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SEABIRD INTERACTIONS WITH LONGLINING OPERATIONS FOR *DISSOSTICHUS ELEGINOIDES* AROUND SOUTH GEORGIA, APRIL TO MAY 1994

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Abstract

Longlining operations for *Dissostichus eleginoides* off South Georgia were assessed for incidental mortality and interactions with seabirds. Twenty-seven line sets were observed and 98 deaths of seabirds were recorded over 20 sets; no deaths occurred during hauls. The 16 sets made at night contributed 15% of overall mortality, all of white-chinned petrels (*Procellaria aequinoctialis*); the four day sets contributed 85% of deaths, with giant petrels (*Macronectes* sp.), grey-headed albatrosses (*Diomedea chrysostoma*) and black-browed albatrosses (*D. melanophrys*) predominating. Grey-headed albatrosses, whose populations at South Georgia are in serious decline, were disproportionately affected in relation to their numbers near the fishing vessel; giant petrels may be disproportionately affected in relation to the size of their breeding population at South Georgia when compared to albatrosses. The average mortality rate for the 20 sets was 0.48 birds/1 000 hooks and maximum mortality 3.12 birds/1 000 hooks. Mortality and interactions of birds with operations varied with site and time of day, and was affected by behavioural interactions between birds. Setting only at night would dramatically reduce the number of albatross deaths, and restrict mortality to white-chinned petrels. A streamer line made to CCAMLR specifications may reduce mortality but may be less effective during calm weather, intense feeding activity by seabirds, or when incorrectly constructed.

Résumé

Une évaluation des opérations de pêche à la palangre de *Dissostichus eleginoides* au large de la Géorgie du Sud a été effectuée pour mesurer la mortalité accidentelle et l'interaction avec les oiseaux de mer. La pose de 27 lignes a été observée; sur 20 d'entre elles, 98 morts accidentelles d'oiseaux marins ont été enregistrées; la remontée des lignes n'a provoqué aucune mort accidentelle. Les 16 poses effectuées de nuit ont causé 15% de la mortalité totale, et n'ont touché que des pétrels à menton blanc (*Procellaria aequinoctialis*); les quatre poses de jour ont causé 85% de la mortalité, et ont affecté principalement des pétrels géants (*Macronectes* sp.), des albatros à tête grise (*Diomedea chrysostoma*) et des albatros à sourcils noirs (*D. melanophrys*). Par rapport à leur nombre à proximité du navire, les albatros à tête grise étaient particulièrement affectés; si on les compare aux albatros, les pétrels géants sont peut-être touchés de manière disproportionnée, vu la taille de leur population reproductrice en Géorgie du Sud. Le taux de mortalité moyen pour les 20 poses était de 0,48 oiseau/1 000 hameçons et la mortalité maximale de 3,12 oiseaux/1 000 hameçons. La mortalité des oiseaux de mer et l'interaction de ces derniers et des opérations de pêche dépendaient du site et du moment de la journée, et étaient influencées par le comportement des oiseaux entre eux. Ne poser les palangres que de nuit réduirait considérablement la mortalité des albatros

et la restreindrait aux pétrels à menton blanc. La ligne de banderoles préconisée par la CCAMLR peut réduire la mortalité, mais risque d'être moins efficace par temps calme, lors de l'approvisionnement intensif des oiseaux de mer, ou lorsqu'elle n'est pas montée correctement.

Резюме

Ярусный промысел *Dissostichus eleginoides* в районе Южной Георгии был исследован с точки зрения побочной смертности морских птиц и взаимодействий между птицами и промыслом. Наблюдения проводились в течение постановки 27 ярусов; было зарегистрировано 98 случаев смерти птиц при 20 постановках. Случаев смерти птиц при выборке ярусов отмечено не было. 15% общей смертности приходилось на 16 постановок, выполненных ночью, все погибшие птицы - белогорлые буревестники (*Procellaria aequinoctialis*). 85% общей смертности приходилось на четыре дневных постановки; среди погибших птиц преобладали гигантские буревестники (*Macronectes* sp.), сероголовые альбатросы (*Diomedea chrysostoma*) и чернобровые альбатросы. Сероголовые альбатросы, размер популяции которых резко сократился, оказались подвержены побочной смертности в размере, непропорциональном к их численности вблизи промыслового судна. По сравнению с альбатросами гигантские буревестники, возможно, оказываются непропорционально подвержены смертности по отношению к размеру их гнездовой популяции на Южной Георгии. В течение 20 постановок ярусов средняя общая смертность составила 0,48 птицы/1000 крючков, а максамальная смертность - 3,12 птицы/1000 крючков. Уровень смертности и взаимодействий между птицами и промыслом меняется в зависимости от промыслового участка и времени суток, а также поведенческих особенностей между птицами. Постановки ярусов только ночью в значительной мере могут сократить число случаев смертности альбатросов, а также ограничить смертность птиц смертностью белогорлых буревестников. Использование линя с отпугивающими флажками, рекомендованного АНТКОМом, можеть понизить уровень смертности, однако его действие может оказаться менее эффективным в случае тихой погоды, интенсивного кормления морских птиц или в случае, если он неправильно сконструирован.

Resumen

Se hizo una evaluación de las operaciones de pesca de palangre de *Dissostichus eleginoides* realizadas alrededor de Georgia del Sur con respecto a la mortalidad incidental y a las interacciones con aves marinas. Se observaron 27 lances y se registraron 98 muertes de aves marinas en 20 calados de la línea; no se registraron muertes durante el izado. Los 16 calados de palangre hechos de noche contribuyeron un 15% a la mortalidad total, constituida exclusivamente de petreles de mentón blanco (*Procellaria aequinoctialis*). Los cuatro calados de palangre hechos de día contribuyeron un 85% a la mortalidad total, constituida predominantemente de petreles gigantes (*Macronectes* sp.), albatros de cabeza gris (*Diomedea chrysostoma*) y albatros de ceja negra (*D. melanophrys*). Los albatros de cabeza gris, cuyas poblaciones en Georgia del Sur están disminuyendo en forma grave, fueron afectados de manera desproporcionada en relación a su número cerca de la embarcación pesquera; es posible que los petreles gigantes sean afectados de manera desproporcionada al tamaño de su población reproductora en Georgia del Sur cuando se le compara con los albatros. La tasa de mortalidad media para los 20 calados es de 0.48 aves/1 000 anzuelos y la mortalidad máxima 3.12 aves/1 000 anzuelos. La mortalidad y las interacciones de las aves con las operaciones variaron según el lugar y hora del día, y fueron afectadas por interacciones entre las aves. Si los calados de palangre se hicieran sólo de noche, se reduciría dramáticamente el número de muertes de albatros, y la mortalidad se limitaría a petreles de mentón blanco. El uso de líneas espantapájaros fabricadas según las normas de la CCRVMA podría reducir la mortalidad, pero ellas podrían ser menos efectivas durante los períodos de calma, o de intensa actividad alimentaria de las aves, o cuando han sido construidas incorrectamente.

Keywords: fishery, incidental mortality, albatross, petrel, streamer line, South Atlantic, CCAMLR

INTRODUCTION

Declines in populations of several species of albatross, usually associated with high adult mortality rates, have been reported from various Southern Ocean breeding sites (Gales, 1993). These declines have been linked to longlining operations, notably those of the fishery for southern bluefin tuna (*Thunnus maccoyi*). Brothers (1991) calculated that in the southern hemisphere the fishery could be killing 44 000 albatrosses annually, and that the introduction of streamer lines to deter albatrosses could save the lives of 30 300 albatrosses and enable fishermen to save $4.9 million in bait lost to birds. Murray *et al.* (1993) estimated a minimum of 3 652 seabirds caught in New Zealand waters in 1988; this figure declined to 360 in 1992, probably due to the introduction of mitigating measures.

Within the area covered by the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), longlining operations for *Dissostichus eleginoides* began in the late 1980s and has so far been confined mainly to the vicinity of South Georgia and Kerguelen Islands. Considerable concern has been expressed about the effect these longline fisheries, in such close proximity to major breeding grounds of several species of albatross, could have on albatross populations. In response to this concern CCAMLR introduced in 1991 the requirement that streamer lines be deployed during longline fishing and encouraged Members to employ scientific observers to acquire accurate data on the effectiveness of these measures and on the nature and magnitude of incidental mortality of seabirds. Accordingly, in 1992/93 observers, including one from the United Kingdom, were placed on board the FV *Friosur V*, a Chilean longliner conducting an exploratory cruise aimed at detecting *D. eleginoides* around the South Sandwich Islands. Although no seabird deaths were recorded during the setting of seven longlines, several species of seabird were shown to be vulnerable to longlining operations around the South Sandwich Islands; observations of high numbers of birds near fishing vessels were also made around South Georgia (Ashford *et al.*, 1994).

At the 1993 CCAMLR meeting, the Scientific Committee recommended that the Commission consider mechanisms for placing scientific observers on a high proportion of longline vessels in the CCAMLR Convention Area for at least one fishing season to collect the data required for a reliable assessment of the number and species of birds incidentally captured on longlines in the Convention Area. For the South Georgia area (Subarea 48.3), in the 1993/94 season, the total allowable catch of *D. eleginoides* and the fishing season were divided up and allocated to five equal time periods, with only one vessel belonging to one CCAMLR Member being permitted to fish in each period. Reports on the effectiveness of measures aimed at mitigating incidental mortality of seabirds were required to be part of the research plan to be submitted by each Member operating in this fishery. Chile agreed to take part in the fishery, and as in 1992/93 the FV *Friosur V* was used, with the same UK observer on board. The aims of the observer were to record seabird deaths and interactions with longlining operations, and the effectiveness of a streamer line as a mitigating measure.

MATERIALS AND METHODS

Fishing equipment and operations were as described in Ashford *et al.* (1994). Most hooks laid were of the type Maruto no. 26. Approximately 5% were of the type Maguro no. 14 which has a curved point (Figure 1); these hooks were laid as either one or two continuous series on each line. Hooks were baited individually by hand but a small proportion of baits was lost during setting. Observations were made during both setting and hauling. Information was recorded on data sheets as used by the New Zealand Ministry of Agriculture and Fisheries in its Fisheries Scientific Observer Program for the southern bluefin tuna

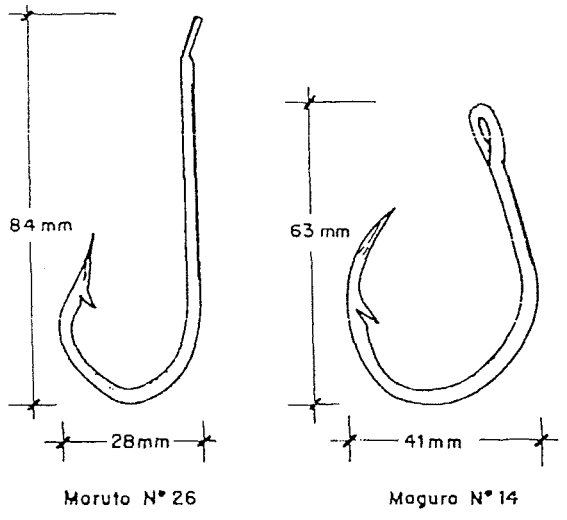

Figure 1:
Fishing hooks used in longline operations by FV *Friosur V* at South Georgia, April to May 1994.

fishery (Murray *et al.*, 1993). Initially, four categories of bird activity were recorded during setting: strikes at baits, birds hooked, bait-stealing (i.e., successful strikes), and baits dived for. The number of birds hooked at haul-in and released alive was also recorded. As there was too much bird activity during daytime sets to record all events accurately, different data were collected for the different sections of the line, delimited by the marker buoys. For two of the four sections, all strikes and dives for bait were combined as strike events and only these recorded; for the other two sections, only the outcomes (i.e., success rate of bait-stealing and number of birds hooked) of a sample of strike events were recorded.

One observer undertook all setting observations, standing at the stern hatches or on the deck directly above. Interactions for the period observed were noted, and the number of birds of each species in the vicinity of the ship was recorded every 30 minutes. Of the 20 sets for which mortality data are available, 16 took place at night. Visibility during the hours of darkness was 50 m when the ship's lights were on: this extended beyond the point at which the baits sank and most bird species could be readily identified at this distance. White-chinned petrels (*Procellaria aequinoctialis*) were more difficult to identify and observe, because of their dark colouration, but could be readily observed within 20 m of the vessel's stern. Observations were made for all setting periods.

A streamer line was used for approximately six of the 20 sets and a noise-emitting scarer, based on regular or irregular releases of compressed air, for another six. The streamer line did not meet CCAMLR specifications: although attached to the ship at the right height from the aft gantry on the port side, the main line was more than 1 cm thick, there were no swivels, and the streamers consisted of lines more than 3 mm thick, each approximately 1.5 m long, along the length of the line; they did not therefore reach the surface of the water until well aft of the ship's stern. The streamer line was located over and close to the main line. After the first 20 sets, a streamer line meeting CCAMLR specifications was used to compare the effectiveness of designs. A streamer line was also hung over the hauling point during the last seven hauls, to deter birds from approaching the incoming longline.

Observations of hauling operations were made on a rota system, the duty observer standing on the factory deck with a clear view of the hauling point. Approximately 90% of hauling operations were observed by at least one observer. Every two hours, estimates were made of the total number of birds of each species within 5 m and 10 m of the hauling point, and within a square running 250 m out from either side of the vessel and 500 m aft of the hauling point; these estimates were all made by a single observer. During hauls comparisons were made of (i) the effect of continuous discharge of offal from a waste chute 2 m from the hauling point with a single discharge of offal at the end of a haul and (ii) bird density when discarding offal from the waste chute with discarding from the opposite (port) side of the vessel. A streamer line was hung over the hauling point during the last seven hauls.

RESULTS

Fishing in waters around South Georgia began on 6 April 1994. On 7 May a serious fire on board prevented any further operations and destroyed all data collected, with the exception of reports previously sent by radio. Samples of birds killed during longline operations were preserved in freezers: 28 of these samples were off-loaded at South Georgia and data from the labels saved. Due to lack of freezer space, the remainder were returned to Chile on FV *Friosur V* where they were accidentally discarded during unloading operations. The data salvaged are presented in this paper; other information, based on observations and data recalled by the observer, is also reported.

Incidental Mortality

Twenty-seven longline set and haul operations were observed; their locations are shown in Figure 2. Their timing and duration, as well as data on incidental mortality of seabirds, are shown in Table 1. The observer recollects a total of 98 birds being caught during the first 20 of these operations. All of these birds were dead on arrival on deck, with most deaths occurring in aggregations. Inspection of the carcasses showed that deaths were caused by hooks catching in the beak and oesophagus during swallowing of hook and bait, by hooks catching in the birds' breasts or by entanglement with hooks and lines. A total of 206 720 hooks was laid, giving a mean mortality rate of 0.47 birds/1 000 hooks laid. The maximum number of deaths on a single line was 34, giving a maximum rate of 3.12 birds/1 000 hooks laid. Some baits were lost during setting, so mortality

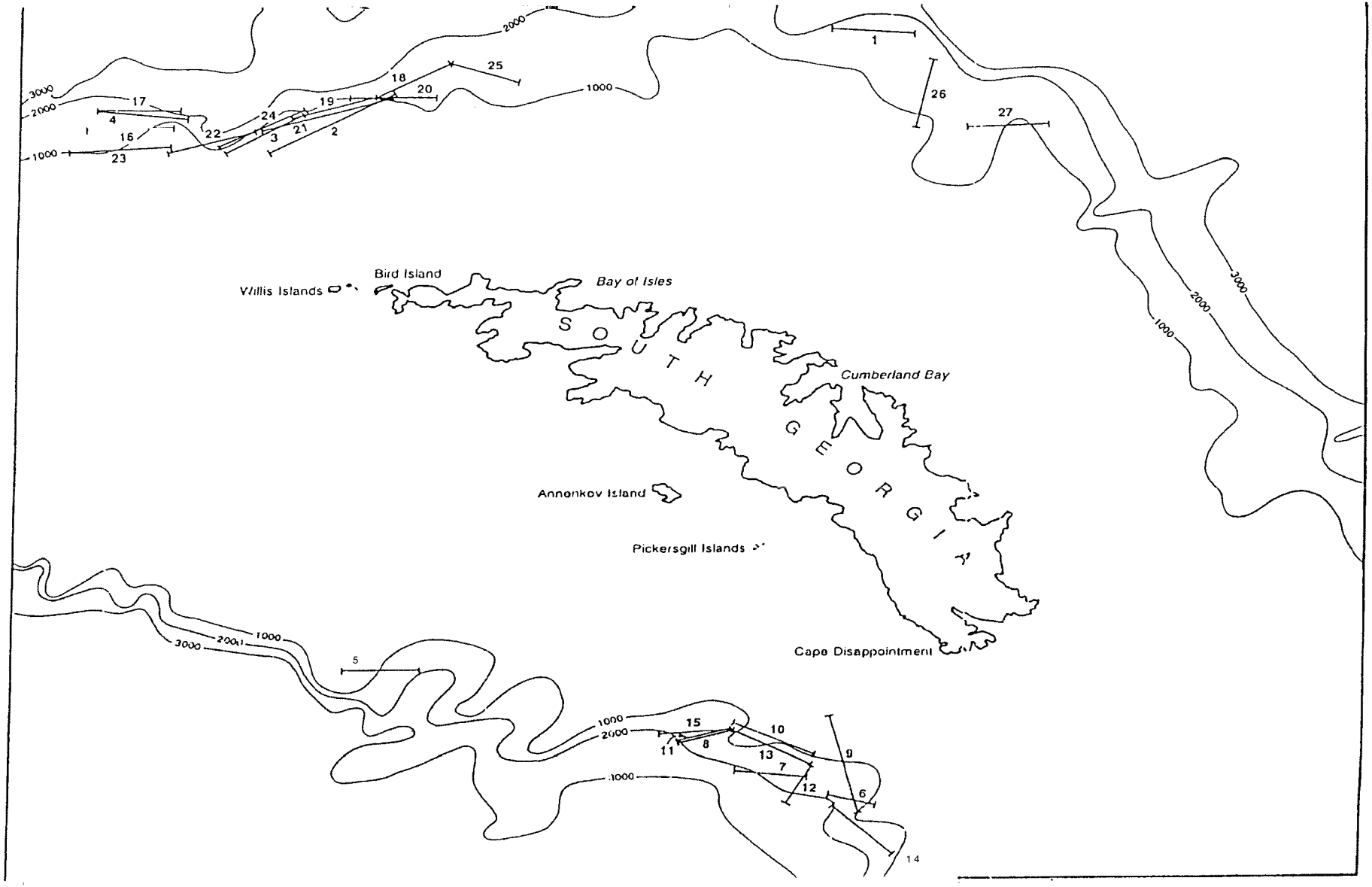

Figure 2: Location of start and finish of each of the 27 longline operations carried out on FV *Friosur V* at South Georgia, April to May 1994.

Table 1: Timing and duration of longlining operations by FV *Friosur V* at South Georgia, April to May 1994, with data on seabird mortalities (data both salvaged and recalled). All times are in GMT. GHA - grey-headed albatross, BBA - black-browed albatross, GP - giant petrel, WCP - white-chinned petrel. Dawn at approximately 0830, sunset at approximately 1700. For streamer lines (STR): A - CCAMLR specification, B - other, N - none, blank - no data.

No.	Longline Set		Day (D) Night (N)	STR A/B	Haul		Seabird Deaths	
	Start	End			Start	End	Total	Comments
01	23.30	01.06	N		26.40	05.40		
02	00.06	01.50	N		03.15	15.50		
03	00.00	01.37	N		03.00	16.00		
04	00.09	01.46	N		03.10	15.50		
05	01.00	02.45	N		04.00	17.15		
06	02.38	04.15	N		05.40	17.40		
07	02.48	04.33	N		05.50	19.00		
08	03.12	04.43	N		06.20	19.40		
09	04.30	05.53	N		07.05	19.35	15	All WCP; min. 4 WCP in
10	03.49	05.25	N		06.50	18.05		set 7; streamer B used in
11	02.05	03.42	N		05.05	19.25		3 sets; noise-emitting scarer
12	03.43	05.20	N		06.55	19.25		in 6 sets; no device in 6 sets.
13	03.35	05.10	N		06.40	18.25		
14	02.35	04.08	N		05.35	18.00		
15	02.13	03.48	N		05.15	17.25		
16	07.04	08.38	D	N	10.05	00.30	27	
17	08.44	10.25	D	B	11.50	01.00	34	
18	09.15	10.58	D	N	12.15	24.50	18	Incl. 7 GHA, 6 BBA, 4 GP
19	01.05	02.47	N	B	11.50	04.30	0	
20	No data	14.00	D	B	18.30	06.35	4	Incl. 2 GHA, 1 BBA, 1 GP
21	14.44	16.31	D	A	18.00	08.20		
22	16.26	18.08	D	A	19.35	09.00		
23	09.30	11.25	D	A	20.10	12.30		
24	20.47	22.28	N	A	06.00	13.35		Mortality rate of
25	21.55	23.27	N	A	00.50	14.00		1-5 birds/line
26	23.16	01.02	N	A	13.45	04.40		
27	12.53	14.26	D	A	16.00	05.20		

in relation to the number of baited hooks laid may be higher. During the first 15 sets, all made at night, 15 white-chinned petrels were caught, with a maximum of at least four birds (on set 7) caught on any one occasion. No birds were caught during the last night-time set (set 19).

The remaining four sets (16 to 18, 20), all to the north and northwest of Bird Island, were made in daylight. A total of 83 birds (85% of the overall total) was caught; of these, 28 birds were off-loaded at South Georgia and identified. These comprised nine grey-headed albatrosses (*Diomedea chrysostoma*), seven black-browed albatrosses (*D. melanophris*), five giant petrels (*Macronectes* sp.), and four Cape petrels (*Daption capense*). Cape petrels were caught by becoming entangled in the lines. It was recollected that the birds caught also included several white-chinned petrels and one juvenile wandering albatross (*D. exulans*). Furthermore, black-browed and grey-headed albatrosses were caught in similar proportions (as can be seen from the specimens retained), but in general giant petrels were more abundant than the other two species.

Taking all these data together, a reasonable assessment of the contribution of each seabird species to the overall rate of incidental mortality is probably as follows:

- day-time hauls: giant petrel 35%, grey-headed albatross 25%, black-browed albatross 25%, white-chinned petrel 7%, Cape petrel 7%, wandering albatross 1%; and
- all hauls: giant petrel 30%, grey-headed albatross 21%, black-browed albatross 21%, white-chinned petrel 21%, Cape petrel 6%, wandering albatross 1%.

For lines 21 to 27, which were a mixture of day and night-time sets, one to five birds were killed per set.

Interactions During Setting

Large numbers of white-chinned petrels were seen to the southwest of South Georgia (sets 5 to 15) during night-time setting. These occurred in aggregations of 20 to 30 birds, flying in and diving at the line within 30 m of the stern. Birds were submerged for up to five seconds, and tended to dive in groups. Observations could not be made of the line near the surface beyond 20 m. Some black-browed albatrosses, giant petrels and Cape petrels also followed the ship, but rarely approached the line.

During setting in daylight to the north and northwest of Bird Island, large numbers of giant petrels (average c. 30), Cape petrels (c. 100) and black-browed albatrosses (c. 30) were present; wandering and grey-headed albatrosses occurred in smaller numbers (c. 5 and c. 7 to 10, respectively). Behavioural differences were observed between species. Black-browed and grey-headed albatrosses were the most persistent bait-stealers: the former approached the line on the surface as close as 15 m behind the stern, grabbed the bait and then pulled until it came free; the latter tended to dive from about 3 m above the water surface, submerging briefly. Once the bait was taken, but often while still on the hook, other birds (giant petrels in particular, but also all three species of albatross) would attempt to steal the bait, forming aggregations which persisted up to 300 m behind the stern. Cape petrels were ubiquitous, approaching close to the vessel and around the margins of the aggregations. Cape petrels, black-browed and grey-headed albatrosses all approached the line before it entered the water, and were vulnerable to hooks flailing in the air. High mortality rates coincided with intense feeding activity when birds acted in a frenzied manner.

Interactions at night during sets 24 to 26 were minimal: a few white-chinned petrels, giant petrels and black-browed albatrosses were observed. Daytime numbers were still high but with few giant petrels and no grey-headed albatrosses seen, and without the intense activity which occurred previously.

No data on bait-strikes survived, but it was recalled that success rate varied between species: approximately 70% for black-browed albatross, 40% for grey-headed albatross, and 70% for giant petrels. Aggregations formed quickly around hooked birds, obscuring further observation and making it difficult subsequently to distinguish between birds pulling on a bait or actually ensnared on a hook. Consequently, no reliable estimate of birds hooked during setting is available.

Interactions During Hauling

No deaths were observed as resulting from hauling operations. The tail of a single giant petrel was observed to catch briefly on an incoming hook but the bird freed itself easily with no obvious damage incurred.

From memory, large numbers of birds were in the vicinity of the vessel during hauling operations both in daylight and at night. These included black-browed, wandering and grey-headed albatross; giant, Cape and white-chinned petrels; Wilson's and black-bellied storm petrels (*Oceanites oceanicus* and *Fregetta tropica* respectively). A plume of birds formed aft of the offal chutes on the port and starboard sides to a distance of up to 1 km aft of the stern of the ship, with white-chinned petrels tending to stay on the flanks of the plume. Numbers of albatross species were considerably reduced at night; storm petrels were not observed at night.

During daytime hauling of lines southwest of South Georgia, the mean total of birds counted within a 500 m square aft of the stern was approximately 700 birds, although this varied between and during operations. Of these, the majority (c. 400) were giant petrels; smaller numbers of Cape petrels (c. 200), white-chinned petrels (c. 50), black-browed (c. 30) and wandering (c. 10) albatrosses, and Wilson's storm petrels (c. 10) were also present.

To the north and northwest of Bird Island, total numbers during daytime hauling rose to an approximate mean of 1 400: giant petrels were again in the majority (c. 800), with Cape petrels (c. 400), black-browed (c. 100), wandering (c. 60) and grey-headed (c. 10) albatrosses, Wilson's (c. 10) and black-bellied (c. 30) storm petrels also present. Very few white-chinned petrels were observed, either at night or during the day.

For the last two sets, numbers of birds were reduced to several hundred: initially, few

giant petrels but increasing later, 80 to 100 black-browed albatrosses and 40 wandering albatrosses. Some kelp gulls (*Larus dominicanus*) were also present but few white-chinned and Cape petrels, and no grey-headed albatrosses were observed.

Up to 70 birds were present within 10 m of the hauling point during operations in daylight and at night. Giant petrels were the most common (approximately 60% of all birds) but Cape petrels (30%) and black-browed albatrosses (10%) were also present. Grey-headed and wandering albatrosses and white-chinned petrels approached this close only occasionally. Birds made no attempt to take baits on hooks. However, they were attracted by offal from the waste chute 2 m away and often encroached on the area around the incoming line, becoming vulnerable to activities associated with gaffing of incoming fish.

Effectiveness of Mitigating Procedures

Little quantifiable information survived concerning the effectiveness of mitigating procedures: the maximum mortality for a set was sustained while using the first streamer line; in contrast, low daytime mortality rates for sets 20 to 24 were associated with use of the streamer line made to CCAMLR specifications.

Both types of streamer line interfered with birds' approach to the baited hooks: the streamers broke up the sweeping flight of white-chinned petrels across the mainline at night, and similarly for grey-headed albatrosses during the day. The CCAMLR-designed streamers and line moved more unpredictably, distracting birds more. In calm weather or during intense feeding activity, the heavier streamers of the initial design had very little effect; birds frequently, however, collided with the CCAMLR-designed line but were not harmed. Both streamer lines caught in the main line and broke, the CCAMLR line also losing a streamer on a couple of occasions.

A noise-emitting scarer was found to have a mitigating effect early in each set but this wore off quickly. A streamer line suspended off the hauling hatch was observed to reduce the number of birds approaching the hauling point; discarding offal from the opposite side of the vessel also reduced the numbers of birds at the hauling point.

DISCUSSION

Seabird Interactions with Longlining

No birds were hooked during hauling: all deaths must therefore have occurred during setting operations. Brothers (1991) found a mean seabird mortality rate of 0.41 birds/1 000 hooks and a maximum mortality rate of 1.8 birds/1 000 hooks for the southern bluefin tuna fishery off Tasmania. These figures were sufficiently high to substantiate claims that serious declines in populations were probably due to pelagic longlining. Both rates are lower than those found in this study, which also indicated a large impact on grey-headed albatrosses, one of the species whose populations are most seriously in decline at South Georgia (Prince *et al.*, 1994). Wandering albatrosses, whose populations are also in decline at South Georgia (Croxall *et al.*, 1990), showed a low frequency of interaction which may be a result of (i) a marginal role during intense feeding activity due to lack of manoeuvrability, and (ii) a tendency, when on the sea surface, to remain well aft of the ship. With the Japanese system of longlining on board FV *Friosur V*, the line is weighted using stones and the baits tend to sink quickly, reducing the opportunity for wandering albatrosses to interact; with other systems where more line or monofilament is used, baits may stay on the surface longer, allowing wandering albatrosses to interact more with setting operations.

Murray *et al.* (1993) showed that a number of variables influenced the mortality of seabirds in the southern bluefin tuna fishery off New Zealand. These included time of day, location, species present and behavioural interactions. This study provided evidence of similar effects off South Georgia: considerably more birds, and species (6), were caught per line during daytime operations to the north and northwest of Bird Island than during night-time operations to the southwest of the main island, when only a single species (white-chinned petrel) was caught.

Observations of birds in the vicinity of longlining operations also showed variations in vulnerability. More white-chinned petrels were observed during both night and day operations to the southwest of the main island than in other areas, whereas albatross species were most common during daylight hours north and northwest of Bird Island and to the northeast of South Georgia; the highest numbers of giant

petrels were found off Bird Island during the day, though large numbers were also observed to the southwest of the main island and during night-time operations at both sites.

Colonies of white-chinned petrels are widely distributed on headlands all around South Georgia, including the southwest coast; albatross colonies are concentrated around northwest and, to a lesser extent, southeast South Georgia (Croxall *et al.*, 1984). These distributions, linked to species' feeding strategies, may contribute significantly to the observed distribution of birds around the longline vessel. The timing of the breeding season when longlining takes place may also be important: the decline in numbers of white-chinned petrels observed coincided with the end of their breeding season.

Behavioural strategies may also be significant. Thus, for grey-headed albatrosses, the proportion of deaths in relation to the number of birds following the ship was very much higher than for other species and may be linked to their diving on the bait from the air; alternatively, there may be a higher turnover in birds observed. In relation to the size of the local breeding population, giant petrels (8 500 pairs; Croxall and Prince, 1987) are caught disproportionately frequently in comparison with black-browed (100 000 pairs) and grey-headed (80 000 pairs) albatrosses (Prince *et al.*, 1994), and white-chinned petrels (c. 2 million pairs) (Prince and Croxall, 1983). White-chinned petrels approached the line and dived in groups, with deaths also appearing to be aggregated. High mortality during daytime sets coincided with intense feeding activity: this was governed by complex behavioural interactions rather than by any observable increase in numbers following the ship; interactions between birds taking bait and those then stealing it appeared important and may also influence the proportion of deaths by entanglement in relation to those by hooks catching in the birds' breasts, beaks or oesophagi.

No evidence of deaths or injury to birds during hauling was recorded. A problem may exist where crewmen use gaffs to disperse birds crowding around the hauling point. Numbers of birds following a ship may be related to the amount of offal thrown overboard; large numbers of birds attracted during a haul may then influence the number of birds present during the subsequent set, especially if this occurs in the same area or follows immediately after the haul.

Mitigating Devices

Streamer lines were observed to interrupt birds' behaviour when taking baits, and to reduce mortality. However, these may not be effective if they do not conform to CCAMLR design, or if they are used during calm weather or periods of intense feeding activity. The CCAMLR design, however, is complicated and labour-intensive to make, and its fragility made it vulnerable to breaking by catching on the mainline: fishermen may therefore be less than willing to use and maintain it. Noise-emitting scarers were unreliable and had a limited effect on birds.

Offal may attract birds, but discarding it only at the end of a haul may be counter-productive: large numbers of birds were still attracted, remaining astern of the ship during hauling. When bait was discarded after hauling, birds converged on the discarding point to compete for the offal, generating intense activity and displaying frenzied behaviour. The problem of birds obscuring visibility of the incoming line during hauling operations was considerably reduced by suspending the streamer line off the hauling hatch; redesigning offal chutes so that they divert all offal to the side of the vessel opposite fishing operations may also reduce the problem.

CONCLUSIONS

From this study, the single measure that could most effectively limit seabird mortality is to set longlines at night only; this would substantially reduce the number of birds taken, and confine the effect to white-chinned petrels. Further work to minimise mortality of white-chinned petrels during night-time setting is required, and monitoring of the population breeding at South Georgia would be desirable.

The use of streamer lines is also effective, but further work is needed on their design. Understanding the behaviour governing the presence of bird species affected and the nature of their interactions with longlining operations also requires further studies.

Discharging all offal at or near the end of a haul may have some adverse effects, in particular as it promotes very intense feeding activity and may attract very large numbers of seabirds. Furthermore, any vulnerability of birds to hauling

operations may be reduced by discharging offal on the side of the ship away from fishing operations.

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