# ANALYSIS OF HAUL DATA FROM THE SOUTH GEORGIA KRILL FISHERY

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Abstract

Data from individual hauls carried out by vessels operating in the South Georgia krill fishery between 1994 and 1996 were examined and a range of descriptive measurements reflecting the fishery operation were produced. The measurements emphasise that the krill fishery at South Georgia was geographically focused, operating in a limited area along the shelf edge on the northern coast of the island. Each day several hauls were undertaken by each vessel (average 7.9 in 1993, 9.9 in 1995, and 7.0 in 1996), with hauls producing higher catch rates during the middle of the day. Individual hauls were examined to establish the time required for each phase of the fishing operation. The times associated with shooting and hauling the net were usually short and showed little variation, whereas the time associated with the actual fishing period was longer and more variable. The time between consecutive hauls was almost as long as the fishing period and showed similar levels of variability. Distances moved between consecutive hauls were generally small, suggesting that little effort was spent searching for fishable swarms beyond the near neighbourhood. The range of measurements describing the fishery indicates that differences existed between years, with 1995 being a better season than either 1994 or 1996. Aspects of mesoscale variability are discussed in relation to previous attempts to model fisheries data and to derive suitable abundance indices that are sensitive to changes in biomass. The focused nature of the fishery at South Georgia suggests that fisheries-based indices may be of value for management purposes, consequently further detailed analysis would be useful.

Résumé

Examen des données de chacun des traits effectués par les navires ayant pêché le krill près de la Géorgie du Sud entre 1994 et 1996 et présentation d'une série de valeurs reflétant les opérations de la pêcherie. Ces données soulignent que dans cette région la pêche de krill était localisée, dans un secteur longeant la bordure du plateau sur la côte nord de l'île. Chaque jour, les navires effectuent plusieurs chalutages (en moyenne 7,9 en 1993, 9,9 en 1995 et 7,0 en 1996), et les taux de capture les plus élevés sont ceux des chalutages effectués vers le milieu de la journée. Les traits sont examinés un par un pour déterminer le temps nécessaire pour chacune des phases d'une opération de pêche. La mise à l'eau et la remontée du chalut sont en général de courte durée et varient peu alors que la pêche même est plus prolongée et de durée plus variable. Le temps passé entre deux traits est presque aussi prolongé que la phase de pêche et présente un niveau semblable de variabilité. La distance parcourue d'un chalutage à un autre est le plus souvent courte, ce qui laisse entendre que la recherche d'essaims exploitable se limitait aux alentours et qu'elle ne nécessitait qu'un d'effort de pêche restreint. L'intervalle de valeurs décrivant la pêcherie met en évidence des différences entre les années : 1995 était une meilleure saison que 1994 ou 1996. Les aspects de la variabilité à échelle moyenne sont discutés par rapport aux anciennes tentatives de modélisation des données de pêche pour en dériver des indices utiles d'abondance qui soient sensibles aux changements de biomasse. Le caractère très localisé de la pêche autour de la Géorgie du Sud indique que les indices dérivés de la pêche peuvent être valables à des fins de gestion. De ce fait, il pourrait être utile de procéder à une nouvelle analyse détaillée.

Резюме

В результате анализа данных по отдельным тралениям, выполненным траулерами, осуществлявшими промысел криля в районе Южной Георгии за период 1994–1996 гг., был получен ряд описательных показателей промысловых операций. Согласно этим показателям промысел криля у Южной Георгии, носивший географически сосредоточенный характер, проводился в ограниченном районе – вдоль границы шельфа у северного побережья острова. Ежедневно каждое судно выполняло несколько тралений (в среднем 7,9 в 1993 г., 9,9 в 1995 г. и 7,0 в 1996 г.), причем уловы были крупнее в середине дня. Отдельные траления были рассмотрены с целью определения того, сколько времени требуется для выполнения каждого этапа промысловых операций. Время, затраченное на установку и выборку сети, обычно было коротким и мало изменялось, в то время как период фактического ведения промысла был более продолжительным и изменчивым. Время между последовательными тралениями было почти такой же продолжительности и такой же степени изменчивости, что и период ведения промысла. Тот факт, что расстояние между последовательными тралениями обычно было небольшим, говорит о том, что мало времени затрачивалось на поиск коммерческих коцентраций криля. Ряд описательных показателей указывает на различия между годами, причем 1995 был более "удачным" годом, нежели 1994 или 1996 гг. Вопросы мезомасштабной изменчивости обсуждаются на фоне предыдущих попыток смоделировать промысловые данные и рассчитать индексы численности, чувствительные к изменениям в биомассе. Сосредоточенный характер промысла у Южной Георгии говорит о возможности применения промысловых индексов для управления, в связи с чем рекомендуется проведение дальнейшего анализа.



Resumen

Se efectuó un análisis individual de los datos de los arrastres realizados por barcos que participaron en la pesquería del kril en Georgia del Sur entre 1994 y 1996, y se elaboraron varias medidas descriptivas que reflejan las operaciones pesqueras. Las medidas confirman que la pesquería de kril en Georgia del Sur se concentraba geográficamente en un área reducida del borde de la plataforma, en la costa septentrional de la isla. Cada barco realizó varios lances diarios (promedio 7,94 en 1993, 9,89 en 1995, y 6,96 en 1996), y los arrastres del mediodía dieron tasas de captura mayores. Se examinaron los arrastres en forma individual para establecer el tiempo que se requiere para cada etapa de las operaciones pesqueras. En general el tiempo empleado en el lance y el izado de la red es corto y demuestra escasa variación, en tanto que el período de pesca es más largo y de mayor variabilidad. El período entre lances consecutivos fue casi tan largo como el período de pesca y demostró niveles similares de variabilidad. Las distancias recorridas entre lances consecutivos fueron por lo general pequeñas, indicando que se empleó escaso esfuerzo en la búsqueda de cardúmenes explotables más allá de las aguas circundantes. El rango de las medidas descriptivas de la pesquería indica que hubo diferencias interanuales, la temporada de 1995 fue mejor que las de 1994 y 1996. Varios aspectos de la variabilidad a mesoescala fueron considerados en relación a tentativas anteriores cuyo objetivo era modelar los datos de las pesquerías y derivar índices de abundancia que sean sensitivos a los cambios de la biomasa. El hecho que la pesquería se concentra geográficamente en un área reducida de Georgia del Sur indica que los índices que se basan en las pesquerías pueden ser de utilidad para los fines de ordenación, y por lo tanto un análisis adicional más detallado sería conveniente.


Keywords: South Georgia, krill fishing, haul positions, haul times, bathymetry, shelf-break, CCAMLR

## INTRODUCTION

In managing fisheries for Antarctic krill, CCAMLR has placed considerable emphasis upon applying information on krill distribution and abundance. The ecosystem approach to management adopted by CCAMLR regards such information as critical to estimating sustainable catch levels as well as ensuring that adequate concentrations of prey remain for dependent species. Many of the recent estimates of standing stock in CCAMLR Area 48 were derived from acoustic surveys (e.g. Biomass, 1986; Miller and Hampton, 1989; Murphy et al., 1991; Trathan et al., 1991; Trathan and Everson, 1994; Brierley et al., 1997). Such surveys, however, only provide single estimates of krill abundance and offer little information on how distribution is varying.

Fishing vessels operate for several months of the year and move around according to the local availability of krill. Consequently, they are potentially a major source of additional information on krill distribution and abundance. This is not a new concept and such data have been used previously (e.g. SC-CAMLR, 1985). However, in order to use fisheries data the operational characteristics of the fishing fleets need to be understood (Butterworth and Miller, 1987; Everson, 1988; Butterworth, 1988a; Mangel, 1988; Fedoulov et al., 1996). Thus, understanding changes in the perceived abundance of krill requires an understanding of a wide variety of environmental (see review by Miller and Hampton, 1989) and socio-economic factors. Although socio-economic factors such as fishing strategy, processing methods, product appeal, market size, value, etc. operate at different levels to environmental factors, they are just as influential in determining where, when, and how a fishery operates.

In order to encourage the recording of appropriate data, Butterworth (1988a) and Mangel (1988), amongst others, highlighted the need to establish careful logging of information by trawlers on an individual-haul basis. Such logging was considered the only means by which sufficient information could be derived for the preparation of any reliable fisheries-based abundance index. Since the late 1980s and early 1990s detailed information about fishing grounds and about individual hauls has become increasingly available (e.g. Endo and Ichii, 1989; Ichii et al., 1994; Murphy et al., 1997), such that it is now possible to re-examine the possibility of providing reliable indices.

As part of any such consideration, the initial step must be to provide a comprehensive summary of the available data. Thus, using data from individual hauls we provide a detailed description of the krill fishery at South Georgia, building upon an earlier spatial analysis of the fishery undertaken by Murphy et al. (1997). Here we describe new information about the location, timing and duration of the fishing season, the number of vessels operating in the fishery, variability in net operations and variability in catch rates. We also make inferences about the probable operation of vessels based on the evidence from the hauls. Finally we also consider other kinds of information not currently available, but probably necessary for the future calculation of reliable abundance indices.

## METHODS

### Database Description

Since August 1993, haul-by-haul data have become available from krill fishing vessels operating close to South Georgia. A spatial analysis of these data was presented by Murphy et al. (1997), and additional recent information has now been incorporated into the haul database. In this paper we describe data up to 25 September 1996. The main krill fishing season at South Georgia occurs during the austral winter and spans the end of one CCAMLR reporting year and the beginning of the next. Therefore to aid clarity in this study, data have been analysed by calendar year. All haul data have been examined and checked to ensure that records were self-consistent and that times and positions were consistent with other records. A few records (~1.5%) contained missing values for some fields.

Each database record contains data taken directly from the fishing logbook, including dates and times for different stages of the fishing process. For example, the time when the net was shot is recorded, as is the time when the net began to fish, the time when hauling started and the time when hauling was completed. Thus, the time interval for each stage of the fishing process has been calculated by using the appropriate date and time fields. The following definitions have been used throughout this paper:

- shoot time:
  the time at the start of shooting the net for each trawl;
- fishing start time:
  the time at which shooting was completed and the net began to fish;
- fishing end time:
  the time at which hauling started and the net stopped fishing;
- haul end time:
  the time at which hauling stopped and the net was back on deck;

- fishing period:
  the time between the start and end of fishing; and

- time between haul:
  the time between the end of one haul and the start of the next haul.

Each record also contains a single nominal position for the haul (at a resolution of one minute of arc for latitude and longitude). Distance between consecutive hauls was estimated as the distance between these given positions.

Each database record contains a value for the total catch (kilogram) from the haul. Thus the catch rate, that is the catch per unit effort, has been calculated as the catch per minute of the fishing period (kilogram per minute).

## Analysis of Records

A basic description of the data was made using statistical analyses undertaken with the program Minitab™ Release 9. Positional information and catch details for individual hauls were also loaded into a marine Geographic Information System (GIS) established using Arc/Info 7.2 (ESRI) software (Trathan et al., 1993a) and a simple spatial analysis was undertaken. The GIS included a digital coastline of South Georgia (McDonald et al., 1987) and bathymetry digitised from the Approaches to South Georgia Chart (Hydrographic Office, 1992).

# RESULTS

Although the haul database starts in the latter part of the 1993 season, the number of records from that year is small. As a consequence, the analysis was only carried out for those years that are complete and for which the full season's data have been collated, i.e. 1994, 1995 and 1996.

## Vessels Present in the Fishery

Between May 1994 and September 1996, krill fishing vessels from Japan, Poland and Ukraine operated at South Georgia and recorded data from individual hauls. For ease of reference, each vessel was assigned an individual identification code (Figure 1). The size of the fleet was variable with different numbers of fishing vessels operating in different years. Most vessels from Poland and Ukraine operated for just a single year, while vessels from Japan were present on a more regular basis, with three vessels present in each season and a fourth in 1995 and 1996.

In some years vessels from the same nation arrived at South Georgia at similar times. For example, in 1995 four vessels from Ukraine arrived within two days of each other (vessels 11, 12, 13 and 14). Similarly, in some years vessels from the same nation left at similar times. For example, in 1994 two vessels from Japan left on the same day (vessels 2 and 3).

Within their main fishing season some vessels did not fish for prolonged periods, for example vessel 5 in 1994. Thus, the total number of vessel fishing days was variable between years, with 255 vessel days in 1994, 307 in 1997 and 410 in 1996.

## Duration of the Fishing Season

Even though different fleets and different vessels were present at South Georgia, it is clear that there was a reasonably well-defined fishing season. Fishing usually commenced during the latter part of May, or in early June (Figure 1) and ended in August or September. A limited number of hauls were also taken outside these dates. For example, in 1994 vessel 6 took eight hauls during March and vessel 5 took three hauls during early October. Those hauls which occurred outside the main season have not been included in subsequent analyses reported in this study.

## Location of the Fishery

During 1994, 1995 and 1996 the South Georgia krill fishery operated along the northern edge of the continental shelf, with little fishing activity close inshore or over deep water. At South Georgia the shelf occurs at depths less than 250 m (Everson, 1984; Hydrographic Office, 1992); the shelf edge is abrupt with depths increasing rapidly over a very short distance (Figure 2). In 1994 the fishery was restricted to a submarine bank north of Cape Charlotte (Figure 3 – label CC). The fishery stayed close to this bank throughout the entire season (Figures 3a, b, c and d), and there was little activity elsewhere in the region.

During 1995 the fishery operated over a wider area than during 1994 (Figure 4). In the early part of the season (Figures 4a and b) the fishery operated in two locations; the first was close to the bank north of Cape Charlotte which had been the focus of the 1994 fishery, while the second was close to a second bank 75 km to the west. Towards the end of the season (Figures 4c and d) the fishery spread to other areas along the northern edge of the shelf.

During the 1996 season fishing activity started in May, again over the bank to the north of Cape Charlotte, although some vessels made a few isolated hauls before they reached their main fishing grounds (Figure 5a). In June and July fishing activity spread to the west (Figures 5b and c), covering the same banks that were fished in early 1995. By August the main fishing location had moved to the west (Figure 5d), and by September (Figure 5e) it was some distance west of South Georgia.

The movement of the fishery along the northern edge of the shelf has been reported previously (Fedoulov et al., 1996; Murphy et al., 1997), however the movement towards the west does not occur in all years (Figure 3). The movement is irregular, with the greatest shift in August and September, at the end of the season when there are fewer vessels in the area (Figure 4d and also Figures 5d and e).

### Number of Hauls per Vessel per Day

Hauls at South Georgia were of short duration with an average of between 7 and 10 hauls carried out each day by each fishing vessel (Table 1). The pattern of hauls per day was generally similar in 1994 and 1996, however in 1995 there was a greater proportion of days when a larger number of hauls were undertaken. In each year the first (Q1) and third (Q3) quartiles were equidistant about the median, with the median very close to the mean number of hauls per day. This would indicate that fishing is a full-time process, with little time spent on other activities such as searching for krill concentrations.

### Effort Recorded for Each Haul

The time intervals for each stage of the fishing process are shown in Table 2. Of the different phases of the operation, the actual fishing period showed the greatest variability in time to complete. This was not unexpected as the time needed to shoot the net and the time needed to haul the net would be approximately constant, both being largely mechanical processes. In contrast the fishing period would be dependent upon both the target species (krill) and the experience of the fishing master; for example, important factors which affect the duration of the fishing period include the local density of krill within the aggregations being fished, the number of swarms encountered during a haul, the skill with which swarms are tracked, and the intended catch rate compatible with the desired krill product.

The time interval between consecutive hauls also showed high levels of variability, with the amount of time being of similar magnitude to the actual time spent fishing (Table 2). That this period was variable with substantial differences between years is consistent with the suggestion that some search effort is associated with each haul and with locating swarms which are of a fishable size and density. However, in each of the three years the interval between hauls was limited and search time would have been very short. This would be the case particularly if the interval between consecutive hauls also included time associated with other operations, for example vessel relocation, processing of catch, or delays caused by bad weather and sea state.

Some of the time intervals between hauls were greater than 24 hours, for example vessel 5 in 1994 (Figure 1). Such intervals may reflect time away from the area, periods of bad weather, time spent re-victualling the vessel or trans-shipping processed krill products. For these longer time intervals, hauls often recommenced within a relatively short distance of where they had previously stopped (n = 109, mean distance = 25.8 km; standard deviation = 45.7; median distance = 7.4 km); these records have been excluded from Table 2. Following exclusion of the longer interval records, the time periods between consecutive hauls were, on average, shorter than those reported previously (cf. Butterworth, 1988a; Mangel, 1988).

In 1995 both the average fishing period, and the average interval between consecutive trawls, were shorter than the corresponding periods for either 1994 or 1996 (Table 2). The total elapsed time for the overall net operation was therefore shorter in 1995, which is consistent with the greater number of hauls made in that year (Table 1).

## Distance between Consecutive Hauls

Distances between hauls were usually small (Table 3), consistent with the restricted area of operation (Figures 3, 4 and 5) and the large number of hauls per day (Table 1). In each year the mean and the median were different, indicating that some hauls were separated by distances which were larger. However, the pattern each year was generally similar, with many hauls separated by distances of less than 2 km, and most (80%) separated by less than 7 km.

To determine whether the average distance between consecutive hauls varied for the different months of the same fishing season, an analysis of variance was used. For 1994 the analysis indicated that the distance between hauls was not significantly different for the different months in the season ($F_{3,1996}$ = 1.48; $P > 0.200$). This is consistent with the restricted scatter in the haul positions around the bank north of Cape Charlotte (Figure 3). In comparison, during 1995 and 1996 the distance between hauls was significantly different for the different months of the season ($F_{3,3019}$ = 16.90; $F_{4,2822}$ = 6.44; $P < 0.001$; for 1995 and 1996 respectively). This difference is consistent with the scatter of hauls evident in 1995 and 1996 (Figures 4 and 5), with the fishery being more tightly clustered in June and July and less tightly clustered towards the end of the season.

After each haul is complete, the distance to the next haul will be dependant upon the strategy of the fishing master, for example a vessel may turn to fish the same krill patch on a reciprocal course, or target a completely different patch. If vessels follow the former approach, then the distance between hauls will be less than the actual distance covered during a haul. To determine whether vessels used this approach, the distance between hauls (Table 3) was compared with the time estimates for each phase of the fishing operation (Table 2). In 1994, 1995 and 1996 respectively, the average time interval between shooting the net and completing the haul allowed a nominal distance of approximately 13.5, 11.3 and 14.4 km to be travelled, assuming a constant speed of 4 knots during the haul. These nominal distances are much greater than the mean distance between consecutive hauls (Table 3). Such a situation is compatible with vessels returning along a reciprocal course and would arise when vessels repeatedly targeted the same patch.

## Catch Size and Catch Rate per Haul

Maximum catch size is generally constrained by the time needed to ensure that the catch does not deteriorate before processing is complete. Thus, in the past catches were generally restricted to less than 8 tonnes per haul, both in the Japanese fleet (Shimadzu, 1985; Butterworth, 1988a) and in the Soviet Union fleet (Dolzhenkov et al., 1988). At South Georgia catches were often larger than this (Figure 6), though individual catches varied considerably. The proportion of medium- to large-sized catches (10 000–20 000 kg) was lowest in 1994, intermediate in 1996 and highest in 1995. The total recorded catch was 17 282, 34 091 and 25 675 tonnes in 1994, 1995 and 1996 respectively, with the Japanese fleet accounting for the largest proportion. Differences between fleets were also evident in the average size of catches in each year, with Poland consistently taking smaller hauls (Table 4).

An analysis of variance indicated that the average catch (kilogram per haul) was different in the separate years ($F_{2,7911}$ = 130.16; $P < 0.001$), as was the average catch rate (kilogram per minute) ($F_{2,7909}$ = 344.11; $P < 0.001$) (Table 5). Overall, catches and catch rates were higher in 1995 than in either 1994 or 1996, though this masked some differences between fleets, for example the Polish catches and catch rates were actually lower in 1995.

There were no areas where catch rates were always high, although in each season almost all of the catch rates which were high occurred towards the east of the fishing area over the bank to the north of Cape Charlotte. Thus, the top 10% of catch rates (kilogram per minute) for each of 1994, 1995 and 1996 (Figure 7) occurred close to the area where the fishery started and remained for much of the season. The high catch rates (top 10%) generally occurred during June and July and became more infrequent towards the end of each season, though in 1994 they also continued into August.

## Time of Day and Catch Rate

During each of the fishing seasons, vessels operated continuously throughout the day with catches taken during the night as well as in daylight hours. There was a slightly greater number of hauls made between 0800 and 1700 hours (local time). An analysis of variance indicated that the catch rates made at different times of day (Figure 8) were different ($F_{23,2001}$ = 34.95;

$F_{23,3009}$ = 13.69; $F_{23,2830}$ = 6.33; $P < 0.001$; for 1994, 1995 and 1996 respectively). Thus, assuming approximately 10 hours between sunrise and sunset (nominally for June and July at 54°00'S; 35°30'W), a two-sample *T*-test based on 10 daylight hours (hours 0700 to 1659) and 14 night-time hours (hours 0000 to 0659 and hours 1700 to 2359) indicated significant differences between daytime and night-time catch rates ($T$ = 25.14; $T$ = 14.35; $T$ = 10.72; $P < 0.001$, assuming unequal variances; for 1994, 1995 and 1996 respectively).

### Depth of Trawling

An analysis of variance indicated that the depths of trawling at different times of day were different ($F_{23,2001}$ = 4.48; $F_{23,3011}$ = 2.90; $F_{23,2830}$ = 5.74; $P < 0.001$; for 1994, 1995 and 1996 respectively). However, the differences in depth were generally small (~10 m) when compared to the likely distance between the trawl headrope and footrope.

## DISCUSSION

Krill fishing vessels from Japan, Panama, Poland and Ukraine have reported data on catch and effort to CCAMLR for Subarea 48.3 since the start of the 1994 fishing season. The historical record of the fishery in Subarea 48.3 is documented in the CCAMLR *Statistical Bulletin* (e.g. CCAMLR, 1997), however this record is presented at a relatively coarse resolution (Murphy et al., 1997). Three of the four nations also recorded data for the individual hauls included in the dataset described here. There are differences in the area of Subarea 48.3 and the area covered by the dataset of individual hauls, however the dataset for individual hauls represents nearly all (78%) the catch reported to CCAMLR for Subarea 48.3 during the corresponding time period (cf. CCAMLR, 1997). Thus, the dataset for individual hauls provides a useful description of the commercial krill fishery, and a valuable insight into how the fishery operates around South Georgia and in Subarea 48.3.

### Operational Description of the Fishery at South Georgia

Since 1990, the start and end dates of the fishing season in Subarea 48.3 have been variable (CCAMLR, 1997), with fishing activity starting in April (1 year), May (5 years) or June (1 year), and ending in August (1 year), September (2 years), October (1 year), November (1 year) or December (1 year). In recent years the end date of the season has been more variable than the start date. This may be related to the prevailing catch rates, the quality and size of available krill, or the date on which water becomes ice-free in the traditional fishing grounds elsewhere in Area 48 (cf. Everson and Goss, 1991). The pattern of start dates and end dates in the dataset of individual hauls conforms to the historical pattern (cf. CCAMLR, 1997), with the start date being more regular than the end date.

As vessels arrive at South Georgia, they sometimes undertake a few isolated hauls as they approach their traditional fishing grounds (Figure 5a). Vessels from the same nation often arrive together and leave together (Figure 1). Some vessels remain close together during much of the season which suggests that these vessels may cooperate by passing information which increases the overall productivity of the fleet. In the past the Soviet fishery operated as a cooperative unit, with the activities of locating and of fishing largely the responsibilities of different vessels (Mangel, 1988), whereas trawlers of the Japanese fleet operated independently of each other (Butterworth, 1988b). The degree to which cooperation occurs between individual vessels in the various national fleets has not been documented in recent times, and a detailed examination of the relationship between vessels would be of considerable interest.

At South Georgia the fishery is almost exclusively located north of the island (Figures 3, 4 and 5), operating at the edge of the continental shelf. In each of the years for which data are available, fishing started in the east of the region, and much of the fleet spent the early part of the season close to a large submarine bank north of Cape Charlotte (Figures 3, 4 and 5). Fishing activity around this bank was highly focused and it appears that these fishing grounds are extremely important, presumably reflecting a reliable availability of krill in that area.

Throughout the 1994 season the fishery remained close to the bank north of Cape Charlotte (Figure 3). In comparison, during 1995 the fishery stayed close to the bank (and another similar bank 75 km to the west) through the early part of the season (Figures 4a and b), but moved away at the end of the season (Figures 4c and d). This movement was also apparent during the latter part of 1996 when the fishery moved away to exploit other areas along the northern shelf edge (Figures 5d and e). Why vessels move away from this bank is unclear, although it presumably relates to availability and quality of krill in the area (cf. Endo and Ichii, 1989).

Around South Georgia fishing occurred throughout the day, with hauls made during the hours of day and night (Figure 8). Each vessel made several hauls per day (Table 1), with hauls, on average, of short duration (Table 2). The times taken to shoot the net and to haul the net were brief and showed only limited variability. In comparison, the time spent trawling and the time spent between hauls was longer and more variable. For many hauls the distance travelled between consecutive hauls (Table 3) was less than the nominal distance travelled during hauls. This is compatible with vessels returning along the reciprocal course to fish through the same patch. Occasionally vessels relocate slightly further afield before the regular pattern is resumed. Such relocations occur at all times of the day and are not restricted to a particular period. More than 32% of hauls occur within 2 km of the previous haul and less than 10% are further apart than 10 km. Such a pattern of operation suggests that most of the time that the fleet is over the fishing grounds is directed towards fishing, and that little time is spent searching beyond the near neighbourhood for fishable aggregations. The South Georgia krill fishery thus appears to be highly directed, with little exploration beyond areas of known concentration; there appears to be little time spent searching, relocating, readying gear, trans-shipping, and little time lost due to bad weather.

The catch per haul and the catch rates per haul (Table 5) were extremely variable, and differed significantly between years. Catches and catch rates also differed between fleets (Table 4), with Polish catches and catch rates being substantially lower than those of Japan and Ukraine. The magnitude of the difference between fleets is compatible with differing fishing strategies and also with the production of different krill products.

In general the hauls with the highest catch rates (top 10%) occurred in the east of the region, close to the bank north of Cape Charlotte (Figure 7). The majority of these hauls occurred during June and July. Only in 1994 did high catch rates continue into August. In each year catch rates were higher during daylight hours than at night (Figure 8), a situation possibly related to differing aggregation characteristics at different times of day (cf. Marr, 1962; Everson, 1982). Diel migration of krill could affect availability to the fleet if krill tended to concentrate in particular regions, for example at levels close to the seasonal thermocline (cf. Kalinowski and Witek, 1980; Hampton, 1985). Availability to the fleet may therefore reflect mesoscale differences in dispersion as well as mesoscale differences in the standing stock. Similar considerations regarding local dispersion and the potential effect upon catch rates have been recognised previously (Dolzhenkov et al., 1988).

## Management Implications of the Operational Description

At South Georgia fishing activity occurs almost exclusively in a narrow band approximately 20 km wide along the northern shelf (Figures 3, 4 and 5), particularly at the shelf edge and close to prominent submarine banks. This restricted distribution contrasts markedly with the distribution of krill reported from acoustic surveys, for example Murphy et al. (1991) have shown that krill occur over the shelf, at the shelf edge and over deep offshore waters. It is therefore interesting to speculate why only some areas of krill are targeted by the fishery. It may be that the character and frequency of aggregations are affected by environmental factors such as bathymetry, hydrography (Witek et al., 1982), primary production (Hamner et al., 1983; Weber and El-Sayed, 1985) and predator disturbance (O'Brien, 1987), or by innate behavioural characteristics such as an ontogenetic migration (cf. Siegel, 1988; Trathan et al., 1993b). Whatever the cause, it is likely that only aggregations of a certain character can be fished profitably (Butterworth, 1988b), and that at South Georgia these mainly occur at the shelf edge.

That fishing vessels return year after year to those areas where predictable concentrations of krill occur highlights the conservative character of the fishery at South Georgia. These areas, such as the bank north of Cape Charlotte, conceivably reflect the highest levels of available krill in the area, particularly during the main fishing season in June and July. Thus, within these areas it is feasible that differences in krill availability are reflected by differences in catch, either of individual vessels, or of national fleets. Furthermore, if the availability of krill within the traditional fishing grounds reflects the availability of krill elsewhere at South Georgia, and if the relationship is proportional (cf. Butterworth, 1988a), then monitoring and analysing catch levels has considerable potential in providing advice for management.

Fisheries-based indices with management potential have been critically examined in the past, in particular by Butterworth (1988a) and Mangel (1988). Both these evaluations considered open oceanic systems where vessels spent time searching for concentrations of swarms, before within-concentration searching for fishable swarms took place. At South Georgia the fishery appears to be highly predictable, so that the within-concentration indices developed by Butterworth (1988a) and Mangel (1988) may have considerable utility. These indices incorporated search time and reflected changes in biomass better than did those which were based on catch per fishing time. Butterworth (1988a) refined his index and divided search time into primary search time (PST) and secondary search time (SST), with the former defined as the time required to find a swarm within a concentration and the latter as the time needed to finish processing the just-completed catch. At South Georgia PST appears to be almost negligible (Table 2), whereas SST may be more important; a situation apparently comparable to that in the Japanese krill fishery north of the South Shetland Islands (cf. Endo and Ichii, 1989).

In order to understand the components of search time and their relevance to the South Georgia krill fishery, further consideration is required. In particular, operational aspects of the fishery such as the differences between fleets, the differences within fleets, the degree to which vessels cooperate and act as a unit, as well as any seasonal and geographical differences, should each be examined. Some of these questions can be addressed with currently available data such as the dataset described here. Others, such as the measurement of PST and SST, are more difficult to address as the necessary data are not currently available, though appropriate analysis of vessel activity data collected at random times of day under the CCAMLR Scheme of International Scientific Observation (SC-CAMLR, 1993) may help.

## CONCLUSION

Certain aspects of krill fishing vessel activity may be viewed as a consequence of variability in either krill abundance or in krill aggregation level. Reliably detecting such variability using currently available fisheries-derived information is difficult, however the nature of the fishery at South Georgia may make this a future possibility. Such a possibility arises because the commercial fishery at South Georgia is highly focused, targeting krill concentrations which occur in known or predictable areas.

A range of fisheries-based indices may be needed to reflect the stock status and resolve differences between years, particularly if different vessels have different operational targets (e.g. high quality compared to high volume). Development of such indices must be based on a detailed understanding of the fishery operation. Therefore future work is needed in order to better understand certain critical aspects of the operation, such as search time, processing time and quality of krill.

## ACKNOWLEDGEMENTS

We are grateful to John Pearce, MRAG for extracting the database records. The marine GIS was developed with assistance from Francis Daunt.

## REFERENCES

Biomass. 1986. Post-FIBEX Acoustic Workshop. *BIOMASS Rep. Ser.*, 40.

Brierley, A., J.L. Watkins and A.W.A. Murray. 1997. Interannual variability in krill abundance at South Georgia. *Mar. Ecol. Prog. Ser.*, 150: 87–98.

Butterworth, D.S. 1988a. A simulation study of krill fishing by an individual Japanese trawler. In: *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*. CCAMLR, Hobart, Australia: 1–108.

Butterworth, D.S. 1988b. Some aspects of the relation between Antarctic krill abundance and CPUE measures in the Japanese krill fishery. In: *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*. CCAMLR, Hobart, Australia: 109–126.

Butterworth, D.S. and D.G.M. Miller. 1987. A note on relating Antarctic krill catch-per-unit-effort measures to abundance trends. *S. Afr. J. Antarct. Res.*, 17: 112–116.

CCAMLR. 1997. *Statistical Bulletin*, Vol. 9 (1987–1996). CCAMLR, Hobart, Australia.

Dolzhenkov, V.N., T.G. Lubimova, R.R. Makarov, S.S. Parfenovich and V.A. Spiridonov. 1988. Some specific features of the USSR krill fishery and possibilities of applying fishery statistics to studies of krill biology and stocks. In: *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*. CCAMLR, Hobart, Australia: 237–252.

Endo, Y. and T. Ichii. 1989. CPUEs, body length and greenness of Antarctic krill during 1987/1988 season in the fishing ground north of Livingston Island. In: *Selected Scientific Papers, 1989 (SC-CAMLR-SSP/6)*. CCAMLR, Hobart, Australia: 323–338.

Everson, I. 1982. Diurnal variation in mean volume backscattering strength of an Antarctic krill (*Euphausia superba*) patch. *J. Plankt. Res.*, 4: 155–161.

Everson, I. 1984. Marine interactions. In: Laws, R.M. (Ed.). *Antarctic Ecology*, 2. Academic Press, London: 783–819.

Everson, I. 1988. Can we satisfactorily estimate variation in krill abundance? In: Sahrhage, D. (Ed.). *Antarctic Ocean and Resources Variability*. Springer-Verlag, Berlin: 199–208.

Everson, I. and C. Goss. 1991. Krill fishing activity in the southwest Atlantic. *Antarct. Sci.*, 3: 351–358.

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.

Hamner, W.M., P.P. Hamner, S.W. Strand and R.W. Gilmer. 1983. Behaviour of Antarctic krill, *Euphausia superba*: chemoreception, feeding, schooling and moulting. *Science*, 220: 433–435.

Hampton, I. 1985. Abundance, distribution and behaviour of *Euphausia superba* in the Southern Ocean between 15 and 30°E during FIBEX. In: Siegfried, W.R., P.R. Condy, and R.M. Laws (Eds). *Antarctic Nutrient Cycles and Food Webs*. Springer-Verlag, Berlin: 294–303.

Hydrographic Office. 1992. Approaches to South Georgia. Admiralty Chart 3596.

Ichii, T.M., M. Naganobu and T. Ogishima. 1994. An assessment of the impact of the krill fishery on penguins in the South Shetlands. *CCAMLR Science*, 1: 107–128.

Kalinowski, J. and Z. Witek. 1980. Diurnal vertical distribution of krill aggregations in the Western Atlantic. *Pol. Polar Res.*, 1: 127–146.

Macdonald, D.I.M., B.C. Storey and J.W. Thomson. 1987. Geological map of South Georgia, 1:250 000, with supplementary text. *BAS GEOMAP Series*, Sheet 1. British Antarctic Survey, Cambridge: 63 pp.

Mangel, M. 1988. Analysis and modelling of the Soviet Southern Ocean krill fleet. In: *Selected Scientific Papers, 1988 (SC-CAMLR-SSP/5)*. CCAMLR, Hobart, Australia: 127–236.

Marr, J.W.S. 1962. The natural history and geography of the Antarctic krill (*Euphausia superba* Dana). *Discovery Rep.*, 32: 33–464.

Miller, D.G.M. and I. Hampton. 1989. Biology and ecology of the Antarctic krill (*Euphausia superba* Dana): a review. *BIOMASS Sci. Ser.*, 9: 166 pp.

Murphy, E.J., I. Everson and A.W.A. Murray. 1991. Analyses of acoustic line-transect data from the waters around South Georgia: estimation of krill (*Euphausia superba*) biomass. In: *Selected Scientific Papers, 1991 (SC-CAMLR-SSP/8)*. CCAMLR, Hobart, Australia: 225–244.

Murphy, E.J., P.N. Trathan, I. Everson, G. Parkes and F.H.J. Daunt. 1997. Detailed distribution of krill fishing around South Georgia. *CCAMLR Science*, 4: 1–17.

O'Brien, D.P. 1987. Description of escape responses of krill (Crustacea: Euphausiacea), with particular reference to swarming behaviour and the size and proximity of the predator. *J. Crust. Biol.*, 7: 449–457.

SC-CAMLR. 1985. *Report of the Fourth Meeting of the Scientific Committee (SC-CAMLR-IV)*. CCAMLR, Hobart, Australia.

SC-CAMLR. 1993. *Report of the Twelfth Meeting of the Scientific Committee (SC-CAMLR-XII)*. CCAMLR, Hobart, Australia.

Shimadzu, Y. 1985. A brief summary of Japanese fishing activity relating to Antarctic krill, 1972/73–1982/83. In: *Selected Scientific Papers, 1982–1984*, Part I. CCAMLR, Hobart, Australia: 439–452.

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

Trathan, P.N., D.J. Agnew, D.G.M. Miller, J.L. Watkins, I. Everson, M.R. Thorley, E.J. Murphy, A.W.A. Murray and C. Goss. 1991. Krill biomass in Area 48 and Area 58: recalculation of FIBEX data. In: *Selected Scientific Papers, 1991 (SC-CAMLR-SSP/9)*. CCAMLR, Hobart, Australia: 157–182.

Trathan, P.N. and I. Everson. 1994. Status of the FIBEX acoustic data from the west Atlantic. *CCAMLR Science*, 1: 35–48.

Trathan, P.N., E.J. Murphy, C.J. Symon and P.G. Rodhouse. 1993a. Ecological and oceanographic relationships in the Southern Ocean. *GIS Europe*, 2 (6): 34–36.

Trathan, P.N., J. Priddle, J.L. Watkins, D.G.M. Miller, and A.W.A. Murray. 1993b. Spatial variability of Antarctic krill in relation to mesoscale hydrography. *Mar. Ecol. Prog. Ser.*, 98: 61–71.

Weber, L.H. and S. El-Sayed. 1985. Spatial variability of phytoplankton and the distribution and abundance of krill in the Indian Sector of the Southern Ocean. In: Siegfried, W.R., P.R. Condy, and R.M. Laws (Eds). *Antarctic Nutrient Cycles and Food Webs*. Springer-Verlag, Berlin: 284–293.

Witek, Z., A. Grelowski and J. Kalinowski. 1982. Formation of Antarctic krill concentrations in relation to hydrodynamic processes and social behaviour. *ICES Biol. Oceanogr. Comm. Memo C.M.*, L:59: 10 pp.

Table 1: Mean number of hauls carried out per vessel each day. Mean, standard deviation (SD) and median with first and third quartile.

| Year | n | Mean | SD | Q1 | Median | Q3 |
|---|---|---|---|---|---|---|
| 1994 | 2 025 | 7.9 | 3.0 | 6.0 | 8.0 | 10.0 |
| 1995 | 3 035 | 9.9 | 4.6 | 7.0 | 10.0 | 13.0 |
| 1996 | 2 854 | 7.0 | 3.1 | 5.0 | 7.0 | 9.0 |

Table 2: Mean time duration in minutes for different stages of the fishing process. Mean, standard deviation (SD) and median with first and third quartile.

| Year | n | Mean | SD | Q1 | Median | Q3 |
|---|---|---|---|---|---|---|
| Time between shooting the net and the start of fishing | | | | | | |
| 1994 | 2 025 | 15.5 | 5.7 | 10.0 | 15.0 | 20.0 |
| 1995 | 3 035 | 15.5 | 8.9 | 10.0 | 15.0 | 15.0 |
| 1996 | 2 854 | 12.4 | 9.1 | 10.0 | 10.0 | 15.0 |
| Time between the start of fishing and the end of fishing | | | | | | |
| 1994 | 2 025 | 70.1 | 40.9 | 45.0 | 65.0 | 85.0 |
| 1995 | 3 035 | 51.9 | 32.5 | 30.0 | 50.0 | 70.0 |
| 1996 | 2 854 | 82.0 | 43.4 | 50.0 | 70.0 | 105.0 |
| Time between the end of fishing and the end of the haul | | | | | | |
| 1994 | 2 025 | 24.1 | 6.9 | 20.0 | 20.0 | 25.0 |
| 1995 | 3 035 | 24.4 | 6.9 | 20.0 | 25.0 | 30.0 |
| 1996 | 2 854 | 22.5 | 6.9 | 20.0 | 20.0 | 25.0 |
| Time between the end of the haul and the next shooting of the net | | | | | | |
| 1994 | 1 991 | 59.2 | 150.0 | 15.0 | 25.0 | 40.0 |
| 1995 | 2 990 | 42.1 | 106.5 | 0.0 | 20.0 | 45.0 |
| 1996 | 2 812 | 78.5 | 131.2 | 30.0 | 45.0 | 70.0 |

Table 3: Mean distance in kilometres between consecutive haul positions for each vessel. Mean, standard deviation (SD) and median with first and third quartile.

| Year | n | Mean | SD | Q1 | Median | Q3 |
|---|---|---|---|---|---|---|
| 1994 | 2 009 | 4.9 | 16.9 | 1.1 | 2.2 | 5.7 |
| 1995 | 3 024 | 5.1 | 10.6 | 1.8 | 3.7 | 5.8 |
| 1996 | 2 827 | 6.2 | 14.6 | 1.8 | 2.9 | 6.6 |

Table 4: Mean catch by fleet and year (kilogram per haul). Mean, standard deviation (SD) and median with first and third quartile.

| Nation | n | Mean | SD | Q1 | Median | Q3 |
|---|---|---|---|---|---|---|
| 1994 | | | | | | |
| Japan | 1 306 | 8 928 | 6 349 | 4 000 | 7 000 | 13 900 |
| Poland | 260 | 4 451 | 2 821 | 2 500 | 4 300 | 6 075 |
| Ukraine | 459 | 9 727 | 6 024 | 4 000 | 10 000 | 15 000 |
| 1995 | | | | | | |
| Japan | 1 259 | 15 018 | 6 934 | 11 100 | 13 500 | 17 000 |
| Poland | 266 | 2 861 | 2 057 | 940 | 3 200 | 4 285 |
| Ukraine | 1 510 | 9 552 | 4 546 | 7 000 | 10 000 | 11 500 |
| 1996 | | | | | | |
| Japan | 1 104 | 11 646 | 5 527 | 7 000 | 11 470 | 15 000 |
| Poland | 1 385 | 5 556 | 3 904 | 2 640 | 5 100 | 7 600 |
| Ukraine | 365 | 14 038 | 11 056 | 4 500 | 10 000 | 20 131 |

Table 5: Catch (kilogram per haul) and catch rate (kilogram per minute) for each year. Mean, standard deviation (SD) and median with first and third quartile.

| Year | n | Mean | SD | Q1 | Median | Q3 |
|---|---|---|---|---|---|---|
| Catch per haul | | | | | | |
| 1994 | 2 025 | 8 534 | 6 147 | 3 830 | 7 000 | 13 000 |
| 1995 | 3 035 | 11 233 | 6 639 | 7 000 | 10 500 | 14 000 |
| 1996 | 2 854 | 8 996 | 6 820 | 4 300 | 7 200 | 12 000 |
| Catch rate | | | | | | |
| 1994 | 2 025 | 158.5 | 153.3 | 50.0 | 107.1 | 230.8 |
| 1995 | 3 035 | 334.7 | 368.2 | 137.3 | 239.4 | 400.0 |
| 1996 | 2 854 | 172.7 | 229.3 | 50.0 | 107.1 | 204.5 |

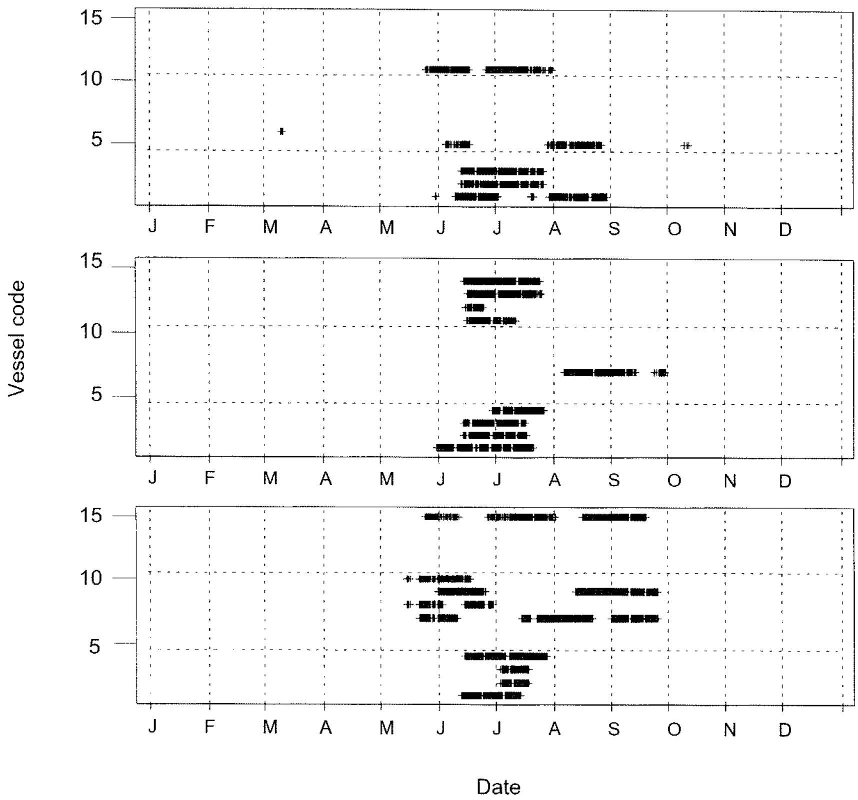



Figure 1: Periods of operation for krill fishing vessels at South Georgia. Vessels 1, 2, 3 and 4 (Japan), vessels 5, 6, 7, 8, 9 and 10 (Poland), and vessels 11, 12, 13, 14 and 15 (Ukraine). Top panel 1994, middle panel 1995, bottom panel 1996.

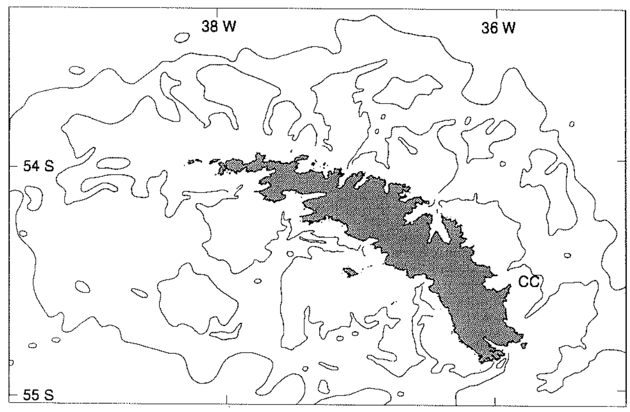



Figure 2: Bathymetry close to South Georgia (Hydrographic Office, 1992), with isobaths at 200 and 1 000 m. Cape Charlotte is identified by the label CC.

(a)

(b)

(c)

(d)

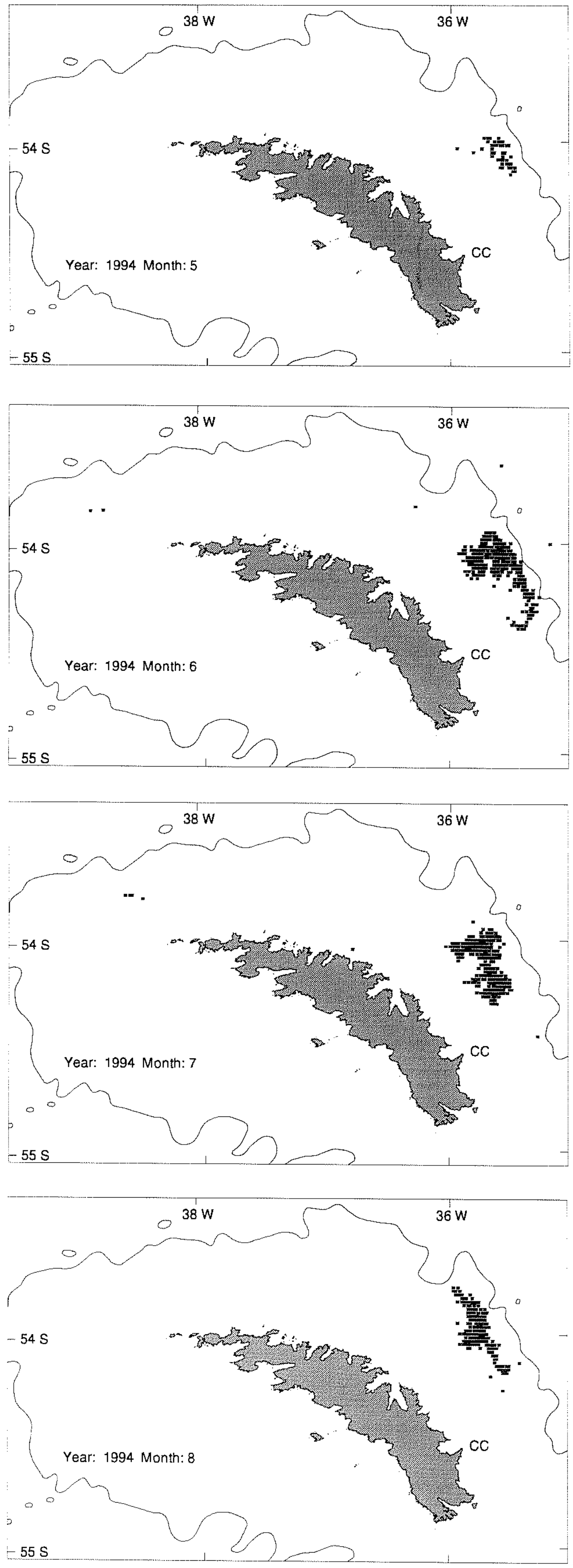



Figure 3: Position of individual hauls made by krill fishing vessels at South Georgia in 1994: (a) May; (b) June; (c) July; and (d) August. Cape Charlotte is identified by the label CC.

(a)
(b)
(c)
(d)

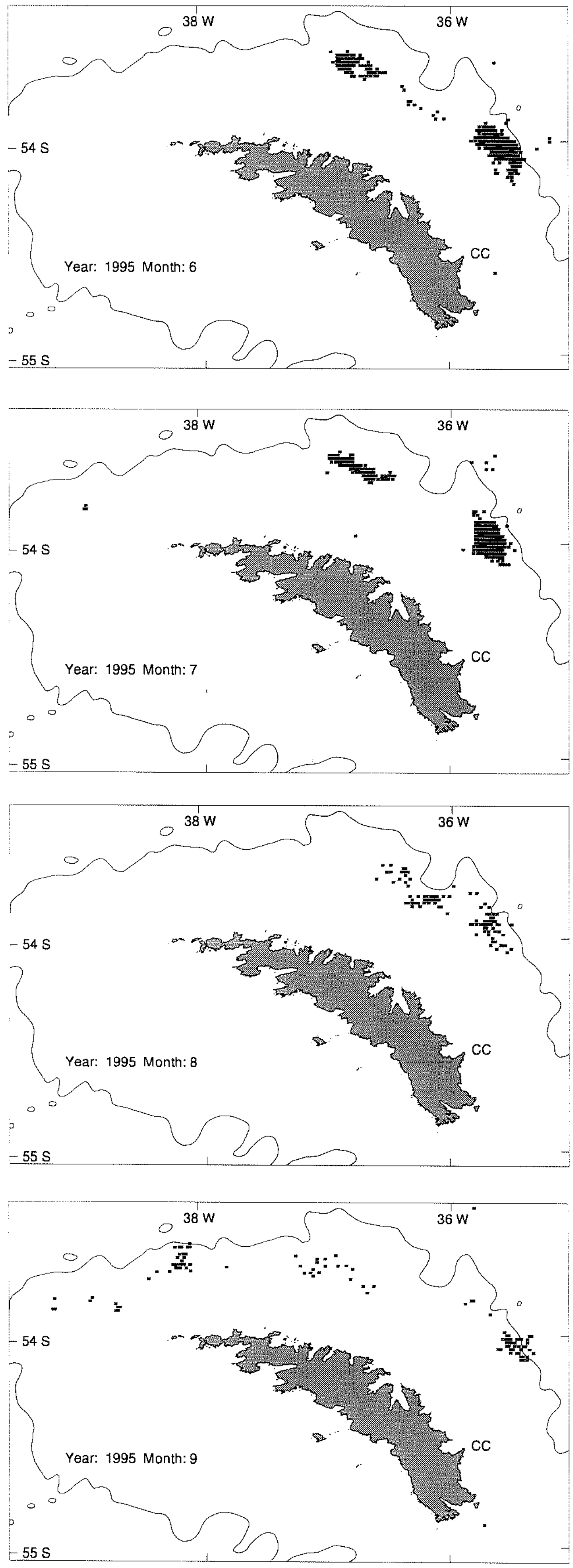
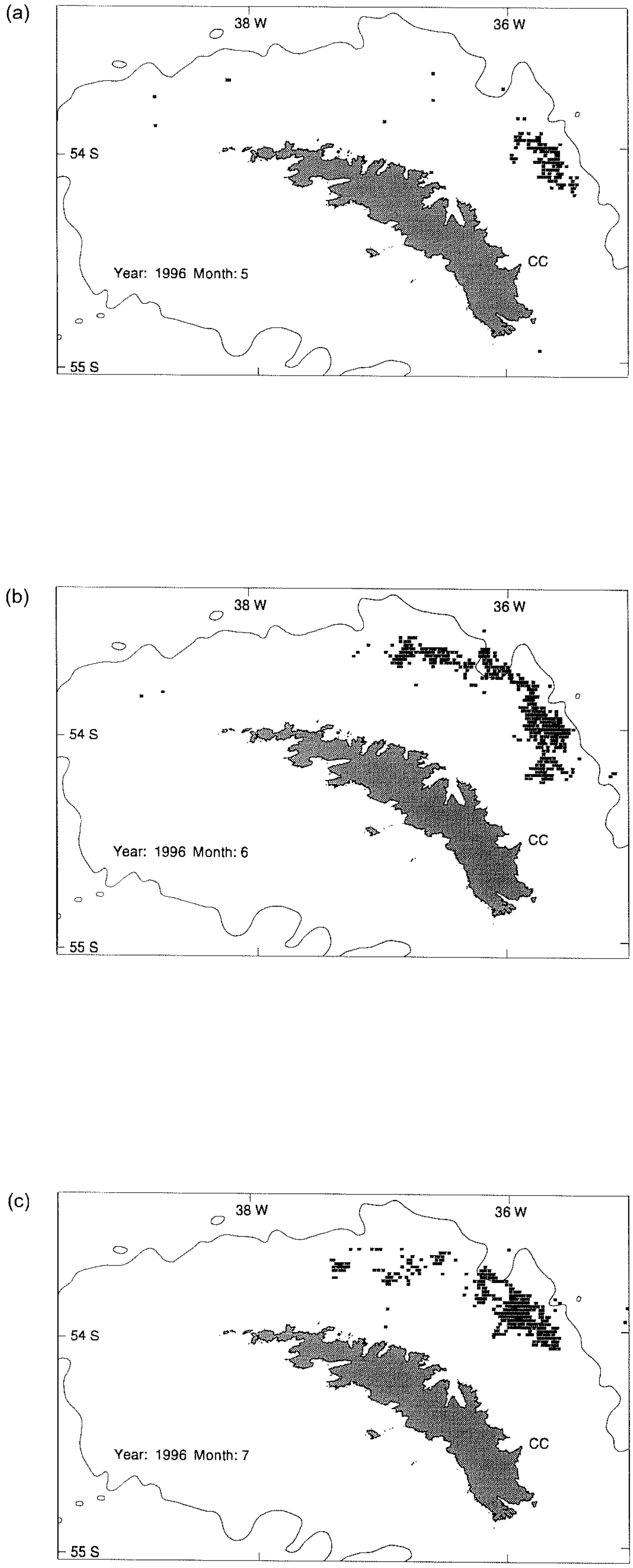
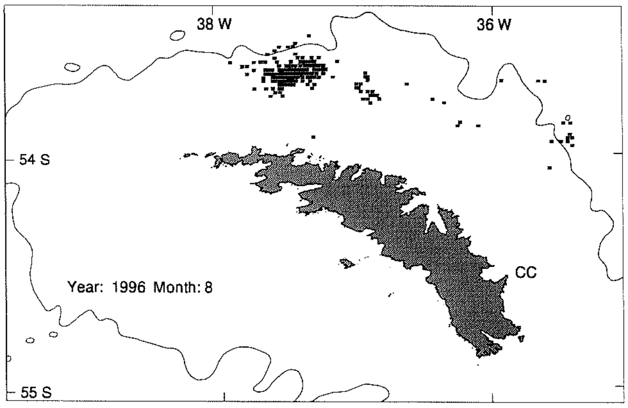



Figure 4: Position of individual hauls made by krill fishing vessels at South Georgia in 1995: (a) June; (b) July; (c) August; and (d) September. Cape Charlotte is identified by the label CC.


(a)
38 W
36 W
54 S
55 S
CC
Year: 1996 Month: 5
(b)
38 W
36 W
54 S
55 S
CC
Year: 1996 Month: 6
(c)
38 W
36 W
54 S
55 S
CC
Year: 1996 Month: 7

(d)




(e)

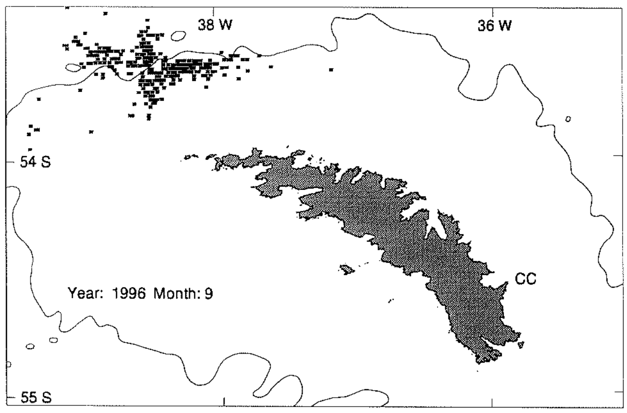



Figure 5: Position of individual hauls made by krill fishing vessels at South Georgia in 1996: (a) May; (b) June; (c) July; (d) August; and (e) September. Cape Charlotte is identified by the label CC.

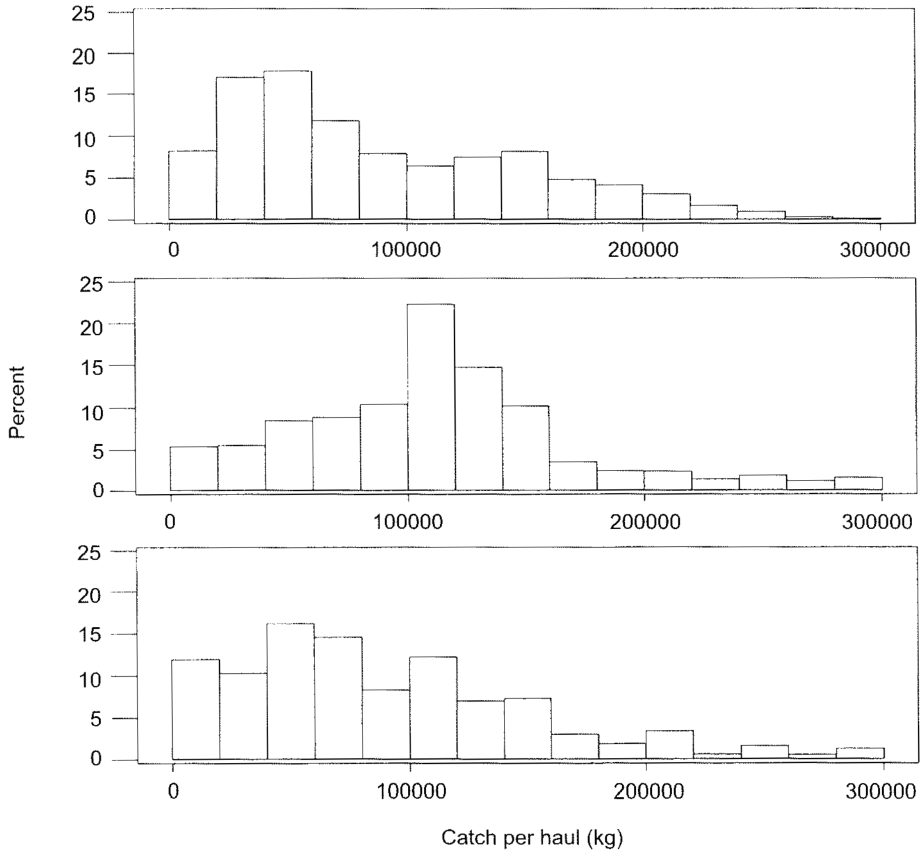



Figure 6: Catch per haul (kilogram) from individual hauls made by krill fishing vessels at South Georgia. Top panel 1994, middle panel 1995, bottom panel 1996.

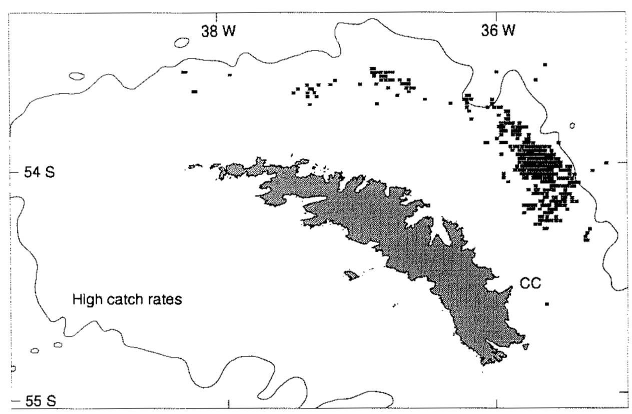



Figure 7: Positions for top 10% of catch rates (kilogram per minute) from each year. Cape Charlotte is identified by the label CC.

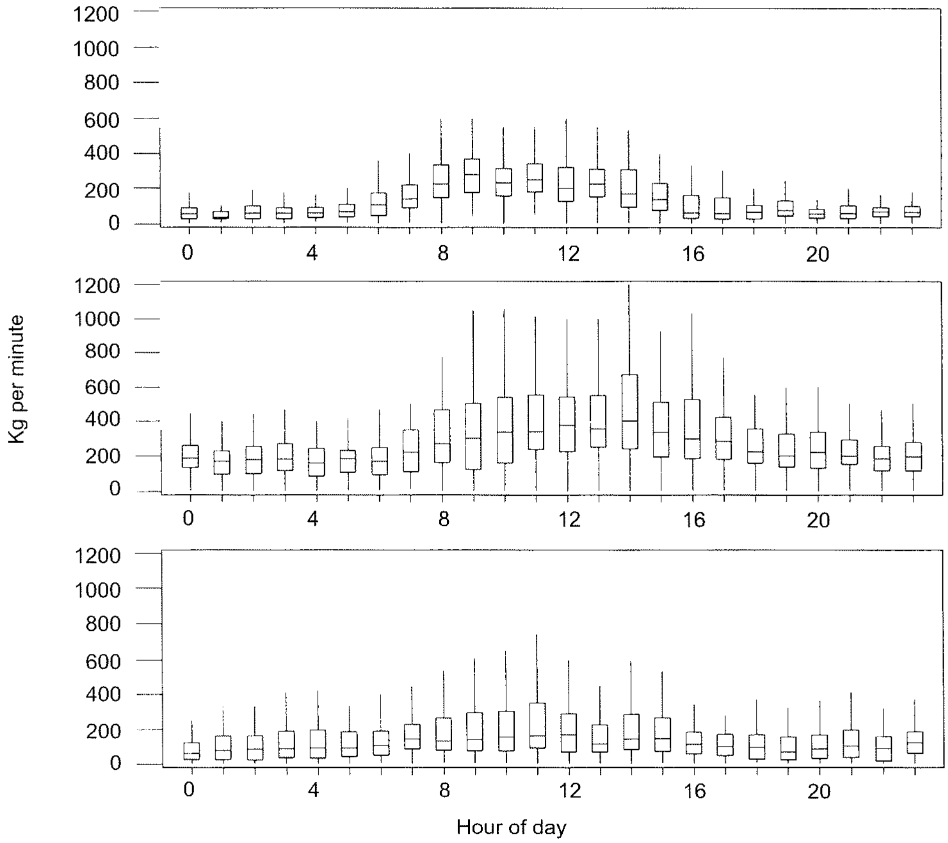



Figure 8: Box and whisker plots of catch rates (kilogram per minute) throughout the day from individual hauls made by krill fishing vessels at South Georgia. The bottom of each box is at the first quartile (Q1), the top is at the third quartile (Q3) and the line near the middle is at the median. The whiskers are the lines which extend from the quartiles to the lowest and highest observations still inside the regions defined as Q1 - 1.5 (Q3 - Q1) and Q1 + 1.5 (Q3 - Q1). Top panel 1994, middle panel 1995, bottom panel 1996.

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Figure 2: Bathymétrie à proximité de la Géorgie du Sud (Hydrographic Office, 1992) et isobathes 200 et 1 000 m. Le cap Charlotte est indiqué par CC.

Figure 3: Position des divers traits effectués par les navires pêchant le krill autour de la Géorgie du Sud en 1994; a) mai; b) juin; c) juillet; d) août. Le cap Charlotte est indiqué par CC.

Figure 4: Position des divers traits effectués par les navires pêchant le krill autour de la Géorgie du Sud en 1995; a) juin; b) juillet; c) août; d) septembre. Le cap Charlotte est indiqué par CC.

Figure 5: Position des divers traits effectués par les navires pêchant le krill autour de la Géorgie du Sud en 1996; a) mai; b) juin; c) juillet; d) août; e) septembre. Le cap Charlotte est indiqué par CC.

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