SBWG-2 Doc 05
Agenda Item No. 2

Agreement on the Conservation of Albatrosses and Petrels

Fourth Meeting of Advisory Committee

Cape Town, South Africa, 22 – 25 August 2008

Seabird bycatch mitigation measures in trawl fisheries:
History (pre-2004) and recent work (2004 - 2008)

ACAP Advisory Committee 3 Work Programme Item 4.8

New Zealand
United Kingdom
Seabird Bycatch Working Group

SUMMARY

This report reviews methods used to reduce seabird bycatch in trawl fisheries. It summarises developments in the field of trawl mitigation prior to 2004 (described in detail in Bull (2007)), and provides an update of recent work including methods that have trialled or proposed during the period of 2004-2008. The body of work investigating and documenting methods to mitigate seabird bycatch in trawl fisheries is significantly less advanced than for longline fisheries. Consequently, new developments in this field in recent years are few. Seabird interactions with trawl vessels fall into two broad categories: those focused on the trawl warps (the thick cables that link the net to the vessel), and those focused around travel nets. For reducing seabird strikes on trawl warps, the use of bird-scaring lines has been proven to be the most effective mitigation device in the two trawl fisheries in which comparative studies have been undertaken. However, the retention or strategic management of fish waste (offal and discards) is recommended as the most effective primary measure for bycatch reduction, and as such should be viewed as the best long-term solution to reducing seabird bycatch in trawl fisheries. Coincident with effective fish waste management, measures such as cleaning the net prior to shooting and reducing the time the net is on the surface should be viewed as best practice measures and incorporated into normal fishing activities. While a number of methods have been trialled to reduce the incidence of warp strikes, there continues to be the need for more work on effective measures for reducing seabird interactions with the trawl net.

<u>NOTE</u>: The Seabird Bycatch Working Group will discuss this paper at their meeting on 17-18 August. Recommendations to the Advisory Committee will be finalized after that discussion.

INTRODUCTION

Incidental mortality resulting from interactions with fisheries operations has been linked to the global declines of some albatross and petrel species (Croxall *et al.* 1990; Brothers 1991; Weimerskirch *et al.* 1997; Weimerskirch *et al.* 1999; Lewison and Crowder 2003). Given that nearly half of the world's 125 petrel species and 18 of the 22 albatross species are classified as threatened (BirdLife.org 28/5/08), effective measures to mitigate against seabird bycatch (including fishing gear modification) need to be investigated in order to reduce the impact of fisheries on seabird populations.

Seabirds are generally attracted to fishing vessels because they have learnt that vessels are potential sources of food (e.g. discards and bait). However, this potential food source increases the risk to seabirds of interactions (potentially fatal) with fishing gear. Global awareness of the potential impact of fisheries on seabird populations heightened in the early 1990s (Bartle 1991; Brothers 1991). Although mortalities were known to occur in trawl fisheries (Bartle 1991; Weimerskirch *et al.* 2000; SC-CAMLR 2001, 2002; Sullivan and Reid 2003), the large numbers of birds caught on longline hooks and hauled onboard meant that this fishing method received most of the early focus surrounding fisheries-seabird interactions (Brothers 1991; Løkkeborg and Bjordal 1992; Gorman 1996; Bergin 1997; Gales *et al.* 1998; Klaer and Polacheck 1998; Løkkeborg 1998; Robertson 1998; Brothers *et al.* 1999). The perception, at the time, that trawl vessels posed less of a threat to seabird populations than longlining, was in part associated with the difficulty in observing mortality events on trawl gear (Weimerskirch *et al.* 2000). Birds that strike trawl cables are rarely ensnared, and therefore those birds that are captured in the trawl net and hauled onboard represent only a sample of those killed by trawling activities (Sullivan *et al.* 2006b). Consequently, trawl-related seabird mortality is likely to have been underestimated in many cases (Weimerskirch *et al.* 2000; Sullivan *et al.* 2006b).

The major causes of mortality in trawl fisheries can be categorised into two broad types: warp cable-related and net-related mortality. The incidence of each of these is thought to be influenced in part by the fishery (i.e. demersal or pelagic trawl), however, within trawl fisheries a greater proportion of seabird mortalities are generally thought to be caused by cable strikes compared to net entanglements (Sullivan and Reid 2003; Watkins *et al.* 2006).

Cable-related mortality

Seabird mortality can occur due to collisions with cables running from the vessel to the net (warp cables) and/or net monitoring devices (third wire, netsonde and paravane). Cable strikes may occur when birds are in the air or on the water, and generally increase as a function of aerial extent of the cable, location of waste discharge chutes relative to the cable entry point into the water, and type of discharge (e.g., whole fish versus macerated) (Dietrich and Melvin 2007).

Historically, reports of cable-related mortalities were attributed predominantly to collisions with netsonde cables (Bartle 1991; Williams and Capdeville 1996; Weimerskirch *et al.* 2000). Third wire and netsonde cables are mounted higher (on the stern gantry) than warp cables, and as such enter the water further astern and have a higher potential to cause seabird interactions (Munro 2005; Dietrich and Melvin 2007). Net-sonde cables are now prohibited in many Southern Hemisphere fisheries including the New Zealand domestic trawl fisheries (1992), Australia's Heard Island and Macquarie Island trawl fisheries (1996), and trawl fisheries managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) (1994) (Wilson *et al.* 2004). However, third-wire cables are still commonly used in several regions (Dietrich and Melvin 2007).

More recently, mortalities associated with warp cable collisions have been identified in a number of trawl fisheries (Sullivan and Reid 2002; Wienecke and Robertson 2002; González-Zevallos and Yorio 2006; Watkins et al. 2006). In such cases, seabirds are struck by the warp cable, often resulting in the bird becoming entangled (e.g. the wing dislocates and wraps around the cable), and the drag created by the forward motion of the vessel forces the bird underwater where it subsequently drowns (Sullivan and Reid 2002; González-Zevallos and Yorio 2006). Although relatively infrequent compared to warp cable strikes, entanglements (a similar process to that which drowns birds on the warp cable) with the side-mounted paravane cable have been observed (Sullivan and Reid 2003; Crofts 2006a).

While the wire splices that join lengths of warp cable have previously been cited as a cause of seabird mortality during hauling (Goñi 1998; Kock 2001), it now appears that birds slide down the cable and become impaled on the splices. The splice therefore serves as the point where drowned birds are snagged. So, the presence of splices may actually increase the detection of warp strikes and mortalities (Sullivan *et al.* 2006b).

Net-related mortality

Birds are attracted to trawl nets by the prospect of feeding from them, and can become entangled after diving into the meshes for fish (Roe 2005). Significant levels of trawl mortality have been shown to be caused by net entanglements, particularly in mid-water/pelagic trawl fisheries (Weimerskirch *et al.* 2000; SC-CAMLR 2001, 2002; Hooper *et al.* 2003; Roe 2005; Baird 2008). Reasons for observed differences in entanglement rates in demersal and pelagic fisheries are in part due to operational and technical differences. Compared to demersal nets, those used in pelagic fisheries are on or near the water surface for longer periods, and have larger mesh size which allows birds to dive through the net and be trapped or crushed as the mesh closes under hauling tension or as it sinks during setting (Hooper *et al.* 2003; Crofts 2006c).

Best practice

There are a number of techniques that, while potentially reducing the likelihood of interactions between seabirds and trawl gear, should essentially be considered best practice measures that are adopted into normal fishing operations. For instance, though not statistically tested for its efficacy, Hooper *et al.* (2003) advocated that cleaning trawl nets to remove unwanted bycatch prior to shooting reduces the attractiveness of the net to seabirds. Net cleaning prior to shooting (along with other mitigation measures) is now mandatory in CCAMLR waters (Conservation Measure 25-03), as are shooting and hauling procedures that minimise the time the net is lying on the surface with the meshes slack.

Identifying and understanding additional methods to reduce or eliminate seabird-fishery interactions is crucial to the conservation of many seabird species. This is particularly so for trawl fisheries, given the relatively low profile that it has been given to date, combined with the fact that approximately 30% of the global annual fishery catch is taken by trawl gear (Watson *et al.* 2006), and 45% of total annual seabird bycatch may be associated with trawling (Baker *et al.* 2007). Factors influencing the appropriateness and effectiveness of a mitigation device include fishery, vessel, location, seabird assemblage present and time of year / season (Bull 2007). Consequently, even within a fishery, individual vessel refinement of mitigation techniques is often required in order to maximize their effectiveness.

A comprehensive review of methodologies designed at avoiding and/or mitigating incidental catch of seabirds by longline, trawl and gillnet fisheries has previously been undertaken with regards to methods trialled and proposed prior to 2005 (Bull 2007). However, continued reports of significant seabird bycatch events on trawl vessels necessitates an update regarding recently proposed and tested methodologies aimed at reducing seabird interactions with trawl vessels.

METHODS AND SCOPE

Recent (post-2004) material investigating mitigation measures to reduce seabird bycatch in trawl fisheries was obtained from various forms of media including peer-reviewed journals, unpublished reports, magazine articles, conference papers, websites, and the literature of government and non-government organisations. 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. Details regarding each mitigation method are summarised in the results section. A compilation of further details of each study can be obtained on request from the Marine Conservation Services Section, New Zealand Department of Conservation[1].

With respect to mitigation methods to reduce contacts with third wires, no post-2005

[1] Johanna Pierre, jpierre@doc.govt.nz, Department of Conservation, P O Box 10-420, Wellington, New Zealand

material was found. As such, information from the latest trials (Melvin *et al.* 2004) in this area was included in this review in order to fully cover possible mitigation measures, and to highlight the potential need for more investigation into this field.

The terms 'heavy contacts', 'light contacts' and 'total contacts' appear frequently within material associated with seabird interactions with trawl gear. Heavy contacts are defined as those contacts with the warps that push part or all the bird under water, whereas light contacts are those that do not result in part or all of the bird being pushed under water (Sullivan *et al.* 2006b). Total contacts are the sum of both heavy and light contacts. These terms are important, because Sullivan *et al.* (2006b) identified a significant positive correlation between total mortalities and contact rates within the Falkland Islands (Islas Malvinas) finfish trawl fishery. While fishery specific validation of this relationship is required, contact rates are increasingly being used as an index of mortality in other trawl fisheries.

RESULTS

Mitigation measures aimed at avoiding or reducing interactions between seabirds and trawl fishing gear can be broadly classified into three categories: (1) management of fisheries discards and waste in such a way that seabirds do not associate the vessel with food; (2) protection of warp cables to reduce the chances of strikes; and (3) reducing the chances of net entanglements. For ease of reference, the following three main sections of the results present each of these three categories. Within each section, individual mitigation measures are reviewed providing a brief description of the method, the results of any studies testing the method, and any associated pros and cons. These three sections are followed by a fourth, which reviews studies that have compared multiple mitigation methods.

Vessel attractiveness – Discharge management:

Presence of offal and discards

A number of recent studies have found the most important factor influencing contacts between seabirds and warp cables is the presence of discharge (Crofts 2006b; Watkins *et al.* 2006; M. Favero pers. comm.). Investigations by Abraham *et al.* (in prep-b) further confirmed the important role of discards in determining the rate of seabird interactions with trawl warps, and also with bird-scaring lines. With regards to the demersal finfish trawl fishery around the Falkland Islands (Islas Malvinas), black-browed albatross (*Thalassarche melanophrys*) had a significantly higher rate of contacts with the warp cable when there was discharge compared to when there was none. This was equally true for birds on the water or in the air. Giant petrels (*Macronectes* spp.) were significantly more likely to make heavy contacts with the warp cable when there was offal discharge (Sullivan *et al.* 2006b). In addition to contacts, Sullivan *et al.* (2006b) also noted that all seabird mortalities occurred at times of factory discharge.

Other factors such as discharge levels and how the discharge is dispersed in water have also been implicated with influencing contact rates. Several studies have recorded positive correlations between discharge levels and seabird warp strikes (Crofts 2006b; Watkins *et al.* 2006), with Abraham *et al.* (in prep-b) finding that counts of both large and small birds in a defined zone around the vessel stern increased with increasing discharge.

Opportunistic observations on a number of stern trawlers in the Falkland Islands (Islas Malvinas) suggest that the nature and movement of discards in the water may be another important factor influencing contact rates (S. Crofts pers. comm.). In particular, the surfacing distance of discards relative to the warp is believed to be a critical factor. On some vessels, it was observed that if discards surface aft of the warp cable–water interface then seabirds forage aft of the warp, and as such are generally not in the danger zone where they are at risk of being hit by warp cables. Observations of warp strikes and total trip mortalities were also notably reduced. In comparison, observations from other trawlers from which discards washed immediately into the vicinity of the warp cables were thought to be associated with increased warp strikes and mortalities (S. Crofts pers. comm.). Factors that are likely to be associated with the movement of discharge relative to the warp include the proximity of the discharge scupper to the stern of the vessel, impact of propeller wash and type of discharge.

Management of offal and discards

Management of offal and discards may be through retention, strategic dumping, processing, or a combination of these. While ideal, the retention of discards and waste during fishing activities may be logistically difficult for many vessels in their existing configurations. Thus, if waste is to be discharged, it should be in a form that is unattractive to birds and preferably not during setting, towing or hauling.

Using information gathered on a mid-water trawler targeting hoki (*Macruronus novaezelandiae*) in New Zealand waters, Abraham *et al.* (in prep-b) investigated the influence of different methods of offal and discharge management on seabird abundance and behaviour around a fishing vessel. The three treatments trialled were discharging unprocessed waste (fish offal and whole discards), minced waste (nominal maximum particle size of 25 mm diameter), and fishmeal (waste converted to fishmeal and reducing discharge to sump water). Mealing resulted in a significant reduction in the number of all seabird groups feeding behind the vessel (relative to the discharge of unprocessed fish waste); this decrease was especially large for the albatross genus *Thalassarche* (Abraham *et al.* in prep-b). The numbers of flying or sitting albatross and petrels (other than giant and cape petrels *Daption capense*) were also significantly reduced in the mealed treatment. Mincing had no significant effect on any of the bird groups attending the vessel, except large albatross (*Diomedea*), which attended the vessel in significantly lower numbers during the mincing treatment across all behavioural categories (particularly in numbers feeding). Though inconclusive, based on a low number of observations it appeared that both mincing and mealing fish waste could have resulted in reduced strike rates with the bird-scaring lines. However, this requires further investigation.

Ideally, a comparison of the suite of options associated with offal and discard management should be trialled within a single experimental setting. This would include testing the relative efficacy of full retention (no discharge), partial discharge (but none during setting, towing or hauling), partial retention with discharge on the same/opposite side during setting, towing or hauling, and no offal management. Furthermore, within the discharge treatments various forms (e.g minced versus mealed) would be trialled. However, such an extensive trial has not yet been undertaken.

Warp cable and third wire protection:

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).

While variation exists, the general design of BSLs used by trawl vessels involves the attachment of a line (backbone) to each of the port and starboard sides of the vessel, above and outside of the warp blocks (see Figure 1). An object, most often a buoy, is attached to the seaward end of each line in order to create sufficient drag to ensure that the line is taut behind the vessel at all times. Branched streamers, attached to the backbones, should reach the sea surface in calm conditions, and act as a visual curtain to deter seabirds from approaching the warp cables.

Initial trials conducted by Watkins *et al.* (2006) in the South African demersal hake (*Merluccius* spp.) trawl fishery found that a pair of short BSLs set over the warps greatly reduced the numbers of birds entering the danger zone where the warps enter the water.

In the Falkland Islands (Islas Malvinas) pelagic finfish trawl fishery, no mortalities were recorded during BSL trials, compared to 0.082 mortalities/hour with no mitigation device (Sullivan *et al.* 2006a). Total contact rates were significantly reduced when using the BSLs (0.91 contacts/hour) compared to no BSLs (55.78 contacts/hour), as were heavy contacts (BSLs – 0.29 contacts/hour; noBSLs – 16.80 contacts/hour) (Sullivan *et al.* 2006a).

Reid and Edwards (2005) investigated changes in seabird mortality following the introduction of BSLs into the Falkland Islands (Islas Malvinas) finfish trawl fleet (2002/03 versus 2004/05). Birds were 79% less likely to be killed on a shot in 2004/05

(BSLs) than during 2003/04 (no BSLs). During 2004/05, BSLs were only deployed once the fishing gear had reached fishing depths, thus leaving a period after the trawl doors enter the water during which the trawl warps are towed through the water unprotected. Comparison of contact rates before and after setting of BSLs within the 2004/05 season showed that average rate of contacts was significantly higher pre-BSLs (27.1 contacts/hour) than post-BSLs (1.6 contacts/hour). Furthermore, seven out of 11 birds (64%) observed killed on the warp cables during 2004/05 observations occurred during the pre-BSL period. Comparisons of pre- and post-BSL deployment were also made during May 2006 (Falklands Conservation 2007). Recorded contact rates in 2004/05 and 2006 were similar with respect to the pre- and post-BSL periods, within an average 15-fold increase in contacts (light and heavy) during pre-BSL deployment (Falklands Conservation 2007).

When undertaking trials in the New Zealand southern squid trawl fishery, Abraham *et al*. (in prep-a) recorded that even when discharge was present, BSLs reduced the average trawl warp strike rates by 11% and 17.6% of the rate in the absence of mitigation, for large birds and small birds respectively. Mortalities of large birds associated with warps were reduced from 9.6 birds/100 tows when using no mitigation to 0.8 birds/100 tows when using BSLs. Abraham *et al*. (in prep-a) did note that while BSLs reduced the numbers of warp strikes, seabirds struck BSLs at a rate similar to that recorded on trawl warps without mitigation. However, the consequences of seabird strikes on BSLs are as yet unclear.

Though relatively low, mortalities have been recorded in the Falkland Islands (Islas Malvinas) finfish trawl fishery as a result of birds becoming entangled with the paravane cable (Sullivan and Reid 2003; Reid and Edwards 2005). Given that BSLs are not set up to solve this problem, Reid and Edwards (2005) suggest two potential solutions: (1) adding flags or streamers to the paravane cable to act in a similar way to the streamers on BSLs; or (2) placing short arms, with a number of streamers attached, forward of the sluices and paravane.

Besides reducing seabird contacts and mortalities associated with warp strikes, other advantages to using BSLs as a mitigation measure include their requirement of little storage space, they are easy to maintain and replace, simple to deploy, and relatively inexpensive compared to other methods (Sullivan *et al.* 2006a). On a cautionary note, mortalities may still occur when BSLs are deployed after shooting and retrieved before hauling. Furthermore, as noted above, seabird contacts with the BSLs have been observed and their consequences (though likely to be relatively minor compared to the consequence of not using BSLs) are currently unknown (Sullivan *et al.* 2006a; Abraham *et al.* in prep-a).

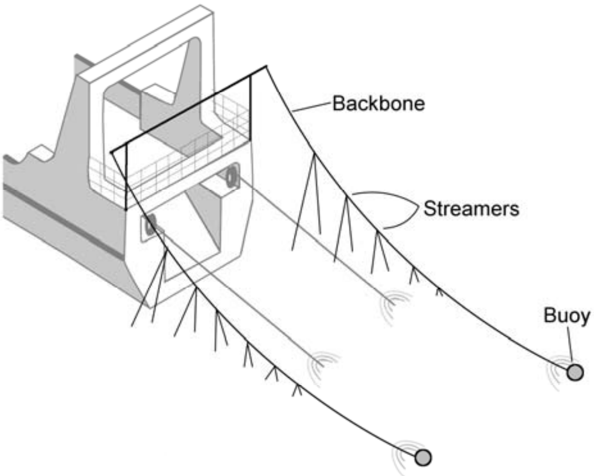


Figure 1. Example of a bird-scaring line set-up used on trawl vessels. (Abraham *et al.* in prep-a, redrawn from Sullivan *et al.* 2006a, and Department of Internal Affairs 2006).

Cones versus buoys on paired BSLs

Although BSLs have achieved significant reductions in seabird mortalities, limitations in their effectiveness have been recognized in cases of strong cross winds and rough seas. Under such conditions, the BSLs tend to be deflected from the warps, thus increasing the potential for seabird warp strikes and the risk of BSL entanglements with the warp cables (Sullivan and Reid 2003; Crofts 2006a, b). In a number of trawl fisheries, buoys are attached to the seaward end of BSLs to create tension, with the aim of keeping the lines straight in the water (Sullivan *et al.* 2006a; Abraham *et al.* in prep-a). Modified road cones have also been used for the same purpose in the eastern tuna and billfish long-line fishery in Eastern Australian waters, and in the South African hake trawl fishery.

Crofts (2006a) tested the performance of paired BSLs using standard Falkland Islands (Islas Malvinas) Fisheries Department regulated buoys against modified road cones to determine their relative performance and practicality in regards to environmental variables (i.e. wind and sea state). During the trials, 82% of all seabird contacts were made on the warp cables, 17% on BSLs, and 1% on the paravane. Seabird entanglements in BSLs were mostly non-detrimental, and were more frequent with the control buoys than cones. The performance difference between the two devices is due to insufficient drag and a high percentage of lines and streamers fouling the surface when using the control buoys. Dragging cones behind BSLs increased line tension and kept a higher overall percentage of the BSLs and streamers aloft off the sea surface compared to when the control buoys were in use. Total (light + heavy) and heavy mean contact rates were low when either buoys (0.72/hour and 0.31/hour respectively) or cones (0.37/hour and 0.28/hour respectively) were used compared to pre-BSL (17.27/hour and 6.07/hour respectively) periods during shooting operations.

Crofts (2006a) concluded that further improvements to and testing of the current cone design are required before recommendations can be made to use cones in preference to buoys in the Falkland Islands (Islas Malvinas) fishery. The shape of the cones, their bouncing nature especially in heavy seas, and the difficulty of retrieving the cones (by one person) with the current set up, all need further investigation.

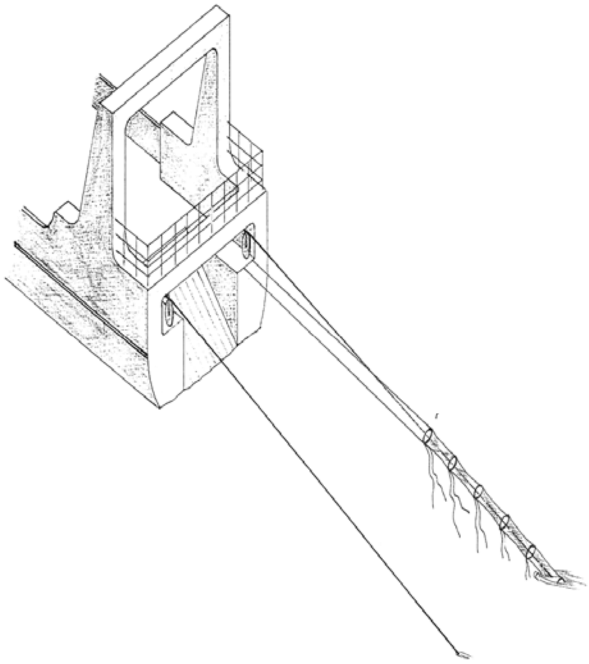
Warp scarers

Warp scarers are weighted devices attached to each warp with clips or hooks, allowing the device to slide up and down the warp freely and stay aligned with each warp (see Figure 2). These devices create a protective area around the warp, and eliminate problems associated with crosswinds as they don’t behave independently from the warps. Warp scarers cannot be deployed while the warp cable is being set. A number of different designs exist and several have been trialled for their effectiveness in reducing contacts and mortalities associated with the warp cable.

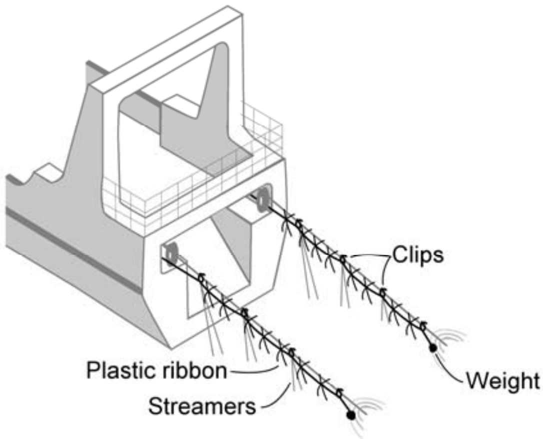
During a trial in the Falkland Islands (Islas Malvinas) demersal finfish trawl fishery, lower bird mortality rates were recorded for the Falkland Islands (Islas Malvinas) warp scarer (0.007 deaths/hour) compared to the control with no mitigation device (0.082 deaths/hour) (Sullivan et al. 2006a). In comparison to the control, the warp scarer substantially reduced total contacts (6.64 contacts/hour compared to 55.78 contacts/hour) and heavy contacts (0.90 contacts/hour compared to 16.80 contacts/hour). The one mortality recorded during the warp scarer trial occurred during shooting (i.e. before the device was deployed).

The Carey device (a modified warp scarer) was trialled by the southern squid trawl fishery fleet in waters to the south and east of New Zealand's South Island (Abraham *et al.* in prep-a). When discharge was present, average trawl warp strike rates per 15 minute observation period were reduced (though not significantly) for both large and small birds when using warp scarers (0.48 and 0.32 respectively) compared to no mitigation (0.62 and 0.67 respectively). Mortalities of large birds associated with the warps were reduced from 9.6 birds/100 tows when using no mitigation to 3.6 birds/100 tows when using warp scarers. A few incidences of bird strikes on the warp scarers were observed (Abraham *et al.* in prep-a).

Although warp scarers have been shown to reduce contact rates, concerns have been raised regarding associated practicality and safety issues (Sullivan *et al.* 2006a; Abraham *et al.* in prep-a). The device is deployed after shooting the net and retrieved prior to hauling, thus leaving a period of time during which the trawl warps are towed through the water unprotected. The warp scarer may also come out of the sea if the vessel is pitching in rough seas (T. Reid pers. comm.), representing another instance during which the risk of interactions between seabirds and the warp cable are increased.



(a)



(b)

Figure 2(a). Falkland Islands warp scarer (Sullivan *et al.* 2006a), and (b) Carey device (Abraham *et al.* in prep-a, redrawn from Sullivan *et al.* 2006a, and Department of Internal Affairs 2006).

Bird bafflers

While a number of versions exist, bird bafflers generally consist of two booms attached to the starboard stern quarter and two attached to the port stern quarter (see Figure 3). Two of these booms extend out from the sides of the vessel and the other two extend backwards from the stern. Dropper lines are attached to the booms, and visual deterrents such as cones and rods are attached to the dropper lines to create a curtain to deter seabirds from the warp-sea interface zone.

The Brady baffler was trialled in the Falkland Islands (Islas Malvinas) demersal finfish trawl fishery, and recorded lower mortality rates (0.007 deaths/hour) compared to the control (no mitigation device; 0.082 deaths/hour) (Sullivan *et al.* 2006a). Mortalities were recorded for black-browed albatross, southern giant petrels and cape petrels. The baffler reduced heavy contacts compared to the control (9.72 contacts/hour and 16.80 contacts/hour respectively), as well as total contacts compared to the control (42.95 contacts/hour and 55.78 contacts/hour respectively), though not significantly (Sullivan *et al.* 2006a).

Bird bafflers were trialled in New Zealand's southern squid trawl fishery fleet (Abraham *et al.* in prep-a). Given the scale of the experiment and logistical constraints, it was not feasible to implement identical bafflers on the vessels in the trial. When discharge was present, average trawl warp strike rates for large birds were 0.80 (per 15 minute observation period) when using the baffler, compared to 0.62 for no mitigation device. For small birds, the average trawl strike rates were 0.52 (per 15 minute observation period) when using the baffler, compared to 0.67 when using no mitigation. Mortality rates for large seabirds associated with the warp cables were greater with the bird baffler (36.9 birds/100 tows) than with no mitigation (9.6 birds/100 tows). A few incidences of strikes on the bird bafflers were observed (Abraham *et al.* in prep-a).

Abraham *et al.* (in prep-a) found that the height of the vessel's block could be an important factor in determining the success of bird bafflers as a mitigation device:

bafflers on the vessels with medium block heights were found to significantly reduce warp strikes, however those on vessels with high blocks were not. When blocks are lower to the water, the baffler gives better protection to the region where the warps enter the water, as this is closer to the stern. However, this result is drawn from a small number of vessels so is not conclusive; more rigorous testing is required.

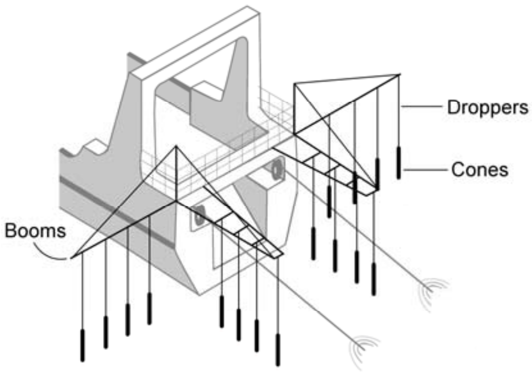


Figure 3. Example of a baffler, a mitigation measure for which designs can vary somewhat, e.g. the number of booms and connectedness of the droppers. (Abraham *et al.* in prep-a, redrawn from Sullivan *et al.* 2006a, and Department of Internal Affairs 2006).

Compared to other baffler designs, the burka baffler (see Figure 4) has an additional line (between the seaward ends of the two booms that extend backwards from the stern) to “box” off the warps (Prendeville 2007). The warps are therefore shot in an “enclosed area”. This device is under development and has not been tested. Anecdotal observations of the Burka indicate that birds sit 20-30 m behind the vessel (Prendeville 2007).

Generally bird bafflers are not regarded as providing as much protection to the warp cables as BSLs or warp scarers (Sullivan *et al.* 2006a). The effectiveness of the burka has, however, not been experimentally tested. The great variability in the design and deployment of bird bafflers may influence their effectiveness. For instance, bird bafflers with dropper lines too short end well above the sea, therefore providing less protection to the warps (Abraham *et al.* in prep-a). Furthermore, as noted above, Abraham *et al.* (in prep-a) found that the height of the vessel’s block is an important factor in determining the success of bird bafflers as a mitigation device.

As a mitigation device, bird bafflers have the advantage in that they can be set at the beginning of a fishing trip, and while most designs need to be retrieved in extreme weather (Sullivan *et al.* 2006a), the burka can be left out in all conditions (Prendeville 2007).

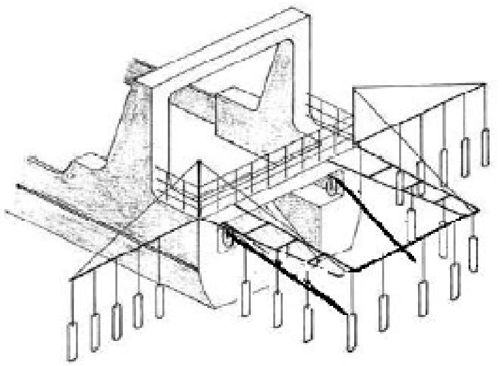


Figure 4. The burka baffler (http://www.fishinfo.co.nz/Newsletters/ 19_Sep07.pdf).

Cones on warp cables

González-Zevallos *et al.* (2007) attached a plastic cone to each warp cable on three trawl vessels targeting Argentine hake (*Merluccius hubbsi*) in the waters of Golf San Jorge. The orange plastic (traffic) cone was 1 m long and tapered out from a 10 cm to 20 cm diameter. The cone opened in half and was placed around the cable from the deck, and a rope attached to it lowered it down the cable to where the warp cable enters the water (González-Zevallos *et al.* 2007).

Most of the observed interactions between seabirds and warp cables during the trials occurred when birds were feeding on discards (González-Zevallos *et al.* 2007). During hauls with the cone device, the number of contacts was significantly reduced by 89% compared to without the device. Furthermore, no seabirds were killed due to contacts with warp cables during the deployment of the device, compared to 11 individuals killed in hauls without the device. Mean distance between seabirds and cables during hauls were significantly increased with the device (2.6 m) compared to without (0.9 m).

Third-wire scarer

Melvin *et al.* (2004) attached scarer devices (four designs) directly to the third wire (see Figures 2 and 4 in Melvin *et al.* 2004) to reduce the likelihood of birds approaching the danger area around the third wire. Anecdotal observations in the Bering Sea pollock (*Theragra chalcogramma*) trawl fishery, found that all but one of the third wire scarer devices were effective at reducing seabird strikes (Melvin *et al.* 2004). Problems that were encountered during these trials included all the third wire scarers being difficult to deploy and manage, creating potentially unsafe conditions for the deck crew (Melvin *et al.* 2004). Furthermore, during retrieval, care had to be taken to keep them clear of fouling the third wire block (Melvin *et al.* 2004).

Snatch block

The third wire can be run through a snatch block directly below the third wire block in order to make the wire enter the water as close to the stern as possible (see Figure 1 in Melvin *et al.* 2004). Observations were collected anecdotally to determine the relative merits of the snatch block in the Bering Sea pollock trawl fishery as a third wire mitigation method (Melvin *et al.* 2004). The contact rate was lower when the snatch block (1.0 contacts/hour) was used compared to no mitigation measure (16.04 contacts/hour). While the snatch block resulted in less of the third wire being exposed, and consequently interactions with seabirds were reduced, it did add wear to the third wire.

Net protection/modification:

Net binding

Net binding aims to prevent the net from opening until after it has sunk below the sea surface during shooting, and as such reduce the time during which seabirds can interact with the net (Sullivan *et al.* 2004).

Net binding trials were undertaken in the pelagic icefish (*Champsocephalus gunnari*) fishery in CCAMLR waters (Subarea 48.3), comparing the effectiveness of one type of cotton binding, and three different strengths of sisal string to bind up 150-800 mm net meshes during shooting (Roe 2005). The 3-ply string, with a breaking strain of 110 kg, was found to be the most suitable option, as the cotton binding and sisal string with lower breaking strains tended to break either on the sea-surface or as the net was being shot from the deck (Roe 2005). Using net bindings resulted in a reduced surface area of the net, and may have decreased net-surface time. However, due to the limited number of trawls, and other factors that affect net-surface time, this could not be quantified. Although seabirds were still attracted to the net on shooting, the chances of entanglement with the bound meshes were greatly reduced (Roe 2005).

Roe (2005) noted that the binding technique was liked by the crew as it is cheap and simple, and doesn't rely on technology that may fail. The process was quick and could easily be adopted into work practices (Roe 2005).

In comparison, in the 2005/06 CCAMLR fishing season, one vessel used a synthetic netting material (not the SC-CAMLR-XXIV recommended organic sisal) to tie slipknots around 150-400 mm sections of the mesh while fishing in CCAMLR waters. The slipknots frequently opened before the doors were paid away, causing the net to loft on the surface (CCAMLR 2006).

Mesh size

In an effort to reduce seabird interactions with the net, Roe (2005) reported on the use of reduced mesh size from 200mm to 140mm in the pelagic icefish fishery in CCAMLR waters (Subarea 48.3). Chains were also added to each side of the body of the net to make it sink more quickly. The reduced mesh size was believed to have caused severe damage to the net through it being subjected to increased water pressure during trawling. However, the Captain did acknowledge that the damage may have been caused by adding the chains to the side of the net (Roe 2005).

Bird-scaring lines

Roe (2005) reported on a trial using BSLs during shooting and hauling of the net in the pelagic icefish fishery in CCAMLR waters (Subarea 48.3). The BSLs failed to protect the net during the haul as tension could not be maintained in the lines. Adding weight to the buoys was found to improve the lines' performance slightly, however not enough to keep them aloft (Roe 2005). Consequently, the BSLs were deemed to be impractical during hauling and their use was discontinued.

COMPARATIVE STUDIES

Recently, two studies have been undertaken in Southern Hemisphere waters comparing the relative effectiveness of BSLs, warp scarers and bird bafflers for reducing seabird interactions with trawl warp cables.

Sullivan *et al.* (2006a) compared the effectiveness of the Falkland Islands (Islas Malvinas) warp scarer, BSLs and the Brady Baffler in the Falkland Islands (Islas Malvinas) trawl fishery. All three mitigation devices reduced the rate of total contacts (light + heavy), heavy contacts and mortalities relative to that of the control. There was however, no significant difference between the control and baffler treatments. Overall, the results indicated a performance hierarchy based on contact rates: the BSLs and warp scarer performed substantially better than the baffler, with the BSLs showing a small, but nevertheless significant, improvement on the warp scarer (Sullivan *et al.* 2006a).

Abraham *et al*. (in prep-a) trialled BSLs, the Carey warp scarer and bird bafflers in the New Zealand southern squid trawl fishery. Of the three devices, BSLs were the most effective. Bird bafflers were less effective and the warp scarer design used in this experiment was not significantly different from the control in which no mitigation was deployed. In general, the mitigation devices appeared to be less effective at reducing small bird strikes. Of the three devices, only BSLs resulted in a significant reduction in small bird warp strikes. With regards to interactions with the mitigation devices, seabirds struck BSLs at a rate similar to that recorded on trawl warps without mitigation, while there were few recorded strikes on bird bafflers or warp scarers (Abraham *et al.* in prep-a).

These independent comparative studies both concluded that BSLs were the most effective of the methods trialled at reducing (in most cases significantly) seabird warp strikes and mortalities. Instances of contacts (and even mortalities) with BSLs have been recorded in a number of fisheries (Otley 2005; Crofts 2006a; Abraham *et al.* in prep-a). While such cases should not detract from the overwhelming efficacy of BSLs at reducing seabird interactions with fishing gear, it would be beneficial to quantify these events and the circumstances leading to them, in order to further improve BSL performance.

DISCUSSION

An important issue surrounding the effectiveness of a number of mitigation devices is both compliance and correct deployment. During the trials undertaken by Abraham *et al.* (in prep-a), all three mitigation devices were recorded as not meeting the trial specification for some of the observation periods. For instance, bird bafflers commonly failed to meet trial specifications due to the dropper lines being too short (Abraham *et al.* in prep-a). Similarly, some warp scarers were deployed too short, resulting in the weight well above the sea surface. With regards to BSLs, on occasions streamers were missing or the buoys were forward of the warp entry point (Abraham *et al.* in prep-a). These seemingly simple departures from the recommended specifications can seriously reduce the effectiveness of the mitigation devices, leaving the danger zone (warp-sea interface) unprotected and exposed to birds. However, when deployed correctly, several methods have been shown to effectively reduce seabird-fisheries interactions.

Of all the mitigation devices trialled, BSLs appear to be consistently the most effective in terms of reducing seabird contacts and mortalities associated with trawl warp cables (Reid and Edwards 2005; Sullivan *et al.* 2006a; Falklands Conservation 2007; Abraham *et al.* in prep-a). There are however, opportunities to further improve the efficacy and performance of this mitigation method. For instance, Crofts' (2006a) trial investigating the impact of using buoys or cones on the performance of BSLs highlighted the need for further refinement of the device to improve drag and line tension as well as resistance to deflection from cross winds. Also, the incidence of bird strikes on BSLs needs further investigation (Abraham *et al.* in prep-a). Quantification of such occurrences, as well as understanding the circumstances leading to such interactions would provide valuable information regarding the extent of this issue and possible solutions. However, as Crofts (2006a) notes, the issue of bird strikes with mitigation devices needs to be kept in context considering the significant reduction in seabird mortalities that have arisen following the adoption of using BSLs.

Few mitigation measures exist for reducing net entanglements, and only a small proportion of these have been tested. While the data are not statistically significant, based on three seasons of operational experience (2005–2007), the CCAMLR's ad-hoc IMAF[2] Working Group view the use of sisal strip to bind nets as a potentially effective and easily accomplished mitigation measure that may reduce seabird mortalities during setting operations of pelagic trawl fisheries (CCAMLR 2007). Consequently, the IMAF Working Group has recommended the use of net binding by the icefish trawl fleet in the Convention Area, and has provided guidelines to assist in a uniform uptake of this mitigation measure (CCAMLR 2005, 2006).

While effective at reducing warp strike and associated mortality rates of seabirds present at a vessel, mitigation devices such as BSLs should be viewed as short-term measures that tackle the end result of the problem: mitigating against the bird aggregations within the danger area of the trawl warps caused by waste discharge (Munro 2005). Long-term options need to be those that tackle the cause of the problem, the discharge of fisheries waste that initially attracts seabirds to the vessels (Munro 2005). The effective management of fishery discards could remove the primary attractant to seabirds and hence the source of the problem (Munro 2005; M. Favero pers. comm.). Discards come from a variety of sources, the two major sources being discharge of offal resulting from fish processing operations onboard, and the discharge of bycatch comprising of non-commercial and undersize fish that are not processed (Munro 2005).

Numerous studies have documented the influence that the presence of discards has on contact rates and mortalities via its effect on the abundance of seabirds attending the vessel (Weimerskirch *et al.* 2000; Sullivan *et al.* 2006a; Abraham *et al.* in prep-b). Consequently, it has generally been recognised that the most effective way to reduce

[2] IMAF = Incidental Mortality Arising from Fishing

warp cable mortality is through controlling, or ideally retaining, the discharge of fish bycatch and processing waste (Wienecke and Robertson 2002).

Munro (2005) identified a number of potential options and changes in waste management practices that would reduce the attractiveness of a vessel to seabirds. While some of these are relatively easy to apply in practice given appropriate safety considerations (e.g. screens and meshes fitted on all potential factory water discharges), others require vessel modification or the installation of specialist processing machinery (Munro 2005). Options that fall in to this latter category include permanent or interim storage on board, freezing of discards into blocks, mincing of fish to a small particle size, processing waste to fishmeal, and discharging out of the danger area.

The long-term, or in some cases interim, storage of bycatch and processing waste on board many vessels may currently be impractical or difficult in a number of fisheries given current operational practices (Munro 2005; Varty *et al.* 2008; Abraham *et al.* in prep-b). Munro (2005) considered that the retention of waste on board was likely to cause severe restrictions to fishing operations through increased crew workload, and reducing storage space and freezer capacity (Munro 2005). However, operational and management practices on some vessels do allow for long-term (e.g. entire tow or daily) waste storage (New Zealand Deepwater Group Ltd, pers. comm.), and in such cases should be encouraged. Therefore, although ideal from a theoretical point of view, the retention of discards on board must be considered in an operational context, and applied vessel by vessel when their characteristics differ.

An alternative in some situations is the use of macerators to convert fish bycatch and processing waste into fishmeal. Weimerskirch *et al.* (2000) noted that quality and form of discards could explain differences in the attractiveness of different vessels to seabirds. Macerating waste to a fine paste reduces the provisioning opportunities for seabirds (particularly larger species), resulting in a reduction in interest and association with the vessel (Munro 2005; Watkins *et al.* 2006). Abraham *et al.* (in prep-b) investigated this potential relationship, trialling the effect of different methods of offal and discharge management (whole discards versus mincing versus mealing) on seabird abundance and behaviour around trawl vessels. Mincing reduced the number of *Diomedea* albatrosses attending the vessel, whereas mealing resulted in a significant reduction in numbers of flying or sitting albatrosses and petrels around the vessel, and a significant reduction in the number of all seabird groups feeding behind the vessel (relative to the discharge of unprocessed fish waste). Consequently, Abraham *et al.* (in prep-b) concluded that of the three treatments, mealing was the method of waste management that would most likely lead to the greatest conservation benefits for seabirds overall. Notably, of the three treatments trialled, mealing minimises the amount of fish waste discharged.

It is important that the adoption of one mitigation measure does not transfer the problem from one part of the fishing operation or gear to another (e.g. from the warp to the paravane cable) (Munro 2005). Thus, while it is assumed that waste management measures adopted to combat warp collision will also prove efficient at reducing mortality associated with the paravane cable, this should be investigated (Munro 2005).

CONCLUSIONS

As mentioned earlier, there are many variables which influence the success of a mitigation measure. Consequently, the results of the methods presented here for particular fisheries may not be as successful on vessels of a different design, or in different operational situations, and these methods may therefore need to be tested for their efficacy and adapted as necessary to individual situations. Nevertheless, the conclusions drawn from the reviewed material are as follows:

- *Presence of fish waste* – Preventing the discharge of discards or other fish waste while trawl gear is in the water would reduce the mortality of seabirds associated with warp cable collisions and net entanglements.
- *Discharge management* – Mealing of all discards and offal has been shown to reduce seabird attendance and, therefore, the risk of incidental seabird mortality (Abraham *et al.* in prep-b).
- *BSLs for cable protection* – BSLs have been shown to substantially reduce seabird

contacts and mortalities associated with warp strikes in several trawl fisheries (Sullivan *et al.* 2006a; Abraham *et al.* in prep-a). However, unresolved issues surrounding their use include the need for methods to refine their effectiveness in all wind speeds and wind directions, and investigations into the potential impact of, and solutions for, BSL strikes on seabirds.

- *Cones versus buoys on BSLs* – In general, the cones created better line tension and improved performance in calm and moderate conditions compared to the buoys. However the bouncing nature of the cones in heavy swells may potentially increase warp entanglements (Crofts 2006a).
- *Warp scarers* – Warp scarers have been shown to reduce contact rates in several trawl fisheries (Sullivan *et al.* 2006a; Abraham *et al.* in prep-a). There is, however, considerable variation in warp scarer design which may result in differing levels of effectiveness. Concerns have also been raised regarding associated crew safety with respect to attaching and detaching warp scarers (Sullivan *et al.* 2006a; Abraham *et al.* in prep-a).
- *Bird bafflers* – Generally bird bafflers are not regarded as providing as much protection to the warp cables as BSLs or warp scarers (Sullivan *et al.* 2006a; Abraham *et al.* in prep-a), however the effectiveness of the Burka has not been tested. The variability in the design and deployment of bird bafflers has been shown to significantly influence their effectiveness as a mitigation device (Abraham *et al.* in prep-a).
- *Cones on warps* – This method of attaching cones to the trawl warps proved effective at reducing contact rates and mortalities associated with the warps in the Argentine hake trawl fishery. The distances between seabirds and warp cables were also significantly greater in hauls with the mitigation device (González-Zevallos *et al.* 2007).
- *Third wire protection* – To date only anecdotal observations are available for several methods aimed at reducing seabird interactions with the third wire. While seabird contacts appeared to be reduced in some cases, further work is needed to ascertain the most effective mitigation method.

- *Net binding* – Limited trials of this method have been undertaken in CCAMLR waters, and while it is yet to be conclusively evaluated, the CCAMLR ad-hoc IMAF Working Group view net binding using sisal string as a potentially effective mitigation measure to reduce seabird mortalities during setting operations of pelagic trawl fisheries (CCAMLR 2007). The size of nets will influence the necessary binding, and as such trials will be needed in other trawl fisheries to determine the most appropriate materials, and the efficacy of this method.
- *Mesh size* – Trials using reduced mesh size were discontinued due to net damage. Consequently, the potential of this mitigation method has not been fully explored or evaluated.
- *BSLs for net protection* – BSLs were not found to protect the net during shooting and hauling because tension could not be maintained in the lines (Roe 2005).
- *Comparative studies* – Two independent comparative studies testing the relative effectiveness of BSLs, bird bafflers and warp scarers at reducing seabird interactions with trawl warp cables, both found the performance of BSLs superior to the other two devices (bird bafflers and warp scarers).

Thus, based on a review of material produced between 2004-2008 on methods to reduce interactions between seabirds and trawl fisheries gear, the recommendations of Bull's (2007) earlier review still hold. That is, a combination of offal and discard management, paired BSLs, and a reduction in the time the net is on or near the surface are likely to be the most effective in reducing seabird interactions with the warp cables and net. However, as stressed in Bull's (2007) review, even within a fishery, individual vessel refinement of mitigation techniques may be required in order to maximize their effectiveness.

Future research needs

- Further comparative studies such those undertaken by Sullivan *et al.* (2006b) and Abraham *et al.* (in prep-a) are required to determine the most effective mitigation measure for individual fisheries.

- Efforts should continue with regards to establishing and evaluating effective means of managing offal and discards in a manner that reduces their attractiveness to seabirds.
- Opportunistic observations on a number of stern trawlers in the Falkland Islands (Islas Malvinas) suggest that the nature and movement of discard in the water may be another important factor influencing contact and mortality rates. The anecdotal conclusions based on these observations warrant further investigation and testing, particular with regards to the influence of discard distance aft of the stern and warps.
- The incidence and cause of BSL strikes on seabirds has not been fully assessed, and thus warrants investigation (Crofts 2006a; Abraham *et al.* in prep-a). In a number of cases, the problem may be arising when the BSLs foul the surface of the sea as a result of insufficient drag and tension (see following recommendation).
- Further work needs to be undertaken with regards to improving the tension and drag of the BSLs so they remain clear of the water. Crofts (2006a) demonstrated that the performance of BSLs can be improved by a different “buoy” design. This methodology does however still need further refinement. Crofts (2006a) recommended testing a similar design using the road cone in which the nose end is shortened so the length of the cone is reduced and the top-end opening widened. The hope is that these alternations may remedy the bouncing action and maintain the improved performance of the BSL.
- The refinement of an effective mitigation method that does not act independently of the trawl warps is essential so that increased protection of the warp cable can be achieved during all wind speeds and directions (Crofts 2006a).
- Experimental trials could be undertaken using the Burka baffler to establish if this device affords any more protection to the warp cables relative to other bird bafflers or mitigation devices.

- Third wire protection continues to be an area in which little work has been done, and as such some effort should be put into finding effective measures to reduce third wire contacts.
- Further testing of net binding is required to evaluate the efficacy of this method.

ACKNOWLEDGEMENTS

This review was prepared by Dr. L. S. Bull. Thanks to the following people for providing relevant information for the review and/or commentary on an earlier draft: B. Baker, J. Cooper, S. Crofts, M. Favero, H. Hall, I. Hay, E. Melvin, H. Otley, J. Pierre, T. Reid, K. Rivera, N. Smith, M. Tasker, M. Tombesi, B. Sullivan and A. Wolfaardt.

REFERENCES

Abraham, E.R., Middleton, D.A.J., Waugh, S.M., Pierre, J.P., Walker, N.A. and Schröder, C. (in prep-a). A fleet scale experimental comparison of devices used for reducing the incidental capture of seabirds on trawl warps.

Abraham, E.R., Pierre, J.P., Middleton, D.A.J., Cleal, J., Walker, N.A. and Waugh, S.M. (in prep-b). Effectiveness of fish waste management strategies in reducing seabird attendance at a trawl vessel.

Baird, S. J. 2008. Net captures of seabirds during trawl fishing operations in New Zealand waters. NIWA Client Report WLG2008-22, March 2008. http://www.doc.govt.nz/templates/MultiPageDocumentTOC.aspx?id=46325.

Baker, G.B., Double, M.C., Gales, R., Tuck, G.N., Abbott, C.L., Ryan, P.G., Petersen, S.L., Robertson, C.J.R. and Alderman, R. 2007. A global assessment of the impact of fisheries-related mortality on shy and white-capped albatrosses: Conservation implications. *Biological Conservation* **137:** 319-333.

Bartle, J.A. (1991). Incidental capture of seabirds in the New Zealand subantarctic squid trawl fishery. *Bird Conservation International* **1**: 351-359.

Bergin, A. (1997). Albatross and longlining - managing seabird bycatch. *Marine Policy* **21**: 63-72.

Birdlife.org (2008). Downloaded 28 May 2008.

http://www.birdlife.org/datazone/species/index.html?action=SpcHTMFind Results.asp&hdnAction=SEARCH&hdnPageMode=0&cboFamily=17&txtGenus =&txtSpecies=&txtCommonName=&cboRegion=-2&cboCountry=-2

Brothers, N. (1991). Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. *Biological Conservation* **55**: 255-268.

Brothers, N., Gales, R. and Reid, T. (1999). The influence of environmental variables and mitigation measures on seabird catch rates in the Japanese tuna longline fishery within the Australian fishing zone, 1991-1995. *Biological Conservation* **88**: 85-101.

Bull, L.S. (2007). Reducing seabird bycatch in longline, trawl and gillnet fisheries. *Fish & Fisheries* **8**: 31-56.

CCAMLR (2005). *Incidental Morality of Mammals and Seabirds Associated with Fishing (Ad Hoc WG-IMAF Report).* CCAMLR, Hobart. 496 pp.

CCAMLR (2006). *Report of the Ad Hoc Working Group on Incidental Morality of Mammals and Seabirds Associated with Fishing (Ad Hoc WG-IMAF).* CCAMLR, Hobart, Australia. 60 pp.

CCAMLR (2007). *Ad Hoc Working Group on Incidental Morality of Birds Associated with Fishing, Part II: Report of the Ad-Hoc WG-IMAF.* CCAMLR, Hobart, Australia. 72 pp.

Crofts, S. (2006a). *Environmental effects and practicality of paired tori-line performance: Testing buoys vs cones.* Falklands Conservation, Stanley, Falkland Islands. 23 pp.

Crofts, S. (2006b). *Seabird Interactions in the Falkland Islands Loligo trawl Fishery 2005/2006.* Falklands Conservation, Stanely, Falkland Islands. 22 pp.

Crofts, S. (2006c). *Preliminary Assessment: Seabird interactions in the pelagic Southern blue-whiting (Micromesistius australis) surimi fishery in the Falkland waters - December 2006.* Falklands Conservation, Stanley, Falkland Islands. 15 pp.

Croxall, J.P., Rothery, P., Pickering, S.P.C. and Prince, P.A. (1990). Reproductive performance, recruitment and survival of wandering albatrosses *Diomedea exulans* at Bird Island, South Georgia. *Journal of Animal Ecology* **59**: 775-796.

Department of Internal Affairs. 2006. Fisheries (Incidental bycatch of seabirds by trawl vessels 28m+) notice 2006. *New Zealand Gazette, 1, 12 January 2006*, 31 - 34. Retrieved February, 2007, from: http://dia.govt.nz/pubforms.nsf/URL/NZGazette1Jan06.pdf/$file/NZGazette1Jan06.pdf

Dietrich, K.S. and Melvin, E. (2007). *Alaska Trawl Fisheries: Potential Interactions with North Pacific Albatrosses.* WSG-TR 07-01. Washington Sea Grant, Seattle, WA. 43 pp.

Falklands Conservation (2007). *Preliminary Tori Line Review in the Falkland Trawl Fishery.* Falklands Conservation, Falkland Islands. 27 pp.

Gales, R., Brothers, N. and Reid, T. (1998). Seabird mortality in the Japanese tuna longline fishery around Australia, 1988-1995. *Biological Conservation* **86**: 37-56.

Goñi, R. (1998). Ecosystem effects of marine fisheries: an overview. *Ocean & Coastal Management* **40**: 37-64.

González-Zevallos, D. and Yorio, P. (2006). Seabird use of discards and incidental captures at the Argentine hake trawl fishery in the Golfo San Jorge, Argentina. *Marine Ecology Progress Series* **316**: 175-183.

González-Zevallos, D., Yorio, P. and Caille, G. (2007). Seabird mortality at trawler warp cables and a proposed mitigation measure: A case of study in Golfo San Jorge, Patagonia, Argentina. *Biological Conservation* **136**: 108-116.

Gorman, T. (1996). Seabird deaths: the difference between surface tuna longlining and bottom longlining. *Professional Fisherman* **18**: 18.

Hooper, J., Agnew, D. and Everson, I. (2003). *Incidental mortality of birds on trawl vessels fishing for icefish in subarea 48.3.* WG-FSA 03/79. CCAMLR, Hobart.

Klaer, N. and Polacheck, T. (1998). The influence of environmental factors and mitigation measures on by-catch rates of seabirds by Japanese longline fishing vessels in the Australian region. *Emu* **98**: 305-316.

Kock, K. (2001). The direct influence of fishing and fishery-related activities on non-target species in the Southern Ocean with particular emphasis on longline fishing and its impact on albatrosses and petrels - a review. *Reviews in Fish Biology & Fisheries* **11**: 31-56.

Lewison, R.L. and Crowder, L.B. (2003). Estimating fishery bycatch and effects on a vulnerable seabird population. *Ecological Applications* **13**: 743–753.

Løkkeborg, S. and Bjordal, J. (1992). *Reduced bait loss and bycatch of seabirds in longlining by using a seabird scarer.* WG FSA-92. CCAMLR, Hobart, Australia. 5 pp.

Løkkeborg, S. (1998). Seabird by-catch and bait loss in long-lining using different setting methods. *ICES Journal of Marine Science* **55**: 145-149.

Melvin, E., Dietrich, K.S. and Thomas, T. (2004). *Pilot tests of techniques to mitigate seabird interactions with catcher processor vessels in the Bering Sea pollock trawl fishery: final report.* WSG-AS 05-05. University of Washington, WA. 12 pp.

Munro, G.M. (2005). *Waste discard management in the Falkland Islands trawl fishery: A discussion document.* Falklands Conservation, Stanley, Falkland Islands. 62 pp.

Otley, H.M. (2005). *Seabird mortality associated with Patagonian toothfish longliners in Falkland Island waters during 2002/03 and 2003/04.* Fisheries Department, Falklands Islands Government, Stanley, Falkland Islands. 45 pp.

Prendeville, M. (2007). Don't be warped - trawl for fish, not birds. *Albert Times* **19**.

Reid, T. and Edwards, M. (2005). *Consequences of the introduction of tori lines in relation to seabird mortality in the Falkland Islands trawl fishery, 2004/2005.* Falklands Conservation, Stanley, Falkland Islands. 41 pp.

Robertson, G. (1998). The culture and practice of long line tuna fishing: implications for seabird by catch-mitigation. *Bird Conservation International* **8**: 211-221.

Roe, J.O. (2005). *Mitigation trials and recommendations to reduce seabird mortality in the pelagic icefish (Champsocephalus gunnari) fishery (Sub-area 48.3).* WG-FSA-05/59, SC-CAMLR XXIV. CCAMLR, Hobart, Australia. 18 pp.

SC-CAMLR (2001). *Report of the 20th Meeting of the Scientific Committee.* CCAMLR, Hobart, Australia.

SC-CAMLR (2002). *Report of the 21st Meeting of the Scientific Committee.* CCAMLR, Hobart, Australia.

Sullivan, B.J. and Reid, T. (2002). *Seabird interactions/mortality with longliners and trawlers in Falkland Island waters 2001/2002.* WG-FSA-02/36. CCAMLR, Hobart, Australia.

Sullivan, B.J. and Reid, T.A. (2003). *Seabird mortality and trawlers in Falkland Island waters 2002/03.* Falklands Conservation, Stanley, Falkland Islands.

Sullivan, B.J., Liddle, G.M. and Munro, G.M. (2004). *Mitigation trials to reduce seabird mortality in pelagic trawl fisheries (subarea 48.3).* WG-FSA04/80. CCAMLR, Hobart, Australia. 8 pp.

Sullivan, B.J., Brickle, P., Reid, T.A., Bone, D.G. and Middleton, D.A.J. (2006a). Mitigation of seabird mortality on factory trawlers: trials of three devices to reduce warp cable strike. *Polar Biology* **29**: 745-753.

Sullivan, B.J., Reid, T.A. and Bugoni, L. (2006b). Seabird mortality on factory trawlers in the Falkland Islands and beyond. *Biological Conservation* **131**: 495-504.

Varty, N., Sullivan, B.J. and Black, A. (2008). *FAO International Plan of Action-Seabirds: An assessment for fisheries operating in South Georgia and South Sandwich Islands.* BirdLife International Global Seabird Programme & Royal Society for the Protection of Birds, Bedfordshire, UK. 96 pp.

Watkins, B.P., Petersen, S.L. and Ryan, P.G. (2006). *Interactions between seabirds and deep water hake trawl gear: an assessment of impacts in South African waters 2004/05. WG-FSA-06/41, SC-CAMLR XXV.* CCAMLR, Hobart, Australia.

Watson, R., Revenga, C. and Kura, Y. (2006). Fishing gear associated with global marine catches I: Database development. *Fisheries Research* **79**: 97–102.

Weimerskirch, H., Brothers, N.P. and Jouventin, P. (1997). Population dynamics of wandering albatross *Diomedea exulans* and Amsterdam albatross *D. amsterdamensis* in the Indian Ocean and their relationships with longline fisheries: conservation implications. *Biological Conservation* **79**: 257-270.

Weimerskirch, H., Catard, A., Prince, P.A., Cherel, Y. and Croxall, J.P. (1999). Foraging white-chinned petrels *Procellaria aequinoctialis* at risk: from the tropics to Antarctica. *Biological Conservation* **87**: 273-275.

Weimerskirch, H., Capdeville, D. and Duhamel, G. (2000). Factors affecting the number and mortality of seabirds attending trawlers and long-liners in the Kerguelen area. *Polar Biology* **23**: 236-249.

Wienecke, B. and Robertson, G. (2002). Seabird and seal — fisheries interactions in the Australian Patagonian toothfish *Dissostichus eleginoides* trawl fishery. *Fisheries Research* **54**: 253-265.

Williams, R. and Capdeville, D. (1996). Seabird interactions with trawl and longline fisheries for *Dissostichus eleginoides* and *Champsocephalus gunnari*. *CCAMLR Science* **3**: 93-99.

Wilson, B., Rivera, K.S., Fitzgerald, S. and Rose, C. (2004). *Discussion paper on seabird interactions with trawl vessel gear.* North Pacific Fishery Management Council,