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Seabird mortality associated with Patagonian Toothfish (*Dissostichus eleginoides*) longliners in Falkland Islands waters

T. A. Reid[A,D], *B. J. Sullivan*[A], *J. Pompert*[B], *J. W. Enticott*[C] *and A. D. Black*[A,B]

[A]Falklands Conservation Seabirds at Sea Team, Jetty Centre, Stanley, Falkland Islands.
[B]Falkland Islands Fisheries Department, Stanley, Falkland Islands.
[C]Consolidated Fisheries Limited, Stanley, Falkland Islands.
[D]Corresponding author. Email: fc.seabirds@horizon.co.fk

Abstract. Seabird mortality in longline fishing has been implicated in the decline of many populations around the world. The population of the Black-browed Albatross breeding in the Falkland Islands has been estimated to have declined by 87 500 pairs between 1995 and 2000. The observed mortality in the Patagonian Toothfish longline fishery in Falkland Islands waters in 2001–02 was 29 seabirds, including 27 Black-browed Albatrosses, giving an estimated total mortality of 134 (95% confidence limits 80–188) birds, including 126 (75–177) Black-browed Albatrosses. This suggests that this fishery in Falkland Islands waters is currently not contributing substantially to observed declines in the local populations. Nevertheless, mortality could be further reduced by night setting and an increase in line weighting, especially during the breeding season of the Black-browed Albatross.

Introduction

Incidental by-catch of seabirds by pelagic (mid-water) and demersal (bottom) longline fishing has been well documented around the world (e.g. Croxall *et al*. 1990; Brothers 1991; Cherel *et al*. 1996; Schiavini *et al*. 1998; Nel *et al*. 2002*b*), including the Falkland Islands (Brothers 1995). Worldwide, a total of 61 seabird species have been recorded as killed by longlining operations on at least one occasion. Partially as a consequence, 25 of these species are listed as threatened by the World Conservation Union (FAO 1999). Of the 61 species identified in the FAO report, 19 have been frequently recorded (>1000 records) in at-sea surveys in Falkland Islands waters (waters within the Falkland Islands Interim (Inner) and Outer Conservation Zones) since 1998 (White *et al*. 2002).

Seabird populations of the Falkland Islands are of international importance (Croxall *et al*. 1984; Woods and Woods 1997). For example, the region contains ~80% of the worlds' breeding Black-browed Albatross (*Thalassarche melanophris*) (Gales 1998) and also provides important foraging grounds for a range of other Procellariiformes potentially vulnerable to fisheries-associated mortality. The islands are located on the Patagonian Shelf, east of southern Patagonia and north-west of the globally critical seabird breeding grounds of the Scotia Arc (e.g. South Georgia, South Sandwich and South Orkney Islands). Therefore, the Falkland Islands are located between one of the world's most important seabird breeding regions and the globally important seabird foraging grounds that extend the length of the Patagonian Shelf. These same resources on the Patagonian Shelf provide rich year-round foraging grounds for seabirds and also attract a large and diverse fishing fleet (fishing for squid (*Loligo gahi* and *Illex argentinus*) and a variety of fin-fish species, including Patagonian Toothfish (*Dissostichus eleginoides,* hereafter toothfish)), resulting in seabird by-catch, which has been identified as probably the region's most serious marine conservation issue (Croxall and Wood 2002).

A complete census of breeding populations of the Black-browed Albatross in the Falkland Islands in 2000–01 identified an estimated population of 382 000 pairs, which, when compared to extrapolated census data from the mid-1990s, indicates an estimated reduction of 87 500 breeding pairs over the previous five years. This includes estimated serious declines at the three largest colonies (Steeple Jason –47 300 pairs, Grand Jason –10 100 pairs and Beauchêne –27 500 pairs) (Huin 2001). Given that the breeding success (proportion of fledged birds to eggs laid) of these colonies is relatively high (45–60%: N. Huin, Falklands Conservation, unpublished data), and there is relatively little colony disturbance and/or predation, it suggests that the cause of the decline, like that for many other albatross species, is related to fisheries mortality.

Longlining for toothfish first commenced around South Georgia in 1988–89 (Dalziell and De Poorter 1993) and then in the southern Indian Ocean around Kerguelen in 1990–91 (Cherel *et al*. 1996). In 1992, experimental longlining commenced within the Falkland Islands Interim Conservation Zone (FICZ), at depths greater than 600 m. In 1994, after negligible longlining effort in 1993, experimental fishing recommenced within the FICZ and in the Falkland Islands

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Outer Conservation Zone (FOCZ) (Des Clers *et al*. 1996), using the same depth restrictions. Prior to May 2001, there was no designated seabird observer program, and hence it is difficult to assess the historical rate of seabird by-catch in the Falklands longlining fishery. However, as recently as the mid 1990s the level of seabird by-catch in waters around the Falkland Islands has been high: 4.3 birds per line during summer and 0.130 birds per 1000 hooks during winter 1995 (Brothers 1995), with recorded events of up to 90 Black-browed Albatrosses killed in a single day (Brothers 1996).

In this paper, we present the first seabird mortality data collected by seabird observers during the 2001–02 season onboard toothfish longliners operating in Falkland Islands waters and assess their role in the current decline of the islands' Black-browed Albatross population.

Methods

Longlining in Falkland Islands waters has always been limited to two licensed vessels at a time in waters deeper than 600 m, which occur throughout the FICZ/FOCZ (Fig. 1). During 2001–02 two toothfish longlining licences were issued (equivalent to 24 months of fishing effort). Of the four vessels operating during the study period, three were registered in the Falkland Islands and one in South Korea and all deployed the Spanish double-line demersal longline system (Robertson 2000).

Data collection

Between July 2001 and June 2002 Seabirds at Sea Team (SAST), Falkland Islands Fisheries Department (FIFD) and Consolidated Fisheries Limited (CFL) observers conducted 13 cruises (representing 321 days' coverage) on longliners operating throughout FICZ/FOCZ. These were mainly concentrated in the southern FOCZ, which broadly reflects the general distribution of longlining effort for 2001–02 (Fig. 1).

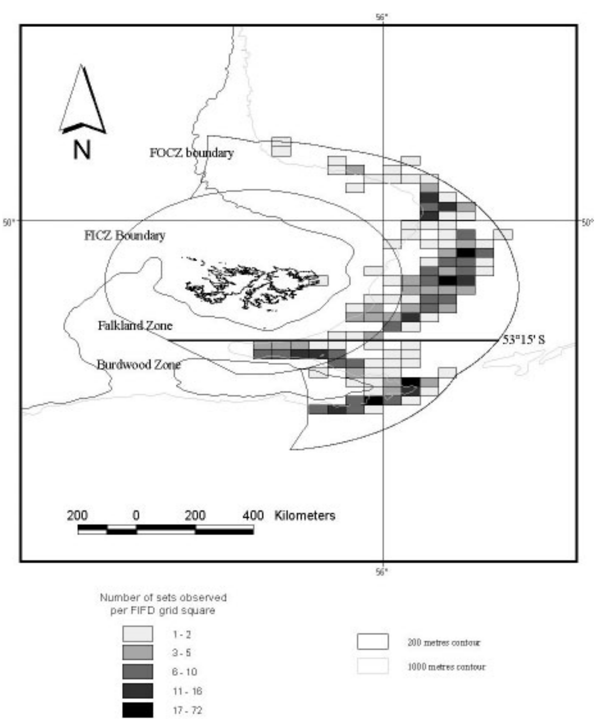

Fig. 1. Longlining observation effort (July 2001–June 2002).

Seabird abundance during line setting

Species abundance in the vicinity of the ship was estimated just before hook setting (i.e. after the tori lines were set and the anchor line released) and at the completion of the set. All counts were conducted from the stern of the ship in a 500 × 500 m area (500 m astern and 250 m on the starboard and port sides). The mean abundance of each species was estimated by averaging the pre- and post-set counts.

Seabird mortality

In order to calculate the most precise estimate of seabird mortality as many cruises as possible were observed, and as many hooks as possible were observed during hauling. Observations of line hauling were conducted from the forecastle, slightly forwards of the hauling bay. As a standard number of hooks are attached between weights an estimate of the number of hooks directly observed during hauling was calculated by counting the number of weights observed. When possible, seabirds hauled aboard were labelled and frozen for later examination. Post-mortems were conducted in Stanley and bill colouration and moulting scores (Prince and Rodwell 1994) were used to age the Black-browed Albatrosses.

Data analysis

Seabird mortality

The estimated number of seabirds killed and its variance was calculated using SAST, CFL and FIFD data, and methods detailed by Klaer and Polacheck (1995), (1997), which follow methods in Cochran (1977) for multistage sampling with unequal-size primary and secondary sampling units. This method increases the accuracy of mortality estimates by stratifying the data, and then sub-sampling from those strata.

Data were stratified temporally and spatially. Temporal divisions were based on the closest whole months of the year as they relate to the various stages of the breeding cycle of Black-browed Albatross (Table 1) in order to most closely match changes in their at-sea foraging behaviour. The spatial component of the stratification process was based on dividing the study area into two regions at the latitude 53°15′S: the Burdwood Bank area (Burdwood Zone) and the rest of the Falkland's longline fishing area (Falklands Zone) (Table 1, Fig. 1). This was considered a logical division as a result of the consistently higher numbers of seabirds (especially Black-browed Albatross) present around longliners in the Burdwood Zone than in the Falklands Zone and the different depth of shelf waters recorded in the two regions. The boundary of the two zones was drawn as the mid-point between the Falkland Island shelf and the Burdwood Bank (see Fig. 1).

The number of hooks observed per line was not available for four FIFD-observed cruises (between August 2001 and February 2002). Instead, to estimate the number of hooks observed per line we assumed a constant observation effort per line and applied the overall percentage of hooks observed per cruise to each individual line.

For the purposes of analysis, any fishing operation conducted by a longliner within a stratum was considered to constitute a cruise, and if an observer was present it was considered to be an observed cruise.

An estimate of the total number of each species killed was made using the proportion of each species killed in each stratum multiplied by the estimated number of birds killed for that stratum. As described in Klaer and Polacheck (1995, 1997), an estimate of the variance for a proportion can be obtained by assuming that the proportions represent a multinomial sample within a stratum of all seabirds caught. Within each stratum, variance comes from proportions of birds sampled, differences in catch rates between cruises, and between sets within a cruise. The variance of the estimated total species catch was calculated from the variance of the total birds caught and the variance of the proportion of each of the species caught, following Seber (1973).

Ideally, hooks should be observed randomly within each sampling unit within each stratum but because of restrictions on observer placement on longliners, and the difficulty of at-sea transfers this was not possible. However, only two boats operated at any time, and once an observer was placed on a vessel, he or she collected data while the vessel operated throughout the various strata, and generally both vessels were observed during any strata. While observers were aboard the vessels, most hauls, and a large proportion of hooks from each haul, were observed. Therefore, it is unlikely that the assumption of random sampling from each stratum was significantly violated.

Seabird abundance and mortality

SAST, CFL and FIFD observer data were used to investigate the relationship between seabird abundance and mortality. All data were analysed using Analysis of Variance (ANOVA). A range of environmental variables were recorded during line setting to determine their relationship with seabird mortality. Black-browed Albatross and White-chinned Petrel (*Procellaria aequinoctialis*) were the only observed mortalities recorded, and formed the basis of all data analysis.

In all, 86% of mortalities were recorded in the Burdwood Zone and 93% occurred during the Black-browed Albatross breeding season (those periods excluding winter), therefore, area and season were thought to be critical variables (cf. Klaer and Polacheck 1998; Brothers *et al*. 1999), and were included in the analysis.

Preliminary data-screening indicated that the seabird abundance data did not meet the ANOVA assumptions of homogeneity of variance, so a square-root transformation was applied to correct for heteroscedasticity after a Box–Cox transformation indicated a square-root transformation to be the most satisfactory. ANOVAs were performed using mortality as a predictor variable along with area, time period and a range of environmental variables in order to investigate their relationship with the abundance of Black-browed Albatross and White-chinned Petrel during setting operations. All ANOVA were conducted in MINITAB and Tukey tests were applied *post hoc* in order to identify significantly different means between groups.

Results

Seabird mortality

During the 12 months from July 2001 to June 2002, 8164939 hooks were set by longliners operating within Falkland Islands waters (Table 1). SAST and FIFD personnel observed 1523155 hooks (18.6%) being hauled, which represents 37.2% of hooks set with observers onboard (SAST observed 53% and FIFD 28% of hooks being hauled). Slightly more than half of all hooks were set in the Falklands Zone (57.2%) compared with 42.8% in the Burdwood Zone. The greatest number of hooks was observed in the Falkland Zone during the Winter Period, whereas the greatest proportion of hooks observed in an area occurred in the Burdwood Zone during Young and Old Chick Periods (Table 1).

We recorded 29 dead birds being hauled (Table 1), with a maximum of seven Black-browed Albatross mortalities recorded on one line in November (Egg Period). Twenty-five of the 29 mortalities (86%) were recorded in the Burdwood Zone during the period from late October to mid-January. Of the 29 deaths, three occurred during the Winter Period, 20 occurred during the Egg Period, and six during the Young Chick Period. In total, 134 birds (coefficient of variance (CV) 20.23%) are estimated to have been killed in Falkland Islands waters during the 12-month period. Although CV and 95% confidence limits are reported here, CV (the standard deviation of a series of measurements expressed as a percentage of their mean) is more informative as a comparative measure of the variation between populations as it does not rely on assumptions about the nature of the error distribution (Klaer and Polacheck 1997).

Twenty-seven of the 29 birds observed killed were Black-browed Albatross and two were White-chinned Petrels. We estimate that 126 Black-browed Albatross (CV = 20.43%) and eight White-chinned Petrel (CV = 17.35%) were killed during the year (Table 1).

One White-chinned Petrel and 17 Black-browed Albatross carcasses were retrieved during longlining operations. *Post mortem* examination revealed that 10 Black-browed Albatross were male and seven were female. All were estimated to be four years and older. The one White-chinned Petrel was an adult female.

Table 1. Estimated numbers of birds killed for each species by fishing area and season in Falkland Islands waters during 2001–02
95% confidence limits calculated as 1.96 times the CV. BBA, Black-browed Albatross; WCP, White-chinned Petrel

Period	Area	Hooks		Cruises		Observed birds killed		Observed catch-rate	Estimated birds killed			CV	
		Total	Observed	Total	Observed	BBA	WCP	(birds per 1000 hooks)	Total	BBA	WCP	BBA	WCP
Winter	Falkland	2248811	386905	5	5	3	0	0.008	17	17	0	22.65	0.00
	Burdwood	741435	163889	4	4	0	0	0.000	0	0	0	0.00	0.00
Prospecting	Falkland	313674	2500	3	1	0	0	0.000	0	0	0	0.00	0.00
	Burdwood	166442	6100	2	1	0	0	0.000	0	0	0	0.00	0.00
Eggs	Falkland	677266	118551	3	3	1	0	0.008	6	6	0	122.95	0.00
	Burdwood	1277939	269664	3	3	18	1	0.070	90	85	5	27.24	27.24
Young chick	Falkland	607029	115500	3	3	0	0	0.000	0	0	0	0.00	0.00
	Burdwood	793631	227136	2	2	5	1	0.026	21	17	3	43.13	11.95
Old chick	Falkland	824091	104702	2	2	0	0	0.000	0	0	0	0.00	0.00
	Burdwood	514621	128206	2	2	0	0	0.000	0	0	0	0.00	0.00
Total	Falkland	4670871	728159			4	0	0.005	23	23	0	34.81	0.00
	Burdwood	3494068	794996			23	2	0.032	111	103	8	23.77	16.48
		8164939	1523155			27	2	0.016	134	126	8	20.43	17.35
95% confidence limits								0.007	54	51	3		

Time of day and mortality

We recorded 24 mortalities on hooks set during the day (23 Black-browed Albatross and one White-chinned Petrel) at a by-catch rate of 0.033 birds killed per 1000 hooks, and five on hooks set during nautical dusk (four Black-browed Albatross and one White-chinned Petrel) at a by-catch rate of 0.019 birds killed per 1000 hooks. No birds were observed killed on hooks that were set at night despite the fact that 38% of observed hooks were set during the night, 45% during daylight and 17% during nautical twilight. The proportion of hooks set at night was lower during summer, when hours of daylight were greater.

Seabird abundance and mortality

Throughout the year Black-browed Albatross are present in Falkland Islands waters in varying numbers and White-chinned Petrel are present in significant numbers only in the austral spring and summer (White *et al*. 2002). In the summer months other species that were frequently recorded scavenging baits included Great Shearwater (*Puffinus gravis*), Sooty Shearwater (*P. griseus*) and Grey Petrel (*Procellaria cinerea*). Grey-headed Albatross (*Thalassarche chrysostoma*) are most abundant in Falkland Islands waters in winter (White *et al*. 2002), when they were also frequently recorded scavenging bait.

Abundance of Black-browed Albatross

Black-browed Albatross were significantly less abundant during the Prospecting Period than during the other three periods and were more abundant in the Egg Period than the Winter or Old Chick periods (Table 2) and they were significantly more abundant during line-setting in the Burdwood Zone than in the Falklands Zone (Table 3). They were more abundant during daylight sets than in twilight sets, but not significantly (Table 4). They were significantly more abundant during sets in which a Black-browed Albatross mortality was recorded than for sets when a mortality was not recorded (Table 5).

Table 2. ANOVA of abundance (± standard deviation) of Black-browed Albatross (BBA) and White-chinned Petrel (WCP) and time of the year
n = the number of observed sets

Season	*n*	Mean	
		BBA	WCP
Winter	11	18.2 ± 14.2	0
Prospecting	20	24.8 ± 57.4	0.5 ± 1.8
Eggs	55	96.8 ± 55.6	6.1 ± 7.0
Young chicks	25	66.5 ± 62.9	10.4 ± 9.8
Old chicks	21	39.3 ± 30.3	7.6 ± 6.4
$F_{4,131}$		14.87	13.46
P		< 0.001	< 0.001

Table 3. ANOVA of Black-browed Albatross (BBA) and White-chinned Petrel abundance and zone
n = the number of observed sets

Area	*n*	Mean	
		BBA	WCP
Burdwood	81	83.9 ± 65.0	5.3 ± 6.7
Falklands	51	33.6 ± 32.6	6.6 ± 8.6
$F_{1,130}$		18.64	0.33
P		< 0.001	0.56

Abundance of White-chinned Petrel

White-chinned Petrels were significantly more abundant during the Egg, Young and Old Chick Periods than during the Winter and Prospecting Periods (Table 2). In contrast to Black-browed Albatross, they were equally abundant in the Falklands Zone and the Burdwood Zone (Table 3). Like Black-browed Albatross, White-chinned Petrels were more abundant at sets conducted during daylight than at those set in the nautical twilight, although not significantly so (Table 4). There was no difference in abundance on sets when White-chinned Petrel mortality occurred, and when it did not occur (Table 5).

Discussion

We estimate that from July 2001 to June 2002, 134 (80–188, 95% CL) birds were killed in Falkland Islands waters, comprising 126 (75–177) Black-browed Albatrosses and 8 (5–11) White-chinned Petrels. The estimated by-catch rate for the longline fishery in Falkland Islands waters for this period was 0.016 (0.009–0.023) birds per 1000 hooks, which is markedly lower than the by-catch rates previously reported for the same region (Brothers 1995). The observed reduction in the by-catch rate is thought to be the result of more effective use of mitigation measures. However it should be stressed that the number of birds hauled aboard during line hauling is probably an underestimate because in pelagic longline fisheries it has been estimated that ~30% of birds killed fall off before line hauling (Brothers 1991; Brothers *et al*. 1998; Gilman *et al*. 2003).

In total, 93% of all observed mortality was recorded during the breeding season, most deaths being early in the

Table 4. ANOVA of Black-browed Albatross (BBA) and White-chinned Petrel (WCP) abundance and time of day
No abundance counts could be made during night sets. *n* = the number of observed sets

Daylight period	*n*	Mean	
		BBA	WCP
Day	116	67.8 ± 61.9	6.1 ± 7.6
Nautical twilight	15	40.9 ± 36.8	4.0 ± 6.8
$F_{1,129}$		1.42	1.3
P		0.24	0.27

Table 5. ANOVA of Black-browed Albatross (BBA) and White-chinned Petrel (WCP) abundance and mortality

Mortality	BBA		WCP	
	n	Mean	*n*	Mean
Sets without mortality	123	61.1 ± 58.6	130	5.8 ± 7.5
Sets with mortalities	9	110.3 ± 63.3	2	5.0 ± 7.1
$F_{1,130}$		4.91		0.01
P		0.03		0.9

season (Table 1). A similar result was highlighted in the toothfish fishery in the Prince Edward Islands where the deaths of all species killed in substantial numbers (White-chinned Petrel, Grey-headed Albatross, and Yellow-nosed Albatross, *Thalassarche chlororhynchos*) except giant petrels (*Macronectes* spp.), occurred almost exclusively during their breeding season (Nel *et al*. 2002*b*). Similar findings have also been made in the Kerguelen Islands (Weimerskirch *et al*. 2000), and in South Georgia, where this led to the closure of the fishery from 1 September to 30 April (in Kock 2001).

Black-browed Albatross

The sex ratio of Black-browed Albatrosses killed (10 : 7, male : female) indicates no marked sex bias. The proximity of longlining effort to seabird breeding colonies has been shown to critically influence by-catch rates in other areas (Moreno *et al*. 1996; Ryan and Watkins 2002; Nel *et al*. 2002*b*). The closest breeding colony to the Burdwood Zone, where all mortalities were recorded, is Beauchêne Island (103 000 breeding pairs, 27% of the Falkland Island population). Around the Prince Edward Islands, by-catch rates in the toothfish fishery were significantly higher for albatross, giant petrels and White-chinned Petrel closer to their breeding sites, with 94% of albatross and giant petrel mortality occurring within 100 km of the Prince Edward Islands (Nel *et al*. 2002*b*). Similarly, in South Georgia, longliners operating closer to the island have been shown to cause a higher level of mortality (Moreno *et al*. 1996).

The fact that 86% mortality was recorded in the Burdwood Zone suggests that it is a critical region in Falkland Islands waters for the conservation of Black-browed Albatross. This is supported by ANOVA results, which highlight a significantly greater abundance of Black-browed Albatross in the Burdwood Zone.

White-chinned Petrel

White-chinned Petrels are one of the most commonly killed species in longline fishing throughout the Southern Hemisphere (e.g. Moreno *et al*. 1996; Weimerskirch *et al*. 1999; Olmos *et al*. 2000; Favero *et al*. 2003; Nel *et al*. 2002*a*, 2002*b*). They comprised >90% of seabird mortality recorded by toothfish longliners in Kerguelen waters between 1994 and 1997 (Weimerskirch *et al*. 2000), 78% of longliner mortality recorded for Chilean and Argentinian longliners operating around South Georgia in 1995 (Moreno *et al*. 1996) and 80% of the mortality recorded for sanctioned longlining between 1996 and 2000 around the Prince Edward Islands (Nel *et al*. 2002*b*). It has been suggested that these levels of mortality are linked with alarming declines in their breeding populations (Weimerskirch *et al*. 1999; Berrow *et al*. 2000; Nel *et al*. 2002*a*).

We recorded only two White-chinned Petrel deaths and estimate that throughout the year 8 ± 3 were killed in Falkland Islands waters. The reason for this low level of White-chinned Petrel mortality compared with that observed for other toothfish fisheries is uncertain. However, it is likely to be related to the distance of the fishery from their breeding populations (Table 6). We also consider it probable that interactions between Black-browed Albatross and White-chinned Petrel associated with longliners in Falkland Islands waters play a role in the low White-chinned Petrel mortality rate. The ratio of breeding pairs of Black-browed Albatross : White-chinned Petrel in the Falkland Islands is inverse to that in South Georgia and Kerguelen and the ratio of longliner-associated mortality also reflects this trend (Table 6). It therefore seems likely that the distance to a substantial breeding colony and therefore the abundance of White-chinned Petrel in Falkland Islands waters during critical times of the year for seabird by-catch (i.e. breeding season) is an important variable affecting their mortality level. White-chinned Petrels have been shown to be highly mobile during breeding, including the incubation period

Table 6. Estimated breeding populations of Black-browed Albatrosses (BBA) and White-chinned Petrel (WCP) around the major toothfish longline fisheries

Adapted from Marchant and Higgins 1990, Woods and Woods 1997, Gales 1998, Huin 2001

Locality	BBA population (pairs)	WCP population (pairs)	Estimated ratio BBA : WCP[A] Breeding population	Mortality
Prince Edward Is (Marion, Prince Edward)	None	10s of 1000s	∞	1 : 262
Isles Kerguelen	3000	100s of 1000s	1 : 20	1 : 25
South Georgia	96 000	2 000 000	1 : 100	1 : 10
Falkland Islands	380 000	1000–5000	125 : 1	12 : 1

[A]Ratios estimated from Moreno *et al*. (1996), Weimerskirch *et al*. (2000), Huin (2001), Nel *et al*. (2002*b*), SAST (this study).

(Weimerskirch *et al*. 1999; Berrow *et al*. 2000), and hence are vulnerable to longliners over a wide area of the Southern Hemisphere. Nevertheless, these results indicate that they are less vulnerable in Falkland Islands waters than in the waters immediately adjacent to their breeding colonies.

Relationship between mortality rates of Black-browed Albatross and White-chinned Petrel

During three years of at-sea surveys, SAST recorded the abundance of Black-browed Albatross and White-chinned Petrel at a ratio of 10:1 (Black-browed Albatross 84000, White-chinned Petrel 8000: White *et al*. 2002). White-chinned Petrel were present in markedly higher numbers in spring and summer (breeding season) than during the winter (non-breeding season), when relatively few were recorded in Falkland Islands waters (White *et al*. 2002). On the basis of satellite tracking data, it is likely that the influx of White-chinned Petrels during the summer months, particularly in the incubation stage (January–March), originate from the large breeding colonies in South Georgia (Berrow *et al*. 2000) (Table 6). The ratio of the abundance of Black-browed Albatross to White-chinned Petrel recorded during setting operations was 11:1 (Black-browed Albatross, mean = 105.80 ± 66.3, n = 374; White-chinned Petrel, mean = 9.19 ± 11.5, n = 326), and the ratio for their mortality was 12:1 (Table 6). These data suggest that not only do White-chinned Petrels attend longliners in relative proportion to their abundance within Falkland Islands waters but they are killed in equivalent proportion.

The approximate ratio of Black-browed Albatross to White-chinned Petrel attending longliners in Kerguelen was 1:4 (Black-browed Albatross, mean = 73.57 ± 82.0; White-chinned Petrel, mean = 269.9 ± 353.5, n = 482), whereas the ratio of mortality was 1:25 (Weimerskirch *et al*. 2000, table 4.1). In contrast to Falkland Islands waters, White-chinned Petrels in Kerguelen waters were killed in considerably higher proportions than expected relative to their abundance attending longliners. A possible explanation for the proportional equality of White-chinned Petrel abundance and mortality in Falkland Islands waters is that interactions with the large numbers of Black-browed Albatross attending longliners indirectly reduces White-chinned Petrel mortality. Generally, White-chinned Petrel tended to dive for baits further astern of the ship (outside the tori lines) than did Black-browed Albatross (authors' observations). This may be because often when White-chinned Petrels return to the surface after diving for baits they are besieged by many Black-browed Albatross, and if the dive was successful the bait is frequently stolen by the Black-browed Albatross. White-chinned Petrels that seize bait and manage to fly away are usually then pursued by Black-browed Albatross (authors' observations). The 11:1 ratio of Black-browed Albatross to White-chinned Petrel attending vessels during setting operations gives an indication of the disproportionate abundance of the two species. This kleptoparasitic behaviour of Black-browed Albatross may lead to fewer foraging attempts by White-chinned Petrel, and/or to a shift in their foraging attempts to sections of the line further from the stern of the ship, where the line is deeper. As White-chinned Petrels dive to an average depth of ~6 m (Huin 1994), such a shift in their foraging behaviour may reduce the probability of their being hooked during setting operations.

Seabird by-catch mitigation measures in the Falkland Islands

The most commonly recommended operational mitigation measures for reducing seabird mortality associated with demersal longliners include night setting, the use of tori lines, increased line weighting, and for Mustad (i.e. single line) longliners the use of underwater setting funnels (Brothers 1995; Cherel *et al*. 1996; Ashford and Croxall 1998; Løkkeborg 1998; Agnew *et al*. 2000; Ryan and Watkins 2002). See FAO (1999) for a comprehensive review of mitigation measures aimed at reducing by-catch in pelagic and demersal longline fisheries. Over the period of this study, the only compulsory by-catch mitigation measure for longliners registered in the Falkland Islands requires the deployment of a streamer line during line setting. The regulations stipulate that this should be constructed to CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources) specifications or to an alternative specification that has been proved to be equally efficient.

All four vessels observed during the year used tori lines at all times, including during night-setting operations. All vessels used 2–4 lines at all times (except when there was a breakage), with a range of structural additions (e.g. side arms and/or a stern gantry to increase the width and height of the attachment point of tori lines). The use of multiple tori lines has been shown to be an effective mitigation measure in demersal longline fisheries (Melvin 2003). This was clearly exhibited during a cruise in November 2001 when a higher seabird mortality occurred when two tori lines were in use, but the greater rate of mortality occurred when, due to tori line breakages, only one bird line was used for two half sets (Table 7).

Information from South Georgia suggests that a weighting regime of 8.5–12.75 kg every 40 m significantly reduces by-catch (Agnew *et al*. 2000.). During the study period, the average line-weighting regime ranged from 5.2 kg per 38 m up to 8 kg per 38 m. However, the latter weight regime was

Table 7. Numbers of hooks observed during hauling, and observed seabird mortality recorded with different number of tori lines on day-time set hooks on Cruise 3

No. of tori lines	No. of hooks observed	No. of birds killed	By-catch rate (birds per 1000 hooks)
1	8307	6	0.722
2	60847	11	0.181
3	85042	2	0.024

used only on one vessel that operated in May and June 2002. Increasing line weighting to meet recommended best practice would be likely to reduce by-catch levels significantly.

Comparative by-catch levels in the toothfish fishery

The average by-catch rate in Kerguelen waters between 1994 and 1997 was 0.59 birds per 1000 hooks, and more than 90% of these deaths were of White-chinned Petrels. This is an order of magnitude higher than what we recorded. In comparison, the average by-catch rate recorded for sanctioned toothfish longliners around the Prince Edward Islands between 1996 and 2000 was 0.076 birds per 1000 hooks, which is comparable with that recorded for Falkland Islands waters in 2001–02. However, it is estimated that Illegal, Unregulated and Unreported (IUU) vessels in the region killed at least three times the number of seabirds (7000) during the same period (Nel *et al*. 2002*b*).

Since the implementation of, and increasing compliance with, CCAMLR Conservation Measure XIX (currently 25-02) the by-catch rate associated with the toothfish fishery around South Georgia (CCAMLR subarea 48.3) has been reduced from 0.66 per 1000 hooks in 1993 to 0.0003 per 1000 hooks in 2003 (CCAMLR 2003). This latter rate is an order of magnitude lower than that recorded in Falkland Islands waters (0.016 birds per 1000 hooks). In addition to the implementation of standard mitigation measures to reduce by-catch (i.e. night setting, appropriate line weighting, tori lines) the spatial and temporal restriction of fishing effort is probably the most effective method of reducing by-catch within a specific region. However, this can have the effect of shifting the problem to other areas without such strict control. Night setting has been shown to reduce seabird by-catch in both pelagic and demersal longline fisheries (e.g. Klaer and Polacheck 1998; Gales *et al*. 1998; Brothers *et al*. 1999; Weimerskirch *et al*. 2000; Nel *et al*. 2002*b*). Our data suggest that night setting during the breeding season of Black-browed Albatrosses (September–March) may successfully reduce by-catch to a negligible level, similar to that achieved in South Georgia. Under licence conditions in Falkland Islands waters there is no requirement for night setting, although it is suggested, where practicable

Additionally, tracking studies of the Falkland Islands Black-browed Albatross population have shown that birds forage widely throughout Patagonian Shelf and adjacent waters, including the economic exclusion zones (EEZs) of Chile, Argentina, Uruguay and Brazil, as well as smaller numbers over international waters (Huin 2002*a*). Satellite tracking and geolocator data from breeding Falkland Islands Black-browed Albatross indicate that male and female birds spend, on average, ~300 days per year at-sea, ~47% of which is spent in Falkland Islands waters and 53% in other regions.(Huin 2002*b*). The relatively low numbers of Black-browed Albatross recorded associating with longliners (see Tables 2, 5) in Falkland Islands waters in relation to their population size is likely to be a result of their preference for foraging in shelf waters (Huin 2002*a*), rather than deeper oceanic waters, such as those where longliners operate in the Falklands (>600 m).

These same waters are fished by numerous longliners from various nations. It is estimated that the annual mortality level for the 12 freezer longliners, fishing mainly for toothfish and Kingclip (*Genypterus blacodes*) on the Argentine shelf and shelf break during 1999–2001 was 1160 seabirds, over 55% of which were Black-browed Albatross (Favero *et al*. 2003). The level of variation associated with this estimate suggests that up to 10 000 birds may have been killed in this three-year period (Favero *et al*. 2003). Similar levels of mortality were recorded for the entire longline fleet in Brazil (4200 in the demersal and 3100 in the pelagic fisheries), a high proportion of which were Black-browed Albatross (Olmos *et al*. 2000). In Uruguay, in the mid-1990s, in the pelagic longline fishery the estimated by-catch rate for albatross was 4.7 per 1000 hooks (Black-browed Albatross comprised 120 of 123 albatrosses observed to be caught), and in the smaller demersal fishery 78 Black-browed Albatross deaths were recorded in a single trip (Stagi *et al*. 1998). Several longliners are known to operate in international waters adjacent to Falkland Islands waters. However, as these vessels are largely unregulated the level of seabird mortality they cause is unknown.

Limited data of historically high by-catch rates in Falkland Islands waters suggests that in the past the local fishery had a significant role in the decline of the Falkland Islands Black-browed Albatross population; for example, the high by-catch rates reported in Brothers (1995). However, while improvements can be made to reduce seabird mortality in Falkland Islands waters, our estimate of 134 seabirds being killed in Falkland Islands waters in 2001–02 suggests that currently, at least, longlining in local waters plays a relatively minor role in any further decline.

Given the high levels of Black-browed Albatross and other species killed on the Patagonian Shelf and in the waters around South American countries in general (Stagi *et al*. 1998; Olmos *et al*. 2000; Favero *et al*. 2003), these fisheries appear to be linked to any further decline in the Falkland Islands Black-browed Albatross population. In addition, SAST data collected in 2001–02 in Falkland Islands waters indicates that finfish trawlers cause significant seabird by-catch, particularly Black-browed Albatross. Considering the size of the finfish trawler fleets operating in the Falkland Islands and the broader Patagonian Shelf, we suggest that this may be a significant threat to many seabird populations. Research is continuing to quantify the level of trawler mortality and investigate effective mitigation measures.

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