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# Mitigation of seabird bycatch in pelagic longline fisheries: Best practice measures, evidence and operational considerations

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# Best practice measures, evidence and operational considerations

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# Executive summary

Commercial fishing for tunas and tuna-like species supports people with food, livelihoods, and economic wellbeing. However, pelagic longline fisheries that catch these fish can also catch seabirds, including albatrosses and petrels of conservation concern. Albatrosses and petrels are long-lived, mature late, and have a limited capacity to replace themselves. Fishing-related mortalities are implicated in the population declines of some albatross and petrel species.

Over time, 'best practice' measures have been identified to reduce seabird mortalities due to pelagic longline fishing. The Advisory Committee of the multilateral Agreement on the Conservation of Albatrosses and Petrels (ACAP) defines best practice measures as having specified design and performance standards, as well as being practical, widely available and cost effective. Best practice measures should also be proven effective through experimental research, maintain target species catch rates, not increase bycatch of other taxa, and be subject to regulatory definition and compliance monitoring.

ACAP-identified best practice for pelagic longline fisheries includes measures that should be used in combination, and measures that are adequate as standalone methods. The best practice use of measures in combination comprises bird-scaring lines (BSLs) (also known as tori lines), branchline weighting, and night setting. ACAP's standards and specifications, and recommendations, for the best practice use of these three measures include:

- design, construction and installation specifications, for BSLs
- mass and distances from the hook, for branchline weighting
- definition of night setting in nautical terms; and,
- where, when and how implementation can be monitored, for all methods.

BSLs have no negative impacts on fish catch, and increased target species catch rates have been reported. Branchline weighting is mostly reported to have no effect on catch rates of tunas and billfish, with numerous weighting configurations investigated. Two studies report reduced catch rates of sharks on weighted branchlines, which could be a positive or negative outcome depending on the fishery. One study reported reductions in unwanted (discarded) catch when branchline weighting was in use. Effects of night setting on catch rates vary. Considering the target species behaviour, habitat use and day/night operational differences (e.g. set duration) is important for understanding any effects.

The combination use of BSLs, branchline weighting and night setting provides an effective multifaceted system of protection against seabird bycatch because each measure operates via a unique mechanism. If one of these measures is not in place, baited hooks are less protected and seabird bycatch risks increase.

More recently developed best practices measures are hookpods and underwater bait-setting devices. There is relatively less information available on these measures. However, both are shown to have no negative impacts on tuna and swordfish catches, and to effectively reduce seabird bycatch. Further, these measures are endorsed by ACAP as standalone best practice mitigation methods.

Each mitigation method has characteristics strengths, limitations, and operational considerations. For fishery practitioners, benefits of implementing best practice (beyond enhancing seabird survival and persistence) include increased bait retention and availability for target catch, avoidance of lost crew time and gear from dealing with bycaught seabirds, and the ability to access premium markets where sustainability credentials may attract higher prices.

The body of evidence available shows that BSLs, branchline weighting, night setting, hookpods and underwater bait setting can all significantly reduce bycatch of albatrosses and petrels in pelagic longline fisheries. Evidence comprises experimental and operational studies with varying scales, geographic scopes, species assemblages, fishery target species, and statistical analyses. Nonetheless, relatively consistent findings have emerged. This enables implementation of best practice to be progressed, alongside appropriate information collection to improve seabird bycatch management over time.

# Contents

# 1. Introduction

Commercial fishing for tunas and tuna-like species supports people with food, livelihoods, and economic wellbeing. However, seabirds occur in the same areas that longline fisheries catch these fish, and birds can be caught and killed on longline fishing gear. The impacts of seabird bycatch have been a significant sustainability concern since the 1980s (Brothers 1991, 2010; Anderson et al. 2011; Phillips et al. 2016). Pelagic longline fisheries are specifically implicated in the decline of seabird populations such as Antipodean, wandering and grey-headed albatross (Pardo et al. 2017; Bose and Debski 2022). Seabird life history characteristics make them particularly vulnerable to fishing-related mortality. Albatrosses and petrels have low reproductive output which limits their ability to replace individuals lost. They are also long-lived with delayed maturity, and have extensive foraging ranges at sea where they may encounter and interact with fisheries (Phillips et al. 2016; Clay et al. 2019).

Seabirds are attracted to longline fisheries by the associated foraging opportunities, such as the availability of bait (on hooks and typically discarded after hauling), catch (including unwanted, discarded catch), and fish processing waste (Bull et al. 2007; Pierre et al. 2012; Melvin et al. 2023). Seabird bycatch in pelagic longline fisheries can be effectively reduced by:

- Avoiding fishing when (and where) interactions with seabirds are most likely
- Reducing seabird access to baited hooks; and,
- Reducing the attractiveness of fishing operations to seabirds, including when hooks are accessible to them.

Over time, effective measures have been developed to reduce seabird bycatch in pelagic longline fisheries (Bull 2007; Løkkeborg 2011), and 'best practice' measures are identified for this fishing method (ACAP 2021b). The Advisory Committee of the multilateral Agreement on the Conservation of Albatrosses and Petrels (ACAP) characterises best practice measures for mitigating seabird bycatch as having specified design and performance standards, as well as being practical, widely available and cost effective. In addition, best practice measures should be proven effective in reducing bycatch through experimental research, maintain target species catch rates, not increase bycatch of other taxa, and be subject to regulatory definition and compliance monitoring (ACAP 2014). ACAP's Advisory Committee regularly reviews potential bycatch mitigation measures against these criteria, including new and emerging measures.

Aside from the obvious benefits of promoting seabird survival and population persistence, other direct benefits of reducing fisheries bycatch of seabirds include increased bait retention and bait availability for the commercial fish catch, and avoidance of the loss of gear and crew time resulting from bycatch-related tangles and the removal of bycaught seabirds from fishing gear (Pierre and Clough 2021). Furthermore, demonstrating fishery sustainability, including in relation to seabird bycatch, facilitates access to markets in which ecolabels are desirable or required. Such markets are typically high-end and can return price premiums on products that are certified as sustainable (e.g., Lallemand et al. 2016; Asche and Bronnmann 2017). The global demand for demonstrably sustainable seafood has surged since the early 2000s. In 2005, 0.5% of seafood produced globally was identified as sustainable. In 2015, that had increased to 14% and the estimated retail value of certified seafood was USD$11.5 billion (Potts et al. 2016). Between 2020 and 2021, despite supply chain and societal disruptions due to COVID-19, sales of tuna products carrying the Marine Stewardship Council (MSC) ecolabel increased by 50%. In addition, 1,267,000 tonnes of certified-sustainable MSC-labelled seafood were sold globally, reflecting a 5.8% increase on the previous year[1].

The purpose of this report is to bring together information available on five ACAP-identified best practice albatross and petrel bycatch mitigation measures for pelagic longline fisheries, specifically:

- Bird-scaring (tori) lines
- Branchline weighting
- Night setting
- Hook-shielding devices; and,
- Underwater bait-setting devices.

The measures are characterised in terms of:

- Key design elements and/or specifications
- Mode of operation
- Effects on target and non-target fish catch
- Efficacy in reducing seabird bycatch
- Strengths and limitations; and,
- Operational considerations.

The combined use of more than one of these measures is also considered as well as the areas above, and the economic costs and benefits of mitigation implementation. The sixth ACAP-endorsed best practice measure for pelagic longline fisheries – time-area fishery closures – is not considered in this review. That is because the focus of the review is measures that enable fishing to continue in a way that minimises seabird bycatch risks.

# 2. Best practice mitigation measures for reducing seabird bycatch in pelagic longline fisheries

## 2.1 Bird-scaring (tori) lines

### 2.1.1 The method

Bird-scaring lines (BSLs) are used to deter birds from approaching longline hooks to feed on baits during line-setting. They are deployed from a high point on the vessel, and comprise a backbone with streamers attached and a terminal section that creates drag. Streamers are ideally brightly coloured and placed along the BSL, and these move with the wind (Figure 1). Together, the aerial extent and streamers attached to the BSL backbone deter and impede seabird access to baited hooks. The terminal section of the BSL must create sufficient drag to maintain aerial extent. The BSL must remain in position protecting baited hooks set astern vessels including in windy conditions. Optimal design specifications (e.g. backbone length, drag section construction) vary with the characteristics of fishing operations (e.g., vessel size and setting speed) (ACAP 2021b).

Design guidance and recommendations provided by ACAP include the following for all BSLs (Table 1):

- The BSL backbone should be as light as possible, such that amount of drag required to hold it aloft is minimised.

[1] https://www.msc.org/media-centre/press-releases/press-release/sustainable-seafood-sales-reached-an-all-time-high-as-shoppers-cooked-at-home-in-2020-21 [Accessed 8 February 2023]

- At the vessel end, attaching the BSL using a swivel will minimise BSL rotation during towing.
- Long streamers should be attached to the backbone using swivels, making them less likely to roll up around the BSL backbone.
- Tangling and foul-hooking should be carefully considered when selecting the terminal drag section. A long length of in-water monofilament line or rope can effectively provide drag.
- Weak links incorporated in the BSL provide a breakaway point, increasing the safety of the BSL and reducing operational issues in case of tangling.
- A secondary point of BSL attachment to the vessel is recommended to enable a BSL that breaks (e.g. at its weak link) during setting to then be clipped onto the mainline for recovery at hauling.

Ideally, BSLs would protect baited hooks when they occur at depths accessible to seabirds. Pragmatically, ACAP's BSL design standards and specifications for smaller and larger pelagic longline vessels balance hook protection and deployment feasibility. ACAP recommends a minimum of 75 m aerial extent for BSLs deployed from vessels less than 35 m in total length, and that BSLs are attached to vessels to achieve a minimum deployment height of 6 m over the water at the vessel stern. For vessels of this size, ACAP (2021b) sets out two streamer configurations:

- Long streamers attached at 5 m intervals along a minimum of 55 m of the BSL, interspersed with short streamers, and noting that long streamers may be shortened in the first 15 m astern to reduce the risk of tangling; and,
- Short streamers a minimum of 1 m in length attached at 1 m intervals along the aerial extent of the BSL.

For vessels of 35 m total length or more, ACAP recommends the use of two BSLs, with one positioned each side of the longline during setting. Bait-casting machines should be adjusted to ensure baits are cast between the BSLs. The minimum aerial extent recommended for BSLs deployed from vessels of this size is 100 m. Deployment to achieve a BSL height of 8 m above the water at the vessel stern is recommended. Long streamers should reach the sea surface. Long and short streamers should be deployed at intervals of 5 m maximum. When a single BSL is used on vessels of this size, positioning it windward of the longline being set is recommended. Similarly, if hooks are set outboard of the vessel wake, the BSL attachment point should be positioned appropriately.

ACAP-recommended best practice BSL design standards and specifications are summarised in Table 1.

Published BSL costs range from USD$0, where BSLs are constructed from repurposed materials that would otherwise be waste, through USD$150 – 350 for purpose-built BSLs. Implementation costs vary with installation method. Simple attachments to existing structures on vessels may carry no to relatively low costs (e.g. USD$200). However, new structures are often required for effective BSL deployment (e.g., a pole or custom-made support structure). In such cases, costs of up to USD$3,500 have been reported (Pierre et al. 2016; Goad and Debski 2017; Parker 2017).

*Table 1. Summary of design standards, specifications and recommendations for the best practice use of bird-scaring lines (BSLs) (Agreement on the Conservation of Albatrosses and Petrels 2021b).*

| **Design standards and specifications** | **Total length of vessel** | |
|---|---|---|
| | **< 35 m** | **≥ 35 m** |
| Key components | Backbone, streamers, terminal drag section | |
| | Single BSL | Two BSLs (deployed either side of longline being set, i.e. to port and starboard of a stern-setting vessel) |
| Key performance standards | Drag section effectively maintains maximum aerial extent<br>Remains in position in windy conditions | |
| Backbone | Lightweight<br>Swivel incorporated into vessel attachment method<br>Has secondary point of attachment to vessel<br>Weak link incorporated as a breakaway point | |
| Streamers | Brightly coloured<br>Long streamers attached to BSL backbone using swivels | |
| | Long streamers at 5 m intervals along ≥ 55 m of BSL (may be shortened over first 15 m of BSL)<br>Short streamers every 1 m between long streamers<br>OR<br>Short streamers at least 1 m long placed 1 m apart along aerial extent | Long streamers 5 m apart along BSL interspersed with short streamers<br>Long streamers reach sea surface |
| Minimum height above water at the vessel stern | 6 m | 8 m |
| Minimum aerial extent | 75 m | 100 m |
| Implementation monitoring | Deployment must be monitored at each set. | |

## 2.1.2 Effect on catch rates

### *Fish catch rates*

Increased catch rates of target and other fish species have been reported when BSLs are in use (Table 2; Mancini 2009). Mancini et al. (2009) reported catch rates increased by 10 fish per 1,000 hooks when BSLs were used in the peak period of seabird bycatch (May – November) in their study area off southern Brazil. By target species and species groups, catch rates when BSLs were used were 32% higher for swordfish, 15% higher for blue shark, 17% higher for other elasmobranchs, and 16% higher for other teleost fish. Increases in catch rates were attributed to increased bait retention due to the BSL restricting seabird access to baits. Further, the reduction in seabird captures meant that more hooks remained available to catch fish.

Based on information collected from a southern bluefin tuna fishing operation in the Southern Ocean, Brothers (1991) estimated a decrease in target catch of 0.8% due to albatross depredation of baits. When a BSL was in place, bait-taking attempts decreased from 62% to 1.4% occurring within the first 50 m astern the vessel.

BSLs are not designed to interact directly with the fishing gear, therefore no negative effects are expected on fish catch rates or catch composition. If the longline gear tangles with the BSL on setting, this may affect longline configuration in the water, though details of any gear effects are undocumented.

*Table 2. Impacts of bird-scaring lines (BSLs) on target species/group catch rates in pelagic longline fisheries. Effects are statistically significant unless otherwise noted. Note that the designs of BSLs varied and were generally not based on best practice as defined by the Agreement on the Conservation of Albatrosses and Petrels (ACAP 2021b).*

| Effect on fish catch rates | Species | Effect size | Location | Source |
|---|---|---|---|---|
| **Increase** | Swordfish<br>Blue shark<br>Other elasmobranchs<br>Other teleost fish | +32%<br>+15%<br>+17.2%<br>+15.7% | Brazil | Mancini et al. 2009 |
| | Tuna | +0.8% (estimate, not statistically tested; considering bait removals by albatrosses) | Southern Ocean | Brothers 1991 |

### *Seabird bycatch rates*

In all except two studies evaluating the efficacy of single BSLs as a standalone mitigation measure, seabird bycatch or contact rates were reported to be significantly lower when BSLs were deployed, compared to when they were not (Table 3). Table 3 addresses BSLs as the only mitigation measure in place, while the use of BSLs in combination with other measures is discussed in section 4.

BSL design affects performance (e.g., Duckworth 1995; Yokota et al. 2007; Domingo et al. 2017), though in operational contexts, BSL designs are often not well documented. In the case of Duckworth et al. (1995), the lack of BSL efficacy was attributed to suboptimal designs in some cases. Other factors such as season, moon phase, and vessel add complexity to the interpretation of bycatch rates reported when BSLs are deployed, and modelling approaches can help tease out such effects. Underpinning the comparison reported by Rollinson et al. (2016), BSLs were mostly used in areas characterised by high seabird bycatch risk. In lower risk areas, BSLs were not used. Additional analysis, e.g. incorporating a spatial component accounting for risk, may inform conclusions about the efficacy of BSLs in that study.

The efficacy of paired BSLs in pelagic longline fisheries has been demonstrated by two studies (Table 3; Sato et al. 2013; Melvin et al. 2014). Melvin et al. (2014) reported fewer than five primary attacks per 1,000 hooks on unweighted branchlines by diving seabirds within the 100 m aerial extent of paired BSLs (Figure 2). No attacks by albatrosses were recorded inside that distance, and no attacks by any species occurred between the paired BSLs. (A primary attack was defined as unambiguous attempt by an individual bird to take bait from a hook – typically a dive, lunge, or plunge directly over a sinking hook (Melvin et al. 2014)). Further, Sato et al. (2013) demonstrated the additional efficacy of paired BSLs in reducing seabird attacks on baited hooks in a pelagic longline fishery, over and above the effect of single BSLs (Table 3). In addition, seabird attacks on bait occurred further astern when paired BSLs were deployed. Bait sank to 2 m deep within the aerial extent of BSLs, thereby reducing the bycatch risk for shallow divers and surface foragers beyond BSLs.

In demersal longline fisheries, similar performance of paired BSLs has been documented (Bull 2007; Løkkeborg 2011). For example, reviewing paired BSL efficacy in demersal longline fisheries, Melvin et al. (2004) found 88-100% reductions in seabird bycatch over two years in sablefish and Pacific cod longline fisheries, compared to when BSLs were not used. A comparison of the performance of single and paired BSLs showed a non-significant reduction in bycatch rates in the same fishery. However, paired BSLs reduced the number of attacks on the longline and almost eliminated albatross attacks. When they did occur, attacks were further astern when paired BSLs were deployed.

### 2.1.3 Strengths

- Simple construction: BSLs can be constructed using a diverse range of materials. Design and construction guidance is available in a variety of forms (e.g. ACAP and BirdLife International 2014a, 2014b; Gilman et al. 2021a, 2021b;). Materials used for construction do affect BSL efficacy, as well as durability and handling.
- No negative effects on fish catch, and positive effects reported.
- Cost: BSLs are highly cost effective. Some investment may be required for mounting structures, but these are then reusable.
- Adaptability: BSLs are adaptable to different operations (e.g. streamer length close to the vessel, installation and deployment mechanisms)
- Monitoring and compliance: The presence of BSLs and deployment infrastructure onboard vessels can readily be assessed in port. This does not necessarily mean a BSL will be used at sea. However, if not present onboard (or there is no deployment mechanism in place), BSLs will definitely not be used at sea. Presence of BSLs can also be detected in EM video imagery (Pierre 2018).

### 2.1.4 Limitations

- Tangling risk requires management. Maintaining appropriate BSL position astern and the choice of terminal object are vital for reducing tangling risks. Incorporating a weak link into the BSL enables rapid release should tangling occur (e.g., Gilman et al. 2021b).
- Cost of structures required for installation may disincentivise adoption.
- Monitoring and compliance: Deployment must be monitored visually for each set to be sure that BSLs are used at sea.
- Skippers report that use in bad weather creates a safety risk (Turner 2021).
- Rough weather increases tangling risk (McNamara et al. 1999).

*Table 3. Examples of average seabird interaction rates reported with and without bird-scaring lines (BSLs) in use. Data presented is captures per 1,000 hooks, unless otherwise specified. Differences are statistically significant unless otherwise stated. (u)=Statistical significance not stated in the source reference. Designs of BSLs varied and were generally not based on best practice as defined by the Agreement on the Conservation of Albatrosses and Petrels (ACAP 2021b). LAAL=Laysan albatross (*Phoebastria immutabilis*); BFAL=Black-footed albatross (*Phoebastria nigripes*); 'contact'=attacks on baited hooks; 'interactions'=contact with the fishing gear; 'attempts'=(# attempts/# seabirds present)/# hooks observed; 'MPUE'=(# mortalities/# seabirds present)/# hooks observed; WCPFC=Western and Central Pacific Fisheries Commission; IATTC=Inter-American Tropical Tuna Commission.*

| **Location** | **Bycatch rate per 1,000 hooks** | | **Notes** | **Source** |
|---|---|---|---|---|
| | **With measure** | **Without measure** | | |
| **Single bird-scaring lines** | | | | |
| Australia<br>(Japanese vessels) | 0.47 | 0.74 | (u)<br>Albatross captures only (one additional petrel caught).<br>Author noted mortalities may be higher due to unobserved mortality. | Brothers 1991 |
| New Zealand<br>(Japanese vessels) | 0.28 | 0.20 | BSL design affected efficacy; modelling found that sets with 'good' BSLs (characterised by deployment height, length, number of streamers) caught fewer birds. Suboptimal designs resulted in higher bycatch rates. | Duckworth 1995 |
| Hawaii, USA | Contact rates:<br>LAAL: 0.02<br>BFAL: 0.02 | <br>0.07<br>0.08 | | Boggs et al. 2001 |
| Hawaii, USA | Attempts:<br>47.1<br>MPUE:<br>0.47 | <br>76.7<br><br>2.23 | Swordfish target sets | McNamara et al. 1999 |
| Hawaii, USA | Attempts:<br>0.8 | <br>10.7 | Tuna target sets | McNamara et al. 1999 |
| Brazil | 0.31 | 0.85 | | Mancini et al. 2009 |
| South Africa | 0.10 | 0.64 | | Petersen et al. 2008c |
| South Africa<br>(Japanese vessels) | 0.11 | 0.33 | (u) | Rollinson et al. 2016 |
| South Africa<br>(Domestic vessels) | 0.16 | 0.01 | (u)<br>Direct catch rate comparisons confounded by more frequent use of | Rollinson et al. 2016 |

| | | | | |
|---|---|---|---|---|
| | | | BSLs in higher risk areas (less frequent use in lower risk areas). | |
| Southwest Atlantic | 0.13 | 0.85 | Conducted in area/season of highest bycatch risk in the region. On BSL sets, 71% of captures occurred after breakages. | Domingo et al. 2017 |
| Uruguay | 2.35 | 5.49 | (u)<br>Authors caution that a small sample size underpins this comparison. | Jiménez et al. 2019a |
| Central North Pacific Ocean around Hawaii | With BSLs deployed:<br>• Albatross contacts with baited hooks 3 times less likely<br>• Attempted contacts 2 times less likely<br>• Albatross captures 1.1 times less likely | | BSLs designed to meet minimum requirements of WCPFC and IATTC. (Inference of albatross capture rates is weak relative to other metrics, due to the number of captures that occurred). | Gilman et al. 2021a |
| New Zealand | With BSLs set over the bait entry point:<br>• 51% reduction in seabird captures | | | Meyer and MacKenzie 2022 |
| **Single c.f. paired bird scaring lines** | **Single** | **Paired** | | |
| Western North Pacific (Japanese vessel) | Attacks:<br>25.7 | 12.3 | | Sato et al. 2013 |

### 2.1.5 Operational considerations

- BSLs must be maintained in good condition to ensure efficacy.
- Some losses occur. Spare parts must be carried to ensure ongoing usage.
- To achieve sufficient aerial extent and ensure baited hooks are protected as they are set, the installation of deployment structures is likely to be required (especially on smaller vessels).
- Weak links enable rapid release should tangling occur (e.g. Gilman et al. 2021b).
- BSLs are a not set-and-forget measure. They require active monitoring during the set to ensure optimal operation, in terms of crew safety, tangle avoidance, and protection of the baited hooks. Such responsibility should be explicitly assigned to a crew member.
- BSL losses can be reduced by attaching a secondary line connecting the BSL to the vessel, which can then be clipped onto the longline backbone if the BSL must be released. Released BSLs may then be recovered at the haul.
- Deployment can be facilitated by effective onboard storage, that minimises tangling risks (e.g. a reel or storage bin that the line is coiled into).
- Anecdotally, fishers report that weighting longlines reduces BSL tangling risks (Turner 2021). This accords with the increased sink rates of weighted gear, and increased vertical distances between the weighted gear and BSL with increasing distance astern.
- Best practice design provides for shorter streamers up to 15 m immediately astern, to reduce tangling risks.

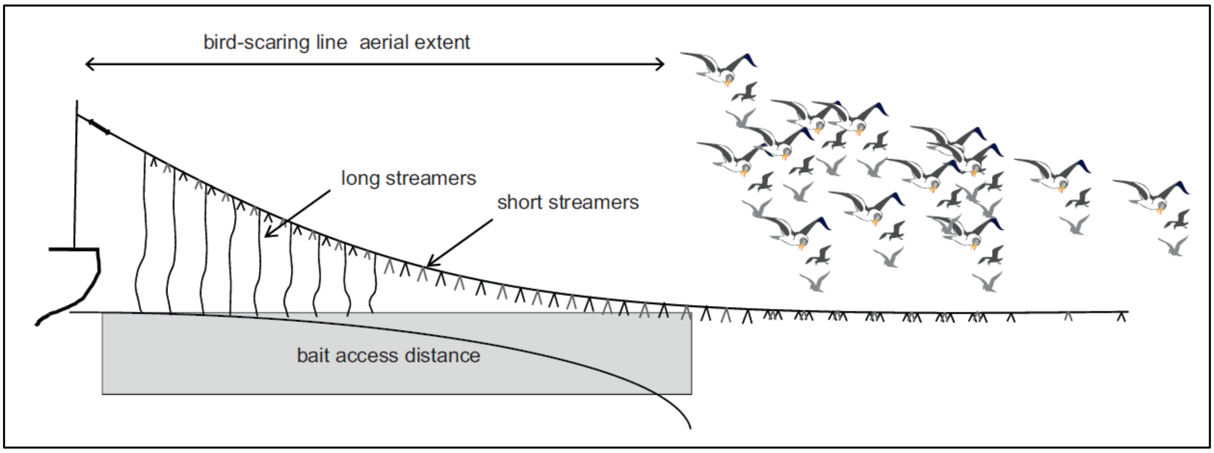


*Figure 1. Schematic diagram of a bird-scaring line deployed astern a pelagic longline vessel. (Modified from Melvin et al. 2014).*

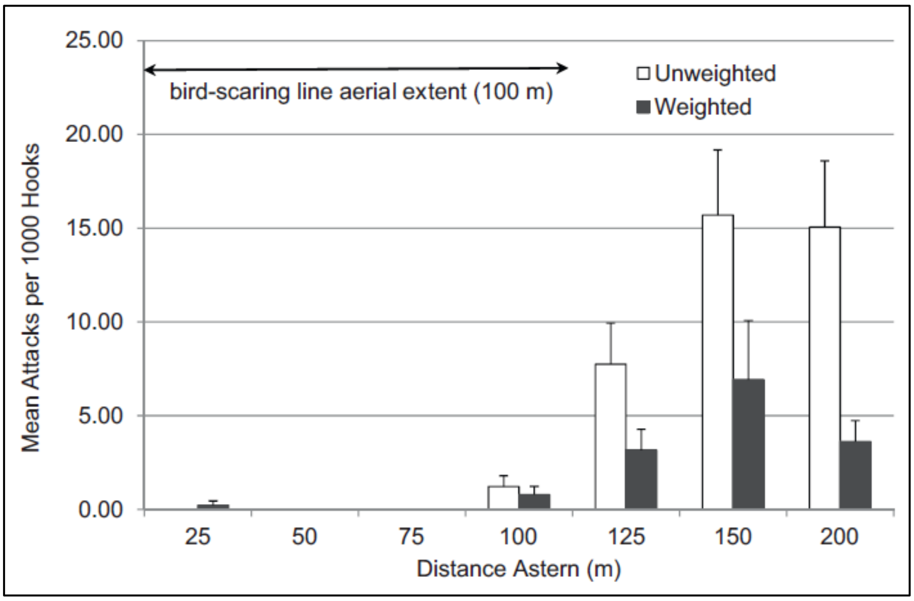


*Figure 2. Distribution of primary attacks of diving seabirds on baited hooks on weighted and unweighted branch lines, by distance astern (m). Paired bird-scaring lines were used in this study. (Source: Melvin et al. 2014).*

## 2.2 Branchline weighting

### 2.2.1 The method

Adding weight to the branchlines attached to longlines sinks baited hooks to fishing depth more rapidly. This reduces the amount of time, and distance, over which seabirds can access baited hooks and potentially be caught (ACAP 2021b). Seabird access to hooks during the soak and hauling periods is also reduced, with commensurate reductions in bycatch risk (Robertson et al. 2012; Gilman et al. 2014). A range of weighting approaches can be applied. This includes weighted swivels or sliding weights (Figure 3), with weights located along branchlines at varying distances from the hook. Hooks are reported to sink fastest and at the most consistent rates when weights are located closest to the hook (ACAP 2021b). Hook sink rates have been used as a proxy for bycatch risk.

ACAP has developed recommended minimum standards for line-weighting, comprising specified weights at distances from the hook (Table 4; ACAP 2021b). Minimum standards were based on studies of sink rates, and seabird attack and bycatch rates. Standards and specifications of line weights and weight placement do not vary with vessel length. However, ACAP requirements for monitoring the implementation of this mitigation measure differ for small and larger vessels, based on how readily weights may be switched for unweighted gear at sea (Table 4). On smaller vessels, removing weights from gear at sea is considered more difficult and impractical, compared to onboard larger vessels. Therefore, confirming all gear onboard a smaller vessel is fitted with branchline weights in port is considered by ACAP to comprise adequate evidence that line-weighting is implemented. On larger vessels, ACAP requires on-vessel monitoring to verify implementation because gear configuration is considered more readily changeable at sea (Winnard et al. 2018; ACAP 2021b).

Crew safety must be considered as part of the adoption and implementation of branchline weighting in pelagic longline fisheries. During hauling, weights may recoil (a 'flyback') towards the vessel/crew at high velocity due to bite-offs or tear-outs. A bite-off occurs when a hooked fish, e.g. a shark, bites through the branchline between the hook and the weight. A tear-out is when the hook is pulled free from a catch item. Both types of events involve the branchline, which was previously under tension, recoiling such that there is a risk of the weight causing injurious impact. It is important to emphasise that these events happen with unweighted gear as well, though the lack of weighting reduces injury risk. Sliding weights can dissipate the energy associated with a flyback, travelling along and (in some cases) falling off the cut branchline. Recoil is also damped if weights are underwater when the flyback starts (ACAP 2021a).

ACAP recommends that line weighting is used in combination with night setting and BSLs (ACAP 2021b); combination mitigation approaches are considered at section 4.

*Table 4. Summary of design standards, specifications and recommendations for the best practice use of branchline weighting (Agreement on the Conservation of Albatrosses and Petrels 2021b).*

| | **Total length of vessel** | |
|---|---|---|
| **Design standards and specifications** | **< 35 m** | **≥ 35 m** |
| Key components | Weights fitted to branchlines | |
| Minimum standards | 40 g or greater attached within 0.5 m of the hook; or<br>60 g or greater attached within 1 m of the hook; or<br>80 g or greater attached within 2 m of the hook. | |
| Implementation monitoring | Inspection of all gear bins before leaving port | At-sea monitoring by observers, cameras, at-sea boarding inspections |

*Figure 3. L: Luminous sliding leads stored onboard pelagic longline vessels. Hooks may be set with weights placed at variable distances from the hook (Photo: Fishtek Ltd). R: Weighted swivels are a conventional approach to branchline weighting in pelagic longline fisheries (Photo: https://www.afma.gov.au/environment-and-research/reducing-bycatch/bycatch-reduction-devices/line-weighting-pelagic).*

Published costs of one type of commercially available sliding weight (GloLeads) are AUD$1.20 and AUD$1.50 per 40 g and 60 g weight. respectively[2]. Lumo Leads produced by Fishtek Marine[3] are priced at £0.65 per 45 g unit, in a batch of 2,000 units (B. Sullivan, pers. comm.). If sliding leads are used, fewer crimps are required in the gear, resulting in a saving per of around USD$0.20 – 0.30 per crimp. Further, when the outer casing of sliding leads is made from luminous materials, fluorescent lightsticks are not required on the gear. Eliminating the need for lightsticks can carry considerable financial savings (Sullivan et al. 2018), as well as environmental benefits. Used lightsticks require disposal and often become marine debris that seabirds can ingest (Donnelly-Greenan et al. 2018).

### 2.2.2 Effect on catch rates

#### *Fish catch rates*

In most reported cases, branchline weighting had no effect on catch rates of tunas (including albacore, bigeye, yellowfin, southern bluefin, Pacific bluefin) and billfish (including swordfish (Table 5)). Rollinson (2017) found no negative effects on catch in most cases, but a reduction in target species catch rates in two of the 45 g treatments considered (Table 6).

Researchers have also investigated how different amounts of weight at a range of distances from the hook affects fish catch (Table 5). This work has often arisen from researchers wishing to compare conventional or preferred gear configurations used by fishers, with alternative configurations that may reduce seabird bycatch risks. In one such study, weighting to reduce seabird bycatch risk resulted in increased yellowfin tuna catch rates, compared to the conventional gear configuration used by fishers (Gianuca et al. 2013). In all others, there were no effects on tuna or swordfish catch.

Two studies reported statistically significant reductions in shark catch rates on weighted branchlines (Table 5; Ochi et al. 2013; Pierre et al. 2015). Reduced shark catch may be positive or negative for fishing operations. For example, reduced shark catch makes more hooks available to catch tuna, while Ochi et al. (2013) noted that blue shark held commercial value in their focal fishery.

Rollinson (2017) also reported that two weighted branchline treatments resulted in reduced unwanted fish catch (i.e. catch that was discarded, not retained).

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[2] https://www.fishinginternational.com.au/index.php/mainmenu-product-catalogue/glow-sticks [Accessed 15 March 2023]

[3] https://www.fishtekmarine.com/reduce-seabird-bycatch/ [Accessed 15 March 2023]

### *Seabird catch rates*

Seabird attack and capture rates are consistently reported to be lower on weighted compared to unweighted branchlines, and on branchlines with relatively shorter distances weight to hook (Table 7). Weights deployed have included sliding weights and weighted swivels, and research has occurred among diverse seabird assemblages.

The use of attack rates as a proxy for weighting efficacy stems from captures being statistically rare events, requiring large numbers of hooks to produce enough data for quantitative analysis. Mortality levels commensurate with such captures rates are problematic especially for taxa of conservation concern. Furthermore, mortalities are unnecessary for experimental investigation of bycatch reduction measures (Pierre and Debski 2013). Similarly, sink rates of baited hooks have been used as a proxy of bycatch risk, considered as the amount of time that hooks remain within seabird core diving depths and/or capabilities.

Using South African pelagic longline fishery records, Petersen et al. (2008a) present a graphical summary of the relationship between sink rate and seabird mortality (Figure 4). When using sink rate as a proxy for risk, a benchmark of sink rate to 10 m depth is commonly considered to encompass most seabird diving activity. Albatrosses do not make deep dives, and many petrel and shearwater dives occur within 10 m of the sea surface (though some can dive to more than 50 m depth (Petersen et al. 2008b; Friesen et al. 2017; Bentley et al. 2021)). Various studies have documented baited hooks on weighted branchlines sinking more rapidly compared to gear with unweighted branchlines, e.g., to depths of up to 10 m (Petersen et al. 2008b; Jiménez et al. 2013; Melvin et al. 2013, 2014; Robertson et al. 2013; Pierre et al. 2015). Results include those tested and shown to have statistical significance (Anderson and McArdle 2002; Melvin et al. 2013, 2014). Faster sink rates also have been documented for weights closer to the hook compared to further away, with statistical significance reported in some cases (Robertson et al. 2013; Santos et al. 2019).

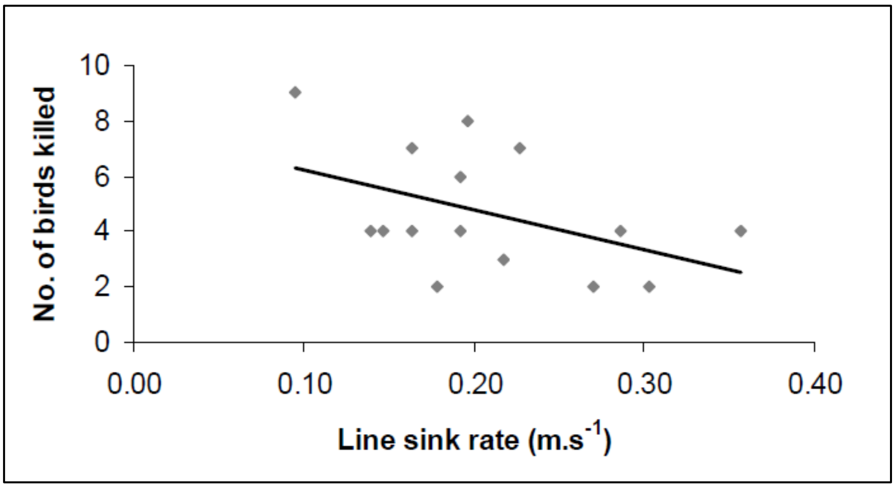



*Figure 4. Number of seabirds killed per set as a function of longline sink rate, in sets during which two or more birds were killed. (Source: Petersen et al. 2008b).*

*Table 5. Experimental and operational research examining the effect of branchline weighting on fish catch, including target catch species. Numeric effect sizes shown are statistically significant. SS=Study compared species-specific catch rates, G=Catch rates for species groups, +'normal' branchlines sometimes included weighted swivels and/or lightsticks and bird-scaring lines were deployed during at the skipper's discretion.*

| Effect on fish catch rates | Control | Treatment(s) | Species/groups | Effect size | Location | Source |
|---|---|---|---|---|---|---|
| **No effect** | 'Normal' branchlines+ | 40 g luminous sliding lead | Tuna, swordfish (G) | | New Zealand | Pierre et al. 2015 |
| | 60 g sliding Safe Lead 3.5 m from the hook | 120 g sliding Safe Lead 2 m from the hook | Yellowfin (SS)<br>Other tuna, swordfish, sharks, common dolphinfish (G) | | Australia | Robertson et al. 2012, 2013 |
| | 60 g sliding Safe Lead 3.5 m from the hook | 40 g luminous sliding weight 0.5 m from the hook | Yellowfin (SS)<br>Bigeye (SS)<br>Swordfish, common dolphinfish, sharks (G) | | Australia | Robertson et al. 2012, 2013 |
| | Unweighted | Double-weighted branchlines, weight unspecified | Bigeye (SS)<br>Albacore (SS)<br>Swordfish (SS) | | Western and Central North Pacific | Ochi et al. 2013 |
| | 60 g weighted swivel 3.5 m from the hook | 60 g luminous sliding weight 1.0 or 3.5 m from the hook | Tuna (G)<br>Sharks (G)<br>Billfish (G)<br>Other fish (G) | | Brazil | Santos et al. 2016 |
| | 60-75 g weighted swivel 5.5 m from the hook | 60-75 g weighted swivel 2 m from the hook | Tuna (G)<br>Sharks, swordfish (G) | | Brazil | Gianuca et al. 2013 |
| | 75 g weighted swivel 4.5 m from the hook | 60 g Safe Lead or 65 g luminous sliding weight 1 m from the hook | Albacore (SS)<br>Yellowfin (SS)<br>Swordfish (SS)<br>Blue shark (SS) | | Uruguay | Jiménez et al. 2019a |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Increase** | 60-75 g weighted swivel 5.5 m from the hook | 60-75 g weighted swivel 2 m from the hook | Yellowfin tuna (SS) | +18% | Brazil | Gianuca et al. 2013 |
| **Decrease** | Unweighted | Double-weighted branchlines, weight unspecified | Blue shark (SS) | -16% | Western and Central North Pacific | Ochi et al. 2013 |
| | 'Normal' branchlines[+] | 40 g luminous sliding leads | Sharks (mostly blue shark) (G) | -19% | New Zealand | Pierre et al. 2015 |

*Table 6. Summary of findings from the line-weighting experiments conducted by Rollinson (2017) on Korean vessels in the Indian Ocean, in South African and western Australian waters. Experimental comparisons involved sliding weights with different coloured plastic coatings placed at different distances from the hook, and unweighted branchlines.*

| Species | Weight | | Colour | | Distance from hook | | | | Effect size |
|---|---|---|---|---|---|---|---|---|---|
| | 45 g | 60 g | Black | Luminous | 5 cm | 60 cm | 100 cm | 200 cm | |
| **No effect** | | | | | | | | | |
| Albacore | ✓ | | ✓ | | | | ✓ | | |
| | | ✓ | | ✓ | | | ✓ | | |
| | | ✓ | | ✓ | | | | ✓ | |
| Bigeye, yellowfin | ✓ | | ✓ | | ✓ | | | | |
| | ✓ | | ✓ | | | | ✓ | | |
| | | ✓ | | ✓ | | | ✓ | | |
| | | ✓ | | ✓ | | | | ✓ | |
| Southern bluefin | ✓ | | | ✓ | ✓ | | | | |
| | | ✓ | | ✓ | ✓ | | | | |
| **Decrease** | | | | | | | | | |
| Albacore | ✓ | | ✓ | | ✓ | | | | -58% |
| | ✓ | | ✓ | | | ✓ | | | -49% |
| Bigeye, yellowfin | ✓ | | ✓ | | | ✓ | | | -41% |
| Unwanted catch (fish discarded) | ✓ | | ✓ | | ✓ | | | | Significant reductions; effect size not stated |
| | ✓ | | ✓ | | | ✓ | | | |

*Table 7. Examples of average seabird interaction rates reported under various branchline weighting regimes. A=Primary attacks on baits or contacts with baited hooks, C=Captures. Effects are significant unless (u) is shown, in which case statistical significance was not presented in the source document. LAAL=Laysan albatross (*Phoebastria immutabilis*), BFAL=Black-footed albatross (*Phoebastria nigripes*). *One additional capture occurred during a gear malfunction in the weighted treatment, which kept the gear at the sea surface. Including this capture event, the rate would be 4.3 birds/1,000 hooks. Safe Leads are a form of sliding weight, without a luminous coating.*

| Control | Treatment 1 | Treatment 2 | Location | Metric | Effect per 1,000 hooks | | | Source |
|---|---|---|---|---|---|---|---|---|
| | | | | | Control | Treatment 1 | Treatment 2 | |
| Unweighted | 60 g weighted swivel 3.7 m from the hook | | Hawaii, USA | A<br>A | LAAL: 0.69<br>BFAL: 0.83 | 0.06<br>0.06 | | Boggs et al. 2001 |
| Unweighted | Double-weighted branchlines, weight unspecified | | Western and central north Pacific | C<br>C | LAAL: 7.7<br>BFAL: 1.6 | 2.4 (u)<br>0.5 (u) | | Ochi et al. 2013 |
| 60 g weighted swivel 3.5 m from the hook | 60 g luminous sliding weight 3.5 m from the hook | 60 g luminous sliding weight 1.0 m from the hook | Brazil | C | 0.85 | 0.33 (u) | 0.11 (u) | Santos et al. 2016 |
| 60-75 g weighted swivel 5.5 m from the hook | 60-75 g weighted swivel 2 m from the hook | | Brazil | Attacks/ min | 0.72 | 0.18 | | Gianuca et al. 2011 |
| 75 g weighted swivel 4.5 m from the hook | 65 g Safe Lead 1 m from the hook | | Uruguay | A<br>C | 215<br>3.3 | 88 (u)<br>1.9 (u) | | Jiménez et al. 2013 |
| 75 g weighted swivel 4.5 m from the hook | 65 g luminous sliding weight 1 m from the hook | | Uruguay | A<br>C | 120<br>6.4 | 47 (u)<br>3.7* (u) | | Jiménez et al. 2019a |

### 2.2.3 Strengths

- Across almost all studies, there are no negative effects of branchline weighting on tuna and swordfish catch. Reduced shark catch reported from some studies would be positive where this species is undesirable catch.
- A reduction in unwanted fish catch has been reported from an investigation of branchline weighting in the Indian Ocean.
- Branchline weights are a component of the fishing gear and therefore can be consistently used with minimal extra work for crew.
- Branchline weights are reusable, and when luminous sliding weights are selected, cost savings ensue because lightsticks are not needed. Further, fewer crimps are required. Environmental benefits also result from avoiding the use of disposable lightsticks.
- Sliding weights offer safety benefits in case of flybacks.
- Fishers report that weighted branchlines tangle less with BSLs than unweighted gear (Turner 2021).

### 2.2.4 Limitations

- Additional safety precautions are required to work with weighted branchlines.
- Compliance monitoring of any weight to hook distance requirements must occur at sea, because weight position on branchlines can be changed (readily for sliding weights).
- Melvin et al. (2014) reported that double-weighted branchlines were more susceptible to tangling than unweighted branchlines. (They did not deploy more conventional single-weighted branchlines).

### 2.2.5 Operational considerations

- Weights require replacement when losses occur (e.g. due to bite-offs). Spares must be available to ensure ongoing use.
- Crew safety must be considered as part of the adoption and implementation of branchline weighting in pelagic longline fisheries (ACAP 2021a). Vessel safety plans and crew training should set out how to implement line-weighting safely.
- As with stored longline gear in general, branchline tangles require management. Sliding weights offer greater flexibility in that distance from the hook can be readily adjusted for storage and at deployment. Placing rubber mats between layers of gear in storage can be effective in reducing tangles (Turner et al. 2021).
- Weight losses due to bite-offs can be reduced, while weighting efficacy is maintained, by placing weights at a short distance from the hook (e.g. < 0.5 m; Robertson et al. 2013).

## 2.3 Night setting

### 2.3.1 The method

Night setting is when longline setting starts after nautical twilight, and setting is complete by nautical dawn (Table 8; ACAP 2021b). Many seabirds are less active at night than during daylight hours. Therefore, setting pelagic longlines at night limits seabird exposure to baited hooks and as a result, captures are significantly reduced (e.g. Petersen et al. 2008a; Jiménez et al. 2009). The method is especially effective for reducing albatross captures, while it is less effective for seabirds that forage before dawn and after dusk (e.g. Jiménez et al. 2020). The times at which nautical twilight and dawn occur vary by date and location, and these must be sourced from a location-appropriate nautical almanac. Night setting does not require any particular equipment or other operational changes.

Night setting is known to be less effective when moonlight is bright (e.g. Duckworth 1995; Brothers et al. 1999; Jiménez et al. 2020; Meyer and MacKenzie 2022). For example, Duckworth

(1995) reported that seabird bycatch rates increased from 0.06 per 1,000 hooks when there was little to no moonlight, to 0.24 birds per 1,000 hooks when moon illumination was high. Petersen et al. (2008c) reported that seabird bycatch rates increased from 0.09 birds per 1,000 hooks during new moon phases to 1.07 per 1,000 hooks during full moon periods (Figure 5).

Implementation monitoring of night setting can be conducted onboard (by human observers) or remotely (using satellite position information and/or EM data) (McNamara 1999; Gilman et al. 2023).

*Table 8. Summary of design standards and specifications for the best practice use of night setting (Agreement on the Conservation of Albatrosses and Petrels 2021b).*

| **Design standards and specifications** | **For all vessels** |
|---|---|
| Key elements | Setting does not take place between nautical dawn and nautical dusk, as defined by Nautical Almanac tables for relevant latitude, local time and date. |
| Implementation monitoring | Requires electronic or direct human assessment of vessel activity relative to nautical dawn and dusk. |

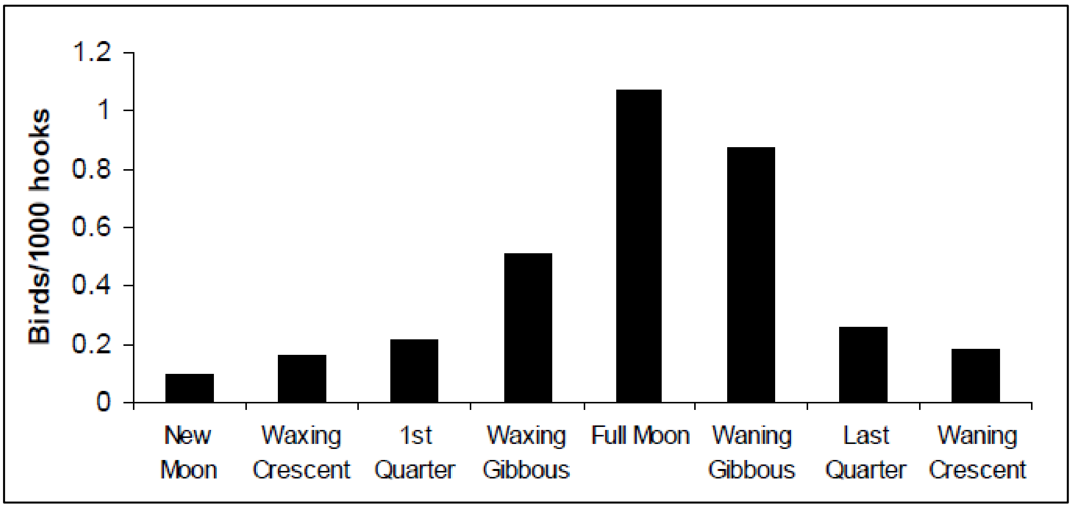



*Figure 5. The effect of moon phase on seabird mortality, recorded on pelagic longliners operating in South African waters 1998 – 2005. (Source: Petersen et al. 2008a).*

### 2.3.2 Effect on catch rates

*Fish catch rates*

Few studies have investigated the effect of night setting on fish catch, in the absence of any other seabird bycatch mitigation measure (Table 9). Gilman et al. (2023) investigated albacore tuna catch rates using information collected using electronic monitoring. While median albacore catch rates were higher for day sets compared to night sets, the difference was not statistically significant (Table 9). Petersen et al. (2008b) described reductions in tuna and swordfish catch for their 'night' setting category (statistical significance unknown) (Table 9). By contrast, when night setting was used in combination with BSLs, Melvin et al. (2013) reported increased catch rates, or no effects on catch rates (see section 4).

Numerous studies report day/night patterns in target species catch rates, irrespective of seabird bycatch considerations. For example, CPUE analysis for swordfish has found catch rates increase with the proportion of soak time that is at night in New Zealand waters (Finucci et al. 2021). Orbesen et al. (2017) found that of 18 taxa caught on pelagic longlines, catch rates of 14 varied significantly with time of day or moon phase. Skipjack and yellowfin tuna, blue and white marlin, and common dolphinfish, had higher daytime catch rates. Furthermore, diel vertical migrations of pelagic longline fishery target species are well-known (e.g. Kitagawa et al. 2000; Childers et al. 2011; Evans et al. 2014), and may affect the likelihood of interactions with fishing gear.

To better understand the potential for night setting to affect target species catch rates, investigating target species depth preferences and habitat use patterns, hook depth, any gear and operational changes between night and day sets, and time- and depth-specific catch rates is important (e.g. Bigelow and Maunder 2007).

*Table 9. Operational research examining the effect of night setting on fish catch, including target catch species. SS=Study compared species-specific catch rates, G=Catch rates compared for species groups, 'Day' and 'Night' catch rate information from Petersen et al. 2008c is used, (u)=Statistical significance is not stated in the source reference.*

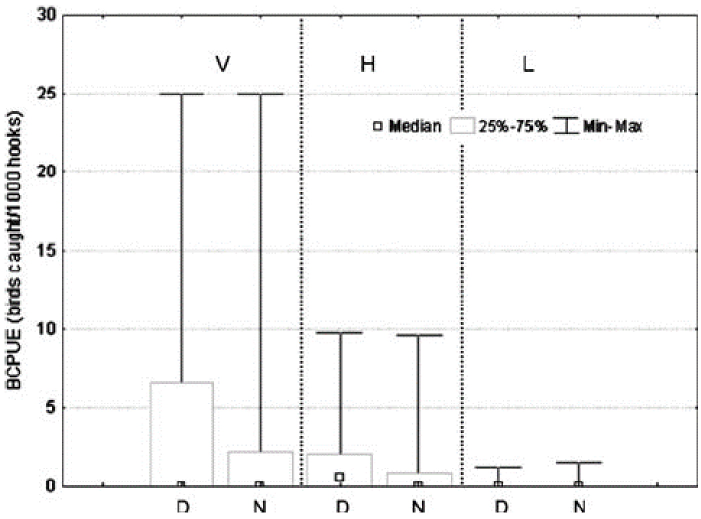
| Effect on fish catch rates | Species | Effect size | Location | Source |
|---|---|---|---|---|
| **No effect** | Albacore (SS) | | Pacific Ocean | Gilman et al. 2023 |
| **Decrease** | Tunas (G) | -14 (u) | South Africa | Petersen et al. 2008c |
| | Swordfish (SS) | -23% (u) | South Africa | Petersen et al. 2008c |

### *Seabird catch rates*

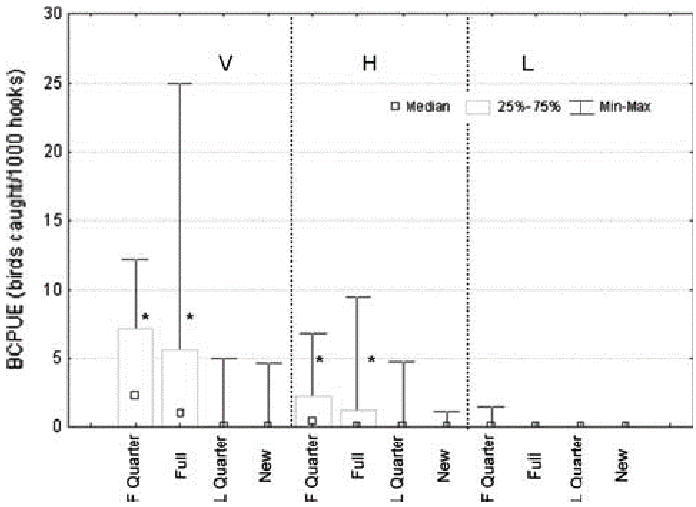
Seabird capture rates are consistently substantially lower at night than during the day (Table 10). However, while night and day are natural delineators and average bycatch rates are lower when setting occurs at night compared to daytime, moon cycle complicates the categorisation of night setting as a consistently effective mitigation measure. In some studies, a significant effect of moon phase is documented, with elevated catch rates reported during the full moon period (Table 10, Figure 5, Figure 6). From the perspective of mitigation best practice, these findings support the necessity for multiple measures to ensure seabird bycatch risk is managed during bright moons.

*Table 10. Examples of average seabird bycatch rates reported when longlines are set at night. Effects are statistically significant unless stated otherwise; ns = not statistically significant; (u)=statistical significance not stated in the source reference.*

| Location | Bycatch rate per 1,000 hooks | | Notes | Source |
|---|---|---|---|---|
| | With measure | Without measure | | |
| **Night setting** | | | | |
| New Zealand | 0.09 | 0.28 | Day/night ns. Moon phase, as a nested factor of day/night, highly significant. | Duckworth 1995 |
| Hawaii | 0.6 | 2.23 | (u) | McNamara et al. 1999 |
| Australia (East coast) | 0.38 | 0.95 | (u) Flesh-footed shearwaters only | Baker and Wise 2005 |
| South Africa | 0.09 | Highest during the day and full moon | | Petersen et al. 2008a |
| Uruguay | Lower | Higher | See Figure 6; note also the significant effect of moon phase. | Jiménez et al. 2009 |
| Uruguay | 1.21 | 5.49 | | Jiménez et al. 2019a |
| South Atlantic and southwestern Indian Oceans | Lower | Higher | Also a significant effect of moon illumination. | Jiménez et al. 2020 |
| Pacific Ocean | 0 Night-deep | 0.19 Day-shallow 0.01 Day-deep | See source for description of 'shallow' and 'deep' gear configurations. 'Day' sets were all sets not meeting the night-setting criteria. | Gilman et al. 2023 |



(a)



(b)

*Figure 6. (a) Seabird captures per 1,000 hooks for day (D) and night (N) sets and (b) during different moon phases, in very high (V), high (H) and low (L) capture areas, for May – November in Uruguayan waters. In (b), * indicates significant differences at P<0.05 (Source: Jiménez et al. 2009).*

### 2.3.3 Strengths

- No equipment or other changes in operational practice are required to implement night setting. Therefore, there are no gear purchase costs, or replacement or maintenance costs.
- The standard for night setting is clear and easily defined.
- Compliance with night setting can readily be monitored remotely electronically (Fujita et al. 2018; Winnard et al. 2018), as well as by human observers onboard vessels and aerial and at-sea patrols.

### 2.3.4 Limitations

- When moonlight is bright, additional measures should be used to mitigate bycatch risks.
- Impacts fishing effort when day sets are the norm, and may constrain effort where nights are short (i.e., high latitudes) (ACAP 2021b).
- Lightsticks and bright deck lighting may reduce efficacy of the measure (Brothers and Foster 1997; McNamara 1999; Parker 2017).
- Further investigation of night setting effects on catch and CPUE is required, and should be considered on a fishery and/or target species specific basis.

### 2.3.5 Operational considerations

- Lighting at safe levels for crew is vital, while not using unnecessary lighting which can increase attraction of fishing operations to seabirds, and associated risks of vessel collisions and bycatch (Montevecchi 2006; Lukies et al. 2021).

## 2.4 Hookpods

### 2.4.1 The method

Hookpods are a hook-shielding device endorsed by ACAP as a standalone best practice mitigation measure (ACAP 2021b). They are effective as a standalone measure because they both protect the hook from being attacked by seabirds by covering it, as well as increasing hook sink rate so the hook travels through the most seabird-accessible depths faster.

Hookpods comprise a polycarbonate case secured on the branchline, 0.5 – 3.5 m from the hook (Figure 7; Sullivan and Barrington 2021). Each hookpod closes around a baited hook for setting, preventing seabirds from accessing the hook and becoming caught. The hookpod then opens via pressure release system, at a pre-set depth (10 m – 20 m) or after a pre-set time period (e.g. 10 mins), freeing the baited hook and enabling it to fish as normal (Figure 8). Once they have opened, hookpods remain open for the duration of the soak and during the haul. Hookpods are reusable and are reset by closing the pod by hand before storage of branchlines for the next set. They can also incorporate an LED light source which eliminates the need for disposable light sticks (Sullivan and Barrington 2021).

Performance requirements set by ACAP for hook-shielding devices such as hookpods are (ACAP 2021b):

- the device shields the hook until a prescribed depth of 10 m or immersion time of 10 minutes is reached, and,
- the device meets current recommended minimum standards for branch line weighting (ACAP 2021b, see section 2.2 above), and,
- experimental research has been undertaken to allow assessment of the effectiveness, efficiency and practicality of the technology against the ACAP best practice seabird bycatch mitigation criteria.

ACAP has endorsed two types of hookpods as meeting best practice requirements. Both of these encapsulate the barb and point of the hook during setting, until the hookpod opens at 10 m depth (ACAP 2021b):

- Hookpod-mini, providing a minimum of 48 g weight at the hook
- Hookpod-LED, providing a minimum of 68 g weight at the hook.

Hookpod-minis are available at a per unit cost of £7.95. Further, Hookpod-LEDs are priced at £9 per unit (B. Ingham, pers. comm.), providing for substantial savings on disposable lightsticks. Sullivan et al. (2018) reported estimated savings of tens of thousands of US dollars resulting from not using lightsticks in Australian and Brazilian pelagic longline fisheries. Environmental benefits due to reduced marine pollution are also expected when single-use lightsticks are not incorporated in the gear set. Cost efficiency of hookpods is improved further by the units being reusable with a lifespan of up to three years or more, and also acting as a standalone seabird bycatch reduction measure in some regulatory contexts (see WCPFC CMM2018-03[4]).

[4] https://www.wcpfc.int/doc/cmm-2018-03/conservation-and-management-measure-mitigate-impact-fishing-highly-migratory-fish [Accessed 24 March 2023]

Port inspections are feasible for assessing potential hookpod use, because hookpods are integral to the gear when fitted (and most easily fitted when the branch line is being built, prior to the hook being crimped on). Removing hookpods would be relatively onerous at sea, with this requiring replacing or cutting and reconfiguring all branchlines to eliminate hookpods (Barrington 2016). It is possible that crew may choose not to set hookpods at sea, and monitoring usage during longline sets is readily achievable by human observers and electronic monitoring systems.

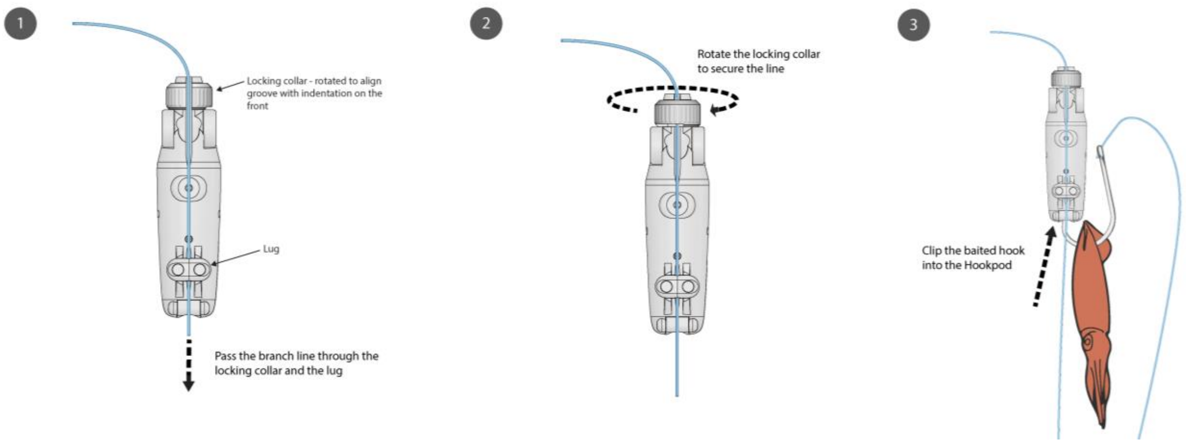



*Figure 7. Hookpod attachment to the branchline of a pelagic longline. (Source: B. Ingram, Hookpod Ltd).*

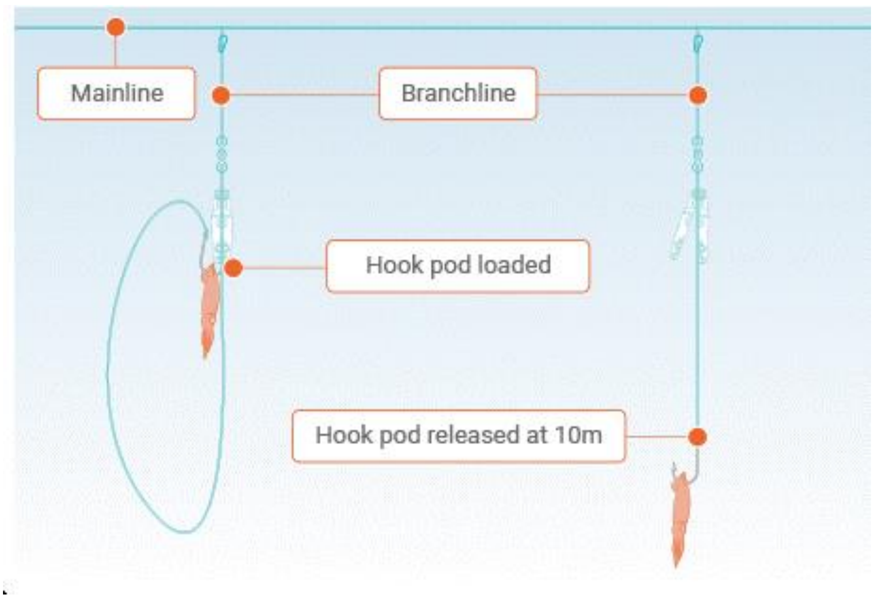



*Figure 8. Schematic showing how the hookpod works to protect baited hooks and open at depth. (Source: B. Ingram, Hookpod Ltd).*

### 2.4.2 Effect on catch rates

#### *Fish catch rates*

In two studies, catch rates of tunas and swordfish did not differ significantly between branchlines carrying hookpods, and weighted branchlines (plus BSL in one study) (Table 11). Results for other fish caught were mixed, with one study each reporting no effect and a significant reduction in catch rates for sharks, and all other fish, on branchlines carrying hookpods (Table 11).

*Table 11. Impact of hookpods on target species/group catch rates in pelagic longline fisheries. BSL=Bird-scaring line, SS=Species-specific catch rates, G=Catch rates for species groups. *Models were fitted treating the number of animals caught/total number of hooks for each species or group as a response variable (Sullivan et al. 2018). Effect sizes are significant where shown.*

| Effect on fish catch rates | Control | Treatment(s) | Species/groups | Effect size | Location | Source |
|---|---|---|---|---|---|---|
| **No effect** | Branchlines with 60-75 g weighted swivel, 3.5 m from the hook | Hookpod-mini (48 g) with 60-75 g swivels, 3.5 m from the hook, opening at 20 m depth | Tunas (G)<br>Swordfish (SS)<br>Sharks (G)<br>All other fish catch (G) | | Brazil | Gianuca et al. 2021 |
| | Branchlines with 60-80 g weighted swivel, 2-7 m from the hook with light stick; BSL | Hookpod-LED (65 g), 1-7 m from the hook, opening at 10 m depth | Tunas (G)<br>Swordfish (SS) | | Australia<br>Brazil<br>South Africa | Sullivan et al. 2018 |
| **Decrease** | Branchlines with 60-80 g weighted swivel, 2-7 m from the hook, plus light stick; BSL | Hookpod-LED (65 g), 1-7 m from the hook, opening at 10 m depth | Sharks (G) | -0.14* | Australia<br>Brazil<br>South Africa | Sullivan et al. 2018 |
| | Branchlines with 60-80 g weighted swivel, 2-7 m from the hook with light stick; BSL | Hookpod-LED (65 g), 1-7 m from the hook, opening at 10 m depth | All other fish catch (G) | -0.21* | Australia<br>Brazil<br>South Africa | Sullivan et al. 2018 |

*Seabird catch rates*

Seabird captures when hookpods are in use were lower than reported for other measures in two studies (Table 12).

Goad et al.'s (2019) work reported very similar bycatch rates for their treatment and control configurations, but with a single bird each caught on branchlines carrying hookpods and other branchlines, inferences that may be drawn regarding bycatch rates are limited.

*Table 12. Seabird bycatch rates reported with and without hookpods in use. *Note that Sullivan et al. (2018) also reported the capture of three additional seabirds during one haul. These were excluded from the analysis due to the circumstances of the capture event (the gear became entangled after a killer whale* Orcinus orca *interaction, and the crew took a lunch break while the hooks remained in surface waters for an extended time).*

| **Location** | **Bycatch rate per 1,000 hooks** | | **Notes** | **Source** |
|---|---|---|---|---|
| | **With measure** | **Without measure** | | |
| South Africa<br>Brazil<br>Australia | 0.04 | (with BSL, branchline weighting)<br>0.8 | (u)<br>A single seabird capture occurred when hookpods were deployed. | Sullivan et al. 2018+ |
| Brazil | 0 | 0.13 | (u)<br>Without measure = vessels without gear containing hookpod-mini units | Gianuca et al. 2021 |

## 2.4.2 Strengths

- Hookpods are an effective standalone best practice seabird bycatch reduction measure. Therefore, BSLs or other measures are not required to meet best practice and some regulatory requirements.
- Hookpods readily integrate into normal crew operations.
- Presence of hookpods on gear can be monitored effectively in port, which does not mean hookpods will be set at sea but is critical for them to be used.
- Use at-sea can be readily monitored by human observers or electronic monitoring.
- Potential for marine litter is reduced as hookpods are reusable, not disposable. In addition, lightsticks are not needed, leading to cost savings and a reduction in litter.

## 2.4.3 Limitations

- There is potential for seabird entanglement in the looped length of branchline, before the hookpod opens (ACAP and Birdlife International 2021a).
- Hookpods appear relatively expensive as a mitigation measure, which may reduce uptake. However, cost effectiveness must be considered throughout the life of a pod unit, including in light of savings on other gear elements (lightsticks, crimps).

## 2.4.5 Operational considerations

- Time taken to set hookpods at longline setting and reset them after hauling is offset where there is no need to attach and remove disposable lightsticks (Sullivan et al. 2018).
- Crew will require initial training on fitting and using hookpods.
- Like any component of fishing gear, over time, hookpods will require replacement as breakages and losses occur. Spares should be carried to ensure ongoing usage.
- Hookpods grip monofilament line in the same way as a sliding weight and reduce hazard to crew in the event of a bite-off. Hookpods are less effective in the event of a tear-out as they can break into fragments.

# 3. Emerging best practice measures

## 3.1 Underwater bait-setting devices

Setting baits underwater takes them out of diving range for albatrosses, and makes accessing baits more arduous (and therefore less attractive) for deeper diving seabirds such as petrels and shearwaters. Underwater setting removes the visual stimulus of bait regularly appearing on the sea surface (Barrington 2021). Associated olfactory stimuli are also likely to be reduced.

Underwater bait setting has been the subject of research and development for more than a decade (Robertson et al. 2015, 2018). Experimental and operational deployments have been conducted, investigating bait retention, seabird captures and fish catch composition (Robertson et al. 2018, 2020; Barrington 2021).

Now, an underwater bait setter is commercially available from Skadia Technologies[5]. It is this device that has been endorsed as a best practice measure by ACAP (ACAP 2021b). The device deploys baited hooks individually underwater via a track installed on the vessel's transom (Figure 9). Hooks are enclosed in a capsule until the target depth is reached. The capsule is pulled quickly underwater to a pre-set target depth. The depth can be adjusted, e.g., in response to the diving capabilities of seabirds attending the vessel. The Skadia Technologies underwater bait setter meets the performance requirements set by ACAP (ACAP 2021b; Barrington 2021), because:

- the device deploys encapsulated hooks in a vertical manner at the stern of the vessel until a minimum prescribed depth of 5 m is reached;
- branchlines are weighted in accordance with ACAP's recommended minimum standards; and
- experimental research has been undertaken to allow assessment of the effectiveness, efficiency and practicality of the technology against the ACAP best practice seabird bycatch mitigation criteria developed for assessing and recommending best practice advice on seabird bycatch mitigation measures.

Monitoring the use of the underwater bait setter can be undertaken at sea by observers, or electronic monitoring (where crew activity patterns evident on the vessel would indicate the underwater bait setter was in use). Use can also be verified retrospectively because the device automatically records the date, time, location and release depth each time it is cycled. Records are stored on a hard drive on the vessel (Barrington 2021).

The underwater setting device is available commercially at an indicative cost of AUD$50,000 (K. Lawton, pers. comm.). To help operators consider their purchase, the Skadia Technologies website provides an online cost-benefit tool. The tool evaluates when the device becomes cost neutral and yields commercial economic benefits, based on monthly vessel operating costs and bait losses, and the device's lifetime cost including maintenance. The device may also be leased, again with the costs and benefits of this able to be explored using the website tool[6].

[5] https://skadiatech.com/ [Accessed 20 March 2023]
[6] https://skadiatech.com/buy#economics [Accessed 20 March 2023]

Effects of the underwater bait setter on catch were reported by Robertson et al. (2018). Commercial fish catch was not significantly different when the underwater bait setter was used. However, non-commercial fish catch and seabird catch both decreased significantly (Table 1). Further, the proportion of sets with no non-commercial catch and no seabird catch increased significantly when the bait setter was used (75% increasing to 95% of sets with zero catch of non-commercial fish, and 85% to 98% of sets with zero seabird catch). Seabird catch rates decreased from 1.3 to 0.16 birds per 1,000 hooks when setting was conducted with the device, compared to normal hand-setting of lines (Robertson et al. 2018).

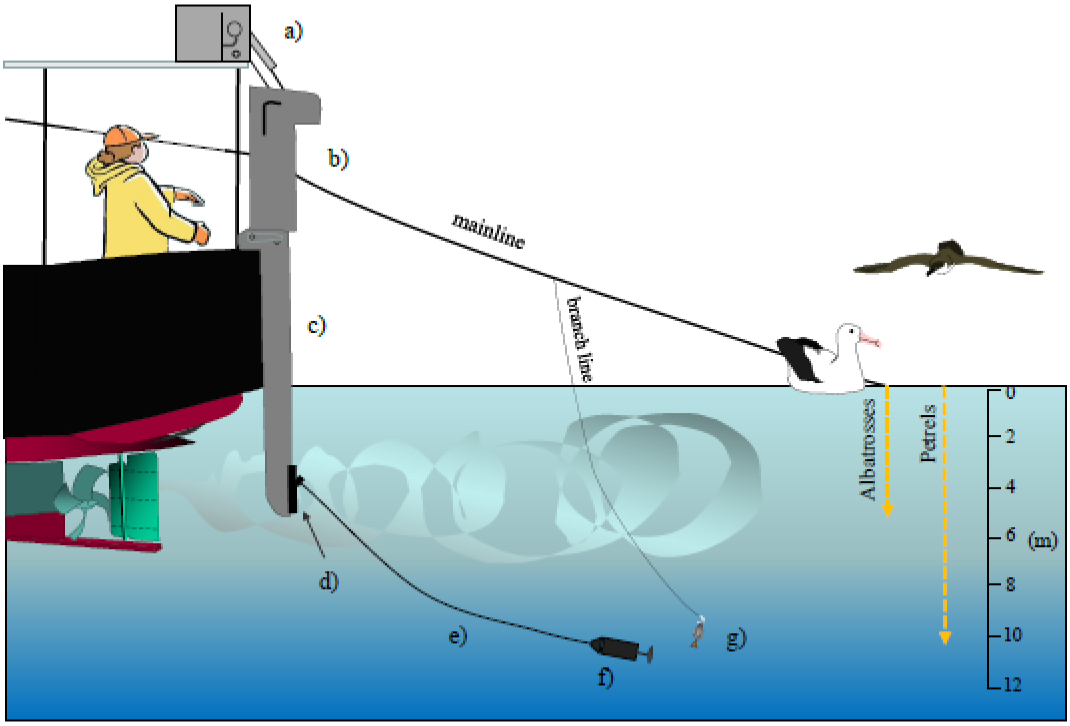



*Figure 9. Schematic of the underwater bait setter recognised as best practice by the Agreement on the Conservation of Albatrosses and Petrels (not to scale). Components parts are: (a) winch assembly, (b) head section of the track assembly, (c) the track attached to the vessel transom, (d) capsule docking cart, (e) Spectra rope connecting the capsule to the recovery motor winch, (f) capsule with bait door fully extended and (g) baited hook following release from the capsule. The system's control unit is located in the wheelhouse and operated by the skipper. Dive depths of the main seabird groups are indicated on the right. The curved shapes above the capsule depict water thrust from the propeller. (Source: Robertson et al. 2015).*

*Table 13. Effects of the underwater bait setter on catch composition (number of catch items). SS=Species specific catch rates, G=Catch rates for species groups. Effect sizes are significant where shown.*

| Effect on fish catch rates | Control | Treatment(s) | Species/groups | Effect size | Location | Source |
|---|---|---|---|---|---|---|
| **No effect** | Hooks set by hand (normal practice) | Hooks set using underwater bait setter | Albacore (SS)<br>Yellowfin (SS)<br>Swordfish (SS)<br>Blue shark (SS)<br>Other commercial fish (G) | | Uruguay | Robertson et al. 2018 |
| **Decrease** | Hooks set by hand (normal practice) | Hooks set using underwater bait setter | Non-commercial fish (G) | -38% | | |
| | | | Seabirds (G) | -87% | | |

# 4. Using seabird bycatch mitigation measures in combination

ACAP recommends the simultaneous use of branchline weighting, night setting and BSLs in pelagic longline fisheries (ACAP 2021b). These measures work in different ways, to provide a multifaceted system of protection. BSLs present a deterrent and physical barrier that limits seabird access to the longline hooks, hooks sink out of seabird reach faster on weighted branchlines (effectively also reducing the distance astern that must be protected by BSL aerial extent), while darkness works to conceal the baited hooks being set (Figure 10). However, if one of the three measures is not in place – e.g. a gear tangle occurs that reduces sink rates, or the moonlight is bright – branchline hooks are less protected and seabird bycatch risks are immediately higher. When viewed as an integrated system of risk management, the logic of using a combination of the three measures is evident as each measure operates via a unique mechanism.

Hookpods and the underwater bait setter are identified as best practice as standalone measures. Hookpods cover the hook barb and point during setting, and sink faster as a result of their weight (noting that additional weight can be incorporated in the unit). The underwater bait setter takes seabird risks associated with the setting process to depth that albatrosses can't reach, and that petrels and shearwaters are unlikely to reach in many dives. Therefore, the way these methods work results in their standalone efficacy.

No negative effects of the use of multiple mitigation measures on target catch rates have been reported (Table 14), and effects of various combinations of measures on seabird bycatch have been documented (Table 15). Statistical significance is not available for most studies, noting the extent of threatened seabird mortality that this would require (see section 2.2.2). However, reductions in bycatch are consistently evident with two and three mitigation measures in place. Further, the efficacy of combinations of mitigation measures (i.e. BSLs, branchline weighting, night-setting) is shown among species assemblages that include white-chinned petrels, a species that presents particular challenges for bycatch reduction. This species is capable of diving below 10 m at velocities faster than pelagic longline gear sink rates, that is active during the day and night, and tenaciously follows fishing vessels (Frankish et al. 2021). Seabird bycatch in assemblages dominated by this species was reduced to zero with BSLs, branchline weighting, and night setting in place (Table 15; Melvin et al. 2014; Jimenez et al. 2019a).

The benefits of implementing more than one measure are also emphasised when secondary attacks are considered. Melvin et al. (2013) defined secondary attacks as one bird bringing a bait/baited hook to the surface, and another bird moving in to attack the bait. Among the seabird assemblage present in South African waters where their work took place, white-chinned petrels retrieved baits that were then targeted at the sea surface by foraging albatrosses. In both their 2013 and 2014 work, Melvin et al. reported that this interaction drove albatross mortalities. The combination of weighting branchlines and BSLs reduced these secondary attacks from 58% to 33%, as a percentage of all attacks, compared to when branchlines were unweighted (Melvin et al. 2014). Melvin et al. (2014) emphasised that the aerial extent of BSLs should be considered in the context of the diving capabilities of species that can bring baits to the sea surface (when the baits then become available to surface foragers).

*Table 14. Research examining the effect of multiple seabird bycatch mitigation measures on fish catch rates in pelagic longline fisheries. (u)=Statistical significance not stated. *Fish catch rates were positively correlated with soak time, and daytime sets were of shorter duration. Safe leads and double-weighted branchlines were used by Melvin et al. (2013) in weighted gear treatments. Albacore was excluded from their 2013 analysis, due to inconsistent catch recording. Double-weighted branchlines were used by Melvin et al. (2014).*

| Effect on fish catch rates | Total catch | Effect size | Location | Source |
|---|---|---|---|---|
| **Bird-scaring lines and night setting (c.f. bird-scaring lines and day setting)** | | | | |
| **Increase** | Tuna, billfish | +52% (u) | South Africa | Melvin et al. 2013 |
| **No effect** | Tuna, billfish | | South Africa | Melvin et al. 2014 |
| **Bird-scaring lines and branchline weighting (c.f. bird-scaring lines and unweighted branchlines)** | | | | |
| **No effect** | Tuna, billfish | | South Africa | Melvin et al. 2013 |
| | Tuna, billfish | | South Africa | Melvin et al. 2014 |
| **Bird-scaring lines, night setting and branchline weighting (c.f. bird-scaring lines, day setting and unweighted branchlines)** | | | | |
| **Increase** | Tuna, billfish | +38% (u)* | South Africa | Melvin et al. 2013 |
| | Tuna, billfish | +* | South Africa | Melvin et al. 2014 |
| **Hookpods, bird-scaring lines and night setting (c.f. bird-scaring lines, night setting)** | | | | |
| **No effect** | Bigeye tuna (SS)<br>Tunas (G)<br>Blue shark (SS)<br>Sharks (G) | | New Zealand | Goad et al. 2019 |
| **Hookpods and night setting (c.f. branchline weighting, night setting)** | | | | |
| **No effect** | Southern bluefin tuna (SS)<br>Tunas (G)<br>Blue shark (SS)<br>Sharks (G) | | New Zealand | Goad et al. 2019 |

*Table 15. Experimental and operational research examining the effect of multiple seabird bycatch mitigation measures on seabird interactions in pelagic longline fisheries. (u)=Statistical significance not stated in the source reference, ns=not statistically significant. C=Captures, A=Attacks on baits, LAAL=Laysan albatross (*Phoebastria immutabilis*), BFAL=black-footed albatross (*Phoebastria nigripes*), BSL=bird-scaring line, [S]=Single BSL, [P]=Paired BSLs. **Double weighted branchlines used, noting that safe leads and double-weighted branchlines were deployed by Melvin et al. (2013) in different weighted gear treatments.*

| Location | Metric | Interaction rate per 1,000 hooks | | Notes | Source |
|---|---|---|---|---|---|
| | | With measures | Without measures | | |
| **Bird-scaring lines and night setting** | | | | | |
| New Zealand | C | 0.10 | 0.28 | After fishing location, BSL quality and set time/moon phase were the factors most explanatory of seabird bycatch rates.<br>(u) for comparison with/without both measures. | Duckworth 1995 |
| Australia | C | 0.02 | (with BSLs)<br>0.25 | BSLs were in place for all sets; bycatch rates of day and night sets were compared (and differed significantly). | Klaer and Polacheck 1998 |
| South Africa (Japanese vessels) | C | 0.44 | (with BSLs)<br>2.0 | (u) [P]** | Melvin et al. 2013 |
| South Africa (Japanese vessels) | C | 0.06 | (with BSLs) 0.63 | (u) [P]** | Melvin et al. 2014 |
| South Atlantic and southwestern Indian Oceans | C | Lower | Higher | Significant bycatch reduction at night with measure; not during the day (may be due to inconsistent usage, quality of BSLs, entanglements/breakages).<br>Authors note caveats on the dataset available for analysis. | Jiménez et al. 2020 |
| Uruguay | C | 0.28 | 5.49 | (u) | Jiménez et al. 2019a |
| **Bird-scaring lines and branchline weighting** | | | | | |
| South Africa (Japanese vessels) | C | 0.06 | (with BSLs)<br>1.07 | (u) [P]** | Melvin et al. 2013 |

| | | | | | |
|---|---|---|---|---|---|
| South Africa (Japanese vessels) | <br>A<br>C | <br>9.8<br>0.12 | (with BSLs)<br>40.6<br>0.63 | <br>[P]** | Melvin et al. 2014 |
| Western and central north Pacific | C<br><br><br>C | LAAL:<br>[S] 0<br>[P] 0.10<br>BFAL:<br>[S] 0<br>[P] 0 | 7.7<br><br><br>1.6 | (u)** | Ochi et al. 2013 |
| Brazil | <br>A | <br>0.17 | (no BSL)<br>0.45 | In this study, attacks/min are quantified. 'With' measures attack rates decreased further, and significantly, when only weights at 2 m from hook considered (0.08 attacks/min). | Gianuca et al. 2011 |
| Uruguay | C | 0 | 5.49 | (u) Authors caution that a small sample size underpins this comparison. | Jiménez et al. 2019a |
| **Night setting and branchline weighting** | | | | | |
| Uruguay | C | 0 | 5.49 | (u) | Jiménez et al. 2019a |
| **Bird-scaring lines, night setting and branchline weighting** | | | | | |
| South Africa (Japanese vessels) | <br>C | <br>0 | (with BSLs)<br>0.63 | [P]**<br>(weighting a significant factor) | Melvin et al. 2014 |
| Uruguay | C | 0 | 5.49 | (u) | Jiménez et al. 2019a |
| **Hookpods, bird-scaring lines, night setting** | | | | | |
| New Zealand | C | 0 | (with BSL, unweighted branchlines)<br>0 | (u) | Goad et al. 2019 |
| **Hookpods and night setting** | | | | | |
| New Zealand | C | 0.18 | (weighted branchlines, sets with and without BSL)<br>0.20 | (u) | Goad et al. 2019 |

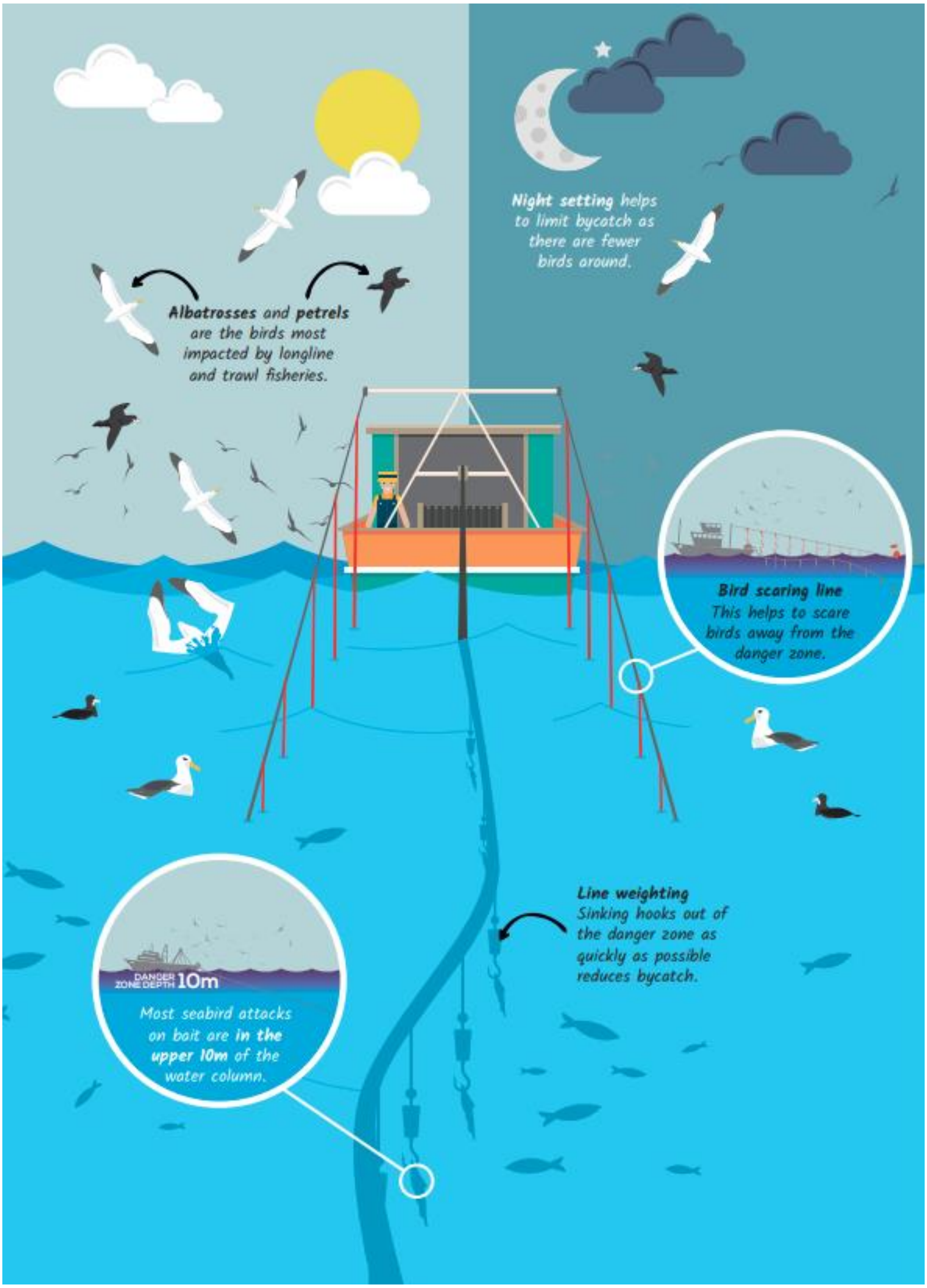



*Figure 10. Overview of the three components of bycatch risk that best practice measures of bird-scaring lines, night setting and branchline weighting address. (Source: ACAP and BirdLife International 2021b).*

# 5. Effects of seabird mitigation measures on other species of conservation concern

ACAP's definition of best practice mitigation for seabirds includes that best practice measures should not increase bycatch of other taxa. As demonstrated in the preceding sections, research investigating seabird bycatch sometimes also investigated the effects of mitigation measures on fish catch. However, impacts on other taxa have rarely been quantified.

Jiménez et al. (2019b) evaluated the effects of branchline weight distance to pelagic longline hooks, and BSLs, on 13 species of elasmobranchs, sea turtles, fur seals and non-target teleost fish. Increased catch rates of these taxa were not linked to experimental treatments. However further research on the effect of branchline weighting on porbeagle was recommended, and the authors noted that power constraints precluded the detection of small effect sizes in the study (Jiménez et al. 2019b).

The effects of hookpods and the underwater bait setter on turtle bycatch rates were considered by Gianuca et al. (2021) and Robertson et al. (2018). There was no significant effect on turtle catch rates (comprising leatherback and loggerhead turtles) between gear fitted with hookpods and the control used (turtle catch per 1,000 hooks of 1.04 and 1.17 on hookpod and control gear, respectively (Gianuca et al. 2021)). Similarly, Robertson et al. (2018) reported no significant difference in loggerhead turtle catch rates during routine surface longline setting, compared to when the underwater bait setter was used.

Habitat use patterns (noting diel vertical migration patterns) will influence the impacts of night setting on other taxa (e.g., Gilman et al. 2019). While not reported from studies investigating seabird bycatch, numerous other studies analysing temporal patterns in catch rates are available. For example, Gilman et al. (2012) reported declines in standardised catch rates for blue and oceanic whitetip sharks for sets made after 07:00, while swordfish and sea turtle catch rates were higher for sets made after 07:00 and 09:00. Santos Rodrigues et al. (2022) also explored catch rates of various taxa in relation to setting time (including tunas, swordfish, sharks, turtles, and excluding seabirds). While results for individual taxa varied, the researchers concluded that starting sets between 18:00 and 0:00 optimised benefits among taxa considered (Figure 11).

Information collected by government fisheries observers deployed on pelagic longline fishing vessels supported a recent exploration of potential effects of seabird bycatch mitigation measures on New Zealand fur seals and marine turtles (Meyer and MacKenzie 2022). Information used in the analyses was collected from smaller longline vessels over a twelve-year period. Fur seal captures decreased with increasing night-time soak hours. Captures increased when a BSL was in use, however the mechanism for this increase is uncertain and BSL usage was correlated with other variables that may account for the relationship (e.g., presence of an onboard freezer). Turtle models had poor predictive ability, attributed to insufficient data (Meyer and MacKenzie 2022).

While often resulting from a piecemeal approach, research findings that are available emphasise the important of considering the effects of bycatch reduction strategies across taxa. Gilman et al. (2019) emphasise the need for fisheries management to transition from considering bycatch on a single species or taxonomic group basis, to an integrated and holistic assessment of fishery risks. An approach to the development of a decision-support tool is set out by Gilman (et al. 2019) to enable this. Managing bycatch across multiple taxa to minimise negative impacts will require fishery managers to make choices about relative priorities for fisheries management, risks, and conservation concerns.

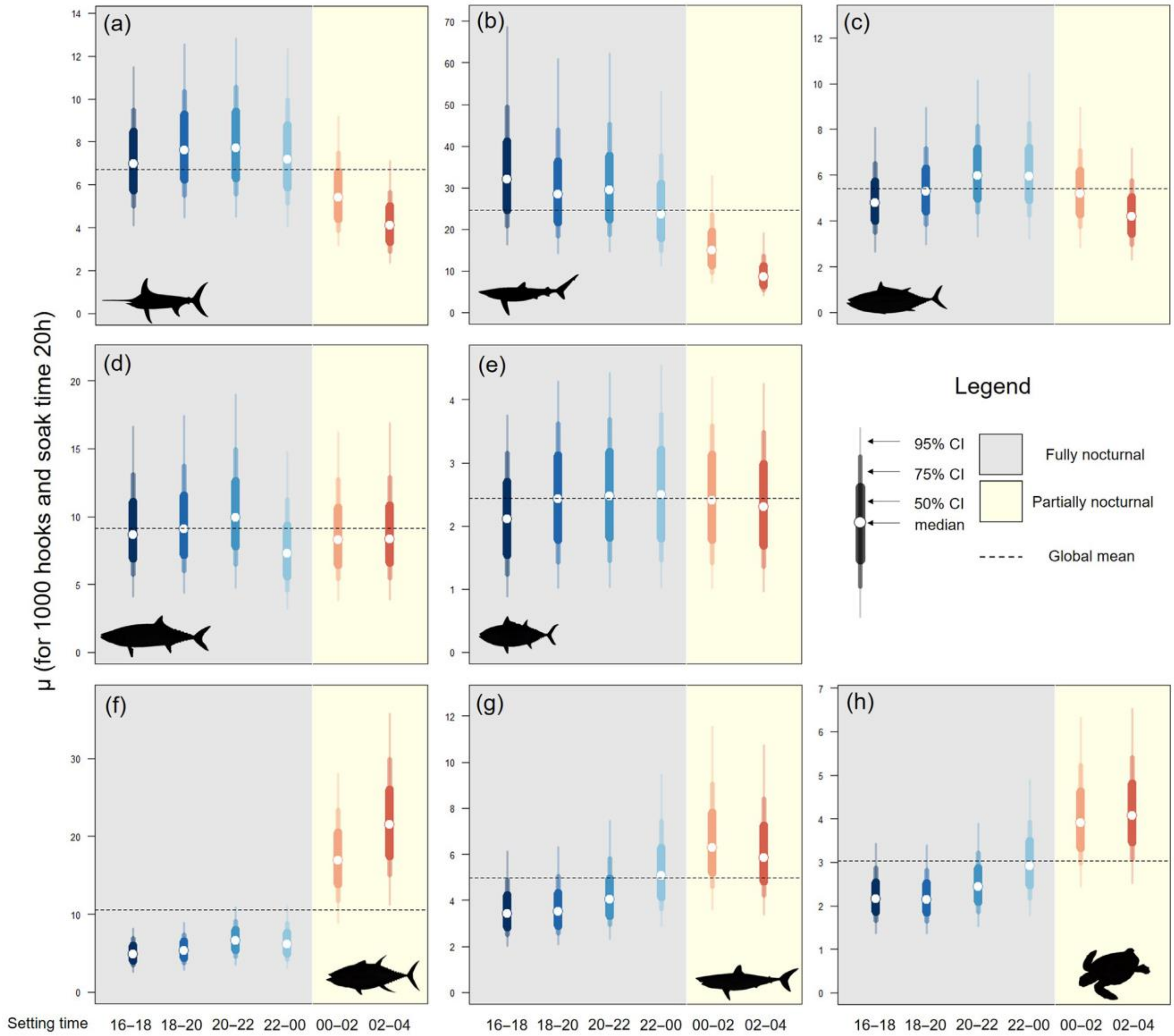



*Figure 11. Posterior distributions by Markov chain Monte Carlo simulation of Bayesian beta mixed regression models for each set start time. The values of μ are the number of individuals caught considering a set with 1,000 hooks and a soak time of 20 h for (a) swordfish, (b) blue shark, (c) albacore, (d) escolar, (e) bigeye, (f) yellowfin, (g) shortfin mako shark, and (h) loggerhead turtle. The coloured bars are the 50, 75, and 95% credibility intervals. These data are the result of selected models chosen using Deviance Information Criteria. Background colours indicate possible fully nocturnal set (grey) or possible partially nocturnal set (yellow). The dashed horizontal line indicates the global mean. (Source: Santos Rodrigues et al. 2022).*

# 6. Economic benefits of seabird bycatch reduction

Specific costs of mitigation measures are presented in the previous sections. However, beyond equipment costs, there are broader costs incurred and benefits accrued from the use of seabird bycatch reduction measures. These are summarized in Table 16, and discussed further in the following sections. Fishing vessel crew are central to realising the economic benefits offered by seabird bycatch mitigation. Crew are expected to be most incentivised when they experience benefit themselves from implementing these measures.

*Table 16. Overview of costs and benefits of best practice seabird bycatch reduction measures for pelagic longline fisheries, from an industry perspective. (Source: Pierre and Clough 2021).*

| Mitigation measures | Branchline weighting | Night setting | Bird-scaring lines | Hookpods |
|---|---|---|---|---|
| **Costs** | | | | |
| Crew training, implementation | ✓ | ✓ | ✓ | ✓ |
| Equipment purchase and installation | ✓ | | ✓ | ✓ |
| Fishing opportunity | | ? | | |
| Monitoring compliance | ✓ | ✓ | ✓ | ✓ |
| **Benefits** | | | | |
| Bait retention | ✓ | ✓ | ✓ | ✓ |
| Crew time saved releasing captured seabirds and repairing gear | ✓ | ✓ | ✓ | ✓ |
| Avoidance of new fishing restrictions (e.g. area/seasonal closures) | ✓ | ✓ | ✓ | ✓ |
| Reduced monitoring costs linked to bycatch risks | ✓ | ✓ | ✓ | ✓ |
| Growth of social licence and brand value | ✓ | ✓ | ✓ | ✓ |
| Shore-based industry supported | ✓ | ✓ | ✓ | ✓ |

## 6.1 Bait retention

Every hook that catches a seabird cannot catch a fish, representing a bait that was not used effectively. Quantitative information on the extent of bait removed from longline hooks by seabirds is scarce. For pelagic longline fisheries, the available estimates range from 0.2 – 2.9% (Brothers et al. 1991; Sànchez and Belda 2003; Rollinson et al. 2017). Depending on their scale, pelagic longline fisheries operating in the Pacific Ocean can use tens to thousands of tons of bait per year (Appendix 1). Losses that render 3% of bait ineffectual appear to be non-trivial at the scale of such fishing operations.

Mancini et al. (2009) reported that the increased fish catch linked to the use of BSLs in their study fishery operating off Brazil resulted in economic gains of around USD$10,000 per 20-25 day trip per vessel. Brothers (1991) reported bait losses of 29.1 baits per 1,000 hooks set to a distance of 200 m astern, when no BSL was used. When a BSL was in place, 8.6 baits were lost per 1,000 hooks (to 200 m astern). Both albatrosses and petrels removed baits (Brothers 1991). Overall, Brothers (1991) concluded that such bait losses could reduce target catch by 0.8%, and an estimated a loss of AUD$7.2 million over 107.9 million hooks set in the Southern Ocean during 1981 - 1986. Further, the use of a BSL represented an annual saving of AUD$4.9 million for this fishery, and a commensurate bycatch reduction of an estimated 30,300 albatross.

## 6.2 Growth of social licence and brand value

Seabirds are charismatic species of high public interest in many countries. Stakeholder (including consumer) knowledge of bycatch and interest in purchasing sustainably, legally and ethically sourced seafood is increasing globally (CARC 2019). Furthermore, globally significant retailers have sustainable sourcing policies for seafood in place, e.g., WalMart, Tesco, WholeFoods, Sainsbury's, Woolworths, Marks and Spencer, CostCo and many others.

Third-party certification schemes and ecolabels provide a form of assurance that seafood has been harvested sustainably (and/or ethically, depending on the scheme). While seafood certification schemes and ecolabels have proliferated over time (Diversified Communications 2020), MSC is currently the most prominent globally, accounting for 14% of global marine wild catch. Retail sales of MSC-labelled products have been reported at USD$10 billion[7]. Price premiums and improved market access (e.g., access to export markets, increased distribution channels) are described among a range of MSC-certified fisheries (Uchida et al. 2013; Agknowledge 2015; Blomquist et al. 2015; Lallemand et al. 2016; Stemle et al. 2016; Asche and Bronnmann 2017; Blandon and Ishihara 2020; van Putten et al. 2020). Other reported benefits include (Agknowledge 2015; Adolf et al. 2016; Lallemand et al. 2016; Blandon and Ishihara 2020; van Putten et al. 2020):

- product differentiation in the market
- improved social licence, noting that the MSC ecolabel represents a well-trusted[8] brand
- better management such that longer term fishery sustainability is assured
- up-to-date management that enables industry to remain competitive amidst emerging market trends
- assurance that supply failure is a low risk, such that business lending opportunities improve
- improvement in stakeholder involvement
- improved resource control by sovereign states.

MSC certification has precipitated improvements in seabird monitoring (e.g., data collection to record bycatch), management (e.g., time/area closures), gear modification (e.g., use of BSLs) and impact assessment (e.g., at the population level). In 2019, 36 seabird-related improvements had been required to secure fishery certification by MSC (MSC 2019). Such examples link seabird-related improvements in fishery performance to direct benefits for industry. The MSC completed a fisheries standard review in 2022. Version 3.0 of the Standard specifically mentions the implementation of best practice bycatch reduction measures (MSC 2022).

## 6.3 Exploratory cost/benefit profile of implementing best practice mitigation

Pierre and Clough (2021) conducted an exploratory analysis of the costs and benefits of using best practice mitigation measures (BSLs, night setting, line-weighting, hookpods) in pelagic longline fisheries, against a counterfactual of operating without mitigation in place. They considered economic benefits for smaller and larger scale operations, with modelling supported by information from published literature.

The results show that under assumptions and information reflected in the published literature, seabird mitigation can have positive economic impacts that exceed the costs of its implementation. To test this further, the authors recommended that their preliminary findings were ground-truthed using information from a specific real-world pelagic longline fishery (Pierre and Clough 2021).

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[7] https://www.msc.org/media-centre/press-releases/press-release/sustainable-seafood-sales-reached-an-all-time-high-as-shoppers-cooked-at-home-in-2020-21 [Accessed 8 February 2023]
[8] https://www.msc.org/understanding-seafood-consumers [Accessed 8 February 2023]

# 7. Conclusion

There is empirical evidence that the use of BSLs, branchline weighting, and night setting all significantly reduce bycatch of albatrosses and petrels in pelagic longline fisheries. There is also evidence that these measures effect significant bycatch reductions when deployed in combination. Hookpods and the underwater bait setter are more recently developed best-practice measures which also deliver reductions in seabird bycatch. Evidence comprises experimental and operational studies with varying geographic scopes, species assemblages, fishery target species, and statistical analyses.

Fishery and conservation managers routinely weigh up evidence that is variable in quantity and quality, in the course of decision-making. A heterogenous body of evidence ought not to constrain decision-making. Rather, the analytical approach taken to support decisions must be appropriate to the evidence available (Gilman and Chaloupka 2022). Through recent decades, information available on the efficacy of seabird bycatch has ascended this evidence hierarchy, starting with qualitative information and observation and now also encompassing observational data to which statistical analyses have been applied, mechanistic studies, and randomised controlled trials. Relative consistency of findings among the diverse studies reported supports a weight-of-evidence conclusion regarding the efficacy of the mitigation measures that are the focus of this report. That does not mean research and the evidence base cannot be improved. However, it should mean that implementation is progressed with knowledge gaps in mind, such that appropriate information collection can continue to improve bycatch management over time.

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## Appendix 1. Characteristics of selected Pacific Ocean pelagic longline fisheries, including bait usage

| Fishery | Hooks per set | Hooks per year | Target species catch (t) | Bait species volume reported per year (t) | Source |
|---|---|---|---|---|---|
| Solomon Islands EEZ albacore and yellowfin tuna | 2,500 – 3,000 | 5 – 8.4 million | Albacore: 416-595<br>Yellowfin: 628-777 | Goldstripe sardinella: 770 | https://fisheries.msc.org/en/fisheries/solomon-islands-longline-albacore-and-yellowfin-tuna-fishery/@@view |
| Marshall Islands EEZ yellowfin and bigeye tuna | 1,250 | ~325,000 | Yellowfin: 1,155-1,322<br>Bigeye: 1,596-1,661 | Indian oil sardine: 3,788<br>Chub mackerel: 233<br>Pacific saury: 195 | https://fisheries.msc.org/en/fisheries/mifv-rmi-eez-longline-yellowfin-and-bigeye-tuna/@@view |
| French Polynesia EEZ albacore and yellowfin tuna | Usually <3,000 | | Albacore: 3,367-2,905<br>Yellowfin: 1,069-758 | Japanese sardine: 933<br>Pacific saury: 467<br>Mackerel/squid: 155 | https://fisheries.msc.org/en/fisheries/french-polynesia-albacore-and-yellowfin-longline-fishery/@@view |
| Australian Eastern Tuna and Billfish Fishery | ~1,600-1,700 | 7.90 – 8.57 million | Yellowfin: 1,517-1,714<br>Albacore: 889-992<br>Bigeye: 367-450<br>Swordfish: 1,027-1,080 | Australian sardine: 90-94<br>Yellowtail scad: 99-169<br>Argentine squid: 679-864<br>Blue mackerel, jack mackerel, redbait: 54-83 | Patterson et al. 2020<br><br>https://fisheries.msc.org/en/fisheries/australian-eastern-tuna-and-billfish-fishery-albacore-tuna-yellowfin-tuna-bigeye-tuna-and-swordfish/@@view<br><br>https://data.gov.au/data/dataset/b36304ae-4e15-4d5c-abe2-097a57a05b25/resource/1149cf90-efe0-4a1f-87f7-24cd0a9db0f2/download/annual-logbook-effort-data-29-06-2020.xlsx |

## Appendix 2. Scientific names of species mentioned in the text

Fish:

Albacore tuna (*Thunnus alalunga*)

Argentine shortfin squid (*Illex argentines*)

Barracouta (*Thyrsites atun*)

Bigeye tuna (*Thunnus obesus*)

Blue mackerel (*Scomber australasicus*)

Blue marlin (*Makaira nigricans*)

Blue shark (*Prionace glauca*)

Chub mackerel (*Scomber japonicus*)

Common dolphinfish (*Coryphaena hippurus*)

Escolar (*Lepidocybium flavobrunneum*)

Goldstripe sardinella (*Sardinella gibbosa*)

Indian oil sardine (*Sardinella longiceps*)

Jack mackerel (*Trachurus declivis*)

Japanese/Australian sardine (*Sardinops sagax*)

Mako shark (*Isurus* spp.)

Oceanic whitetip shark (*Carcharhinus longimanus*)

Pacific bluefin tuna (*Thunnus orientalis*)

Pacific cod (*Gadus macrocephalus*)

Pacific saury (*Cololabis saira*)

Redbait (*Emmelichthys nitidus*)

Requiem  sharks (*Carcharhinus* spp.)

Sablefish (*Anoplopoma fimbria*)

Shortfin mako shark (*Isurus oxyrinchus*)

Skipjack tuna (*Katsuwonus pelamis*)

Southern bluefin tuna (*Thunnus maccoyii*)

Striped marlin (*Kajikia audax*)

Swordfish (*Xiphias gladius*)

Thresher sharks (*Alopias* spp.)

White marlin (*Kajikia albida*)

Yellowfin tuna (*Thunnus albacares*)

Yellowtail scad (*Trachurus novazelandiae*)

Seabirds:

Antipodean albatross (*Diomedea antipodensis)*

Black-footed albatross (*Phoebastria nigripes*)

Flesh-footed shearwater (*Ardenna* (formerly *Puffinus*) *carneipes*)

Grey-headed albatross (*Thalassarche chrysostoma*)

Laysan albatross (*Phoebastria immutabilis*)

Wandering albatross (*Diomedea exulans*)

Turtles:

Leatherback turtle (*Dermochelys coriacea*)

Loggerhead turtle (*Caretta caretta*)

Marine mammals:

New Zealand fur seal (*Arctocephalus forsteri*)