CCSBT-ERS/0602/09

A review of methodologies aimed at avoiding and/or mitigating incidental catch of seabirds in longline fisheries.

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Abstract

Information on methods aimed at mitigating incidental mortality resulting from fisheries interactions have been released in a variety of local, national and international media. This report presents the results of a review to reduce contacts and mortalities of seabirds due to interactions with longline fishing gear. The application of these mitigation methods to New Zealand fisheries were assessed, recommendations for the fisheries management made, and areas for further research in New Zealand identified. While having a New Zealand fisheries focus, the results of this review are likely to be applicable to longline fisheries worldwide. Factors influencing the appropriateness and effectiveness of a mitigation device include the fishery, vessel, location, seabird assemblage present and time of year (i.e. season). As such, there is no single magic solution to reduce or eliminate seabird bycatch across all fisheries. Realistically a combination of measures is required, and even within a fishery there is likely to be individual vessel refinement of mitigation techniques in order to maximise their effectiveness at reducing seabird bycatch. Retention or strategic management of offal and discards are has the potential to avoid seabird bycatch. Other methods recommended to mitigate against seabird bycatch include paired bird-scaring lines, line weighting and night setting.

Keywords: seabirds; avoidance; bycatch mitigation; mortality; longline fisheries.

1. Introduction

1.1 Fisheries and seabird bycatch

In New Zealand, seabirds have been recorded caught in longlines, trawl, set nets and pots (NPOA 2004; Robertson et al. 2003, 2004a). Robertson et al. (2003) identified at least 50 bird species which breed only in New Zealand, or have part of their breeding populations there, that have been recorded in fishery interactions worldwide. In New Zealand, 24 seabird species have been caught in New Zealand fisheries (Robertson et al. 20003). Incidental mortality though interactions with fisheries operations has been linked with a global declines of some albatross and petrel species (Croxall et al. 1990; Brothers 1991; Weimerskirch et al. 1997; Weimerskirch et al. 1999; Lewison & Crowder 2003). Given that nearly half of the world's 125 petrel species and 16 of the 21 albatross species are classified as threatened (BirdLife International 2000), effective measures to mitigate against seabird bycatch (including fishing gear modification) need to be investigated in order to reduce the impact of these fisheries operations on global seabird populations.

Longline gear can be set throughout the water column, on the seabed (demersal longlining), floated off the bottom at various fishing depths (semipelagic longlining) or suspended from floats drifting freely at the surface (pelagic longlining) (Brothers et al. 1999a). Pelagic and demersal longlining operations differ in the gear used: compared to demersal fisheries, pelagic fisheries use longer snoods, have multiple buoys at the surface and use whole baits. The longer snoods on the pelagic gear increases the chances of seabird takes during hauling. These differences in gear mean that different mitigation measures may be required between pelagic and demersal longline fisheries.

When compared to drift-netting, longlining is perceived as a relatively environmentally friendly fishing method in terms of being target species and size-selective, and does not directly damage the sea floors (Brothers et al. 1999a; Brooke 2004). However the versatility of this fishing method has resulted in a large number of vessels having the potential to catch seabirds; ranging from small open boats operating in shallow coastal waters, to large ocean-going vessels operating on high-seas fishing grounds at depths down to 3000 m (Brothers et al. 1999a). Although no observations describing the nature of seabird interactions in longline fisheries 20 or 30 years ago exist, it is likely that the factor of sink rate was not then as acute, because gear in the past was heavier (Brothers et al. 1999a). Furthermore, the mechanisation of fishing operations has greatly expanded the scope of these operations (Brothers et al. 1999a).

From 1993, the use of tori lines became mandatory for all tuna longline fishing vessels (foreign and domestic) in the New Zealand Exclusive Economic Zone (EEZ) (Regulation 36A of the Fisheries (Commercial Fisheries) Regulations 1993) (Duckworth 1995).

1.2 Seabird biology and foraging behaviour

Understanding the biology and foraging behaviour of the seabird species that a mitigation method is being designed to avoid catching is an essential first step in the conception of the technique and assessing the likelihood of its effectiveness (Sánchez & Belda 2003).

The assemblage of seabirds attending fishing vessels will differ depending on the number of fishing vessels present in the same fishing grounds, the location, time of day and season (Weimerskirch et al. 2000). Interaction of different seabird species with fishing gear will be influenced by their feeding method, dive depth abilities and seabird size. The smaller birds (e.g. terns, storm petrels and auklets) are unable to swallow such large food items as longline baits, and as such are rarely found captured in this way (Brothers et al. 1999a). Scavenging seabirds particularly, have large gapes and are thus able to swallow large food items whole, making them liable to get caught on longline hooks (Brothers et al. 1999a).

Seabirds such as albatrosses and petrels are long-lived, monogamous, have delayed maturity, high adult survival, a long breeding life, and relatively low reproductive rates (generally one egg/chick per season per breeding pair). As a result of these factors, seabird populations can only increase slowly under highly favourable environmental conditions (unless they are at carrying capacity) (Furness 2003). Therefore, any additional factors increasing the rate of adult mortality will have a strong negative impact on population dynamics and the species as a whole.

Most seabirds (particularly albatrosses and petrels) exhibit strong mate and site fidelity, generally returning to the same site (often the same nest) to breed with the same mate in successive seasons. Within a pair, both birds share parental duties including feeding the chick. As such, if one parent dies during a breeding season, the widowed parent is unable to sufficiently feed the chick. Furthermore, there is often a lag-period following the death of a partner before the widowed bird will next breed, as it must find a new mate and form a pair bond before breeding will commence.

The foraging ecology of many seabird species is still largely unknown, along with the degree to which each seabird species relies on visual and olfactory cues to locate food (Verheyden & Jouventin 1994; Nevitt 1999; Brooke 2004; Nevitt et al. 2004). Such information would be beneficial to the design of many mitigation devices.

Both diving and scavenging seabirds present at fishing vessels are susceptible to interactions with fishing gear. Divers are capable of diving considerable distances to retrieve baited hooks, thus exposing them to being hooked. Larger birds, for example the wandering albatross (*Diomedea exulans*), do not have the same diving capabilities, instead they harass the diving birds when they come to the surface and attempt to take the retrieved bait and hook (Cherel et al. 1996).

The Southern Ocean is home to many of the most capable diving seabirds, namely shearwaters and some petrels. Studies of *Puffinus* shearwaters have found that the maximum dive depths of these species ranges between 35.4–70.6 m (Weimerskirch & Cherel 1998; Keitt et al. 2000; Burger 2001; Aguilar et al. 2003). White-chinned petrels (*Procellaria aequinoctialis*), a common bycatch species, has a recorded maximum dive depth of 12.8 m (Huin 1994). Grey-headed (*Thalassarche chrysostoma*) and black-browed (*T. melanophrys*) albatrosses are also skilled divers and are therefore able to catch sinking baits underwater (Prince et al. 1994). It is these species (*Puffinus*, *Procellaria* and the small albatrosses) that generally account for a large percentage of seabird mortality in the longline and trawl fisheries (Brothers 1991; Murray et al. 1993; Robertson et al. 2004a).

Some seabird species partition their foraging ranges according to sex or breeding status, leading in some cases to bycatch events having a species-specific sex or age bias (Bartle 1990; Croxall & Prince 1990; Ryan & Boix-Hinzen 1999). These biases in bycatch rates can in turn cause age or sex biases in the population, which has further implications on the productivity and hence population size of the species.

Seabirds are capable of foraging considerable distances; some albatross and petrel species are known to travel hundreds of kilometres on single foraging trips (Jouventin & Weimerskirch 1990; Weimerskirch & Cherel 1998). Such large foraging ranges increases the number of vessels birds are vulnerable to beyond those fishing adjacent to the breeding colonies.
Some seabirds are attracted to vessels because they have learnt that it can be a source of food through scavenging offal and bait. Removing the source of food either directly (i.e. ‘discards’) or indirectly (i.e. bird-scaring lines etc) should in the long-term discourage seabirds from following vessels (Weimerskirch et al. 2000).

1.3 Seabird-fishing gear interactions

When devising new, or modifying existing, gear for reducing incidental captures, measuring gear selectivity and monitoring for potential adverse impacts are necessary (Bache 2003). Understanding the circumstances that lead to the death of birds in a fishery is essential to determine how future mortalities can be prevented. Describing these circumstances will provide a clearer understanding of how and when a mitigation measure can reduce mortality (Brothers et al. 1999a; Bache 2003).

Seabirds may become entangled on the line or caught during line setting and hauling (primarily with pelagic gear) (Brothers et al. 1999a). Brothers & Foster (1997) observed three situations in which baited hooks on longlines pose a threat to seabirds following astern of the vessel: (1) as the hooks were cast into the water and before sinking; (2) if the hooks float on or near the surface as a result of current or tide action during their soak time; or (3) when hooks with unused bait were hauled back aboard the vessel. Therefore, reduction in seabird bycatch through modifications to fishing practices and/or equipment can be achieved through the following processes: preventing baited hooks being visible to birds; preventing access to baited hooks; reducing the potential of hooks to kill birds that take them; and decreasing the incentive for birds to follow longline vessels (Brothers et al. 1999a).

1.4 Successful bycatch mitigation

Gilman et al. (2003a) listed the following criteria as being important for seabird mitigation method(s): (1) reduce seabird mortality to insignificant levels; (2) not cause increases in bycatch of other sensitive species; (3) require minimum alteration of traditional fishing practices and provide operational benefits; (4) be simple for crew to employ and not increase safety hazards to crew; (5) increase fishing efficiency; and (6) be feasibly enforced when limited resources for enforcement are available.

Bycatch mitigation may take the form of area/seasonal closure of fishing grounds, modifications to fishing gear, and new fishing practices and equipment (Brothers et al. 1999a). While area/seasonal closures have occurred, or have been suggested, the greatest potential in terms of fisher response and support lies with the alternatives (Brothers et al. 1999a; Melvin et al. 1999; Kock 2001; Gilman et al. 2003a).

The development of techniques to avoid and mitigate incidental mortality of seabirds and marine mammals resulting from fisheries interactions is a growing field internationally. A global review of methodologies designed at avoiding and/or mitigating incidental catch of seabirds was recently completed by Bull (in press). This report summarises the longline component of that global review, seeking to consolidate the experience and information gathered worldwide in the field of bycatch mitigation and avoidance and evaluate these for application in New Zealand, as well as serving as a means to assess past lessons learnt and therefore avoid any future attempts at reinventing the wheel.

2. Methods

Material (post-1990) investigating mitigation measures to reduce seabird bycatch in longline (demersal and pelagic) fisheries was obtained from various forms of media including peer-reviewed journals, unpublished and anecdotal reports, magazine articles, conference papers, websites, government and Non-government Organisations' literature. Material reviewed included mitigation and avoidance methods that have been proposed but not tested, tested but demonstrated to be unsuccessful, or tested and demonstrated to be successful. Relevant factors were extracted from the material and recorded in detailed tables (Bull in press) for each fishery. Information regarding the mitigation method, the reference source, the fishery the method was trialled in, the seabird taxa observed in the study, the effectiveness of the mitigation technique on reducing bycatch, and the effect on fishing efficiency are recorded for longline fisheries mitigation methods in Appendix 1. The individual mitigation methods are reviewed below, with a brief summary of the results from various trials, and the pros and cons of each method.

For the context of this paper, bycatch is defined as the non-target species that are obtained whenever fishing gear is not perfectly selective (Terry 1995), and mitigation measures are defined as the modification to fishing practices and/or equipment that reduces the likelihood of seabird incidental catch (Brothers et al. 1999a). A contact is defined as an event during which a seabird comes into contact with gear near baited hooks (Gilman et al. 2003b). A capture is based on a count of the number of seabirds hauled aboard, and not the number of seabirds observed caught during setting (Gilman et al. 2003b).

3. Results

The different gear configurations used in pelagic and demersal longlining mean that not all mitigation measures are appropriate for both fishing methods. Table 1 lists some of the major mitigation measures reviewed in this document, and their applicability to demersal or pelagic longline fisheries.

3.1 Avoidance - Offal and discard management

The presence of offal is probably a major factor affecting seabird numbers attending vessels (Weimerskirch et al. 2000; Robertson & Blezard 2005). Seabirds feed on the offal discharged and subsequently associate the vessel with food. Therefore, offal discharge reinforces the behaviour of birds to attend vessels (Weimerskirch et al. 2000). Managing offal and discards through retention or strategic dumping may reduce seabird bycatch.

Weimerskirch et al. (2000) analysed fisheries observer data from demersal longliners around the Kerguelen Exclusive Economic Zone (EEZ). The release of offal from longliners had a positive influence on the total number of birds attending, especially on the number of large species and white-chinned petrels.

The cons associated with offal retention include the possible logistical implications due to vessel storage capacity. The pros of retaining offal during fishing operations reduces seabird bycatch rates (Abraham 2005; Robertson & Blezard 2005; Sullivan et al. in press).

3.2 Avoidance - Area/seasonal closure

Areas where high levels of seabird bycatch have been recorded, or where the range of an endangered species overlaps with a fisheries operation, are closed to fishing effort for a specific season or period.

The restriction of fisheries operating in CCAMLR waters to fishing only during the winter months has resulted in a decline in the incidental mortality of seabirds from approximately 0.2 birds/1000 hooks in 1995 to <0.025 birds/1000 hooks in 1997 (SC-CAMLR 1995; SC-CAMLR 1998).

While area/season closures may be beneficial in some circumstances, it is unlikely to be adequate as a mitigation measure for general use (Brothers et al. 1999a). Knowledge regarding seasonal/annual variability in patterns of species abundance is required to accurately allocate seasonal/area closures (Melvin et al. 1999).

3.3 Concealing hooks and bait – Funnel (lining tube)

Mustad underwater setting funnel is a commercially available underwater setting device (Brothers et al. 1999a). In contrast to other underwater setting devices, both the mainline and branchlines are fed through the funnel. Furthermore, this device delivers the groundline one metre below the surface in the propeller wash – much shallower than the pelagic chutes (E. Melvin pers. comm.).

The funnel has been trialled in demersal longline fisheries in South Africa, Alaska and Norway under normal fishing operations, all of which noted a reduction, sometimes significant, in seabird bycatch when the funnel was used (Løkkeborg 1998; Løkkeborg 2001; Melvin et al. 2001; Ryan & Watkins 2002). Despite these reductions, in some cases, the number of birds being caught while using the funnel was still relatively high (Løkkeborg 1998). Therefore, results from studies to date have found the funnel's performance to be inconsistent at reducing seabird capture.

The problems and costs associated with the funnel include: (1) suitable for demersal longline fisheries only (Brothers et al. 1999a); (2) can increase bait loss (Løkkeborg 1998), which can result in reduced catch rates (Ryan & Watkins 2002); (3) underwater setting tubes are expensive to fit (approximately UK£40,000) (Brooke 2004); (4) the line would periodically jump out of the slot that runs along the side of the tube, rendering the tube useless as a seabird deterrent for that entire set (Melvin et al. 2001); (5) during high seas and when the vessel was front heavy, the bottom of the funnel was lifted out of the water during setting, resulting in the depth of the setting funnel decreasing and therefore making baited hooks available to seabirds (Løkkeborg 1998); (6) uncertain if it has the ability to set at sufficient depths in rough weather, particularly in the Southern Ocean in the presence of pursuit diving species such as the white-chinned petrel (Brothers et al. 1999a).

The benefits of the funnel include: (1) Løkkeborg (2001) noted that catch rate for target fish species was higher; (2) reduction in seabird bycatch compared to when no deterrent was used (Løkkeborg 1998; Løkkeborg 2001; Melvin et al. 2001; Ryan & Watkins 2002).

3.4 Concealing hooks and bait – Chute

The earlier versions of the chute system relied on a paravane mechanism; a combination of water injection and venturi force accelerate baited hook passage down the chute (Brothers et al. 1999a). Later versions have had weights slipped into the hollow cavity down the length of the chute to hold the chute in the water (J. Molloy pers. comm.).

The concept of the chute and early developmental trials in New Zealand (Barnes & Walshe 1997; Molloy et al. 1999). Brothers et al. (2000) undertook a comprehensive development trial off the waters of Tasmania. During this trial, modifications were made to the chute which demonstrated its capacity to minimise seabird interactions during line setting in pelagic longline fishing. However these results needed to be tested under normal fishing conditions.

Gilman, Brothers et al. (2003) tested the efficiency of a 6.5 m and 9 m chute in the Hawaii pelagic longline tuna and swordfish fisheries. The 6.5 m and 9 m chutes deployed baited hooks 2.9 m and 5.4 m underwater respectively (Gilman et al. 2003b). Both chutes were found to be effective at reducing seabird captures: 6.5 m chute - 0.01 captures/1000 hooks/bird for tuna gear; 9 m chute - 0.05 and 0.03 captures/1000 hooks/bird for tuna and swordfish gear respectively. Expressed as contact rate per 1000 hooks per albatross (normalised for albatross abundance), the chute was 95% effective at reducing albatross contacts with fishing gear compared to the control. Based on bait retention and hook setting interval, vessels would experience a gain in efficiency of between 14.7% and 29.6% when using the chute versus setting conventionally, when albatrosses were abundant behind the vessel (Gilman et al. 2003a).

During at-sea trials (with no control) under normal fishing operations in the Australian East Coast tuna and billfish pelagic longline fishery, high bycatch rates (1.081 birds/1000 hooks) were reported while using the chute (Baker & Robertson 2004). The majority (97%) of the birds caught were flesh-footed shearwaters (*Puffinus carneipes*).

The problems and costs associated with the chute include: (1) the chutes trialled in Hawaii performed inconsistently and was inconvenient due to manufacturing flaw and design problems (Gilman et al. 2003b); (2) slower hook setting rate with the chute compared to normal setting (Gilman et al. 2003a); (3) relatively expensive - US$5,000 for the hardware, plus additional cost of installation (Gilman et al. 2003b); (4) use of the chute in large swells caused fouled hooks and tangled gear (Gilman et al. 2003b); (5) requires a lot of deck space to stow (Gilman et al. 2003b); (6) high bycatch (1.081 birds/1000 hooks) recorded while using the chute in Australian trials (Baker & Robertson 2004).

The benefits associated with using the chute included: (1) seabird contacts and captures were reduced in Hawaiian trials (Gilman et al. 2003b); (2) may increase fishing efficiency due to increased bait retention (Gilman et al. 2003b).

3.5 Concealing hooks and bait – Capsule

Since it's original conception in New Zealand by Dave Kellian, the capsule has gone through two design phases (Smith & Bentley 1997; Brothers et al. 2000). A weighted transportation capsule clamps the baited snood until the capsule reaches its determined depth. At this point the carry-over action of the capsule and retrieval action releases the bait (Smith & Bentley 1997). Baits set by the capsule can be delivered to a pre-selected depth which can be varied; cycle time is dependent upon the depth selected (Brothers et al. 2000). The most recent development to the method of deployment and retrieval of the capsule is a track that transports the capsule (J. Molloy pers. comm.).

Development trials have been undertaken on pelagic longliners in New Zealand and Australian waters (Smith & Bentley 1997; Brothers et al. 2000). Despite design flaws being identified in these trials, the capsule noticeably lowered bird activity in the area immediately behind the vessel in comparison to hooks set manually, and no diving attempts were made. During the Australian trial, the capsule was capable of setting hooks at sufficient depth to avoid seabird interactions (excluding those occasions when tangles occurred). Brothers, Chaffey et al. (2000) noted that the majority of tangles were the result of the branchline catching on the capsule as it returned, or due to the hook catching on the ball.

The problems and costs associated with the capsule include: (1) suitable for pelagic longline systems only (Brothers et al. 1999a); (2) further development required to solve problems with tangling (Brothers et al. 2000); (3) relatively expensive.

The benefits associated with the capsule include: (1) versatility in the depths at which baits can be delivered (Brothers et al. 1999a); (2) compact and easily fitted to any size vessel, irrespective of associated gear configuration (Brothers et al. 1999a); (3) birds generally remained further astern roaming more widely (Brothers et al. 2000).

3.6 Concealing hooks and bait – Bait casting/throwing machine

Bait-casting machines (BCMs) are used in pelagic longlining to mechanically cast the baited branchlines, placing them in the water at a distance from the longline in order to minimise line tangles (Brothers et al. 1999a).

The utility of the BCM as a means of reducing seabird deaths was not fully tested during the trials conducted in the Southeastern Indian Ocean by Brothers (1993). Brothers (1993) noted that the effectiveness of the BCM is reliant on a number of factors, including using thawed baits and the deployment of properly constructed bird-scaring lines (BSLs) and poles (one for the port side throwing and one for the starboard side throwing).

Studies using observer data from Japanese longliners fishing in the Australian Fishing Zone (AFZ) and New Zealand EEZ, both recorded lower seabird bycatch rates when using a BCM compared to not using one (Duckworth 1995; Klaer & Polacheck 1998).

Problems associated with BCMs include: (1) applicable to pelagic longlining only (Brothers et al. 1999a); (2) the original bait-casting machines (Gyrocast) were designed with functions to mitigate seabird bycatch as well as labour saving; however such machines proved expensive to produce ($A20,000). Subsequent cheaper models were produced with only the labour saving functions (Brothers et al. 1999a).

The benefits associated with using BCMs include: (1) possible increase in fishing effort or maintaining present fishing effort but reduced actual work due to reduced cycle time (Brothers 1993); (2) baits are not lost from hooks during machine throwing (Brothers 1993).

3.7 Concealing hooks and bait – Blue-dyed bait

Thawing and dyeing bait blue is thought to reduced the seabirds' ability to see the bait through camouflage (Gilman et al. 2003b), thus reducing interactions with fishing gear. However, Lydon & Starr (2005) proposed an aversion response by seabirds as the possible mechanism for reducing the attractiveness of blue-dyed baits to the birds.

When blue-dyed bait was tested in the Hawaii swordfish pelagic longline fishery, Boggs (2001) recorded significantly lower contact rates for Laysan (*Phoebastria immutabilis*) and black-footed albatross (*P. nigripes*) compared to the control treatment (undyed bait). However, a subsequent comparative study of mitigation methods in this and the tuna fishery found that blue-dyed bait was less effective (significantly in some cases) at avoiding bird interactions than side-setting and the underwater chute (Gilman et al. 2003b). When combining the effects of bait retention and hook setting rates on fishing efficiency for seabird avoidance treatments employed using tuna gear, blue-dyed bait had the third highest fishing efficiency and would produce a gain in efficiency of 45.2% over fishing with the 6.5 m chute (Gilman et al. 2003b).

In a comparative study of Japanese Southern bluefin tuna pelagic longline vessels fishing off of Capetown, Minami & Kiyota (2004) recorded a lower seabird bycatch when using blue-dyed bait compared to using a BSL. During this study, one vessel recorded a reduction in catch rate of the target species when using blue-dyed bait.

Two blue-dyed bait pilot trials have been undertaken in New Zealand on pelagic longliners (Lydon & Starr 2005; DOC unpubl. report). Both studies recorded bird captures on undyed bait sets, but none when using dyed bait; however these results were not significant. Furthermore, Lydon & Starr (2005) observed a contrast in seabird behaviour around the longline between the two bait types (dyed and undyed) on six of the seven longline sets; while apparently indifferent to the blue-dyed bait in the first six sets, seabirds actively attacked both bait types on the final set.

Lack of blue-dyed bait trials in demersal fisheries may be due to the fact that they deploy many more hooks and as such use considerably more bait, making this approach less practical for the demersal fishery compared to the pelagic fisher (E. Melvin pers. comm.).

Problems associated with blue-dyed bait include: (1) currently pre-dyed bait is not sold commercially, making the thawing and dying of bait impractical and inconvenient for the crew (Gilman et al. 2003b); (2) insufficient in minimizing bird mortality (Gilman et al. 2003b); (3) may not be employed consistently by different crew (Gilman et al. 2003b); (4) variable results with regards to fishing efficiency (Manami & Kiyota 2004); (5) birds may habituate to the blue-dyed bait rendering it ineffective as a long-term mitigation solution (Lydon & Starr 2005); (6) reduction in target species catch rate has been recorded when using blue-dyed bait (Manami & Kiyota 2004); (7) to date trialled only on pelagic longline vessels.
Benefits associated with using blue-dyed bait include: (1) relatively inexpensive, approximately US$14 per set or US$1.00 per 100 squid (Gilman et al. 2003b); (2) safe to use; (3) catch rates of fish were greater in the Hawaiian tuna longline fishery when blue-dyed bait was used (Gilman et al. 2003a).

3.8 Concealing hooks and bait – Side-setting

By setting fishing gear from the side of the vessel, the bait is thought to be sufficiently deep (i.e. out of seabird reach) by the time it reaches the stern (Gilman et al. 2003b; Sullivan 2004). A comparative at-sea trial in the Hawaii swordfish and tuna pelagic longline fisheries, found side-setting more effective at reducing seabird contacts and captures (in both fisheries) than blue-dyed bait or underwater setting chutes (9 m and 6.5 m) (Gilman et al. 2003b). To increase the efficiency of side-setting, a bird curtain was deployed when this method was used. There were no statistically significant differences between contact and capture rates for the three different side-setting positions (a short distance from the stern, port or starboard side) tested using tuna gear. When combining the effects of bait retention and hook setting rates on fishing efficiency for seabird avoidance treatments employed using tuna gear, side setting had the second highest fishing efficiency and would produce a gain in efficiency of 52.7% over fishing with the 6.5 m chute.

In New Zealand, side-setting was used at-sea on the Daniel Solander while fishing for ling; a total of six voyages were undertaken, each 6-7 weeks duration during which setting was from the side (P. Ballantyne pers. comm.). Four of the six voyages were observed by Ministry of Fisheries observers (generally two observers per trip). Seabird bycatch appeared to be reduced; however the line became tangled around the propeller on the third voyage while side-setting. Operational difficulties were encountered, with the side-setting depending on the prevailing weather and how the vessel set the gear in relation to the conditions. This was overcome, to some extent, by extending the line away from the vessel 1.5 m in a tube and also lowering the line closer to the water. Time loss was also a consideration in some conditions. In the case of Daniel Solander a change to side-setting was not too difficult as the line setting machinery was mounted forward in the vessel.

Sullivan (2004) reported that this method (=mid-ship setting) has been used in some demersal fisheries, and that seabird interactions with baited hooks were negligible on these vessels. In comparison, some side-setting demersal fishing vessels in Alaska have caught seabirds (E. Melvin pers. comm.).

Costs and problems associated with side-setting include: (1) some costs associated with initial alterations to vessel's deck design for side setting (Gilman et al. 2003a); (2) bird curtain (estimated cost US$50) recommended to be used concurrently when side-setting (Gilman et al. 2003a); (3) potential increased safety risk to crew member clipping branchlines (Gilman et al. 2003a); (4) when side setting in heavy weather it may be unavoidable to have the swell come on to the side of the boat; this may potential cause discomfort to crew, particularly on smaller boats (Gilman et al. 2003a); (5) the line became tangled around the propeller in the New Zealand trials, however this was overcome by extending the line away from the vessel 1.5 m in a tube and also lowering the line closer to the water (P. Ballantyne pers. comm.); (6) potential benefits of side-setting for reducing seabird bycatch may be limited to larger vessels (i.e. if bait sinks out of the range of seabirds at 80 m astern and the gear is moved 10 m forward of the stern, this yields a saving of lonely 10 m) (E. Melvin pers. comm.).

Benefits associated with side-setting include: (1) shown to be effective at reducing seabird interactions and mortality in some fisheries (Gilman et al. 2003a); (2) practicable for crew to use (Gilman et al. 2003a); (3) crew in the Hawaiian trials perceived this method as causing fewer gear tangles compared to conventional stern setting (Gilman et al. 2003a); (4) requires a nominal amount of initial expense to employ (Gilman et al. 2003a); (5) no additional effort required to implement the method once the initial conversion is made (Gilman et al. 2003a); (6) potential to increase fishing efficiency through the effects of bait retention and hook setting rates (Gilman et al. 2003a); (7) potentially effective at reducing seabird interactions on a wide range of longline vessel deck designs (Gilman et al. 2003b); (8) no incidences of gear being fouled in the propeller while side-setting from any of the three positions in the Hawaiian trials (Gilman et al. 2003a).

3.9 Concealing hooks and bait – Night-setting

Night-setting may reduce seabird mortality either because fewer birds are active at night, thus reducing the numbers of seabirds exposed to fishing operations, or because the birds have more difficulty seeing the baited hooks (Murray et al. 1993; Cherel et al. 1996; Barnes & Walshe 1997; Belda & Sánchez 2001). Night-setting is particularly beneficial if slow sinking baits are being set (Brothers et al. 1999a).

Belda & Sánchez (2001) investigated the influence of the time of setting on seabird bycatch in the Mediterranean demersal and pelagic longline fisheries. Significant differences were found in the number of seabirds caught at different hours weighted by the number of hooks set at each hour for both fisheries: birds were more abundant in setting operations taking place during sunrise (demersal fishery) and in the hours previous to sunset (pelagic fishery) (Belda & Sánchez 2001).

In the Patagonian toothfish longline fishery in the Kerguelen EEZ, Weimerskirch et al. (2000) reported night-setting significantly reduced the overall number of birds caught (0.91±1.72 birds/1000 hooks during the day, 0.17±0.82 birds/1000 hooks at night). This significant reduction in bycatch was observed for white-chinned petrel and all albatross species except the wandering albatross. In the demersal (Spanish system) Patagonian toothfish longlining fishery around the Falkland Islands, Reid & Sullivan (2004) recorded no birds being caught in the night sets.

Studies using observer data from Japanese longliners fishing in the AFZ and New Zealand EEZ, both recorded lower seabird bycatch rates when setting at night compared to during the day (Duckworth 1995; Klaer & Polacheck 1998). Klaer & Polacheck (1998) noted that seabird bycatch was five times greater during the day sets (0.252 birds per 1000 hooks) compared to night sets (0.022 birds per 1000 hooks).

Associated with night-setting is the influence of moon phase on seabird abundance and bycatch rates; the chance of catching seabirds during the full half-phase of the moon is greater than during the new half-phase (Ashford & Croxall 1998; Klaer & Polacheck 1998; Baird & Bradford 2000).

Shiode et al. (2001) investigated the influence of night-setting on target species catch rates in the Japanese Southern bluefin tuna longline fishery. Using data from Japanese Real Time Monitoring Program, fluctuations (both increases and decreases) in target catch rate were recorded in relation to night setting ratios.

Problems associated with night-setting include: (1) crew safety may be compromised due to reduced lighting levels under which to work (Brothers et al. 1999a); (2) concerns regarding the possibility of a negative impact on target fish catch rates. Fluctuations (both increases and decreases) in target catch rate have been recorded (Shiode et al. 2001); (3) possible lowering of the bycatch rate of one suite of seabird species (diurnal feeders) at the expense of another (crepuscular/nocturnal feeders) (Brothers et al. 1999a); (4) night-setting has limited potential as a comprehensive approach, particularly in high latitude fisheries there is little to no night for part of the year, and coupled with full moon limitations (Brothers et al. 1999a).

Benefits associated with night-setting include: (1) suitable for both bottom and pelagic longline fisheries (except for fisheries in high latitudes during the summer) (Sánchez & Belda 2003); (2) can be used in both large and small vessels (Sánchez & Belda 2003); (3) night-setting has been found to be an effective mitigation measure to reduce seabird incidental capture in a range of locations and fisheries (Duckworth 1995; Klaer & Polacheck 1998; Reid & Sullivan 2004).

3.10 Bird deterrent – Bird-scaring lines

Bird-scaring line devices are known by a variety of names, including: streamer lines (paired and single), tori lines, tori pole streamers, bird lines and bird scarers. This review encompasses all such devices, but refers to them collectively throughout the text as bird-scaring lines (BSLs).

Brothers et al. (1999a) define a BSL as any device that when deployed astern during line setting deters birds from taking baited hooks. Brothers (1995) describes a BSL that is correctly constructed and correctly used as a conspicuous moving fence, which creates an impassable barrier excluding seabirds from the area of the water where the baited hooks enter. BSL design differs between fisheries: in the Southern Hemisphere tuna pelagic longline and demersal fisheries, the BSL are generally lines with suspended streamers, whereas those used in the Alaskan fisheries are a line with towed objects such as a buoy bag (Brothers et al. 1999a). The main components of a BSL are the line, streamer lines and mounting pole (or high point for attachment) (Brothers 1995). A mechanised deployment and retrieval reel is not essential, but does eliminate bird line tangles and manual labour (Brothers 1995).

A reduction, significant in most cases, in seabird contacts and captures have been noted in a number of studies testing BSLs in the Norwegian commercial demersal longline fishery (Løkkeborg & Bjordal 1992; Løkkeborg 1998; Løkkeborg 2001; Løkkeborg & Robertson 2002; Løkkeborg 2003), Hawaiian pelagic swordfish longline fishery (Boggs 2001), Chilean demersal Patagonian toothfish Spanish-style longline fishery (Ashford & Croxall 1998), Alaskan demersal longline fishery (Melvin et al. 2001), Japanese Southern bluefin tuna pelagic longline fisheries (Manami & Kiyota 2004) and the New Zealand pelagic tuna longline and demersal ling autoline fisheries (Imber 1994; Smith 2001).

Trials in the New Zealand ling (*Genypterus blacodes*) demersal autoline fishery on the Chatham Rise found that the aerial section of the BSL appeared to keep all seabird species except cape pigeons (*Daption capense*) away from the longline (Smith 2001). Smith (2001) described the BSL as having most effect on the larger seabird species, especially *Diomedea* albatrosses. This is in part reflected in the species composition of the 12 birds (0.0093 seabirds per 1000 hooks set) caught during the trial: 10 grey petrels (*Procellaria cinerea*), one Chatham albatross (*Thalassarche eremita*) and one cape pigeon.

Løkkeborg (2001) tested an advanced and a simple BSL in the Norwegian demersal longline fishery: both types of BSL significantly reduced seabird bycatch (no BSL – 1.06 birds per 1000 hooks; simple BSL – 0.03 birds per 1000 hooks; advanced BSL – 0.00 birds per 1000 hooks), reduced bait loss and significantly increased the catch rate of the target species.

Both the paired-BSLs (flying streamer lines from both the port and starboard side of the vessel) and single-BSLs trialled by Melvin et al. (2001) in the Alaskan demersal longline fishery reduced seabird bycatch; however the paired-BSL was found to be the more effective of the two designs (no BSL – 0.094 birds per 1000 hooks; single-BSL – 0.006 birds per 1000 hooks; paired-BSL – 0.00 birds per 1000 hooks).

Observer data analysed for both New Zealand domestic and Japanese tuna longlining in the New Zealand EEZ, found that the presence or absence of a BSL had no statistically significant effect on seabird bycatch rates during either the day or night (Duckworth 1995; Baird & Bradford 2000).

A number of factors have been shown to influence the effectiveness of a BSL, including weather conditions, quality and mounting height (Duckworth 1995; Løkkeborg 1998; Brothers et al. 1999a). Correct mounting height of a BSL is critical for achieving maximum effectiveness; it increases the distance of hooked bait protection and prevents the fishing longline interfering with the bird line (Keith 1998; Brothers et al. 1999a).

Costs and problems associated with BSLs include: (1) the design of a BSL must be refined on individual vessels in order to achieve maximum effectiveness at reducing seabird bycatch. For example, the placement of streamers on the BSL is dependent on the length of the aerial section and the height of the attachment point on the vessel or pole (Brothers 1995; Keith 1998); (2) commercially-produced BSLs range in cost from $A200–300. A mounting ("tori") pole may be a further associated cost (Brothers et al. 1999a).

Benefits associated with BSLs include: (1) in most situations, BSLs significantly reduce seabird interactions with fishing gear and mortality (Løkkeborg & Bjordal 1992; Imber 1994; Ashford & Croxall 1998; Løkkeborg 1998; Boggs 2001; Løkkeborg 2001; Melvin et al. 2001;

Smith 2001; Løkkeborg & Robertson 2002; Manami & Kiyota 2004); (2) reduced bait loss has been recorded when using a BSL, which may result in an increase in target species catch rates (Løkkeborg 1998; Løkkeborg 2001); (3) deployment is relatively quick and easy; (4) BSLs are the most cost effective deterrent and are applicable to most longline and trawl fisheries (E. Melvin pers. comm.).

3.11 Bird deterrent – Brickle curtain

A protective curtain positioned around the hauling bay to reduce hook-ups by deterring birds from approaching too close to the hauling bay (Sullivan 2004). The curtain consists of a series of lines hanging seaward from a rope positioned around the hauling bay (Sullivan 2004).

Anecdotal evidence indicates that the Brickle curtain can effectively discourage birds from seizing baits in the hauling area (Brothers et al. 1999a). With regards to the Falkland Islands longline fisheries, Sullivan (2004) noted that some species (particularly black-browed albatross and cape petrels) can become habituated to the curtain when used over long periods; therefore they are best used periodically (i.e. when there are high densities of birds around the hauling bay) in order to remain effective as a mitigation method.

A problem associated with the Brickle curtain is the possible habituation by birds to the curtain (Sullivan 2004).

Benefits associated with the Brickle curtain include: (1) suitable for pelagic and demersal longline fisheries (Brothers et al. 1999a); (2) low cost for materials (Brothers et al. 1999a); (3) safe for the crew to use (Brothers et al. 1999a); (4) no negative impact on target fish catch rates or non-bird bycatch (Brothers et al. 1999a).

3.12 Bird deterrent – Fish oil

Oil is extracted from fish bycatch species and dispensed over the stern of the vessel, creating a slick in the water over the longline (Pierre & Norden in prep.).

At-sea trials (preliminary and under normal fishing operations) of school shark (*Galeorhinus galeus*) liver oil in the snapper pelagic longline fishery in the Hauraki Gulf of New Zealand resulted in a significant reduction in the numbers of seabirds and the numbers of dives on baits, compared to the seawater and canola oil (Pierre & Norden in prep.). This method was effective in a mixed species inshore seabird community numerically dominated by flesh-footed shearwaters (*Puffinus carneipes*).

Problems associated with fish oil may include: (1) unknown effect on ecosystem of introducing large amounts of fish oil into the marine environment (Pierre & Norden in prep.); (2) unknown effect of fish oil on feather surface of the birds (Melvin et al. 2004; Pierre & Norden in prep.); (3) unknown potential for habituation over time (Pierre & Norden in prep.).
Benefits associated with fish oil include: (1) produced from fish bycatch or discards (Melvin et al. 2004; Pierre & Norden in prep.); (2) proven to significantly reduce the numbers of seabirds and the numbers of dives on baits (Pierre & Norden in prep.); (3) no significant differences between the total numbers of fish, or the numbers of the target fish species, captured on longlines deployed while using shark liver oil compared to the seawater control (Pierre & Norden in prep.).

3.13 Bird deterrent – Water cannon

A high pressure hose is used to shoot water over the setting area in order to scare birds from the area where the baited hooks enter the water.

Trials conducted on Japanese pelagic longliners tested various combinations of nozzle tips, flow stabilizers, and emission angles and mixing ice particles to maximize the range of the water jet (Kiyota et al. 2001). Observations from the trial indicated that seabirds avoided the water jet and did not try to fly under the water curtain, but the water jet was deteriorated by cross wind. Also, the use of this device during cold windy conditions adversely affected the crew and as such was switched off during these instances (Brothers et al. 1999a).

Problems associated with the water cannon included: (1) the effectiveness of the water jet system is limited and insufficient to avoid incidental takes of seabirds by itself (Kiyota et al. 2001); (2) risks to crew safety and comfort (Brothers et al. 1999a).

If adopted, the water cannon could be used by pelagic and demersal longline fisheries (Brothers et al. 1999a).

3.14 Bird deterrent – Acoustic deterrents

Any noise used to deter birds away from the vessel. Methods used include firing a shotgun, canons, hitting the steel hull, or commercial devices that emit high frequency and loud noises or distress calls (Brothers et al. 1999a).

Anecdotal observations have reported acoustic deterrents as being effective at temporarily scaring birds away (Crysell 2002). However, no detectable response was found during a trial in which seabirds at a breeding colony were subjected to high-frequency and loud noise as well as distress calls (Brothers et al. 1999a).

Problems associated with acoustic deterrents include: (1) birds may habituate to the noise, making acoustic deterrents ineffective as long-term mitigation measures (Brothers et al. 1999a); (2) noise may not repel birds over distances sufficient to reduce bycatch (especially deep-diving species).

3.15 Bird deterrent – Magnetic deterrents

Commercially available magnetic devices claim to interfere with receptors that birds have for detecting magnetic fields (Brothers et al. 1999a).

The magnetic device was trialled at-sea on a Japanese tuna longliner within the AFZ, and near a shy albatross (*Thalassarche cauta*) breeding colony in Tasmania (Brothers et al. 1999b). The device did not significantly affect the catch of seabirds during the at-sea trials, and there was no apparent effects in the behaviour of birds at the breeding colony (Brothers et al. 1999b). Therefore magnetic deterrents are unlikely to offer protection to the 100 m or more astern required with present line-setting methods (Brothers et al. 1999a).

3.16 Bird deterrent – Electric deterrents

The Super DC pulse system is a device designed to produce an electric pulse field in the water in order to deter birds.

Kitamura et al. (2001) tested the Super DC pulse system on adult mallards in an experimental tank, observing the bird's behaviour under various levels of voltage and pulse stimulation. The mallards jumped out of the tank at 400–500 V. The feasibility study for producing electric fields in the open water concluded that carrying the huge generator on a southern bluefin tuna fishing vessel required to produce an effective electric pulse field was impractical in terms of cost, space and safety (Kitamura et al. 2001).

3.17 Increased sinking speeds – Integrated and external line weighting

Increasing line sink rates are likely to decrease the chance of interactions between seabirds and fishing gear, and consequent incidental mortality of seabirds during fishing. Adding weights to the fishing gear (either the branchlines or the mainline), or integrating weight into the line, may achieve a faster line sink rate (measured by time depth recorders).

Line weighting studies can be categorised as those investigating line sink rates of various weighting and spacing regimes, and those which investigate the effectiveness of reducing seabird bycatch by these different regimes. Both types of studies are described below in order to provide approximate guidelines for useful weighting regimes.

Brothers et al. (2001) tested the effect of line weighting (20 g, 40 g and 80 g swivels) on sink rate and bycatch on 10 pelagic longline vessels within the AFZ. The fastest sink rates were recorded for hooks with 80 g at 0 m or 1 m (0.68 and 0.71 m/s respectively). A baited hook with no weight attached sank 43% slower than a baited hook with an 80 g weight. Irrespective of how much weight was added, hooks sank more rapidly in the first 4 m than they did to 10 m. Vessels with faster line sink rates were recorded as having lower seabird bycatch rates than those with slower line sink rates.

In their study on a Southern bluefin tuna pelagic longline vessel off the southeast coast of the South Island, Anderson & McArdle (2002) recorded the depth of a baited hook after 30 seconds on an unweighted branchline (5.57 m), a monofilament branchline with a 60 g lead swivel (13.44 m), and a branchline composed of lead core cord (7.27 m). Based on these sink rates it was concluded that the addition of a 60 g weight removes the baited hooks from the recorded diving range of white-chinned petrels, shy albatross, black-browed albatross, grey-headed albatross and light mantled sooty albatross (*Phoebetria palpebrata*), but not sooty shearwaters (*Puffinus griseus*) (Anderson & McArdle 2002).

Boggs (2001) tested the effectiveness of attaching 60 g swivel weights 3.7 m above the bait in the Hawaii-based pelagic longline swordfish fishery. Contact rates were significantly lower for weighted lines compared to unweighted lines: expressed as contact rate per bird per 100 branchlines, the weights were 93% and 91% effective for black-footed and Laysan albatrosses respectively.

Two external line weighting regimes (38 g swivels and 60 g swivels placed 7.3 m and 5.5 m from the hook respectively) were trialled (no control) under normal fishing operations in the Australian East Coast tuna and billfish pelagic longline fishery (Baker & Robertson 2004). Recorded bycatch rates 0.167 and 1.04 birds/1000 hooks for the 38 g and 60 g trials respectively. The majority of birds caught were flesh-footed shearwaters.

Robertson (2000) tested different line weighting regimes (6.5 kg every 30, 50, 70, 100, 140 and 200 m) on a Patagonian toothfish autoline demersal longline vessel fishing on the Patagonian shelf near the Falkland/Malvinas Islands. As expected, sink time increased as weight spacing increased; however, sink rates to any depth did not vary greatly with weight spacings >70 m. Sink rates with weight spacings of 35 and 50 m were greatest close to the surface.

Smith (2001) analysed line sink rates using external weighting (2.5 kg and 5 kg) and no weighting on a New Zealand ling demersal autoline fishing vessel working on the Chatham Rise. Line sink rate varied significantly between sampling positions; however, the maximum line weighting regime (5 kg per 400 m) was not found to accelerate line sink rate on the vessel, suggesting that weights would need to be added at much closer intervals (e.g. 40 m) (Smith 2001).

Results from a study investigating weight regimes (4.25, 8.5 and 12.75 kg attached at 40 m intervals) on a Spanish-rigged demersal longline for the toothfish fishery around South Georgia, reported a significant reduction in seabird mortality when 8.5 kg was used compared to 4.25 kg, but no further significant reduction when 12.75 kg was used (Agnew et al. 2000).

Melvin et al. (2001) reported the effect of weighted gear on seabird bycatch to be variable when tested in the Alaskan cod (10 lb/90 m) and sablefish (0.5 lb/11 m) demersal longline fisheries. In the first year of the trial, adding weight to gear significantly reduced seabird bycatch relative to no deterrent by 37% and 76% for the sablefish and cod fisheries respectively. However, in the second year of the trial, the addition of weights did not improve the already high bycatch reduction of paired-BSLs (Melvin et al. 2001).

The effectiveness of integrated weight (IW) (50g lead/m) in reducing white-chinned petrel and sooty shearwater mortality was tested in the New Zealand ling demersal autoline longline fishery off of Solander Island, New Zealand (Robertson et al. 2004b). When using IW compared to unweighted (UW) line, a 98.7% and 93.5% reduction in mortality of white-chinned petrels was recorded during 2002 and 2003 respectively. For sooty shearwaters, a 100% and 60.5% reduction in mortality was recorded during 2002 and 2003 respectively. Catch rates of ling and non-target fish species were not affected by use of IW lines (Robertson et al. 2004b).

Using two different vessels, Robertson, Smith et al. (2004) recorded line sink rates of UW silver line, IW silver line and IW polyester line in the New Zealand ling demersal autoline longline fishery off of Solander Island (NZ) and the Patagonian toothfish demersal longline fishery around Heard Island. While there was no difference in sink rates between vessels, there was a statistically significant difference between line types; the mean sink rate for UW silver was 0.109±0.022 m/s, IW silver was 0.239±0.018 m/s and IW polyester was 0.272±0.022 m/s. However, adding external weights to unweighted lines resulted in a sink profile similar to IW lines.

Associated costs and problems with line weighting include: (1) concern for crew safety when using added external weights (Brothers et al. 2001; Melvin et al. 2001; Anderson & McArdle 2002); (2) use of lead weighting (either external or integrated) increases the risk of this potentially harmful compound accumulating in the marine environment; (3) increased cost due to the extra swivels/weights (Brothers et al. 2001); (4) attaching external weights close to the hook may incur an extra cost due to increased loss of weights when lines are cut by bycatch (especially sharks) (Brothers et al. 1999a); (5) variable results regarding the effectiveness of line weighting were recorded in the Alaskan demersal longline fishery (Melvin et al. 2001).

Benefits associated with line weighting include: (1) reduced seabird bycatch in demersal and pelagic longline fisheries (Agnew et al. 2000; Boggs 2001; Robertson et al. 2004b); (2) lead core line is safe for crew to use (Anderson & McArdle 2002); (3) appropriate weighting can keep hooks in the right depths for longer, so improving catch potential in both demersal and pelagic fisheries (Brothers et al. 2001; Melvin et al. 2001); (4) catch rates of target and non-target fish species were not affected by use of IW lines (Robertson et al. 2004b).

3.18 Increased sinking speeds – Line shooter

Setting a demersal longline under tension may result in hooks remaining on the surface and accessible to seabirds for a longer period (Sullivan 2004). A line shooter sets the line without tension, enabling the line to set closer to the vessel and perhaps increase the sink rate (Melvin et al. 2001; Løkkeborg & Robertson 2002). This device consists of a pair of hydraulically operated wheels that pull the line through the auto-baiter, delivering the line slack into the water.

The results of the Mustad line shooter trials in the Norwegian and Alaskan demersal longline fisheries have shown remarkably varying results with regards to reducing seabird bycatch (Melvin et al. 2001; Løkkeborg & Robertson 2002). Løkkeborg & Robertson (2002) reported a reduction (though not significant) in the number of seabirds caught when using a line shooter (32 birds caught using no mitigation device, 13 in sets with the line shooter).

Lines set with the shooter reached 3 m depth in 22.6±4.1 s (15% faster), compared to 26.6±7.3 s without the shooter. However, sinking rates were similar beyond 3 m depth (Løkkeborg & Robertson 2002). In contrast, Melvin et al. (2001) reported total seabird (including short-tailed shearwaters *Puffinus tenuirostris*) catch per unit effort significantly increased by 54% when a line shooter was used compared to sets made with out the shooter.

Observations were made on the Avro Chieftain while using a line setter in the Ross Sea in conjunction with IWL, with the aim of trying to sink the IWL at the CCAMLR requirement of 0.3 m/sec, without putting weights on. Sink rates were monitored as per CCAMLR requirements. Using bottle test sink rates, the sink rates were found to exceed 0.7 m/sec (over twice the required CCAMLR sink rate at that time) and getting up to 2 m/sec. More accurate sink trials were to be conducted in order to assess the profile of the sink rate using TDRs, however these were never done as CCAMLR altered the sink rate to one that was achievable without using the line setter when using IWL (M. McNeill pers. comm.).

Problems associated with using the line shooter include: (1) using a line shooter was shown to increase seabird bycatch in the Alaskan cod demersal longline fisheries (Melvin et al. 2001); (2) requires additional crew to set gear (Melvin et al. 2001); (3) results of trials using line shooters have been variable (Melvin et al. 2001; Løkkeborg & Robertson 2002).

One benefit recorded when using the line shooter was that target fish catch rate did not vary compared to not using one (Løkkeborg & Robertson 2002).

3.19 Increased sinking speeds – Bait condition

The condition of the bait (frozen/thawed, swim-bladder inflated/deflated) can influence its buoyancy and therefore availability to birds (Brothers et al. 1999a).

Results from an experiment assessing the sink rates in a tank of stationary salt water found that bait size (large versus small), bait condition (frozen versus thawed), and bait species (mackerel scad *Decapterus macarellus*, chub mackerel *Scomber japonicus*, Japanese pilchard *Sardinops melanostichus* and squid *Todarodes pacificus*) had significant effects on sink rates (Brothers et al. 1995). Bait condition had the most powerful effect, with thawed baits sinking and frozen baits floating. Fish with inflated swim bladders were the exception, floating even when they were thawed. The sink rate of bait with inflated swim bladders may be solved by adding a 20 g lead sinker or swivel to a baited hook (Brothers et al. 1995).

Analyses of observer data from New Zealand domestic and Japanese pelagic tuna longlining in the New Zealand EEZ and for Japanese pelagic longliners fishing in the AFZ, have reported reduced seabird bycatch (only in the summer for the AFZ data) when using thawed bait compared to using frozen or poorly thawed bait (Duckworth 1995; Klaer & Polacheck 1998; Brothers et al. 1999b).

Contrary to previous studies, Anderson & McArdle (2002) study using squid baits, recorded partially thawed baits sinking faster than thawed baits. These results provide further support for Brothers et al. (1995) suggestion that sink rates may vary between bait species.

Problems associated with thawed bait include: (1) compared to frozen baits, thawed baits pull off the hooks more easily when they are thrown from the ship (Brothers et al. 1999a); (2) many vessels have inadequate thawing facilities, which lead to inconsistency in the thaw state of bait (Brothers et al. 1999a); (3) possible costs of installing thaw racks which incorporate a sprinkler system (Brothers et al. 1999a); (4) applicable only to pelagic longlining.

Benefits associated with thawed bait include: (1) compared to frozen baits, thawed baits are easier to apply to hooks (Brothers et al. 1999a); (2) remove discomfort for crew through handling thawed rather than frozen bait (Brothers et al. 1999a); (3) observer data recorded a reduction in bycatch when using thawed bait compared to frozen or partially thawed bait (Duckworth 1995; Klaer & Polacheck 1998; Brothers et al. 1999b); (4) bait size (large versus small), bait condition (frozen versus thawed), and bait species had significant effects on sink rates (Brothers et al. 1995).

3.2 Concepts not trialled

Methods designed to conceal bait include the Bait Spider, smart lures, and hull-integrated underwater setting (Anonymous 1998; Brothers et al. 1999a; Anonymous 2000). Deterrent methods that have not been trialled include the Hose, the 'Brigette Bardot' laser gun, the Ultrasonix electronic protection bird scarer, and emitting smoke from refuse disposal incinerators (Brothers et al. 1999a; Crysell 2002). Frozen block bait or glazed bait have been suggested as methods for improving sink rates (Anonymous 2000).

4. Discussion

4.1 Mitigation studies

Melvin & Robertson (2000) discussed the difficulties in evaluating mitigation research and making comparisons between studies. Goals, methodologies and sampling protocols are rarely similar across studies, sample sizes are rarely adequate to make robust comparisons, and controlled studies conducted aboard fishing vessels are few. Melvin & Robertson (2000) suggested that the following criteria should be incorporated into research programmes testing seabird bycatch deterrents in longline fisheries: (1) a single, common goal: to reduce seabird bycatch significantly without reducing the catch rate of the target species or increasing the bycatch of other non-target species; (2) compare deterrent strategies to a standard: either a control of no deterrent or some other rational measure; (3) collaborate with fishers and conduct research on active fishing vessels; and (4) use consistent measures of bird interactions (such as abundance and attacks) and bird catch per unit effort and explore the relationship among them.

While much information can be obtained from data collected by observer programmes, because of its method of collection, there are limitations imposed on its use (i.e. this work is done without controls, time restraints are placed on the observer to do other tasks, and the observer is not necessarily trained at seabird identification). Controlled studies do require comparatively more resources compared to the use of observer programme data, however they are necessary in order to draw robust conclusions from the data collected and conduct comparisons between studies. Previously, research through controlled studies has been rare; however with the growth and development of bycatch mitigation research internationally, an increasing proportion of recent studies in longlining mitigation have incorporated the above criteria, and as such the same should be done in the emerging field of trawling research (Melvin et al. 2001; Gilman et al. 2003a; Løkkeborg 2003; Robertson et al. 2004b; Sullivan et al. 2004b).

Despite a number of studies in this review not fulfilling the above criteria, there was sufficient information to provide recommendations for mitigation measures to reduce seabird captures in the New Zealand longline fisheries.

Factors influencing the appropriateness and effectiveness of a mitigation device include the fishery, vessel, location, seabird assemblage present and time of year (i.e. season). As such, there is no single magic solution to reduce or eliminate seabird bycatch across all fisheries. Realistically a ***combination of measures*** is required, and even within a fishery there is likely to be ***individual vessel refinement*** of mitigation techniques in order to maximise their effectiveness at reducing seabird bycatch.

4.2 Recommended methods

Based on the reviewed material, a combination of BSLs, line weighting, night setting (in some fisheries), and retention of offal during fishing operations is likely to be the most effective regime at mitigating seabird bycatch in New Zealand demersal and pelagic longline fisheries.

The presence of offal has been shown to influence seabird numbers attending vessels, the species present, and interactions with fishing gear in both trawl and longline fisheries in New Zealand and overseas (Weimerskirch et al. 2000; Robertson & Blezard 2005; Sullivan et al. in press). The most important observation made in several studies was that all mortalities occurred at times of offal discharge (Robertson & Blezard 2005; Sullivan et al. in press). If managed and implemented correctly, the retention or strategic management of offal and discards has the potential to be used as an avoidance tool, rather than simply mitigating seabird bycatch.

Studies have reported BSLs effectively reducing (significantly in most cases) seabird contacts and mortalities in both pelagic and demersal longline fisheries in New Zealand and overseas waters (Løkkeborg & Bjordal 1992; Imber 1994; Ashford & Croxall 1998; Løkkeborg 1998; Boggs 2001; Løkkeborg 2001; Melvin et al. 2001; Smith 2001; Løkkeborg & Robertson 2002; Løkkeborg 2003; Manami & Kiyota 2004). Contrary to the majority of studies, Duckworth (1995) and Baird & Bradford (2000) reported that the presence or absence of a BSL had no statistically significant effect on seabird bycatch rates when analysing observer data for both New Zealand domestic and Japanese tuna longlining in the New Zealand EEZ. The use of observer data for these two studies may limit the quality of the data compared to the controlled studies.

Factors shown to influence the effectiveness of a BSL include the seabird assemblage present, fishing grounds, target fish species, fishing method, vessel size, time of day/year, weather conditions, BSL quality and mounting height (Duckworth 1995; Løkkeborg 1998; Brothers et al. 1999a). Correct mounting height is critical for achieving maximum effectiveness; it increases the distance of bait protection and prevents interference with the longline (Keith 1998; Brothers et al. 1999a). Therefore, individual vessel refinement of BSLs is likely to be necessary in order to achieve maximum effectiveness.

BSLs fulfil many of the criteria necessary for a successful mitigation measure, including: reduced seabird bycatch rate, reduced bait loss which may lead to a possible increase in target fish catch rates (Løkkeborg 2001), easy and relatively quick to deploy and retrieve, reasonably priced, and can be used in both demersal and pelagic longline fisheries.

External and integrated line weighting have been shown to increase line sink rates and hence decrease the chance of incidental seabird mortality in both pelagic and demersal longline fisheries in New Zealand and overseas waters (Agnew et al. 2000; Robertson 2000; Boggs 2001; Brothers et al. 2001; Melvin et al. 2001; Robertson et al. 2004b). A number of variables affect line sink rate, including both environmental (e.g. weather conditions, swell height) and equipment (e.g. propeller wash and turbulence) factors; identifying the variables that are most influential to sink rates will be necessary to design a line-weighting regime that will achieve faster line sink rates (Smith 2001).

With regards to external weighting on pelagic longlines, the line sinks faster the closer the weight is to the hook (Brothers et al. 2001; Anderson & McArdle 2002). There is an abundance of proficient diving seabird species in New Zealand and Australian waters, and to date prescribed weight regimes to achieve sink rates of 0.26–0.30 m/s for pelagic longlines in these waters include using an 80 g within 3 m of the hook, a 60 g weight 1–2 m from the hook, or a 40 g weight at the hook (Brothers et al. 2001; Anderson & McArdle 2002).

The recent trial of IW (50g lead/m) in the New Zealand ling demersal autoline longline fishery off Solander Island (New Zealand), recorded a significant reduction in sooty shearwater and white-chinned petrel captures over two consecutive seasons (Robertson et al. 2004b). These result were encouraging given that both these species are highly proficient divers and a regular bycatch species in New Zealand longline fisheries (Robertson et al. 2004a). Furthermore, catch rates of ling and non-target fish species were not affected by use of IW lines (Robertson et al. 2004b).

Bait condition (thawed and with deflated swim bladders) is a further mitigation measure that should be used in pelagic longline fisheries, but in combination with other measures (Brothers et al. 1995; Brothers et al. 1999a).

4.3 Future research

Underwater setting devices have shown to be more effective at reducing bycatch in Northern Hemisphere seabird assemblages than those in the Southern Hemisphere (Gilman et al. 2003a). The composition of Southern Hemisphere seabird assemblage includes proficient divers, therefore a device is required that consistently achieves setting depths to 10 m. Ryan & Watkins (2000) noted structural limitations of the tube-type setting devices such as the funnel (particularly those that are stern-mounted), which may not enable them to be built to the lengths necessary to prevent the incidental capture of species such as white-chinned petrels which are able to dive to depths of at least 10 m. Increasing setting depths to avoid diving seabirds, has the adverse affect of increasing fishing cycle time. Furthermore, the chute, funnel and capsule all exhibited inconsistencies in line setting performance and reducing bycatch. Therefore, further development and at-sea trials under normal fishing operations are required before these devices reach their full potential (perhaps not sufficient to reduce Southern Hemisphere seabird bycatch) and therefore ready for commercial use. In terms of future advances in effective underwater systems, they should be considered in the vessel design (i.e. hull integrated underwater setting system) rather than an afterthought (E. Melvin pers. comm.).

While Melvin et al. (2001) found single-BSLs reduced seabird bycatch relative to no mitigation measure in the Alaskan demersal longline fishery, paired-BSLs were even more effective (no BSL – 0.094 birds per 1000 hooks; single-BSL – 0.006 birds per 1000 hooks; paired-BSL – 0.000 birds per 1000 hooks). As such, it would be beneficial to trial paired-BSLs in New Zealand longline fisheries to test their effectiveness relative to single-BSLs.

For the time of setting to be used as a mitigation measure, it is first necessary to have knowledge of the seabird species implicated in attacking lines and their foraging habits (i.e. time of day, dive depths etc). Therefore, while night-setting may provide additional protection, further studies are required in New Zealand waters to determine the potential impact of this measure on night-foraging species such as the white-chinned petrel (Brooke 2004). Weimerskirch et al. (2000) reported a significant reduction in the bycatch rate of white-chinned petrels when lines were set at night compared to during the day. However, given the relatively high numbers of both grey and white-chinned petrels in New Zealand fisheries bycatch (Robertson et al. 2004a), specific research needs to be undertaken to assess the effectiveness of night-setting for birds and for fish.

Despite encouraging results (both in terms of reducing seabird bycatch and the potential to increase fishing efficiency), side-setting has been reported from a limited number of longline fisheries (Gilman et al. 2003a; Sullivan 2004). The uptake of this method may be limited by the vessel size and the initial costs of the vessel alterations. Pilot observations were made in a New Zealand ling fishery, and the results suggest that side-setting should not be ruled out as a possible mitigation measure for future trial in New Zealand longline fisheries (especially those employing larger-sized vessels).

Initial studies of fish oil have shown this to be an effective measure at reducing seabird interactions with fishing gear, particularly in the New Zealand snapper longline fishery (Pierre & Norden in prep.). However, this is a recently reported concept and requires further investigation, particularly with regards to the mechanism behind its effectiveness (i.e. why does it reduce the dives made by seabirds?) and the impacts on the birds and marine ecosystem of introducing potentially large quantities of fish oil into environment (Melvin et al. 2004; Pierre & Norden in prep.).

While certain fisheries currently set conditions around offal discharge (i.e. when, where and in what form), further research is required in order to eliminate the uncertainty regarding the influence of offal discharge on seabird bycatch, particularly in New Zealand fisheries. In the Patagonian toothfish demersal longline fishery around the Kerguelen EEZ, Weimerskirch et al. (2000) reported that the release of offal increased the number of birds attending the vessel, especially on the number of large species and white-chinned petrels.

4.4 Miscellaneous mitigation measures

Bait-casting machines can reduce bait loss to birds in pelagic fisheries by half when used with a BSL (Brothers 1993). However, the neglect of some bait-throwing machines to incorporate the initial designs to mitigate against seabird bycatch (cycle time, direction reversal, immediate distance dial, and low arc of throw) in favour of the labour saving functions, has greatly reduced the value and potential of this device to reduce incidental captures (Brothers et al. 1999a).

While Løkkeborg & Robertson (2002) recorded a reduction (though not significant) in seabird bycatch during line shooter trials in the Norwegian demersal longline fisheries, an increase in seabird bycatch was found when this device was tested in the Alaskan demersal longline fisheries (Melvin et al. 2001). Throughout the course of this review, this was the only instance in which a mitigation measure was found to increase seabird bycatch, and as such is not recommended for use in New Zealand longline fisheries.

Limited tests were conducted on magnetic deterrents, water cannons, electric deterrents, acoustic deterrents, the Brickle curtain, and blue-dyed bait; however these methods seem unlikely to be effective as long-term mitigation measures due to logistical or possible habituation issues.

Thawing and dying of bait blue was initially employed to improve swordfish catch in the United States East Coast longline fishery (Boggs 2001). Fishermen considered the dyed bait to be more visible to target fish, however it was also observed to reduce seabird scavenging on longline bait. While blue-dyed bait was shown to be initially effective at reducing seabird bycatch, is unlikely to be a feasible long-term mitigation measure. One of the New Zealand studies recorded a change in the bird's behaviour towards the blue-dyed bait at the end of the trials, actively attacking both the dyed and the un-dyed baits on the final set; behaviour indicative of habituation (Lydon & Starr 2005).

Temporal variation in seabird abundance at vessels, contact and bycatch rates have been documented, with the majority of birds being caught during the breeding seasons (Melvin et al. 1999; Weimerskirch et al. 2000; Robertson et al. 2004a). In New Zealand waters, area closures would be particularly beneficial in areas close to major seabird breeding colonies.

Seasonal closures would need to incorporate the breeding seasons of both summer- and winter-breeding seabirds.

Acknowledgements

This work was funded by the Conservation Services Programme, Department of Conservation, New Zealand. I am grateful to the members of the project's steering committee for their advice, feedback and guidance: Greg Lydon (Seafood Industry, New Zealand), Ed Melvin (Washington Sea Grant Program, Alaska), Janice Molloy (New Zealand Department of Conservation), Johanna Pierre (New Zealand Department of Conservation), and Neville Smith (New Zealand Ministry of Fisheries).
Thanks to Wendy Norden (Conservation Services Programme, New Zealand) for analysing Conservation Services Programme unpublished data and providing useful discussions and suggestions that improved this report.
Many thanks to Nigel Brothers, Kim Duckworth, Masashi Kiyota, Svein Løkkeborg, Ed Melvin, Graham Robertson and Ben Sullivan, for providing permission to use their material. Barry Baker, Ed Melvin and Ben Sullivan provided material from recent studies.

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Table 1
Appropriate (✓) mitigation methods for demersal and pelagic longline fisheries.

Mitigation method	Pelagic	Demersal
Area/seasonal	✓	✓
Bait condition	✓	
Bait-casting machine	✓	
Bird-scaring lines	✓	✓
Blue-dyed bait	✓	
Brickle curtain	✓	✓
Capsule	✓	
Chute	✓	
Funnel		✓
Line shooter		✓
Line weighting	✓	✓
Night-setting	✓	✓
Offal retention	✓	✓

Appendix 1 – Longline mitigation methods

Mitigation method	Reference	Rigour	Fisheries	Seabird taxa observed	Reduction to bycatch	Fishing efficiency
Bait-throwing machine	Brothers (1993)	• At-sea trials. • Observations during normal fishing operations. • Trialed in two fishing grounds, but information on machine use in Indian Fishing ground only are reported.	•Indian Ocean Southern bluefin tuna fishing ground and the Fremantle big eye tuna fishing ground (30°S 101°E).	• Black-browed albatross (*Diomedea melanophrys*) • Grey-headed albatross (*D. chrysostoma*) • Royal albatross (*D. epomophora*) • Giant petrel (*Macronectes* spp.) • Fleshy footed shearwater (*Puffinus carneipes*)	• A total of 19 seabirds were caught from 149,840 hooks set, an average of 0.12 birds per 1000 hooks. Twelve of the birds caught took floating muro aji baits that had inflated air bladders.	• Possible increase in fishing effort or maintaining present fishing effort but reduced actual work due to reduced cycle time. • Baits are not lost from hooks during machine throwing.
Bait-throwing machine	Duckworth (1995)	• Analysis of observer data	• Japanese pelagic southern bluefin tuna fishery within NZ EEZ	Not recorded.	• Bait throwers significantly reduced levels of bycatch: 6 birds (0.04 birds/1000 hooks) were caught when a bait thrower was used, compared to 209 (0.19 birds/1000 hooks) when a bait thrower was not used.	Not recorded.
Bait-throwing machine (+ bait thawing)	Klaer & Polacheck (1998)	• Australian Fishing Zone (AFZ) observer data collected at sea. • Quantitative analyses.	• Japanese longline fishing within the AFZ	Not recorded.	• Bait thawing was the most significant measured factor, followed by use of a bait thrower. • Fair and good thawing decrease the seabird bycatch rate in comparison with poorly thawed bait. • Not using a bait thrower increases the seabird bycatch rate in comparison with using one.	Not recorded.

Bird-scaring line	Ashford & Croxall (1998)	• Experimentally tested - control (without a streamer line) vs. experimental (with streamer line). • At-sea trials under normal fishing conditions. • Observations. • Quantitative analyses.	• Chilean Patagonian toothfish (*Dissostichus eleginoides*) Spanish-style demersal longline fishery	• Black-browed albatross (*Diomedea melanophris*) • Wandering albatross (*D. exulans*) • Grey-headed albatross (*D. chrysostoma*) • Giant petrels (*Macronectes* spp.) • White-chinned petrels (*Procellaria aequinoctialis*) • Cape petrels (*Daption capense)*	• A total of 12 dead seabirds (nine white-chinned petrels, two black-browed albatrosses and one unidentifiable bird) were recorded, giving an average mortality rate/night of 0.099 birds/1000 observed hooks. • During the streamer line trials, four mortalities were observed, consisting of two black-browed albatrosses, one white-chinned petrel and one bird too damaged to be identified.	Not recorded.
Bird-scaring line	Baird & Bradford (2000)	• New Zealand Ministry of Fisheries Scientific Observer data collected at sea. • Quantitative analyses.	• Japanese tuna pelagic longline fishery	Not recorded.	• The use of tori lines and night-setting did not show up as statistically significant in reducing seabird bycatch.	Not recorded.
Bird-scaring line	Baird & Bradford (2000)	• New Zealand Ministry of Fisheries Scientific Observer data collected at sea. • Quantitative analyses.	• New Zealand domestic tuna pelagic longline fishery	Not recorded.	• Mitigation measures did little to explain variance in seabird catch; no significant effects due to moon phase, use of tori lines, and night-setting were found when all birds were included.	Not recorded.
Bird-scaring line	Boggs (2001)	• Experimentally tested - control (no streamer lines) vs. experimental (streamer lines). • Comparative assessment between 3 experimental mitigation devices (streamer lines, blue-dyed baits and weights added to baits).	• Hawaii pelagic swordfish (*Siphias gladius*) longline fishery	• Black-footed albatross (*Phoebastria nigripes*) • Laysan albatross (*P. immutabilis*)	• The effectiveness of the deterrents was calculated as the percent reduction in contact rates in comparison with control results. Expressed as contact rate per bird per 100 branch lines, the streamer line was 75% and 77% effective for black-footed and Laysan albatrosses respectively.	Not recorded.

		• At-sea trials. • Quantitative analyses.				
Bird-scaring line	Duckworth (1995)	• Analysis of observer data	• Japanese southern bluefin tuna longliners fishing within the NZ EEZ	Not recorded.	• The presence or absence of a tori line has no statistically significant effect on seabird bycatch rate during either the day or night. • About half of the tori lines included in this study appeared to have little or no effect in reducing the seabird bycatch rate. The others were effective and resulted in significant reductions in seabird bycatch. Therefore, the effectiveness of tori lines in reducing seabird bycatch rates varies greatly depending on the physical properties of the tori line.	Not recorded.
Bird-scaring line	Imber (1994)	• At-sea observations made during fishing operation. • Quantitative analyses.	• New Zealand-owned tuna (big-eye tuna *Thunnus obesus*) pelagic longlining	• Wandering albatross (*Diomedea exulans* subspp.) • Salvin's mollymawk (*D. cauta salvini*) • NZ black-browed mollymawk (*D. melanophris impavida*) • Yellow-nosed mollymawk (*D. chlororhynchos carteri*) • Light-mantled sooty albatross (*Phoebetria palpebrata*) • Sooty shearwater (*Puffinus griseus*) • Grey petrel (*Procellaria*	• The mortality rate of seabirds was 0.27/1000 hooks set. • Nearly all the bait-taking occurred beyond the aerial part of the bird-scaring lines. • The vessel's bird-scaring line seemed to reduce but not eliminate bait-taking.	• During the 8 mainly daytime sets (setting starting between 0800 and 1830h), 4 tuna and all (6) of the seabirds were caught. • During the 6 night time sets (setting starting between 0130 and 0530), 10 tuna and no seabirds were caught.

				cinerea) • White-chinned petrel (*P. aequinoctialis*) • Cape pigeon (*Daption capense australe*) • Northern giant petrel (*Macronectes halli*) • Fairy prion (*Pachyptila turtur*) • Grey-faced petrel (*Pterodroma macroptera gouldi*) • White-headed petrel (*P. lessonii*) • Soft-plumaged petrel (*P. mollis*) • Australasian gannet (*Morus serrator*)		
Bird-scaring line	Keith (1998)	• At-sea trials during normal fishing operations. • Observations.	New Zealand domestic pelagic longliners	Not recorded.	• No seabirds were caught during setting by either boat, though two were hooked and released alive during retrieval of the gear. • Both boats reported a large bird presence during the trials, with numerous attempts to take baits aborted due to the streamers on the tori line. • The crew found it difficult to assess whether the line was visible to seabirds when setting was done at night.	Not recorded.
Bird-scaring line	Løkkeberg & Bjordal (1992)	• Experimentally tested - control (no bird-scaring line) versus experimental (bird-scaring line). • At-sea trials. • Quantitative analyses.	• Norwegian commercial longline	• Northern fulmar (*Fulmarus glacialis*)	• No birds were caught when using the bird-scarer, compared to three fulmar caught without the bird-scarer.	Not recorded.

Bird-scaring line	Løkkeberg & Robertson (2002)	• Experimentally tested - control (no mitigation measure) versus 3 experimental treatments (bird-scaring line, line shooter, bird-scaring line + line shooter). • Comparative assessment between 3 mitigation measures (bird-scaring line, line shooter, bird-scaring line + line shooter). • At-sea trials under normal fishing operations. • Quantitative analyses.	• North Atlantic demersal longline fishery (Torsk *Brosme brosme*, Ling *Molva molva*)	• Estimated 70–600 northern fulmar (*Fulmarus glacialis*) followed the vessel during setting operations	• No birds were caught using the bird-scaring line alone, however a single fulmar was caught when the bird-scaring line was used in combination with the line shooter. Thirty-two fulmar (0.55 birds/1000 hooks) were caught in sets with no mitigation device. • For the bird line there was a significant difference on seabird captures both between the bird line and the control.	• There was no significant difference between fish catch rates between the setting methods.
Bird-scaring line	Løkkeberg (1998)	• Experimentally tested - control (no bird-scaring line) versus experimental (bird-scaring line). • Comparative assessment between 2 mitigation measures (bird-scaring line and underwater setting funnel). • At-sea trials under normal fishing operations. • Quantitative analyses.	• North Atlantic demersal longline fishery (Torsk *Brosme brosme*, Ling *Molva molva*)	• The majority (>95%) of the birds caught were fulmars.	• There were significant differences between the setting methods in the bycatch of seabirds; lines set without any devices caught 99 birds (1.75 birds per 1000 hooks) and lines set with the bird scarer caught two birds (0.04 birds per 1000 hooks). • The bird-scaring line was less efficient during strong wind conditions and when setting lines across the wind direction, as the wind will bring the streamers out of their ideal position right above the line; the two birds caught when using the scarer were caught under such conditions.	• No increase in the catches of target species.

Bird-scaring line (paired streamers)	Melvin, Parrish, Dietrich & Hamel (2001)	• Control (no deterrent) vs. experimental (paired streamer BSL). • At-sea trials under normal fishing operations. • Trialed in two fisheries. • Quantitative and comparative analyses.	• The Gulf of Alaska / Aleutian Island Individual Fishing Quota (IFQ) demersal fishery (sablefish *Anoplopoma fimbria* and halibut) • Bering Sea catcher-processor demersal longline fishery (Pacific cod *Gadus macrocephalus*)	• Northern fulmar (*Fulmarus glacialis*) • Laysan albatross (*Phoebastria immutabilis*) • Gulls • Shearwaters (mostly *Puffinus tenuirostris*)	• Paired streamer lines successfully reduced seabird bycatch in all years, regions, and fleets, and were robust in a wide range of wind conditions and required little adjustment as physical conditions changed. • In addition to decreasing total attacks, paired streamer lines increased the distance at which peak attacks occurred astern of the vessel by 20 m to 40 m, depending on species and fishery, reducing the likelihood of hookings.	• The use of paired streamer lines had no effect on catch rates of target fish species.
Bird-scaring line (single streamer)	Melvin, Parrish, Dietrich & Hamel (2001)	• Control (no deterrent) vs. experimental (single streamer BSL). • At-sea trials under normal fishing operations. • Trialed in two fisheries. • Quantitative and comparative analyses.	• The Gulf of Alaska / Aleutian Island Individual Fishing Quota (IFQ) demersal fishery (sablefish *Anoplopoma fimbria* and halibut) • Bering Sea catcher-processor demersal longline fishery (Pacific cod *Gadus macrocephalus*)	• Northern fulmar (*Fulmarus glacialis*) • Laysan albatross (*Phoebastria immutabilis*) • Gulls • Shearwaters (mostly *Puffinus tenuirostris*)	• SABLEFISH FISHERY - Single streamer lines reduced seabird bycatch by 96% (0.006 birds/1000 hooks) (a single northern fulmar was caught) relative to controls (0.094 birds/1000 hooks). • COD FISHERY - Single streamer lines were less effective and not significantly different from controls. • Single streamer lines were slightly less effective than paired streamer lines, reducing seabird bycatch by 96% and 71% in the sablefish and cod fisheries respectively.	Not recorded.

Bird-scaring line	Smith (2001)	• At-sea trial during fishing operations. • Observations.	• New Zealand demersal autoline longline fishery (•ling *Genypterus blacodes*)	• Royal albatross (*Diomedea epomophora*) • Sanford's albatross (*D. sanfordi)* • Antipodean albatross (*D. antipodensis*) • Gibson's albatross (*D. gibsoni*) • Snowy albatross (*D. chionoptera*) • Light-mantled sooty albatross (*Phoebetria palpebrata*) • Chatham albatross (*Thalassarche eremita*) • Salvin's albatross (*T. salvini*) • White-capped albatross (*T. cauta*) • Black-browed albatross (*T. melanophrys*) • Southern Buller's albatross (*T. bulleri*) • Northern giant petrel (*Macronectes halli*) • Southern giant petrel (*M. giganteus*) • Cape pigeon (*Daption capense*) • Grey petrel (*Procellaria cinerea*) • Westland petrel (*P. westlandica*) • Sooty shearwater (*Puffinus griseus*) • Brown skua (*Catharacta maccormicki*)	• The aerial section of the tori line appeared to keep all species, except Cape pigeons (*Daption capense*) away from the longline.	Not recorded.

Bird-scaring line (advanced BSL)	Løkkeberg (2001)	• Experimentally tested - control (no bird-scaring line) versus experimental (advanced bird-scaring line). • Comparative assessment between 3 mitigation measures (simple bird-scaring line, advanced bird-scaring line and underwater setting funnel). • At-sea trials under normal fishing operations. • Quantitative analyses.	• North Atlantic demersal longline fishery (torsk *Brosme brosme*, ling *Molva molva*, haddock *Melanogrammus aeglefinus*)	• Northern fulmar (*Fulmarus glacialis*)	• 74 birds (1.06 birds per 1000 hooks) were caught when no mitigation measure was used, compared to zero birds when using the advanced bird-scaring line.	• The catch rates of target species was significantly higher with lines set using one of the mitigation measures, than those without any measure. The differences in catch rates among the three mitigation measures were not significant. • The highest catch rate was obtained by lines set with the advanced bird-scaring line, which gave a 32% catch increase compared with the control. • Mackerel-baited lines that were set without a mitigation device or through the setting funnel, had significantly higher bait losses than lines set using the bird-scaring lines. For lines baited with squid, the three mitigation measures resulted in similar rates of bait loss, but these lines lost fewer squid baits than lines set without any measure.

Bird-scaring line (simple BSL)	Løkkeberg (2001)	• Experimentally tested - control (no bird-scaring line) versus experimental (simple bird-scaring line). • Comparative assessment between 3 mitigation measures (simple bird-scaring line, advanced bird-scaring line and underwater setting funnel). • At-sea trials under normal fishing operations. • Quantitative analyses.	• North Atlantic demersal longline fishery (torsk *Brosme brosme*, ling *Molva molva*, haddock *Melanogrammus aeglefinus*)	• The majority of birds caught were northern fulmars (*Fulmarus glacialis*).	• 74 birds (1.06 birds per 1000 hooks) were caught when no mitigation measure was used, compared to two birds (0.03 birds per 1000 hooks) when using the simple bird-scaring line.	• The catch rates of target species was significantly higher with lines that were set using one of the mitigation measures, than those without any measure. The differences in catch rates among the three mitigation measures were not significant. • Mackerel-baited lines that were set without a mitigation device or through the setting funnel, had significantly higher bait losses than lines set using the bird-scaring lines. For lines baited with squid, the three mitigation measures resulted in similar rates of bait loss, but these lines lost fewer squid baits than lines set without any measure.
Blue-dyed bait	Boggs (2001)	• Experimentally tested - control (non-dyed bait) vs. experimental (blue-dyed bait). • At-sea trials. • Quantitative analyses.	• Hawaii swordfish pelagic longline fishery	• Black-footed albatross (*Phoebastria nigripes*) • Laysan albatross (*P. immutabilis*)	• No injuries or mortalities were observed. •The effectiveness of the deterrents was calculated as the percent reduction in contact rates in comparison with control results. Expressed as contact rate per bird per 100 branch lines, blue-dyed baits were 95% and 94% effective for black-footed and Laysan	Not recorded.

					albatross respectively.	
Blue-dyed bait	DOC unpublished report	• Experimentally tested - control (non-dyed bait) (no tori line) vs. experimental (dyed bait) (tori line). • At-sea trials. • Observations and some quantitative analyses.	• Pelagic tuna longline	• Grey-faced petrels (*Pterodroma macroptera*) • Black petrels (*Procellaria parkinsoni*) • Westland black petrel (*P. westlandica*)	• Out of five sets, seabird bycatch was recorded on only one set. Two Westland black petrels were caught; one when using a tori line and one when no tori line was used. Both were caught on hooks baited with undyed squid. • The results when using a tori line, in all cases, showed that dyed baits have a reduced number of interactions.	Not recorded.
Blue-dyed bait	Gilman, Brothers, Kobayashi, Martin, Cook, Ray, Ching & Woods (2003)	• Experimentally tested. • At-sea trials. • Quantitative analyses.	• Hawaii tuna and swordfish pelagic longline fisheries	• Black-footed albatross (*Phoebastria nigripes*) • Laysan albatross (*P. immutabilis*) • Short-tailed shearwater (*Puffinus tenuirostris*) • Sooty shearwater (*P. griseus*)	• Blue-dyed bait was less effective (significantly in some cases) at avoiding bird interactions than side setting and the underwater chute.	• When combining the effects of bait retention and hook setting rates on fishing efficiency for seabird avoidance treatments employed using tuna gear, blue-dyed bait had the third highest fishing efficiency and would produce a gain in efficiency of 45.2% over fishing with the 6.5 m chute.

Blue-dyed bait	Lydon & Starr (2005)	• Experimentally tested - control (non-dyed bait) vs. experimental (dyed bait). • At-sea trial under altered fishing operations (i.e. dayling setting, no tori line, and offal released during setting). • Quantitative analyses.	• New Zealand domestic pelagic tuna longline fishery	• Antipodean wandering albatross (*Diomedea antipodensis)* • Campbell albatross (*Thalassarche impavida*) • Black-browed albatross (*T. melanophrys*) • Salvin's albatross (*T. salvini)* • Buller's albatross (*T. bulleri*) • Black petrel (*Procellaria parkinsoni*) • Flesh-footed shearwater (*Puffinus carneipes)* • Grey faced petrel (*Pterodroma macroptera gouldi*)	• When the control bait was used, seabirds landed on the water, fought over bait, investigated the baited hooks by placing their head underwater or by occasionally diving. When the blue-dyed bait section of the longline was deployed, seabird flight patterns behind the vessel appeared to change; the number of seabirds following the longline setting also appeared to reduce in six of the seven observed longlines.	• A total of 197 fish were taken in the seven sets representing 14 fish species. • A total of 79 fish were captured using *'Brilliant Blue'* dyed bait; 108 fish and two albatross were captured with the control bait; 10 fish were taken with the Brazilian *'Mix'* dyed bait.
Blue-dyed bait	Minami & Kiyota (2004)	• Experimentally tested - control (non-dyed bait) (no tori-pole streamers) vs. experimental (dyed bait) (tori-pole streamers). • At-sea trials. • Quantitative analyses.	• Japanese pelagic Southern Bluefin Tuna longline fisheries	Not recorded.	• Incidental take of seabirds was lower for blue-dyed bait than that for the tori-pole streamer. • The combination of the blue-dyed bait and the tori-pole streamer reduces the incidental take of seabirds to one tenth of the unmitigated take.	• The catch rates of tuna with the blue-dyed bait were not significantly changed compared with the non-dyed bait, except in the case of the Southern bluefin tuna conducted by Fukuseki-maru No. 33 during the survey in 2002.
Fish oil	Pierre & Norden (in review.)	• Experimental (shark liver oil) vs control (canola oil or seawater). • At-sea trials - preliminary and under normal fishing operations. • Quantitative analysis	• New Zealand snapper (*Pagrus auratus*) pelagic longline fishery	• Flesh-footed shearwater (*Puffinus carneipes*) • Black petrel (*Procellaria parkinsoni*) • Black-backed gulls (*Larus dominicanus*) • Buller's shearwater (*Puffinus bulleri*) • Storm petrel • Australasian gannet (*Morrus serrator*)	• Preliminary trials: Compared to canola oil and seawater, shark oil rapidly and significantly reduced the number of birds behind the vessel and dives were observed during the shark oil treatments. • Fishing trials: The effect of oil versus seawater treatment was statistically significant: fewer birds gathered behind the vessels during the shark liver oil	• There were no significant differences between the total numbers of fish, or the numbers of the target species, captured on longlines deployed while using shark liver oil compared to the seawater control.

				• Skua	treatments from 3 and up to 12 minutes. Significantly fewer dives occurred during 0–6 minutes and 9–12 minutes compared to the seawater treatment.	
Line weighting (external and integrated)	Robertson, Smith, Wienecke & Candy (2004)	• Experimentally tested - control (unweighted - UW) vs. experimental (integrated weight - IW). • At-sea trial during fishing operations. • Quantitative analyses.	• New Zealand demersal autoline longline fishery (ling *Genypterus blacodes*) • Patagonian toothfish (*Dissostichus eleginoides*) demersal longline fishery	• White-chinned petrels (Procellaria aequinoctialis) • Sooty shearwaters (*Puffinus griseus*).	• White-chinned petrels - A reduction in mortality of 98.7% (80 caught on UW and one on IW) and 93.5% (46 caught on UW and three on IW) was recorded in 2002 and 2003 respectively. Catch rates were 0.0005/1000 hooks and 0.011/1000 hooks in 2002 and 2003 respectively. • Sooty shearwaters - In 2002, one sooty shearwater was caught on UW magazines and none were caught on IW magazines. In 2003, a reduction of mortality of 60.5% (38 on UW lines and 15 on IW lines) was recorded. Catch rate was 0.053/1000 hooks.	• There was not statistically significant difference between the mean percent difference in number and mass of ling caught using IW and UW line.
Line weighting (external)	Agnew, Black, Croxall & Parkes (2000)	• Two experiments were conducted: (1) a comparison of the use of one stone (4.25 kg) at each attachment site (control) against the use of two stones (8.5 kg) (treatment); and (2) a comparison of the use of two stones (8.5 kg) at	• Spanish-rigged demersal longline toothfish (*Dissostichus* spp.) fishery	• White-chinned petrel (*Procellaria aequinoctialis*) • Black-browed albatross (*Diomedea melanophrys*) • Grey-headed albatross (*D. chrysostoma)*	• Experiment 1 - 63 birds were caught and killed on single-weight lines and 13 on double-weight lines, resulting in bird bycatch rates per 1000 hooks set as 2.37 and 0.42 respectively. • Experiment 2 - 4 birds were caught and killed on double-weight lines and 5 on triple-weight lines, resulting in bird bycatch rates per 1000 hooks set as 0.18 and 0.18 respectively.	• Total catch of toothfish in all set was 42.6 tonnes.

		each attachment site (control) against the use of three stones (12.75 kg) (treatment).			• There was a significant reduction in bird mortality when 8.5 kg was used compared to 4.25 kg (Experiment 1), but no further significant reduction when 12.75 kg was used (Experiment 2).	
Line weighting (external)	Boggs (2001)	• Experimentally tested - control (no weights) vs. experimental (baits weighted). • Comparative assessment between 3 experimental mitigation devices (streamer lines, blue-dyed baits and weights added to baits). • At-sea trials. • Quantitative analyses.	• Hawaii pelagic longline fishery (swordfish *Siphias gladius*)	• Black-footed albatross (*Phoebastria nigripes*) • Laysan albatross (*P. immutabilis*)	• All of the deterrent treatments had significantly lower contact rates than the control treatment, however statistical tests did not indicate that any of the deterrents was significantly better than any other. • The effectiveness of the deterrents was calculated as the percent reduction in contact rates in comparison with control results. Expressed as contact rate per bird per 100 branch lines, weights were 93% and 91% effective for black-footed and Laysan albatrosses respectively.	Not recorded.
Line weighting (external)	Brothers, Gales & Reid (2001)	• Experimentally tested - control (no weight) vs. experimental (weighted). • At-sea trials during normal fishing operations. • Quantitative analyses.	• Pelagic tuna longline fishery (big eye tuna, yellowfin tuna, broadbill swordfish and Southern bluefin tuna). • Demersal longline fishery (ling)	Not recorded.	• Both weighted and unweighted hooks observed during setting were found to sink more slowly than when the vessel was stationary. • Hooks were found to sink more rapidly in the first 4 m than they did to 10 m; irrespective of the weight but with a tendency for the difference to increase with increasing weight. • Vessels B1-3 recorded sink rates of approx. 0.17 m/s; while fishing during summer between 1994-98, 27 000 hooks were observed set which had a bycatch rate of 0.48 birds killed/1000 hooks and 0.78	• Appropriate weighting can keep hooks in the right depths for longer, some improving catch potential.

					birds caught/1000 hooks. Vessel A3 had a similar observed sink rate. It was observed during summer fishing off southern New South Wales (where a total of 4 000 hooks observed set), and had a catch rate of 0.95 birds killed/1000 hooks and 1.18 birds caught/1000 hooks. Vessel C2, which used the most line weighting and had the greatest observed sink rate, was observed setting 13 000 hooks during which it did not catch any birds. • A vessel using 80 g weights placed 7 m from the hook in combination with a bird line operating in waters generally with a high seabird bycatch rate, did not catch birds.	
Line weighting (external)	Melvin, Parrish, et al. (2001)	• Control (no deterrent) vs. experimental. • At-sea trials under normal fishing operations. • Trialed in two fisheries. • Quantitative and comparative analyses.	• The Gulf of Alaska / Aleutian Island Individual Fishing Quota (IFQ) demersal fishery (sablefish *Anoplopoma fimbria* and halibut) • Bering Sea catcher-processor demersal longline fishery (Pacific cod *Gadus macrocephalus*)	• Northern fulmar (*Fulmarus glacialis*) • Laysan albatross (*Phoebastria immutabilis*) • Gulls • Shearwaters (mostly *Puffinus tenuirostris*)	• SABLEFISH FISHERY - Compared to controls of no deterrent (0.371 birds/1000 hooks), added weight reduced bycatch rates by 37% (0.234 birds/1000 hooks). • COD FISHERY - Seabird bycatch significantly decreased in weighted sets (76%). • The effect of weighted gear on seabird bycatch was variable. In 1999, adding weight to the gear significantly reduced seabird bycatch relative to the control (no deterrent) by 37% and 76% for the sablefish and cod fisheries respectively. In 2000, the addition of weight to the groundline in both fisheries provided no	• Weighting gear had no negative effect on target catch in either fishery.

					improvement in the already high bycatch reduction of paired streamer lines. • Although adding weight to groundlines caused gear to sink faster, differences in vessel speed and vessel characteristics proved much more important.	
Line weighting (external)	Robertson (2000)	• Experimentally tested. • At-sea trials during normal fishing operations. • Quantitative analyses.	• Patagonian toothfish (*Dissostichus eleginoides*) demersal autoline longline fishery	• Black-browed albatross (*Diomedea melanophrys*) • Grey-headed albatross (*D. chrysostoma*) • Light-mantled sooty albatross (*Phoebetria palpebrata*) • White-chinned petrel (*Procellaria aequinoctialis*) • Wandering albatross (*D. exulans*)	• At the start of the voyage 40 m long paired bird-scaring streamer lines were used, slung 10 m apart from the deck hand rail with 1 m long streamers every 3–4 m. The line weighting regime was 12 x 6.5 kg weights/magazine. On day 4, 19 black-browed albatrosses and 1 giant petrel were caught during a daytime set of 8 magazines; 5 black-browed albatrosses were caught the next day. Streamer lines were extended to 60 m in length and placed every 1.7 m; streamer lines were slung from poles 3 m above the deck and weights were deployed every 70 m (i.e. 16 weights/magazine) on the longline. No further fatalities were recorded, even though the number of albatrosses	Not recorded.

					around the vessel during line setting remained unchanged.	
Line weighting (external)	Smith (2001)	• Experimentally tested - control (unweighted) vs. experimental (weighted). • At-sea trial during fishing operations. • Quantitative analyses.	• New Zealand demersal ling (*Genypterus blacodes*) autoline longline fishery	• Royal albatross (*Diomedea epomophora*) • Sanford's albatross (*D. sanfordi)* • Antipodean albatross (*D. antipodensis*) • Gibson's albatross (*D. gibsoni*) • Snowy albatross (*D. chionoptera*) • Light-mantled sooty albatross (*Phoebetria palpebrata*) • Chatham albatross (*Thalassarche eremita*) • Salvin's albatross (*T. salvini*) • White-capped albatross (*T. cauta*) • Black-browed albatross (*T. melanophrys*) • Southern Buller's albatross (*T. bulleri*) • Northern giant petrel (*Macronectes halli*) • Southern giant petrel (*M. giganteus*) • Cape pigeon (*Daption capense*) • Grey petrel (*Procellaria cinerea*) • Westland petrel (*P. westlandica*) • Sooty shearwater (*Puffinus griseus*) • Brown skua (*Catharacta maccormicki*)	• 12 incidental seabird mortalities: 10 grey petrels, 1 Chatham albatross, 1 Cape pigeon. • Incidental mortality was 0.0093 seabirds per 1000 hooks set. • The line sink rate varied between sampling positions and a significant interaction between position on the longline and sink rate was noted. Most variation in sink rate occurred in measurements to 5 m depth at all sample positions with a significant interaction between depth and sink rate. • Line sink rate was not accelerated at the sample points by the line weighting regimes trialed (maximum this trial, an additional 5 kg per 400 m). However, direct observations at sea indicated that weights did have an effect on line sink for 20–40 m either side of the attached weights.	Not recorded.

Line weighting (external)	(Baker & Robertson 2004)	• At-sea trials during normal fishing operations. • No control.	• Eastern tuna and billfish pelagic longline fishery	• Flesh-footed shearwaters (*Puffinus carneipes*)	• 21 birds (16 flesh-footed shearwaters) were caught during the 60 g swivel trials, resulting in a bycatch rate of 0.167 birds/1000 hooks. • 44 birds (20 flesh-footed shearwaters) were caught during the 38 g swivel trials, resulting in a bycatch rate of 0.104 birds/1000 hooks. • Both the 60 g and 30 g weighting trials failed to achieve the Threat Abatement Plan target of 0.05 birds/1000 hooks.	Not recorded.
Magnetic deterrent	Brothers, Gales & Reid (1999)	• At-sea observations. • Breeding colony observations.	Not recorded.	Not recorded.	• The magnetic device was not found to significantly affect the catch of seabirds during the at-sea trials. • No effects were apparent in the behaviour of birds at the Albatross Island colony.	Not recorded.
Mustad line shooter	Løkkeberg & Robertson (2002)	• Experimentally tested - control (no mitigation) versus line shooter. • Comparative assessment between 3 mitigation measures (bird-scaring line, line shooter, bird-scaring line + line shooter). • At-sea trials under normal fishing operations. • Quantitative analyses.	• North Atlantic demersal longline fishery (torsk *Brosme brosme*, ling *Molva molva*)	• Estimated 70–600 northern fulmar (*Fulmarus glacialis*) followed the vessel during setting operations	• 32 fulmar were caught in sets with no mitigation device and 13 in sets with the line shooter alone. • The line shooter had no significant effect on seabird captures, either alone or in combination with the bird line. • Loss of mackerel bait was reduced when the bird-scaring line was used, but not by using the line shooter alone.	• There was no significant difference between fish catch rates between the setting methods.

Mustad line shooter	Melvin, Parrish et al. (2001)	• Control (no deterrent) vs. experimental. • At-sea trials under normal fishing operations. • Quantitative and comparative analyses.	• Bering Sea catcher-processor demersal longline fishery (Pacific cod *Gadus macrocephalus*)	• Northern fulmar (*Fulmarus glacialis*) • Laysan albatross (*Phoebastria immutabilis*) • Gulls • Shearwaters (mostly *Puffinus tenuirostris*)	• COD FISHERY - Total CPUE significantly increased by 54% over controls in sets made with the line shooter. Like total seabird CPUE, fulmar and shearwater increased in sets made with the line shooter relative to controls.	Not recorded.
Mustad underwater setting funnel	Løkkeberg (1998)	• Experimentally tested - control vs. experimental. • Comparative assessment between 2 mitigation measures (bird-scaring line and underwater setting funnel). • At-sea trials under normal fishing operations. • Quantitative analyses.	• Norwegian commercial demersal longline (torsk and ling)	• The majority (>95%) of the birds caught were Northern Fulmars (*Fulmarus glacialis*).	• There were significant differences between the setting methods in the bycatch of seabirds; lines set without any devices caught 99 birds (1.75 birds per 1000 hooks), lines set through the funnel caught 28 birds (0.49 birds per 1000 hooks), and lines set with the bird scarer caught two birds (0.04 birds per 1000 hooks).	• No increase in the catches of target species.
Mustad underwater setting funnel	Løkkeberg (2001)	• Experimentally tested - control vs. experimental. • Comparative assessment between 3 mitigation measures (simple bird-scaring line, advanced bird-scaring line and underwater setting funnel). • At-sea trials under normal fishing operations.	• Norwegian commercial demersal longline (torsk, ling and haddock)	• The majority of birds caught were Northern Fulmars (*Fulmarus glacialis*).	• 74 birds were caught (1.06 birds per 1000 hooks) when no mitigation measure was used, compared to six birds (0.08 birds per 1000 hooks) when using the underwater setting funnel, two birds (0.03 birds per 1000 hooks) when using the simple bird-scaring line, and zero birds when using the advanced bird-scaring line.	• The catch rates of target species was significantly higher with lines set using one of the mitigation measures, than those without. The differences in catch rates among the three mitigation measures were not significant. • Mackerel-baited lines set without a mitigation device or through the setting

		• Quantitative analyses.				funnel, had significantly higher bait losses than lines set using the bird-scaring lines.
Mustad underwater setting funnel	Melvin, Parrish, Dietrich & Hamel (2001)	• Experimentally tested - control vs. experimental. • At-sea trials under normal fishing operations. • Quantitative and comparative analyses.	• Being Sea catcher-processor demersal longline fishery (Pacific cod)	• Northern fulmar (*Fulmarus glacialis*) • Laysan albatross (*Phoebastria immutabilis*) • Gulls • Shearwaters (mostly *Puffinus tenuirostris*)	• Seabird bycatch significantly decreased in sets using the lining tube (79%). Only fulmar CPUE decreased in sets using the lining tube.	Not recorded.
Mustad underwater setting funnel	Ryan & Watkins (2002)	• Experimentally tested - control vs. experimental. • At-sea trial during fishing operations. • Quantitative analyses.	• Patagonian toothfish demersal longline fishery	• White-chinned petrel (*Procellaria aequinoctialis*) • Grey petrel (*P. cinerea*) • Indian yellow-nosed albatross (*Thalassarche [chlororhynchos] carteri*) • Grey-headed albatross (*T. chrysostoma*) • Southern giant petrel (*Macronectes giganteus*) • Northern giant petrel (*M. halli*) • Plus six other species not listed in the reference	• Bycatch was three times (statistically significant) lower when the funnel was used both by day and at night. At night the summer bycatch rate was 0.031 birds per 1000 hooks for control sets, but only 0.009 for experimental, underwater sets. Comparable rates for summer day sets were 0.050 and 0.020, for control and experimental sets, respectively. • Daytime catch rates with the funnel were less than those attained during night sets without the funnel.	Not recorded.

Night setting	Belda & Sánchez (2001); Sánchez & Belda (2003)	• Observations during normal fishing operations. • Quantitative analyses.	• Mediterranean bottom longliners targeting hake (*Merluccius merluccius*), red common sea bream (*Pagrus pagrus*) and toothed bream (*Dentex dentex*). • Mediterranean pelagic longliners targeting swordfish (*Xiphias gladius*).	• Cory's shearwater (*Calonectris diomedea*) • Audouin's gull (*Larus audouinii*) • Yellow-legged gull (*L. cachinnans*) • Balearic shearwater (*Puffinus mauretanicus*) • Common tern (*Sterna hirundo*) • Northern gannet (*Sula bassana*) • Great skua (*Stercorarius skua*)	• Bottom longlines: Average bycatch rate 0.69±1.78 and 0.16±0.49 birds per 1000 hooks in 1998 (n=26 settings) and 1999 (n=79 settings) respectively. During the setting operations 77.5% (n=608) of birds attempting to take baits were observed during sunrise, 15% during daytime hours and 7.5% at night. In both years most of the incidental captures of seabirds occurred around sunrise. The number of seabirds caught at night, sunrise and daytime weighted by number of hooks set at each period were significantly different in both 1998 and 1999. • Pelagic longlines: Average bycatch rate 0.25±0.50 birds per 1000 hooks in 1999 (n=24 settings). No incidental captures of seabirds during the first 5 hours of setting activities in spite of the fact that 52.7% of the hooks were set during that period. There were significant differences in the number of seabirds caught at different hours weighted by the number of hooks set at each hour.	Not recorded.
Night setting	Shiode, Takeuchi & Uozumi (2001)	• Quantitative analyses using data from Japanese RTMP (Real Time Monitoring Program).	• Japanese pelagic southern bluefin tuna longline fishery	Not recorded.	Not recorded.	• In 1999 and 2000, catch rate of southern bluefin tuna had the tendency to decrease with increasing night setting ratio, and the rate of decrease was more than 80%. • The level of catch rate of southern

						bluefin tuna decreased by 30-50% with increasing night setting ratio in 1997-98, though increase and decrease were seen. • Percentages of operations without southern bluefin tuna catch increased with increasing night setting ratio through years.
Night setting	Sullivan, Reid, Pompert, Enticott & Black (2004)	• Experimentally tested - control (day setting) versus experimental (night setting). • At-sea observations under normal fishing operations. • Quantitative analyses.	• Falklands demersal longline Patagonian toothfish (*Dissostichus eleginoides*) fishery	• Great shearwater (*Puffinus gravis*) • Sooty shearwater (*P. griseus*) • Grey petrel (*Procellaria cinerea*) • White-chinned petrel (*P. aequinoctialis*) • Black-browed albatross (*Thalassarche melanophris*) • Grey-headed albatross (*T. chyrsostoma*)	• Of the 29 mortalities, 24 (23 black-browed albatross and one white-chinned petrel) were recorded from hooks set during the day (0.033 birds killed per 1000 hooks). Five (four black-browed albatross and one white-chinned petrel) were killed on hooks set during nautical dusk (0.019 birds killed per 1000 hooks). No birds were killed on hooks set at night, despite 38% of observed hooks were set during the night, 45% during daylight and 17% during nautical twilight.	Not recorded.
Night setting	Weimerskirch, Capdeville & Duhamel (2000)	• At-sea observations under normal fishing operations.	• Japanese demersal longliner targeting Patagonian toothfish (*Dissostichus eleginoides*)	• Wandering albatross (*Diomedea exulans*) • Black-browed albatross (*D. melanophris*) • Grey-headed albatross (*D. chrysostoma*) • Giant petrels (*Macronectes* spp.) • Southern fulmar (*Fulmarus glacialoides*)	• Only two albatross were caught, of which one occurred during night-time line setting. • Night-setting significantly decreased the number of white-chinned petrels caught.	Not recorded.

				• Cape pigeon (*Daption capense*) • White-chinned petrel (*Procellaria aequinoctialis*) • Prions sp. (*Pachyptila* spp.) • Wilson's storm petrel (*Oceanites oceanicus*) • Black-bellied storm petrel (*Fregetta tropica*)		
Night setting / moon phase	Klaer & Polacheck (1998)	• Australian Fishing Zone (AFZ) observer data collected at sea. • Quantitative analyses.	• Japanese longline fishing within the AFZ	Not recorded.	• The environmental factor that most influenced seabird catch rate was the time (day or night) of line setting. The chance of catching seabirds during day sets was five times greater than for night sets. For night sets, the chance of catching seabirds during the full half-phase of the moon was five times greater than during the new half-phase. • Overall catch seabird catch rate was 0.18 per 1000 hooks for all observed sets. • The catch rate during the day was 0.252 per 1000 hooks. • For hooks set at night, the catch rate was 0.022 per 1000 hooks — a reduction of 91% compared to the day catch rate. • During the new moon, the night catch rate was 0.006 per 1000 hooks — a reduction of 98% compared to the day catch rate.	Not recorded.
Night-setting	Duckworth (1995)	• Analysis of observer data	• Japanese southern bluefin tuna longliners fishing within the NZ EEZ	Not recorded.	• Significantly lower bycatch rates occurred for sets made at night (0.12 birds/1000 hooks) compared to those made during the day (0.43 birds/1000 hooks). • Generally bycatch rate at night	Not recorded.

					increases as moonlight increases.	
Night-setting	Reid & Sullivan (2004)	• At-sea observations.	Demersal Spanish system (double-line) Patagonian toothfish (*Dissostichus eleginoides*) longlining	• Black-browed albatross (*Thalassarche melanophris*)	• No birds were caught in the night sets. • Black-browed albatross were less likely to be killed on lines set during twilight than those set during daylight. • Mortality decreased significantly with an increase in the number of tori lines used.	Not recorded.
Night-setting	Weimerskirch, Capdeville & Duhamel (2000)	• At-sea observations under normal fishing operations.	• Ukrainian demersal longliners in the Kerguelen EEZ targeting Patagonian toothfish (*Dissostichus eleginoides*)	• Wandering albatross (*Diomedea exulans*) • Black-browed albatross (*D. melanophris*) • Grey-headed albatross (*D. chrysostoma*) • Giant petrels (*Macronectes* spp.) • Southern fulmar (*Fulmarus glacialoides*) • Cape pigeon (*Daption capense*) • White-chinned petrel (*Procellaria aequinoctialis*) • Prion spp. (*Pachyptila* spp.) • Wilson's storm petrel (*Oceanites oceanicus*) • Black-bellied storm petrel (*Fregetta tropica*)	• Night-setting significantly reduced the overall number of birds caught from 0.91±1.72 birds/1000 hooks during the day to 0.17±0.82 birds/1000 hooks at night. • Only one albatross was caught when line setting occurred at night. Night/day setting was therefore significant for all albatross species except for wandering albatross.	Not recorded.

Offal discharge	Sullivan, Reid & Bugoni (in press)	• At-sea trials observations (made by specifically tasked seabird observers) under normal operating conditions. • Quantitative analysis.	• Demersal Patagonian longfin squid fleet and finfish trawl fleet targeting Patagonian longfin squid (*Loligo gahi*), Southern blue whiting (*Micromesistius australis australis*), hoki (*Macruronus magellanicus*), hake (*Merluccius hubbsi*, *M. australis*), kingclip (*Genypterus blacodes*) and red cod (*Salilota australis*).	In total, 23 species of bird were recorded around trawlers, including: • Black-browed albatrosses • Southern giant petrels (*Macronectes giganteus*) • Northern giant petrels (*M. halli*) • Cape petrels (*Daption capense*) • Southern royal albatrosses (*Diomedea epomophora*) • White-chinned petrels (*Procellaria aequinoctialis*) • Sooty shearwaters (*Puffinus griseus*) • Wilson's storm-petrels (*Oceanites oceanicus*)	• Black-browed albatross had a significantly higher rate of contacts with the warp cable when there was discharge than when there was no discharge. This was equally true for birds on the water, in the air, or heavy contacts. There was no significant differences in contact rate between different discharge levels. • Giant petrels were significantly more likely to make heavy contacts with the warp cable when there was offal discharge.	Not recorded.
Offal discharge	Weimerskirch, Capdeville & Duhamel (2000)	• Observations collected by fisheries observers during normal fishing operations.	• Demersal Ukrainian and French trawlers in the Kerguelen EEZ targeting Patagonian toothfish (*Dissostichus eleginoides*) and Mackerel icefish (*Champsocephalus gunnari*).	• Wandering albatross (*Diomedea exulans*) • Black-browed albatross (*D. melanophris*) • Grey-headed albatross (*D. chrysostoma*) • Giant petrels (*Macronectes* spp.) • Southern fulmar (*Fulmarus glacialoides*) • Cape pigeon (*Daption capense*) • White-chinned petrel (*Procellaria aequinoctialis*) • Prions sp. (*Pachyptila* spp.) • Wilson's storm petrel (*Oceanites oceanicus*) • Black-bellied storm petrel (*Fregetta tropica*)	• The presence of offal had no significant influence on the number of birds attending trawlers. • Patagonian toothfish fishery, no netsonde cable, offal discharge - One white-capped albatross killed (0.002 birds/trawl). • Patagonian toothfish fishery, netsonde cable, no offal discharge - No birds killed. • Icefish fishery, no netsonde cable, no offal discharge - Five white-capped and one black-browed albatross killed (0.02 birds/trawl). • Icefish fishery, netsonde cable, no offal discharge - 13 white-capped, one black-browed and one	Not recorded.

					grey-headed albatross killed (0.114 birds/trawl). Seven of these birds (including four albatross) were killed by the netsonde cable: they were found between this cable and the headline of the net.	
Offal discharge	Weimerskirch, Capdeville & Duhamel (2000)	• At-sea observations made by fisheries observers under normal fishing operations.	• Demersal Ukrainian longliners in the Kerguelen EEZ targeting Patagonian toothfish (Dissostichus eleginoides).	• Wandering albatross (*Diomedea exulans*) • Black-browed albatross (*D. melanophris*) • Grey-headed albatross (*D. chrysostoma*) • Giant petrels (*Macronectes* spp.) • Southern fulmar (*Fulmarus glacialoides*) • Cape pigeon (*Daption capense*) • White-chinned petrel (*Procellaria aequinoctialis*) • Prions sp. (*Pachyptila* spp.) • Wilson's storm petrel (*Oceanites oceanicus*) • Black-bellied storm petrel (*Fregetta tropica*)	• Two main factors affected the number of birds attending longliners: the release of offal and the year. • The release of offal from longliners had a positive influence on the total number of birds attending, especially on the number of large species and white-chinned petrels.	Not recorded.
Shot gun for firing star blasts	Crysell (2002)	• Concept not trialed. • Observations.	Not recorded.	Not recorded.	"These have proved very effective. … The observer was most impressed with the star shells."	Not recorded.

Side-setting	Gilman, Brothers, Kobayashi, Martin, Cook, Ray, Ching & Woods (2003)	• Experimentally tested. • Comparative assessment between 4 experimental mitigation devices (6.5 and 9 m underwater setting chute, side-setting, blue-dyed bait) when used with tuna and swordfish gear. • At-sea trials. • Quantitative analyses.	• Hawaii pelagic longline tuna and swordfish fisheries	• Black-footed albatross (*Phoebastria nigripes*) • Laysan albatross (*P. immutabilis*) • Short-tailed shearwater (*Puffinus tenuirostris*) • Sooty shearwater (*P. griseus*)	• Based on mean contact and capture rates, side setting was the most effective (significantly) treatment tested in this trial when used with both Hawaii longline tuna and swordfish gear. • Tuna gear: 0.01 contacts/1000 hooks/bird and 0.00 captures/1000 hooks/bird. • Swordfish gear: 0.08 contacts/1000 hooks/bird and 0.01 captures/1000 hooks/bird. • There was no statistically significant differences between contact and capture rates for the three different side setting positions, however there was a small sample size.	• When combining the effects of bait retention and hook setting rates on fishing efficiency for seabird avoidance treatments employed using swordfish gear, side setting would have the highest fishing efficiency and would produce a gain in efficiency of 7.8% over fishing with blue-dyed bait. • When combining the effects of bait retention and hook setting rates on fishing efficiency for seabird avoidance treatments employed using tuna gear, side setting had the second highest fishing efficiency and would produce a gain in efficiency of 52.7% over fishing with the 6.5 m chute.
Super DC Pulse System	Kitamura, Kumagai, Koyama, Nakamura & Nakano (2001)	• Laboratory experiment testing effect of electric pulse stimulation on mallards in a tank. • Observations.	Not recorded.	Not recorded.	• The mallards responded at 120 V; however the level of stimulation required to produce escaping action of the mallards was over 200-250 V. In this case, underwater voltage, current and field strength were 96 V, 25 mA, and 19.2 V/cm respectively. The mallards jumped out of the tank at 400-50 V. The results suggested	Not recorded.

					that bird scaring electric pulse field was more than about 200 V, 50 mA and 4 V/cm in the water.	
Thawed bait	Duckworth (1995)	• Analysis of observer data	• Japanese southern bluefin tuna longliners fishing within the NZ EEZ	Not recorded.	• 98 birds (0.26 birds/1000 hooks) were caught using frozen bait compared to 129 (0.08 birds/1000 hooks) when using thawed bait. This lower bycatch rate when thawed baits were used was not statistically significant.	Not recorded.
The 'Brigette Bardot' laser gun	Crysell (2002)	• Concept not trialed. • Observations.	Not recorded.	Not recorded.	"The laser had no effect whatsoever."	Not recorded.
The Capsule	Brothers, Chaffey & Reid (2000)	• Experimentally tested - control (manual bait setting) vs. experimental (capsule). • At-sea trials. • Quantitative analyses.	• Pelagic longline fisheries	• Shy albatross (*Diomedea cauta*) • Royal albatross (*D. epomorphora*) • Wandering albatross (*D. exulans*) • Yellow-nosed albatross *(D. chlororhynchos*) • Black-browed albatross (*Thalassarche melanophrys*) • Buller's albatross (*T. bulleri*) • Giant petrel sp. (*Macronectes* sp.) • Great-winged petrel (*Pterodroma macroptera*) • Cape petrel (*Daption capense)* • Fairy prion (*Pachyptila turtur*)	• On all cruises where the capsule was used for line setting, birds were observed to have few interactions with the baited hooks. • During two cruises in June no birds were observed caught, and nine baits were observed taken, a rate of 1.5/1000 hooks (most of which were due to tangling). • There was no significant difference in average hook setting depth when the capsule was moved along the stern, nor when the two rope lengths were tested (11.5 m rope averaged at 6.7 m; 8 m rope averaged 5.5 m). • Manually baited hooks sank much more slowly than did the hooks released by the capsule.	

				• Antarctic prion (*P. desolata*) • Crested tern (*Sterna bergii*) • Australasian gannet (*Morus serrator*) • Sooty shearwater (*Puffinus griseus*)	• Using the capsule noticeably lowered bird activity in the area immediately behind the vessel by comparison to hooks set manually, and no diving attempts were made.	
The Capsule (Transportation capsule)	Smith & Bentley (1997)	• At-sea trials development trials.	• Pelagic longliners	Not recorded.	• The first trials identified the following deficiencies and subsequent refinements: (1) The tow weight drifted either side of the propeller wash - an additional 50% of weight was attached to the tow cable (final tow weight 12 kg); (2) Pre-release of the bait - shift the position of stops on the operating rode, and a spring was added to assist the nose cone clamping action; and (3) Retrieval orientation - adjust speed of retrieval. • The second of the at-sea trials proved successful with a 100% bait release rate achieved, and 98% correct orientation of the capsule on retrieval.	Not recorded.
The Hose	Crysell (2002)	• Concept not trialed.	Not recorded.	Not recorded.	"Unfortunately, the propeller was prone to pick up the line and the nozzles tangled as well. It was expensive to have (around $35,000) and to operate. Ultimately it was not effective. The birds weren't overly scared of it."	Not recorded.

Underwater setting chute (backward facing U tube)	Barnes & Walshe (1997)	• Trialed at-sea but not under normal fishing conditions. • Observations.	• Commercial pelagic longline fishery	Not recorded.	• First stage trials: Baits were flushed down the tube to sea level and carried underwater down the full length of the tube without obstruction. In 87 trial releases of bait there were no snags as the bait moved down the tube. Observations by diving and underwater video record showed the bait and water in the tube was carried down the full length of the tube even at vessel speeds of less than a knot. • Second stage trials: None of the 203 bait releases snagged in the tube. On 27 releases the baits were timed from entry into the tube and release out of the 6 m long tube; on average the bait took 6.7 seconds to travel down the tube, the maximum time of release was just over 9 seconds.	Not recorded.
Underwater setting chute	(Baker & Robertson 2004)	• At-sea trials during normal fishing operations. • No control.	• Eastern tuna and billfish pelagic longline fishery	• Flesh-footed shearwaters (*Puffinus carneipes*)	• 235 birds (228 flesh-footed shearwaters) were caught, resulting in a bycatch rate of 1.081 birds/1000 hooks. • The chute failed to achieve the Threat Abatement Plan target of 0.05 birds/1000 hooks.	Not recorded.
Underwater setting chute	Brothers, Chaffey & Reid (2000)	• Experimentally tested - control (manual bait setting) vs. experimental (chute). • At-sea trials. • Quantitative analyses.	• Pelagic longline fisheries	• Shy albatross (*Diomedea cauta*) • Royal albatross (*D. epomorphora*) • Wandering albatross (*D. exulans*) • Yellow-nosed albatross *(D. chlororhynchos*) • Black-browed albatross (*Thalassarche melanophrys*)	• The modifications made to the chute during the trials changed the effect of it on bird behaviour quite significantly. Thus, on the first two cruises, while 3,246 hooks were set, eight birds were caught during line setting. On the final cruise, while 3,642 hooks were observed, no birds were caught on the hooks.	Not recorded.

				• Buller's albatross (*T. bulleri*) • Giant petrel sp. (*Macronectes* sp.) • Short-tailed shearwater (*Puffinus tenuirostris*) • Sooty shearwater (*P. griseus*) • Silver gull (*Larus novaehollandiae*) • White-chinned petrel (*Procellaria aequinoctialis*) • Great-winged petrel (*Pterodroma macroptera*) • Cape petrel (*Daption capense)* • Fairy prion (*Pachyptila turtur*) • Crested tern (*Sterna bergii*) • Australasian gannet (*Morus serrator*)	• A total of eight birds (all shy albatross) were caught during the development trials but none were in the last 61% of hooks set once design and operational deficiencies were rectified. • Using the chute noticeably lowered bird activity in the area immediately behind the vessel by comparison to hooks set manually, and no diving attempts were made.	
Underwater setting chute	Gilman, Boggs & Brothers (2003)	• Experimentally tested - control vs. experimental. • At-sea trials. • Quantitative analyses.	• Hawaii pelagic tuna longline fishery	• Black-footed albatross (*Phoebastria nigripes*) • Laysan albatross (*P. immutabilis*)	• No birds were observed caught during setting with the chute nor were any albatrosses hauled aboard during chute treatment replicates. • Expressed as contact rate per 1000 hooks per albatross (normalized for albatross abundance), the chute was 95% effective at reducing albatross contacts with fishing gear compared to the control.	• Based on an assessment of bait retention and hook setting interval when using the chute versus setting conventionally, vessels would experience a gain in (fishing) efficiency of between 14.7% and 29.6% when albatrosses are abundant.

Underwater setting chute (= 6.5 m underwater setting chute)	Gilman, Brothers, Kobayashi, Martin, Cook, Ray, Ching & Woods (2003)	• Experimentally tested. • Comparative assessment between 4 experimental mitigation devices (6.5 and 9 m underwater setting chute, side-setting, blue-dyed bait) when used with tuna and swordfish gear. • At-sea trials. • Quantitative analyses.	• Hawaii pelagic longline tuna fisheries	• Black-footed albatross (*Phoebastria nigripes*) • Laysan albatross (*P. immutabilis*) • Short-tailed shearwater (*Puffinus tenuirostris*) • Sooty shearwater (*P. griseus*)	• Two lengths (9 m and 6.5 m) of an underwater setting chute were relatively effective at reducing bird interactions, but performed inconsistently and were inconvenient due to manufacturing flaw and design problems. • The engineering deficiencies of the two chutes prevented a meaningful comparison of the two different length chutes' effectiveness at reducing seabird interactions, and prevented a meaningful comparison of the chutes' effectiveness to the other experimental treatments.	• When combining the effects of bait retention and hook setting rates on fishing efficiency for seabird avoidance treatments employed using tuna gear, the 6.5 m chute would have the lowest fishing efficiency.
Underwater setting chute (= 9 m underwater setting chute)	Gilman, Brothers, Kobayashi, Martin, Cook, Ray, Ching & Woods (2003)	• Experimentally tested. • Comparative assessment between 4 experimental mitigation devices (6.5 and 9 m underwater setting chute, side-setting, blue-dyed bait) when used with tuna and swordfish gear. • At-sea trials. • Quantitative analyses.	• Hawaii pelagic longline tuna and swordfish fisheries	• Black-footed albatross (*Phoebastria nigripes*) • Laysan albatross (*P. immutabilis*) • Short-tailed shearwater (*Puffinus tenuirostris*) • Sooty shearwater (*P. griseus*)	• The 9 m chute had the second lowest mean seabird contact and capture rates when used with swordfish gear, with a significant difference in terms of contacts when compared to blue-dyed bait. • Tuna gear: 0.28 contacts/1000 hooks/bird; 0.05 captures/1000 hooks/bird. • Swordfish gear: 0.30 contacts/1000 hooks/bird; 0.03 captures/1000 hooks/bird.	• When combining the effects of bait retention and hook setting rates on fishing efficiency for seabird avoidance treatments employed using swordfish gear, the 9 m chute would produce a gain in efficiency of 2.5% over fishing with blue-dyed bait. • When combining the effects of bait retention and hook setting rates on fishing efficiency for seabird avoidance treatments employed using tuna gear, the 9 m chute had the highest fishing efficiency and would

						produce a gain in efficiency of 55.9% over fishing with the 6.5 m chute.
Underwater setting chute (Venturi assisted water flow)	Barnes & Walshe (1997)	• Concept not trialed.	• Commercial pelagic longline fishery	Not recorded.	Not recorded.	Not recorded.
Underwater setting chute - Trial #2	Molloy, Walshe & Barnes (1999)	• At-sea trials under normal fishing conditions. • Observations.	• Small New Zealand pelagic longliner	Not recorded.	• Entanglements occurred during four of the five trial sets. • Chute - During the first trial, a cracked weld on the chute prevented any further trials on this trip. • Trough - There wasn't enough water flushing around the sides of the trough, and baits stuck to the trough base. This was compounded by an additional difficulty of the chute being placed too far to the port. • Paravane - No difference was observed to the effectiveness of the paravane during differing weather conditions. When the chute was fully extended in the deployed situation, it was noticeable that it had a 10 to 15 degree offset angle to starboard (as was observed during the FV *Daniel Solander* trials). • Bait type - Squid is an ideal bait	Not recorded.

					for the chute as they are flexible, moulding themselves to any shape without being damaged or affecting the hook placement. Furthermore, should they jam at the neck of the trough, to block the water flow, allowing build-up to a volume where the water then forces the bait through the neck of the trough. In comparison, the long and slender shape of sanmar resulted in difficulties in getting the baits to move through the feed trough.	
Underwater setting chute - Trial # 3.	Molloy, Walshe & Barnes (1999)	• At-sea trials under normal fishing conditions. • Observations.	• Domestic longline fishery	Not recorded.	• The chute performed well during the two hours of steaming to the fishing grounds. • After 13 minutes of the setting trial, the mainline carried across the transom to the chute and become tangled around the shackles connecting them. The skipper removed the chute and continued shooting in the normal manner. • During the short period the chute operated, the device successfully deployed bait under the water and was very close to achieving its initial objective of a successful 4000 hook trial.	Not recorded.

Underwater setting chute - Trial # 4.	Molloy, Walshe & Barnes (1999)	• At-sea trials under normal fishing conditions and while steaming to fishing grounds. • Observations.	Not recorded.	Not recorded.	• The chute delivered 5270 baited hooks without entanglements during the four sets. • The chute did not meet its requirement for setting hooks at a depth of 3 m, by the fifth set more than half of the hooks were being set at a depth less than 3 m. This was probably due to the elasticity of the Forsheda mooring compensator deteriorating over the four sets, which reduced the setting angle and depth of the chute. The crew of the vessel and the observer believed that under strong conditions the rubber would have snapped.	Not recorded.
Underwater setting chute - Trial #1.	Molloy, Walshe & Barnes (1999)	• At-sea observations made regarding seaworthiness of chute while being towed behind the vessel on the way to fishing grounds, and between sets during the fishing period.	• Commercial New Zealand longlining.	Not recorded.	• Bait run times - bait flushing times were 3-4 seconds. After 14 baits were fed through the chute, a hook-up occurred on the paravane wire resulting in the abandonment of snood timings. • Paravane operation - All three paravanes worked at keeping the chute down in the water column. The Arrowhead and Flexiwing were the most effective in terms of the angle of the chute and the setting depth. All three paravanes used in the five trials were affected by the vessel's propeller wash. With the second set of trials, the length of wire strop was increased in an attempt to clear the paravane from the propeller wash, but the effect was the same. • Base plate and hinge operation - no part of the base plate hinge or	Not recorded.

					chute malfunctioned during the trials. • Retrieval and deployment system - difficulties were experienced. During the second set of trials, in gale conditions, considerable bending occurred as the chute was retrieved.	
Underwater setting chute (enclosed tube)	Barnes & Walshe (1997)	• Concept not trialed.	Not recorded.	Not recorded.	Not recorded.	Not recorded.
Underwater setting chute (forward facing U tube)	Barnes & Walshe (1997)	• Trialed at-sea but not under normal fishing conditions. • Observations.	• Commercial pelagic longline fishery	Not recorded.	• The baits were flushed down the tube to sea level, however they remained in the tube at this level and did not submerge. The forward facing U tube was ineffective and no further trials were undertaken.	Not recorded.
Underwater setting device (shooter-type apparatus)	Sakai, Fuxiang & Arimoto (2004)	• Experimentally tested - control (no underwater setting device) vs. experimental (underwater setting device). • At-sea trial. • Quantitative analyses.	• Japanese large longliners	Not recorded.	• The effectiveness of the underwater setting device was verified by this experiment because the average release time (4.2 seconds) was shorter than the 8.3-second average for fishhooks to reach the underwater depth of 1.3 m without the underwater setting device. • The water depth for six seconds after line casting was deeper when the underwater setting device was used than when it was not. • The water depth was reversed, but the underwater setting device was verified to effectively prevent incidental catch of seabirds.	Not recorded.

Water jet device	Kiyota, Minami & Takahashi (2001)	• Some at-sea trials. • Observations.	• Tuna pelagic longline fishery	Not recorded.	• Experiment 1 using river water showed that decreasing nozzle diameter would not improve the range of water jet reached, and that emission angle had little effect on it. A fire-fighting nozzle and EX adapter tube, which has radial ribs inside, recorded the maximum range of 60 m. • In experiment 2 at sea, seabirds avoided the water jet and did not try to fly under the water curtain, but the water jet was deteriorated by cross wind. • In experiment 3, ice particles mixed with water jet did not improve the range of water or ice reached.	Not recorded.