SEABIRD MORTALITY IN THE PATAGONIAN TOOTHFISH LONGLINE FISHERY AROUND CROZET AND KERGUELEN ISLANDS, 2001–2003

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Abstract

The legal Patagonian toothfish (*Dissostichus eleginoides*) longline fishery operating in the French Exclusive Economic Zones (EEZs) of Crozet and Kerguelen Islands (Subarea 58.6 and Division 58.5.1 respectively) killed 26 668 seabirds between September 2001 and August 2003. Overall, the white-chinned petrel (*Procellaria aequinoctialis*) was the most frequently killed species, with males being more frequently caught than females. Grey petrels (*Procellaria cinerea*) were caught accidentally in large numbers over this same period. Giant petrels (*Macronectes* spp.), black-browed albatrosses (*Diomedea melanophrys*) and grey-headed albatrosses (*D. chrysostoma*) were also caught over this period.

A multivariate analysis suggests that a combination of factors (environmental and relating to fishing techniques) have an effect on the observed numbers of seabirds caught incidentally. The results of this study suggest that a significant part of the mortality of white-chinned petrels and grey petrels is explained by the time of year, geographical area and type of longliner (manual versus automatic baiting). Almost all of the incidental mortality occurred exclusively during the breeding season, except for giant petrels. The highest mortality of white-chinned petrels, grey petrels, black-browed albatrosses and grey-headed albatrosses corresponded to the chick-rearing period. In addition, the vessels using automatic baited longlines caught many more birds than those using manual baited longlines. Based on the results of this analysis, several recommendations are made with the aim of reducing the incidental mortality of the various species concerned in the French EEZs of Crozet and Kerguelen Islands (Subarea 58.6 and Division 58.5.1 respectively).

Résumé

La pêcherie à la palangre de la légine australe (*Dissostichus eleginoides*) autorisée dans les zones économiques exclusives (ZEE) françaises des îles Crozet et Kerguelen (sous-zone 58.6 et division 58.5.1 respectivement) a provoqué la mort de 26 668 oiseaux de mer de septembre 2001 à août 2003. En général, le pétrel à menton blanc (*Procellaria aequinoctialis*) était l'espèce la plus touchée, les mâles plus que les femelles. Cette même période a également connu la capture accidentelle de pétrels gris (*Procellaria cinerea*) (en grand nombre), de pétrels géants (*Macronectes* spp.), d'albatros à sourcils noirs (*Diomedea melanophrys*) et d'albatros à tête grise (*D. chrysostoma*).

Une analyse multivariable laisse supposer que le nombre observé d'oiseaux capturés par accident est le résultat d'une combinaison de facteurs (environnementaux et liés aux techniques de pêche). Il semblerait, d'après cette étude, que la mortalité des pétrels à menton blanc et des pétrels gris dépende en grande partie de l'époque de l'année, du secteur géographique et du type de palangrier (appâtage manuel ou automatique). La mortalité accidentelle a principalement eu lieu pendant la saison de reproduction, sauf pour les pétrels géants. La mortalité la plus forte du pétrel à menton blanc, du pétrel gris, de l'albatros à sourcils noirs et de l'albatros à tête grise correspond à la période d'élevage des jeunes. De plus, les navires utilisant des palangres à appâtage automatique ont capturé davantage d'oiseaux que les navires utilisant des palangres à appâtage manuel. Au vu des résultats de cette analyse, plusieurs recommandations sont émises dans le but de réduire la mortalité accidentelle des diverses espèces concernées dans les ZEE françaises des îles Crozet et Kerguelen (sous-zone 58.6 et division 58.5.1 respectivement).

Резюме

В ходе законного ярусного промысла патагонского клыкача (*Dissostichus eleginoides*), который велся в исключительных экономических зонах (ИЭЗ) Франции в районе о-вов Крозе и Кергелен (соответственно Подрайон 58.6 и Участок 58.5.1), в период с сентября 2001 по август 2003 гг. погибло 26 668 морских птиц. В целом, наиболее часто погибали белогорлые буревестники (*Procellaria aequinoctialis*), причем самцы попадались чаще, чем самки. В течение этого же периода было случайно поймано большое число серых буревестников (*Procellaria cinerea*). Также в это время наблюдался прилов гигантских буревестников (виды *Macronectes*), чернобровых альбатросов (*Diomedea melanophrys*) и сероголовых альбатросов (*Diomedea chrysostoma*).

Многомерный анализ позволяет предположить, что на наблюдавшееся количество случайно пойманных морских птиц влияет комбинация факторов (связанных с окружающей средой и с промысловыми методами). Результаты этого исследования дают основание полагать, что смертность белогорлых и серых буревестников в значительной мере объясняется временем года, географическим районом и типом ярусолова (ручное или автоматическое наживление крючков). Почти все случаи побочной смертности происходили исключительно во время сезона размножения (кроме гигантских буревестников). Самая высокая смертность белогорлых и серых буревестников, чернобровых и сероголовых альбатросов приходится на период выращивания птенцов. Кроме того, суда, использующие автоматически наживляемые ярусы, поймали гораздо больше птиц, чем те, которые используют ярусы, наживляемые вручную. На основе результатов этого анализа дается ряд рекомендаций, цель которых – сократить побочную смертность различных рассматриваемых видов во французских ИЭЗ о-вов Крозе и Кергелен (соответственно Подрайон 58.6 и Участок 58.5.1).

Resumen

La pesquería reglamentada de palangre de austromerluza negra (*Dissostichus eleginoides*) que opera en las zonas de exclusividad económica francesas (ZEE) de las Islas Crozet y Kerguelén (Subárea 58.6 y División 58.5.1 respectivamente) causó la muerte de 26 668 aves marinas entre septiembre de 2001 y agosto de 2003. En general, la especie más afectada fue el petrel de mentón blanco (*Procellaria aequinoctialis*), siendo los machos capturados con más frecuencia que las hembras. Durante el mismo período se capturó un gran número de petreles grises (*Procellaria cinerea*), además de petreles gigantes (*Macronectes* spp.), albatros de ceja negra (*Diomedea melanophrys*) y albatros de cabeza gris (*D. chrysostoma*).

Un análisis de múltiples variables sugiere que una combinación de factores (ambientales y relacionados con las técnicas de pesca) ha influido en la captura incidental de aves marinas observada. Los resultados de este estudio demuestran que una gran parte de la mortalidad de petreles de mentón blanco y grises depende de la época del año, la zona geográfica y el tipo de palangrero utilizado (cebado manual o automático). Casi toda la mortalidad incidental ocurrió exclusivamente durante la temporada de reproducción, excepto en el caso de los petreles gigantes. La mortalidad más alta de petreles de mentón blanco, petreles grises, albatros de ceja negra y albatros de cabeza gris ocurrió en la época de cría de polluelos. Además, los barcos que utilizaron el sistema automático para cebar los anzuelos capturaron más aves que los que utilizaron el sistema manual. Sobre la base de los resultados de este análisis, se formulan varias recomendaciones con miras a reducir la mortalidad incidental de diversas especies en las ZEE francesas de las Islas Crozet y Kerguelén (Subárea 58.6 y División 58.5.1 respectivamente).

Keywords: incidental mortality, seabirds, longline fishery, French EEZ, procellariids, albatross, petrel, CCAMLR

Introduction

Seabirds form an integral part of marine ecosystems. They depend entirely on the resources of the ocean for their survival, but must return to land to breed. Since the development of industrial fishing, seabirds, particularly species such as petrels, albatross and gulls, have been attracted to fishing vessels, following vessels to recover offal (Tasker et al., 2000). This additional food can have a positive effect on populations (Montevecchi, 2001). The presence of food in 'self-service' form – bait and offal discarded at sea – attracts many seabirds to fishing vessels. Seabirds are attracted by the baited hooks during the setting of the longline. Once attracted to the vessel some birds take baits and are hooked and consequently drown as the line sinks.

The high mortality rates of albatrosses induced by the longliners coupled with the concomitant decline of the number of birds in many breeding colonies of the Southern Ocean (Croxall et al., 1990; Brothers, 1991; Weimerskirch et al., 1997, 1999; Robertson and Gales, 1998) led CCAMLR to adopt in 1992 mitigation measures (use of streamer lines, night fishing and controls on the discard of offal) in an attempt to reduce the incidental by-catch of seabirds. In spite of these measures and the reduction in incidental mortality, it can still be significant, particularly in illegal and unauthorised fisheries (IUU – illegal, unregulated and unreported), assumed to apply few measures, if any, to reduce the incidental catch of seabirds (Tuck et al., 2003).

The Kerguelen and Crozet Islands are breeding areas for many species of seabirds, which number nearly 25 million individuals on each island, and appear very significant for seabird conservation (Catard, 2001). The world populations of albatrosses and large petrels are not very abundant, and some species are regarded as threatened world-wide (Baillie et al., 2004). In the Southern Ocean, incidental mortality resulting from longline fisheries represents the principal threat for many species of seabirds, especially albatrosses and petrels, which have experienced a global decrease in population size (Croxall et al., 1990; Brothers, 1991; Barnes et al., 1997; Weimerskirch et al., 1997; Cherel et al., 1996; Schiavini et al., 1998; Brothers et al., 1999b; Nel et al., 2002). Several factors may contribute to the risk of incidental capture: fishing practices and fishing equipment used, food accessibility (e.g. bait and rejected offal), environmental conditions (e.g. sea state), behaviour (foraging behaviour and feeding), body size and condition of the birds (e.g. moult, migration, general health), and the abundance and distribution of seabirds (Moreno et al., 1996; Barnes et al., 1997; Brothers et al., 1999a; Weimerskirch et al., 2000).

The aim of this paper is to present information on the incidental mortality caused by the legal longliners operating in the French Exclusive Economic Zones (EEZs) around Crozet (Subarea 58.6) and Kerguelen (Division 58.5.1) Islands. The characteristics of these vessels are detailed, and the main factors related to seabird mortality are identified by the analysis of data collected by observers during the fishing seasons 2001/02 and 2002/03. This analysis should make it possible to provide further recommendations for the reduction of the incidental catch of seabirds in these areas.

Materials and methods

Collection of data

The fishing year extends from 1 September to 31 August. There are two types of longliners, classified by hook-baiting method: manual baiting and automatic baiting. The main difference between the hook-baiting methods is that the manual method results in 100% of all hooks being baited, while sometimes only 75% are baited using the automatic baiting system. Another key difference is that the manually baited lines are weighted more heavily than the automatically baited ones. The vessels set longlines with several thousand hooks (mean ± SE manual = 7 697 ± 330 hooks, automatic = 8 992 ± 123 hooks; min. 1 100 hooks and max. 40 500 hooks per longline) and can set several longlines during one night.

Fourteen observers were employed, (one on board each of the nine licensed authorised vessels) during 2001/02 and 2002/03. The observers were instructed to collect statistical and biological data on fishing operations and to quantify the incidental mortality of seabirds by the observation of hauled hooks. It is known from other fisheries that crew members tend not to report all seabirds caught in the absence of an observer, resulting in an underestimate of the by-catch rate (Gales et al., 1998; Weimerskirch et al., 2000). It thus should be stressed that the quality of the analysed data is entirely related to the work carried out by the observers.

All the birds caught incidentally were taken aboard during hauling of the mainline and were identified at the species, genus or family level (0.05% of the birds were not identified at species level). Giant petrels (*Macronectes* spp.) were not identified at the species level.

An additional range of factors describing the interaction between seabirds and the fishing vessels were collected during each set, including number of hooks set and hauled, vessel course, swell direction, moon intensity, cloud cover, wind speed and direction, sea state, set and haul time, bait type, estimated quantity of discarded offal, line-weighting mode, number of bird-scaring lines used (mitigation measure), fish catch (Patagonian toothfish (*Dissostichus eleginoides*)). The bird-scaring system consists of one, two or three streamer lines attached at the stern. Details on the design of the streamer line and how it was set up (exact position, height

Table 1: Parameters used in the analysis of incidental mortality.

Parameters	Data
Year	Year 2001/02: from 11 September 2001 to 27 July 2002 Year 2002/03: from 1 September 2002 to 31 August 2003
Season	Summer (September to April) Winter (May to August)
Sea	Beaufort
Bait	Squid, mackerel, mackerel – squid, mackerel – horse mackerel, sardine or mixed (more than two different types).
Estimated quantity of offal	
Longline ballast (weights)	Weights of 6 to 12 kg were placed at different intervals on the mainline; data have been converted to g/m.
Vessel speed during setting	Miles per hour
Angle between vessel course and wind direction	
Angle between vessel course and swell direction	
By-catch rate	Number of seabirds per thousand hooks.
Moon brightness	Taking into account moon phase, moon position above the horizon and cloud cover.
Fishing zone	Crozet and Kerguelen subdivided into the six zones (northwest, centre-west, southwest, northeast, centre-east and southeast).
Set number	Order in which longlines are set (e.g. no. 1 is set first).

above the water) were not reported for each voyage and each vessel. Thus, it was assumed that it was in accordance with the published regulations (Official Journal of the French Southern Territories) and consistent for each voyage. More recently, the colour of the longline and the part of the body by which the bird was hooked were also recorded. The sex of white-chinned petrels (*Procellaria aequinoctialis*) was determined for 13 longlines by dissection of the body and identification of reproductive organs.

Data analysis

This analysis aims to explore the factors influencing incidental seabird mortality observed on the vessels. Comparable data were not available from unobserved vessels. The Kerguelen area was subdivided into six fishing zones to correct for unbalanced sampling and to increase the accuracy of the information.

The data analysis used parameters collected in the field (e.g. sea state, bait type, setting speed, estimated quantity of discarded offal, and weighting mode), calculated parameters regrouping several individual field parameters (e.g. angle between vessel and wind direction, and angle between vessel and swell direction) and supplementary information (e.g. moon brightness and the fishing zone) (Table 1).

Relationships between seabird by-catch (number of seabirds caught per longline) and a range of spatial, temporal, physical and inherent parameters describing the longline fishery (explanatory variables) were explored using statistical models. The analysis was based on generalised linear mixed models (GLMMs) to account for autocorrelation of the data. Indeed some factors were linked from one day to the next (e.g. sea state), while others were intrinsically linked to vessels throughout the entire trip (the vessel cannot change fishing methods mid-trip). As a result, 'vessel' was considered as a random factor in the mixed models, and all other factors as fixed effects to explain variation in the number of seabirds caught per longline. The statistical software SAS (SAS, 1998–2001) was used to analyse the data. The modelling approach used was developed by building general models that included all individual factors and interactions. Interactions to be tested were selected by *a priori* graphical exploration of the data. This led us to include the following interactions: season–type of longliner, area–type of longliner, moon brightness–season, setting rank–season and area–season. All relevant parameters were tested for each analysis (except vessel and observer as they are redundant). The redundancy of the variables fishing observer, vessel and longline type, made it impossible to determine whether or not there was an observer effect. Type 3 tests of fixed effects were used to infer the statistical significance of factors and interactions on the number of seabirds killed. The deviance ratio of

Table 2: Summary of observed incidental mortality of seabirds.

	2001/02	2002/03	Total
Period	12 months	12 months	24 months
Total (number of seabirds)	12 057	14 611	26 668
Number of hooks set	18 994 603	33 432 123	52 426 726
Mean mortality rate	0.63 ± 0.04	0.46 ± 0.02	
(Number seabirds/thousand hooks)	(0–52.5)	(0–20.8)	

the saturated model, the constant model and the model including the fixed factors were calculated to obtain an estimate of the proportion of variance explained by fixed factors.

Data concerning each year of the study were analysed separately, as were data on white-chinned petrels and grey petrels (*Procellaria cinerea*), because of the strong data heterogeneity and the very low occurrence of by-catch of the other species (giant petrel, black-browed albatross (*Diomedea melanophrys*) and grey-headed albatross (*D. chrysostoma*)). The effectiveness of the mitigation measure in reducing incidental mortality (bird-scaring line) could not be analysed because of data scarcity and heterogeneity. However, the effect of the mainline colour on by-catch could be analysed using a subsample of data for all species combined (1 633 white-chinned petrels, 98 grey petrels, 6 grey-headed albatrosses, 6 black-browed albatrosses and 1 giant petrel).

Results

Incidental mortality

This study gives the results for 5 892 longlines (52 426 726 hooks) deployed from 1 September 2001 to 31 August 2003. A total of 26 668 seabirds were counted as having been killed during this period with a mean by-catch rate of 0.63 and 0.46 birds/thousand hooks respectively in 2001/02 and 2002/03 (Table 2). Although the number of seabirds caught in 2002/03 was greater than the number caught in 2001/02, the associated by-catch rate was less (due to a greater fishing effort, the number of deployed hooks increased by 76%, Tables 2 and 3). Also noteworthy is the fact that mortality is higher in summer than in winter, and higher at Kerguelen than at Crozet (Table 3).

The spread of fishing effort extended considerably in the Kerguelen area during the two years whereas the spread in effort decreased in the Crozet area. The effort of the fishing vessels was very heterogeneous according to the year, the EEZ and the month, with fishing pressure much more significant during 2002/03.

Temporal variation in incidental mortality

The seabird by-catch occurs mainly during two periods (Figure 1): from October to November (in 2001/02, 17.2% of mortality for 20.3% of the hooks compared to 32.1% of mortality for 16.3% of the hooks in 2002/03) and from January to April (in 2001/02, 78.1% of mortality for 38.9% of the hooks compared to 64.5% of mortality for 37.6% of the hooks in 2002/03). Fishing effort is temporally more evenly dispersed throughout the year, although it does vary considerably between months and between years. Overall, fishing effort and mortality are higher for each month in 2002/03. Consequently, the mean by-catch rate varies between months and according to the year (min. 0.03 ± 0.004 and max. 2.17 ± 0.26 birds/thousand hooks) with increased by-catch rates from October to November (0.34 ± 0.06–1.01 ± 0.11 birds/thousand hooks) and from January to April (0.21 ± 0.02–2.17 ± 0.26 birds/thousand hooks).

Geographic variation in incidental mortality

A significant part of the yearly variation observed during the two periods with high incidental mortality can be accounted for by the area (Crozet and Kerguelen subdivided into six zones) (Figure 2). Incidental by-catch (by-catch rate Figure 2a and numbers of birds Figure 2b) varies considerably for a particular year according to the geographical area, and for a particular zone according to the year.

Geographical variations in by-catch also differs during the year. However, the number of seabirds killed incidentally remains fewer at Crozet, whatever month and year (Figures 3a and 3b), for a lower or similar fishing effort compared to Kerguelen. In 2001/02, the mean by-catch rate observed was 0.95 ± 0.07 birds/thousand hooks (0–52.5) at Kerguelen and 0.17 ± 0.01 birds/thousand hooks (0–4.67) at Crozet. Mortality varies at Kerguelen from 0.08 ± 0.02 (December) to 4.68 ± 0.47 birds/thousand hooks (February) and at Crozet from 0.003 ± 0.003 (September) to 0.51 ± 0.06 birds/thousand hooks (March).

Table 3: Summary of fishing effort, incidental seabird mortality and of fishing per year and offal discarded.

	Summer (September to April)				Winter (May to August)			
	2001/02		2002/03		2001/02		2002/03	
Duration of fishing:	8 months		8 months		4 months		4 months	
EEZ:	Kerguelen	Crozet	Kerguelen	Crozet	Kerguelen	Crozet	Kerguelen	Crozet
Effort								
Hooks set	8 930 630	4 170 773	18 098 500	5 404 075	2 618 000	3 275 200	8 761 598	1 167 950
Lines set	922	508	1 986	616	339	367	1 044	130
Total observed mortality	10 451	1 153	13 166	684	363	90	742	19
White-chinned petrel (*Procellaria aequinoctialis*)	10 055	1 110	12 965	627	34	3	24	0
Giant petrel (*Macronectes* spp.)	4	26	15	33	17	41	3	8
Grey petrel (*Procellaria cinerea*)	354	1	117	10	311	28	711	11
Unidentified petrel	1	0	0	0	0	2	0	0
Black-browed albatross (*Diomedea melanophrys*)	17	1	49	12	0	0	0	0
Grey-headed albatross (*Diomedea chrysostoma*)	15	10	10	0	0	11	1	0
Unidentified albatross	2	2	0	0	0	0	0	0
Unidentified seabird	1	1	0	0	1	4	1	0
Estimated mortality *	10 653	1 168	13 346	701	366	95	752	20
Lines with mortality	68.1% (628)	50.6% (257)	56.8% (1 128)	33.9% (209)	37.5% (127)	12.5% (46)	27.9% (291)	11.5% (15)
Lines > 1 seabird	510	169	939	124	87	20	163	4
Maximum mortality (number of seabirds/line)	190	49	209	58	25	12	12	2
Mortality rate (number of seabirds/thousand hooks)	1.24 ± 0.09 (0–52.5)	0.27 ± 0.02 (0–4.7)	0.78 ± 0.04 (0–20.8)	0.15 ± 0.02 (0–4.4)	0.15 ± 0.02 (0–3.3)	0.03 ± 0.01 (0–2.4)	0.09 ± 0.007 (0–3.9)	0.02 ± 0.004 (0–0.3)
Offal (tonnes)	1 524	368	2 389	377	358	241	1 005	83

* Calculated taking into account the loss of hooks between setting and hauling.

In 2002/03, the mean by-catch rate observed at Kerguelen was 0.53 ± 0.03 birds/thousand hooks (0–20.8) and 0.12 ± 0.01 birds/thousand hooks (0–4.4) at Crozet. At Kerguelen, the rate varied from 0.036 ± 0.005 (May) to 1.475 ± 0.126 birds/thousand hooks (February), while at Crozet it ranged from 0.003 ± 0.003 (July) to 0.412 ± 0.12 birds/thousand hooks (February).

Variation with vessel type: automatic versus manual baiting

Fishing effort varies considerably during a year (2001/02: 1 500 000–4 000 000 hooks; 2002/03: 2 820 000–5 600 000 hooks) and the mean by-catch rate varies according to the vessel (2001/02: 0.14 ± 0.03–1.41 ± 0.13 birds/thousand hooks; 2002/03: 0.14 ± 0.02–0.91 ± 0.09 birds/thousand hooks).

During 2001/02 incidental by-catch differs for the various vessels, with 90% of mortality unevenly distributed between four of the seven fishing vessels, with one of the vessels taking nearly half of all incidental by-catch. Nearly 80% of incidental by-catch for each species was caused by only two vessels (Table 4).

Although the incidental by-catch was more evenly distributed between the fishing vessels in 2002/03, 89% of mortality occurred on five of the seven vessels and nearly half on just two vessels. The contribution of the vessels to the mortality of the various species is however different from the previous year. Between 70 and 80% of the incidental mortality of giant petrels, black-browed and grey-headed albatrosses was caused by only one or two vessels, whereas the mortality of white-chinned and grey petrels was distributed in a more homogeneous way on all the vessels: 80% of the incidental catch were due to four different vessels.

During the years considered, vessels using manual baiting had a lower by-catch rate than those using automatic baiting (Figures 4a and b). The by-catch rate was up to 13 times higher for automatic than for manual vessels (and the sample size is more than twice as large). Variability of the by-catch rate between automatic vessels was observed (2001/02: min. 0.17 ± 0.02, max. 1.41 ± 0.13 birds/thousand hooks; 2002/03: min. 0.24 ± 0.02, max. 0.91 ± 0.09 birds/thousand hooks).

Species composition of incidental mortality

From September to April, white-chinned petrels represent 96 to 98% of mortality (Table 3) irrespective of year, followed by grey petrels, giant petrels and two species of albatrosses (grey-headed albatross and black-browed albatross). During the remaining part of the year (May to August), grey petrels account for 75 to 95% of total mortality, followed by white-chinned petrels and giant petrels, the latter constituting a significant part of the by-catch.

A total of 130 individual albatrosses (grey-headed and black-browed) were caught incidentally during these two years. Among the anecdotal catch were one king penguin (*Aptenodytes patagonicus*), one gentoo penguin (*Pygoscelis papua*), two macaroni penguins (*Eudyptes chrysolophus*) and seven cape petrels (*Daption capense*). Five banded black-browed albatrosses were reported incidentally killed at Kerguelen. All have been ringed at the breeding colony at 'Caňon des sourcils noirs' (Kerguelen), a colony monitored for long-term demographic studies. Two individuals had been banded as chicks in 1994 and 1996 (9 and 7 years old), three had been banded as adults between 1991 and 2002 (7, 9 and 17 years old) and all were breeding in this colony (D. Besson, pers. com.).

The temporal distribution of mortality is comparable for the two years, and is linked to the reproductive cycle of the species most frequently caught (Figure 5). Almost all mortality occurs during the breeding season except in the case of giant petrels. The highest mortality of white-chinned petrels, grey petrels, black-browed and grey-headed albatrosses corresponds to the chick-rearing period.

Catch details and sex ratio of the incidental by-catch

The body parts by which seabirds were caught on the hooks was recorded for a subsample of 7 299 individuals (including 6 452 white-chinned petrels, 13 giant petrels, 792 grey petrels, 9 grey-headed albatrosses and 30 black-browed albatrosses). The majority of individuals were hooked in the body, i.e. foul-hooked (76% in the wing, 2% in the neck and 3% in the foot), while a smaller number were hooked by the beak (19%).

The sex of 379 white-chinned petrels was determined. These birds were caught incidentally by vessel 3, on 13 lines set from 19 January to 12 February 2003 (chick-rearing period), in the Kerguelen EEZ. The sex ratio is significantly skewed towards the males ($\chi^2 = 58.74$, d.l. = 12, $P < 0.0001$; 79% of males and 21% of females).

Table 4: Incidental by-catch of seabirds by species and vessel during 2001/02 and 2002/03. Highlighted lines refer to manual-baiting longliners (vessels 5 and 7).

Vessel	White-chinned petrel (%)		Giant petrel (%)		Grey petrel (%)		Grey-headed albatross (%)		Black-browed albatross (%)	
	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03	2001/02	2002/03
1	11.3	16.6	-	7.1	5.0	32.2	38.9	-	-	-
2	2.9	-	-	-	60.8	-	-	-	-	-
3	23.4	20.5	13.6	-	2.4	6.1	-	-	22.2	1.6
4	0.3	15.2	42.0	1.8	26.8	4.2	47.2	18.2	-	13.1
5	2.6	-	-	-	0.1	-	11.1	-	5.6	-
6	12.4	10.2	-	3.6	0.1	22.7	-	45.5	-	11.5
7	-	3.0	-	-	-	4	-	-	-	-
8	47.1	7.5	44.3	14.3	4.6	17.3	2.8	-	72.2	-
9	-	27.0	-	73.2	-	13.4	-	36.4	-	73.8

Table 5: Results of the model of the factors influencing the variation of incidental catch of white-chinned petrels in 2001/02 and 2002/03. ns: not significant; - : data not available; DF: degree of freedom.

Factor	2001/02				2002/03			
	Num DF	Den DF	*F* Value	*P* Value	Num DF	Den DF	*F* Value	*P* Value
Season	1	1464	31.61	<0.0001	1	2436	2.01	ns
Type of longliner	1	1464	5.00	<0.05	1	2436	35.37	<0.0001
Bait	1	1464	0.21	ns	1	2436	6.15	<0.05
Longline ballast	-	-	-	-	1	2436	55.56	<0.0001
Moon brightness	1	1464	0.48	ns	1	2436	0.16	ns
Sea	1	1464	2.54	ns	1	2436	1.72	ns
Number of hooks hauled	1	1464	28.96	<0.0001	1	2436	7.09	<0.01
Setting speed	-	-	-	-	1	2436	33.64	<0.0001
Quantity of offal	1	1464	21.97	<0.0001	1	2436	36.98	<0.0001
Set number	1	1464	5.14	<0.05	1	2436	2.96	ns
Area	6	1464	1.63	ns	6	2436	12.22	<0.0001
Wind/vessel angle	5	1464	1.89	ns	5	2436	0.86	ns
Swell/vessel angle	-	-	-	-	5	2436	0.89	ns
Season–type of longliner	1	1464	1.72	ns	1	2436	86.24	<0.0001
Area–type of longliner	5	1464	7.47	<0.0001	4	2436	2.61	<0.05
Moon brightness–season	1	1464	0.02	ns	1	2436	0.44	ns
Setting rank–season	1	1464	8.05	<0.01	1	2436	6.15	<0.05
Area–season	5	1464	18.52	<0.0001	6	2436	10.47	<0.0001

Deterrent systems

Information on the use and number of streamer lines was available for 49.5% of the sets: 39.9% used single, 57.6% used double and 2.5% used triple streamer lines. A failure in the use of this mitigation measure was reported in 2.6% of the sets: 87% of the failures involved a single streamer line, 3.9% a double streamer line and 9.1% a triple streamer line. The sets for which problems were reported caught 492 birds (including 478 white-chinned petrels, eight grey petrels and three giant petrels) and correspond to 3 499 676 hooks set. This means that 2.3% of the total effort occurred without any deterrent in place.

Data on line weighting were available for 48.5% of the sets and the regime used varied considerably from 155.7 ± 0.8 g/m for the manual-baiting longliners (6 kg every 40 m; min. 139.5 and max. 166.7 g/m) to 34.6 ± 0.2 g/m for the automatic-baiting longliners (8 kg every 250 to 500 m; min. 14.3 and max. 58.3 g/m).

Analysis of the factors influencing the variation of incidental catch

White-chinned petrel

The results of the multivariate analysis (GLMM) are presented in Table 5.

The incidental mortality of white-chinned petrels varied significantly according to vessel type, quantity of discarded offal, set number and number of hooks hauled (Figures 6, 7; Table 5) irrespective of year. The mean number of white-chinned petrels caught by the manual-baiting longliners was much lower than for automatic-baiting ones (in 2001/02: 1.4 ± 0.3 and 5.7 ± 0.4 seabirds/line; in 2002/03: 0.9 ± 0.1 and 3.9 ± 0.2 seabirds/line respectively). In addition, this relation differed according to the area as suggested by the significant interaction area–type of longliner (Figure 6; Table 5). This reflects the strong heterogeneity of fishing effort of vessels of different types in different areas.

The by-catch of white-chinned petrels varied with set number, with more birds being caught by the first set than by the following sets (Figure 7). This trend appeared mainly in summer and differed between years. The quantity of discarded offal affected the mortality of white-chinned petrels, with more petrels tending to be caught when the quantity of offal increased.

The numbers of white-chinned petrels caught differed greatly between areas in summer, the lowest by-catch being observed in Crozet irrespective of year (Figure 8). There were also important differences between the zones in the Kerguelen sector both within and between years. Irrespective of year, the lowest number of seabirds caught were observed in winter, with a more marked difference in 2001/02.

The number of hooks hauled influenced the mean number of white-chinned petrels killed. Mortality appeared to increase when the number of hooks hauled increased.

Longline weight and setting speed, although not available during 2001/02, significantly affected the mortality of white-chinned petrels. The numbers killed decreased when setting speed and weight increased.

Moon brightness, sea state, angle between vessel course and wind or swell direction appeared not to have an effect on mortality.

Grey petrel

The results of the multivariate analysis (GLMM) are presented in the Table 6. A lower number of factors seemed to affect the mortality of grey petrels on longlines.

The incidental mortality of grey petrel was affected by moon brightness and area (Figures 9, 10; Table 6) irrespective of year. The number of grey petrels caught differed between areas, the lowest by-catch being observed at Crozet regardless of year (Figure 9). Irrespective of year, fewer seabirds were observed to be caught in summer, with a more marked difference in 2001/02. As for the white-chinned petrel, the interaction between area and season was significant, which probably revealed the heterogeneous fishing effort between areas and seasons.

The number of grey petrels caught was affected by moon brightness (Figure 10) irrespective of year, with more seabirds being caught when moon brightness increased. The lowest mean number of grey petrels was caught with no moon. However, this relationship varied between seasons, as suggested by the significant interaction between season and moon brightness.

In 2001/02, the by-catch of grey petrels varied with set number and season. In winter more birds were caught by the first set than by the following sets (Figure 11), and in summer the trend was reversed.

Table 6: Results of the model of the factors influencing variations in incidental catch for grey petrels in 2001/02 and 2002/03. ns: not significant; - : data not available; DF: degree of freedom.

Factor	2001/02				2002/03			
	Num DF	Den DF	*F* Value	*P* Value	Num DF	Den DF	*F* Value	*P* Value
Season	1	1464	31.88	<0.0001	1	2436	0.81	ns
Type of longliner	1	1464	0.37	ns	1	2436	0.74	ns
Bait	1	1464	0.18	ns	1	2436	0.12	ns
Longline ballast	-	-	-	-	1	2436	0.10	ns
Moon brightness	1	1464	17.28	<0.0001	1	2436	55.35	<0.0001
Sea	1	1464	2.01	ns	1	2436	2.18	ns
Number of hooks hauled	1	1464	0.52	ns	1	2436	0.16	ns
Setting speed	-	-	-	-	1	2436	3.39	ns
Quantity of offal	1	1464	0.02	ns	1	2436	0.79	ns
Setting rank	1	1464	16.13	<0.0001	1	2436	0.15	ns
Area	6	1464	5.95	<0.0001	6	2436	12.93	<0.0001
Wind/vessel angle	5	1464	0.85	ns	5	2436	0.47	ns
Swell/vessel angle	-	-	-	-	5	2436	0.71	ns
Season–type of longliner	1	1464	0.13	ns	1	2436	14.13	<0.01
Area–type of longliner	5	1464	0.14	ns	4	2436	7.74	<0.0001
Moon brightness–season	1	1464	14.84	<0.01	1	2436	59.27	<0.0001
Setting rank–season	1	1464	15.07	<0.01	1	2436	2.67	ns
Area–season	5	1464	21.74	<0.0001	6	2436	8.77	<0.0001

Table 7: Results of analysis of the effect of mainline colour on incidental catches in 2002/03. ns: not significant; DF: degree of freedom.

Factor	2002/03			
	Num DF	Den DF	*F* Value	*P* Value
Month	1	240	16.12	<0.0001
Bait	1	240	0.02	ns
Longline ballast	1	240	0.00	ns
Moon brightness	1	240	8.38	<0.01
Sea	1	240	4.88	<0.05
Number of hooks hauled	1	240	0.70	ns
Setting speed	1	240	2.16	ns
Quantity of offal	1	240	0.23	ns
Setting rank	1	240	2.10	ns
Area	5	240	7.28	<0.0001
Wind/vessel angle	5	240	0.17	ns
Swell/vessel angle	5	240	0.35	ns
Mainline colour	1	240	12.95	<0.01
Mainline colour–area	6	240	4.86	<0.01
Mainline colour–setting rank	1	240	3.42	ns
Moon brightness–month	1	240	4.36	<0.05
Setting rank–month	1	240	0.37	ns
Area–month	5	240	6.24	<0.0001

In 2002/03, the mean number of grey petrels caught in summer was much lower than in winter regardless of vessel type (manual baiting: 0.06 ± 0.02 and 0.13 ± 0.05 seabirds/line in summer and winter respectively; automatic baiting: 0.05 ± 0.01 and 0.72 ± 0.05 seabirds/line in summer and winter respectively). In addition, mortality differed with vessel type and area (automatic: 0.028 ± 0.007 to 0.381 ± 0.058 seabirds/line; manual: 0 to 0.588 ± 0.299 seabirds/line). This probably reflected the strong heterogeneity of the fishing effort of vessels of different types in different areas (all areas are not fished by both types of vessels).

Effect of mainline colour on by-catch

Data for a subsample of three vessels during the 2002/03 summer were analysed for all species caught.

In addition to the factors mentioned in the previous analyses (Table 5), the incidental catch varied with the colour of the mainline (Table 7). The number of seabirds killed was higher for black mainlines than for white ones irrespective of area (Figure 12). The mortality observed for black mainlines varied greatly according to the area (1.5 ± 0.4–20.4 ± 6.5 seabirds/line) but remained higher than that observed for white mainlines (0–1.34 ± 0.5 seabirds/line).

Discussion

Incidental mortality

A minimum of 26 668 seabirds were counted as having been killed from September 2001 to August 2003 and overall, the white-chinned petrel was the most frequently killed species (75–98% depending on the season), with more males being caught than females. The data on incidental mortality reported here are amongst the highest observed for the CCAMLR statistical areas. Night setting has reduced considerably the incidental catch of albatrosses, and even eliminated this problem for some very threatened species. However, it also caused an increase of incidental mortality for other species, particularly the white-chinned petrel, which seems particularly vulnerable due to its nocturnal behaviour and long foraging trips. Thus, white-chinned petrels can potentially interact with several longline fisheries during a single foraging trip (Weimerskirch et al., 1999).

The seasonality observed in by-catch should be compared to the constraints related to the reproductive cycle of the species caught incidentally (cf. Figure 5). Mortality occurred exclusively during the breeding period except in the case of the giant petrel. Several studies have shown that albatrosses and petrels reduce their foraging areas during the chick-rearing period, due to the constraints related to the frequent feeding of chicks (Berrow et al., 2000; Catard et al., 2000; Weimerskirch et al., 1997). Whereas during incubation they forage over several thousand kilometres, during the chick-rearing period they spend a significant part of their foraging time at the edges of the peri-insular shelf where the fisheries are located. This results in a significant overlap between the main seabird foraging zones and the fishing zones exploited by the longliners, and explains the increased mortality during the chick-rearing period.

Five banded black-browed albatrosses were reported incidentally killed at Kerguelen and two of these adults were breeding (egg and chick stage), implying a disruption of the pair bond and breeding failure.

Catch details and sex ratio

Birds killed on longlines are hooked mostly through the wing. Similar results were reported for the longliners fishing around the Prince Edward Islands (Nel et al., 2002). This may be related to the speed of lines bearing the hooks changing significantly in the water column due to changes in line tension caused by wave action (Nel et al., 2002). This can be due either to the operation of the fishing vessel (vessel speed too high during setting, or problems during the setting) or to environmental conditions (heavy sea or strong wind and/or current). It is also possible that lines are not sufficiently 'detectable' by birds, particularly as a consequence of the large proportion of unbaited hooks on automatically baited longlines.

Several studies reported an incidental mortality skewed towards one sex for Procellariiformes, towards females for wandering albatrosses and grey petrels (Weimerskirch and Jouventin, 1987; Bartle, 1990), and towards males for white-chinned petrels, grey-headed albatrosses and yellow-nosed albatrosses (Nel et al., 2002; Ryan and Boix-Hinzen, 1999). Several hypotheses were proposed: a difference in foraging area between males and females and/or male/female competition on the foraging grounds (during the discarding of offal or during setting) excluding the females with a smaller body size and those displaying less aggression. It is suspected that such a sex-biased mortality also exists for the northern giant petrel, as females and males present very different foraging ecology (González-Solís et al., 2000). The white-chinned petrel is a monogamous Procellariiform and its reproductive success depends on the bond fidelity of the pair. Consequently, we suspect that pair bond disruption caused by longline mortality of adults significantly reduces the potential for breeding success, especially when accompanied by artificial sex-biases. Thus, it appears necessary to have information on the sex of the birds caught for a greater proportion of the by-catch, and also their breeding status.

Factors implied in variations in the incidental catch of white-chinned and grey petrels

The absence of homogeneous sampling makes data analysis complex and difficult to interpret. The models used for the analysis only partly explain the variability in mortality (30–40%). General trends can nevertheless be highlighted for the two main species caught (white-chinned and grey petrels): year, season and geographical area are factors influencing incidental catch. Similar results have been shown in several studies (Klaer and Polacheck, 1998; Brothers et al., 1999a; Weimerskirch et al., 2000; Reid and Sullivan, 2004). Mortality varies with season and is higher during the breeding period, particularly during the chick-rearing period: the mean number of white-chinned petrels killed per line is higher in summer (September–April), and the mean number of grey petrels killed per line is higher in winter (cf. Figures 1 and 5). In addition, incidental mortality is much higher at Kerguelen than at Crozet (cf. Figures 1, 2 and 3) irrespective of month and year. The estimate of incidental mortality for Crozet can be compared with that observed for the Prince Edward Islands (Subarea 58.7) at the end of the 1990s. We propose that the size of breeding populations, which is much greater at Kerguelen than at Crozet (see Table 8), probably explains this difference. Inside the Kerguelen EEZ, mortality is variable with some particularly problematic areas (north and centre-east) having by-catch rates of more than 1 bird/thousand hooks.

An impact index was built for the breeding populations, based on the mean by-catch rate for the year 2001/02 (highest rates) compared to the size of breeding populations estimated by area. Even though white-chinned petrels represent the main component of the mortality, the impact on the population is also very significant for grey petrels, grey petrel populations being 10 to 20 times smaller than those of the white-chinned petrels. Thus, the relative impact (calculated using the lowest estimate of population size) on the local populations of the two main species caught in the fisheries, white-chinned and grey petrels, is considerable (Figure 13; Table 8).

All the species caught on longlines breed at Crozet and Kerguelen (Table 8), and it can be assumed that a large proportion of the birds caught are breeding adults from these sites. Thus, for the petrels, a significant proportion of the breeding population is killed each year, which is likely to cause a decline in the populations of white-chinned

Table 8: Estimates of the number of breeding pairs, population size and number of seabirds accidentally caught by year. The available estimate of the breeding populations are for 1984 at Crozet and for 1989 at Kerguelen (Jouventin et al., 1984; Jouventin et al., 1988; Weimerskirch et al., 1988). Accuracy varies according to the species, certain species being more difficult to estimate because of their nesting habits (e.g. white-chinned petrel and grey petrel which are burrow-nesting species).

	Estimated number of breeding pairs	Estimated breeding population size	Number of birds killed per year		Percentage of population captured per year (based on the minimum number of pairs)	
			2001/02	2002/03	2001/02	2002/03
Crozet						
Grey-headed albatross	5 940	11 880	21	0	0.18	0
Northern giant petrel	1 000	9 252	67	41	0.72	0.44
Southern giant petrel	1 313					
White-chinned petrel	20 000–30 000	80 000	1 113	627	1.39	0.78
Grey petrel	2 000–5 000	8 000	29	21	0.36	0.26
Kerguelen						
Black-browed albatross	3 115–3 215	6 230	17	49	0.27	0.79
Grey-headed albatross	7 900	31 600	15	11	0.05	0.04
Northern giant petrel	1 450–1 800	5 812	21	18	0.36	0.31
Southern giant petrel	3–5					
White-chinned petrel	100 000–300 000	400 000	10 462	12 989	2.62	3.25
Grey petrel	5 000–10 000	20 000	665	828	3.33	4.14

Table 9: Summary of measures recommended to reduce seabird mortality, index of reliability and number of birds 'saved' by the application of these measures, calculated on the basis of observed mortality in 2001/02 (total of 12 057 birds killed) except for (a) for which the number of 'saved' birds corresponds to the average over the two years of fishing.

Recommendation	Measure to be applied	Number of 'saved' birds	Index of reliability of measure
a	No fishing during chick-rearing periods for petrels:		
	February–March	–5900	* * *
	October–November	–3500	
b	Fishing effort: Crozet +30%, Kerguelen –30%	–2100 to –2600	* *
c	White mainline	–2000 to –3000	* *
d	Reduction of fishing effort in the zones: northeast, northwest and centre-east	–3000	*

and grey petrels. The impact is likely to be more significant at Kerguelen than at Crozet (Table 8; white-chinned petrel: 2.6 and 3.3% of the population and grey petrel: 3.3 and 4.2% of the population in 2001/02 and 2002/03 respectively). It should be noted that mortality is not negligible for the black-browed and grey-headed albatrosses, particularly for the black-browed albatross, for which one colony seems particularly affected. It therefore appears important to be able to confirm the breeding status of the birds killed.

The approach developed above is only exploratory as there are still some major uncertainties regarding the size of the breeding populations, particularly for white-chinned and grey petrels. Specific surveys are needed for these species to estimate precisely and accurately the size of their breeding populations. Demographic parameter estimates are also needed so that these can be integrated into population models. This would make it possible to model the impact of the numbers of birds caught in fisheries on specific population growth rates.

The results indicate that the set number has an effect on the mortality of white-chinned and grey petrels, which differs between seasons. In summer, more white-chinned petrels were caught during the first set of the night than in the following ones. The same trend was observed for grey petrels but only in winter (the trend was reversed in summer). Among the petrels following the vessel, it is possible that the more 'famished' birds are more 'motivated' or show riskier behaviours towards baited hooks and are thus caught during setting.

The incidental mortality of white-chinned petrels varied according to the vessel type: less seabirds were caught by manual-baiting longliners than by the automatic-baiting ones. This may be partly related to the proportion of baited hooks and to the line weighting (the manual-baiting longliners use more heavily weighted longlines). These characteristics may make manual vessels less attractive for birds and the baited lines may be less accessible if they sink more quickly. However, it should be noted that data on other factors related to fishing practices could not be taken into account in the analysis (e.g. time between offal discharge and the beginning of the set, bait thawing, line sink rate or type and quality of mitigation measures used), which may explain why one vessel may catch more birds than another. Further investigation of the comparison between the two methods (automatic/manual) appears necessary as vessel type seemed not to affect the number of grey petrels killed.

As mentioned in other studies (Gales et al., 1998; Weimerskirch et al., 2000), moon brightness had no effect on the number of white-chinned petrels caught, whereas it significantly affected the number of grey petrels killed (Moreno et al., 1996; Barnes et al., 1997; Brothers et al., 1999a).

Other factors affected the mortality of white-chinned petrels: the number of hooks hauled, longline weight, setting speed and quantity of offal discarded. Mortality appeared to increase when the number of hooks hauled increased, and decreased when setting speed and line weight increased. More petrels tended to be caught when the quantity of offal increased. Regarding this latter effect, contradictory results have been obtained by several studies (see Cooper et al., 2001). It can be assumed that with increasing offal discharge, the attractiveness of the vessels increases and that seabirds are attracted to and then follow the vessel. The interspecific competition for discards with larger species (giant petrel or black-browed albatross) has become stronger and increases the seabirds' motivation to take baits during setting. Diving capability and high motivation for baits on baited hooks may explain their capture. A behavioural study of the birds (attacks on and capture rates of offal, interspecific competition etc.) during the discharge of offal could increase the understanding of this interaction.

Finally, some factors appeared to affect the mortality of seabirds, but the underlying behavioural mechanisms remained unclear. For example, the number of grey petrels, not white-chinned petrels, caught increased with moon brightness. This may be due to the species' specific foraging behaviour at night, but this remains to be demonstrated, using satellite telemetry for example.

Streamer lines and colour of line

It was not possible evaluate the effect of the number of streamer lines on by-catch on French EEZ during the study period. Nevertheless, of all deterrent devices available, streamer lines are being recommended and used with greater frequency in the majority of the longline fisheries throughout the world. Some studies show the effectiveness of these measures (Ashford et al., 1994; Melvin et al., 2001) and some results suggest that the use of double streamer lines is more effective than the use of single streamer lines (Melvin et al., 2001), reducing the incidental catch by 94% compared to sets without a streamer line (as against 71% for the use of a single line). In this context, it appears necessary to determine the optimal design and the configuration of streamer lines for the species which most commonly interact with the fisheries, via an experimental approach (in particular the study of quantifiable measures of seabird behaviour). It is therefore recommended that a minimum of two streamer lines be used in the French EEZ.

The number of seabirds killed was higher for black mainlines than for white ones irrespective of area. It is hypothesised that when the birds dive, they detect and avoid more easily white-coloured lines and thus the hooks. More experimental work is needed to test the effect of the colour of the lines, which may constitute an effective way of reducing incidental mortality.

Conclusions

The results presented in this study, and the complexity of the factors affecting the mortality of seabirds, mean that no single solution exists. Even the closure of the legal fisheries would be likely to involve an increase in illegal fishing and therefore be even more lethal to seabirds (unless the EEZs were put under permanent continuous surveillance by the French navy). Insofar as certain factors are worse than others, the authors attempt to treat in a hierarchical manner measures which could have an impact by decreasing by-catch. These conclusions are tentative, because the application of a measure can produce unforeseeable effects (prohibiting daytime fishing solved the problem with albatrosses, but exacerbated the problem with white-chinned petrels). Another difficult problem is to identify the objectives in reduction of the mortality of seabirds. If the objective is to reduce total mortality (absolute number), moving the fishing season to operate in winter only would reduce considerably the total number of birds killed, principally white-chinned petrels, as is recommended by the CCAMLR and applied in South Georgia. However, this measure would potentially involve a significant mortality (in relative numbers) of grey petrels (which do not reproduce in South Georgia), catastrophic for the Kerguelen population, and even for the species, whose world population size is relatively low. Thus, it is a difficult conservation choice.

In order to reduce mortality significantly, the authors propose that the following measures be applied to the French Southern Territories. These recommendations are made to reduce incidental mortality, and have not considered the impact on the fishers' ability to catch fish. If accepted, these measures should be optimised to try not to penalise the legal fishers. The number of birds that might be saved by each measure independently is summarised in Table 9.

(i) Prohibit fishing during the critical breeding period (chick rearing) of white-chinned and grey petrels, i.e. a minimum of 50 days in February–March and 60 days in October–November.

(ii) Increase fishing effort at Crozet by 30%, and reduce fishing effort at Kerguelen by 30%.

(iii) Require the use of white mainlines on automatically baited longlines.

(iv) Reduce fishing effort in the following zones around Kerguelen: northeast, northwest and centre-east.

The data would allow for further investigation of the comparison between the two methods (automatic/manual), and of reasonable line-weighting regimes on automatic-baiting longline vessels.

The numbers of 'saved' birds reported in Table 9 are not directly cumulative. Unless radical measures are taken (application of all measures to the whole fleet), it would seem that the ideal is to partially apply a series of measures. For instance, if measures a, b and c are applied partially, it is predicted that the decrease of mortality could reach 6 000 to 8 000 seabirds/year, a very encouraging result. In addition, it appears essential to use the most efficient measures (double streamer lines and weighting of the mainline to avoid as far as possible the interactions between seabirds and baited hooks). The authors consider that fishing only in winter as in other CCAMLR sectors would not solve the problem, because increased effort during winter would still endanger a species more vulnerable than the white-chinned petrel: the grey petrel.

The difficulty is clearly to find a reasonable trade-off between the fishery and seabird conservation. To reach an effective compromise in terms of mortality reduction, the application of these measures must be the result of a dialogue between the French Southern Territories administration, the fishermen and the scientists. The conciliation meetings organised by the French Southern Territories administration are a step in this direction. The closing, since 2003/04, of the Patagonian toothfish longline fisheries during February for the Kerguelen EEZ and the consequences in terms of reduction in by-catch of seabirds during the 2003/04 season, appears to have yielded encouraging results.

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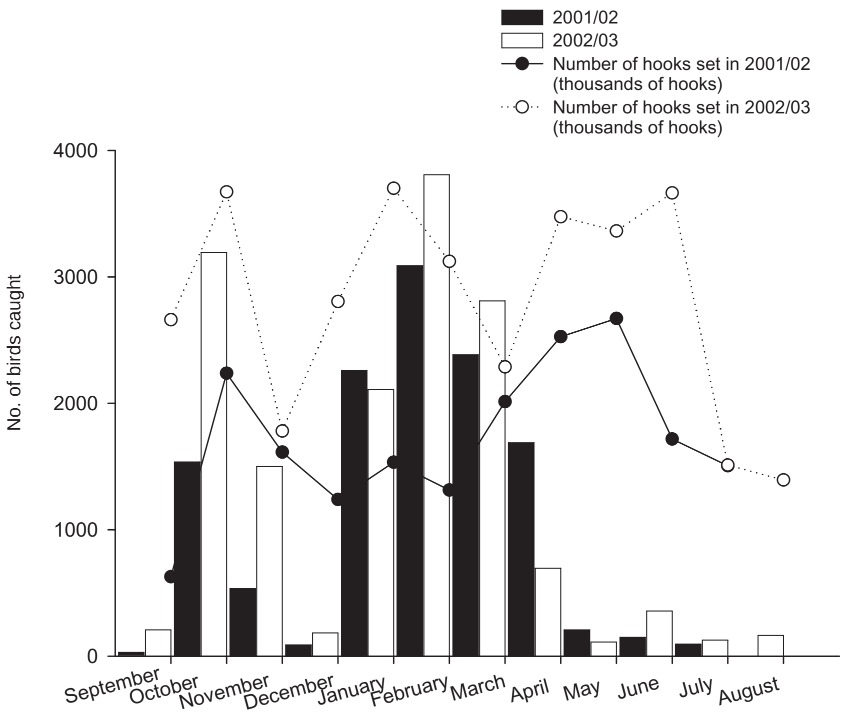

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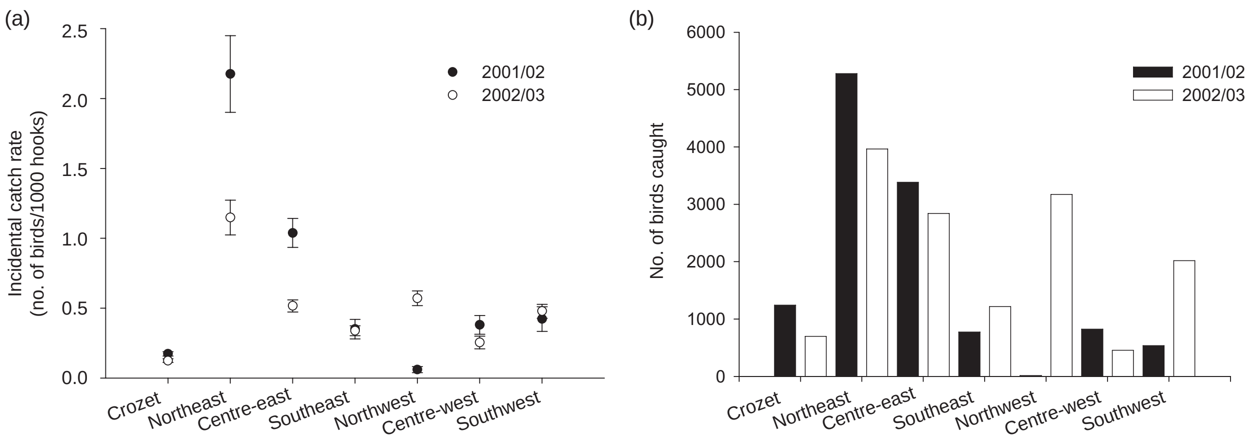

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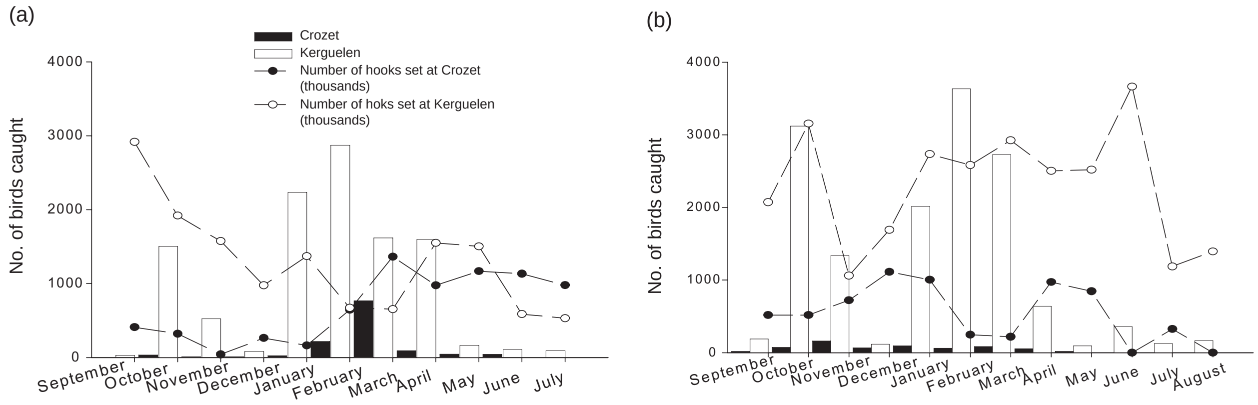

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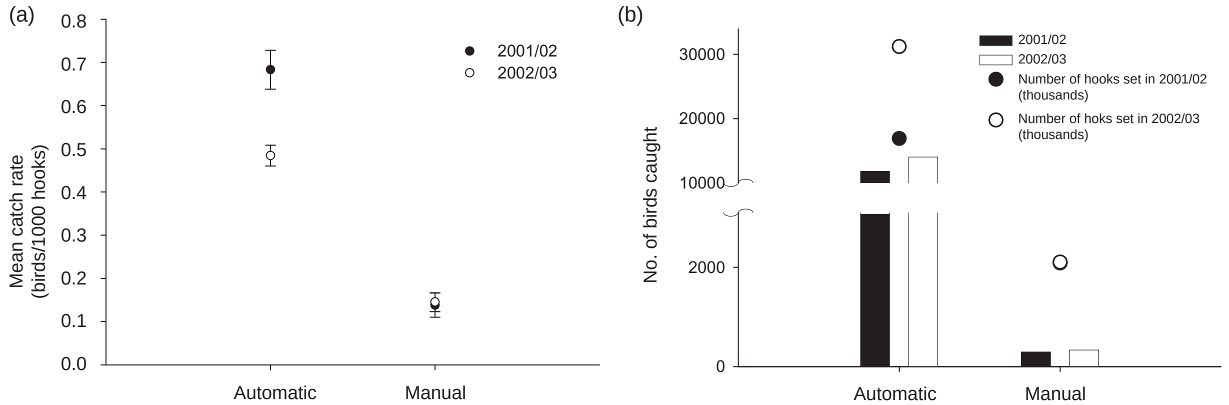

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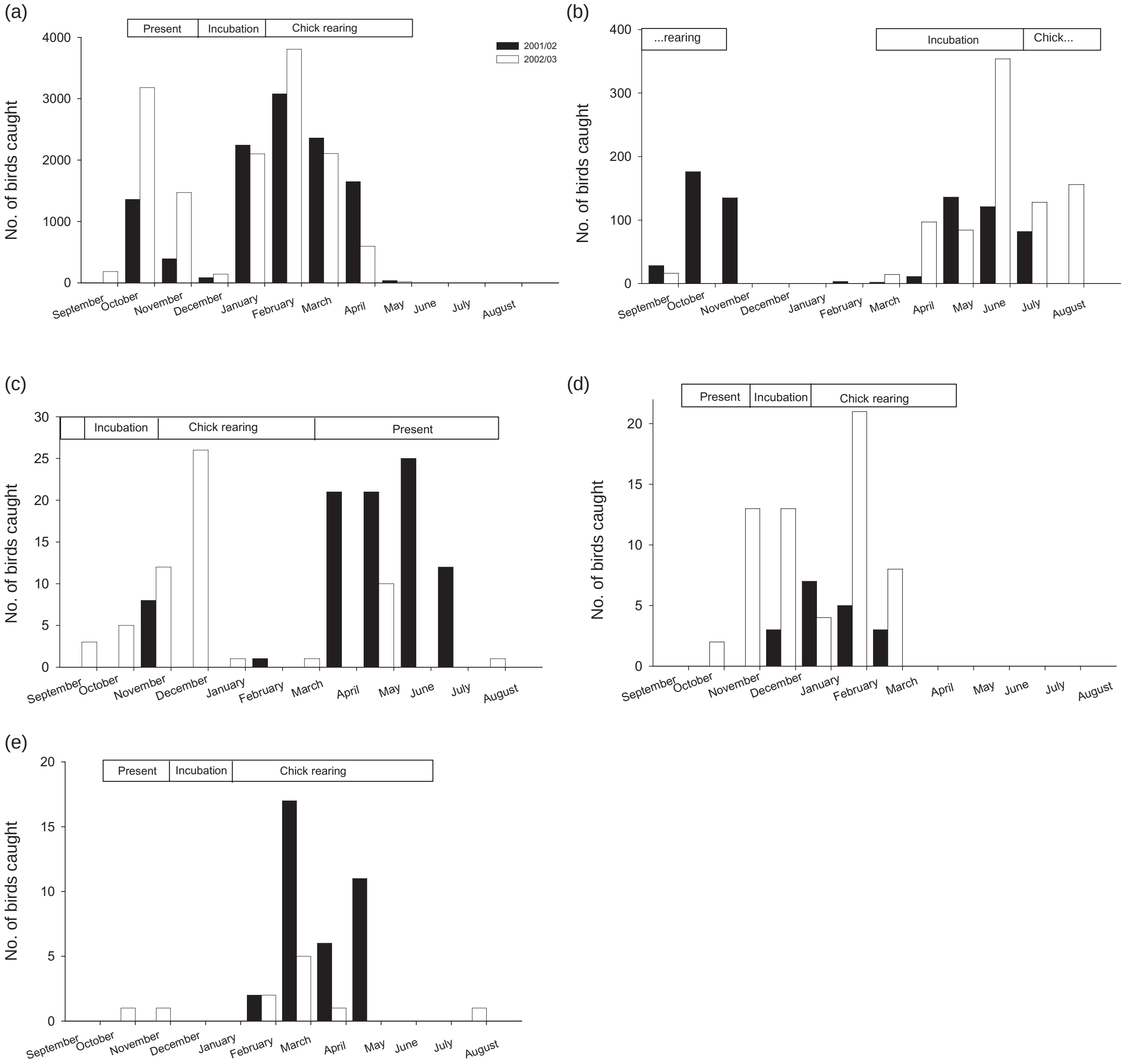

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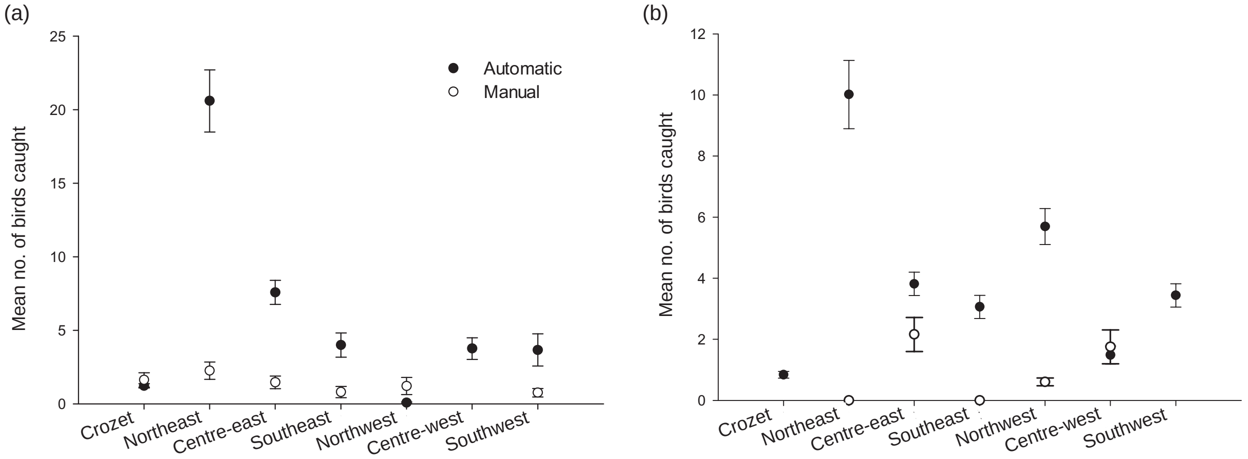

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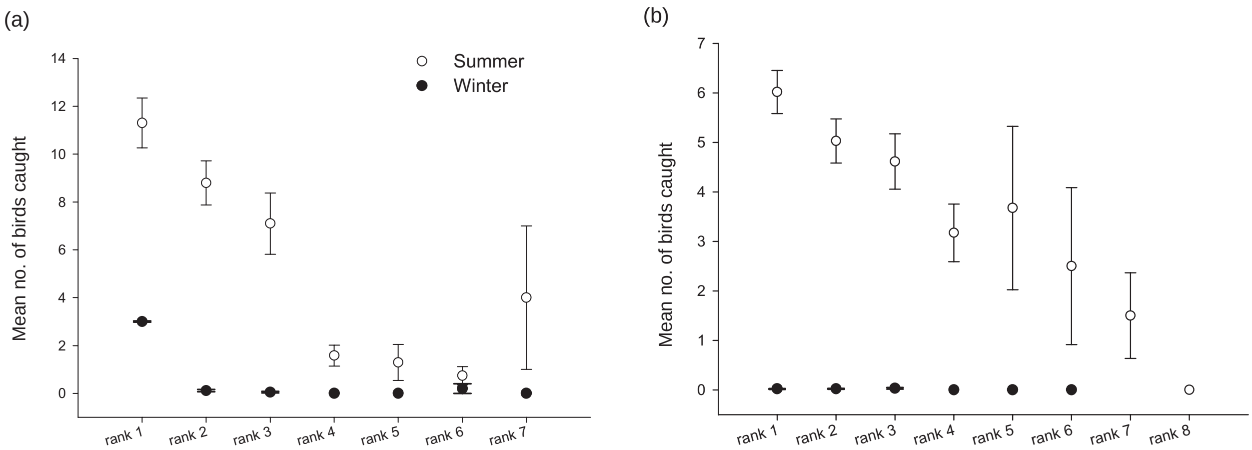

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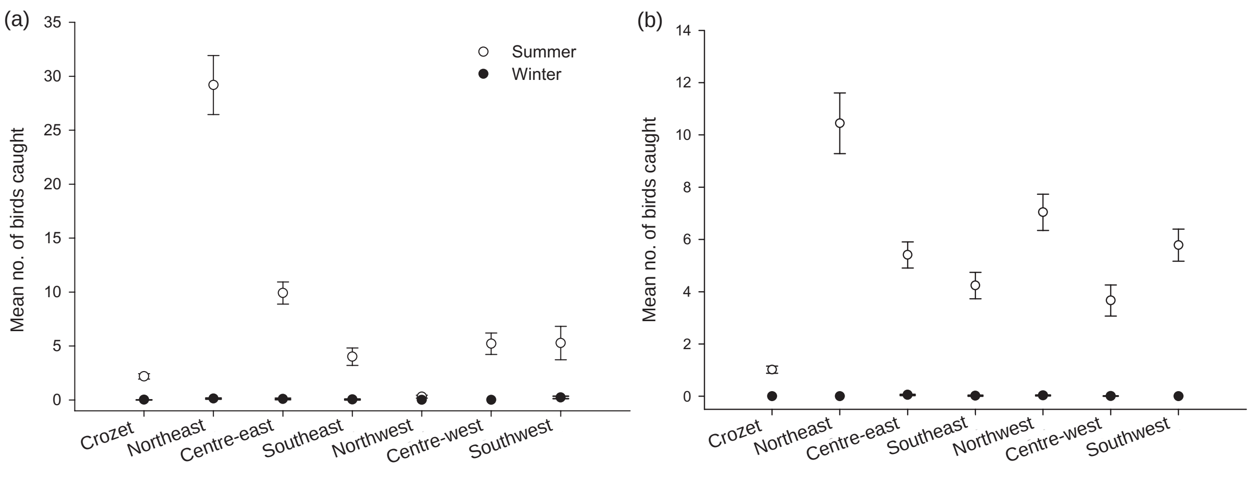

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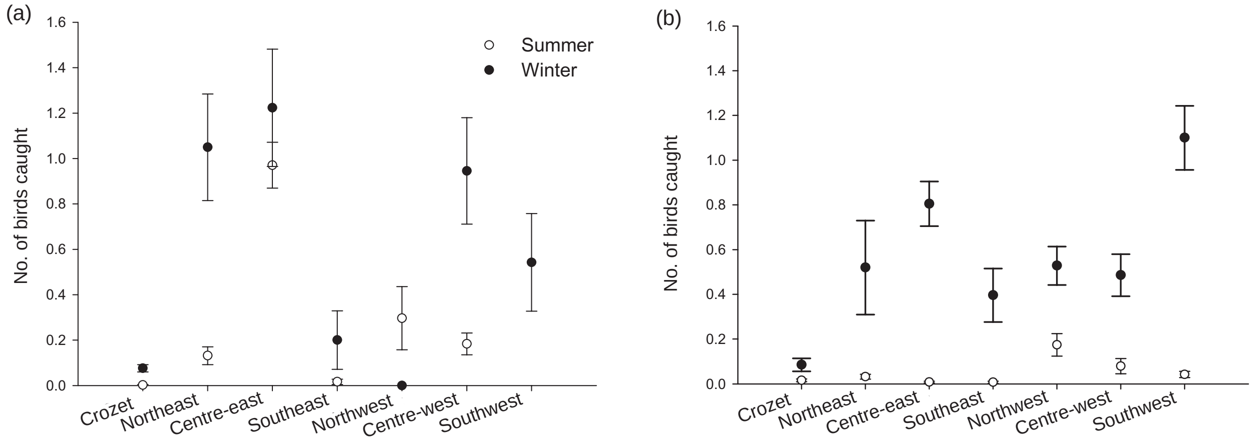

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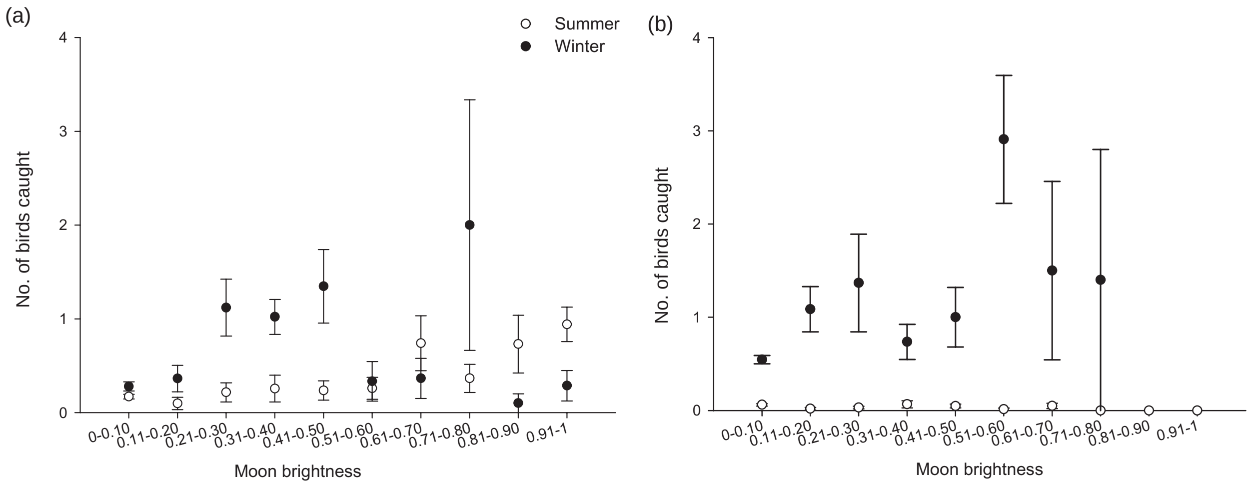

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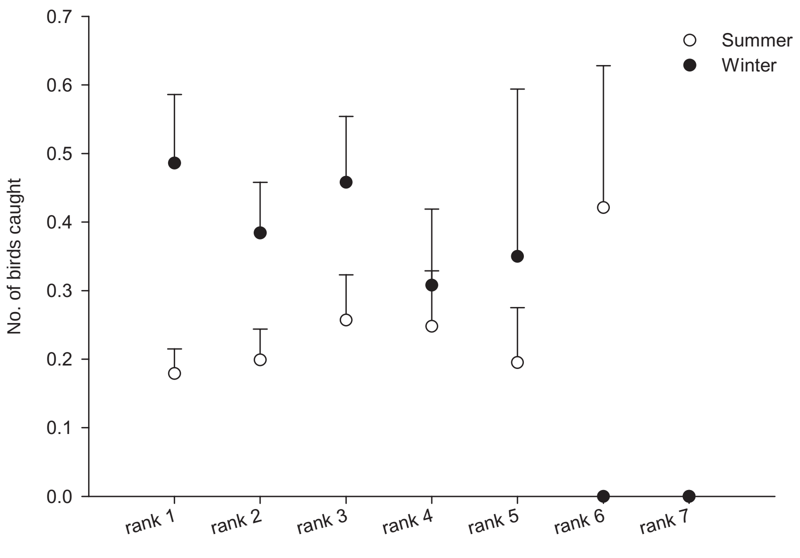

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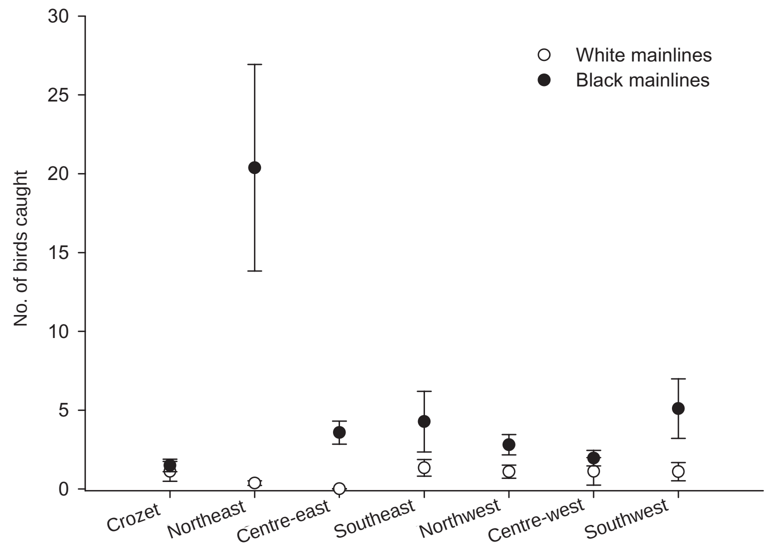

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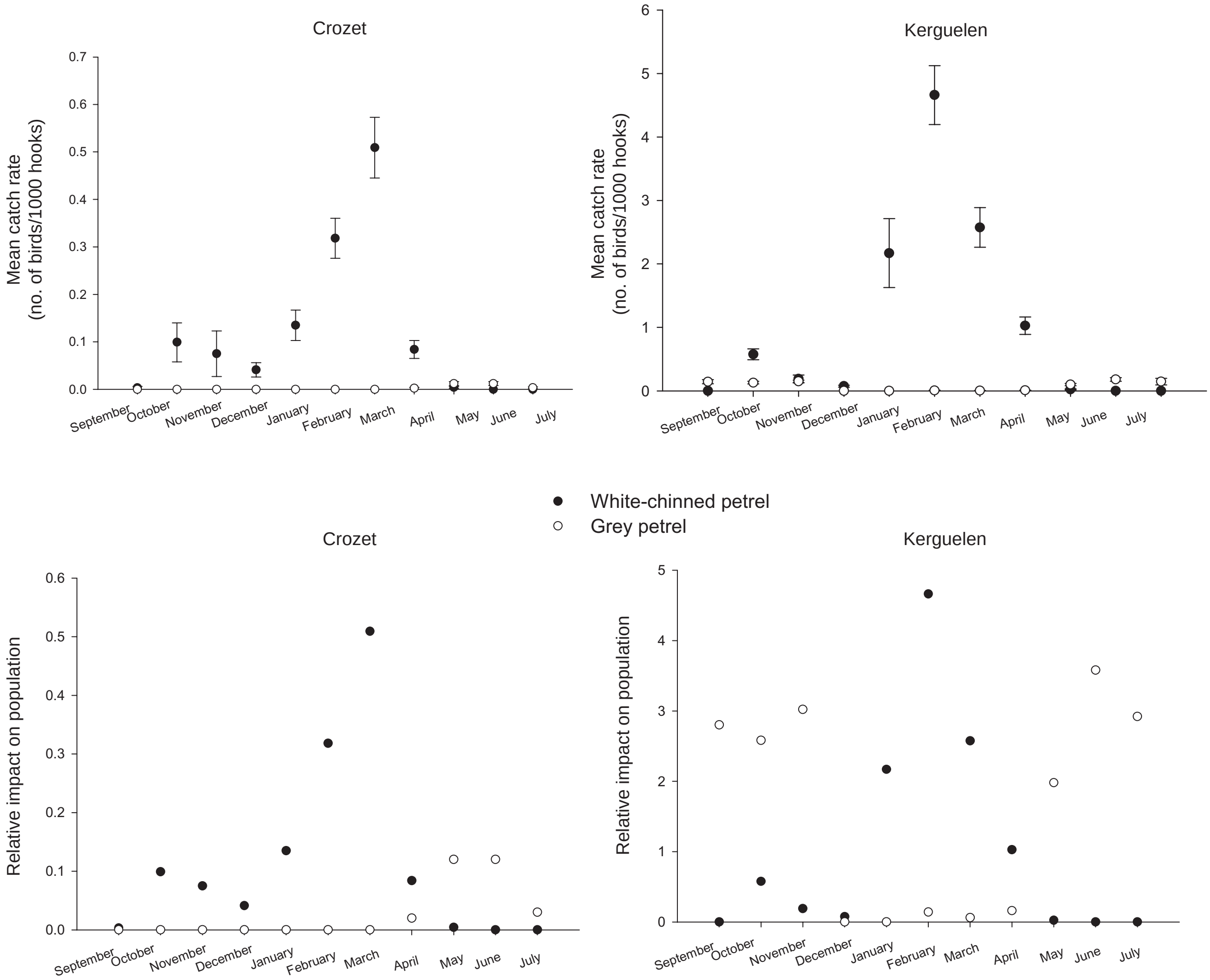

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