A review of seabird bycatch mitigation measures, including experimental work, within South Africa's tuna longline fishery

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ABSTRACT
Both foreign and domestic pelagic longline fleets operate in South Africa's Exclusive Economic Zone (EEZ) and adjacent international waters. Roughly 360 birds are killed each year by the longline fleets operating off South Africa; this includes bycatch from observed Japanese vessels, observed South African vessels and extrapolations of observed to unobserved South African vessels, between 2010 and 2013. This rate was even higher for the entire period between and 2013 when seabird bycatch averaged c. 45o birds per year. Permit conditions apply equally to domestic and foreign longline vessels, and are aligned with IOTC Resolution 12/06. Specifically, vessels must use two of three measures: bird-scaring lines, night setting or line-weighting. The domestic fleet typically uses 60-80 g swivels and sets exclusively at night, therefore they seldom use bird-scaring lines. Japanese-flagged vessels employ line weighting (60 g within 2.8 m of the hook) and bird-scaring lines, with most sets partially conducted at night and part during daylight (in international waters only). Encouragingly, concurrent with 100% observer coverage, significant reductions in seabird bycatch rates have occurred in this fleet after 2007, and the resultant bycatch rates now approximate the national target (0.05 birds per 1000 hooks). South Africa has also encouraged significant research into new or improved seabird bycatch mitigation options. These include research into sliding leads, hook pods and smart tuna hooks. Through the FAO's Common Oceans Tuna Project (or ABNJ project), South Africa is piloting port-based outreach to foreign-flagged tuna longline vessels that offload, refuel or revictual in Cape Town harbor. The outreach is specifically to provide information to skippers on Regional Fisheries Management Organisation (RFMO) regulations and to explain available bycatch mitigation options.

INTRODUCTION
The Benguela upwelling system off the west and south coasts of southern Africa is one of the world's most productive marine ecosystems (Crawford et al. 1987). South Africa's oceans support both a wide diversity and a high abundance of seabirds (Crawford et al. 1991). Only eight countries have recorded more species of seabird in their waters (Croxall et al. 2012). Amongst the most important threats to seabirds at sea is incidental catch by fishing gear (Croxall et al. 2012). Fisheries operating off South Africa that have caught substantial numbers of birds include the demersal trawl and demersal and pelagic longline operations (Watkins et al. 2008, Peterson et al. 2009a, 2009b). The bycatch has consisted mostly of albatrosses, petrels and shearwaters migrating into the region, and of one resident species, the Cape gannet *Morus capensis* (Watkins et al. 2008, Peterson et al. 2009a, 2009b).

Albatrosses and petrels are arguably the world's most pelagic seabirds, breeding on remote oceanic islands and migrating vast distances while ranging over oceans far away from continental shores (Nel and Taylor 2003). Several species, notably the albatrosses, can undertake movements that encircle the Southern Ocean, either as non-breeding adults or as juveniles, whereas others may range from Antarctic to subtropical waters including the Exclusive Economic Zone (EEZ) of South Africa. These movements take them out of EEZs and onto the High Seas and into EEZs of nations other than those of their breeding grounds, making them truly international animals. Thus, their conservation is a matter of international concern and shared responsibility. This led to the establishment of the Agreement on the Conservation of Albatrosses and Petrels (ACAP), which came into force on 1 February 2004, following South Africa's ratification of it in November 2003. The objective of the ACAP is to achieve and maintain a favourable conservation status for albatrosses and petrels.

Seabird bycatch mitigation measures within South African longline fishing permit conditions have been in place in various iterations since the 1990s (Table 1); some of the most important mitigation measures include: vessels targeting tuna (Japanese-flagged) under the South African allocation must ensure lines are set between nautical sunset and nautical sunrise, with a bird-scaring line deployed during setting operations. For vessels fishing on the high seas, day time setting is permitted as long as a minimum of 60 g of weight is added to branchlines within 2 m of the hook (DAFF 2013). Permit regulations are similar for vessels targeting swordfish (South African-flagged). However fishers need to ensure that a minimum of 60 g of weight is added to branchlines within 2 m of the hook; because of the additional weight vessels are allowed to set fishing lines at any time of the day or night, provided they use a bird-scaring line.

In 2006 BirdLife International created the Albatross Task Force (ATF) with an initial objective to reduce seabird bycatch in longline fisheries. The first ATF team was hosted by BirdLife South Africa, which commenced work on the deep-sea hake trawl fishery, pelagic longline fishery and the hake longline fleet. The ATF was involved in implementing new permit conditions after the termination of foreign bilateral agreements in 2005 meant that no Asian-flagged vessels were issued with South African fishing permits in 2006. Permits were re-issued in 2007 and required 100% coverage for scientific observers on all foreign-flagged vessels to collect data related to fishing operations, including catch and bycatch (DEAT 2008). In 2008 permit regulations were changed to include vessel-specific seabird bycatch limits. Vessels catching 25 birds in a calendar year were required to return to port for inspection of mitigation measures (e.g. adequately designed bird-scaring lines), and to stop fishing for the remainder of the year, unless they were able to demonstrate compliance with seabird bycatch permit regulations (DEAT 2008). The permits called for fishing to cease if a further 25 birds were caught, and only resume with a researcher onboard to assess why bycatch rates were so high. The one occasion in which it was enforced resulted in collaborative research onboard two Japanese vessels, ultimately allowing fishing masters within that fleet to understand the principles of line weighting for pelagic fishing and to adopt this seabird bycatch measure in various forms (distance of weight from hook, use of sliding leads, single or multiple weights, etc.).

Table 1 Summary of amendments to seabird bycatch mitigation measures in South African permit conditions for Japanese Vessels fishing South African quota under Joint Ventures and South African flagged vessels within the South African EEZ (from Rollinson et al. in press).

Mitigation measure	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Joint Venture vessels	-	-	-	-	-	-	-	-
Night setting only	NA	Yes	Yes	Yes	Yes	Yes	Yes[A]	Yes[B]
Bird-scaring line	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Line weighting (achieving 0.3 $m.s^{-1}$)	NA	Yes	Yes	Yes	No	No	No	No
Line weighting (60 g < 2m of hook)	NA	No	No	No	Yes	Yes	Yes	Yes
Thawed bait before setting	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reduced lighting	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Offal management	NA	Yes	Yes	Yes	No	No	No	No
25 bird bycatch limit per year	NA	No	Yes	Yes	Yes	Yes	Yes	Yes
South African-flagged vessels	-	-	-	-	-	-	-	-
Night setting only	No	No	No	No	No	No	No	No
Bird-scaring line	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Line weighting (achieving 0.3 $m.s^{-1}$)	Yes	Yes	Yes	Yes	No	No	No	No
Line weighting (60 g < 2m of hook)	No	No	No	No	Yes	Yes	Yes	Yes
Thawed bait before setting	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reduced lighting	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Offal management	Yes	Yes	Yes	Yes	No	No	No	No
25 bird bycatch limit per year	No	No	Yes	Yes	Yes	Yes	Yes	Yes

[A]Day-time setting is permitted for one vessel at any given time within the South African EEZ, provided that the vessel has obtained prior permission, and ensuring that the vessel uses line weighting and flies two bird-scaring lines.
[B]Day-time setting is permitted for vessels fishing in international waters, provided that the vessel has obtained prior permission from the Department of Agriculture, Forestry and Fisheries, and ensuring that the vessel uses line weighting and flies two bird-scaring lines.

Here we assess seabird bycatch associated with the pelagic longline fishery operating in South Africa and adjacent high seas waters, for the period 2006-2013, updating the previous assessment, carried out for the period 1998-2005 (Petersen et al. 2009a). This is summary information only, for a more thorough examination see Rollinson et al. (in press).

METHODS

Data were collected by independent fishery observers onboard South African- and Japanese-flagged pelagic longline vessels operating under South African fishing rights from 2006–2013, henceforth referred to the 'South African pelagic longline fishery'. Data from vessels which fished in international waters adjacent to the South African EEZ without South African fishing permits were excluded.

The difference in bycatch rates between Japanese-flagged and South African-flagged vessels was explored. The target species differs between these fleets, although often this is more nominal than actual, with the latter fleet switching regularly between multiple target species. Possible explanatory variables investigated are investigated more fully elsewhere (Rollinson et al. in press) and are not reported on in detail here, but include year, season, time of setting, branchline length, wind speed, fishing area, lunar luminance and use of a bird-scaring line. Time of setting was classified as day (lines set after nautical sunrise and finished before nautical sunset), night (lines set after nautical sunset and finished before nautical sunrise), or twilight (sets that straddled nautical sunrise/sunset). Wind speed was recorded by fisheries observers at the commencement of setting, and scored using the Beaufort scale (0–8). Lunar luminance was calculated as the proportion of overlap of moon presence during setting operations. Bird-scaring lines were only recorded as 'used' if they were deployed before commencement of line setting and until completion of line setting. Vessels either used one or two bird-scaring lines simultaneously, however for simplicity, neither the number of bird-scaring lines deployed nor their design were incorporated into analyses. Statistical models are being developed to explore more fully the factors influencing seabird bycatch, however these are not presented here. Seabird species identity was confirmed from birds returned to port for autopsy. Rough linear stratified extrapolations were performed (Rollinson et al. in press) for unobserved effort to estimate total mortalities for the period 2006-2013.

Data on individual vessel's line-weighting specifications were not available for analysis. However, observer debriefs in 2016 confirmed that Japanese-flagged vessels in South Africa all used line weighting that conformed, or closely conformed, to the specified regime (as permit conditions) of ≥60 g within 2 m of the hook (ATF unpublished data). All South African-flagged vessels use either 60 g or 80 g lead swivels, typically placed at 3.5 m from the hook.

RESULTS

Fishery characteristics

During the period 2006–2013, 35.1 million hooks (17 448 sets) were set by individual 66 vessels: 29 Japanese-flagged vessels targeting tuna (67% total effort) and 37 South African-flagged vessels targeting swordfish (33% total effort). Observer coverage was 100% on Japanese vessels but variable (average of 6.2% p.a.) on South African vessels; 10.9 million hooks (69% of the total effort) were observed. Due to differences in target species, Japanese vessels use longer branchlines (36 ± 4.7 m, 93% of sets had branchlines > 30 m) than South African vessels (21 ± 9.1 m, 82% of sets had branchlines < 30 m), and unlike South African vessels do not use light-sticks. Fishing effort was

greatest in 2011 with a combined total of 6.4 million hooks set by both fleets, whereas only 1.1 million hooks were set by South African-flagged vessels in 2006 (zero Japanese-flagged fishing effort in 2006). Japanese-flagged vessels set on average 3.3 million hooks per year, whereas South African vessels set an average of 1.4 million hooks per year for the same period.

Japanese fishing effort peaked between April and October, with fishing conducted throughout the South African EEZ and regularly venturing farther into international waters. South African vessels fished throughout the year, concentrating fishing effort within the South African EEZ. Japanese vessels averaged more hooks per set (2700 ± 380) than South African vessels (1300 ± 240) and typically set their lines at night (89%) whereas South African vessels set mostly around sunset (68%, Fig. 1).

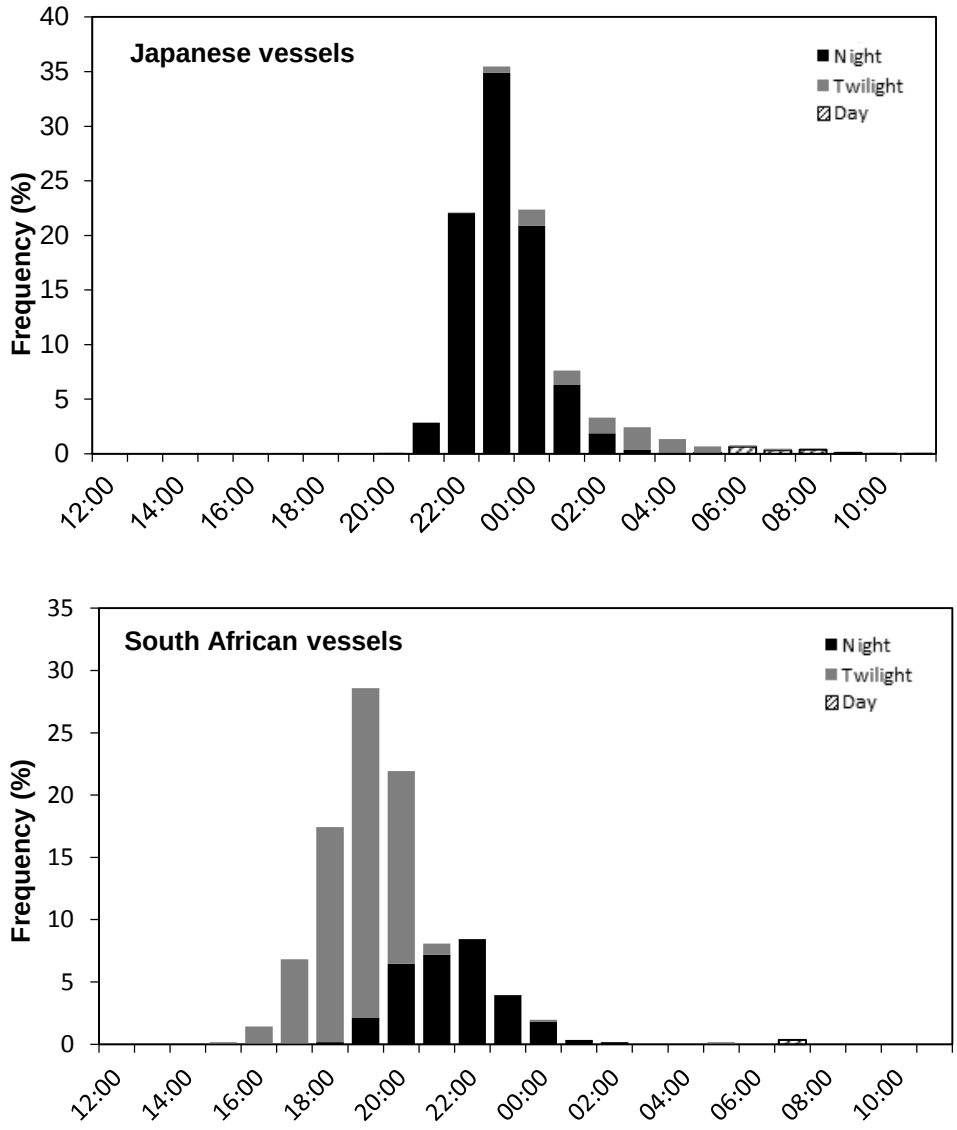

Figure 1. Time of commencement of setting for Japanese and South African flagged vessels, 2006–2013. See methods for definition of night, twilight and day sets (from Rollinson et al. in press).

Seabird bycatch

From 2006–2013, 2851 seabird mortalities were recorded as bycatch in the (observed) pelagic longline fishery off South Africa. A further 307 birds (11% of total reported bycatch mortality) were

caught alive and released. From 2006 to 2012, the bycatch rate was 0.119 birds per 1000 hooks; from 2010 to 2013, the bycatch rate was 0.07 birds per 1000 hooks. Japanese-flagged vessels caught 343 birds per year (cumulatively) between 2006 and 2013, however this reduced (to 228 per year) between 2010 and 2013. South African vessels averaged 22 birds per year (observed sets only) between 2006 and 2010, with no observer coverage between 2010 and 2013. Extrapolation from the observed bycatch to the 2256 unobserved sets from South African-flagged vessels suggests that an additional 94 ± 48.8 (SD) birds were caught per year by this fleet. Combined total seabird bycatch for both fleets (recorded and extrapolated) averaged 451 birds per year between 2006 and 2013. However bycatch was reduced to 361 birds per year between 2010 and 2013 – likely reflecting lower effort and improved compliance with seabird bycatch mitigation measures.

Use of bird-scaring lines on South African vessels was variable, perhaps because they were deployed selectively in areas with larger numbers of birds. Of the observed South African sets which used a bird-scaring line, many were in the high bycatch areas (76%), compared to 62% bird-scaring line compliance for sets in low bycatch areas. Birds were caught at a rate of 0.110 and 0.160 birds per 1000 hooks on sets which correctly deployed bird-scaring lines and at 0.333 and 0.010 birds per 1000 hooks, on sets without bird-scaring lines, on Japanese and South African vessels, respectively. Compliance with the requirement to use bird-scaring lines was far greater for Japanese vessels than observed South African vessels, and compliance improved with time for both fleets (Table 2). Lunar luminance had a strong effect on bycatch rates, irrespective of bycatch mitigation measures used; highest seabird bycatch rates always occurred around full moon (Fig. 2).

Table 2. Summary of bird-scaring line deployment for Japanese and South African vessels (observed sets only), 2006–2013 (from Rollinson et al. in press).

Fishing sets	**Number of sets observed**			**Percent with bird-scaring lines**		
	Japanese	**South African**	**Total**	**Japanese**	**South African**	**Total**
2006	0	139	139	-	38.8	38.8
2007	1329	37	1366	81.8	48.6	80.9
2008	1148	80	1228	96.4	78.8	95.3
2009	1128	138	1266	99.9	84	98.2
2010	1319	121	1440	99.8	81	98.3
2011	1557	6	1653	99.9	100	99.9
2012	1014	0	1014	99.7	-	99.7
2013	1003	0	1003	100	-	100
Total	8498	521	9019	96.6	68.1	94.9

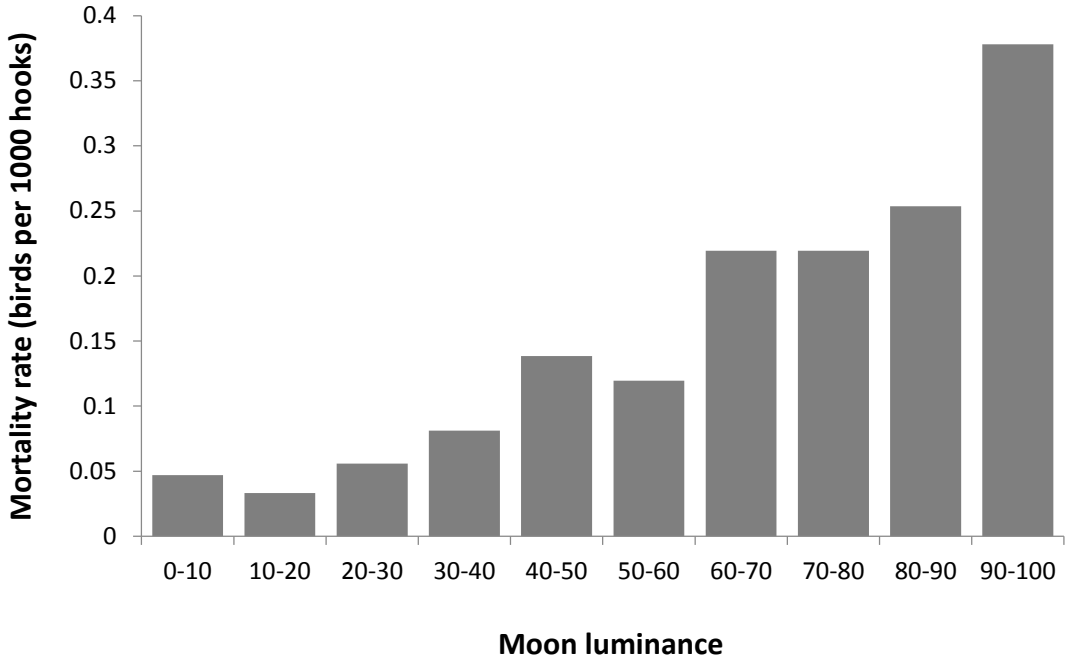

Figure 2. The effect of moon influence on bird mortality on longlines set at night off South Africa, 2006–2013 (from Rollinson et al. in press).

DISCUSSION

Seabird bycatch rates were generally similar to or lower than those reported by other seabird studies from pelagic longline fisheries in the Southern Hemisphere. South American fisheries recorded higher seabird bycatch rates (range 0.095–5.03 birds per 1000 hooks; see review by Bugoni et al., 2008), with a slight decrease in bycatch rates in recent years attributable to better sampling coverage (which increases detection of rare events) rather than improved conservation actions. Rates for the eastern tuna and billfish fishery off Australia (2001-2006) were similar (Trebilco et al. 2010) to rates from our study, with bycatch rates lower in later years (2004–2006). Waugh et al. (2008) estimated ca 500 birds were killed per year between 1998 and 2004 (no rate per 1000 hooks supplied) in the New Zealand pelagic longline fishery. This is a large reduction from 1988–1992 figures (attributable to improved mitigation measures) where an estimated 3600 birds were killed in one year (Murray et al. 1993).

Seabird bycatch rates in the South African pelagic longline fishery during 2006–2013 (2851 observed mortalities, 0.132 birds per 1000 hooks) were 3–12 times lower than bycatch estimates for this fishery prior to 2006 (Ryan et al. 2002, Petersen et al. 2009a). However, the most important change occurred in 2008, when vessel-specific bycatch limitations were put in place for both South African and foreign-flagged vessels. This resulted in a significant drop in reported bycatch rates for both fleets. From 2010–2013 bycatch rates were reduced to 0.07 birds per 1000 hooks (range 0.05–0.10 birds per 1000 hooks). Clearly the presence of observers and the imposition of a meaningful cost for catching lots of seabirds changed fishers' behaviour and reduced reporting of seabird bycatch. However, low observer coverage, deliberate dislodgement of hooked birds from lines before they are hauled aboard and counted by observers (Gilman et al. 2005) and non-reporting by observers (ATF unpublished data) are all likely to result in mortality higher than recorded in our study. Despite these shortcomings (which are not believed to be unique to South Africa), the general pattern of low seabird bycatch rates in South Africa is cause for optimism.

The higher bycatch rates by South African vessels compared to the Japanese-flagged fleet is most likely related to the differences in target species, fishing operations and line weighting

specifications between these fleets. The less-frequent use of bird-scaring lines by the South African fleet, and because South African vessels are allowed to set during the day, are believed to be important factors. More recently, permit conditions have changed so that only one fishery is recognised, removing the permit-related distinction between the two fleets, but this change happened after the period under review in this study (S Kerwath in litt.). Also, in recent years, the Japanese-flagged vessels have conformed more closely to the specified line weighting regime, whereas the South African-flagged vessels typically have weights >3 m from the hook, a configuration that no longer conforms to Best Practice advice (Wolfaardt et al. 2016).

South Africa's fishery department has authorized significant research into seabird bycatch mitigation since 2010. The initial research by Melvin et al. (2013) onboard Japanese vessels had the effect of greatly improving that fleets understanding of, and willingness to accept, line weighting. ACAP's most recent seabird bycatch Best Practice advice (Wolfaardt et al. 2016) has been built on experimental research, much of which has been undertaken in South Africa, through research permits granted to allow experiments to be undertaken during production fishing. This includes research into sliding leads (Sullivan et al. 2012) for line weighting. The WPEB's scientific recommendation to the Science Committee (IOTC 2016) included advice to update the range of options for seabird bycatch mitigation – specifically to include 'hook shielding devices'. Currently ACAP recognizes two such devices, both of which have been tested in South Africa as part of the evidence base for the devices' effectiveness.

We are encouraged by the high levels of compliance with South African permit conditions, particularly by Japanese-flagged vessels, as indicated by onboard observers' data. It now appears that these vessels routinely set 100% of their lines at night, use one or two bird-scaring lines, and place up to 60 g weights within 2 m of the hook. Conversely, the South African-flagged vessels are subject to little or no observer coverage, particularly in recent years. The bycatch rate in this sector is appreciably higher than in the Japanese-flagged vessels, suggesting both that there's much scope to reduce this sector's seabird bycatch rates, as well as that there is an effect of having scientific observers onboard that results in vessels following permit conditions more closely.

We conclude that tuna fishing can be undertaken profitably while simultaneously using all three Best Practice seabird bycatch mitigation measures. South Africa encourages the IOTC to adopt hook shielding devices as options for fishers, and further supports the revision of IOTC's seabird conservation measure (currently Res 12/06) to align with ACAP's Best Practice recommendations. Through the FAO's Common Oceans (ABNJ) tuna programme, BirdLife South Africa is trialing port-based outreach to communicate RFMO regulations to foreign-flagged vessels using Cape Town harbor. This work will shed light on levels of understanding, within various fleets, of key precepts of Res 12/06, as well as give an indication of where additional effort is required to improve the use of mandatory seabird bycatch mitigation measures, where fishers find difficulty with certain measures, and what other methods may be employed by crew to avoid high bait-loss from seabirds.

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