DISTRIBUTION OF KRILL (*EUPHAUSIA SUPERBA* DANA) CATCHES IN THE SOUTH SHETLANDS AND SOUTH ORKNEYS

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Abstract

A set of concentric zones of 20 km width was defined around selected colonies of penguins distributed around the coasts of the South Shetland and South Orkney Islands. Krill catches in these zones are shown to have a consistent pattern in Subarea 48.1 but an unpredictable distribution in Subarea 48.2, probably as a result of more variable hydrographic conditions. About 50% of the catch in Subarea 48.1 from December to March was taken within 40 km of the coast, and 90% within 80 km in all years 1988 to 1991. In 1987, 1988 and 1991, 75% of the catch in Subarea 48.2 between December and March was taken within 80 km of colonies in the South Orkneys. Estimates of consumption rates, foraging ranges and population sizes from the literature are used to show that for some years catches within 100 km of predator colonies between December and March may be up to 45% of the land-based predator consumption. Whilst the normal ratio of catch to consumption is relatively low (less than 27%), and the fishery may have to increase by a factor of 2 or 3 before ratios of catch to consumption approach maximum sustainable levels, any competition between the fishery and predators as a result of large increases in catch is likely to emerge in areas of high overlap between predators and the fishery earlier than would be expected considering the fishery as a whole.

Résumé

Un ensemble de zones concentriques de 20 km de large a été défini autour de colonies de manchots sélectionnées sur les côtes des îles Shetland du Sud et des Orcades du Sud. Dans ces zones, les captures de krill présentent une tendance régulière dans la sous-zone 48.1 mais une distribution imprévisible dans la sous-zone 48.2, vraisemblablement en raison des conditions hydrographiques plus variables. 50% environ de la capture de la sous-zone 48.1 de décembre à mars avait été effectuée à moins de 40 km de la côte, et 90% à moins de 80 km de 1988 à 1990. En 1987 et 1988, de décembre à mars, 75% de la capture de la sous-zone 48.2 provenait d'un rayon de 80 km autour des colonies des îles Orcades du Sud. Des estimations des taux de consommation, des secteurs d'alimentation et de la taille des populations extraites de la littérature sont utilisées pour indiquer qu'en certaines années, à des distances variant entre 20 et 60 km des colonies de prédateurs, les captures peuvent atteindre 48% de la consommation par les prédateurs terrestres en janvier et février. Bien qu'au total, la proportion capture-consommation soit relativement faible (27%), toute compétition entre la pêcherie et les prédateurs, à la suite d'une augmentation substantielle des captures, risque de se manifester dans ces zones plus tôt que ne le porterait à croire un examen global de la pêcherie.

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Резюме

На карте были нанесены серии концентрических зон, каждая шириной 20 км. Вокруг нескольких колоний пингвинов, расположенных вдоль побережья Южных Шетландских и Южных Оркнейских о-вов, показано, что распределение уловов криля в этих зонах Подрайона 48.1 имеет закономерный характер. В Подрайоне 48.2 такой закономерности не наблюдатеся, вероятно в результате более изменчивых гидрографических условий. Ежегодно в период 1988-1990 гг. приблизительно 50% вылова в Подрайоне 48.1 с декабря по март было получено в радиусе 40 км от берега и 90% в радиусе 80 км от берега. В 1987 и 1988 гг. 75% вылова в Подрайоне 48.2 за период декабрь-март было получено в радиусе 80 км от колоний на Южных Шетландских о-вах. Из литературы взяты оценки уровней потребления криля, нагульных ареалов и размеров популяции хищников чтобы показать, что для некоторых лет на расстоянии 20-60 км от колоний хищников, в январе-феврале уловы могут составлять до 48% криля, потребляемого обитающими на суше хищниками. Хотя общее отношение вылова к потреблению относительно низко (27%), конкуренция между промыслом и хищниками в результате больших увеличений в вылове вероятно возникнет в этих районах раньше, чем следует ожидать при рассмотрении промысла в целом.

Resumen

Se ha definido un grupo de zonas concéntricas de 20 km de ancho alrededor de colonias seleccionadas de pingüinos que están distribuidas a lo largo de las costas de las islas Shetland del Sur y Orcadas del Sur. Las capturas de kril en estas zonas han mostrado una distribución regular en la Subárea 48.1 pero no en la Subárea 48.2, probablemente debido a las condiciones hidrográficas más variables en esta última. Desde 1988 a 1991, alrededor del 50% de las capturas de diciembre a marzo en la Subárea 48.1 se realizaron en un radio de 40 km de la costa; y un 90% a 80 km de la costa. En 1987, 1988 y 1991, el 75% de la captura de la Subárea 48.2 fue extraída en un radio de 80 km de las colonias de Orcadas del Sur en el período entre diciembre y marzo. Se han utilizado las estimaciones publicadas de los niveles de consumo, de las áreas de alimentación y del tamaño de las poblaciones, para demostrar que por varios años las capturas realizadas entre diciembre y marzo - a 100 km de distancia de las colonias de depredadores - pueden representar hasta un 45% del consumo de los depredadores terrestres. Mientras la proporción normal de la captura en relación al consumo es relativamente baja (menos del 27%), y la pesquería tendría que aumentar por un factor de 2 o 3 antes de que la proporción de captura/consumo se aproxime a los niveles máximos sustentables, cualquier competencia entre la pesquería y los depredadores que se da como resultado de los aumentos considerables de las capturas es muy probable que ocurra antes de lo que se podría esperar en estas áreas, si se considera la pesquería en un contexto global.

1. INTRODUCTION

Since 1974 when fishing for Antarctic krill first started in the Southern Ocean a fundamental concern has been to ensure that harvesting did not proceed like that of seals, whales and fin-fish, whereby substantial over-exploitation brought at least some stocks to the verge of extinction. A further concern was that harvesting should not have detrimental effects on species that depend on krill for their primary food source (Edwards and Heap, 1981). In this light the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) was negotiated, coming into effect in 1982, the first 'fisheries' convention to have a so-called 'ecosystem perspective' and to require the well-being of dependant species to be considered in the management of commercial harvesting.

After an initially rapid expansion to 500 000 tonnes in 1981/82, the krill harvest has remained stable since 1985/86 at around 300 000 tonnes (Miller, 1989). This is small in comparison to the tens to thousands of millions of tonnes estimated for the total biomass of krill in the Southern Ocean (see review of Miller and Hampton, 1989) and in comparison to the total consumption of krill by birds and seals (estimated by Miller and Hampton, 1989 to be about 144 million tonnes).

CCAMLR divides the Southern Ocean into three major areas, each of which is divided further into subareas. Everson and Goss (1991) have shown that there is a consistent pattern to the fishery within the Atlantic Sector of the Southern Ocean, Statistical Area 48, where over 90% of the total world catch is currently taken. Fishing around South Georgia in the winter months is followed by a shift to fishing to around the South Orkneys and South Shetlands in the summer, as the retreating ice allows. Between 24 and 70% of the total world catch of Antarctic krill is from the Southern part of the Scotia Sea around these two archipelagos, in Subareas 48.1 and 48.2. Moreover, examination of the CCAMLR *Statistical Bulletin* (CCAMLR, 1992) reveals that the patterns of catches around these islands is fairly consistent from year to year, and is located over the shelf break to the north and west of and close to the islands. The study of Everson and Goss (1991) and data published in the *Statistical Bulletin* were the first clear suggestions that the fishery might be regularly located in quite restricted geographical areas in proximity to substantial concentrations of breeding sea-birds and seals.

This observation gives rise to the concern that although the total catch of krill in the Southern Ocean is low relative to estimates of total stock, high localised catches may be having a detrimental effect on some predators, especially during the months in which they are breeding and having to forage for food in the vicinity of their breeding sites where these are situated on land.

The aim of this paper is to make a preliminary assessment of the magnitude of the overlap between the fishery for krill in Subareas 48.1 and 48.2 and the requirements of predators. Croxall *et al.* (1985) have calculated that in the southern Scotia Sea crabeater seals and penguins are the main consumers of krill, accounting for 45% of the total krill consumed each year. Crabeater seals (*Lobodon carcinophagus*), which are not restricted to land-based sites, and fur seals (*Arctocephalus gazella*) whose estimated consumption of krill in the southern Scotia Sea is less than 1%, are not considered here.

2. METHODS

2.1 Predator Consumption

Identification of the times and areas of coincidence between the fishery and predator foraging areas required identification of the relevant times of overlap, the distances that penguins are likely to forage over, their population numbers and estimated consumption of krill.

The three major species of penguin in the southern Scotia Sea are chinstrap, Adélie and gentoo penguins (*Pygoscelis antarctica*, *P. adeliae* and *P. papua*). These penguins arrive at their breeding colonies from October to November and the chicks complete fledging in mid to late February (SC-CAMLR, 1991). Chicks and adults probably continue to be restricted to areas close to the breeding sites into March (J. Croxall, pers. comm.). Conversely, Croxall *et al.* (1985) estimate that total prey consumption declines in November before egg laying. Thus to cover all periods when predators may be restricted in their foraging range the present analysis used the four months December to March.

The extent of foraging of these species is estimated as within a 10 to 90 km radius of breeding sites at these times of year: Adélie penguin, 50 to 80 km (Everson, 1987), 80 to 120 km (Lishman, 1985), 50 km (Sadleir and Lay, 1990; Trivelpiece *et al.*, 1987); chinstrap penguin 40 to 60 km (Everson, 1987), 66 to 92 km (Lishman, 1985), 27 km (Trivelpiece *et al.* (1986), 25 to 50 km (CCAMLR, 1990); gentoos 10 km (Croxall *et al.*, 1984), 17 km (Trivelpiece *et al.*, 1986). For the purpose of estimating food requirements of penguins with dependent offspring they were assumed to be foraging equally over ranges of 80, 60 and 20 km (Adélie, chinstrap and gentoo) from their colonies.

Although there are penguin colonies throughout the Antarctic Peninsula and on all the Subantarctic island groups in Statistical Area 48, the selection of colonies for the study was restricted to the South Shetland and South Orkney Islands (Figure 1). Elimination of the Antarctic Peninsula colonies was done because the krill fishery in Subarea 48.1 is restricted to the western side of the South Shetland Islands north of 63°30'S only, and has not so far exploited the Bransfield Strait (CCAMLR, 1992). This is too far (greater than 80 km) for penguins from colonies on the Peninsula, Anvers and Brabant Islands to swim to during the period when they have dependent offspring, and these colonies are therefore unlikely to be directly affected by fishing activity.

The total number of pairs of penguins in the South Shetlands was calculated from Woehler (1991) as:

South Shetlands:	Adélie	60 000
	chinstrap	1 457 000
	gentoo	34 000
South Orkneys:	Adélie	215 000
	chinstrap	600 000
	gentoo	11 000

Croxall *et al.*, (1985) have described detailed calculations of total food consumption by birds and seals in the Scotia Sea. Using their Table 1 it is possible to calculate mean monthly consumption rates of krill by selected predators: Adélie (51.6 kg/pair/month), chinstrap (50 kg) and gentoos (50 kg). More recent calculations have been performed by Croll (1990) for the South Shetlands, yielding mean consumption over the period December to March of 80, 64 and 68 kg krill/pair/month for Adélies, chinstraps and gentoos respectively. Both models indicate that for gentoos and chinstraps consumption is depressed by about 15% in December and increased by 15% in January and February. For Adélies, Croll (1990) estimated that this increase occurs in December and January. For the present study, intermediate consumption figures of 65, 57 and 59 are used, and these monthly figures are adjusted by -15% (December), +15% (January, February) for gentoos and chinstraps, and +15% (December, January) for Adélies.

2.2 Krill Catches

The distribution of krill catches in Statistical Area 48 is published by CCAMLR in its *Statistical Bulletin* (CCAMLR, 1992 - Figure 25). Krill catches are displayed in map form, with

data given for each CCAMLR fine-scale square (1° longitude by 30' latitude) for each quarter (three months) of the year. Total catches are shown by a series of ranges, distinguished by shading on the map corresponding to the ranges 1 to 4, 5 to 24, 25 to 124, 125 to 624, 625 to 2 999 and ≥3 000 tonnes. Data are available from 1988 for Subarea 48.1 and 1987 for Subarea 48.2.

Because only ranges of catches are available from CCAMLR (1992) the total catch in each fine-scale square was estimated by first taking the initial estimate of the catch to be equal to the lower catch bound for that square, and they applying the calculation.

Estimated catch in a quarter for square =

$$\text{Initial estimate for square} \times \frac{\text{total catch in the subarea in that quarter}}{\text{sum of initial estimates for all squares in that quarter}}$$

The total catch in the subarea in a quarter was taken from the STATLANT column of Table 15 of CCAMLR (1992).

In order to compare catches with predator data, a critical period for predators of December to March was defined. Total catches in the period January to March were easily obtained from data for quarter 3, using the calculation above. Catches for December were obtained similarly using data for quarter 2 (October to December) but a correction factor was applied which corrected for the proportion of quarter 2 catches which were taken in December. For Subarea 48.1 this correction is unnecessary because all catches in quarter 2 were taken in December. For Subarea 48.2 the correction is small because most catches were taken in December (CCAMLR, 1992 - Tables 9.2 and 9.3).

Having obtained estimated total catches of krill in each fine-scale square for December to March, the pattern of krill catches in relation to predator colonies was investigated by dividing the sea into concentric zones around the major colonies with radii in 20 km increments. Major colonies (greater than 20 000 pairs) of the most abundant penguin species, chinstraps, were used for this purpose and were identified from Woehler (1991) (Figure 1). For each fine-scale square, the catches were assigned to different zones in the proportion that each zone covered water estimated deeper than 50 m (and therefore available to the fishery) within the square.

3. RESULTS

Total catches and estimated penguin consumption by month and zone are shown in Tables 1 and 2, and Table 3 shows the proportion of the total catch for the split year that was taken in the four months December to March within 100 km of predator colonies. The total consumption of krill by penguins from December to March was calculated as 370 000 tonnes in Subarea 48.1, and 195 000 tonnes in Subarea 48.2, and by far the largest component of this was due to chinstrap penguins. The former figure is similar to that calculated by Croll (1990) for the South Shetlands (345 000 tonnes). The total consumption, however, (565 000 tonnes) is only about a third of the 1 445 000 tonnes estimated by Croxall *et al.* (1985) for the whole of the southern Scotia Sea over four months. The difference is explained by the greater population estimates used by Croxall *et al.* which apply not only to the South Shetlands and South Orkneys, but to the Antarctic Peninsula as well.

The pattern of catches for Subareas 48.1 and 48.2 over the period 1988 to 1992 is shown in Figure 2. Three areas of high concentration are apparent, north of Livingston Island, northwest of Elephant Island and northwest of Coronation Island, South Orkneys. The pattern of catches for Subarea 48.1 was similar for each of the years examined whereas that for Subarea 48.2 changed each year (Figures 3 and 4). In only three years (1987, 1988 and 1991) were the majority of catches in Subarea 48.2 taken within 100 km of colonies during these months.

The years with the greatest fishery impact were 1989 in Subarea 48.1 and 1988 in Subarea 48.2 (Table 3). In these years, the catch within the 21 to 40 km zone was 23 to 27% of the calculated consumption in this zone for the months December to February. The ratio of the total catch in theSubarea in December to March to total consumption for these years was 0.26 for Subarea 48.1 and 0.27 for Subarea 48.2. The greatest impact of the fishery was in Subarea 48.2 in 1991, however, when the catch was equivalent to 45% of the predator consumption (Table 3). In other years and zones the proportionate impact of the fishery was much lower.

4. DISCUSSION

The consistency in the distribution of catches appears to be a feature of the fishery around the South Shetlands, with its pattern of increased fishing intensity to the north of Livingston Island and to the north and west of Elephant Island (Figure 2; see also Everson and Goss, 1991; CCAMLR, 1992). Everson and Goss (1991) have shown that the gross pattern of krill catches in the Scotia Sea is determined by the extent of ice cover; the major fishing effort switches from South Georgia in the winter to the South Orkneys and South Shetlands in the Antarctic summer, following the ice edge as it moves south. Data from Jacka (1983 and pers. comm.) on mean monthly sea ice edge position along longitudes 60°, 50° and 40°W shows that for most of these months and years the South Shetlands and South Orkneys were ice-free, and it is therefore difficult to explain the detailed location of catches with reference to sea-ice distribution. The only time when the ice edge was close to the South Orkneys (50°W to 40°W) was January 1989, and the fishery in this year moved further north, taking place over a bank to the north of the South Orkney Islands around 59°S 44°W. This could explain the major shift in catch positions and the very low catch within 80 km of predator colonies in 1989 (Table 3). However, in general the localised distribution of krill catches cannot be explained by ice distribution.

In Subarea 48.1, krill is known to be generally concentrated to the north of Livingston and Elephant Islands (Nast *et al.*, 1988; Ichii *et al.*, 1991). The main hydrographic phenomenon in the area, the Weddell-Scotia confluence, was implicated by Nast *et al.*, (1988) in producing the hydrographic conditions that brought about persistent concentrations of krill around Elephant Island, although it is not clear how it could influence concentrations further west. Ichii *et al.* (1991) attribute the concentration of krill to the north of Livingston Island to retention in topographic eddies or to active swarming around concentrations of phytoplankton. Hydrographic conditions are much more unstable around the South Orkneys (Sievers and Nowlin, 1987), and the Weddell-Scotia confluence much more variable from year to year and this may account for the high variability in fishing pattern in Subarea 48.2. Reference to Figures 1 and 2 also suggests that the major catches are located over areas of the shelf break and in very steep shelf slopes, at positions where the bottom topography is considerably disturbed; this applies to all three major areas of krill catches, north of Livingston and Elephant Islands and to the west of the South Orkney Islands.

The ratio of catch to natural mortality is important. The assumption that fish (and krill) populations may show their maximum sustainable yield at the point where fishing mortality (catch) equals natural mortality (natural predation) (Gulland, 1971) have been challenged by Beddington and Cooke (1983) who showed through simulations that a 'safe' maximum sustainable yield usually occurs at levels of fishing mortality that are lower than natural mortality. The assumption here is that predator populations are utilising the food resource (krill) at levels of natural mortality that allow the same sorts of ratios of catch to be withstood by the prey stock as in other ecosystems, and that ratios of catch/consumption (ρ in Table 3) that approach 1 indicate a stock that is close to the maximum sustainable exploitation rate, with the implication that these levels will not impact adversely on predator populations.

When calculating the ratio ρ, it is necessary to take into account all potential predators of krill. Inclusion of non-breeding penguins, and crabeater seals (calculated by Croxall *et al.*,

1985 to consume 45% of all krill in the southern Scotia Sea) if they are in the vicinity of predator colonies will decrease the ratio of catch to consumption. Other predators important in the Antarctic as a whole, such as whales, fish and squid (Everson, 1977; Miller and Hampton, 1989) may also be expected to consume krill around the study sites. Details of the consumption by squid and whales is unknown in the area. Commercial fish stocks in Subareas 48.1 and 48.2 have been at low levels for several years, the last significant catches being in the early 1980s (Kock and Köster, 1990; CCAMLR, 1991), and despite their known concentrations in areas of persistent krill occurrence (Nast *et al.*, 1988) are unlikely to be major consumers of krill.

The accuracy of the present estimates of predator consumption may be examined by application of various estimates of natural mortality rates derived from investigations of the demographic parameters of krill to current estimates of total krill biomass. The definition of krill stocks in the Scotia Sea is not yet clear (Miller and Hampton, 1989). However, restricting the calculations to January to March in Subarea 48.1, Siegel (1991) has calculated that the exchange rate of water masses within the subarea means that the population of krill around the South Shetlands will be changed every three months. Based on four years of survey data Siegel calculated that total biomass around the South Shetlands, including productivity during this period, would be about 2 million tonnes each year, and this result is similar to that obtained by Ichii (1991). Siegel and Kalinowski (1991) have reviewed natural mortality estimates for krill, and if it is assumed that $^1/_4$ of the yearly natural mortality of about 0.9 occurs by predator consumption in January to March, then about 400 000 tonnes of the 2 million estimated above should be consumed in this period. The predator consumption calculated in Table 1 of 293 000 tonnes in January to March is only 73% of this estimated total, and therefore ρ may be overestimated.

Whilst the results in Table 3 indicate that for some months and years the catches within the foraging ranges of penguins approached 50% of the estimated consumption, for most years the fishery was much lower than this, even within the critical periods and zones. For the South Shetlands and South Orkneys, an historical upper limit for ρ was calculated as about 0.25 and 0.45. Thus the fishery would have to increase at least three-fold from its current maxima in Subarea 48.1 and twofold in Subarea 48.2 before it approached a theoretical limit of sustainability, and more if other predators were taken into account.

However, the overlap between fisheries and predators would be likely to become critical well before this on local scales, and in particular 20 to 60 km from predator colonies. In addition, it is possible that predators could respond adversely to temporary decreases in krill density, the availability of certain swarm sizes or other factors influenced by fishing operations even though assessments indicate the overall catch of krill to be relatively low. These effects may be offset by the concentration of krill stocks in the areas of highest consumption as observed, for example, by Ichii *et al.* (1991). Whilst there is as yet no evidence that predators are being adversely affected by fishing operations in these areas monitoring for the effects of the fishery on predators should concentrate on this zone.

CCAMLR currently has imposed a precautionary limit of 1.5 million tonnes on the krill catch from Statistical Area 48. Should further regulation be necessary, the consistency of pattern of the Subarea 48.1 fishery (Figure 3) would make definition of time and space for the operation of a management plan that utilised closed areas and seasons, and assessment of the impacts of such a plan on the returns from the fishery, relatively easy to determine. For instance, a closure of a 40 km zone off the coastline of the South Shetlands from December to March would exclude the fishery from about 45% of its traditional catch in Subarea 48.1 (50% [from Figure 3] x 90% [percentage of the catch in Subarea 48.1 taken between December and March from Table 3]). Determination of the impacts of such plans on the fishery around the South Orkneys is less easy because of the unpredictability of this fishery.

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Table 1: Subarea 48.1. Krill catch and predator consumption from December to March at various distances from penguin colonies. Catches are estimated from CCAMLR (1992).

Distance from colonies	Catches by Year, December to March				Predator Consumption				
	1988	1989	1990	1991	DEC	JAN	FEB	MAR	Total
0-20	8206	10890	4318	10551	26357	35263	32117	30664	124401
21-40	21415	32819	13031	17613	24652	32956	32810	28658	119076
41-60	23070	30383	9744	14526	24652	32956	32810	28658	119076
61-80	8594	14477	6559	4117	1121	1121	975	975	4192
81-100	5008	6311	3989	1632					
101-120	23	1410	266	158					
121-140	549	291	25	128					
141-160	667	113	4	29					
161-180	949	47	4	10					
181-200	117	9	0	1					
Total	68598	96750	37940	48765	76782	102296	98712	88955	366745
Total in Subarea	68848	96798	37941	49159					

Table 2: Subarea 48.2. Krill catch and predator consumption from December to March at various distances from penguin colonies. Catches are estimated from CCAMLR (1992).

Distance from colonies	Catches by Year, December to March					Predator Consumption				
	1987	1988	1989	1990	1991	DEC	JAN	FEB	MAR	Total
0-20	696	13636	83	347	7219	14430	17563	16655	13522	62170
21-40	3449	14063	744	3125	28970	13866	16830	15921	12957	59574
41-60	5146	10441	1715	6666	33031	13866	16830	15921	12957	59574
61-80	4509	2019	3833	12292	18020	3948	3948	3040	3040	13976
81-100	1965	11482	6414	18125	917					
101-120	1632	1282	6005	28890	33					
121-140	203	34	1919	14862	11					
141-160	328	27	1497	4584	4					
161-180	120	12	1918	0	2					
181-200	23	4	11963	0	1					
Total	18071	53000	36091	88891	88208	46110	55171	51537	42476	195294
Total in Subarea	18103	53004	78254	88890	88211					

Table 3: Catch of krill in the subarea and in the critical period-distance (CPD, defined as 100 km from colonies from December to March inclusive). The percentage of the total catch in the subarea for the year which is caught in the CPD is given, together with the catch as a percentage of total krill demand for December to March (predators + the fishery) which is caught in the CPD. Data from CCAMLR (1992).

Year	Total Catch in Subarea for the Year	Catch in Subarea from December to March	Catch within the CPD	Percentage of Yearly Catch Within the CPD	CPD Catch as % of Estimated Predator Consumption (ρ-see text)	CPD Catch as % of Estimated Total Demand (predators and fishery)
Subarea 48.1						
1988	78918	68848	66292	84.0	17.9	15.2
1989	105554	96798	94880	89.9	25.7	20.4
1990	42477	37941	37642	88.6	10.2	9.2
1991	64641	47948	48440	74.9	13.1	11.6
Subarea 48.2						
1987	19902	18102	15765	79.2	8.1	7.5
1988	94659	53003	51641	54.6	26.4	20.9
1989	82406	78253	12789	15.5	6.5	6.1
1990	220518	88890	40555	18.4	20.8	17.2
1991	167257	88211	88158	52.7	45.1	31.1

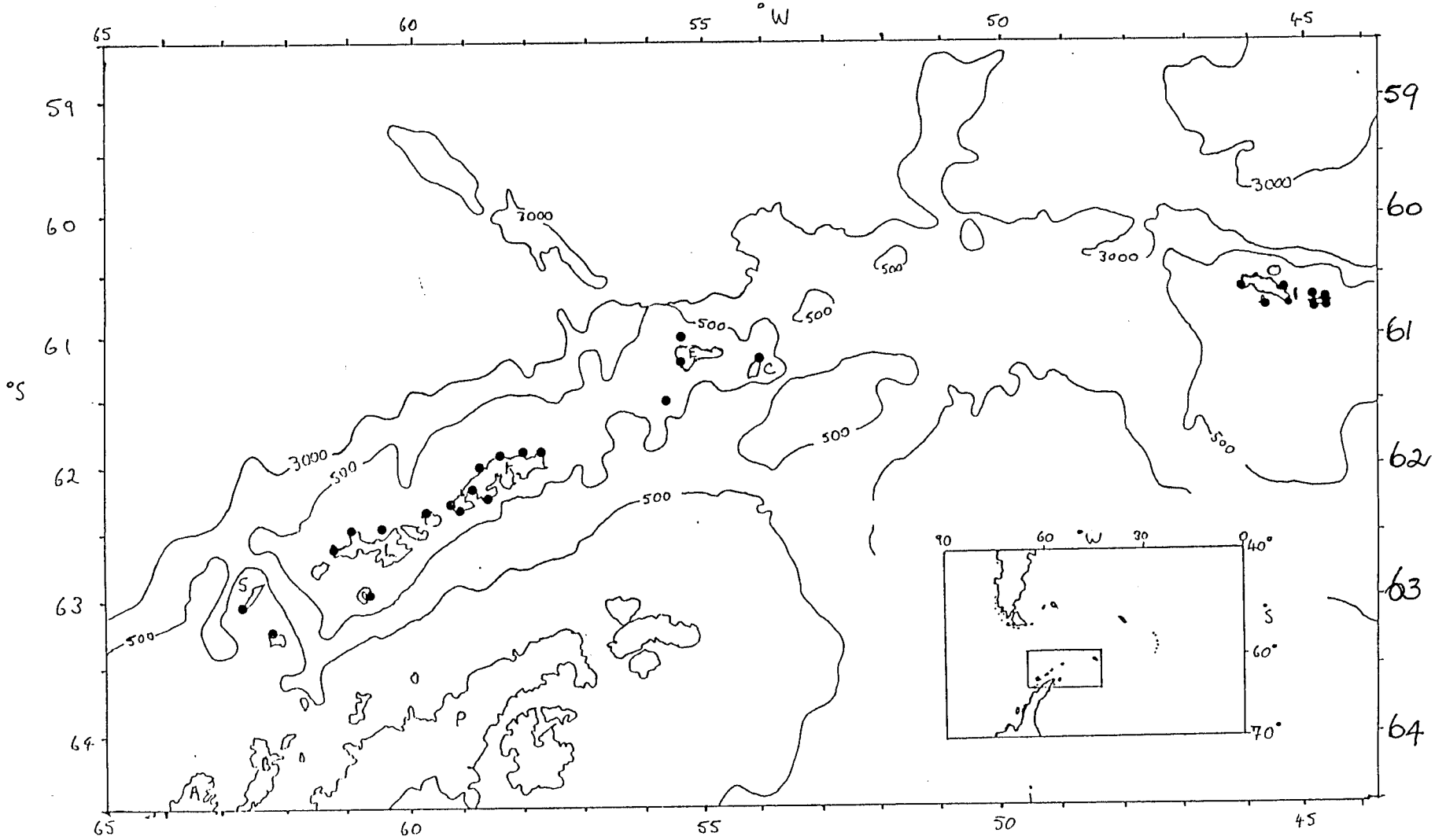


Figure 1: Map showing the study area in the south Scotia Sea. Colonies selected for determination of zones (see text) (o) and 500 and 3 000 m depth contours (start and end of the continental slope are shown. A = Anvers Island, B = Brabant Island, L = Livingston Island, K = King George Island, E = Elephant Island, C = Clarence Island, S = Smith Island, O = South Orkney Islands group, P = Antarctic Peninsula. The islands from S to C form the South Shetland Islands group.

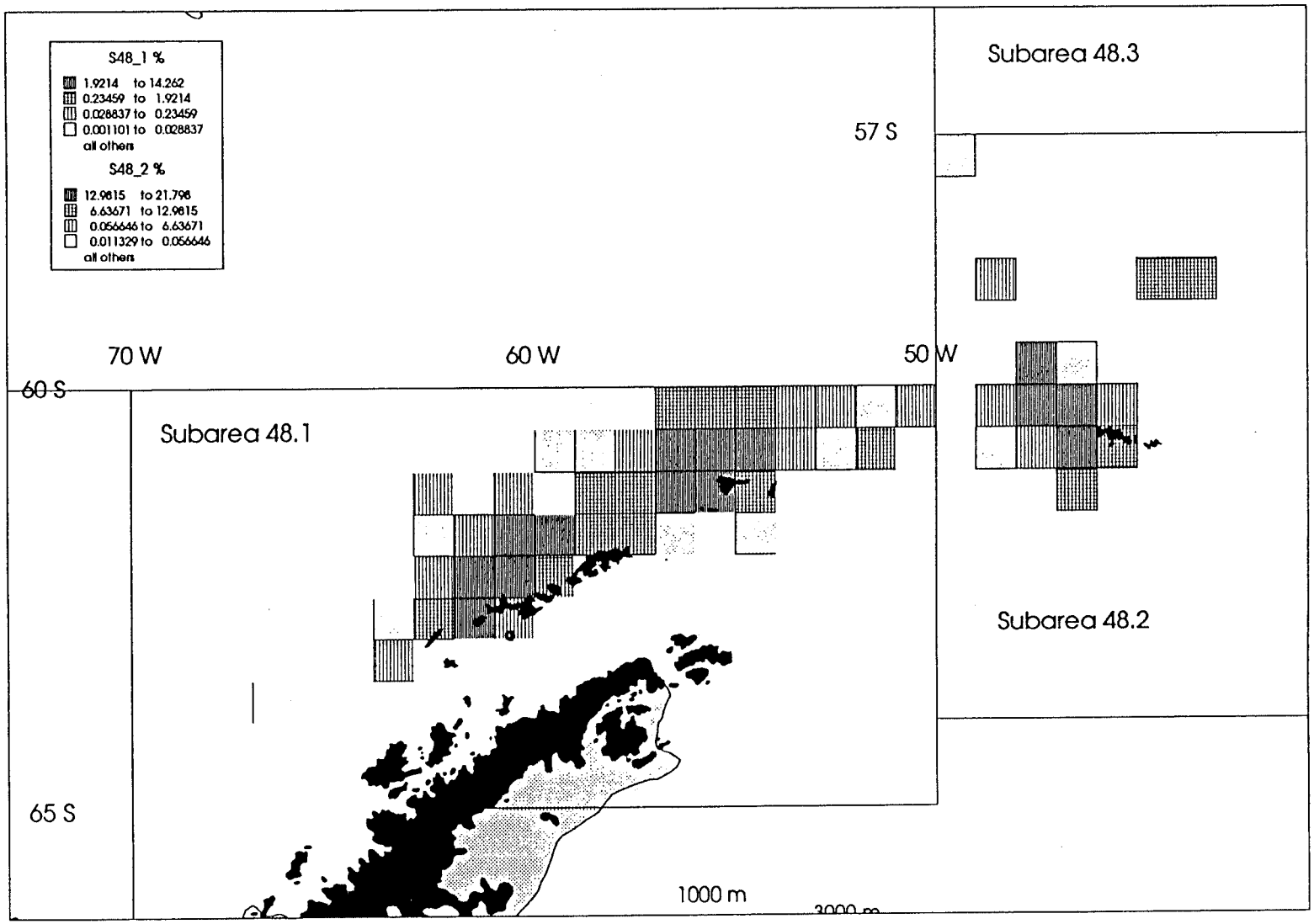


Figure 2: Estimated distribution of catches from January to March over the period 1988 to 1991. Catches are given as a percentage of total catch in January to March. The analysis is separated for Subareas 48.1 and 48.2.

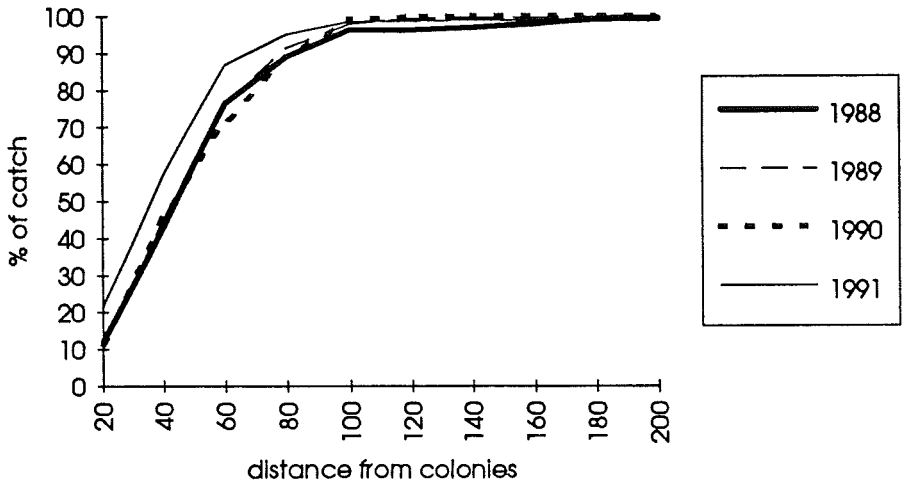
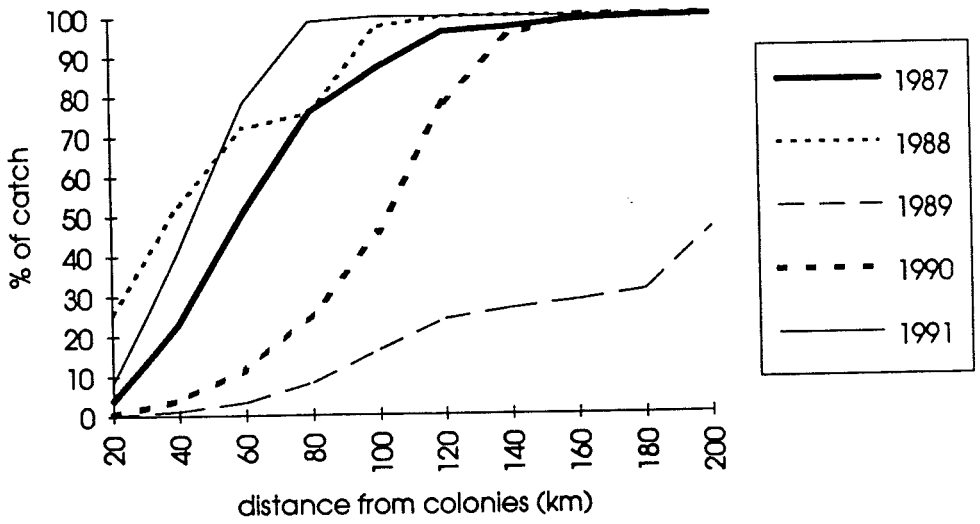


Figure 3: Catches of krill in relation to distance from penguin colonies in the South Shetland Islands, expressed as a percentage of the total krill catch in Subarea 48.1, over the months December to March.



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Légende des tableaux

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Tableau 2: Sous-zone 48.2. Captures de krill et consommation par les prédateurs de décembre à mars, à des distances diverses des colonies de manchots. Les captures sont estimées selon CCAMLR (1992).

Tableau 3: Captures de krill effectuées dans la sous-zone pendant la période et à une distance critiques (CPD (période-distance critiques), définie comme étant un rayon de 100 km autour des colonies, de décembre à mars inclus). Le pourcentage de la capture totale de l'année dans la sous-zone, pris pendant la CPD est donné, conjointement avec la capture en tant que pourcentage de la demande totale de krill de décembre à mars (prédateurs + pêcherie) ayant été pris pendant la CPD. Les données proviennent de CCAMLR (1992).

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Figure 1: Carte de la zone considérée en mer du Scotia du sud. Les colonies sélectionnées pour déterminer les zones (cf. texte) (o) et les profils bathymétriques de 500 et 3 000 m (début et fin du talus continental) sont représentés. A = île Anvers, B = île Brabant, L = île Livingston, K = îles du Roi George, E = île Eléphant, C = île Clarence, S = île Smith, O = archipel des Orcades du Sud et P = péninsule antarctique. Les îles de S à C forment l'archipel des îles Shetland du Sud.

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Рисунок 3: Вылов криля относительно расстояния от колоний пингвинов на Южных Шетландских о-вах, который выражается как процентная доля общего вылова криля, полученного в Подрайоне 48.1 в течение периода декабрь-март.

Рисунок 4: Вылов криля относительно расстояния от колоний пингвинов на Южных Оркнейских о-вах, который выражается как процентная доля общего вылова криля, полученного в Подрайоне 48.2 в течение периода декабрь-март.

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