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Agenda item 9

Agreement on the Conservation of Albatrosses and Petrels

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Bycatch Mitigation Fact Sheets

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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.

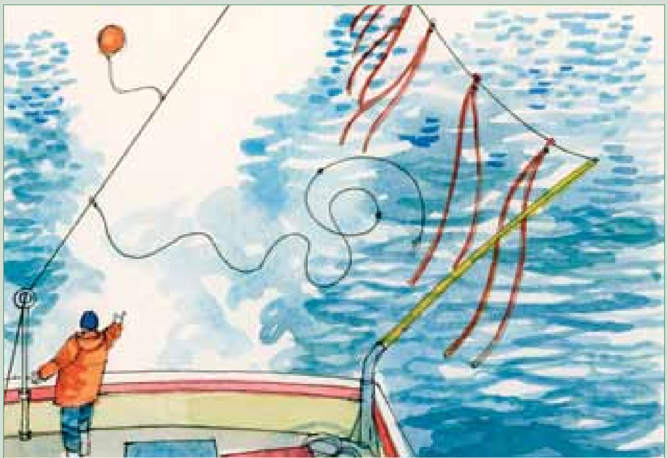

Figure 1. Streamer lines are an example of a cheap seabird bycatch mitigation measure, which can be used in combination with other measures to great effect.

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.

References

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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 1 (Version 1)

Practical information on seabird bycatch mitigation measures

Demersal Longline: Streamer lines

Streamer lines are the most commonly prescribed mitigation measures for longline fisheries and are regarded as one of the most effective known mitigation measures (a primary measure). Streamer lines are cheap, simple to use and do not require modification of the fishing gear.

What are streamer lines?

Streamer lines (also called tori or bird scaring lines) consist of lengths of rope with brightly coloured streamers towed behind longline vessels during line setting to deter seabirds from attacking baited hooks. Currently, the design most commonly recommended for demersal longline fisheries is that prescribed by the Commission for the Conservation of Antarctic Marine Living Resources (SC-CAMLR, 2006). The CCAMLR recommended streamer line configuration is described in detail later in this Fact-sheet, under Technical Specifications.

Effectiveness at reducing seabird bycatch

When deployed properly under suitable conditions, streamer lines can be very effective at reducing seabird mortality. For example, in the North Atlantic experimental trials showed a 98% reduction in seabird bycatch (Løkkeborg, 2003) when a streamer line was used. In Alaska, paired streamer lines have the potential to reduce seabird bycatch of surface feeding species, primarily northern fulmars and Laysan albatrosses, by 88–100% (Melvin *et al*., 2001). However, in this fishery shearwater bycatch rates remained unchanged, as their superior diving abilities allow them to target baits beyond the effective protection of the streamer lines.

Figure 1. Streamer lines deter seabirds from feeding on baited hooks.

Key to the effective use of a single streamer line, are the aerial extent achieved, the ability to adjust the line's position, the attachment height above sea level (>7 m), and the overall length (150 m). The spacing and length of streamers and type of materials used in the line's construction are also important considerations.

Streamer lines are more effective as a seabird deterrent when multiple lines are deployed. Reid *et al*. (2004) showed a significant decrease in seabird mortality when demersal longline vessels used multiple streamer lines. Two lines resulted in 75% reduction and three lines a 97% reduction in seabird mortality when compared with a single streamer line. Melvin *et al*. (2001) found strong statistical evidence for reduced seabird attacks on baits, resulting in lower bycatch rates, when paired streamer lines were used.

In several demersal longline fisheries, where the risk of seabird bycatch is high (Alaska, Heard Island and the French territories within CCAMLR), paired streamer lines are compulsory. Many biological and environmental factors influence the performance of a streamer line.

Seabird species

The number and species of seabirds associating with a fishing vessel are important considerations, as increased competition results in increasingly frenzied feeding activity. Under these conditions, birds are less likely to be distracted by streamer lines. Certain species of seabirds, particularly shearwaters, some petrels and albatrosses dive to considerable depths and can access hooks beyond the protection of a streamer line. Where diving species are numerous, experimental trials of streamer lines have been less convincing (Melvin *et al*., 2004). Although effective in isolation, streamer lines alone are not sufficient to eliminate bycatch; a combination of mitigation measures is required.

Environmental variables

Wind strength and direction in relation to vessel course, can deflect the streamer line away from its desired position over the hook line. If the hook line is exposed, a single streamer line becomes ineffective.

Best practice recommendation

The key factors affecting the performance of a streamer line are the degree of aerial extent and the position of streamers in relation to the hook line.

- The aerial section is the active part of the line, and acts as a 'scare-crow' keeping birds from reaching baited hooks. Aerial extent is achieved through a combination of attachment height above sea level, overall length of the line and the drag caused by a towed object. Greater aerial extent will contribute to improved protection of the hookline. In order to give hooks sufficient time to sink, the aerial section of a streamer line should extend at least 100 m past the stern of a vessel.

- To be effective, a single streamer line has to be placed directly above the hook line (or slightly to the windward side of the hookline). In order to achieve this in all weather conditions it must be possible to adjust the attachment position of the line.
- Paired or multiple streamer lines give better protection to the hook line in all weather conditions.
- The use of appropriate materials is an important consideration; if the line is too heavy it will sag under its own weight and not achieve the desired aerial extent, which is not only crucial to the line's function as a bird deterrent but also reduces the chances of entanglements with the fishing gear (Melvin, 2000).
- The Technical Specifications section of this Fact-sheet describes the recommended streamer line design.

Operational factors

Streamer lines should be deployed before the first hook enters the water and retrieved after the last hook has been set.

Deployment
- Casting the towed object to the port or starboard side of the vessel (depending which is the lee side) will allow the streamer line to drift astern of the vessel without interfering with the deployment of anchor lines.
- Once the streamer line has reached its full extent, its position should be adjusted to protect the area directly above the hooks as they sink astern of the vessel.

Retrieval
- Constructing the streamer line from lightweight materials allows a single man to easily recover the line at the end of setting. The drag produced by the towed object at the far end of the line is an important consideration. There is a trade-off between creating sufficient drag to achieve the desired aerial extent and creating too much drag, hampering retrieval.

Figure 2. Streamer lines should be deployed before the first hook leaves the vessel.

Potential problems and solutions

- There are instances when a streamer line becomes tangled with the hook line. This is a hindrance and potential danger to fishermen and usually results in the loss of the streamer line, which increases the risk of seabird bycatch. The key to reducing tangles is in the design; by achieving the required height above sea level, any aerial extent tangles should be minimal.
- In strong crosswinds, streamer lines can be blown away from the hook line, which increases the likelihood of seabird bycatch. The towed object is a critical feature of the streamer line design. It should maintain a steady course in strong crosswinds, create sufficient drag to achieve the desired aerial extent yet be easily retrievable. Many different towed objects have been tried (e.g. buoys, road cones, thick rope) but there is currently no definitive recommendation for the most efficient towed object.

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-sheets 2, 3 and 4)
- ***Night-setting*** (Fact-sheet 5)
- ***Offal management*** (Fact-sheet 12).

Further research

- The CCAMLR design of streamer line has been tested through deployment in CCAMLR fisheries for several years. However, there have been no empirical tests of its effectiveness compared with alternative configurations. Many variations on the CCAMLR design are in common use in commercial fisheries, but the details of these designs are mostly unrecorded. Key components requiring further testing are materials, towed object designs, and means of adjusting the position of the streamer line in relation to the hook line.
- Trials to investigate the relationship between streamer line extent, hook line sink rate, vessel speed, and the influence they have on seabird bycatch would help to refine the best practice recommendations.

Compliance and implementation

- The use of streamer lines is widely accepted as a seabird bycatch mitigation measure in many longline fisheries. Prior to the issuing of a licence, a vessels streamer line should be inspected to ensure it conforms to the regulation requirements.
- Without the deployment of onboard observers, the use of streamer lines at-sea is difficult to monitor.

Technical Specifications

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

- The streamer line should be a minimum of **150 m in total length**, be attached to the vessel at a point **>7 m above the sea surface** (using a pole if necessary) and **tow an object** at its seaward end, which creates drag and stability. These specifications are critical to achieve the desired **aerial extent (100 m)**, the active portion of the streamer line.
- Each branch streamer should consist of two or more strands and should be constructed from **brightly coloured, UV-protected rubber tubing**. Streamers should be spaced at **intervals of less than 5 m** along the streamer line backbone. Branch streamers should be long enough to reach the sea surface in calm conditions.
- Swivels positioned at the attachment point to the vessel, the towed object and where streamers join the backbone help to avoid twisting and wear. These can also incorporate breakaway points, in the event of snags with the hook line.
- A means of adjusting the position of the streamer line, such as a boom-and-bridle system, will increase the versatility of a streamer line and allow side-to-side movement to maintain protection of the hook line in crosswinds.
- Streamer lines should be deployed in pairs, one on each side of the hook line, during line setting.
- Swivels or other attachment devices to attach branch streamers to the streamer line are recommended as they reduce the branch streamers tangling around the streamer line. However, they do add weight to the streamer line.
- A spare streamer line should be carried onboard the vessel to be deployed in the event of lost or broken streamer lines.

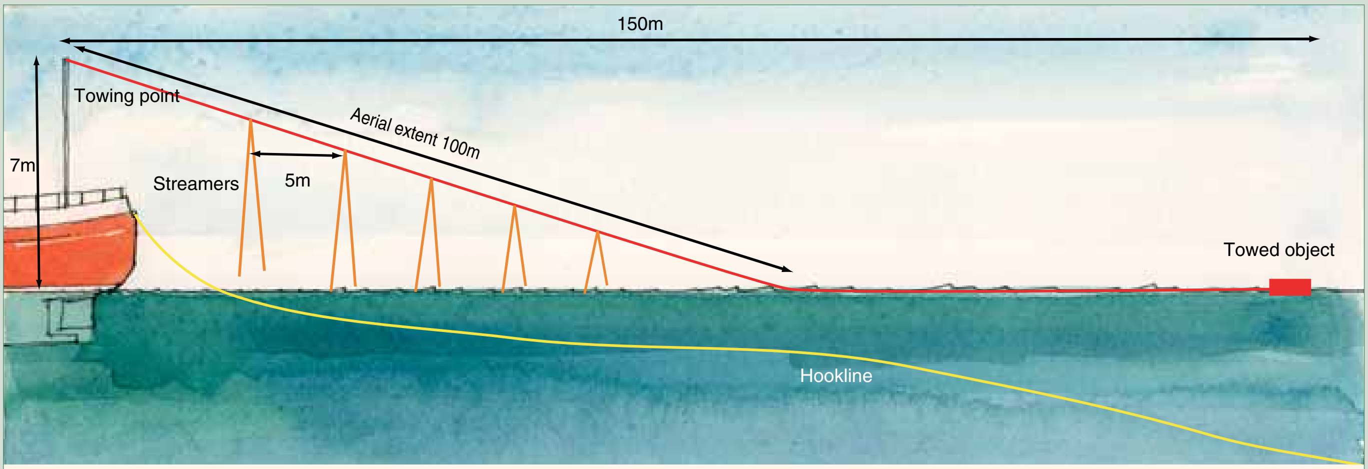

Figure 3. Recommended streamer line configuration.

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Bycatch Mitigation FACT-SHEET 2 (Version 1)

Practical information on seabird bycatch mitigation measures

Demersal Longline: Line weighting – external weights

Seabirds are vulnerable to mortality during the short period between hooks leaving the vessel and sinking beyond the bird's diving range. Line weighting is an essential component of seabird bycatch mitigation strategies, being one of the more effective known mitigation measures (a primary measure). Best practice weighting regimes should result in rapid initial line sink rates that will reduce the likelihood of seabird bycatch.

What is external line weighting?

In demersal longline fisheries, lines are weighted in order to deliver hooks to the target fishing depth as efficiently as possible and maintain the line on the seabed. Demersal longline gear can be configured in various ways, each with different weighting requirements. The methods discussed here rely on fishermen attaching individual external weights to the line as it is deployed.

The Autoline System

Autoline gear consists of a single line with baited hooks attached at regular intervals. The gear is highly automated and was designed for use without additional external weights, which makes any addition problematic. Further information concerning weighting strategies on autoliners can be found in Fact-sheet 3.

The Spanish System

This system is commonly used to target Patagonian toothfish. The gear consists of two, 'mother' and 'father', lines joined in parallel. The 'mother' line is usually thick (18 mm) polypropylene rope, which takes the weight during hauling. The hooks and weights are attached to the lighter 'father' line, which is joined to the 'mother' line by branch lines in a ladder-like arrangement (Figure 1). It is relatively easy to attach weights at regular intervals as the line is prepared for setting. The mass, density and distance between weights affect the line sink rate. Traditionally, demersal longlines have used stone cobbles encased in net bags as weights.

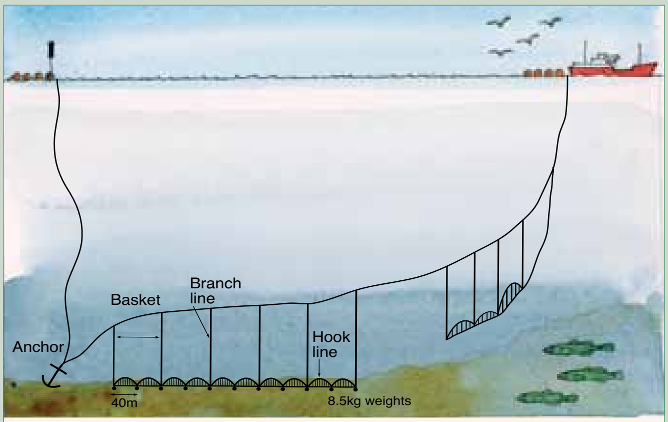

Figure 1. The Spanish System longline configuration.

Semi-pelagic

Semi-pelagic gear is designed to target species that travel from the seabed into the water column on a daily basis, such as hake. The lines are configured in such a way that hooks are suspended above the seabed. This is achieved by attaching a sequence of weights and floats to the hook line. Sink rates on these lines are highly variable, with hooks positioned near floats remaining accessible to seabirds for prolonged periods.

Effectiveness at reducing seabird mortality

Seabird bycatch experiments

Agnew *et al*. (2000) conducted controlled experimental trials on a longline vessel deploying Spanish System gear. These experiments took place in the summer months, near breeding colonies and sets were made during daylight hours, representing the worst-case scenario for seabird bycatch. Despite 4.25 kg weights placed every 40 m and the use of a streamer line to CCAMLR specifications, very high levels of bycatch were recorded (4.5 birds/1,000 hooks). Doubling the weight to 8.5 kg saw a significant reduction in bycatch (0.9 birds/1,000 hooks), although this is still unacceptably high. Additional weight did not result in further bycatch reduction. CCAMLR line weighting requirements in Conservation Measure 25-02 (8.5 kg per 40 m or 6 kg every 20 m) are based on the results of this experiment.

Sink rate experiments

In order to avoid the unnecessary capture of seabirds and allow robust statistical analysis, some experimental trials have used line sink rate to evaluate the potential for reducing seabird bycatch. Sink rate experiments use electronic time depth recorders (TDRs) or bottle tests to calculate sink rates under a range of weighting regimes.

Robertson (2000) experimented with various line weighting regimes on Spanish System gear. The results showed that to achieve a steady sink rate, weight spacing, as well as mass, is an important factor. Recorded sink rates were used to calculate the time taken for hooks to sink to specific depths. Combining this information with vessel speed allows the distance astern of the vessel at which specified depths are reached to be determined. Robertson concluded that a sink rate >0.3 m/s was desirable.

Semi-pelagic longlines

Petersen *et al.* (2005) experimented with semi-pelagic longlines targeting hake in South Africa. In line with the results of Agnew *et al.* (2000), they found a threshold above which adding further weight had little affect on sink rates. They recommend reducing the distance between weights to achieve a faster, more even sink rate. However, this is likely to affect the performance of the gear resulting in lower catch of target species and higher fish bycatch. In semi-pelagic lines, seabirds are far more likely to be caught on hooks positioned near floats than elsewhere. Seco Pon *et al*. (2007) found over 93% of all birds killed were caught within 30 m of a float.

Both the mass of weights applied to lines, and the spacing between weights, are equally important. To achieve a uniform sink rate, weight should be evenly distributed along the entire line. A number of other factors influence the line sink rate, including:

Hydrodynamics

The drag created by the fishing line and the weights themselves retard the speed at which lines sink. Research by Robertson *et al.* (2007) indicates that netted stone weights are far less efficient than torpedo shaped metal weights. Due to better hydrodynamics, the same sink rate can be achieved with lighter metal weights (a 5 kg metal weight is equivalent to a 8.5 kg stone weight).

Operational

Longlines are usually deployed into the propeller wash at the stern of the vessel. The turbulent upwelling created by this wash reduces the initial sink rate. Tension on the line, caused by hook fouling or improper deployment of weights, reduces the sink rate.

Environmental

In rough seas, heavy swell can maintain the line close to the surface and expose it in the troughs between waves. The pitching of a vessel increases tension in the line and can bring hooks back to the surface.

Buoying effect of caught birds

Seabirds are often caught in clusters, several birds over a short distance. Once a bird is caught, it acts as a buoy exposing adjacent hooks to foraging birds. Along with reducing the probability of catching birds, good weighting regimes limit the time hooked birds are on the surface and reduce the likelihood of multiple hook ups.

Best practice recommendation

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 standard streamer line, without compromising catch rates. Specifying a desired sink rate should be an integral part of any performance standard. It is currently recognised that a sink rate of 0.3 m/s is desirable (Robertson, 2000). To achieve this, the prescribed weighting regime will depend on the type and configuration of gear used. CCAMLR specify two line weighting options, 8.5 kg at 40 m intervals or 6 kg weights at 20 m intervals. following the aforementioned trials by Robertson *et al.* (2007). CCAMLR subsequently adopted a third line weighting option of 5 kg metal weights spaced at 40 m intervals. Achieving a desired sink rate is not just a matter of adding sufficient weight to a line. The way in which gear is handled and deployed influences the sink rate.

Line tension

- During setting, external weights should be pushed from the setting table to avoid tension in the line.
- Lining hook boxes with metal reduces the likelihood of hooks snagging and results in less tension in the line.

Line lofting

When the distance between weights is too great, the hook line tends to loft immediately before the deployment of a weight. This leaves hooks vulnerable to seabird attack. Reducing the distance between weights reduces this problem and leads to a more even sink rate.

With **semi-pelagic gear**, hooks positioned near floats have a lower sink rate than those elsewhere on the line and are responsible for nearly all the seabird bycatch. Removing hooks adjacent to floats or increasing the length of the line connecting the float to the hook line would help to reduce seabird mortality in these fisheries.

Problems and solutions

- Traditional netted stone weights or concrete blocks are notoriously variable in weight. Cast metal weights would give a far greater consistency in the distribution of weight along the line. Additionally, streamlined metal weights achieve a faster sink rate than stone weights of the same mass.
- Adding weight to longlines does slightly increase the workload for the crew and can potentially increase the strain on hauling gear and the risk of line breakages. The adoption of lighter metal weights would help lessen these concerns.

Figure 2. Pushing weights from the setting table and using metal lined boxes helps to reduce tension and improve line sink rate.

Combinations of measures

Adequate line weighting is critical to the prevention of seabird bycatch in demersal longline fisheries. However, to be effective line weighting must be used in combination with other measures, including:
- ***Streamer lines*** (Fact-sheet 1)
- ***Night-setting*** (Fact-sheet 5).

Further research

There has been considerable research to determine the influence of line weighting on sink rates and seabird bycatch. Where line-weighting regimes of 8.5 kg per 40 m are applied, along with a suite of other measures, seabird bycatch is consistently low.

The inter-relationship between line weighting, vessel speed and streamer line extent should be further investigated in order to refine the best practice recommendations.

Compliance and implementation

In fisheries where specific weighting regimes are stated in the regulations, vessels should be inspected prior to the issuing of licences to ensure weights and gear onboard meet required standards.

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Demersal Longline: Integrated weight longlines

Line weighting is an essential component of seabird bycatch mitigation strategies, being one of the most effective known mitigation measures (a primary measure). Best practice weighting regimes should result in rapid initial line sink rates that will reduce the likelihood of seabird bycatch. Integrated weight lines with lead beads in the core were developed to address this problem.

What are integrated weight longlines?

Seabirds are vulnerable to mortality during the short period between hooks leaving the vessel and sinking beyond the bird's diving range. In demersal longline fisheries, lines are weighted in order to deliver hooks to the target fishing depth as efficiently as possible and maintain the line on the seabed.

Autoline gear consists of a single line with baited hooks attached at regular intervals (Figure 1). On autoliners, the addition of external weights at regular intervals is problematic. Prior to the development of integrated weight lines, fishermen using the Autoline System generally applied less external weight than was necessary to achieve the high initial sink rate needed to minimise bycatch. Integrated weight lines were developed to improve sink rates in autoline gear. The weight is distributed evenly throughout the line, which results in a uniform linear sink rate from the sea surface.

Effectiveness at reducing seabird mortality

To avoid catching seabirds and allow robust statistical analysis, experimental trials have used the sink rate of lines under different weighting regimes to evaluate the potential for reducing seabird bycatch.

Early sink rate experiments

- Smith (2001) examined the sink rate of autolines under varying weighting regimes and found that adding external weight at large intervals (every 400 m) made no difference to the overall sink rate of the line.
- Robertson (2000) experimented with various external line weighting regimes on autoline gear. The results highlight the importance of weight spacing to achieving a steady sink rate After examining several alternative regimes, Robertson concluded that a sink rate >0.3 m/s was desirable to minimise the exposure of the line to seabird strikes across a variety of setting speeds and weighting regimes.

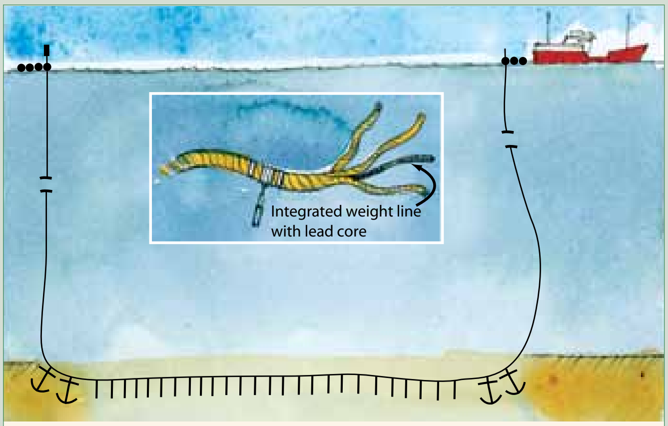

Figure 1. Autoline gear configuration.

Integrated weight experiments

- Trials in New Zealand found that the sink rates of lines with integrated lead beads (50 g/m) were similar to unweighted lines with 6 kg external weights every 42 m. Of particular importance to seabird bycatch is the initial sink rate – unweighted lines may float on or near the surface, held up by propeller turbulence, for up to 80 m astern. Integrated weight lines commenced sinking almost instantly and maintained a steady linear sink profile. These properties are reflected in the recorded sink rates of each line type: integrated lines averaged 0.2 m/s to 2 m depth and 0.24 m/s to 20 m, compared to unweighted lines, which lofted in propeller turbulence for >20 seconds before sinking and averaged only 0.11 m/s to 20 m depth (Figure 2).
- Improvements in the initial sink rate and sink rates to 20 m depth translated into a 95% and 60% reduction in white-chinned petrel mortality and sooty shearwater mortality, respectively (Robertson *et al*., 2006) in the New Zealand ling fishery when using integrated weight lines.
- Integrated weight lines have also proven effective in reducing seabird bycatch in northern hemisphere fisheries (see Dietrich *et al*., 2008), thus demonstrating the extensive applicability of the method. This study also demonstrated that integrated weight lines, when used in combination with paired streamer lines, very nearly eliminated seabird bycatch in the fishery in which it was undertaken.

In addition to the amount of weight applied to longlines, several other factors influence the sink rate of autoline gear:

Weight spacing

The mass of weight added to lines is clearly an important consideration but spacing between weights is equally important. To achieve a uniform sink rate, weight should be evenly distributed along the entire line. Integrated weights minimise line lofting in propeller turbulence resulting in a linear sink profile.

Environmental

In rough seas, heavy swell can maintain the line close to the surface and expose it in the troughs between waves. The pitching of a vessel in rough seas reduces the sink rate and can bring hooks back to the surface.

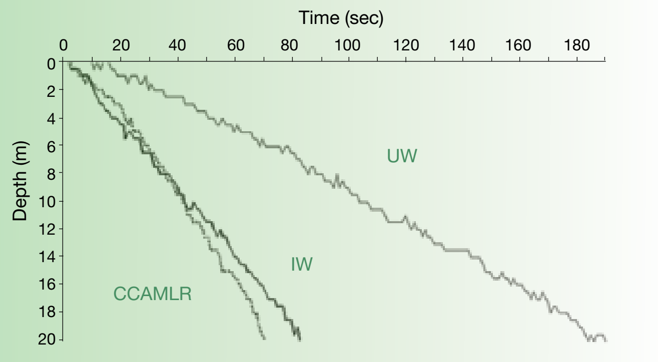

Figure 2. Sink rate profiles for integrated lines (IW) and unweighted lines (UW) adapted from Robertson *et al.* (2006).

Buoying effect of caught birds

Seabirds are often caught in clusters of several birds in quick succession. Once a bird is caught, it acts as a buoy exposing adjacent hooks to foraging birds. Good weighting regimes limit the time hooked birds are on the surface and reduce the likelihood of multiple captures.

Best practice recommendation

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 standard streamer line, without compromising fish catch rates.

Setting a desired sink rate should be an integral part of any performance standard. For autoliners, integrated weight gear (50 g/m) achieves a sink rate of around 0.24 m/s to 20 m, which has proved to reduce the bycatch rates of white-chinned petrels and sooty shearwaters by over 90% and 60%, respectively, in the New Zealand ling fishery. Externally weighted autolines require 6 kg weights attached every 42 m to achieve a comparable sink rate to 50 g/m integrated weighted line (Robertson *et al.,* 2006).

The recent innovation of integrated weight autolines require no modification of fishing practices and may actually increase the efficiency of fishing operations. The adoption of integrated weight lines with a minimum of 50 g of lead beading per metre is recommended.

Properties of integrated weight lines

There are certain operational advantages and disadvantages associated with using integrated weight gear (Robertson *et al.* 2006).

- Integrated weight lines are about 10% weaker than conventional lines of the same thickness, which could lead to more gear losses. However, age of gear was shown to be the most important factor influencing breaking strengths (Dietrich *et al*., 2008) and in fisheries where integrated weight gear has been routinely used, gear loss does not appear to be a serious problem.
- Length for length, integrated lines weigh 70% more than conventional lines.
- In 2006, integrated weight lines cost 14–23% more than conventional lines.
- Experienced fishermen indicate that integrated weight line is easier to coil and passes smoothly through hauling and setting gear reducing the incidence of line tangles.
- Superior handling properties and the lack of external weights reduce labour.
- Early indications suggest that there may be some benefits in terms of fish catch but more research is needed. Catch is likely to depend on the foraging behaviour of the target fish species.

Combinations of measures

Like many mitigation measures, it is not sufficient to rely solely on line weighting to manage seabird bycatch. Line weighting is one of the most important primary mitigation measures but to be effective must be used in combination with:

- ***Streamer lines*** (Fact-sheet 1)
- ***Night-setting*** (Fact-sheet 5).

Further research

- In some instances, there are indications that the target fish catch may be improved when integrated weight longlines are used (Robertson *et al.,* 2006). Trials should be extended to cover other demersal longline fisheries to establish whether this relationship is consistent across a range of fisheries.
- The time available for hooks to sink before they become exposed to foraging seabirds is a function of line sink rate, streamer line extent and vessel speed. Vessel speed is an important factor yet is not considered in current fishery regulations. Further research is needed to investigate the inter-relationship between these factors.
- The potential for incorporating integrated weight lines into other demersal longline gear types (such as the Spanish System) should be investigated.

Compliance and implementation

- Where fishing regulations require vessels to achieve a specified sink rate, integrated weight lines provide an efficient means of meeting these targets. With the potential for improved target fish catch, there is the possibility of voluntary uptake of integrated weight lines.
- Once integrated weight lines are installed on a vessel, they form an integral part of the fishing gear and therefore the need for further compliance monitoring is minimal.
- Line sink rate testing using bottle tests or Time-Depth-Recorder deployment is used in some fisheries to ensure that each vessel has a specific strategy regarding setting speed, streamer line coverage and line weighting to ensure adequate protection of the line from seabird strikes.

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 4 (Version 1)

Practical information on seabird bycatch mitigation measures

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Demersal Longline: Line weighting – Chilean System

Seabirds are vulnerable to mortality on longline hooks during the short period between hooks leaving the vessel and sinking beyond the bird's diving range. The Chilean System was developed primarily to combat the problem of depredation by cetaceans, however, the configuration of the gear leads to very high initial hook sink rates, which results in near zero seabird bycatch rates.

What is the Chilean System?

In commercial demersal longline fisheries, lines are weighted in order to deliver hooks to the target fishing depth as efficiently as possible and maintain the line on the seabed. The Chilean System was developed to combat the problem of depredation of fish by cetaceans (Moreno *et al*., 2007). The system uses a configuration borrowed from Chilean artisanal fisheries. It consists of a single main line with secondary branch lines attached every 40 m. Each branchline is around 15 m long and has a weight (ranging from 4–10 kg) attached to the terminal end, hooks are attached directly to the branchline (Figure 1). The gear resembles that of the Spanish System minus the 'mother' line with hooks attached directly to branch lines, in clusters of up to ten.

The Chilean System differs from artisanal gear by the addition of a buoyant net funnel that shrouds fish during hauling, concealing them from predatory cetaceans.

Effectiveness at reducing seabird mortality

In terms of seabird bycatch mitigation, the extremely fast initial sink rate (0.8 m/s) is the critical factor. Hooks are attached close to weights, once deployed they literally sink like a stone until the branchline becomes taut, at a depth of 15 m. Once the branch line is taut the sink rate slows due to the buoyant effect of the mainline (Figure 2). Hooks sink out of sight within the propeller wash and do not attract foraging attempts from seabirds.

The Chilean System has been trialled in the Patagonian toothfish fishery in Southern Chile. When compared with unmodified demersal longline gear, the Chilean System performs extremely well. Baseline data suggest, prior to the introduction of mitigation measures, 1,555 birds were killed each year (98% albatrosses) in Chilean fisheries. The use of streamer lines and other mitigation measures reduced this figure to 448 birds per year (100% albatrosses). Following the introduction of the Chilean System observers recorded zero seabird bycatch; with over 39% of hooks observed (Moreno *et al.,* 2007).

Effectiveness at reducing depredation by cetaceans

Associations between cetaceans (e.g. sperm and killer whales) and longline vessels have been recorded in longline fisheries around the world. The relationship is complex and difficult to quantify. Although the highest numbers of associating cetaceans can coincide with very high catch rates, it is generally accepted that the presence of toothed whales has a negative impact on fish catch. Several mitigation measures have been tried with little success, these include; acoustic harassment devices, magnets attached to fishing lines, turning off acoustic equipment, retaining offal and leaving an area when whales are present (Purves *et al.,* 2004). The driving force behind the development of the Chilean System was depredation by cetaceans. Trials indicate that this system successfully deters whales from taking fish from the lines.

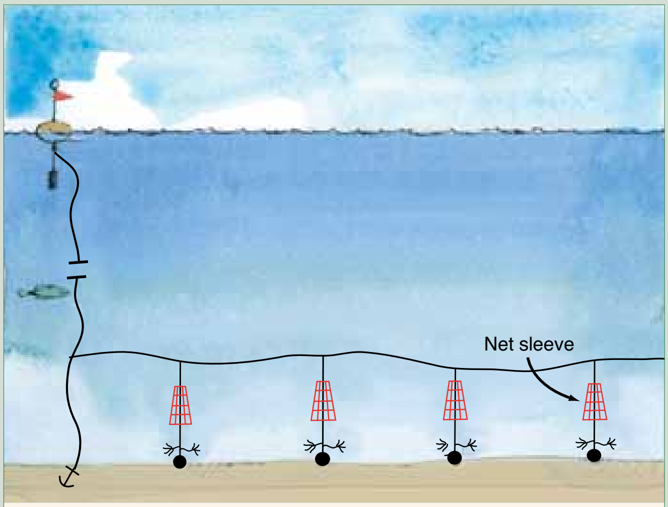

Figure 1. The configuration of Chilean System gear.

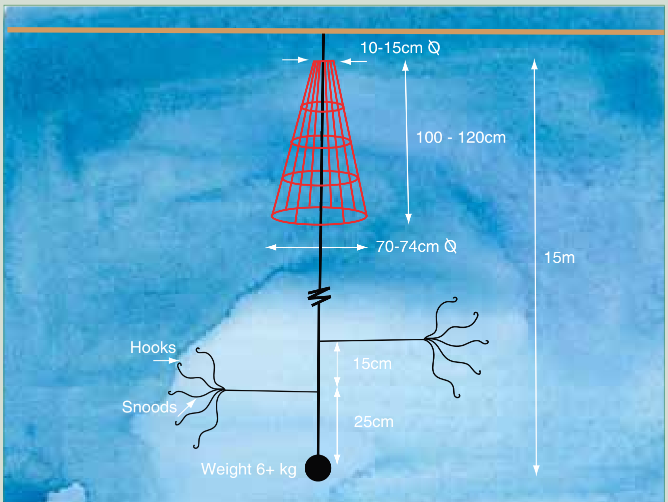

Figure 2. Branch line configuration.

Best practice recommendation

At present, the Chilean System has shown great potential as a deterrent to cetacean depredation of target catch and as a means of seabird bycatch mitigation.

- The mass of weights used is highly variable, ranging from 4–10 kg, Moreno *et al.* (2007) report an average initial sink rate of 0.8 m/s. Although this far exceeds the sink rate reported for other demersal longline configurations, the relationship between weight mass, weight type and sink rate should be investigated to determine the minimum weight requirement.
- An unrelated consequence of the gear modifications to combat cetacean depredation is a very high initial sink rate of hooks during setting, which ensures zero, or close to zero, seabird bycatch.
- Most mitigation measures require minor modifications to fishing gear or practices, the Chilean System requires a considerable restructuring of the fishing gear. Once adopted, the mitigating effect of the gear is integral to the day-to-day fishing operations.

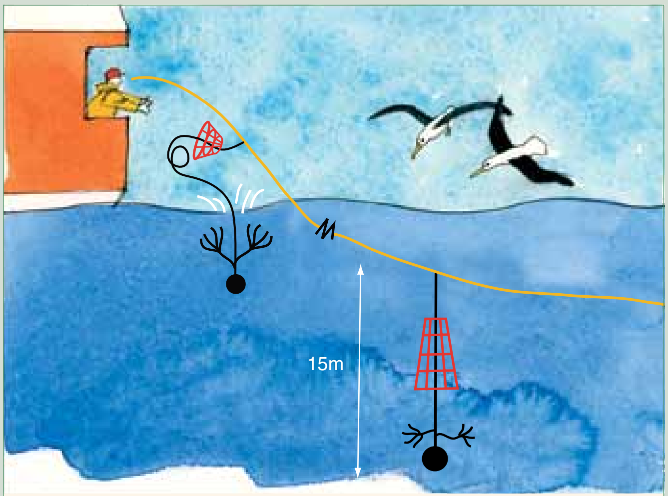

Figure 3. The rapid initial sink rate means seabirds are unable to access baited hooks.

Potential problems and solutions

- The configuration of the Chilean System more than halves the number of hooks set per metre of main line, although the simplicity of the Chilean System may allow a greater length of longline to be hauled per day. Under certain circumstances, when catches are good, this may reduce the number of fish caught. The distance between branchlines could be reduced to increase the number of hooks set but this is likely to result in more tangles between branchlines.
- Over time, cetaceans could become habituated to the net shrouds and resume fish depredation. Continued monitoring is required to observe the interactions between the Chilean System gear and cetaceans.
- A consequence of cetacean depredation is the unknown number of fish caught that are removed by whales before they reach the surface. Sometimes remains are left on the hook but the majority are likely to leave no trace. This unknown loss could have implications for fish stock assessment. Reducing the level of depredation will assist in the management of many fisheries.

Combinations of measures

Initial trials indicate that the Chilean System alone is sufficient to eliminate seabird bycatch. If this proves to be the case, there is no need to use the Chilean System in combination with other mitigation measures.

Further research

The ability of the Chilean System to eliminate seabird bycatch is a by-product of efforts to prevent depredation by cetaceans. Trials are needed in other fisheries where depredation by cetaceans is regarded as a problem.

Long-term studies are needed to ensure the Chilean System continues to deter cetaceans.

Compliance and implementation

The potential of the Chilean System to reduce cetacean depredation is likely to lead to high levels of voluntary uptake. The adoption of the Chilean System throughout Chile's toothfish longline fleet was largely down to word of mouth. Fishermen from comparable fisheries in the South Atlantic are already trialling the system.

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Bycatch Mitigation FACT-SHEET 5 (Version 1)

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.

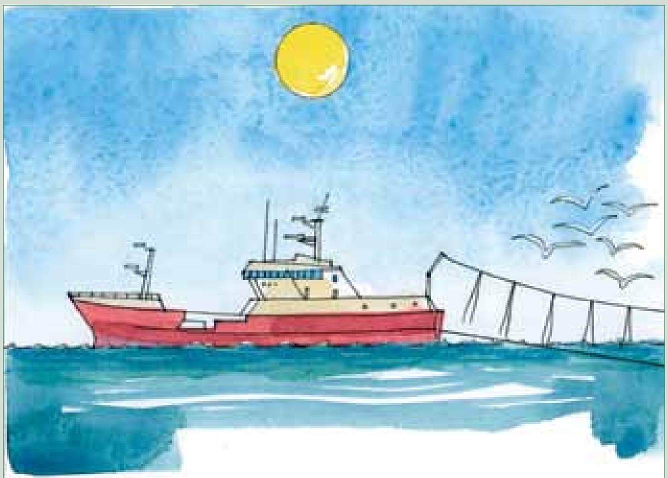

Figure 2. Seabirds, and albatrosses in particular, are more active during the day.

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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Bycatch Mitigation **FACT-SHEET 6** (Version 1)

Practical information on seabird bycatch mitigation measures

Demersal Longline: Underwater setting chute

Seabirds are at greatest risk of becoming hooked and drowned when baited hooks are at, or within a few metres of, the surface. In theory, setting hooks below the surface of the water should greatly reduce the likelihood of catching seabirds. It should be noted that this is currently a secondary measure, as underwater setting cannot be used in isolation to reduce seabird bycatch.

What is underwater setting?

Underwater setting is a means of deploying hooks below the sea's surface and therefore out of the reach and sight of foraging seabirds. This has traditionally been achieved by setting through a tube (termed a 'chute' in demersal fisheries) attached to the stern of the vessel that opens 1–2 metres below the surface. These setting chutes have been developed for use with the single line Autoline system and are commercially produced by Mustad and Sons, a Norwegian gear manufacturer (www.mustad-autoline.com/produkter/deepsea/settingtube_eng.php). Despite some experimentation, underwater setting chutes have not been successfully developed for the Spanish (double line) system.

Effectiveness at reducing seabird mortality

The Mustad chute was developed to improve fishing efficiency in the North Atlantic by reducing the number of baits taken by foraging seabirds. The potential to reduce seabird bycatch rates is of greater relevance to demersal fisheries elsewhere.

- Trials in Norway have shown that the use of a setting chute significantly reduces bycatch of Northern Fulmars when compared with standard fishing practices (from 1.75 to 0.49 birds per 1,000 hooks, Løkkeborg, 1998). Although this is a large reduction, the use of streamer lines in the same trial caught significantly less birds (0.04 birds per 1,000 hooks).
- Melvin *et al*., (2001) conducted experimental tests in the Alaskan demersal cod fishery and found bycatch was reduced by 79% compared with a control of no mitigation measures. Like Norway, most of the Alaskan bycatch was Northern Fulmars; a surface feeding species.
- Extensive trials in the Patagonian toothfish fishery around Prince Edward Islands, Southern Ocean, produced encouraging results in the presence of albatrosses and petrels. When used with a suite of other mitigation measures, the addition of a setting chute reduced bycatch threefold. Bycatch rates recorded during day-time sets with the chute were lower than night-time sets without the chute. However, bycatch was not completely eliminated (Ryan and Watkins, 2002). Like many mitigation measures, environmental and operational factors influence the effectiveness of setting chutes.

Environmental

In heavy seas, the pitching of a vessel can raise the end of the chute clear of the water's surface, making it less effective.

Operational

- The trim of the vessel affects the depth of the chute opening. As a trip progresses, bait are typically removed from the hold at the stern of the vessel and catch is added to the forward and middle holds, while fuel loads are reduced. Thus, the stern of the vessel is raised, decreasing the depth of the chute opening.
- Setting chutes are positioned in such a way that baited hooks emerge into the turbulence created by the propeller wash, which retards the line sink rate and can take baited hooks back

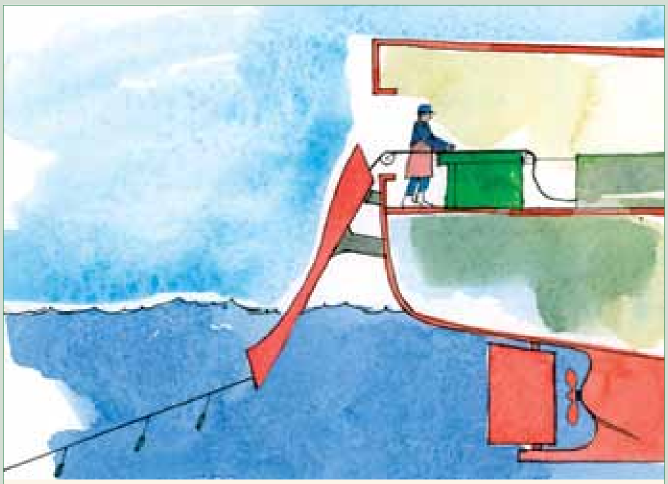

Figure 1. The setting chute in use.

Figure 2. In rough weather, the setting chute becomes less effective.

to the surface. Melvin *et al*. (2001) report that hooks deployed 1 m below the surface would appear at the surface 40–60 m astern of the vessel, probably due to propeller turbulence.
- Considerable time, possibly an entire fishing season, is needed for crew to become accustomed to using a setting chute. This may have implications for the results of experimental trials.
- Melvin *et al*. (2001) estimate that in 10% of setting operations the line jumps out of the slot, that runs down the length of the chute, rendering the chute useless.

Best practice recommendation

The current setting chute design appears to have limited potential to reduce seabird bycatch rates to acceptable levels when used in isolation (a secondary measure). However, when used in combination with a suite of other measures, setting chutes could play an important role in reducing seabird bycatch. In particular, further trials are required to determine whether the use of a setting chute could allow daytime setting in high latitude fisheries without increasing the risk of seabird bycatch. Daytime setting would result in greater fishing efficiency where the hours of darkness are limited.

Problems and solutions

Despite some encouraging trials, for several reasons setting chutes are not widely used in commercial fisheries.
- The chute purchase and installation costs are considerable (approximately US$20,000).
- Bait loss and wear on fishing lines due to abrasion can be high, resulting in significant costs.
- The chute is an add-on attachment to the vessel and is exposed to considerable stresses and strains. Manufacturing a device that can cope with prolonged use in all weather conditions is challenging.
- Despite some trials, a satisfactory design for use with the Spanish (double line) System (see Fact-sheet 2 for more details) has yet to be devised.

Combinations of measures

As a secondary mitigation measure, setting chutes should always be used in combination with other mitigation measures. Underwater setting is most effective when used in combination with:
- ***Streamer lines*** (Fact-sheet 1)
- ***Integrated weight longlines*** (Fact-sheet 3)
- ***Night-setting*** (Fact-sheet 5).

Future research

Intuitively, underwater setting has a part to play in seabird bycatch mitigation but there are certain technical issues that require further research.
- At best, current designs deliver hooks 1–2 metres below the surface, in heavy swell or under certain vessel trim the end of the chute may break the surface. Increasing the depth of the chute would improve its performance but also reduce its ability to resist mechanical stress.
- Previous trials of underwater setting chutes have used line-weighting regimes (for example 8–12 kg per 600 m in Ryan and Watkins, 2002) that have proved to be inadequate. The recent innovation of integrated weight lines have greatly improved line sink rates and are being adopted in demersal longline fisheries where seabird bycatch is a problem. The combined use of integrated weight lines and underwater setting chutes, to further reduce bycatch and may allow daytime setting, merits further investigation.
- The addition of an underwater setting chute on a vessel is retrospective and its location is determined by the pre-existing position of the setting hatch. This results in baited hooks emerging into the turbulence created by the propeller wash, which generally retards the line sink rate and can bring hooks back to the surface. To increase the effectiveness of underwater setting, chutes should be positioned to release hooks outside the influence of propeller wash. Alternatively, vessel architects should consider how to incorporate setting chutes into the fabric of the vessel.

Compliance and implementation

The considerable cost incurred to purchase and install an underwater setting chute makes it imperative that fishermen have a good incentive to use one. If the incentive is attractive enough, voluntary adoption may be a realistic proposition.

In the North Atlantic, bait loss to seabirds can be as high as 70% (Løkkeborg, 1998) and clearly there is an incentive for fishermen to reduce the amount of bait taken. Elsewhere, the major incentive to employ underwater setting chutes is the potential to allow daytime setting in high latitude fisheries.

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Bycatch Mitigation FACT-SHEET 7 (Version 1)

Practical information on seabird bycatch mitigation measures

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.

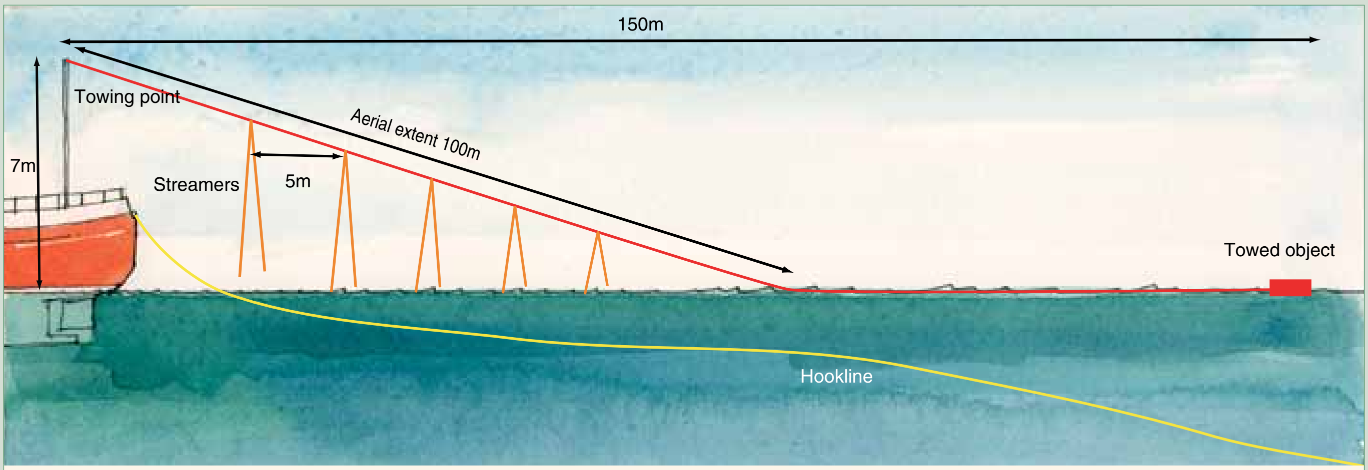

Figure 1. Streamer line prescribed by CCAMLR Conservation Measure 25-02 for demersal longline fisheries.

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.

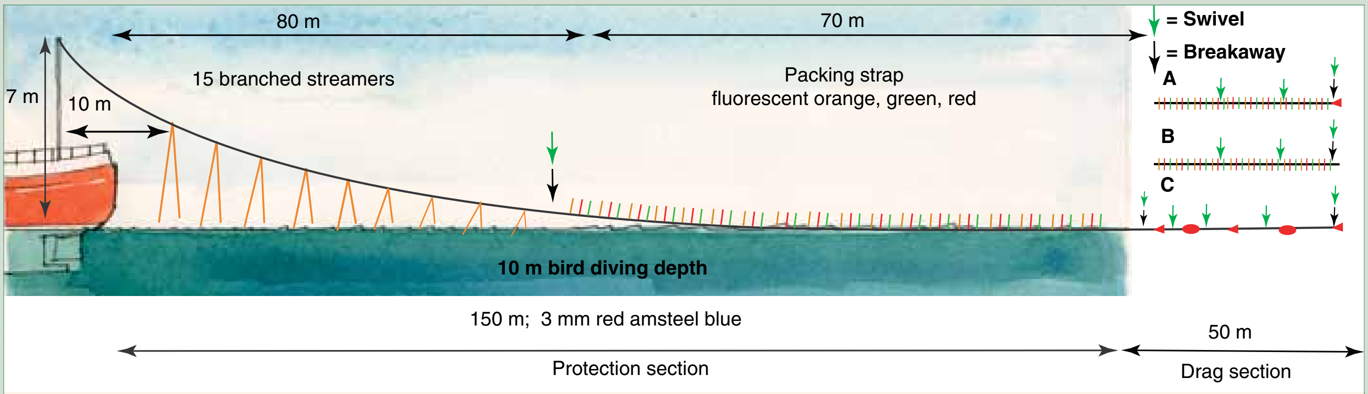

Figure 2. Proposed optimal streamer line for pelagic longline fisheries (design taken from Melvin *et al.*, 2009).

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** (Version 1)

Practical information on seabird bycatch mitigation measures

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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.

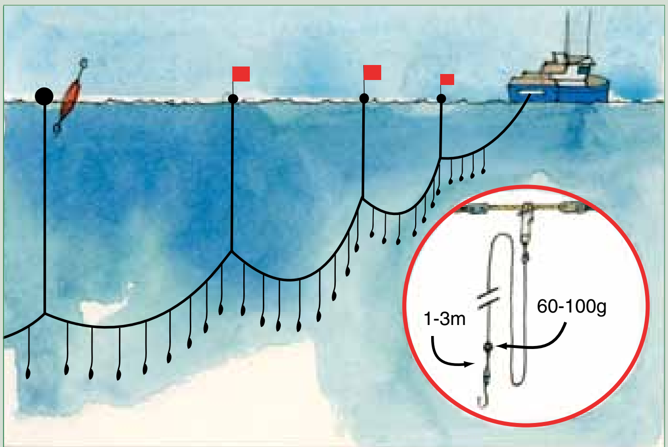

Figure 1. Pelagic longline gear configuration with line weighting. Note the distance between the weight and the hook.

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.

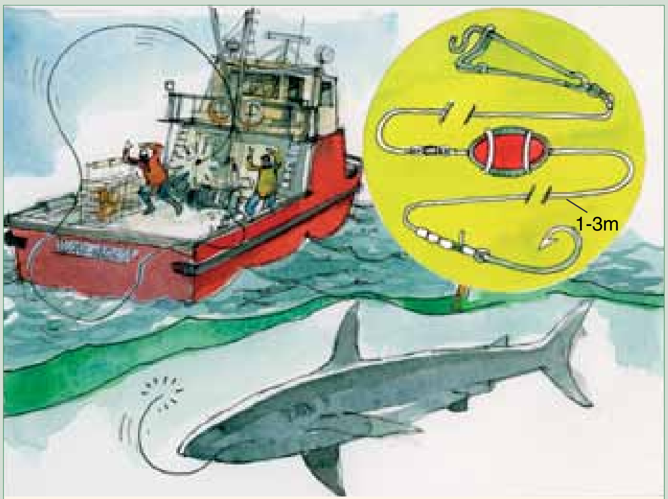

Figure 2. Fishermen can be injured by weights when the line suddenly breaks. Inset, shows the *Safe Lead*, a new weighting system being developed to reduce the risk of injury.

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 (Version 1)

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 (Version 1)

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.

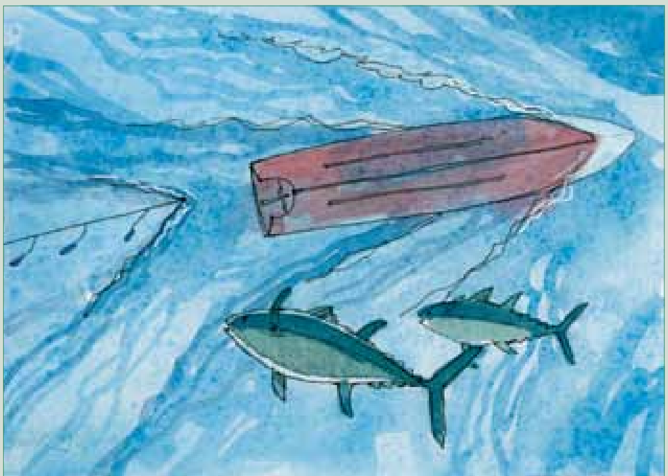

Figure 2. From below, dyed bait remains visible to target fish species.

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 (Version 1)

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.

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Bycatch Mitigation FACT-SHEET 13 (Version 1)

Practical information on seabird bycatch mitigation measures

Trawl Fisheries: Warp strike

In recent years, dedicated seabird observers on trawl vessels have identified significant bycatch problems. These fall into two categories, net entanglement (Fact-sheet 14) and collisions with cables, predominantly those used to tow the net (warp strikes), but also net monitoring equipment.

What is warp strike?

Warp strike occurs when birds collide with trawl warps, netsonde or paravane cables. If the warp hits the outstretched wing of a bird, the wing wraps around the cable and the drag created by the forward motion of the vessel and/or rough seas pulls the bird underwater, where it drowns. This is a cryptic form of mortality with the only obvious evidence coming from dead birds that are returned to the surface during hauling, after becoming snagged on splices. It is thought that many birds fall from the warps leaving no evidence of mortality. For many years, this source of mortality went unobserved. However, in recent years warp strike has been identified as a major problem in trawl fisheries that overlap with the distribution of albatrosses (Sullivan *et al.,* 2006a; Baird and Smith, 2007; Watkins *et al.*, 2008).

What causes warp strike?

Dedicated seabird observers in the Falkland Islands (Islas Malvinas), South Africa and New Zealand indicate that warp strike is only a problem when birds are attracted close to the vessel to feed on discards and offal discharge. In the absence of offal discharge, birds tend to stay outside the danger area, where cables enter the water, and near zero levels of mortality have been observed.

Species impacted

Many species of seabird have been observed colliding with warp cables but generally, it is the large, long-winged species of albatrosses and petrels that suffer from this type of mortality. These species tend to forage aggressively with outstretched wings. Smaller petrels, such as Cape petrels, are less likely to become wrapped around a warp cable following a collision.

Environmental variables

In calm conditions, the likelihood of warp strike is reduced. In heavy weather, the vessel pitches and rolls and consequently the warp cable cuts in and out of the water at considerable speed, increasing the probability of warp strike events.

Mitigation measures

Offal management

The long-term solution to the problem of warp strike is to reduce the attractiveness of vessels to foraging seabirds by managing the discharge of discards and offal. Several strategies have been proposed that have the potential to eliminate discharge while fishing; mealing waste, mincing waste, storage of waste onboard (for disposal when not fishing) and stowing frozen waste in the hold (Munro, 2005).

- In several fisheries around the world, vessels are already required to convert fish waste into fishmeal on board. However, in the majority of fisheries this is not the case and retro fitting vessels with meal plant is very expensive and often impractical.
- There is some evidence, from preliminary experimental trials, that mincing fish waste and discards before discharging reduces the number of *Diomedea* albatrosses associated with a trawler (Abrahams *et al.*, in press). However, this alone is not regarded as an effective mitigation measure.
- Storage of waste, for discharge at night and/or periods when not fishing, potentially requires large holding tanks (hoppers), which in turn often requires a significant vessel refit.
- Long-term storage of fishery waste can be achieved by freezing and stowing in the hold. Waste and discards can make up 60% of the catch; the freezer time and hold space required to store this quantity of waste will reduce the potential to process the target catch. An added consequence of the long-term storage of frozen waste is the need for more frequent transhipment.

Deterrent devices

As an interim solution to the problem, several seabird deterrent devices have been developed to prevent contact with fishing gear.

Warp cables

Measures designed to deter birds from feeding close to warp cables fall into three categories; streamer lines, bird bafflers and warp scarers.

- Streamer lines (also known as tori lines or bird scaring lines) deployed parallel to, and within two metres of the warp cable, deter birds from feeding in the area where warp cables enter the water (Figure 1 top).
- Bird Bafflers were developed in New Zealand and consist of four arms attached to the stern quarters of the vessel, two project aft directly over the warp cables and two to the sides of the vessel (Figure 1 bottom). Streamers are attached to these arms to form a protective curtain. These need to be rigid or re-enforced to maintain their coverage of the risk areas, and 'stayed' to avoid

tangling around themselves or the attachment booms. The arms can be stowed in a raised position, although the Baffler is designed to remain in the lowered (operational) position throughout a fishing trip.
- Warp scarers are designed to be attached directly to the warp cable (Figure 2), several different designs have been tested.

Netsonde cables
In the Alaskan pollock fishery, passing the netsonde cable through a 'snatch block' reduced the distance astern of the vessel that the cable enters the water.

Netsonde cables are now largely banned in southern hemisphere fisheries and trawl warps are the major cause of mortality.

Effectiveness at reducing seabird bycatch

The effectiveness of these devices has been tested by experimental trials in the Falkland Islands (Islas Malvinas) (Sullivan *et al.,* 2006b), New Zealand (Middleton and Abraham, 2006; Abraham *et al*., submitted) and Alaska (Melvin *et al*., 2004) all experiments produced similar results (discussed below).

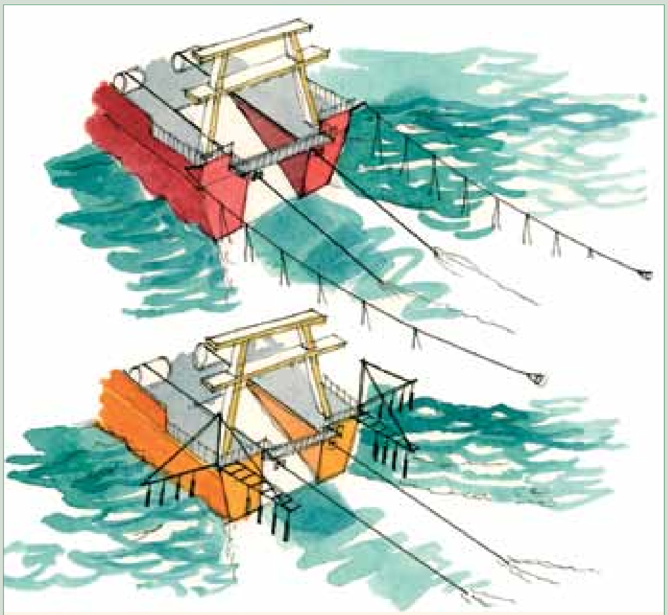

Figure 1. Streamer lines and the Brady Baffler.

Streamer lines

Experimental trials in the Falkland Islands (Islas Malvinas) and New Zealand found that streamer lines out performed the other mitigation measures on trial, bafflers and warp scarers. The introduction of streamer lines to commercial trawl fisheries has shown that they are practical and effective at reducing seabird bycatch. For example, following the introduction of streamer lines to the demersal finfish trawl fisheries of the Falkland Islands (Islas Malvinas), observed seabird mortality was reduced by 90% (Reid and Edwards, 2005), similar results have been found in the South African hake trawl fishery.

Streamer lines are by far the simplest, cheapest and the most effective mitigation measure currently available.

Bird Bafflers

Trials of the '***Brady Baffler***' indicate that the arms projecting to port and starboard prevent birds from flying down the sides of the vessel, where they feed on waste as it leaves the scuppers. However, the arms projecting aft, to protect the warp cables, are not long enough to give satisfactory protection to the warp/sea surface interface. Trials indicate that bafflers have limited capacity to reduce seabird bycatch on most vessels. The baffler may be more effective on vessels with lower trawl blocks, closer to the water's surface, or deep-water fisheries where the cables enter the water at a steep angle, close to the vessel.

A modification of the Brady Baffler design, known as the '***Burka***', incorporates a line of vertically hanging streamers between the two aft pointing arms of the baffler (Prendeville, 2007). This design was developed for use in deep water trawl fisheries, which were experiencing difficulties with streamer lines. In these fisheries, the warps enter the water at a steep angle, close to the stern of the vessel and may be effectively protected by this modified Baffler.

Warp scarers

Although they can be difficult and dangerous to deploy and retrieve, warp scarers generally work well in calm weather. However, in rough weather these devices often leave the warp cable unprotected as the vessel pitches and can become tangled around the warp cable. Most designs do not allow cable splices to pass freely and therefore potentially interfere with fishing operations. In an attempt to overcome these problems the '***Falkland Islands Warp Scarer***' was developed (Sullivan *et al*., 2005). Although it worked well, the device proved to be cumbersome to use and was regarded as impractical for use on commercial vessels.

Currently, two designs are in use, '***Carey's Cunning Contraption***' and the '***Road Cone***'. Carey's device consists of a series of streamers attached to the warp by karabiners. Trials in New Zealand found this design to be unsatisfactory (Middleton and Abraham, 2006). The Road Cone is hinged and is designed to be closed around the warp. Although the sample size is small, trials of the road cone device on small coastal vessels in Argentina reported an 89% reduction in contacts between birds and warp cables when compared with no mitigation measures (Gonzalez-Zavallos *et al*., 2006).

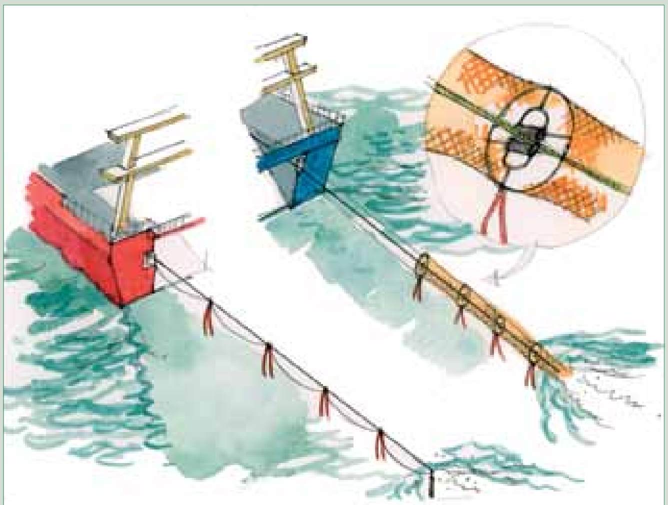

Figure 2. The Falkland Islands Warp Scarer and Carey's Cunning Contraption.

Netsonde cables

In Alaska, observations showed that the use of a snatch block reduced the number of collisions between seabirds and the cable (Melvin *et al.,* 2004). On the same trip, several designs of scarer (devices attached directly to the netsonde cable) proved to be difficult and potentially dangerous to deploy and retrieve.

Best practice recommendation

Due to their proven effectiveness, low cost and ease of use, streamer lines are regarded as best practice in most trawl fisheries, until such time that effective offal and discard management can be put in place.

- The recommended design specifications for streamer lines are outlined in the Technical Specifications section of this Fact-sheet.
- There are some fisheries where the use of streamer lines is problematic (see Potential problems and solutions).

Potential problems and solutions

The results of experimental trials indicate that streamer lines are the most effective mitigation measure at preventing seabird contacts with trawl warp cables. However, there are certain times when streamer lines can cause problems.

- In some deep-water fisheries, where there is a danger that nets may become snagged on the seabed and vessels may suddenly go astern to prevent damage to their nets. In these instances, streamer lines can be dragged underwater and become wrapped around the propeller. This destroys the streamer line and could potentially damage the propeller or shaft.
- When hauling, vessels will often go astern to reduce the strain on the winches. For the reasons stated above, it is important to ensure streamer lines are retrieved before hauling.
- Conventional (spherical) buoys are prone to being blown away from the warps in strong crosswinds, rendering them less effective. At times, buoys do not generate sufficient drag to keep the streamer line taught, which also makes them less efficient. To further improve the performance of streamer lines alternative towed objects are needed. Substituting buoys with road cones creates more drag and improves performance. However, the modified lines are more difficult to retrieve and in rough seas the cone has a tendency to jump clear of the water, which could result in tangles with the warp cables (Crofts, 2006).
- Some concern has been raised regarding the impact of contacts between birds and streamer lines (Middleton and Abraham, 2006). The available information suggests the impact is insignificant compared with collisions with trawl warps (Crofts, 2006).

Further research

- The key to warp strike prevention is offal and waste management. Further research is needed to investigate novel means of waste storage or discharging away from the stern of the vessel.
- The development of an effective towed object (replacement for spherical buoys) will improve the performance of streamer lines.
- The effect of streamer line strikes on seabirds should be quantified.

Compliance and implementation

The use of streamer lines is proving to be an effective means of reducing seabird bycatch. The lines remain in place throughout the trawl, and thus fishery patrol vessels and planes can monitor compliance. Additional port inspections will ensure streamer lines are on board and maintained.

Technical Specifications

Streamer lines for demersal trawlers:

- The main line should consist of **50 m of 9 mm** line.
- Streamers should be attached at **5 m intervals** and be long enough to reach the water in calm conditions.
- It is essential that streamers are made from semi-flexible tubing of high visibility. The recommended material is UV-protected fluorescent red polythene tubing and alternatives such as fire hose; old waterproofs and dark coloured tubing are not acceptable.
- A **netted buoy** (or alternative towed object such as a modified road cone) should be attached to the end of the streamer line to maintain the aerial extent of the line yet allow easy retrieval.
- The lines should be mounted **two metres outboard** of the trawl blocks on both the port and starboard sides. It may be necessary to weld short extension arms to the handrail in order to achieve this distance.
- Streamer lines should be deployed once the trawl doors are submerged and retrieved as net hauling commences. It is important to retrieve the streamer lines before hauling as vessels often go astern during this process, which can suck the buoys underwater and lead to problems.
- A spare streamer line should be carried and deployed in the event of loss or damage of a line.

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Bycatch Mitigation FACT-SHEET 14 (Version 1)

Practical information on seabird bycatch mitigation measures

Trawl Fisheries: Net entanglement

In recent years, dedicated seabird observers on trawl vessels have identified significant bycatch problems. These fall into two categories, collisions with the cables used to tow the net (Warp strike, Fact-sheet 13) and net entanglement.

What is net entanglement?

Net entanglement occurs when trawl nets are at, or close to, the surface during shooting and hauling. Birds attempting to seize fish from the net become entangled and drown if caught during shooting and can be drowned or crushed during hauling. Many birds caught during hauling are brought aboard the vessel alive. Entanglement is generally a far greater problem in pelagic rather than demersal trawl fisheries, due to the greater overall size of nets and large mesh size used in pelagic fisheries.

Net entanglement has been recorded in some demersal trawl fisheries but seems to only be a problem for certain species (e.g. Cape gannets in South Africa, Watkins *et al*., 2008). Observations in the Falkland Islands (Islas Malvinas), where albatrosses and large petrels predominate, indicate net entanglement in demersal trawl fisheries was not a significant problem (Sullivan *et al*., 2006). However, under certain conditions, such as when the net is ripped or bursts, demersal trawl nets can catch large numbers of birds.

What causes net entanglement?

Net entanglement occurs when the net is floating slack on the surface for prolonged periods. Vessel design (deck length) and the winch gear (net drum) onboard will affect the speed with which nets can be hauled aboard. Several additional factors can prolong the time the net is on the surface. These include; winch gear failure, fishing strategy (some vessels will haul the net to the surface in order to turn, others align the net on the surface before paying out the warps) and in poor weather several attempts may be required to shoot the net.

Species impacted

Any species that associates with trawlers is potentially vulnerable to becoming caught in pelagic trawl nets. Diving species, such as white-chinned petrels, gannets and shearwaters appear to be particularly vulnerable, but albatrosses can also be impacted.

Mitigation measures

Mitigation measures should attempt to reduce the attractiveness of the net to foraging birds and limit the time that the net is on the surface. Most of the measures listed below have not undergone rigorous trials to determine how effective they are at reducing seabird bycatch.

Net shooting mitigation

Net cleaning

Prior to shooting, all stickers (fish caught in the meshes of the net) should be removed. This reduces the attractiveness of the net to seabirds during shooting operations by removing the source of food. Observations indicate this is an effective measure (Hooper *et al.,* 2003), although the effectiveness of net cleaning has not been quantified.

Offal management

Prohibiting the discharge of offal and discards prior to, and during, net shooting and hauling reduces the number of birds associated with vessels at this critical time.

Net binding

In pelagic fisheries, prior to setting, the net (where mesh size are 150–800 mm) should be bound with 3-ply sisal string (or similar) with a breaking strength of 110 kg. This prevents the mesh opening on the surface, increasing the density of the net and reducing the time the net is on the surface. Once the trawl doors are in the water, the net is forced open and the string breaks (Sullivan *et al.,* 2004). Fishermen regard net binding as cheap and simple (Roe, 2005) but further trials are needed to determine its effectiveness in isolation. However, evidence collected in recent years led to CCAMLR making net binding mandatory in the South Georgia icefish trawl fishery.

Net weighting

Adding weight to the belly of the net increases the rate and angle at which the net sinks during shooting and increases the angle it ascends at during hauling.

Deck lighting

Deck lighting should be directed inboard and kept to the minimum level necessary for the safety of the crew.

Figure 1. Net binding reduces the amount of time the net is on the surface.

Haul mitigation

Streamer lines

It has been suggested that streamer lines could be used to deter birds from interacting with the net. Roe (2005) found that the lack of forward momentum and the distance astern of the net on the waters surface made streamer lines ineffective during net hauling. At present, the use of streamer lines to prevent net entanglement during hauling in trawl fisheries is not recommended as a mitigation measure.

Reduce mesh size

Birds are prone to becoming caught in mesh sizes greater than 150 mm. Limited trials of pelagic nets with reduced mesh size or with 'jackets' that cover the largest mesh have proved impractical (Roe, 2005). The added drag puts strain on the gear and engine resulting in higher fuel consumption, gear and mechanical breakdown.

Attempts to reduce the amount of undersized fish catch or bycatch often use mesh size, especially in the upper panels as a mechanism. It would therefore appear that mesh size, as a primary mechanism to reduce seabird bycatch may lead to complex side effects and is currently not known to be effective.

Operational measures (good deck practices)

Periods when the net is on the surface and slack/lofting should be avoided. By maintaining tension in the net, even when at the surface, the meshes remain closed and the likelihood of catching birds is reduced. Once a net reaches the surface, it should be hauled aboard as quickly as possible.

Removing caught birds

Birds caught during hauling are often brought aboard the vessel alive. Care is needed to remove these birds without causing injury. Waterlogged birds should be kept in a dry place (cardboard box) to allow the bird's feathers to dry and be reconditioned prior to release.

Best practice recommendation

- Discards and factory waste should not be discharged prior to or during setting and hauling. Minimising the number of birds associated with the fishing vessel will help to reduce the bycatch due to net entanglement.
- A combination of net cleaning prior to shooting and a means of increasing the sink rate of the net (net binding is the most promising) are required to minimise seabird mortality during net shooting. For reference, the guidelines issued to pelagic trawl fisheries in Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) waters can be found in the Technical Specifications section of this Fact-sheet.
- Net entanglement becomes a major problem when the net lies slack on the surface for extended periods. Minimising this time through good operational practice is essential. This is particularly important during net hauling, when the rapid retrieval of the net is the key to minimising seabird bycatch.
- Care should be taken to remove birds caught in the net without causing injury. Waterlogged birds should be given time to recover onboard before being released.

Further research

The range of mitigation measures available to prevent net entanglement is limited and most have not been tested quantitatively. There is a real need to look for new innovative ways of solving the problem of net entanglement in trawl fisheries, particularly during hauling operations.

- Net binding has shown great promise, however, further trials are needed to determine the effectiveness of this measure in isolation.
- Further research is needed to better understand the causes of bird entanglement during net hauling and develop mitigation measures that prevent it.

Compliance and implementation

Most of the measures recommended here can only be monitored if an onboard observer is present during the shooting and hauling of the net. This makes compliance monitoring very labour intensive and reliant on high observer coverage.

Technical Specifications

Net mitigation

These specifications follow SC-CAMLR guidance on net binding for icefish trawlers operating in the Convention Area (SC-CAMLR 2006).

Net binding

- When the net is on the deck, prior to shooting, the application of 3-ply sisal string (which typically has a breaking strength of around 110 kg), or a similar organic material, at intervals of approximately 5 m prevents the net from spreading and lofting at the surface. Net binding should be applied to mesh ranging from 120–800 mm. These mesh sizes have been shown to cause the majority of entanglements for white-chinned petrels and black-browed albatrosses, which are the most vulnerable species to this form of mortality in the South Atlantic CCAMLR fishery area, Subarea 48.3.
- When applying the 'string', tie an end to the net prevent the string from slipping down the net and ensure that it can be removed when the net is hauled.

Net weighting

- Added weights to the cod end should be used in conjunction with net binding to increase the sink rate of the net and increase the angle of the net's ascent during hauling, therefore reducing surface net time.

Net cleaning

- Net cleaning should be used in conjunction with added weight and net binding to reduce seabird captures during shooting operations.

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