

**AN ASSESSMENT OF CCAMLR MEASURES EMPLOYED TO
MITIGATE SEABIRD MORTALITY IN LONGLINING OPERATIONS
FOR *DISSOSTICHUS ELEGINOIDES* AROUND SOUTH GEORGIA**

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Abstract

Longlining operations for *Dissostichus eleginoides* off South Georgia were assessed for interactions with seabirds and the effectiveness of measures employed by CCAMLR to mitigate seabird mortality. Following an agreement between the Governments of the United Kingdom and Chile, a UK observer was placed aboard a Chilean longliner, the BF *Cisne Verde*, fishing in CCAMLR Subarea 48.3 during the 1996/97 season. In this study 61 lines were laid from March to May 1997 using the Spanish double-line method. In accordance with CCAMLR conservation measures, lines were set at night, weights (6–7 kg) were set at 50 m intervals along the line, all deck lights were extinguished and no offal was discarded during setting. A streamer line made to CCAMLR specifications was also used, except during an experiment that attempted to assess the effectiveness of the streamer line in mitigating incidental mortality of seabirds during night-time setting. Data were recorded during hauling using a randomised cluster sampling method, developed to allow representative data to be collected when 100% observer coverage could not be achieved. A total of 12 dead seabirds were recorded, giving an average mortality rate/night of 0.099 birds/1 000 observed hooks, substantially lower than other vessels fishing around South Georgia during the same period. Mortalities consisted of nine white-chinned petrels, two black-browed albatrosses and one unidentifiable bird caught on hooks. One giant petrel was also killed as a result of flying into the side of the vessel. Generally, few birds were seen following the vessel during setting operations. During April, however, large numbers of white-chinned petrels were seen occasionally, and large numbers of black-browed albatrosses were seen when the moon was full. Live birds were observed to become caught on hooks during hauling on 23 occasions; all birds were released alive. Black-browed albatrosses concentrated on taking returning bait off the line and accounted for 18 birds caught; giant petrels concentrated on taking discarded offal, and accounted for five birds caught.

Résumé

Évaluation des opérations de pêche à la palangre de *Dissostichus eleginoides* au large de la Géorgie du Sud dans le but de déterminer l'interaction avec les oiseaux de mer et l'efficacité des mesures employées par la CCAMLR pour limiter la mortalité accidentelle des oiseaux de mer. Suite à un accord passé entre le Royaume-Uni et le Chili, un observateur britannique a été placé à bord d'un palangrier chilien, le *Cisne Verde*, pêchant dans la sous-zone 48.3 de la CCAMLR pendant la saison 1996/97. Cette étude porte sur le déploiement de 61 palangres de mars à mai 1997, par la méthode espagnole à palangre double. Conformément aux mesures de conservation de la CCAMLR, les lignes ont été posées de nuit, des lests (6–7 kg) ont été fixés à 50 m d'intervalle sur toute la longueur de la palangre, tout l'éclairage du pont était éteint et aucun déchet de poisson n'a été rejeté pendant la pose. De plus, une ligne de banderoles aux spécifications de la CCAMLR était utilisée, sauf lors d'une expérience réalisée pour tenter d'évaluer l'efficacité de la ligne de banderoles en ce qui concerne la réduction de la mortalité accidentelle des oiseaux de mer pendant les poses effectuées de nuit. Les données ont été fournies par la méthode d'échantillonnage en grappes au hasard mise

au point pour permettre de collecter des données représentatives lorsqu'il n'est pas possible de faire couvrir la campagne à 100% par un observateur. Au total, 12 oiseaux de mer ont été tués soit un taux moyen de mortalité par nuit égal à 0,099 oiseau/millier d'hameçons observés, ce qui est nettement inférieur aux autres navires pêchant autour de la Géorgie du Sud pendant la même période. Composition des oiseaux tués et accrochés aux hameçons : neuf pétrels à menton blanc, deux albatros à sourcils noirs et un oiseau non identifiable. Par ailleurs, un pétrel géant a trouvé la mort en heurtant en vol le flanc du navire. En général, peu d'oiseaux semblaient suivre le navire durant les opérations de pose. En avril, pourtant, de nombreux pétrels à menton blanc pouvaient parfois être observés derrière le navire pendant les opérations de pose et, lors de la pleine lune, de nombreux albatros à sourcils noirs. En 23 occasions, des oiseaux vivants se sont pris aux hameçons pendant la remontée de la palangre; tous ont été relâchés vivants. Les albatros à sourcils noirs, qui cherchaient en particulier à prendre les appâts revenant sur la palangre, représentaient 18 des oiseaux accrochés; les pétrels géants, soit cinq des oiseaux accrochés, recherchaient surtout les déchets de poissons rejetés.

Резюме

Ярусный промысел *Dissostichus eleginoides* в районе Южной Георгии был рассмотрен с целью изучения взаимодействия промысловых операций с морскими птицами и эффективности мер АНТКОМа по сокращению уровня смертности морских птиц. Согласно соглашению между правительствами Соединенного Королевства и Чили на чилийском судне *Cisne Verde*, работавшем в Подрайоне АНТКОМа 48.3 в течение сезона 1996/97 г., был размещен британский наблюдатель. В ходе данного исследования с марта по май 1997 г. согласно испанской системе была выполнена 61 постанковка яруса. В соответствии с мерами АНТКОМа по сохранению постанковка яруса производилась ночью, грузила (6–7 кг) размещались на линии через 50-метровые интервалы, все палубные огни были выключены и никаких отходов переработки во время постанковки выброшено за борт не было. За исключением случая с экспериментом по оценке эффективности повода для отпугивания птиц в сокращении побочной смертности морских птиц, во время ночной постанковки применялся поводец указанной АНТКОМом конструкции. Во время выборки данные регистрировались с помощью случайного гнездового метода, позволяющего сбор репрезентативных данных при отсутствии 100%-ного охвата наблюдением. Было зарегистрировано 12 случаев мертвых морских птиц, что дает общий коэффициент смертности/ночь в 0,099 птицы/1000 наблюдаемых крючков – намного ниже, чем для других судов, осуществлявших промысел в районе Южной Георгии в тот же период. Погибли 9 белогорлых буревестников, два чернобровых альбатроса и одна неопознанная птица, пойманная на крючке. Кроме этого один гигантский буревестник погиб, влетев в борт судна. Как правило мало птиц следило за судном во время постанковочных операций. В апреле, однако, время от времени наблюдалась большая численность белогорлых буревестников и, при полнолунии, чернобровых альбатросов. Наблюдалось 23 случая запутывания птиц на крючках; всех птиц высвободили живыми. Чернобровые альбатросы в основном старались снять наживку в ходе выборки (было поймано 18 особей этого вида), в то время как белогорлых буревестников чаще всего привлекали выброшенные отходы переработки (было поймано 5 особей этого вида).

Resumen

Las actividades de pesca de palangre de *Dissostichus eleginoides* desarrolladas frente a Georgia del Sur fueron estudiadas en detalle a fin de evaluar sus interacciones con las aves marinas y la eficacia de las medidas adoptadas por la CCRVMA para reducir la mortalidad incidental. Tras un acuerdo intergubernamental entre el Reino Unido y Chile, se designó un observador del RU a bordo del palangrero chileno *Cisne Verde*, que faenó en la Subárea 48.3 de la CCRVMA durante la temporada 1996/97. Durante el estudio realizado entre marzo y mayo de 1997 se calaron 61 líneas dobles de tipo 'español'. En cumplimiento de las medidas de conservación de la CCRVMA, las líneas se calaron por la noche con pesos (6–7 kg) colocados cada 50 metros a lo largo de la línea, todas las luces de cubierta fueron apagadas y no se botaron restos de pescado durante el calado. También se utilizó una línea espantapájaros construída de acuerdo a las especificaciones de la CCRVMA, excepto durante un experimento que intentó

evaluar la eficacia de este tipo de líneas en la reducción de la mortalidad incidental de aves marinas durante el calado nocturno. Los datos se recopilaban durante el virado utilizando el método aleatorio de muestreo por conglomerados, diseñado para recopilar datos representativos cuando no se puede alcanzar una cobertura de observación de un 100%. Se registraron 12 aves marinas muertas, lo que equivale a una tasa promedio de mortalidad por la noche de 0,099 aves/1 000 anzuelos observados, cifra bastante más baja que la alcanzada por otros barcos que pescaron alrededor de Georgia del Sur durante el mismo período. Entre las aves que murieron se encontraron nueve petreles de mentón blanco, dos albatros de ceja negra y un ave no identificada enganchada en un anzuelo. Un petrel gigante también murió a raíz del impacto con el barco de pesca. En general se vieron pocas aves siguiendo a la embarcación durante el calado de los palangres. No obstante, durante el mes de abril en ocasiones se observó un gran número de petreles de mentón blanco, y en plenilunio se observó un gran número de albatros de ceja negra. Las observaciones del virado incluyeron 23 enganches de aves en anzuelos; todas ellas fueron liberadas vivas. Los albatros de ceja negra trataron de coger la carnada de los anzuelos lo que ocasionó una captura de 18 aves; los petreles gigantes se concentraron en los restos de pescado, lo que dio un total de cinco aves capturadas.

Keywords: fishery, albatross, petrel, streamer line, conservation measures, cluster sampling, South Atlantic, CCAMLR

INTRODUCTION

Population declines in several species of albatross have been reported from breeding sites in the Southern Ocean, and have been linked to the incidental mortality of seabirds associated with longlining operations in fisheries for southern bluefin tuna (*Thunnus maccoyi*) and Patagonian toothfish (*Dissostichus eleginoides*) (e.g. Brothers, 1991; Croxall et al., 1990, 1997; Duhamel, 1991; Gales, 1993; Murray et al., 1993; Prince et al., 1994, 1997; Weimerskirch, et al., 1997).

In the area covered by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), seabird interactions with the toothfish fishery were first reported in 1993 around South Georgia and the South Sandwich Islands by observers designated under the CCAMLR Scheme of International Scientific Observation (Ashford et al., 1994). In the following year, CCAMLR-designated observers reported extensive interactions of the fishery with seabirds and sea mammals around South Georgia and considerable seabird deaths (e.g. Jones and Parkes, 1994; Ashford and Rubilar, 1994; Ashford et al., 1995; Ashford et al., 1996). Ashford et al. (1995) found that deaths were highest when line setting occurred during the day, with giant petrels (*Macronectes* spp.), grey-headed and black-browed albatrosses (*Diomedea chrysostoma* and *D. melanophris*) accounting for most deaths; during night-time setting, white-chinned petrels (*Procellaria aequinoctialis*) were almost exclusively affected. Ashford et al. (1995) concluded that night-time setting would most effectively reduce

the number of birds taken (and confine these to white-chinned petrels), and that the use of a streamer line may also be effective.

Capdeville (1996) reported similar results around the Kerguelen Islands during three fishing seasons from 1993 to 1996, but no giant petrels were killed. High variability in mortality rate was found between years and between months, but the presence of a streamer line was not found to have a significant mitigating effect; setting at night did not reduce the mortality rate significantly, but did confine mortalities largely to white-chinned petrels. Moreno et al. (1996) analysed most of the fine-scale seabird data recorded by observers around South Georgia for the 1995 fishing season, and found that distance from land, lunar phase, hook size, and the use of streamer lines were important factors determining catch of birds per unit of fishing effort. Kock and Selling (1996) reported that seabird mortality appeared to decline towards the end of April/beginning of May. They also noted a statistical problem in calculating total mortalities by extrapolating from subsamples of hooks observed during hauls.

As a result of these studies and further analysis of observer data from the 1995/96 season, the CCAMLR Working Group on Fish Stock Assessment (WG-FSA) concluded that: seabird mortality from longlining was a serious problem; black-browed albatrosses were especially susceptible to capture during the day; catch rates of these and white-chinned petrels were reduced after early May, therefore

restrictions on the timing of the fishery may reduce mortality; and daylight setting and incorrect use of streamer lines were major causes of high levels of seabird mortality (SC-CAMLR, 1996). WG-FSA asked CCAMLR Members to assess the effectiveness of streamer lines.

Following an agreement between the Governments of the United Kingdom and Chile, a UK observer was placed aboard a Chilean longliner, the *BF Cisne Verde*, fishing in CCAMLR Subarea 48.3 during the 1996/97 season. The aims of the observer included recording seabird mortalities and interactions with longlining operations over the period of fishing, and assessing methods used to reduce mortalities. As part of the development of a protocol for sampling longlines and their catch requested by CCAMLR (SC-CAMLR, 1996), the observer developed and tested a method of randomly sampling hauling operations for seabird interactions and mortalities.

METHODS

The Spanish double-line system was used for fishing aboard the *BF Cisne Verde*. This consisted of a retaining line, and a mother line made up of a series of coils of line attached end to end. The two lines were connected by lines attached from the end of each coil to the retaining line. Every tenth connecting line was marked with spliced lengths of different colours which were used to monitor the amount of line remaining to be hauled. Every coil of 98 m length carried two weights of c. 6 to 7 kg at a c. 50 m interval, one half-way along and the other at the end. Each coil also carried 52 hooks, each hook on a secondary line attached to the mother line. Hooks were Ancora recto size 5, and were baited manually with a single thawed sardine of c. 15 cm SL, the hook placed through its head. Surface buoys were placed at either end of the longline.

All setting operations occurred at night except for five lines when setting continued into the early dawn. A similar number of hooks was laid each night, either on one or two shorter longlines. All deck lights were turned off after the leading buoys had been cast away, and were not turned on again until the end of setting. A streamer line made to CCAMLR specifications was deployed from the port side of the aft upper deck, 4.5 m above the sea surface. The streamer line was used for all sets, except when the observer requested otherwise. It broke once while in use, and was replaced for the following set. No offal was

discarded during sets. Observations were made by naked eye over a period of approximately one hour, during which the observer made at least two 10-minute observations of general bird activity at half-hour intervals; the observation period was assigned haphazardly over the setting period, which lasted c. 2.5 hours. When more than low levels of seabird activity were observed, three observations were made lasting 20 minutes each over an observation period of 1.5 to 2 hours. Observations were made from the upper deck above the setting hatch at the stern of the vessel. As lights were extinguished during setting, data on behavioural interactions with operations could not be taken; counts of visible seabirds, and observations of their activity were made instead. Lighter-coloured seabirds were visible to c. 100 m aft of the vessel; darker-coloured seabirds were more difficult to see, and count data may be conservatively biased. The number of coils laid was determined during the set by the Fishing Master, depending on a number of factors, including the nature of the seafloor, weather conditions and time available before dawn.

Hauling operations began generally c. 8 hours after setting, and hauling of the line(s) laid the previous night occupied c. 15 hours of each 24-hour period. Hauling was carried out from a platform on the starboard side of the vessel, below and directly aft of the bridge, supervised by the Fishing Master or his assistant from a work station on the aft and starboard quarter of the bridge. Two winches were used to bring in the retaining and mother line simultaneously. Generally the winch for the mother line was attended by one or two winchmen working a watch of c. 3 to 4 hours. As they came to the surface, fish caught were gaffed by the winchman and two men handling gaff hooks with handles c. 6 m long stationed on the upper deck above and aft of the winch. Offal, returning bait and fish heads were discarded through ports 7 m aft of the winch.

All hauling observations were made from the Fishing Master's work station. Data were recorded on mortalities, the number of live birds hooked and the number of hooks observed. After each observation period, counts of birds following the vessel were made from the stern. Initially, observations were made during up to three periods of one hour for each day's hauling. Periods were selected in one of two ways: haphazardly over the line when no sampling of toothfish was taking place, and as far as possible to cover the early, middle and late stages of



Figure 1: Location of start and finish of each of the 61 longlining operations by *BF Cisne Verde* at South Georgia, from March to May 1997.

hauling each line; or at the end of toothfish sampling periods, which were randomly selected using a cluster sampling method (Ashford and Duhamel, 1997). A regime of two sampling periods of 1.5 hours per line was also tried, and this was found to be more sustainable for the observer and crew members involved.

After 14 April, a randomised cluster sampling method (Thompson, 1992) was employed, using the known number of coils laid during the set as the sampling frame. For sampling units, the mother line was divided into lengths of 30 coils using sequences of three marked connecting lines. At the start of hauling, four 30-coil lengths were randomly selected for sampling using random number tables; two of these were then randomly allocated to sampling of catch in the factory and the remaining two to sampling of the incoming line at the hauling point.

From 17 April, an experiment was conducted for one month to assess the effectiveness of the streamer line in mitigating seabird mortalities. The independent variable was the treatments with/without a streamer line. Setting operations with a streamer line were randomly allocated to 15 of the 30 nights planned for the experiment. The remaining operations were allocated to the condition without streamer line. All hauling of lines was sampled using the randomised method outlined above. The experiment was interrupted on 27 April to transfer an injured fisherman to the Falkland/Malvinas Islands, and resumed on

8 May. Data were analysed using SAS for a Wilcoxon two-sample test (Dilorio and Hardy, 1996).

RESULTS

Incidental Mortality

Sixty-one sets were laid on 48 nights from 25 March to 27 April and 8 May to 23 May 1997, with 654 420 hooks laid (mean = 13 634 hooks/night; SD = 1 650). Set locations are shown in Figure 1. The number of hooks (laid the previous night) observed being hauled was 130 936 (mean = 2 910 hooks/day's hauling; SD = 790), giving an observer coverage of 20%. The total number of dead birds recorded was 13, of which one giant petrel was killed as a result of flying into the side of the vessel. The other 12 were recorded during hauling; all were hanging from hooks on the returning longlines, and had been dead for several hours when they reached the hauling point. Two white-chinned petrels were recorded during hauling after setting of the line had continued into early daylight hours on 3 April: these were included in the analysis. The mean mortality rate/night for all seabirds caught on hooks observed was 0.099 birds/1 000 hooks; the highest mortality rate/night for a set was 1.18 birds/1 000 hooks.

White-chinned petrels accounted for nine of the hooked mortalities, of which eight were recorded between 1 and 7 April (with four on a

single line on 1 April), when streamer lines were in use for all setting operations. Seven of the eight were caught on lines 7–9, set between Shag Rocks and the western South Georgia shelf. Black-browed albatrosses accounted for two mortalities (on 23 and 24 April, coinciding with full moon on 24 April), and one dead bird recorded on 18 May was too badly damaged by amphipods to be identified (though it was too small to be an albatross, and may have been a white-chinned petrel).

Effectiveness of Streamer Line

The experiment to test the effectiveness of the streamer line during setting was run for 27 nights, with a break of 10 nights from 27 April. Data therefore covered two periods of full moon conditions. A mean of 3 237 hooks (SD = 553) laid each night was observed in the following hauls, and a mean of 12 990 hooks (SD = 1 539) was laid each night. Four mortalities were observed, consisting of two black-browed albatrosses, one white-chinned petrel and one bird too damaged to be identified. All mortality data were corrected to give the rate of mortalities/1 000 hooks for each set. The data were not normally distributed (Kruskal-Wallis $P < |W| = 0.0001$) and did not fulfil the assumptions for ANOVA, so a Wilcoxon two-sample test was used instead. Under the conditions of night-time setting, no deck lights and a well-weighted line, no significant difference due to the streamer line was found ($P > |Z| = 0.2237$).

Interactions during Setting

Seabirds were recorded following the vessel on 26 of the 48 nights during which setting operations were observed. The number of seabirds was averaged for each observation period during the voyage. All albatrosses seen were of a similar size to grey-headed and black-browed albatrosses; in the low light conditions, it was not possible to distinguish albatross species, and all albatrosses were counted in one group. The mean number of birds following the vessel was calculated at 10.7 birds (SD = 23.7) (Table 1). The large numbers of birds coinciding with the full moon around 24 April were due to an increase in the number of albatrosses present (Figure 2). A second, much smaller, increase in bird numbers was recorded with a full moon around 21 May. This consisted of cape petrels (*Daption capense*) and giant petrels, with some unidentified birds which were the

Table 1: Mean numbers of seabirds following setting operations of the BF *Cisne Verde* around South Georgia during April and May 1997.

	n	Mean	SD
All birds:	48	10.69	23.75
April	30	15.73	28.85
May	18	2.28	4.36
White-chinned petrels:	30	2.53	6.56
April	18	0	0
May			
Albatrosses:	30	13.03	28.78
April	18	0	0
May			

same size and shape as cape petrels but could not be identified due to poor light conditions. Very few birds were otherwise seen during May. White-chinned petrels were seen on seven nights, but not after 12 April.

Most seabird activity consisted of birds flying behind the vessel. Birds were generally observed flying 20 to 30 m behind the vessel, except during the full moon when albatrosses were visible up to 150 m behind the vessel. Birds were also observed to fly into the wind when approaching the stern of the vessel, so that a course into the wind meant that birds approached from aft of the vessel, while a course downwind meant that birds approached along the sides of the vessel. Apart from flying, white-chinned petrels were observed diving on four nights between 4 and 11 April; albatrosses were observed sitting on the sea surface during setting between 21 and 27 April, and diving on 24 April. Cape petrels were seen on the surface on 21 May but none were observed taking bait off hooks or being hooked.

Interactions during Hauling

Seabirds were recorded interacting with hauling operations on all of the 47 days when hauling was observed. Seventy-four counts of seabirds were made over 40 of these days (Figure 3). A mean of 351.9 (SD = 289.9) birds was calculated, composed largely of black-browed albatrosses (mean = 109.2, SD = 126.1) and giant petrels (mean = 179.1, SD 197.74). White-chinned (mean = 14.3, SD = 25.6), and Cape petrels (mean = 44.3, SD = 63.5) were seen in smaller numbers; a few wandering albatrosses (mean = 4.6, SD = 11.1) were also seen, but very few grey-headed albatrosses.

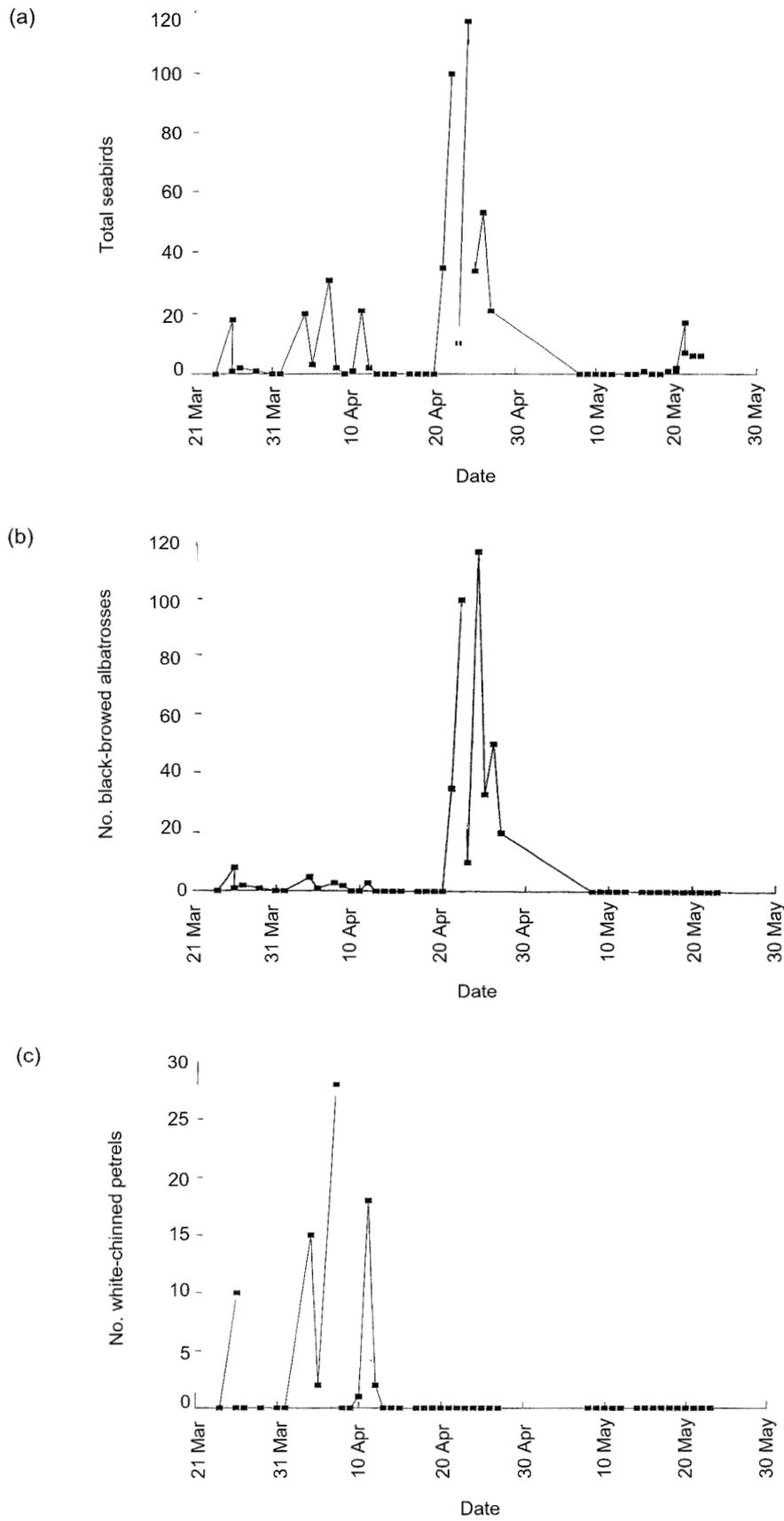


Figure 2: Numbers of (a) all seabirds, (b) black-browed albatrosses and (c) white-chinned petrels recorded following the BF *Cisne Verde* during setting operations around South Georgia, from March to May 1997.

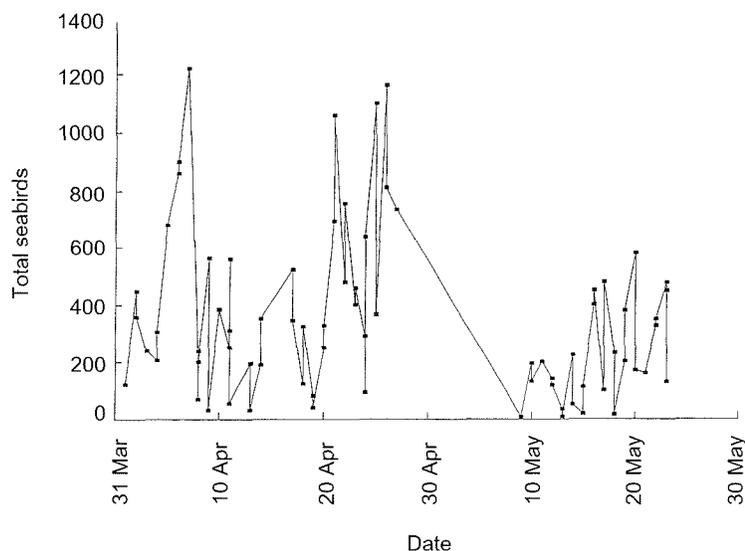


Figure 3: Total number of seabirds recorded following the BF *Cisne Verde* during hauling operations around South Georgia, from March to May 1997.

Table 2: Significance results from ANOVA on rank-transformed data, to test for seasonal and lunar differences in the number of birds following hauling operations on board BF *Cisne Verde* around South Georgia during April and May 1997 ($\alpha = 0.05$).

	April v May	April Full v Waxing df = 7 df = 5	May Full v Waxing df = 7 df = 8
All birds	$P < 0.001$	$P < 0.001$	$P = 0.019$
Black-browed albatrosses	$P < 0.0001$	not sig.	no birds
Wandering albatrosses	not sig.	not sig.	not sig.
Giant petrels	not sig.	$P < 0.0001$	$P = 0.009$
White-chinned petrels	$P < 0.0001$	0.049	no birds
Cape petrels	$P = 0.003$	$P < 0.01$	not sig.

Randomised data taken after 14 April fell into two periods, corresponding to the same phase of the lunar cycle during April and May. To test for differences due to season and between phases of the lunar cycle, each period was divided into two blocks of seven to eight days corresponding to full moon (including three nights either side of full moon) and waxing moon (the week immediately preceding) conditions, and comparisons made between months and between blocks within months. Data were not normally distributed so a rank transformation was performed. The data were then analysed using a four-level Model I ANOVA with orthogonal contrasts. The total number of birds was found to be significantly higher in April than May, and under full moon conditions. These and results for individual species are given in Table 2. Cape petrels increased significantly in numbers between April and May, whereas black-browed albatrosses and

white-chinned petrels largely disappeared. Giant petrels increased in numbers during full moon conditions for both months; Cape petrels increased in numbers during the full moon in April only. White-chinned petrels decreased significantly during full moon conditions in April, but this was most likely linked to their seasonal decline in numbers.

Twenty-three birds were also observed to be snagged on hooks on the incoming line. All were released alive by the two winchmen using methods recommended by CCAMLR. Eighteen black-browed albatrosses were caught, all during April and all but one during the day. Ten were hooked in the beak, three in the gullet, and five were hooked but the location was not recorded. Five giant petrels were also caught, one hooked during the day on 5 April, and another on 31 March during the day; three were caught in

May at night with a leg or wing wrapped in the line. Birds were seen on three occasions around the vessel with hooks and lines through their beaks and feet.

The winch and offal ports were separated by 7 m on board the BF *Cisne Verde*, and a corresponding separation was observed by species: black-browed albatrosses concentrated around the incoming mother line, taking bait left on the hooks, whereas giant petrels congregated around the offal ports. Black-browed albatrosses rarely scavenged for offal; equally, giant petrels rarely approached the mother line, even when few black-browed albatrosses were present. However, broken coils often passed through the group of giant petrels on the surface when being hauled in, and several birds were snagged by trailing hooks. Activity of black-browed albatrosses and giant petrels was also observed to increase when the vessel headed into the wind, and when wind velocity increased.

DISCUSSION

Randomised Sampling Method

The randomised method of sampling hauling in this study meant that data recorded after 14 April were statistically representative. Despite encouragement by CCAMLR, it has rarely proved possible to achieve 100% coverage of each line due to the expense of placing two observers aboard each vessel; where partial coverage only has been possible, data have often been collected haphazardly or systematically. Seabird interactions are unlikely to occur at random, therefore systematic sampling may be biased; data taken haphazardly do not allow an estimation of variance with known confidence (Thompson, 1992). The rarity of mortality events means full observer coverage is desirable, but where a single observer has to divide limited effort among several tasks, the sampling method developed and tested in this study allows estimation of unbiased means, variances and confidence intervals for statistical comparisons such as those identified during the meeting of WG-FSA in 1996 (SC-CAMLR, 1996). Random sampling of all hauling operations also enables the calculation of total mortalities from subsamples (Kock and Selling, 1996), as estimates of totals are interpolated from within the inferential limits of the data sampled.

Effectiveness of Streamer Line

The experiment did not demonstrate that the streamer line had an effect in preventing seabird mortalities. However, because of the low variability in the data, the experimental power was insufficient to show the converse, i.e. that the streamer line had no effect. Nevertheless, the low mortality rate with and without streamer line suggests that, if night-time setting and the other mitigating measures are properly employed, mortalities are likely to be so low that the additional use of a streamer line may give little extra advantage. Moreno et al. (1996), however, found that use of a streamer line affected the number of mortalities but that setting was frequently conducted during the day, while conversely, Capdeville (1996) found no streamer line effect around Kerguelen, even though lines were set at night and during the day. Further work is needed to establish under what conditions the streamer line is important, and when deployment may be unnecessary.

Experiments with a design similar to that used in this study can test fully the effectiveness of the streamer line under different conditions, especially where other measures are not used correctly. However, using the data from Ashford et al. (1995) to calculate an approximate mean (4.4 birds/line) and standard deviation (8.32) for mortality rate, and setting the detection level between treatments with/without a streamer line at a difference of three birds/line, it can be calculated (Thompson, 1992) that 125 replicates are needed for each treatment to achieve the required power of $1-\beta = 0.8$. As fishing voyages in the CCAMLR area rarely last more than 70 days of actual fishing, any test of the streamer line capable also of demonstrating ineffectiveness would therefore have to be designed to include data from more than one vessel.

Effectiveness of CCAMLR Measures Employed to Mitigate Seabird Mortality

Mortality rates calculated in studies in which data were sampled non-randomly (including data in this study taken before 14 April) may reflect sampling biases. Furthermore, non-random data may not fulfil the assumption of independence and identical distribution required to test for statistically significant differences between means. The present discussion is therefore limited to qualitative comparisons between

studies: data taken with either full observer coverage, or in future using the random sampling method outlined, would allow quantitative comparisons.

The seabird mortality rate found in this study included two white-chinned petrels taken when line setting continued into the early daylight hours: the rate may therefore have been lower if setting had occurred exclusively at night. Otherwise, longlining operations were in accordance with current CCAMLR conservation measures and the mortality rate was considerably lower than that of 0.48 birds/1 000 hooks reported by Ashford et al. (1995) for the 1994 season (before several of the current measures came into force) when setting occurred during the day as well as at night, deck lights were not all extinguished at night, fewer weights were attached to the line, and the streamer line was not used on every set. The mortality rate reported here was also lower than rates reported by Kock and Selling (1996) of 0.235 birds/1 000 hooks and 1.012 birds/1 000 hooks taken during the night and day respectively. Mortality rates were low for all species, with mortalities confined to white-chinned petrels and black-browed albatrosses; giant petrels and grey-headed albatrosses, found by Ashford et al. (1995) to be disproportionately affected were not caught.

Kock and Selling (1996) observed that the mortality rate declined after early May, therefore comparisons between rates calculated by observers need to account for differences in the seasonal period. In this study, hauling operations occurred on 32 days before and 16 days after 1 May; 11 of the 12 hook-related mortalities were recorded before 1 May giving a rate of 0.12 birds/1 000 hooks observed, compared to a rate of 0.02 birds/1 000 hooks observed after 1 May. The rate before 1 May is still substantially lower than those found by Ashford et al. (1995), where fishing terminated in early May, and by Kock and Selling (1996), where fishing continued from 22 February to 17 May.

No mortalities were recorded outside observation periods. This may have been due to fishermen not reporting mortalities, or to differences in definition of what constituted a mortality: the observer found that black-browed albatrosses were often referred to as seagulls and sometimes considered extraneous to the problem of albatross and petrel mortality. The condition in which dead birds arrived on board varied greatly; skeletons were considered by many fishermen to be loose corpses from previous fishing activity

randomly hooked on the seafloor, whereas they may have been mortalities from the corresponding setting operation that had been scavenged by amphipods. As all three skeletons observed in this study were hooked through the beak or gullet, the observer included them as mortalities.

The low rate of mortalities may reflect interannual variation in the marine ecosystem at South Georgia, similar to that reported from Kerguelen (Capdeville, 1996). The high rate found by Ashford et al. (1995) in 1994 was during a year marked by exceptionally low reproductive success in many marine predators. Success rates were much higher in 1997, the year of this study, which may indicate that birds had other food sources available and so did not need to take bait as intensively as during April/May 1994. Alternatively, since the fishery has been operating off South Georgia for several seasons, low mortality may be due to learned avoidance behaviour or to the cumulative effect of selective mortality on those sections of the population most vulnerable to hooking.

Seven of the nine other observers around South Georgia during the period April/May 1997 found mortality rates considerably higher than in this study, ranging from 0.23 to 0.58 birds/1 000 hooks (with one observer reporting a rate of 9.31 birds/1 000 hooks for the period from 13 March to 9 April; observer coverage for all vessels ranged from 5 to 100%, with half of the observers achieving 5 to 23% coverage, similar or lower than this study). One observer recorded an average rate of 0.02 birds/1 000 hooks but this was low because it included data from the full season through until 11 August (SC-CAMLR, 1997): eight mortalities were recorded during April, and none after 30 April (D. Keith, Scientific Observer, *Koryo Maru 11*, pers. comm.). There is therefore little evidence that the low mortality rate found in this study can be viewed as a generally reduced rate due to interannual variation or biological trends; instead, it is more likely due to the effectiveness of the mitigating measures used.

The numbers of birds recorded during setting operations were generally lower than those reported by Ashford et al. (1995), and largely confined to white-chinned petrels and albatrosses. As large numbers of birds were seen daily during most hauling operations throughout the voyage, the low numbers were not due to low availability of birds and were more likely due to setting at night.

However, numbers varied with time: the seasonal decline in numbers of white-chinned petrels and black-browed albatrosses (similar to that found by Kock and Selling (1996)) may be linked to the end of the breeding season for both species on South Georgia and northward migration of adults and fledglings away from South Georgia waters. Moreno et al. (1996) reported that the lunar cycle affected the number of bird mortalities; in this study, both albatross mortalities occurred during the full moon in April and large numbers of albatrosses were observed during setting operations but not on other nights, despite large numbers of black-browed albatrosses recorded during daytime hauling throughout April.

Mortalities were not significantly higher when the numbers of birds following the vessel were higher, which means that on these occasions other factors must have been responsible for reducing the vulnerability of birds to setting operations. The presence or absence of a streamer line had little effect; instead, low vulnerability may have been due to low light levels compared to daytime, extinguishing deck lights, or the level of weighting on the line. Weighting used in this study was lower than that found to be optimal by Brothers (1994), but produced sink rates which, with the other CCAMLR measures (including setting at night) in place, clearly did not result in any substantial mortality, even when the streamer line was not used. More work is needed to determine how CCAMLR conservation measures mitigate bird mortality, and under different conditions.

Interactions during Hauling

The number of birds hooked during hauling was higher than reported by vessels during the 1995 season (Moreno et al., 1996), and largely confined to black-browed albatrosses during daylight hours in April. Wandering albatrosses, though present, never approached close enough to the hauling point to be vulnerable; and Cape petrels rarely approached close enough to be caught in lines, even when present during May in larger numbers with no black-browed albatrosses present. Giant petrels were often present in large numbers during daylight hours and at night, and a few giant petrels were hooked by broken lines trailing past the offal ports. This may be reduced by discarding offal on the opposite side of the vessel to hauling operations. A sludge of returned bait discarded with the offal frequently contained loose hooks, and this may be a source of hooks found in nests.

Ashford et al. (1995) reported frenzied feeding behaviour when offal was discarded only after a haul was finished. In this study, the offal was discarded periodically during the haul and the behaviour was not observed. More work is needed to determine the optimal way to discard offal.

CONCLUSIONS

- (i) The available evidence indicates that current mitigating measures, most importantly night-time setting, substantially reduced mortalities and restricted mortalities to white-chinned petrels and black-browed albatrosses, when correctly applied.
- (ii) Data on mortality rates and the abundance of vulnerable seabird species indicated that delaying the start of the fishing season to the end of April could effectively reduce mortalities further.
- (iii) Where observer coverage of hauling is incomplete, randomised sampling methods are necessary to give unbiased estimates of means and variation with known levels of confidence.

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