actively foraging. Available information suggests that albatrosses and petrels detect food items at close range by sight and so darkness effectively conceals baited hooks from most foraging seabirds. Additionally, many seabirds, particularly albatrosses, are most active during daylight hours, including dusk and dawn. Data from stomach temperature gauges (Weimerskirch and Wilson, 1992) suggest that wandering albatross, at least, feed primarily during daylight hours and rest at night. This is reflected in bycatch studies, which frequently show that time of day is an important factor affecting the number of birds caught during longline setting (e.g. Baker and Wise, 2005). In particular, dawn and dusk are times when birds are most active and consequently most vulnerable to longline bycatch (e.g. Belda and Sanchez, 2001).

Effectiveness at reducing seabird bycatch

On moonless cloudy nights, night-setting can be highly effective at limiting seabird bycatch. However, for up to two weeks every month the moon may provide enough light to significantly reduce the effectiveness of night-setting (Klaer and Polacheck, 1998; Petersen, 2008).

Seabird species

The effectiveness of night-setting is also dependent on the species assemblage. In some instances, where albatrosses compose the majority of bycatch, night-setting can effectively reduce seabird bycatch. Around the Prince Edward Islands, Southern Ocean, experimental trials indicate albatross bycatch rates are ten times higher during the day than at night whereas white-chinned petrel bycatch was halved when setting at night (Ryan and Watkins, 2002). Off the east coast of Australia, where shearwaters predominate, night-setting alone is less effective, although bycatch rates are still lower than day sets (Baker and Wise, 2005).

Best practice recommendation

To be effective, vessels should not commence line setting until at least one hour after nautical dusk and should complete setting at least one hour before nautical dawn. Combined with night-setting, deck lights should be kept at the minimum level appropriate for crew safety and directed inboard so the line is not illuminated as it leaves the vessel.

Potential problems and solutions

- Night-setting is only truly effective on dark nights (i.e. the new moon half of the lunar cycle). On clear nights with a full moon, night-setting becomes far less effective (Klaer and Polacheck, 1998; Petersen, 2008).
- In the highest latitudes during the summer months, the time between nautical dusk and dawn is limited. In these circumstances, fishing opportunities are greatly reduced.

Figure 1. At night, seabirds are generally less active and have difficulty locating baits.

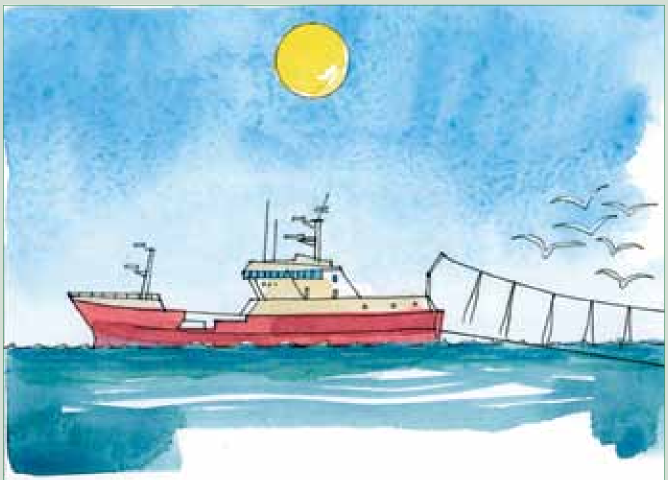

Figure 2. Seabirds, and albatrosses in particular, are more active during the day.

Careful planning is required to minimise the amount of lost time and the associated cost of lost fishing potential and fuel.
- Depending on the target species, the time of setting may have consequences for the catch rate of target species. This is more likely to be an issue in pelagic longlines where many species undergo daily vertical migrations.
- Night-setting can raise concerns over crew safety. This can be overcome by ensuring adequate deck lighting is in place.

Combinations of measures

Due to variations in the lunar cycle and the ability of some species to forage at night, night-setting is not an effective measure when used in isolation. It is recommended that night-setting is used in combination with a selection of other measures:
- ***Line weighting*** (Fact-sheets 2, 3, 4 and 8)
- ***Streamer line*** (Fact-sheets 1 and 7)
- ***Blue-dyed bait (squid)*** (Fact-sheet 10).

Further research

There is concern that night-setting may transfer bycatch pressure from seabirds onto other vulnerable bycatch species such as sharks and turtles. Further research is needed to evaluate the effect of setting time on target fish catch and bycatch rates of seabirds, sharks and turtles.

Compliance and implementation

Compliance with the requirement to set at night can be monitored with onboard observers, and is potentially monitored through VMS and other electronic monitoring of fishing activity. The simplicity and the effectiveness of the measure make it attractive in demersal longline fisheries but the implications for catch and non-seabird bycatch in some pelagic longline fisheries require further investigation.

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Pelagic Longline: Streamer lines

Streamer lines are the most commonly prescribed seabird bycatch mitigation measures for longline fisheries and one of the most effective (a primary measure). Streamer lines were an innovation of Japanese tuna fishermen to prevent bait loss to birds. They are inexpensive, simple and require no modification to fishing gear.

What are streamer lines?

A streamer line (also called a tori or bird scaring line) is a line with streamers that is towed from a high point near the stern as baited hooks are deployed (Figure 1). As the vessel moves forward, drag on the line creates an aerial segment (extent) from which streamers are suspended at regular intervals. With streamer lines, the aerial extent is critical when attempting to scare birds away from baited hooks. A towed object is used to create additional drag to maximise the aerial extent. The goal is to maintain the streamer line over the sinking baited hooks in such a way that the streamers prevent seabirds from attacking bait, becoming hooked and subsequently killed. Currently, the most proven and recommended streamer line is the one prescribed by the Commission for the Conservation of Antarctic Marine Living Resources (SC-CAMLR, 2006) and used in Alaskan demersal longline fisheries. Streamer line designs for pelagic longline fisheries are being developed and tested, but until those tests are complete the CCAMLR streamer line design is recommended.

Effectiveness

Definitive trials on the effectiveness of streamer lines come from research in demersal longline fisheries (Melvin *et al.*, 2004; Løkkeborg, 2008). Peer reviewed publications of streamer line trials in pelagic fisheries are few and limited in scope.

- Brothers (1991), looking at seabird behaviour with and without a tori line over several days, suggested that one streamer line could reduce bait loss by roughly 69%. The scope of the trial (i.e. number of hooks observed with and without a streamer line) is unclear.
- Boggs (2001) reported a 70% reduction in albatross contacts with baits using one streamer line, compared to a control of no deterrent, during trials conducted on a research vessel. However, the streamer line aerial extent was only 40 m, far short of recommended standards today.

A number of non-peer reviewed technical reports on aspects of pelagic streamer lines are available; however, they provide primarily qualitative information and recommended technical specifications are sometimes conflicting.

Seabird Interactions

How different seabird species interact with pelagic longlines is a function of their diving ability as well as their relative size and aggressiveness. Certain species, particularly shearwaters and some petrels, can attack bait at depths of 10 m or more. Albatrosses, in general, make shallower dives – some dive up to 5 m, but around 2 m is most common and great albatrosses are unable to dive.

Unlike demersal longline fisheries, interactions can be primary as well as secondary. An interaction is 'primary' when a bird takes a piece of bait, and in the process can become hooked and drown. Due to the long (up to 35 m) branchlines unique to pelagic longlining, interactions can also be 'secondary'. In this case, a bird – most typically a diving bird – seizes a piece of bait at depth and is met at the surface by other aggressive seabirds that compete for the bait. This scrum can result in the hooking of a different bird – typically a larger, aggressive bird – such as an albatross. Due to secondary interactions, effective seabird bycatch mitigation must exclude deep *and* shallower diving birds to protect the albatrosses. Because slow sinking bait are available to deep diving birds further astern of the vessel, the streamer line aerial extent must extend as far as 150 m to prevent seabird takes.

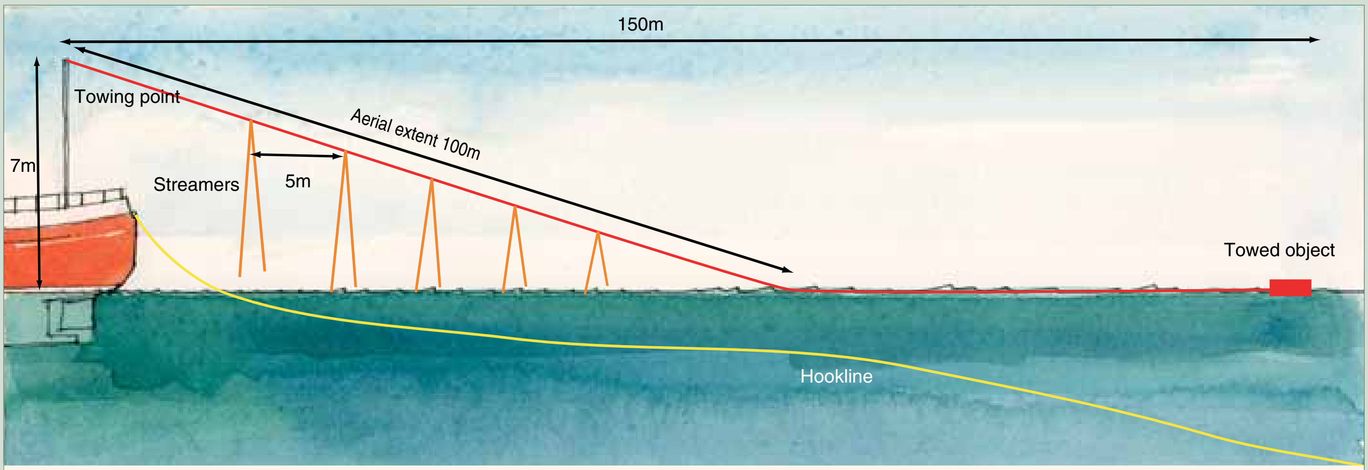

Figure 1. Streamer line prescribed by CCAMLR Conservation Measure 25-02 for demersal longline fisheries.

Environmental variables

Environmental variables, in particular the strength and bearing of the wind relative to the vessel, are important. Crosswinds can render the streamer line ineffective by pushing the streamer line away from its desired position over the baited hooks and large swells can increase the chance of surface floats fouling on a streamer line.

Best practice recommendation

The key factors affecting the performance of a streamer line are its aerial extent, the position of streamers in relation to sinking baited hooks, and the strength and position of the attachment point to the vessel.

- The aerial extent of streamers is the active deterrent of a streamer line. It acts as a 'scare-crow' keeping birds from reaching baited hooks. Aerial extent is achieved through a combination of the height of the attachment point to the vessel, the drag caused by a towed object or the overall length of the line, and the overall weight of the materials making up the streamer line. Maximizing aerial extent also reduces the chances of tangles with the fishing line (Melvin *et al*., 2004). The aerial extent of a streamer line should protect baited hooks until they sink beyond the access of both shallow and deeper diving birds (~10 m). Without weighted branchlines this distance is likely to be well beyond 100 m. For this reason weighted branchlines and streamer lines are a very effective combination of mitigation measures.
- A single streamer line must be placed directly above, or to windward, of baited hooks to be effective. In crosswinds, the attachment point and backbone of the streamer lines should be adjusted to windward in such a way that individual streamers extend over baited hooks as they sink. Two or more streamer lines placed on either side of the water entry point of baited hooks will protect them in all wind conditions.
- In high seas pelagic longline fisheries, bait-casting machines are commonly used. They serve to uncoil the latter 10 m of long branchlines and deliver each baited hook beyond the wake where, if cast properly, they sink faster. In order to protect bait from bird attacks, baited hooks must either land beneath streamers or between the wake and the streamers of the streamer line. If two streamer lines are used, baited hooks should land between them. Failure to align streamer lines with bait tossed via a bait-casting machine can have devastating results (Melvin and Walker, 2008).
- The attachment point to the vessel must be strong and should be adjustable. It must support the drag necessary to create an aerial extent of 100 m or more. It also must be able to withstand the sudden tension should a float or debris foul on a streamer line. Davits, that can position a pole and streamer line outboard of the baited hook delivery point, are essential to effective use of streamer lines in situations where baited hooks are delivered outside the wake, as with casting machines.
- Streamers should be a bright colour, such as safety orange or fluorescent green, and should extend from the backbone of the streamer line to the water in the absence of wind or swell as recommended by CCAMLR. Yokota *et al.* (2008) report that Japanese coastal fishermen prefer 'light' streamer lines with short streamers (1 m or less); however, the seabird bycatch rates reported in this research were extremely high for the light and conventional streamer line designs tested, suggesting that neither was well designed or effective. Strong support for the use of 'conventional' streamer lines – streamers that extend to the water – comes from their effective use in both CCAMLR and Alaskan demersal longline fisheries and from other research (Løkkeborg, 2008).

Potential problems and solutions

Streamer lines are very effective at reducing seabird mortality, but can be challenging to use in the context of pelagic longline fishing. In general, pelagic longlines are set at faster vessel speeds and hooks sink slower than in demersal longline fishing. These factors extend the distance at which baited hooks sink beyond the reach of seabirds, thus creating a longer distance astern that needs to be protected.

Surface floats, unique to pelagic longlines, can foul on streamer lines making some fishermen reluctant to deploy them properly, or to use them at all. Fouling events can hinder the fishing operation, pose danger to the crew, and increase seabird bycatch. These events usually occur when floats catch on the towed object (on the streamer line), but they can also occur when a swell throws a float and line over the streamer line backbone when no towed device is used. It is essential to find a solution to this problem. First and foremost, the crew should develop a plan to deploy floats in such a way that the likelihood of them fouling with the streamer lines is minimised by giving consideration to current, wind and position of the streamer line. Preliminary research has found that using packing strap material tied into the backbone at high density (more than ten 1 m strips per metre for 30–40 m) can minimise the chance of entanglement, while providing sufficient drag to achieve aerial extent of >100 m (Melvin *et al.,* 2009).

Combinations of measures

Streamer lines are regarded as a primary mitigation measure. That is, when used alone they significantly reduce seabird bycatch. However, they work even more effectively when used in combination with other mitigation measures including:

- ***Line weighting*** (Fact-sheet 8)
- ***Night-setting*** (Fact-sheet 5)
- ***Offal management*** (Fact-sheet 12).

Further research

- Definitive tests of competing streamer line designs are needed to determine a best practice streamer line design for pelagic fisheries. Optimal streamer and backbone lengths, materials and configurations must be determined.
- Strong and adjustable davits and tori poles are needed to achieve the necessary aerial extent, and to position streamer lines effectively under the many physical conditions that can occur at sea.
- Research is needed to develop strategies that minimise or eliminate streamer line fouling – the major obstacle to their voluntary use. Ongoing research is attempting to develop a towed device that will position the end of a streamer line outside the wake, where fouling with surface gear is less likely.

Compliance and implementation

- The use of streamer lines is widely accepted as a seabird bycatch mitigation measure in most longline fisheries. Streamer lines should be inspected to ensure they conform to requirements before a vessel leaves port to fish. At-sea, the use of streamer lines can only be monitored by onboard observers or through aerial reconnaissance.
- Inadequate streamer line design and deployment can lead to poor compliance and/or deploying streamer lines in such a way that they are ineffective.

Technical Specifications

A fusion of Alaskan and Japanese concepts, the streamer line includes two sections: a 'protection section' and a 'drag section'. The aerial extent is the distance that baited hooks sink beyond 10 m – the presumed depth beyond which birds cannot access baits. The backbone of the aerial extent section is a light, high-tensile strength line and the drag section is a lower tensile strength line with breakaways. The orange tubing streamers are alternated along the aerial extent and 5 m intervals where the backbone is 1 m or more from the water. A variety of bold coloured (orange and fluorescent green) packing straps are attached to the remaining aerial extent of the backbone where it is <1 m from the surface. The drag section creates drag to achieve the necessary aerial extent and disturbs the water to deter birds. The drag section can be composed of different elements and includes breakaways to protect the expensive and important 'protection' section from loss due to fouling on surface floats.

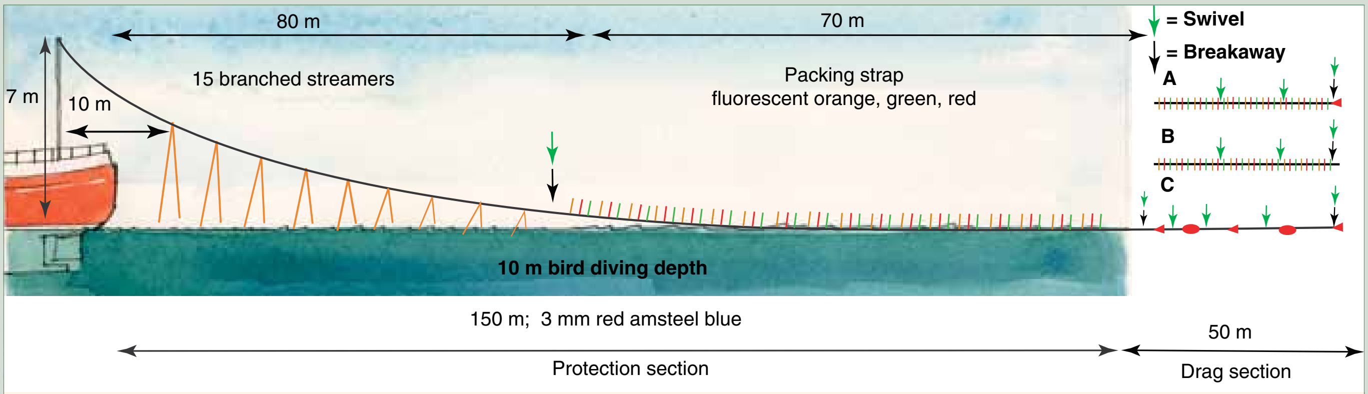

Figure 2. Proposed optimal streamer line for pelagic longline fisheries (design taken from Melvin *et al.*, 2009).

The recommended best-practice streamer line for pelagic longline fishing is:

- Streamer lines should be deployed before the first hook enters the water and retrieved after the last hook has been set.
- **The streamer total length: 200 m**; the 'protection section' should be a light weight high tensile strength line 3 to 4 mm in diameter while the 'drag section' should be a heavier and lower tensile strength line with breakaways.
- Vessel attachment height: **>7 m above the sea surface**.
- **Minimum aerial extent: 100 to 150 m**, or the distance that baited hooks sink beyond a depth of 10 m – the presumed depth beyond which birds cannot access bait.
- Streamers: each streamer should be constructed from lightweight brightly coloured, UV protected rubber tubing and **spaced less than 5 m apart** along the streamer line backbone, and start at a minimum of 10 m from the stern.
- There should be at least 15 clip-on streamers per streamer line; the remaining length of the aerial extent should have strips of tubing or packing strap material tied into the line at similar intervals.
- Streamers should be **long enough to reach the sea surface** in calm conditions.
- Swivels positioned at the attachment point to the vessel and the towed object help to avoid twisting and wear. These can also incorporate breakaway points, in the event of snags with the hook line.
- Lightweight swivels or light line should be used to attach streamers to the backbone of the streamer line as they reduce the frequency of streamers tangling around it.
- The vessel attachment point should be strong – able to withstand the drag of an towed device and withstand surface floats fouling on streamer lines – and adjustable to allow positioning of streamer lines windward of where baited hooks land in the water.
- Streamer lines should be deployed in pairs, one on each side of baited hooks, during line setting.
- Spare streamer lines should be carried onboard the vessel to be deployed in the event of lost or broken streamer lines.
- Streamer lines should be examined regularly and maintained as necessary.

Thanks to Dr Ed Melvin (Washington Sea Grant) for his contributions to the content of this Fact-sheet.

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Environmental Issues

The primary research discussed in this Fact-sheet used package strapping as an integral part of the towed device. Given concerns about potential marine debris related issues, researchers are currently investigating biodegradable alternatives, which will ensure best practice mitigation incorporates wider marine conservation issues.

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Bycatch Mitigation FACT-SHEET 8

Practical information on seabird bycatch mitigation measures

Pelagic Longline: Line weighting

Line weighting is one of the most effective known mitigation measures (a primary measure). It is widely applicable to pelagic longline fishing, and has been demonstrated to lead to reductions in seabird bycatch. It is recommended that it be used in combination with streamer lines, night setting and other measures as required.

Reducing seabird mortality in pelagic longline fisheries with line weighting regimes is more complicated than in demersal longline fisheries because of 'secondary' interactions with baited hooks. Secondary interactions occur when diving seabird species, such as *Procellaria* petrels and *Puffinus* shearwaters, bring sinking bait back to the surface where they can be ingested by larger and more dominant species, such as great albatrosses. Secondary interactions rarely, if ever, occur in demersal longline fisheries because snoods/branch lines are extremely short (<0.6 m) and the mainline is heavy. In contrast, pelagic branchlines can be 15–40 m in length and lightweight. Secondary interactions are implicated in a significant proportion of seabird bycatch in pelagic longline fisheries.

What is line weighting?

Seabirds are vulnerable to mortality on pelagic longline hooks during the short period between hooks leaving the vessel and sinking beyond the diving range of foraging seabirds. Preventing contact between seabirds and baited hooks at this time is crucial. In many pelagic longline fisheries, weights are added to branchlines to deliver hooks to target fishing depths as efficiently as possible. The best practice weighting regimes recommended here are intended to take baited hooks beyond the diving range of seabirds while under the protection of a well designed and properly deployed streamer line (tori line), without compromising fish catch rates.

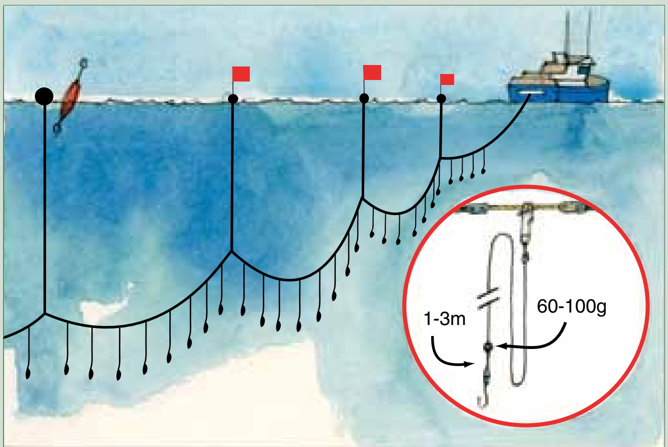

Figure 1. Pelagic longline gear configuration with line weighting. Note the distance between the weight and the hook.

Important aspects of line weighting

Two aspects of pelagic branch line construction are critically important to achieving fast sink rates – the length of the leader (length of monofilament line joining leaded swivel to baited hook) and the weight of the leaded swivel. Leader length is the main determinant of 'initial' sink rate, whereas swivel weight is the main determinant of 'final' sink rate. The initial sink phase occurs immediately upon baited hooks landing in the water, when the leaded swivel sinks at a faster rate than the baited hook. At this stage, the sinking swivel has not begun to influence the sink rate of the baited hook. Final sink rate occurs when the slack in the leader length has been taken up and the leader becomes taut. Only then is the hooked bait placed under maximum load (pull-down) by the swivel. The initial sink phase, which occurs in the 0–1 m, 0–2 m, or 0–3 m ranges (depending on leader length), is expedited by moving the swivel closer to the hook, which more quickly exhausts the slack in the leader. The final sink phase occurs at deeper depths (e.g. 3–5 m and beyond) and is hastened using heavier swivels or adding alternative weights. To minimise seabird interactions, it is important to increase both the initial and final phases of sink profiles; this can be achieved by using heavier swivels closer to hooks.

Sink rate experiments

Sink rate experiments are currently being undertaken in many southern hemisphere countries. Over the next few years, new information will become available on the effectiveness of line weighting regimes in reducing seabird bycatch. In the meantime, the following provisional conclusions are relevant, along with that above dealing with leader lengths and swivel weights.

Swivel weights and leader lengths: Swivels used in southern hemisphere pelagic longline fisheries vary between 0–80 g, with 60–80 g being most common. Leader lengths also vary; but are usually between 3–4 m. High seas fisheries either use no additional weight in branch lines or amounts that are unlikely to result in improved sink rates. In fisheries with high seabird interaction rates, much heavier line weighting regimes – perhaps as much as 120 g placed <2 m from hooks – may be required, in combination with effective streamer lines, to effectively reduce seabird mortality.

Propeller turbulence: Turbulence created by propeller wash produces an upwelling effect that slows sink rates. The fastest sink rates are achieved by deploying the mainline away from water affected by propeller turbulence. For this reason, baited hooks should not be deployed into propeller turbulence but into the wake zone of vessels.

Bait thaw status: In fisheries where leaded swivels as light as 60 g are used, as long as bait (fish, squid) are thawed to an extent that permits hooks to be inserted without undue force, bait thaw status has no effect on sink rates. In fisheries where leaded swivels are not used (e.g. the high seas), bait thawed to the point that allows a hook to be inserted, results in slower sink rates than bait that is fully thawed. However, the difference is slight and less important than other factors that affect gear sink rates.

Best practice recommendation

Line weighting is recommended as a primary measure for reducing seabird bycatch, and there is increasing understanding of how it works in combination with other measures. The effectiveness of line weighting on pelagic longlines should be measured, taking into account both initial and final hook sink rates, as well as vessel speed. With the protection of an effective streamer line (i.e. an aerial extent of at least 100 m), sink rates of ≥0.3 m/s to 2 m depth and ≥0.5 m/s to 5 m depth should be sufficient to take hooks beyond the reach of most surface-seizing birds (in the absence of diving species returning baited hooks to the surface). Different fisheries and gear types will require different weighting regimes to achieve this standard.

To achieve the best possible sink rates, several vessel and operational effects need to be considered:

- ***Vessel effects:*** The length of streamer line deployed and speed at which lines are set will vary between vessels. These factors influence the time available to foraging seabirds to target baited hooks. Large industrial and small artisanal vessels may require different weighting regimes to attain the same reduction in seabird bycatch.
- ***Operational effects:*** In order to achieve the fastest practicable sink rates, hooks must be cast beyond the propeller wash, and yet remain under the protection of the streamer line/s.

Other benefits

Target species catch rates

There is some speculation that applying weights to pelagic longline gear results in higher catch rates of target fish. Further experimental trials are needed to investigate this relationship.

Potential problems and solutions

Fishermen are rightly concerned about the safety implications of using weighted lines. When the line is stretched during hauling and suddenly breaks (a 'bite-off', usually due to shark bycatch), the lead weights attached to branch lines can be launched back towards fishermen on deck, and in a few cases serious injury and even death have resulted. In some fisheries, protective helmets are worn to reduce the risk of injury. To combat the safety issues associated with lead swivels, new weighting systems are in development (see Further research).

Combinations of measures

Line weighting is one of the most important mitigation measures, but to ensure effectiveness it is recommended that it be used in combination with other measures, including:

- ***Streamer lines*** (Fact-sheet 7)
- ***Night-setting*** (Fact-sheet 5)
- ***Side-setting*** (Fact-sheet 9)
- ***Blue-dyed squid*** (Fact Sheet 10).

Further research

Research is urgently required to determine the effects of heavier line weighting regimes on a) the catch rates of target and non-target fish species, and b) the incidental capture of seabirds. Research is also required to investigate options for minimising the safety concerns of fishermen associated with using line weighting. One new weight type under development by Fishtek (Ltd, UK) and BirdLife International is the **Safe Lead**. Safe Leads are not crimped onto the line but are designed to slide on and off. If the line breaks under tension, the weight slides down the line, dissipating the energy in the stretched line. It is hoped that with further testing and development Safe Leads will prove a safe alternative to weighted swivels and increase the uptake of effective line weighting regimes.

Compliance and implementation

Compliance with specific line weighting requirements can be monitored through in-port and at-sea inspections. However, the safety concerns associated with the use of weighted swivels must be addressed before line weighting in pelagic longline fisheries becomes universally accepted.

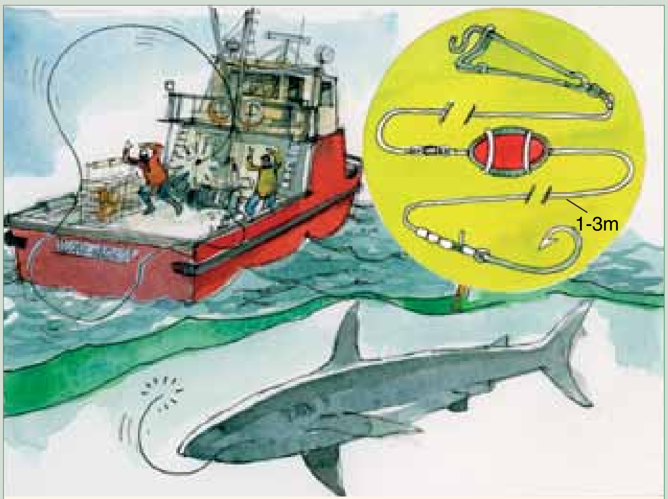

Figure 2. Fishermen can be injured by weights when the line suddenly breaks. Inset, shows the *Safe Lead*, a new weighting system being developed to reduce the risk of injury.

Thanks to Dr Graham Robertson (Australian Antarctic Division) for his contributions to the content of this Fact-sheet.

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Bycatch Mitigation **FACT-SHEET 9**

Practical information on seabird bycatch mitigation measures

Pelagic Longline: Side-setting

Side-setting appears to be effective in the waters of the North Pacific where it was developed. The ability to generalise its use across other oceans, with a higher diversity of seabirds with greater diving capabilities and more demanding sea conditions, remains untested.

What is side-setting?

Traditionally, hooks are deployed (set) from the stern of the vessel. As the name suggests, side-setting requires the setting operation to move to the side of the vessel. Birds are unable or unwilling to forage for bait close to the side of a vessel. Additionally, side-setting avoids setting baited hooks into the propeller wash, which slows the sink rate of stern set hooks. Deploying hooks from the side as far forward as possible enables the baited hook to sink to a certain depth before reaching the stern of the vessel.

Figure 1. Casting baited hooks forward and close to the hull of the vessel allow baits to start sinking before passing the stern of the vessel.

Figure 2. Side-setting with a bird curtain in use.

Effectiveness at reducing seabird bycatch

All experimental trials of side-setting have occurred in the North Pacific near Hawaii on relatively small vessels. Results indicate that side-setting was more effective than other simultaneously trialled mitigation measures, including setting chutes and blue-dyed bait, in a single pilot scale trial (14 days; Gilman *et al.,* 2003). It should be noted that these tests were conducted with an assemblage of surface-feeding seabirds, and this method requires testing in the Southern Ocean with diving species and at a larger scale. Preliminary trials suggest that this method is operationally feasible on larger vessels (Yokota and Kiyota, 2006).

Best practice recommendation

Fishery regulations in Hawaii require side-setting vessels to also use line weighting (45 g within a metre of the hook, NOAA 2006) and a bird curtain. These combined standards were adopted by the Western Central Pacific Fisheries Commission (WCPFC, 2007). For the best results, side-setting should be used in combination with line weighting in order to increase sink rates forward of the vessel's stern, and hooks should be cast well forward of the setting position, but close to the hull of the vessel, to allow hooks time to sink as far as possible before they reach the stern. Bird curtains, a horizontal pole with vertical streamers, positioned aft of the setting station, may deter birds from flying close to the side of the vessel. The combined use of side-setting, line weighting and a bird curtain should be considered as a single measure.

Other benefits

Operational efficiency

In Hawaii, not only has side setting proved to be effective at reducing seabird bycatch but it has also been found to deliver several operational advantages.

- By utilising a single work area for setting and hauling, more space may be available on deck for the crew to work in;
- The Captain is likely to have a better view of a side workstation, which has safety and efficiency implications; and
- Less bait may be lost in propeller turbulence and line tangles may be less common.

Potential problems and solutions

Conversion costs

A single one-off cost is incurred to refit the deck gear. In terms of overall running costs, this is a relatively minor expense.

Fouled gear

Side-setting could increase the likelihood of gear becoming entangled in the propeller especially in rough seas, although, in the Hawaii trial deliberate attempts to entangle gear in the propeller were unsuccessful.

Combinations of measures

Although baited hooks should be below the surface by the time they reach the stern of the vessel, diving seabirds would still be able to access them. To minimise seabird bycatch, side-setting should be used in combination with other measures including

- ***Streamer lines*** (Fact-sheet 7)
- ***Line weighting*** (Fact-sheet 8).

Further research

Further experimental trials are required to establish whether side-setting is feasible for all size classes of vessel, under a range of sea conditions and across diverse seabird assemblages. In particular, trials are lacking in southern hemisphere fisheries.

Compliance and implementation

Once converted there are very few issues concerning compliance, which could negate the need for costly monitoring. Further research is required before side-setting can be implemented in southern hemisphere fisheries.

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Bycatch Mitigation **FACT-SHEET 10**

Practical information on seabird bycatch mitigation measures

Pelagic Longline: Blue-dyed bait (squid)

Blue-dyed bait is a measure under development and, while there are some promising results, there is some uncertainty about its long-term effectiveness at reducing seabird bycatch and the practicality of widespread application. Current evidence suggests that blue-dyed squid is effective but dyed fish bait is not.

Why dye bait blue?

In the 1970s, fishermen experimented with dyed bait as a means of improving their target fish catch. More recently, experiments have been directed towards using blue-dyed bait to reduce seabird bycatch in pelagic longline fisheries.

In theory, dyeing bait blue reduces the contrast between the bait and the surrounding seawater making it more difficult for foraging seabirds to detect. Alternative theories suggest that seabirds are simply less interested in blue-dyed bait compared with undyed controls.

Effectiveness at reducing seabird bycatch

The effectiveness of blue-dyed bait at reducing seabird bycatch has varied considerably between different trials. Some trials have shown reductions in contacts between albatrosses and bait of over 90%, outperforming other mitigation measures (Boggs, 2001; Kiyota *et al*., 2007) while others indicate that blue-dyed bait used alone was less effective than other mitigation measures under investigation, including side-setting and setting chutes (Gilman *et al*., 2003).

Cocking *et al*. (2008) highlight the importance of bait type, blue-dyed fish was far less effective than squid at reducing seabird attack. Blue-dyed squid shows promise as an effective mitigation measure whereas blue-dyed fish appears less promising.

Several factors have been identified that could influence the effectiveness of blue-dyed bait;

- Fishermen perceive that several environmental factors (weather, light, sea colour) and operational factors (how bait is deployed) influence the behaviour of seabirds towards dyed bait.
- Competition and seasonal food requirements of foraging birds are likely to influence their response to blue-dyed bait.
- In the long-term, birds may become habituated to blue-dyed bait.

Generally, there appears to be potential to reduce seabird mortality but long-term trials are needed to understand the complex relationships between seabird behaviour, bait colour, environment and operational factors.

Best practice recommendation

The dyeing process requires bait to be fully thawed before they can take up sufficient dye. Food colouring, such as Virginia Dare FD C Blue No. 1 or E133, is commonly used. In Brazil, a company that specialises in food colouring, Mix Industria, has developed a dye to specifically to colour fishing bait. Depending on the concentration of the dye and the desired colour, bait is soaked from 20 minutes to four hours. Comparison with a colour card determines when the desired colour has been achieved. Bait is often refrozen after dyeing and used in a semi-frozen state to improve bait retention on hooks.

Figure 1. From the air, blue-dyed squid merge with the surrounding water.

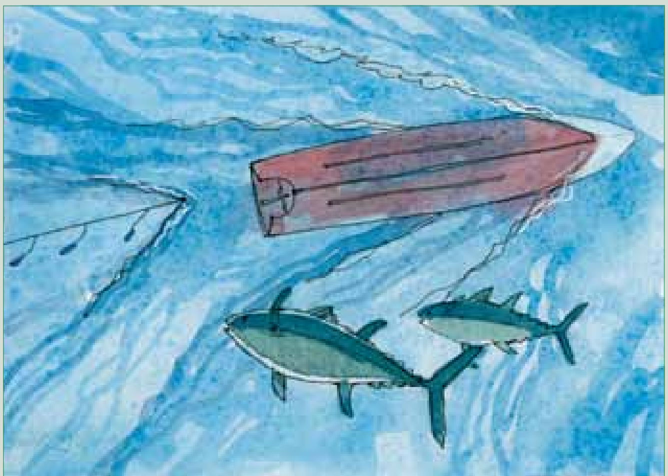

Figure 2. From below, dyed bait remains visible to target fish species.

Bait type

The type of bait used, squid or fish, can affect the up-take of dye and the birds' response. Squid take on the colouring far more effectively than fish. Fish easily lose dyed scales and there is considerable contrast between the dorsal and ventral surfaces of fish. Additionally, once thawed fish are more easily lost from hooks.

Other benefits

Target catch rates

The first experiments with dyed bait were designed to improve the catch of target fish species. It is unclear whether this is due to the reduction in bait loss to foraging seabirds or due to bait being more attractive to fish in the water column. Further trials are needed in order to quantify these subtle differences in catch.

Potential problems and solutions

Operational limitations

Several factors can make this measure inconvenient for fishermen.

- Bait needs to be fully thawed before it will take up sufficient dye. Thawed bait, particularly fish, is less likely to remain on the hook and thawing requires considerable preparation time.
- Dyeing bait at-sea can be a messy business: hands, clothes and the boat become coated in blue dye.
- In Hawaii, it is estimated that it costs US$14 to dye each longline set, which equates to about US$ 8 per 1,000 hooks.
- Additionally, the use of dyed of bait at-sea is very difficult to enforce.

Many of these issues would be resolved if pre-dyed bait were commercially available. Until such time, blue-dyed bait is unlikely to be widely used by fishermen.

Combinations of measures

At present, the practical issues of dyeing bait at-sea and the inconsistent results of experimental trials suggest that blue-dyed bait is not an appropriate primary mitigation measure. Blue-dyed bait has greater potential when limited to squid bait and used in combination with other mitigation measures including:

- ***Streamer lines*** (Fact-sheet 7)
- ***Side-setting*** (Fact-sheet 9)
- ***Night-setting*** (Fact-sheet 5).

Further research

More trials are needed to evaluate the effects of blue-dyed squid on seabird bycatch and target fish catch. Fishermen are encouraged to voluntarily use dyed squid bait if they consider this will improve their catch.

Long-term studies are underway in Brazil preliminary results are promising and suggest reduced seabird bycatch with no effect on fish catch. Similar trials are required elsewhere to determine the effectiveness of blue-dyed squid in preventing bycatch in other seabird assemblages.

Compliance and implementation

Compliance monitoring and implementation of blue-dyed bait would be far easier if pre-dyed squid bait were commercially available. Until such time, blue-dyed bait is unlikely to be widely accepted as a mitigation measure.

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Pelagic Longline: Bait caster and line shooter

Some measures, used by fishermen to improve the economic or operational efficiency of fishing, are also considered effective measures to reduce seabird bycatch. Such measures may contribute to reducing seabird bycatch when used in combination with a suite of other measures, but lack efficacy when used in isolation. This Fact-sheet covers technical measures that, if used correctly, may add to the effectiveness of other mitigation measures, and if used inappropriately may render other measures ineffective.

What is a Bait Casting Machine?

A Bait Casting Machine (BCM) is a hydraulically operated device designed to deploy baited hooks during pelagic longline setting (prior to the development of BCMs, individual hooks were cast by hand). The original BCM – developed by Gyrocast Pty Ltd – improved fishing efficiency and, if used correctly, had the potential to reduce the risk of seabird bycatch. Gyrocast BCMs had a five second cycling time, variable power control, the ability to cast hooks up to 23 metres, directional control (i.e. able to switch between port and starboard) and a gimballed mount to compensate for vessel movement (Brothers *et al.*, 1999). These features help to reduce bait loss to birds and seabird bycatch by allowing fishermen to 'place' baited hooks under the protection of a streamer line, even in strong winds.

Gyrocast machines were highly engineered and were therefore expensive to manufacture. Despite this, uptake within the pelagic longline industry was good (Brothers *et al.*, 1999).

Figure 1. Bait-casting machine in action.

Before long cheaper alternative brands appeared on the market that were adopted by the industry. Unfortunately, these new machines only incorporated the labour saving features of BCMs and not the features that helped to reduce bycatch (they are mainly used to straighten branch lines to reduce tangling). They had no control over distance or direction hooks were cast and the arc of the cast resulted in interference with streamer lines, or baited hooks landing outside the protection of streamer lines.

Effectiveness at reducing seabird bycatch

In theory, BCMs improve fishing efficiency by:
- Reducing tangles in branchlines.
- Reducing bait loss by avoiding propeller turbulence.
- Reducing bait losses to seabirds by better positioning of hooks below streamer lines.

Trials of the early BCMs (Gyrocast), indicated that these machines substantially reduced bait loss to seabirds) provided bait was consistently landed beneath streamer lines (Brothers *et al.*, 1999a). As mentioned, later models of BCMs have not incorporated the key features necessary to reduce seabird bycatch, in particular distance control. Currently, there is inadequate data to quantify the effectiveness of the current version of these machines.

Best practice recommendation

The original Gyrocast machine showed great promise as an aid to reducing seabird bycatch, however, these devices are no longer in production. Current models of BCM are designed to improve fishing efficiency and should not be regarded as seabird bycatch mitigation measures.

Problems and solutions

The BCMs currently used lack control over casting power. Consequently, the arc of the cast can interfere with streamer lines and bait may be landed well beyond the location of the streamer line. The ability to adjust the distance and direction of cast are critical performance features of BCMs and should be built into future machines if they are to be regarded as contributing to the reduction of seabird bycatch.

Combinations of measures

If used to improve fishing efficiency, bait casters should be used with a suite of mitigation measures, including:
- ***Streamer lines*** (Fact-sheet 7)
- ***Line weighting*** (Fact-sheet 8).

Further research

No further research is considered necessary at this stage. As mentioned previously, the critical next step is to manufacture BCMs with variable power control and to ensure they are operated in such a way that baited hooks are consistently placed beneath the area of the water protected by the streamer line(s).

Compliance and implementation

BCMs are commonly used in high seas pelagic longline fisheries and are an integral part of the line setting process. Therefore, there is great potential for voluntary uptake in commercial fisheries. However, to be regarded as a mitigation measure best practice features have to be built into the design of future machines.

Line shooter in pelagic longline fisheries

What is a line shooter?

A line shooter is a hydraulically operated device designed to deploy the mainline at a speed faster than the vessel's forward motion, which removes tension from the longline. This allows the mainline to enter the water immediately astern of the vessel, rather than up to 30 m behind the vessel. It is possible that variation in tension on the mainline will affect the sink rates of baited hooks and therefore the risks to seabirds.

Effectiveness at reducing seabird bycatch

Trials to investigate the effect of line shooters on seabird mortality rates in pelagic longline fisheries are needed. With respect to sink rates, research in the Australian tuna fishery revealed that setting mainline loose with a line shooter resulted in slower sink rates of baited hooks in surface waters compared to baited hooks attached to mainline set without a line shooter (Robertson *et al*., in prep.). The most likely reason for this is that propeller turbulence slowed the sink rates of loose mainlines which, in turn, slowed the sink rates of baited hooks. Although tests against seabirds are required, this result suggests that mainline set loose with a line shooter is likely to increase (not decrease) the risk to seabirds during line setting operations. Regarding the actual fishing (soak) period, baited hooks attached to loose mainline settle deeper in the water column than hooks attached to mainline set without a line shooter, which may affect accessibility to diving seabird species. However, the evidence to date suggests the primary – if not all – interactions occur immediately after line setting when baited hooks are clearing surface waters. Until evidence to the contrary is produced it should not be considered that line shooters reduce exposure of baited hooks to seabirds.

Best practice recommendation

As outlined, there is some doubt regarding the status of line shooters as effective primary (or even secondary) mitigation measures. Therefore, line shooters should not be regarded as mitigation measures until they are proven effective.

Combinations of measures

Until proven otherwise, line shooters should not be regarded as an effective mitigation measure. If used to improve fishing efficiency, they should be used with a suite of mitigation measures, including:

- ***Streamer lines*** (Fact-sheets 1 and 7)
- ***Line weighting*** (Fact-sheets 2, 3 and 8)
- ***Night-setting*** (Fact-sheet 5).

Further research

Further research is needed to determine the relationship between mainline tension and hook sink rate under a range of sea states and other environmental conditions.

Compliance and implementation

Mitigation measures that can be integrated into the everyday operations of a vessel and convey definite advantages, in terms of fishing efficiency, will be relatively easy to implement. If there are real advantages in using a line shooter there is potential for voluntary adoption by fishermen. However, given that line shooters have the potential to slow the sink rate of bait it is unlikely that line shooters are effective in deterring seabirds during the period of line setting.

Thanks to Dr Graham Robertson (Australian Antarctic Division) for his contributions to the content of this Fact-sheet.

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Bycatch Mitigation **FACT-SHEET 12**

Practical information on seabird bycatch mitigation measures

Demersal and Pelagic Longline: Haul mitigation

Seabirds are attracted to longliners during hauling to feed on discards, offal and spent bait. Birds can easily become hooked, in the bill, foot or wing, as the line returns to the surface or swallow hooks left in discards or bait. These interactions are rarely lethal at the time but the injuries sustained could have serious implications for the long-term survival of the individuals concerned.

What measures prevent haul hooking?

The strategies used to prevent hooking during hauling are in principle similar to those used to prevent bycatch during line setting. They consist of a mixture of deterrent devices to keep birds away from hooks and discard management to make the hauling area less attractive.

Offal management

Birds are attracted to fishing vessels to feed on processing waste and discarded fish. Removing this source of food would greatly reduce the number of birds associating with fishing vessels. Until recently, most longliners were designed in such a way that offal discharge occurred adjacent to the hauling hatch. This resulted in large numbers of birds feeding amongst hooks that were being hauled aboard. Now, a minimum requirement in many fisheries is to position the scupper, through which waste is discharged, on the port side of the vessel (opposite to the hauling hatch). This helps to divert the birds' attention away from the area where hooks return to the surface.

Hauling efficiency

Branchline (snood) hauler

In pelagic longline fisheries, branchlines can be 40 m long. During hauling, each branchline is hauled individually on, or close to, the surface. At this time, birds will attempt to snatch retained bait. The use of a branchline hauler can speed up the hauling process making it more difficult for birds to catch bait.

Moon pool

A moon pool is a well in the hull of the ship through which longlines can be hauled, in the absence of foraging birds. Very few vessels are designed with moon pools and those that are, do not always use them.

Deterrent devices

Brickle Curtain

The 'Brickle Curtain' is a deterrent device that forms a protective barrier around the hauling hatch. It is composed of vertically hanging streamers supported by poles fixed to the railing above the hauling hatch (Figure 2). This measure is very effective at deterring birds from approaching the hauling hatch.

Water cannon/fire hose

Some vessels have experimented with water cannons or fire hoses to deter birds from approaching the hauling station. Using 30 kw electric centrifugal pump, Kiyota *et al*. (2001) experimented with various nozzle tips, flow stabilisers and angles of attack to determine the maximum range of the water jet. Under ideal

Figure 1. Birds can become hooked during hauling, often sustaining non-lethal, but detrimental injuries.

Figure 2. The Brickle Curtain.

conditions, the maximum distance attained was 60 m and considerably less in crosswinds. This falls considerably below the recommended aerial extent of a streamer line. Additionally, it was found that under contrary wind conditions, the jet could be blown back towards the ship soaking the fishermen on deck.

Further research

Although water cannons are not suitable to replace streamer lines in longline fisheries, due to insufficient range, there is possibly potential for use in trawl fisheries, where streamer lines are considerably shorter.

Research is required to identify standard specifications for a Brickle Curtain specifically for demersal and longline fisheries.

Effectiveness at reducing haul hooking

There is little data to suggest how effective individual measures are at preventing haul hooking. However, a combination of measures aimed at haul mitigation has been shown to potentially reduce bycatch in the CCAMLR Patagonian toothfish fishery. These include the use of a Brickle Curtain and offal discharge on the opposite side to the hauling hatch (CCAMLR Conservation Measure 25-02).

Best practice recommendation

The minimum standard for offal management is the requirement to discharge on the opposite side to the hauling hatch. Appropriate use of a Brickle Curtain, can also greatly reduce the number of birds hooked during hauling.

Potential problems and solutions

Brickle Curtain

In heavy weather, the vertically hanging streamers, often weighted at the bottom, can flick up and interfere with fishermen working at the hauling hatch.

Figure 3. Water cannons lack the range to effectively deter seabirds from feeding on baited hooks.

Compliance and implementation

Most fishermen do not regard haul hooking as a serious problem, birds are nearly always released alive and the long-term implications of injuries sustained are not considered. Measures such as strategic offal management, which can be inconvenient during operational processes, generally have low compliance. Even with strict regulations and 100% observer coverage to monitor these measures, 100% compliance is not easy to achieve. Greater awareness is needed among fishermen of the long-term implications for birds that are hooked on hauling, as even those released alive face reduced likelihood of long-term survival.

References

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