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Seabird bycatch mitigation measures in demersal long-line fisheries

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SUMMARY

This report summarises the results of studies that have been carried out to develop, test and improve seabird mitigation measures in demersal longline fisheries. A comprehensive range of technical and operational mitigation methods have been designed or adapted for use in demersal and semi-pelagic longline fisheries. These methods aim to reduce incidental mortality of seabirds by avoiding peak areas and periods of seabird foraging activity, reducing the time baited hooks are near the surface and thus available to birds, actively deterring birds from baited hooks, and making the vessel less attractive to birds and minimising the visibility of baited hooks. Apart from being technically effective at reducing seabird bycatch, mitigation methods need to be easy and safe to implement, cost effective, enforceable and should not reduce catch rates of target species. There is no single solution that will eliminate seabird bycatch; the most effective approach is to use a combination of measures. The suite of measures available may vary in their feasibility and effectiveness depending on the area, seabird assemblages involved, fishery and vessel type and gear configuration. Some of the mitigation methods are now well established and explicitly prescribed in longline fisheries. However, other measures are relatively recent and require further testing and refinements, and there is a need to ensure that the collaborative approach to research and monitoring that has characterised field of seabird bycatch mitigation continues.

INTRODUCTION

The incidental mortality of seabirds, mostly albatrosses and petrels, in longline fisheries has been of growing global concern. A large number of mitigation methods to reduce and eliminate seabird bycatch have been developed over the last 10 to 15 years (Brothers et al. 1999; Melvin & Parrish 2001; Melvin & Robertson 2001). When considering mitigation methods for longline fisheries, it is important to distinguish between pelagic and demersal longline fisheries. Although some mitigation measures will be broadly applicable, the feasibility, design and effectiveness of many will be informed by the type of longlining method and gear configuration used. Even within demersal longlining, there are different systems – the autoline system, the Spanish double line system, and more recently the Chilean or Mixed system (Moreno et al. in press), with variations of these systems (Moreno et al. 2006; Seco Pon et al. 2007).

Many studies have been carried out to develop, test and improve seabird bycatch mitigation methods. In addition to being effective at minimising bird mortality, it is important that mitigation methods are simple, safe for fishers to implement, cost effective, enforceable, and do not negatively impact catch rates of target species. In this respect, those mitigation methods that are fully integrated into the specific fishery because they are practical, effective and easy to use are likely to be more effective in the long term than measures which require constant supervision or oversight by on-board observers to ensure adherence to performance standards. Education and training of fishers and observers is clearly also vital to ensure proper use of mitigation methods.

A compilation of the mitigation methods that have been tested (or have potential) in the demersal longline fishery is included in Table 1, which includes studies that have performed post hoc analyses of observer data, as well as studies which have adopted an experimental approach. Mitigation measures can be broadly divided into technical (e.g. bird scaring lines, line weighting regimes and underwater setting funnels and operational (e.g. spatial and temporal closures of fishing areas) (Brothers et al. 1999). Mitigation methods are classified into four main categories, which have been adapted from Brothers et al. (1999) and Gilman et al. (2005):

1. Avoiding peak areas and periods of seabird foraging activity
2. Reducing the time baited hooks are near or on the surface and thus available to birds

3. Actively deterring birds from baited hooks
4. Reducing attractiveness and visibility of baited hooks and attractiveness of vessel to birds

As has been stressed in almost all studies and reviews on the subject, there is no single solution to reduce or avoid incidental mortality of seabirds in longline fisheries. A combination of methods is required, and these may vary in their efficacy and feasibility depending on the area, season, seabird assemblages present, and weather conditions. Ongoing research and monitoring is required to refine or adapt current methods and to investigate and test additional mitigation methods. It is important that the collaborative approach to mitigation research which has been followed to date continues, not only amongst scientists, but including fishers.

Table 1. Review of seabird bycatch mitigation measures for Demersal Longline Fishing and identification of knowledge gaps

Mitigation measure	Scientific evidence for effectiveness in demersal fisheries	Caveats /Notes	Need for combination	Research needs	Minimum standards
1. Avoiding peak areas and periods of seabird foraging activity					
Night setting	(Ashford et al. 1995; Cherel et al. 1996; Moreno et al. 1996; Barnes et al. 1997; Ashford & Croxall 1998; Weimerskirch et al. 2000; Belda & Sánchez 2001; Nel et al. 2002; Ryan & Watkins 2002; Sánchez & Belda 2003; Reid et al. 2004)	Bright moonlight and decklights reduce the effectiveness of this mitigation measure (Cherel et al. 1996). Not as effective for crepuscular/nocturnal foragers such as the white-chinned petrel but even for these species night setting is more effective than setting during the day (Ashford et al. 1995; Gómez Laich et al. 2006; Weimerskirch et al. 2000; Nel et al. 2002). In order to maximise effectiveness of this mitigation measure, decklights should be off or kept to an absolute minimum, and used in combination with additional mitigation measures, especially when setting in bright moonlight conditions. Night setting is not a practical option for fisheries operating at high latitudes during summer. Setting should be completed at least 3 hours before sunrise to avoid the predawn activity white-chinned petrels (Barnes et al. 1997)	Recommend combination with bird scaring lines and/or weighted lines, especially to reduce incidental mortality of birds that forage at night	Effect of night setting on catch rates of target species for different fisheries.	Night defined as the period between the times of nautical twilight (nautical dark to nautical dawn)
Area and seasonal closures	A number of studies have reported marked seasonality in seabird bycatch rates, with the majority of deaths taking place during the breeding season (Moreno et al. 1996; Ryan et al. 1997; Ashford & Croxall 1998; Ryan & Purves	It's difficult to separate the temporal closure from the increased uptake/implementation of other mitigation measures, but it is clearly an important and effective management response, especially for high risk areas, and when other measures prove ineffective. There is a risk that temporal/spatial closures could displace fishing effort into	Must be combined with other measures, both in the specific areas when the fishing season is opened, and also in adjacent areas to ensure displacement of fishing effort does not merely lead to a spatial	Further information about the seasonal variability in patters of species abundance, and particularly how these interact with the spatial and temporal characteristics of fishing effort, especially for high risk areas (e.g. adjacent	Currently, the area around South Georgia (CCAMLR Subarea 48.3) is open from May 1st. to Aug. 31st or till established catch limit is reached, as provided for by CCAMLR Conservation Measures in force. (41-02/2007).

	1998; Ryan & Watkins 1999; Ryan & Watkins 2000; Weimerskirch et al. 2000; Kock 2001; Nel et al. 2002; Ryan & Watkins 2002; Croxall & Nicol 2004; Reid et al. 2004; Delord et al. 2005). In some studies, mortality has been almost exclusively within the breeding season. Several studies have also shown that proximity to breeding colonies is an important determinant of seabird bycatch rates (Moreno et al. 1996; Nel et al. 2002). The much higher rate of seabird bycatch during the breeding period led to the temporal closure of the fishery in CCAMLR sub-area 48.3 from 1998, which contributed to a ten-fold reduction in seabird bycatch (Croxall & Nicol 2004). Movement of fishing effort away from the Prince Edward Islands coincided with a reduction in seabird bycatch in the sanctioned Prince Edward Island fishery.	neighbouring or other areas which may not be as well regulated, thus leading to increased incidental mortality elsewhere.	shift in the incidental mortality.	to important breeding colonies). In some studies, incidental mortality has been greatest during the chick-rearing period (Nel et al. 2002; Delord et al. 2005), whereas others have reported highest mortality during the incubation period (Reid et al. 2004). This difference likely relates to where the birds are foraging in relation to fishing effort at the time, and highlights the importance of understanding this interaction. Research is also required to determine the regional impact of closures on catches of target species	
2. Reducing the time baited hooks are near or on the surface and thus available to birds					

Externally weighted lines	(Agnew et al. 2000; Robertson 2000; Melvin et al. 2001; Moreno et al. 2006)	It is important that tension astern is minimised to optimise the sink rate of the line weighting regime. This can be done by preventing hooks snagging on baskets/boxes and by ensuring that weights are released from the vessel before line tension occurs (Robertson et al. 2008). Various methods are used to ensure smooth flow of hooks and avoid entanglements. On autoliners, this is achieved by ensuring the correct looping of the line on racks and oiling the line. On the Spanish system it is achieved by correct packing of the lines and hooks and using boxes with smooth edges. Externally attached weights must be attached and removed for each set-haul cycle, which is onerous and potentially hazardous for crew members. Weights made up of rocks enclosed in netting bags and concrete blocks deteriorate and require ongoing maintenance/replacement and monitoring to ensure the required mass is made up (Otley 2005); standard mass weights of steel are better in this respect, both from a handling and compliance perspective (Robertson et al. in press). Longlines with externally added weights sink unevenly, faster at the weights than at the midpoint between weights, Gear configuration and setting speed influence the sink rate profiles of the hook lines (Seco Pon et al. 2007). See later section on the Chilean Mixed System	Must be combined with other measures, especially bird scaring lines, judicious offal management and/or night setting.	Sink rates and profiles of line weighting regimes may vary according to vessel type, setting speed, how the line is set (relative to the propeller wash for example). It is important that the sink rate relationships of different line weighting regimes are understood for a particular fishery (or fishery method) and that the effectiveness of the line weighting regime and the sink profile in reducing seabird mortality is tested.	Global minimum standards not established. Requirements vary by fishery and vessel type. For example, CCAMLR minimum requirements for vessels using the Spanish method of longline fishing are 8.5kg mass at 40m intervals (if rocks are used), 6kg mass at 20m intervals for traditional (concrete) weights, and 5kg weights at 40m intervals for solid steel weights. For autolines, CCAMLR requires as a minimum 5kg mass at intervals no more than 40m. It is also required that weights be released before line tension occurs. In the New Zealand fisheries, a minimum of 4kg (metal weight) or 5kg (non-metal weight) be attached every 60m if the hook bearing line is 3.5mm or greater in diameter, and a minimum of 0.7kg of weight every 60m when the line is less than 3.5mm diameter. The New Zealand minimum standards also include requirements relating to the use of floats.

Integrated weighting of lines	Apart from the practical advantages of integrated weight (IW) longlines – superior handling qualities and practically inviolable – the IW longlines sink more quickly and uniformly out of reach of most seabirds compared with externally weighted lines. IW longlines have been shown to reduce substantially mortality rates of surface foragers and diving seabirds, while not affecting catch rates of target species (Robertson et al. 2002; Robertson et al. 2003; Robertson et al. 2006; Dietrich et al. 2008)	Restricted to autoline vessels. The sink rate of IW longlines can vary depending on vessel type, setting speed and deployment of line relative to propeller wash (Melvin & Wainstein 2006; Dietrich et al. 2008). Setting speed influences the extent of the seabird access window – the area in which most seabirds are still able to access the baited hooks in the absence of bird scaring lines (Dietrich et al. 2008)	Recommended combination with bird scaring lines, judicious offal management and/or night setting	The relationship between line-weighting regime, setting speed, sink rates/profiles and the seabird access window should be investigated for other fisheries (i.e. those that haven't already been tested – Bering Sea, Alaska, and New Zealand ling fishery) including with additional mitigation measures (particularly bird scaring lines); these investigations would be useful in determining the necessary aerial extent of the bird scaring lines.	Global minimum standards not in place. CCAMLR currently require as a minimum IW lines with a lead core of 50g/m, which is also required in the New Zealand demersal longline fishery.
Side setting	Has not been widely tested in demersal longline fisheries. In trials in the New Zealand ling fishery, side setting appeared to reduce seabird bycatch; however, the results were not convincing and there were practical/operational difficulties, with the line becoming entangled in the propeller (Bull 2007). Sullivan (2004) reported that side setting has been used in some demersal fisheries (e.g. shark fisheries) which have experienced negligible incidental mortality.	Practical difficulties, especially in difficult weather/sea conditions. In many cases it may be difficult and expensive converting the vessel's deck design to employ a side setting system.	Must be used in combination with other mitigation measures, especially the use of a bird curtain (Gilman et al. 2007), and bird scaring lines.	Largely untested in the demersal fisheries, especially in the Southern Ocean, where the seabird assemblages include proficient diving seabirds. Research urgently needed.	Only in Hawaii for the pelagic longline fisheries, where it is used in conjunction with a bird curtain; side setting is defined as a minimum of 1m forward of the stern.

Underwater setting funnel	An underwater setting funnel has been tested in demersal longline fisheries in Alaska, Norway and South Africa, with all studies showing a reduction in the mortality rate, although the extent of the reduction varied between studies (Løkkeborg 1998, 2001; Melvin et al. 2001; Ryan & Watkins 2002).	Present design is mainly for a single line system. Results from studies to date have been inconsistent, likely due to the depth at which the device delivers the baited hooks and the diving ability of the seabirds in the fishing area studied. The pitch angles of the vessel, which are influenced by the loading of weight and sea conditions, affect the performance of the funnel (Løkkeborg 2001).	Must be used in conjunction with other mitigation measures – bird scaring lines, weighted lines, night setting and judicious offal management.	Need to investigate improvements to the current design to increase the depth at which the line is set, especially during rough seas. Also need to investigate optimal use of device together with other mitigation measures (bird scaring lines and weighted lines).	Not yet established
Line shooter	Reduced bycatch of northern fulmars relative to sets with no mitigation measures in trials conducted in Norway, but not significantly (Løkkeborg & Robertson 2002; Løkkeborg 2003). However, seabird bycatch in Alaska increased when a line shooter was used (Melvin et al. 2001).	A significant reduction in seabird bycatch when setting with a line shooter has not yet been demonstrated. At this stage it should be seen as a supplementary measure in need of further refinement.	Must be combined with other measures, such as bird scaring lines, night setting, weighted lines and judicious offal management.	Need to investigate whether refinement/modification of the device will be able to overcome the problem of propeller wash and ensure consistently rapid sink rates and significantly reduced seabird mortality.	Not yet established

Thawing bait	Not as much of an issue compared with pelagic longlining. For autoliners, the bait must be at least partially thawed before they can be sliced by the automated baiting system; in the Spanish system, the interval between manually baiting the hooks and setting the lines is sufficiently long to allow for thawing (except in very low ambient temperatures); and the line weighting regime overcomes most of the problems with frozen bait (Brothers et al. 1999).	Supplementary measure. Must be combined with the range of other measures already described. Well thawed bait comes off the hooks more easily when deployed from the vessel than half-thawed or frozen bait (Brothers et al. 1999).		There is some evidence that the number of seabirds caught varies according to the type of bait used (Weimerskirch et al. 2000). This should be investigated further.	
3. Actively deterring birds from baited hooks					
Single bird scaring line	The use of a single bird scaring line has been shown to be an effective mitigation measure in a range of demersal longline fisheries, especially when used properly (Moreno et al. 1996; Løkkeborg 1998, 2001; Melvin et al. 2001; Smith 2001; Løkkeborg & Robertson 2002; Løkkeborg 2003)	Effective only when streamers are positioned over sinking hooks. Single bird scaring lines can be less effective in strong crosswinds (Løkkeborg 1998; Brothers et al. 1999; Agnew et al. 2000; Melvin et al. 2001; Melvin et al. 2004). In the event of strong crosswinds, bird scaring lines should be deployed from the windward side. This problem can also be overcome by using paired bird scaring lines (see below).The effectiveness of the bird scaring lines is also dependent on the design, the aerial coverage of the bird scaring line , seabird species present during line setting (proficient divers being more difficult to deter from baits than surface feeding birds) and the proper use of the bird scaring line. The aerial coverage and the position of the bird scaring line relative to the sinking hooks are the most important factors influencing their performance. There	Effectiveness is increased when used in combination with other measures – e.g. night setting, appropriate weighting of line and judicious offal management.	The use and specifications/performance standards are fairly well established in demersal longline fisheries. However, there is scope to improve further the effectiveness and practical use of bird scaring lines on individual vessels or vessel type.	Current minimum standards vary. CCAMLR was the first conservation body that required all longline vessels in its area of application to use bird scaring lines (Conservation Measure 29/X adopted in 1991). The bird scaring line has gone on to become the most commonly applied mitigation measure in longline fisheries worldwide (Melvin et al. 2004). CCAMLR currently prescribes a range of specifications relating to the design and use of bird scaring lines. These include the minimum length of the line (150m), the height of the attachment point on the vessel (7m above the water), and details about streamer lengths

		have been a few incidents of birds becoming entangled in bird scaring lines (Otley et al. 2007). However it must be stressed that the numbers are minuscule, especially when compared with the number of mortalities recorded in the absence of bird scaring lines. Bird scaring lines remain a highly effective mitigation measure, and efforts should be directed to improving further their design and use so that their effectiveness can be improved further.			and intervals between streamers. Other fisheries have adapted these measures. Some, such as those in New Zealand and Alaska have set explicit standards for the aerial coverage of the bird scaring lines, which varies according to the size of the vessel.
Paired or multiple bird scaring lines	Several studies have shown that the use of two or more streamer lines is more effective at deterring birds from baited hooks than streamer line (Melvin et al. 2001; Sullivan & Reid 2002; Melvin 2003; Melvin et al. 2004; Reid et al. 2004). The combination of paired streamer lines and IW longlines is considered the most effective mitigation measure in demersal longline fisheries using autoline systems (Dietrich et al. 2008).	Potentially increased likelihood of entanglement with other gear. Use of an effective towed device that keeps lines from crossing surface gear essential to improve adoption and compliance. See also above comment about bird entanglements in bird scaring lines. Manually attached and operated paired or multiple bird scaring lines requires some effort to operate (a 150m double line takes about 8-10 men to retrieve). One way of overcoming this is to make use of electronic winches.	Effectiveness is increased when used in combination with other measures – e.g. night setting, appropriate weighting of line and judicious offal management.	Further trialling in fisheries which currently only use single streamer lines.	Paired streamer lines required in Alaskan fisheries and encouraged/recommended by CCAMLR, except in the French exclusive economic zone (CCAMLR Subarea 58.6 and Division 58.5.1), where paired streamer lines have been compulsory since 2005. Paired streamer lines have also been required in the Australian longline fisheries off Heard Island since 2003 (Dietrich et al. 2008)
Brickle curtain	Anecdotal evidence indicates that the use of a Brickle curtain can effectively reduce the incidence of birds becoming foul hooked when the line is being hauled (Brothers et al. 1999; Sullivan 2004; Otley et al. 2007).	Some species, such as the black-browed albatross and cape petrels, can become habituated to the curtain, so it is important to use it strategically – when there are high densities of birds around the hauling bay (Sullivan 2004).	Must be used in combination with other mitigation measures – bird scaring lines at setting, line weighting, night setting and judicious offal management.		A device designed to discourage birds from accessing baits during hauling operations is required in high risk CCAMLR areas (exact design not specified). Also required in the Falkland Islands longline fishery, where the Brickle Curtain is recommended.

Olfactory deterrents	Dripping shark liver oil on the sea surface behind vessels has been shown to effectively reduce the number of seabirds (restricted to burrow-nesting birds) attending vessels and diving for bait in New Zealand (Pierre & Norden 2006; Norden & Pierre 2007).	The shark liver oil did not deter albatrosses, giant petrels, or Cape Petrels from boats (Norden & Pierre 2007). The potential impact of releasing large amounts of concentrated fish oil into the marine environment is unknown, as is the potential for contaminating seabirds attending vessels and the potential of seabirds to become habituated to the deterrent (Pierre & Norden 2006).	Must be used in combination with other mitigation measures – bird scaring lines at setting, line weighting, night setting and judicious offal management – especially until further testing has been conducted.	Testing should be extended to candidate/suitable species of conservation concern, such as white-chinned petrels and sooty shearwaters. Research is also required to identify the key ingredients in the shark oil that are responsible for deterring seabirds, and the mechanism by which the birds are deterred. The potential "pollution" effects also need to be investigated.	None yet.
4. Reducing attractiveness and visibility of baited hooks and attractiveness of vessel to birds					
Strategic management of offal discharge	Some studies have shown that dumping homogenised offal (which is generally more easily available and thus attractive to seabirds than bait) during setting attracts birds away from the baited line to the side of the vessel where the offal is being discharged, and thus reduces bycatch of seabirds on the baited hooks (Cherel et al. 1996; Weimerskirch et al. 2000).	Although strategic offal discharge has been shown to be effective at reducing seabird bycatch around Kerguelen Island, there are many risks associated with the practice. Offal discharge needs to be continued throughout the setting operation so as to ensure the birds do not move on to the baited hooks. This will only be possible in fisheries where line setting is short, and there is sufficient offal to sustain the line-setting period. This measure also has the potential to foul hook birds if offal is discharged with hooks. It is crucial, then, that all offal is checked for hooks before being discharged. Given these risks, and the fact that the presence of offal is a critical factor affecting seabird numbers attending vessels, most fisheries management regimes require that no offal can be discharged during line setting, and that if discarding is necessary at other times it should take place on the side of the vessel opposite to where the lines are being hauled.	Must be used in combination with other mitigation measures – bird scaring lines. line weighting, and night setting.	Further information needed on opportunities to manage offal more effectively – considering both practical aspects and seabird bycatch mitigation – in the short and long term.	In CCAMLR demersal fisheries, discharge of offal is prohibited during line setting. During line hauling, storage of waste is encouraged, and if discharged must be discharged on the opposite side of the vessel to the hauling bay. A system to remove fish hooks from offal and fish heads prior to discharge is required. Similar requirements are prescribed by other demersal longline fisheries (e.g. Falkland Islands, South Africa and New Zealand)

Blue dyed bait	The performance of this measure has only been tested in the pelagic longline fishery (Boggs 2001; Minami & Kiyota 2004; Gilman et al. 2007; Cocking et al. 2008), and with mixed success.	New data suggests that this measure is only effective with squid bait (Cocking et al. 2008). It has not been tested in demersal fishes, possibly due to larger number of hooks deployed and thus the need for considerably more bait (Bull 2007). There is no commercially available dye. Onboard dyeing is practically onerous, especially in inclement weather.	Must be used in combination with other mitigation measures – bird scaring lines. line weighting, night setting and judicious offal management	Need for tests of efficacy and practical feasibility in demersal longline fisheries, especially in the Southern Ocean to determine its effectiveness as a long-term mitigation measure. Research would also need to determine the effect of dyed bait on catches of target species.	Mix to standardized colour placard or specify (e.g. use 'Brilliant Blue' food dye (Colour Index 42090, also known as food additive number E133) mixed at 0.5% for a minimum of 20 minutes).
5. Other					
Hook size and shape	Hook size was found to be an important determinant in seabird bycatch rates of Argentinean and Chilean longline vessels fishing in Subarea 48.3 in the 1995 season, with smaller hooks killing significantly more seabirds than larger hooks (Moreno et al. 1996)	Other than the finding in Moreno et al (1996), little or no work has been conducted to investigate the impact of hood design and shape on seabird bycatch levels.	Must be used in combination with other mitigation measures – bird scaring lines. line weighting, night setting and judicious offal management	Determine impact on seabird bycatch and on catch of target species	No global standard
Gear configuration – Chilean method (linked with the sink rates)	A new method of demersal longline fishing, called the Chilean or Mixed System, developed from the Chilean artisanal toothfish fishery, has been shown to reduce significantly seabird bycatch as a consequence of significantly faster sink rates compared with traditional longline systems (Moreno et al. 2006; Moreno et al. in press; Robertson et al. in press). This system makes use of net sleeves or 'cachaloteras' which slide	This is a new system and should be monitored and possibly refined further.	Must be used in combination with bird scaring lines, judicious offal management and/or night-setting.	Test broader applicability	No global standards yet

	down over the hooks and captured fish during hauling and thus protect fish from toothed whales. The configuration of the Chilean system is such that all the hooks are directly above the weights ensuring a rapid sink rate. This system was first tested on large vessels in 2005, and because of the effectiveness of the system in reducing impacts of toothed whales, it is currently used by the entire Chilean and Falkland Islands toothfish longline fleets (Moreno et al. in press).				

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