CCAMLR Science, Vol. 8 (2001): 25–36

ANALYSIS OF KRILL TRAWLING POSITIONS NORTH OF THE SOUTH SHETLAND ISLANDS (ANTARCTIC PENINSULA AREA), 1980/81–1999/2000

S. Kawaguchi✉ and K. Segawa
National Research Institute of Far Seas Fisheries
5-7-1 Orido, Shimizu, 424-8633 Japan
Email – kawaso@enyo.affrc.go.jp

Abstract

Inter- and intra-annual variability of commercial krill trawling positions for the 1980/81 to 1999/2000 seasons in the area north of the South Shetland Islands were analysed in relation to biological and environmental factors. Commercial fishing operations concentrated on the outer shelf in the early 1980s, along the shelf slope in the mid to late 1980s, and from the shelf across to the outer shelf in the early to late 1990s. Intra-annually, trawling positions generally started from the outer shelf and proceeded towards the shelf later in the season. Trawling positions seemed to be primarily governed by the distribution of larger mature krill, especially at the beginning of fishing operations each season. In summer, biological factors that affect product quality, such as salp abundance and the proportion of green krill, also seemed to have an increasing effect on trawling positions. Ice conditions for recent fishing periods were also demonstrated to have an effect.

Résumé

La variabilité, tant d'une année à une autre qu'en une même année, de l'emplacement des chalutages commerciaux de krill des saisons 1980/81 à 1999/2000 au nord des îles Shetland du Sud, a été analysée relativement aux facteurs biologiques et de l'environnement. Les opérations de pêche commerciales étaient concentrées sur le plateau extérieur au début des années 80, le long de la pente du plateau vers la fin des années 80 et du plateau vers l'extérieur du plateau dans les années 90. En une même année, les chalutages étaient généralement effectués vers l'extérieur du plateau pour commencer, pour progresser sur le plateau au fil de la saison. L'emplacement des chalutages semble dépendre principalement du krill mature de grande taille, notamment au début des opérations de pêche de chaque saison. En été, les facteurs biologiques qui affectent la qualité du produit, tels que l'abondance des salpes ou la proportion de krill vert, semblent également avoir de l'influence sur la position des chalutages. L'importance des conditions de la glace des dernières périodes de pêche ont de plus été mises en évidence.

Резюме

Внутри- и межгодовые изменения мест проведения коммерческого тралового промысла криля в районе к северу от Южных Шетландских о-вов в период 1980/81–1999/2000 гг. были проанализированы по отношению к биологическим факторам и окружающей среде. оммерческие промысловые операции концентрировались на внешнем шельфе в начале 1980-х гг., вдоль склона шельфа в середине–конце 1980-х гг., и от шельфа до внешнего шельфа в 1990-е гг. В течение года траления, как правило, начинались с внешней части шельфа и к концу сезона перемещались к самому шельфу. Представляется, что места траления в основном зависели от распределения более крупного, половозрелого криля, особенно в начале промысловых операций в каждом сезоне. Летом биологические факторы, влияющие на качество продукта (например, численность сальп и доля зеленого криля), также оказывали возрастающее влияние на места проведения тралений. роме этого доказано влияние ледовой обстановки в последние промысловые периоды.

Resumen

La varibilidad inter e intra anual de las posiciones de los arrastres de la pesquería comercial de kril desde la temporada 1980/81 a la 1999/2000 al norte de las islas Shetland del Sur fue analizada en función de factores biológicos y ambientales. Las operaciones de pesca comercial se concentraron en la periferia de la plataforma continental a principios de los ochenta, a lo largo de la pendiente a mediados y fines de la misma década, desplazándose desde la costa hasta la periferia de la plataforma durante la década del 90. Cada año los arrastres se inician en la periferia de la plataforma y se desplazan hacia la costa en el curso de la temporada. La distribución del kril maduro y de mayor tamaño aparentemente fue el factor determinante en la distribución de los arrastres, especialmente al inicio de cada temporada. Se cree que algunos factores biológicos que afectaron la calidad del producto, tales como la abundancia de salpas y la proporción de kril verde, también afectaron significativamente los arrastres de kril en el verano. También se demostró que las condiciones del hielo en las últimas temporadas de pesca influyeron en la distribución de los arrastres.

Keywords: krill fishery, trawling positions, Antarctic krill, salps, sea-ice, bathymetry, South Shetland Islands, CCAMLR

INTRODUCTION

Interannual fluctuations in krill recruitment, abundance and distribution have been suggested for the area around the Antarctic Peninsula (e.g. Loeb et al., 1997; Siegel, 1988). Many of the analyses have revealed the importance of environmental factors (e.g. sea-ice extent or timing of sea-ice retreat) in this variation.

The area around the South Shetland Islands is one of the main commercial krill fishing grounds. An enormous amount of fishing logbook data has been accumulated from the area, which may provide useful information about the inter- and intra-annual variation in krill distribution and flux patterns. At the same time, however, many other factors may also affect fishing position. It may be that fishing position is determined by a combination of factors such as krill distribution, density and colour, by-catch, environmental conditions etc.

Antarctic krill (*Euphausia superba*) in the South Shetland Islands area is characterised by offshore–onshore segregation in both size and maturity stages (e.g. Siegel, 1988; Ichii et al., 1998). Since fishing vessels can select larger krill by knowing such patterns (Ichii, 2000), it may be appropriate to analyse trawling positions according to bottom topography in order to describe the behaviour of krill trawlers in relation to krill distribution.

In this paper, trawling positions from fishing logbooks for the 1980/81 to 1999/2000 seasons were converted into distances from specific isobaths (0, 200, 500 and 1 000 m), standardised and analysed for intra- and interannual variation. Factors that may have influenced trawling positions were discussed.

MATERIALS AND METHODS

The National Research Institute of Far Seas Fisheries has been continuously accumulating logbook data from Antarctic krill fisheries since the 1973/74 fishing season. Fishing operations around the South Shetland Islands started in the 1980/81 fishing season. Minimum distances (n miles) from the trawling positions to the 500 m isobath, which indicates the position of the shelf slope, were calculated using information from the GEBCO-97 digital bathymetric data (BODC, 1997) (Figure 1). Trawling positions were grouped into three local areas (Smith Island area, 64–62°W; Livingston Island area, 62–60°W; and King George Island area, 60–57°W). Positional data which were near the isobaths but outside the 57–64°W range were not used in the analysis.

Distances with positive values indicate they are located offshore of the shelf, while the negative values indicate onshelf. Mean distances were calculated for each of the local areas, and were standardised according to their standard deviations (Standardised Trawling Positions – STP). This standardisation was performed to take into account possible operational differences due to differences in the width of the shelf and the degree of the shelf slope among the three local groups.

Non-parametric pairwise correlation tests (Kendall's rank correlation; Zar, 1996) were applied to the available data to elucidate trends of association between biological factors (krill and salp density) (Table 1) and trawling positions over the survey period.

RESULTS

Inter- and Intra-annual Variability of STP

In total, 45 088 distances between trawling positions and the 500 m isobath were calculated and plotted in a box diagram. The median distance from the isobath was slightly greater in the King George Island group than in the Smith or Livingston

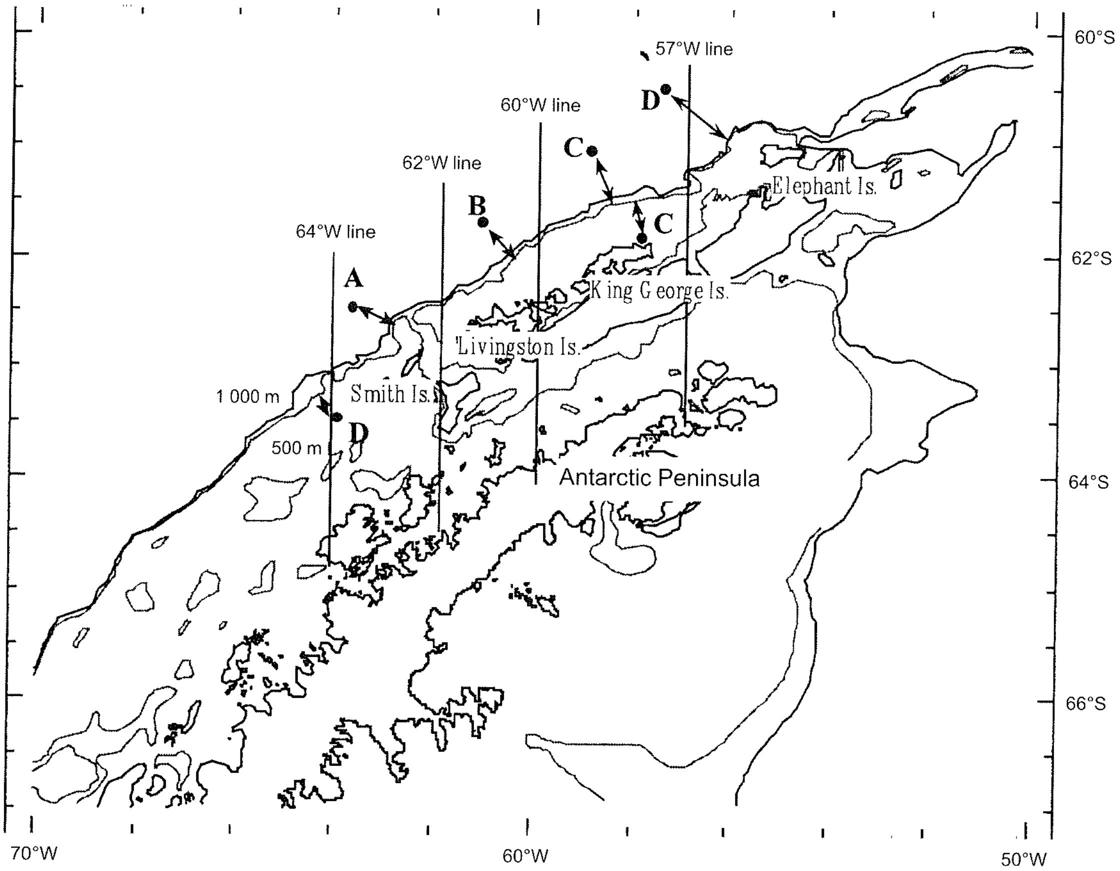

Figure 1: Map of the Antarctic Peninsula area showing 500 and 1 000 m isobaths. Arrows are examples of distances to the 500 m isobath. Trawling positions were grouped into the Smith Island (A), Livingston Island (B) and King George Island (C) areas. Trawling positions near the isobaths but outside the 57–64°W range (minimum distances, D) were not used in the analysis.

Table 1: Salp, krill and chlorophyll *a* abundance in the Elephant Island area.

Fishing Season	Salp[1] (ind./m²)	Krill[2] (ind./m²)	Chlorophyll[1] (mg/m²)
1980/81	24.1	161.4	
1981/82	25.3	324.9	
1982/83	No data	276.7	
1983/84	167.6	241.7	
1984/85	42.1	85.9	
1985/86	79.5	No data	
1986/87	No data	No data	
1987/88	1.2	27.6	
1988/89	200.0	79.8	
1989/90	3 489.0	15.4	46.7
1990/91	No data	6.5	65.2
1991/92	94.3	19.9	32.3
1992/93	1 399.6	29.2	30.1
1993/94	713.5	33.0	47.6
1994/95	14.9	73.3	60.6
1995/96	29.4	120.0	19.5
1996/97	733.5[3]	212.5	
1997/98	958.5[3]	59.9[4]	
1998/99	253.3[3]	No data	

1 Loeb et al. (1997)
2 Siegel et al. (1998)
3 Loeb (pers. comm.)
4 Hewitt and Siegel (pers. comm.)

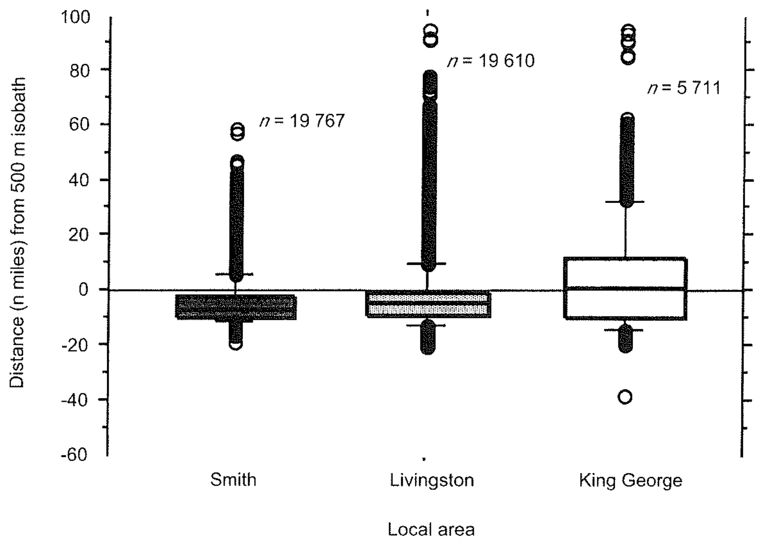

Figure 2: Box diagrams of minimum distances between trawling position and the 500 m isobath. Trawling positions were grouped into the Smith Island, Livingston Island and King George Island areas. The boxes indicate the 25–75 percentile range, vertical bars indicate the 10–90 percentile range. Open circles are plots for outside the 10–90 percentile range.

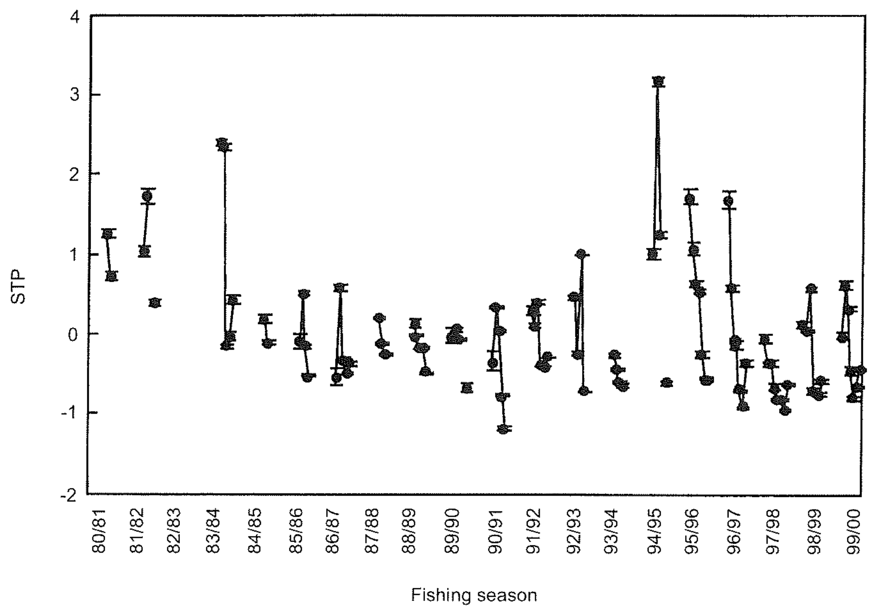

Figure 3: Values of monthly mean standardised trawling position. Vertical bars indicate standard errors.

Island groups. This shows that trawlers tended to operate slightly more offshore when they were operating north of King George Island compared to the areas around Livingston and Smith Islands. Ninety percent of the fishing opera-tions were performed within approximately 20 n miles of the shelf break (Smith and Livingston) and approximately 50 n miles of the shelf break (King George) (Figure 2).

Figure 3 shows the variation of monthly mean STP for the 1980/81 to 1999/2000 seasons. Only data with more than 20 hauls per month were used. Starting with December, most of the months had a valid number of fishing operations, however there were some exceptions (in 1981/82 and 1983/84 they started from November, in 1984/85, 1987/88, and 1992/93–1994/95 they started from January, and in the 1982/83 season there were no valid data) (Table 2). The variation of STP for each fishing season showed a general pattern with operations starting from the outer shelf, and proceeding towards the shelf, with some exceptions (1981/82, 1986/87, 1992/93) (Figure 3).

The mean STPs for each fishing season were initially large with a gradual decrease in the early 1980s. Mean STP for November 1983 was exceptionally large, indicating fishing further offshore. From the 1984/85 to 1989/90 seasons, both intra- and interannual variation was very small, and the mean STPs were close to zero, indicating that fishing was mostly conducted around the shelf slope. From the 1990/91 to 1999/2000 seasons, intra-annual variation increased compared to the earlier period, and the maximum mean STPs for each season increased. At the same time, the minimum values remained low. This suggests that during this period, movement of fishing positions became active across the shelf slope, except for the 1993/94 season. The highest mean STP was obtained for February 1995. Fishing operations from 1995/96 onwards always started in the outer shelf and proceeded towards the inner shelf, and at some point (April or May) they again moved towards the outer shelf (Figure 3).

Correlation of STP with Biological Factors

Mean krill and salp abundance around Elephant Island (Table 1) were plotted against the mean STP observed north of the South Shetland Islands (Figure 4; Table 3). The biological dataset from the Elephant Island area was used because Elephant Island is located downstream of the current in the South Shetland Islands area (Siegel and Loeb, 1995), and the plankton community structure is stratified parallel to the South Shetland Islands including Elephant Island (Siegel and Piatkowski, 1990). Therefore, the plankton community observed around Elephant Island could be assumed to be the same as the community north of Livingston and King George Islands. Plots for November, June and July are not shown due to the small number of data points (<5). In December the mean STP was positively correlated with krill abundance ($p < 0.01$), but not with salp abundance. In January the STP did not show any trend with krill abundance, but showed a significant negative trend ($p < 0.05$) with salps. In February and March trends for both krill and salp were insignificant, however mean STPs were always below 0 whenever high salp density was observed. In April salps had a significant negative correlation with STP ($p < 0.05$).

DISCUSSION

Possible Factors affecting Trawling Operation

A conceptual figure of seasonal krill distribution around the Antarctic Peninsula area was developed by Siegel et al. (1997). From austral spring towards summer the distribution area of Antarctic krill gradually extends towards the outer shelf, reaching its maximum extent in high summer, and from late summer onwards the extent recedes. Larger mature krill tend to be located further offshore than the smaller immature animals. Ichii et al. (1998) suggested that the result of interactions between ontogenetic migration and surface segregation may be the reason for this spatial difference in size and maturity stages. Similar seasonal variability in the distribution, due to changes in krill behaviour, was also described west of the Antarctic Peninsula (Lascara et al., 1999). These studies confirm that the pattern of spatial segregation among different maturity stages is similar to that to the west of and throughout the Antarctic Peninsula area.

Trawling positions analysed here followed a similar pattern of movement from the outer shelf towards the shelf from high summer onwards (Figure 2), as Siegel et al. (1997) described for krill. Krill trawlers target large krill.33 This does not simply mean, however, that krill trawlers operate at the edge of the distribution, since krill density must be at least high enough to justify commercial fishing. Fishing operations also avoid salp by-catch (Kawaguchi et al., 1998) and green krill (krill

Table 2: Number of trawls in the study area. Shaded cells denote the months with valid number of trawls.

Fishing Season	October	November	December	January	February	March	April	May	June	July
1980/81		13	279	166	16					
1981/82		102	252	8	119	5				
1982/83	6	11								
1983/84		361	998	1 913	360	381				
1984/85			16	136	384					
1985/86		13	37	619	544	202	3			
1986/87		16	29	280	184	182	98			
1987/88				1 223	1 793	1 112				
1988/89			96	375	2 040	1 040	756			
1989/90			67	931	341	7	476			
1990/91			23	1 169	785	534	40			
1991/92			139	1 147	982	949	1 332	482		
1992/93				315	534	872	458			
1993/94				489	653	899	139	14		
1994/95				204	610	538		149		
1995/96			184	266	667	545	375	1 058	585	13
1996/97			137	211	635	549	862	1 089	149	
1997/98			177	230	173	199	625	402	487	458
1998/99			152	285	654	141	11	25	61	
1999/2000			21	275	691	161	258	599	232	

Table 3: Results of pairwise correlations (Kendall's tau test) between STP and the mean abundance of krill or salps. (Loeb et al., 1997). T: tau coefficient of rank correlation, P: probability, N: number of data points. Significance level of <0.01 is darkly shaded, level of <0.05 is lightly shaded. Biological data are listed in Table 1.

		December	January	February	March	April	May
	T	0.733	0.121	0.121	0.455	0.278	-0.400
Krill	P	0.003	0.547	0.547	0.052	0.297	0.327
	N	10	14	14	11	9	5
	T	-0.345	0.410	-0.333	-0.364	-0.714	-0.467
Salp	P	0.139	-0.033	0.083	0.099	0.013	0.189
	N	11	15	14	12	8	6

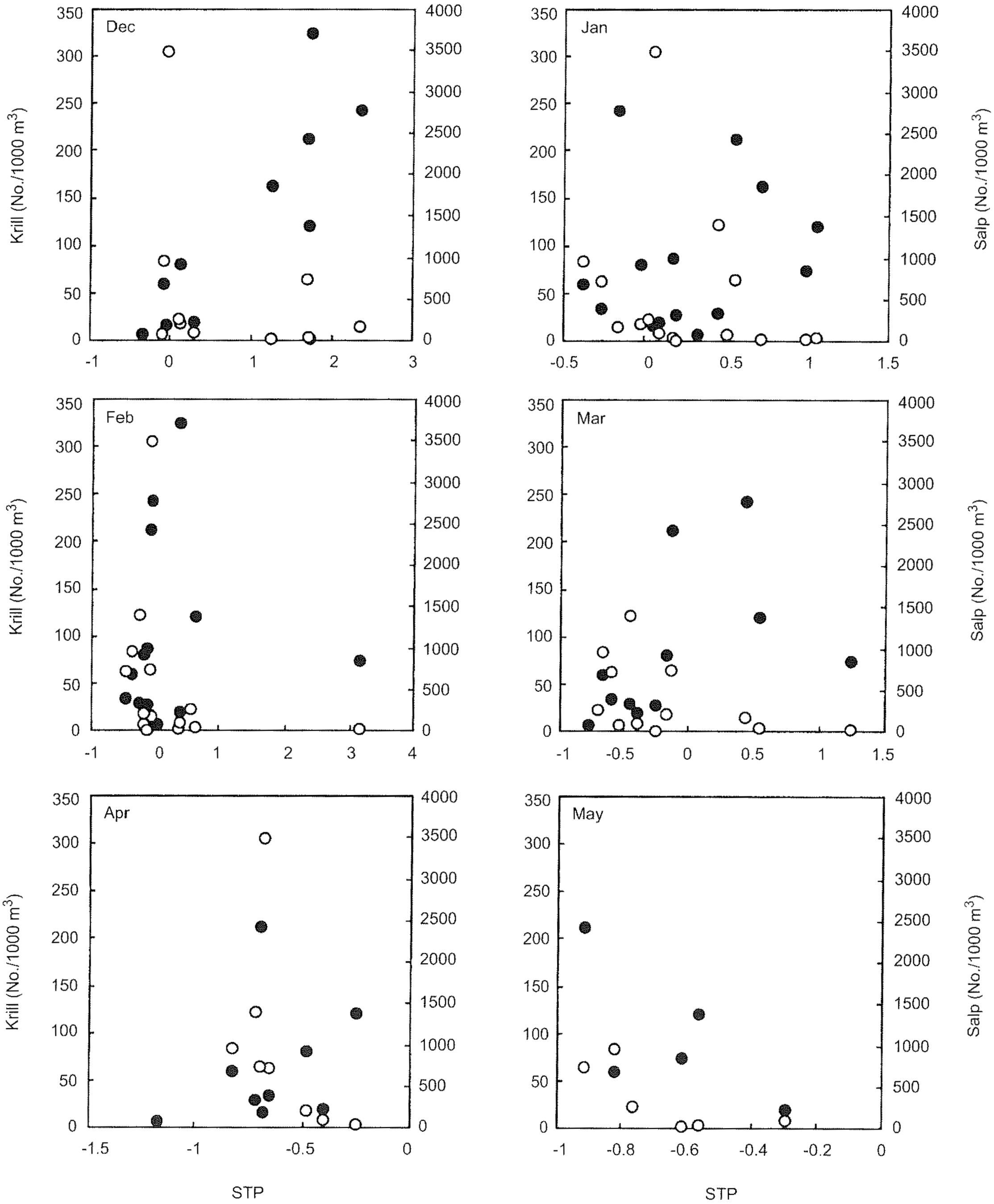

Figure 4: Mean krill and salp abundance around Elephant Island plotted against the standardised trawling positions observed north of the South Shetland Islands. Closed and open circles denote krill and salp respectively.

discoloured green due to heavy ingestion of phytoplankton) (Kawaguchi et al., 1997). Environmental conditions such as sea-ice extent may also have direct and indirect effects on krill fishing operations. Therefore, decisions regarding area of operation may be a function of all these factors.

Effect of Krill and Salp Abundance and Distribution on Trawling Positions

The area north of the South Shetland Islands is generally ice free from December to April. November 1982 and 1984 were also ice free (NASA, 1992). Therefore, during these periods the direct effect of ice extent on fishing operations should be negligible. The effect of salp by-catch may also be small in December, since the main period of observed salp by-catch around this area was January to March (Kawaguchi et al., 1998).

Therefore, the fishing positions in December should mainly be governed by the distribution pattern of large mature krill. From January to March, salp by-catch as well as krill distribution may have effects. From April onwards, the direct effect of increasing ice extent may be the major factor.

When mean STP was plotted against krill density, a significant positive correlation was observed for fishing operations in December (Table 3). In other words, for fishing seasons with high krill density, trawling positions of krill trawlers extended to the outer shelf, suggesting an expanded area of krill distribution. This agrees well with the idea developed by Siegel et al. (1997), which suggests increased krill abundance as krill distribution extends towards the oceanic region.

From January to March trawling positions did not have any significant correlation with krill abundance. On the other hand, in January there was a significant negative correlation with salp abundance ($p < 0.05$), and insignificant but still negative trends were observed between salps and STP for February and March (Table 3). This pattern implies that in fishing seasons with generally high salp density, trawlers were operating inshore. Salps belong to the oceanic community, which is mainly distributed in waters dominated by the warm Antarctic Circumpolar Current (Piatkowski, 1989) offshore of the South Shetland Islands. Whenever salp densities have been high, fishing operations may have shifted towards the shelf to avoid salp by-catch.

For fishing operations in January there were some fishing seasons when trawling positions were observed in the oceanic region (relatively high STP) (Figure 4). These were the 1989/90, 1992/93 and 1993/94 seasons. According to reports from fishing vessels, the reasons for changing fishing grounds in January of these years were either a high percentage of green krill or dispersal of krill patches (Japan Deep Sea Trawlers Association, pers. comm.). This implies that although mean salp densities were generally high in these years, salp density in January may have been low, or krill trawlers might have found an area of low salp abundance in the oceanic region containing commercially profitable krill concentrations.

Possible Effect of Phytoplankton Concentration

Loeb et al. (1997) reported a very high chlorophyll concentration in the 1990/91 and 1994/95 seasons (Table 1). Interestingly, the monthly variation of mean STP for these two years showed unusual patterns. In 1990/91 most trawling positions were located from the shelf break to the shelf (STP < 0). On the other hand, from January to March trawling positions were distributed in the oceanic region (high STP value). Phytoplankton blooms around the South Shetland Islands are known to be concentrated along the oceanic to shelf break region in early summer (December) and move towards the inshore zones in mid-summer (January to February) (Ichii et al., 1998). Therefore, it is likely that fishing on the shelf during mid-summer has a high risk of catching green krill.

Krill abundance in the 1990/91 season was the lowest in the last two decades (Table 1), so trawlers may have had difficulties finding commercially profitable aggregations. This theory is confirmed by reports from the trawlers, which noted that low krill densities had forced them to change fishing locations (Deep Sea Trawlers Association, pers. comm.). Although the proportion of green krill was relatively high in the 1990/91 season (Kawaguchi et al., 1998), vessels continued fishing as it may have been difficult to find other commercial aggregations. On the other hand, krill abundance in 1994/95 was normal (Table 1). In that season's reports from trawlers it was noted that the high proportion of green krill was the reason for changing fishing location. Salp abundance was relatively low (Table 1). Therefore, trawlers may have decided to fish for non-green krill distributed in the oceanic area without taking a by-catch of salp often encountered there.

Effect of Sea-ice

In the early 1980s fishing took place from November to March. From the mid-1980s the period of fishing gradually extended. From the 1995/96 season fishing lasted until June or July (Table 2). Small differences between the maximum and minimum mean STP for the early to late 1980s may be explained by the relatively short fishing period in these years. However, from the 1996/97 season the fishing pattern showed a 'V' shape. Fishing began with high mean STP, decreased and reached its minimum in April or May, and again increased until the end of fishing. This pattern may have occurred because of an increase in sea-ice extent, which may have directed the fishing operation towards the offshore region.

Another important environmental factor is the indirect effect of sea-ice extent on krill and salp distribution in subsequent seasons. It is still unclear whether ice influences the movement and distribution of krill aggregations (Fedoulov et al., 1996). However, Siegel and Loeb (1995) have shown that the abundance of gravid females had positive, and salp abundance had negative correlations with ice condition in the preceding winter. As we have discussed earlier, krill abundance may be related to the extent of its distribution. This evidence also suggests that ice condition in preceding winters may affect trawling positions through its indirect effect on krill and salp abundance and/or distribution.

CONCLUSION

In this paper, an analysis of trawling positions relative to bottom topography was performed, revealing that the behaviour of krill trawlers varied according to biological and environmental factors. Trawling positions were effectively described by standardising their distances from shelf breaks. The position of the krill fishing operations seemed to be primarily governed by the distribution of larger mature krill, especially at the beginning of each fishing season. Biological factors affecting product quality, such as salp abundance and the proportion of green krill, also seemed to have an increasing effect in mid-summer. The direct effects of ice conditions were also demonstrated, especially for the recently extended fishing period. However, the indirect effect of sea-ice extent and other environmental factors is still to be evaluated in detail.

The STP index has allowed us to conduct a one-dimensional analysis of trawling positions (latitudinal and longitudinal movement). In reality, however, trawlers also operate in two other dimensions, trawling depth and time. Generally, when skippers change their trawling positions, they do not aim to move across isobaths but are moving between different local areas. Most often, movements between the Livingston and King George Island areas were recorded (Japan Deep Sea Trawlers Association, pers. comm.) and were taken into account in our analyses. Therefore, the movements across isobaths we observed were solely the result of trawlers' movements perpendicular to the shelf break, in response to biological and environmental factors such as krill and salp abundance/distributions, green krill and ice condition.

ACKNOWLEDGEMENTS

We would like to thank Denzil Miller and Robin Ross for their critical comments on an earlier draft of the manuscript. Thanks are extended to Andrew Constable for providing useful comments, and to Steve Nicol for reviewing the later draft of the manuscript. We also would like to thank Roger Hewitt, Rennie Holt, Valerie Loeb and Volker Siegel for kindly providing recent values of krill and salp densities (ownerships of unpublished data are as mentioned in footnotes of Table 1). This is contribution No. 430 from the National Research Institute of Far Seas Fisheries.

REFERENCES

BODC. 1997. GEBCO-97. *The Second Release of the GEBCO Digital Atlas.* British Oceanographic Data Center.

Fedoulov, P.P., E.J. Murphy and K.E. Shulgovsky. 1996. Environment–krill relations in the South Georgia marine ecosystem. *CCAMLR Science*, 3: 13–30.

Ichii, T. 2000. Krill harvesting. In: Everson, I. (Ed.). *Krill: Biology, Ecology and Fisheries.* Blackwell Science, Oxford: 228–261.

Ichii, T., K. Katayama, N. Obitsu, H. Ishii, and M. Naganobu. 1998. Occurrence of Antarctic krill (*Euphausia superba*) concentrations in the vicinity of the South Shetland Islands: relationships to environmental parameters. *Deep-Sea Res.*, I, 45 (8): 1235–1262.

Kawaguchi, S., T. Ichii and M. Naganobu. 1997. Catch per unit effort and proportional recruitment indices from Japanese krill fishery data in Subarea 48.1. *CCAMLR Science*, 4: 47–63.

Kawaguchi, S., T. Ichii, M. Naganobu and W.K. de la Mare. 1998. Do krill and salps compete? Contrary evidence from the krill fisheries. *CCAMLR Science*, 5: 205–216.

Lascara, C.M., E.E. Hofmann, R.M. Ross and L.B. Quetin. 1999. Seasonal variability in the distribution of Antarctic krill, *Euphausia superba*, west of the Antarctic Peninsula. *Deep-Sea Res.*, I, 46: 951–984.

Loeb, V., V. Siegel, O. Holm-Hansen, R. Hewitt, W. Fraser, W. Trivelpiece and S. Trivelpiece. 1997. Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. *Nature*, 387: 897–900.

NASA. 1992. *Arctic and Antarctic Sea Ice, 1978–1987: Satellite Passive-Microwave Observations and Analysis*. National Aeronautics and Space Administration, Washington, DC: 290 pp.

Piatkowski, U. 1989. Macroplankton communities in Antarctic surface waters: spatial changes related to hydrography. *Mar. Ecol. Prog. Ser.*, 55: 251–259.

Siegel, V. 1988. A concept of seasonal variation and abundance west of the Antarctic Peninsula. In: Sahrhage, D. (Ed.). *Antarctic Ocean and Resources Variability*. Springer-Verlag, Berlin, Heidelberg: 219–230.

Siegel, V. and V. Loeb. 1995. Recruitment of Antarctic krill (*Euphausia superba*) and possible causes for its variability. *Mar. Ecol. Prog. Ser.*, 123: 45–56.

Siegel, V. and U. Piatkowski. 1990. Variability in the macrozooplankton community off the Antarctic Peninsula. *Polar Biol.*, 10 (5): 373–386.

Siegel, V., W.K. de la Mare and V. Loeb. 1997. Long- term monitoring of krill recruitment and abundance indices in the Elephant Island area (Antarctic Peninsula). *CCAMLR Science*, 4: 19–35.

Siegel, V., V. Loeb and J. Gröger. 1998. Krill (*Euphausia superba*) density, proportional and absolute recruitment and biomass in the Elephant Island region (Antarctic Peninsula) during the period 1977 to 1997. *Polar Biol.*, 19 (6): 393–398.

Zar, J.H. 1996. *Biostatistical Analysis*, 3rd Edition. Prentice-Hall, USA.

Liste des tableaux

Tableau 1: Abondance des salpes, du krill et de la chlorophylle *a* dans la région de l'île Éléphant.

Tableau 2: Nombre de chalutages dans la région étudiée. Les mois dont le nombre de chalutages est valide sont indiqués dans les cases en gris.

Tableau 3: Résultats des corrélations par paire (test tau de Kendall) entre STP et l'abondance moyenne de krill ou de salpes (Loeb et al., 1997). T : coefficient tau de la corrélation de rang, P : probabilité, N : nombre de points de données. Le seuil de signification <0,01 est donné en gris foncé, celui de <0,05 en gris clair. La liste des données biologiques paraît au tableau 1.

Liste des figures

Figure 1: Carte de la région de la péninsule antarctique avec indication des isobathes 500 et 1 000 m. Les flèches donnent des exemples de distances de l'isobathe 500 m. Les chalutages étaient regroupés dans les régions des îles Smith (A), Livingston (B) et du roi George (C). Les chalutages réalisés près des isobathes mais en dehors de l'intervalle de 57–64°W (distances minimales D) n'ont pas été pris en compte dans l'analyse.

Figure 2: Diagrammes des distances minimales entre la position des chalutages et l'isobathe de 500 m. Les chalutages étaient regroupés dans les régions des îles Smith, Livingston et du roi George. Les cadres indiquent l'intervalle de centile 25–75, les barres verticales, celui de 10–90. Les cercles vides indiquent des valeurs situées en dehors de l'intervalle du centile 10–90.

Список таблиц

Список рисунков

Lista de las tablas

Lista de las figuras

Figura 2: Diagrama de flujo de bloques sobre la distancia mínima entre arrastres y la isóbata de 500 m. Los arrastres se agruparon por área alrededor de las islas Smith, Livingston y Rey Jorge/25 de Mayo. Los bloques muestran los percentiles de 25 a 75% y las barras verticales los percentiles de 10 a 90%. Los círculos blancos están fuera de los percentiles de 10 a 90%.

Figura 3: Promedio mensual de la posición estándar de los arrastres. Las barras verticales muestran el error estándar.

Figura 4: Abundancia promedio de kril y salpas alrededor de isla Elefante en función de la posición estándar de los arrastres observados al norte de las islas Shetland del Sur. Los círculos blancos y negros representan el kril y las salpas respectivamente.