SC-CAMLR-SSP/4

SCIENTIFIC COMMITTEE FOR THE CONSERVATION OF ANTARCTIC MARINE LIVING RESOURCES

SELECTED SCIENTIFIC PAPERS 1987

COMMUNICATIONS SCIENTIFIQUES SELECTIONNEES 1987

DOCUMENTOS CIENTIFICOS SELECCIONADOS 1987

ИЗБРАННЫЕ НАУЧНЫЕ РАБОТЫ 1987

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August 1988

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Abstract

This document contains a selection of the scientific papers presented at meetings of the Scientific Committee and Working Groups of the Scientific Committee in 1987. The text of the papers is reproduced in the original language of submission ; abstracts of the papers and captions of tables and figures are translated into the official languages of the Commission (English, French, Spanish and Russian). Abstracts only are presented for papers that have been accepted elsewhere for publication.

Résumé

Le présent document contient une sélection de communications scientifiques présentées aux réunions du Comité Scientifique et aux Groupes de travail du Comité Scientifique en 1987. Le texte de ces communications est reproduit dans la langue originale dans laquelle celles-ci ont été présentées ; les résumés des communications ainsi que les titres des tableaux et des figures ont été traduits dans les langues officielles de la Commission (anglais, français, espagnol et russe). Seuls des résumés sont présentés lorsqu'il s'agit de communications qui ont été acceptées pour être publiées.

Resumen

Este documento contiene una selección de los documentos científicos presentados en las reuniones del Comité Científico y de los Grupos de Trabajo del Comité Científico en 1987. El texto de estos documentos está reproducido en el idioma original para su presentación ; los resúmenes de estos documentos y los títulos de los cuadros y figuras están traducidos a los idiomas oficiales de la Comisíon (inglés, francés, español y ruso). Los resúmenes son presentados solamente para cuando los documentos hayan sido aceptados para su publicacíon en alguna otra parte.

Резюме

Настоящий документ содержит подборку научных работ, представленных на совещаниях Научного комитета и Рабочих групп Научного комитета в 1987 г. Они представляются на языке оригинала ; резюме докладов, названия таблиц и подписи к рисункам переведены на официальные языки Комиссии (английский, французский, испанский и русский) . Если работа принята к печати где-нибудь в другом месте, то здесь приводится только ее резюме.

Translation by :
Document traduit par :
Traducción realizada por :
Переведено фирмой :

Conference Interpreter Services,
66 King Street, Sydney,
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PRELIMINARY APPRAISAL OF ANTARCTIC FISH SELECTION BY THE 32/36 BOTTOM TRAWL COMBINED WITH VARIOUS CODENDS

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Abstract

Selectivity properties of single and doubler-layer twine codends (mesh size 120 mm) and single-layer tape codends with a mesh size of 60 and 100 mm were determined. It was found that the selectivity properties of twine codends are unsatisfactory in the case of Antarctic icefish, bumphead notothenia, and Scotia Sea icefish. This was primarily caused by the heavy net material used for their construction, incorrectly chosen mesh size, and certain morphological features of some Antarctic fish, which make it difficult for them to escape from the codend. Selectivity properties of both tape codends were much better. It was found that an optimum mesh size of this codend for selection of Antarctic icefish and bumphead notothenia ranges from 60 to 100 mm. For other Antarctic fish, especially Scotia Sea icefish and South Georgia icefish the determination of a proper mesh size of trawls used in fishing for them requires further research. It should first of all cover twine codends with a mesh size of 80 mm, currently used on factory trawlers, as well as codends with a structure resembling tape codends.

Résumé

Ont été déterminées les propriétés de sélectivité des culs de chalut simples ou doublés à cordes (taille du maillage 120 mm) et des culs de chalut simples à rubans plats (taille du maillage 60 et 100 mm). Il s'est avéré que les propriétés de sélectivité des culs de chalut à cordes n'étaient pas adéquates dans le cas des poissons des glaces de l'Antarctique, des _Notothenia gibberifrons_ et des poissons des glaces de la Mer de Scotia; les raisons principales étant : l'utilisation d'un matériau lourd dans leur construction, le choix inapproprié de la taille du maillage, et certains aspects morphologiques de certains poissons antarctiques qui les empêchent de s'échapper du cul de chalut. Les propriétés de sélectivité des deux culs de chalut à rubans plats étaient bien meilleures. L'on a constaté que la taille de maillage optimale de ce cul de chalut pour la sélection des poissons des glaces de l'Antarctique et des _Notothenia gibberifrons_ allait de 60 à 100 mm. Pour ce qui est des autres poissons antarctiques, en particulier les poissons des glaces de la Mer de Scotia et ceux de la Géorgie du Sud, des recherches complémentaires seront nécessaires pour déterminer la taille de maillage appropriée des chaluts servant à les pêcher. Ces recherches auront tout d'abord pour objet les culs de chalut à cordes dont la taille de maillage est de 80 mm et qui sont actuellement utilisés sur les chalutiers-usines, ainsi que les culs de chalut dont la structure ressemble aux culs de chalut à rubans plats.

Resumen

Se determinaron las propiedades de selectividad de las mallas de corona de soga trenzada de simple y doble capa (luz de malla de 120 mm) y las mallas de corona de cinta de capa simple con una luz de malla de 60 y 100 mm. Se encontró que las propiedades de selectividad de las mallas de corona de soga trenzada son insatisfactorias en el caso del pez de hielo de la Antártida, Notothenia gibberifrons (bumphead notothenia) y del pez de hielo del Mar de Scotia. Esto fue causado principalmente por el pesado material de red usado para su construcción, la luz de malla incorrectamente escogida y ciertas características morfológicas de algunos peces antárticos, que dificultan su escape de la corona. Las propiedades de selectividad de ambas mallas de corona de cinta resultaron ser mucho mejores. Se encontró que el rango óptimo de la luz de malla de esta corona para la selección del pez de hielo de la Antártida y de Notothenia gibberifrons (bumphead notothenia) es de 60 a 100 mm. Para otro peces de hielo de la Antártida, especialmente el pez de hielo del Mar de Scotia y el pez de hielo de Georgia del Sur, la determinación de una luz de malla adecuada de los arrastres usados para la pesca de los mismos requiere mayor investigación. En primer lugar debería cubrir las mallas de corona de soga trenzada con una luz de malla de 80 mm, utilizada actualmente en los arrastreros factoría, así como las mallas de corona de estructura semejante a las mallas de corona de cinta.

Резюме

Были определены селективные способности одно- и двуслойных веревочных кутков (размер ячеи - 120 мм) и однослойных ленточных кутков с размером ячеи в 60 и 100 мм. Селективные способности веревочных кутков были найдены неподходящими в случае ледяной рыбы, зеленой нототении и ледяной рыбы моря Скотия. В первую очередь это было вызвано использованием тяжелого сетного полотна при их конструировании, неправильным выбором размеров ячей и определенными морфологическими характеристиками некоторых антарктических рыб, что создает затруднения при попытке рыбы высвободиться из кутка. Селективные

способности обоих ленточных кутков были гораздо лучше. Было найдено, что оптимальный размер ячей такого кутка при селекции ледяной рыбы и зеленой нототении варьируется от 60 до 100 мм. Для других видов антарктической рыбы, особенно для ледяной рыбы моря Скотия и ледяной рыбы Южной Георгии, определение подходящих размеров ячеи в тралах, используемых при промысле этих видов, требует дальнейших исследований. Они должны в первую очередь охватить веревочные кутки с размером ячеи в 80 мм, используемые в настоящее время на плавучих рыбзаводах, а также кутки, структура которых напоминает ленточные.

PRELIMINARY APPRAISAL OF ANTARCTIC FISH SELECTIVITY BY THE 32/36 BOTTOM TRAWL WITH VARIOUS CODENDS

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The necessity of introducing regulatory measures for the Antarctic fishery is no longer a disputable matter; the problem is to select the best measures from the biological, technical and legal point of view. One of the effective methods of regulating catch may be the determination of minimum allowable mesh size in the codend for each commercial species of fish. Since no extensive investigations of this kind have been carried out in the Antarctic so far, it is valuable to publish the results of Polish experimental research in the 1978/1979 season despite the fact that types of net materials, their mesh sizes, and constructions (tape nettings) used in the codends were not typical for fishing operations in the Antarctic. The results presented below may constitute a starting point for further work in this field but are not in themselves a basis for regulating mesh size in the codend of trawls used for fishing in the Antarctic.

1. GENERAL INFORMATION ABOUT THE CRUISE AND TRAWL SELECTIVITY INVESTIGATIONS

The investigations of trawl selectivity were just a part of complex oceanographical and ichthyological investigations carried out between December 1978 and March 1979 on the research vessel Professor Siedlecki. The selectivity investigations were conducted in the following areas :

1. South Georgia, i.e. fishing grounds on the shelf of South Georgia and Shag Rocks,

2. South Orkney Islands,

3. Antarctic Peninsula, including the following fishing grounds : Elephant Island, Joinville Island, South Shetland Islands, Palmer Archipelago and Biscoe Archipelago.

A total of 139 tows were made during the whole cruise, including 118 bottom ones. The selectivity of various codends was tested in bottom tows (in 14 mid-water tows only krill was taken). Out of 112 tows, in which a total of 94 877 fish were measured (65 954 in the codend itself and 28 923 in the fine meshed liner), only those were selected for the determination of trawl selective properties which fulfilled the basic assumptions, described in more detail in the section on methods. All selectivity investigations were described in a report from the IVth Polish Antarctic expedition in the 1978/1979 season. On the basis of those results, it is possible to present here the results of investigations of those fish species for which the most abundant and representative data were collected. Fishing areas and the number of tows constituting the basis for calculations for each species and type of codend are given when discussing individual selectivity ogives.

2. STRUCTURE OF CODENDS

Two types of codends (single- and double-layer) were used for selectivity studies. A single-layer codend was made of one type of net material forming codend walls while a double-layer construction consisted of two types of net materials : the net with smaller meshes ensuring fish selectivity and an outer chafer with larger meshes, reducing and preventing damage of the codend. Table 1 presents details of the trawl construction and the characteristics of materials used for various codends tested. Single- and double-layer twine codends were very similar in construction to standard ones used in other fishing grounds, with a nominal mesh size of 120 mm (dry). Tape codends were made of different materials and had different material characteristics. Size of meshes in these codends was converted for comparison to a value known in literature as "mesh size". This value was much lower for both tape codends than for standard twine codends. It may be generally said that all investigated codends were different from each other in their material, technology, and finishing details. This fact should be borne in mind when comparing the results; the conclusions reached should not be generalized.

All investigated codends were 4-wall constructions, widening in the front to form a square inlet with sides of 4.5 m length measured with meshes stretched. All investigated codends could easily be substituted one for another and attached to the same trawl. Schematic construction of the investigated codends is presented in Figure 1 for a tape codend with 60 mm mesh size.

It was assumed during experiments that selectivity investigations should be conducted under the conditions resembling as closely as possible those in which the gear would be normally used. Therefore, a 32/36 bottom trawl, mastered on other fishing grounds, was used. A schematic construction of this trawl is presented in Figure 2. Figure 3 shows a plan of rigging for a 32/26 trawl.

For selectivity investigations, a method with a fine-meshed liner was used. However, since the bottom on the fishing grounds was stony, a semi-liner construction was used in practice. Thus, a loose fine-meshed liner was placed on the upper part of the codend, reaching down to the middle of the codend side walls.

The codend bottom was deprived of its selective properties up to the middle of side walls by placing inside it, the same fine-meshed inset. In this way, fish in the codend could escape only through the meshes of the upper trawl part to the cover. The fine-meshed liner was made from a steelon twine with a thickness of 2 mm and having a mesh size of 20 mm. A schematic drawing of a 4-wall codend with fine-meshed liner is presented in Figure 4.

In order to make it easier to empty the trawl on board, the codend and cover were equipped like a standard commercial codend with 4 splitting straps made of a rope with a thickness of 30 mm (version I), Figure 5. Since there was a danger that those heavy straps lying on the fine-meshed liner might change selectivity results, a second version without them was worked out during investigations : the codend used had open splitting straps. Only after hauling the codend on board, both ends of straps were connected with a shackle and the codend and liner were emptied. A schematic drawing of the modified codend gear (version II) is presented in Figure 6.

3. MATERIAL AND METHODS

In order to determine selective properties of the investigated codends, the above-mentioned method with a fine-meshed liner was used.

Mesh sizes were measured wet, after a certain number of hours of towing time, with an ICES slide caliper (load of 4 daN) and calculated as a mean from 30 measurements.

For investigations, only those tows were selected which fulfilled the following basic requirements :

- estimated total yield of the tow could not be smaller than 500 kilograms of fish,
- the investigated species constituted at least 20% of the total catch weight.

The number of tows studied and number of fish measured are presented in Tables 2 - 5, separately for various codends.

On the basis of measurements of the length of all fish, separately for the codend and fine-meshed liner, standard calculations were made to obtain selectivity parameters and ogives for a tested codend with respect to a given fish species. Basic selectivity factors, i.e. mean fish length for three main selectivity levels : 25, 50 and 75%, were determined graphically. In addition, the following basic selectivity parameters were calculated :

- selectivity interval consisting of the difference in cm between the mean length of fish for selectivity levels 75 and 25%;

- selectivity coefficient (F_s) obtained from the following formula :

$$F_s = \frac{L_{50\%}}{A}$$

where :

$L_{50\%}$ = fish length at a 50% selectivity level,
A = mean mesh size in the codend determined for a given stage of investigations (wet) ;

- selection quality coefficient (W_s) obtained from the ratio :

$$W_s = \frac{L_{50\%}}{L_{100\%}}$$

where :

$L_{50\%}$ = fish length at a 50% selectivity level,
$L_{100\%}$ = smallest fish length retained in full by the codend

If it was impossible to build a typical selectivity curve on the basis of the data collected (or even a curve resembling a typical one), the points obtained were connected by straight lines without attempting to interpolate the results.

4. RESULTS AND DISCUSSION

4.1 Selective Properties of a Double-Layer Codend

The object of investigations was a typical codend used by the Polish fishery in NAFO and NEAFC areas, with a nominal mesh size in the codend of 120 mm. This codend was equipped with a chafer with a nominal mesh size of 240 mm.

The tests were run on the fishing grounds of South Georgia, Shag Rocks and South Orkney Island on the species predominating in the catch : mackerel icefish (Champsocephalus gunnari), bumphead notothenia (Notothenia gibberifrons), and Scotia Sea icefish (Chaenocephalus aceratus).

Mackerel icefish

The ogives (Figure 7) did not resemble typical selectivity curves. A characteristic feature of mackerel icefish selection by a double-layer codend was a similar ratio of fish allowed to pass to those retained for almost all length classes. This was especially visible in catches made off South Orkney Island, where for many length classes this ratio was almost identical - slightly over 50%. On South Georgia fishing grounds, the same was true for fish of up to 35 cm in length. There could have been several reasons for this fact. It seems, however, that one of the most important was the badly chosen mesh size, which had lost selectivity ability for this species, and the double-layer structure of the codend only deepened this effect.

Bumphead notothenia

Selectivity ogives were drawn separately for South Georgia fishing grounds and South Orkney grounds (Figure 8). Both ogives were almost identical. Their initial sections fluctuated at the same level (50-70%) and starting from a certain length of fish - 35 cm - began to ascend up to a length of 46 cm; above this level a 100% of fish was retained by the codend. However, it was impossible to convincingly explain why small fish with lengths of 16-33 cm were retained at the same, equally high level in the double-layer codend.

Scotia Sea icefish

On the basis of the data presented in Table 2, only one selectivity ogive was drawn; it referred to South Georgia grounds, as the material collected off South Orkney Island was too scarce to fit the ogive (Figure 9).

The selectivity ogive for Scotia Sea icefish is similar to the ogives discussed before, its initial part reflecting the degree of retention of small fish with a length of 20 and 21 cm at a 40-50% level and fish with a length of up to 35 cm at a 80-90% level clearly ends at this length. With respect to longer fish, the codend material exhibits increasing selectivity - the curve ascends quite regularly reaching a 100% retention for icefish with a length of 44 cm. Since this curve closely resembled the previous ones, it may be said that the fish selectivity process has the same nature.

4.2 Selective Properties of Single-Layer Codends

Single-layer codends, which are not equipped with a protective chafer, are today among constructions used most frequently by commercial fisheries of various countries. That is why they were the main object of investigations on Antarctic fishing grounds.

4.2.1 Twine Codend

The twine codend made from double polyamide twines with a nominal thickness of 7 mm had a nominal mesh size of 120 mm (dry), i.e. the same as the codend in a double-layer construction.

This codend was tested on the fishing grounds off the Antarctic Peninsula (Joinville, South Shetland Island, Elephant Island) and off South Georgia and Shag Rocks. Data for the following species were collected there : mackerel icefish, bumphead notothenia, Scotia Sea icefish, ocellated icefish (*Chionodraco rastrospinosus*) and Patagonian toothfish (*Dissostichus eleginoides*).

Mackerel icefish

Separate selectivity ogives were drawn for mackerel icefish caught with the help of a single-layer twine codend on fishing grounds of South Georgia and South Shetland Islands (Figure 10). Although the curves were characterized by an upward tendency, they differed distinctly from typical selectivity curves. They were similar to the ogives for a double-layer codend with a similar mesh size, analyzed above. For similar reasons as in the case of a double-layer construction, the codend material did not have the required selective properties with respect to mackerel icefish. Only fish with a length of 51 cm were wholly retained by the codend. In this case it was also impossible to find convincing arguments to explain the reasons for the considerable retention in the codend of relatively small fish, although their shape is such that they should quite easily escape through the meshes.

Bumphead notothenia

Two selectivity ogives were drawn, separately for each fishing ground, South Georgia and South Shetland Islands (Figure 11). Both ogives are similar, consisting of two sections : the initial one characterizes the selectivity for fish with a length of up to 32 cm, the second- the selectivity for longer fish. The analysis of these ogives leads one to conclude that the codend in question retains smaller fish at a relatively high level (35-60%) and only for fish with a length exceeding 32 cm, it assumes selective properties. Starting with a length of 45 cm, all notothenia are retained by this codend.

Scotia Sea icefish

Selectivity ogives (Figure 12) for South Georgia and South Shetland Islands were fairly similar despite quite large quantitative differences. Each of the curves consisted of two segments (sections) : the first, depicting retention properties of fish up to 34 cm in length at a relatively high level of up to 80-90%, and a second one, resembling a typical selectivity ogive. Unfortunately, this part of the curve constitutes only its final, short segment. Scotia Sea icefish with a length exceeding 43 cm were fully retained by the codend. It was difficult to explain why the net material with relatively large meshes retained fish with lengths of 16-19 cm at a level of 50-60%, and fish with lengths of 23-27 cm at a level as high as 80-90%. It is possible that the body features of Scotia Sea icefish (large head and spines on opercular bones) are responsible for small fish retention by the codend. It should be emphasized, however, that there were very few fish with lengths of 21-26 cm in the stock under investigation, which could have resulted in a misleading arrangement of selectivity data collected.

Ocellated icefish

Ocellated icefish occurred in greater quantities only on the fishing grounds of the South Shetland Islands and Elephant Island. A characteristic feature of these tows was their high yield. The length composition of ocellated icefish caught did not favour selectivity studies since fish with a length below 29 cm were very rare.

The shape of the selectivity ogive in Figure 13 resembles a typical selectivity ogive with a large descent, resulting from a narrow selection interval, equalling barely 1.6 cm. Fish with a length of 27 cm reached a 50% selection level. Under these conditions, selectivity coefficient F_s equalled 2.21, selection quality $W_s = 0.61$. The length of fish fully retained by the codend was 44 cm. Analyzing the values obtained, it was obvious that the values of selectivity parameters were very low, which could not have been anticipated. This could have been caused by the insufficient quantity of materials collected, especially as regards smaller fish. Another reason might have been the fact that materials collected came from relatively abundant tows, in which investigated fish, packed together with many other fish in the codend, could not escape as easily as in the case of a smaller catch. Another reason for the low selectivity could have been the body shape of ocellated icefish or badly chosen mesh size. Whatever the reasons for the deformation of the selectivity curve, it must be said that the calculated data point out to the low level of selective properties of the net material examined.

Patagonian toothfish

Patagonian toothfish was caught in greater quantities only on the fishing grounds off Shag Rocks. The curve obtained (Figure 14) resembled in its middle and final part a typical selectivity curve. It was characterized by a gentle sloping towards the X-axis. It reached a 100% retention factor for fish with a length of 54 cm. Because of such a shape of the selectivity curve for Patagonian toothfish, selectivity interval was relatively wide (8.1 cm). A 50% selection level was reached for relatively small fish (with a length of 34.4 cm). Selectivity coefficient F_s was 2.81, and selection quality coefficient W_s = 0.64. Both of them did not give a high appraisal of the selective properties of the tested material for Patagonian toothfish.

Changes of material properties of the twine codend

Material properties of the twine codend were very good as regards the ability to maintain constant mesh size during its use. Before use, wet mesh size was 123.6 mm, after the first two and after 30 hours of the codend exploitation its mesh size remained the same - 122.4 mm. The thickness of the twines did not undergo any changes either during the study and their kinks maintained their size, shape and stability.

4.2.2 Tape codend with a nominal mesh size of 60 mm

The tape codend, code-named "60" in the text, was made from special steelon tapes with a thickness of 3.5 mm and a width of 20 mm. The meshes of this codend were rectangular in shape. Although their size was determined in a different way, a value thus obtained may be believed to be identical to mesh size of twine netting. During the measurements made, it equalled 62.5 mm dry and 61.9 mm wet. A change in the size of mesh after submerging in water was very slight, which was probably a result of the physico-chemical finish of this codend by means of a water emulsion of polyurethane resin and its drying at a temperature of 140°C.

During the study, the codend rigging was slightly changed. At the beginning, the codend and the cover were encircled by 4 thick (Ø = 30 mm) splitting straps connected by heavy shackles (Figure 5). After the changes, the 4 straps remained open, holding on to the bottom part of the codend by only two rings (Figure 6). Thus, the fine-meshed liner could easily float above the codend, which, according to the author, improved selection properties of the construction tested. The detailed description of the influence of the rigging upon the selective properties of the codend will be presented on the example of bumphead notothenia.

This codend was tested on the following fishing grounds : Elephant Island, Joinville Island, Shouth Shetland Islands, Palmer Archipelago and Biscoe Archipelago. The main species taken included : spiny icefish (Chaenodraco wilsoni), ocellated icefish, mackerel icefish, Scotia Sea icefish, bumphead notothenia and Notothenia kempi.

Mackerel icefish

The shape of the selectivity curve (Figure 15) corresponded quite well to a theoretical selectivity ogive. It was characterized by a sharp ascent in the area of relatively small length classes of fish. A 50% selectivity level was achieved for fish with a length of 22.2 cm. Full retention was obtained for fish with a length of 33 cm. The selectivity interval was 3.6 cm. Selectivity coefficient F_s was 3.63, and selection quality coefficient W_s was 0.67. Although both coefficient values were not too high, they nevertheless signified a positive appraisal of the selectivity of this net material in the case of mackerel icefish.

Bumphead notothenia

For the analysis of the "60" tape codend selectivity for bumphead notothenia, 14 tows were selected, including 9 made with the codend equipped with 4 splitting straps and 5 made without them. Separate selectivity ogives were drawn for each of the two phases of the experiment (Figure 16).

The analysis of both ogives led to the conclusion that the alterations made in the codend gear increased its selective properties, which could be seen in the increase of fish length for the 50% selectivity level from 20.2 to 21.1 cm and the decrease of selection interval by about 20%. That is why a modernized codend version without straps was used for further selectivity investigations. For this second codend version, the selection interval equalled 4.0 cm, selection coefficient F_s = 3.45, and selection quality W_s was 0.7. The length of fish wholly retained by the codend was 30 cm. The parameters thus obtained gave a general appraisal of the selective capability of the codend with respect to bumphead notothenia at an average level which was connected with too small a mesh of this codend; as a result, a low value of length of fish, the 50% selection level, was obtained.

Scotia Sea icefish

The shape of the curve presented in Figure 17 departs greatly from a typical selectivity ogive. It seems that this was caused by the small amount of material collected, especially as regards smaller length classes. Eight tows in which this species was quite abundant happened to be small tows, as in larger ones, the percentage share of Scotia Sea icefish was negligible. Under these conditions, a broken line was used to show the hypothetical continuation of the ogive. For both the actual and hypothetical ogives, a 50% selection level covered the class of very small fish with a length of 19.2 cm for the true curve and 20.2 cm for the hypothetical one. Selection interval was 2.4 cm, and the length of fish fully retained by the codend - 32.0 cm. Selectivity coefficient F_s = 3.14

and selection quality coefficient W_s was 0.6. These values give an appraisal of this codend's selectivity at a level below average. It may be said that the selectivity of the "60" tape codend for Scotia Sea icefish was much worse than for other Antarctic fish species.

Spiny icefish

Seven tows selected for analysis were characterized by a relatively large yield and short duration. The characteristic feature of the selectivity curve (Figure 18) is the narrow selection interval, equalling 1.7 cm. Unfortunately, it covers very small fish: a 50% selectivity level was determined for fish with a length as small as 17.6 cm. Beginning with a length of 31 cm, fish were fully retained by the codend. Selectivity coefficient F_s was 2.88 and selection quality coefficient W_s = 0.6. It seems that the selection parameters obtained were mostly influenced, apart from the shape of fish, by their length composition in the stock under study, high yield, and short tow duration. Small fish packed together with a large number of larger fish did not have a chance to get near the net material and escape although in theory they should have been able to do so with ease. Under these conditions, the length of fish for the 50% selection level could have been underestimated.

Ocellated icefish

Five tows selected for the study were all characterized by not too large yields. The main species caught in these tows was spiny icefish.

The curve (Figure 19) resembles a theoretical selectivity ogive. It is characterized by a relatively narrow selection interval equalling 2.0 cm. A 50% selection level comprised fish with a length of 28.8 cm. Selectivity coefficient F_s was 4.71, and selection quality coefficient W_s = 0.90. The length of fish retained by the codend in 100% of cases was 32.0 cm. All parameters obtained for ocellated icefish resulted in an exceptionally favourable appraisal of selective capabilities of the "60" tape codend. It seems that the ability of fish to pass through the meshes in this experiment was very good, and this might have had its influence on the selective properties of the codend tested unlike in the case of spiny icefish, for which conditions of correct selection were unfavourable.

Notothenia kempi

A selectivity ogive is presented in Figure 20. The selection interval for Notothenia kempi was 3.8 cm. A 50% selection level was achieved by the codend for fish with a length of 20.4 cm. Selectivity coefficient F_s was 3.30, and selection quality coefficient was W_s was 0.64. The length of fish fully retained by the codend was 32.0 cm. The above values give a modest appraisal of the "60" tape codend's selective capabilities for Notothenia kempi. The mesh size in the codend was too small to efficiently protect immature fish against capture.

Material properties of the "60" tape codend

Changes in the mesh size in the "60 " tape codend are presented in Table 6. It appears from these measurements that the mesh size was the same during the trawl use and that is why the value of 60 mm was assumed as the mesh size for calculation of selectivity parameters.

4.2.3 Tape codend with a nominal mesh size of 100 mm

This codend, code-named "100" in the text, had a similar structure to that of the "60" codend, the only difference being that the "100" codend did not have the physico-chemical finish. This codend was tested on the following fishing grounds : South Georgia, South Orkney Island, South Shetland Islands and Elephant Island.

Mackerel icefish

Curves for the South Orkney Islands and for the South Shetland Islands and Elephant Island fishing grounds (Figure 21) were similar in shape and represented the same type of selection. In fact, they constituted the middle and final part of a typical selectivity ogive, which was connected with the occurrence at these grounds of mackerel icefish with lengths exceeding 30 cm. Selection interval was similar for both areas, equalling 7.0 cm on the average. Mean length of mackerel icefish for the 50% selection level could also be assumed as identical for both areas; it equalled 33.5 cm. Under these circumstances selectivity coefficient F_s was 3.3. Selection quality coefficient could also be assumed as identical for both curves : $W_s = 0.72$. The length of fish fully retained by the codend was 47.0 cm. The data obtained allow for a favourable appraisal of the "100" tape codend's selectivity for mackerel icefish.

Bumphead notothenia

Selectivity curves for the three investigated areas (Figure 22) had a similar shape, corresponding rather well to a standard selectivity ogive. The following values of basic selectivity parameters of the codend tested for fish caught at South Georgia grounds were determined on the basis of the analysis of these ogives : selection interval - 5.4 cm, mean length of fish for the 50% selection level - 35.7 cm, selectivity coefficient F_s = 3.51, selection quality coefficient $W_s = 0.83$, length of fish fully retained by the codend - 43.0 cm. On the basis of these parameters, it may be said that the selectivity of the codend for bumphead notothenia was relatively good.

The values of the basic selectivity parameters for bumphead notothenia taken on South Orkney and South Shetland grounds were similar. They were the following : selection interval - 10.7 cm, mean length of fish for the 50% selection level - 29.8 cm, selectivity coefficient $F_s = 2.43$, selection quality coefficient $W_s = 0.75$. Parameters obtained were slightly worse than those for bumphead notothenia from South Georgia fishing grounds.

These data clearly confirmed that selectivity depends not only on the material properties of the codend itself but also on many other factors, the most important of them being the yield attained, tow duration, species composition of tow, and the length composition of fish in the stock exploited. That is why the same codend may get seemingly different appraisals as regards its selectivity properties for the same species of fish, depending on the exploitation conditions, in which it is being used.

Scotia Sea icefish

During the study period, only on the South Georgia fishing gounds, material suitable for the analysis of the codend for Scotia Sea icefish was collected in 5 tows.

The analysis of the selectivity ogive (Figure 23) made it possible to determine the following values of basic selectivity parameters : selection interval - 14.2 cm, mean length of fish for the 50% selection level - 24.2 cm, selectivity coefficient F_s = 2.38, selection quality coefficient W_s = 0.49, length of fish fully retained by the codend - 49.0 cm. The values thus obtained signified that selective properties of the codend with respect to Scotia Sea icefish were unsatisfactory. This was seen in a tendency of the codend to retain a large number of relatively small specimens. It is possible that the unfavourable results were influenced by the presence of various bottom organisms taken together with Scotia Sea icefish as well as the lack of physico-chemical finish of the codend.

Ocellated icefish

Selectivity ogives were drawn for the two fishing grounds (Figure 24). The shape of both curves was almost identical. It must be stressed, however, that in both cases the number of specimens in the classes of smaller fish having a strong influence on the shape of the curve, was exceptionally low. That is why a more detailed analysis will deal only with the curve for South Orkney Island, where fish were diversified in length. The main selectivity parameters for Scotia Sea icefish caught on the South Orkney fishing grounds were the following : selectivity interval - 2.3 cm, mean length of fish for the 50% selection level - 26.8 cm, selectivity coefficient F_s = 2.67, selection quality coefficient W_s = 0.69, length of fish fully retained by the codend - 39.0 cm. The values of these parameters estimate selective properties of this codend at a moderate level. The value of selectivity coefficient is especially low. However, taking into account the possibility of improving the codend's material properties, one may hope that it will be later given a favourable estimate, after a new set of data for the corrected versions has been collected.

Spiny icefish

Spiny icefish was found in greater numbers only on the South Shetland fishing grounds. During the study it was possible to select only one tow, very abundant, in which 8.2 tons of fish, mostly spiny icefish were taken. The tow duration was relatively short. Most fish were quickly packed together in the codend and it may be expected they did not have a chance to escape through the meshes. Thus, despite the great number of fish measured (Table 5) the above reservations should be borne in mind when interpreting the data obtained in this experiment.

The selectivity ogive drawn on the basis of measurements and calculations made is presented in Figure 25. This curve served as a basis for the calculations of the following main selection parameters of the codend for spiny icefish : selectivity interval - 2.7 cm, mean length of fish for the 50% slection level - 22.0 cm, selectivity coefficient F_s = 2.17, selection quality coefficient W_s = 0.65, length of fish fully retained by the codend - 34.0 cm. It could be expected that due to circumstances described above, i.e. the difficult escape of fish through the codend material, the values estimating selectivity will have relatively low values, reflecting a negative appraisal of this codend's selectivity. This appraisal, however, must be related to a given experiment. It seems that when its conditions change and a situation favouring the correct process of fish selection is created, it will remain at the same level as was the case with ocellated icefish. It is clear that in case of such abundant catches, when within a short time tons of fish enter the codend, it is difficult to speak about selectivity as such.

South Georgia icefish

This species occurred in greater quantities only on the fishing grounds of South Georgia. A characteristic feature of the material collected was the small number of specimens with lengths below 25 cm and the absence of fish in certain length classes, e.g. 26-29 cm. Larger fish were represented in greatest numbers. On the basis of measurements and calculations made, a selectivity ogive for South Georgia icefish was drawn (Figure 26).

As a result of the analysis of selectivity of the big tape codend for South Georgia icefish, the following values of main selection parameters were obtained : selection interval - 8.5 cm, mean length of fish for the 50% selection level - 23.0 cm, selectivity coefficient F_s = 2.26, selection quality coefficient W_s = 0.58, length of fish fully retained by the codend - 40.0 cm. These parameters give a negative appraisal of the codend. It seems, however, that the collection of more numerous material and an improvement of material properties of the codend would improve this appraisal.

Material properties of the "100" tape codend

The mesh size of the "100" tape codend changed during the trawl use in the manner presented in Table 7.

Although the changes in mesh size were not great, the tape net material could hardly be classified as stable. Mesh size changed because of the unstable tape junctions.

CONCLUSIONS

The value of main selection parameters for each type of codend for selected fish species are listed in Table 8. Our trawl selectivity studies were conducted for the first time in the Antarctic and that is why the mesh size of net materials from which codends were made was not selected well. During the experiment two different constructions were appraised unfavourably : double-layer codend and single-layer codend, made of twine and having a similar selectivity characteristic for several commercial fish species taken in the Antarctic. The mesh size in these codends (120 mm) turned out to be too big for almost all species of Antarctic fish studied. This net material may be used in practice only for Patagonian toothfish.

Data collected during selectivity studies for both tape codends seemed quite interesting. It was demonstrated that net materials of this type had selective properties and may be used in practice for the construction of codends used for the capture of Antarctic fish. Unfortunately, none of the tested mesh sizes may be recommended for practical use because one of them, 60 mm, was too small for most fish species while the other, 100mm, was too large. The positive impact of a change of mesh size from 60 to 100 mm on an increase in fish length for the 50% selection level and the length of fish fully retained by the codend was noted during the tests with both tape net materials. An increase in mesh size also brought about an increase in selection interval, which may have been connected with the different physico-chemical finish of both tape materials, and increase in the selection quality coefficient though there were exceptions to this rule. It was most difficult to interpret changes in selectivity coefficients because for some fish species, e.g. bumphead notothenia and mackerel icefish, this coefficient did not change significantly while for others it decreased, which should be related to a deterioration of the codend material properties.

The experiments indicated that the protection of juvenile Antarctic fish is possible by the choice of proper mesh size in the codend. The results obtained, however, should be treated as preliminary. Selectivity studies of codends used in the Antarctic should be continued with additional mesh sizes of 70 and 80 mm in the codends with a very fine physico-chemical finish. Further studies should also take into account the observed different behaviour of fish in the codend, their number and length composition, amount and species composition of the by-catch and other factors. It turned out that these conditions may considerably influence the selectivity of codends.

Table 1 : Characteristics of codend net materials

Type of codend		Materials used for construction: Staple product	Final or width	Thickness of (mm)	Technology chemical production	Physico-finish	Mesh bar length dry (mm): Nominal	Actual	Mesh size dry (mm)
single-layer		polyamide	double twine	Ø 7.0	tied	factory made	80	84	124
single-layer		steelon	tape	3.5 x 20	braided	polyurethane	36x25	36x25	61
single-layer		steelon	tape	3.5 x 20	braided	no finish	-	-	102
double-layer	outer chafer	steelon	twisted rope	Ø 10	braided	no finish	120	119	220
double-layer	codend	steelon	double	Ø 3.5	tied	osolan S	57	59	125

Table 2 : Material for selectivity studies of a double-layer codend (mesh size 120 mm)

Species	Fishing Ground	No of tows	No of fish measured in codend	in liner
Mackerel Icefish	South Gerogia and Shag Rocks	6	430	421
	South Orkney Is.	4	2 272	1 905
Bumphead notothenia	South Georgia and Shag Rocks	9	1 898	979
	South Orkney Is.	6	6 562	2 288
Scotia Sea icefish	South Georgia	9	1 008	325
	South Orkney Is.	3	164	36

Table 3. Material for selectivity studies of a single-layer twine codend (mesh size 120 mm)

Species	Fishing Ground	No of tows	No of fish measured in codend	in liner
Mackerel icefish	South Georgia	9	2 864	2 274
	South Shetland Is. Elephant I.	8	3 501	1 084
Bumphead notothenia	South Georgia	7	1 663	1 093
	South Shetland Is. Elephant I.	8	10 609	4 253
Scotia Sea icefish	South Georgia	7	3 490	1 161
	South Shetland Is. Elephant I.	7	827	106
Ocellated icefish	South Shetland Is. Elephant I.	7	4 901	153

Table 4. Material for selectivity studies of a single-layer tape codend (mesh size 60 mm) collected in the Antarctic Peninsula area.

Species	No of tows		No of fish measured	
	codend with straps	without straps	in codend	in liner
Mackerel icefish	7	–	10 809	82
Bumphead notothenia	9	–	4 424	2 706
		5	3 776	1 160
Scotia icefish	8	–	523	42
Spiny icefish	7	–	69 147	379
Ocellated icefish	5	–	742	130
Notothenia kempi	5	–	1 190	778

Table 5. Material for selectivity studies of a single-layer tape codend (mesh size 100 mm)

Species	Fishing Ground	No of tows	No of fish measured in codend	in liner
Mackerel icefish	South Orkney Is.	3	10 615	2 771
	South Shetland Is. Elephant I.	3	1 687	454
Bumphead notothenia	South Georgia	5	795	1 156
	South Orkney Is.	3	1 178	1 059
	South Shetland Is. Elephant I.	3	2 670	3 826
Scotia Sea icefish	South Georgia	5	1 646	1 272
Ocellated icefish	South Orkney Is.	3	1 263	50
	South Shetland Is.	3	2 386	56
Spiny icefish	South Shetland Is.	1	36 400	5 856
South Georgia Icefish	South Georgia	5	560	62

Table 6 : Changes in the mesh size (mm) in the "60" tape codend

After first tow	After 20 hours	After 40 hours	After 60 hours	Mean
61.8	60.7	61.0	61.9	61.2

Table 7 : Changes in mesh size of the "100" tape codend

Value measured	Before use Dry	Before use Wet	After 2 hours	After 10 hours	After 25 hours	Mean assumed for calculation
Mean (mm)	98.0	100.9	101.1	101.1	102.0	101.6

Table 8. Values of main selectivity parameters of codends tested

Type of codend / selectivity parameter	Double-layer codend			single-layer codends																
				twine					"60" tape					"100" tape						
	Mackerel icefish	Bumphead notothenia	Scotia Sea icefish	Mackerel icefish	Bumphead notothenia	Scotia Sea icefish	Ocellated icefish	Patagonian toothfish	Mackerel icefish	Bumphead notothenia	Scotia Sea icefish	Spiny icefish	Ocellated icefish	Notothenia kempi	Mackerel icefish	Bumphead notothenia	Scotia Sea icefish	Ocellated icefish	Spiny icefish	South Georgia icefish
Selectivity interval	–	very wide	very wide	–	very wide	very wide	1.6	8.1	3.6	4.0	2.4	1.7	2.0	3.8	7.0	5.4	14.2	2.3	2.7	8.5
Length of fish for 50% selection level	·	·	·	·	·	·	27.0	34.4	22.2	21.1	19.2	17.6	28.8	20.4	33.5	35.7	24.2	26.8	22.0	23.0
Selectivity coefficient	·	·	·	·	·	·	2.21	2.81	3.63	3.54	3.15	2.85	4.74	3.30	3.30	3.51	2.38	2.67	2.17	2.26
Selectivity quality coefficient	·	·	·	·	·	·	0.61	0.84	0.67	0.70	0.60	0.60	0.90	0.64	0.72	0.83	0.49	0.69	0.65	0.58
Length of fish fully retained	·	46.0	44.0	51.0	45.0	43.0	44.0	54.0	33.0	30.0	32.0	31.0	32.0	32.0	47.0	43.0	49.0	39.0	34.0	40.0

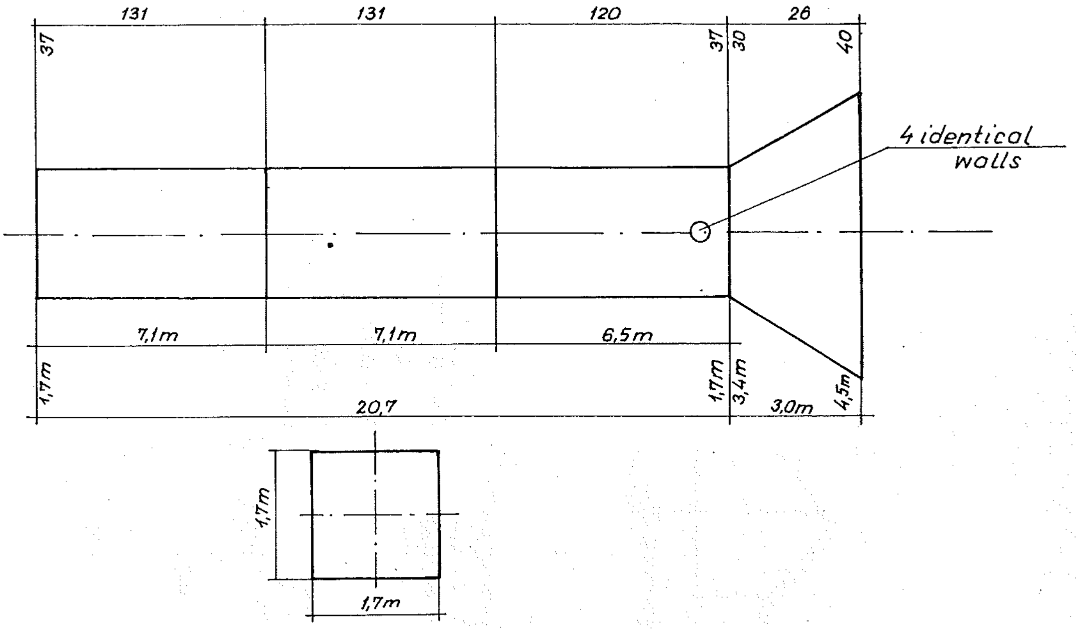

Figure 1 Plan of tape codend construction.

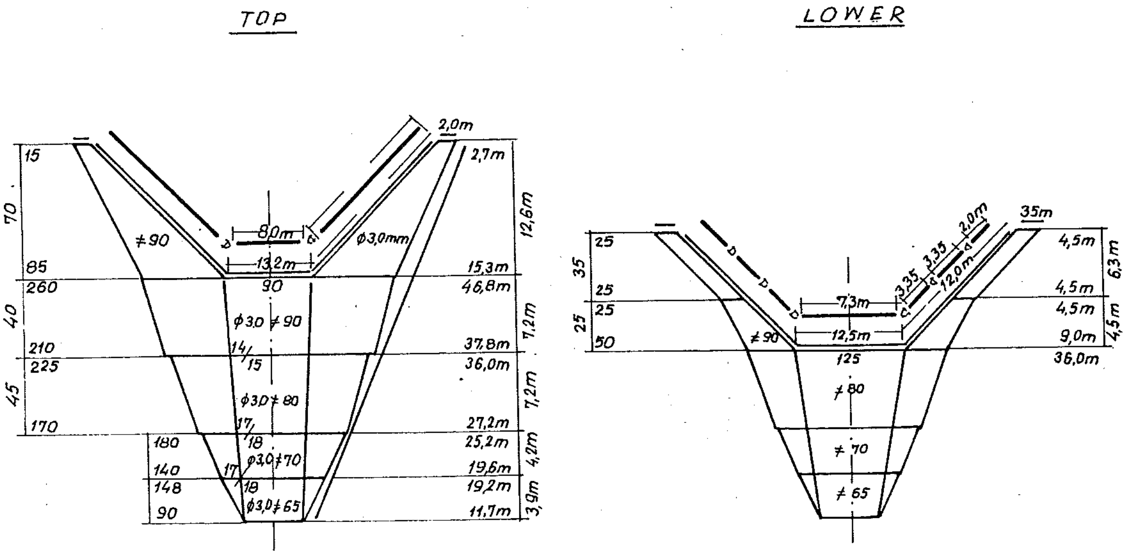

Figure 2 Plan of 32/36 bottom trawl construction.

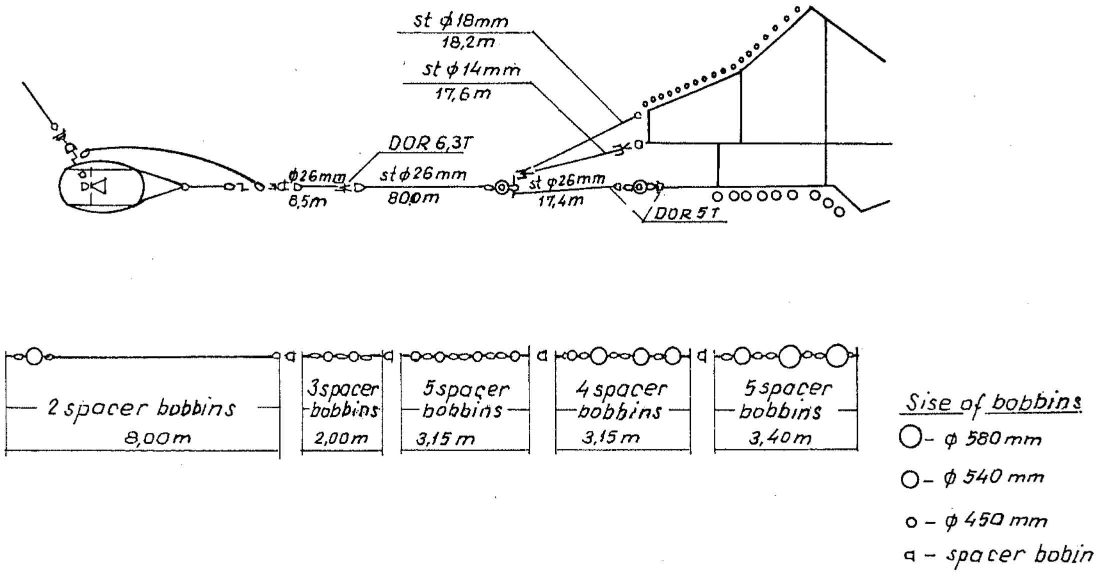

Figure 3 Plan of gear rigging for 32/36 bottom trawl.

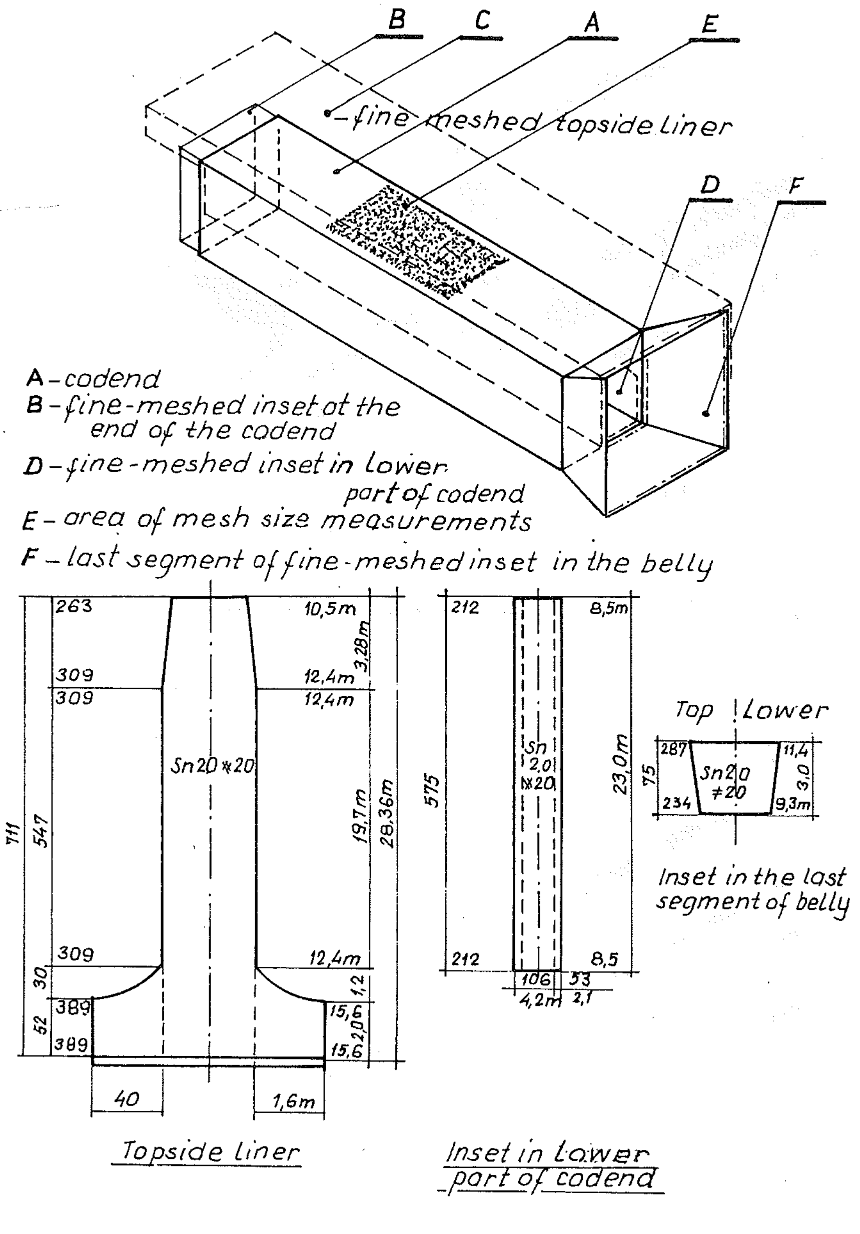

Figure 4 Plan of tape codend with fine-meshed topside liner and fine-meshed inset in lower part of codend.

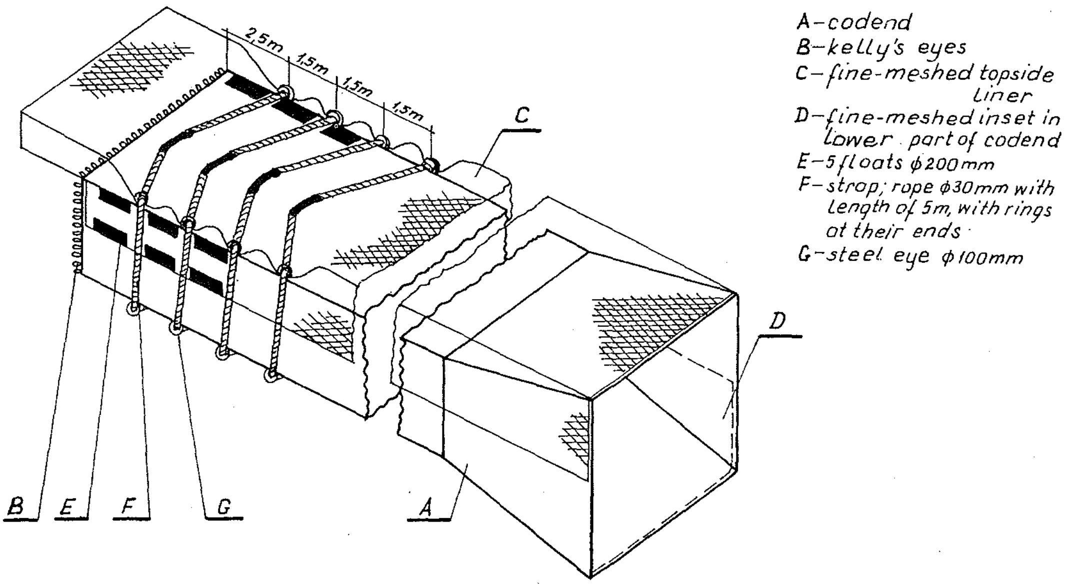

Figure 5 Plan of standard codend rigging (version I).

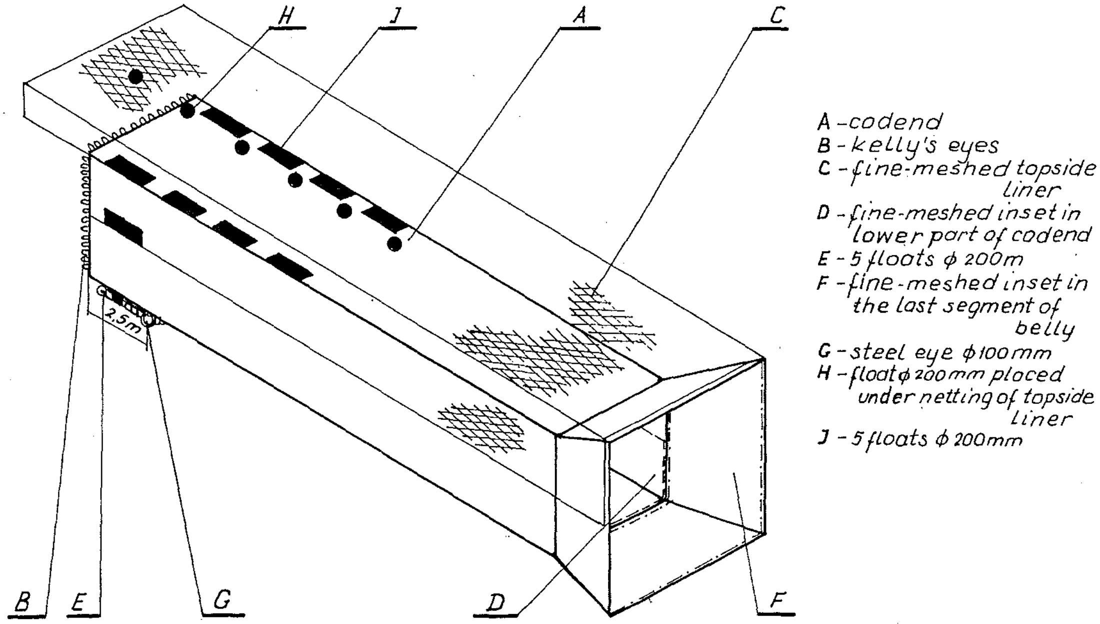

Figure 6 Plan of modified tape codend rigging (version II).

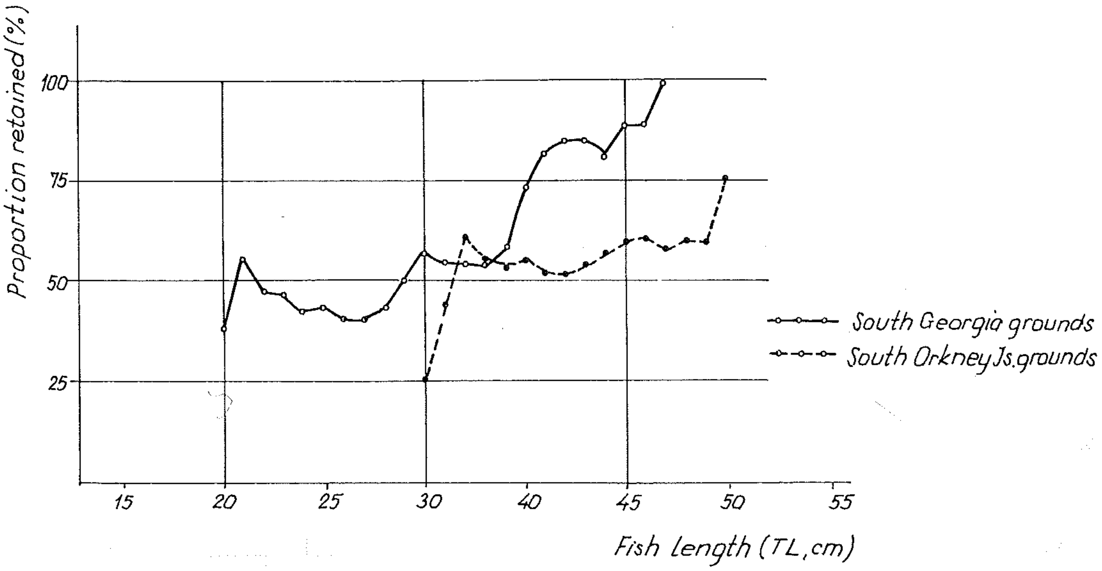

Figure 7 Double-layer codend (mesh 120 mm) selectivity ogive for mackerel icefish.

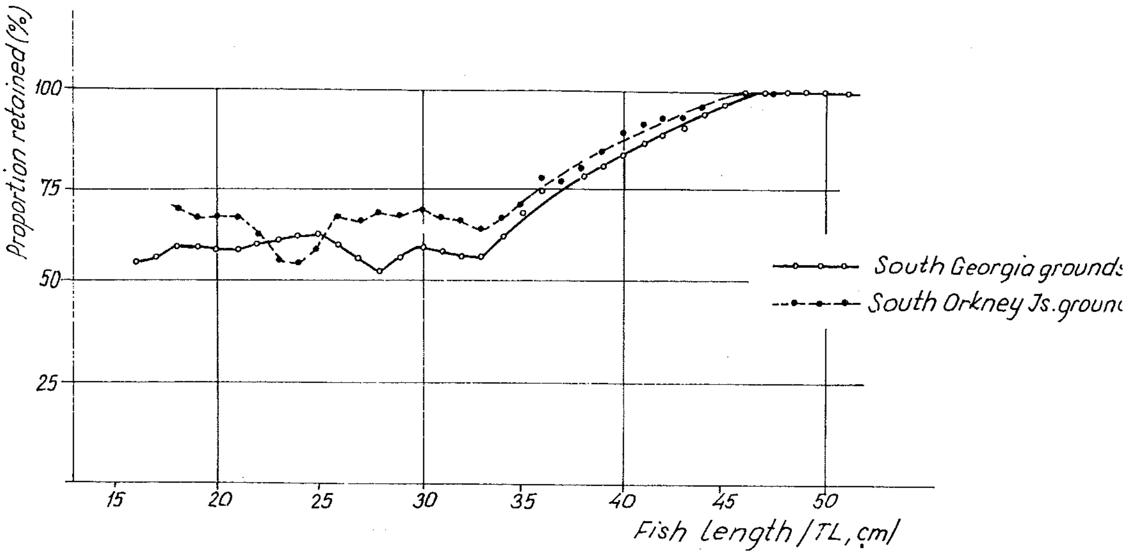

Figure 8 Double-layer codend (mesh 120 mm) selectivity ogive for bumphead Notothenia.

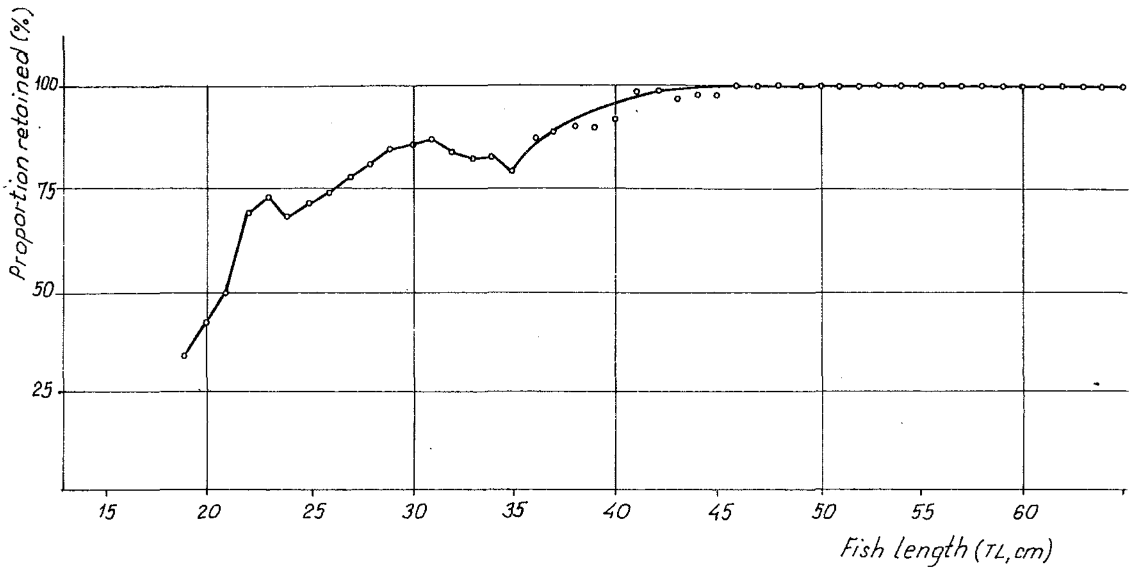

Figure 9 Double-layer codend (mesh 120 mm) selectivity ogive for Scotia Sea icefish on South Georgia grounds.

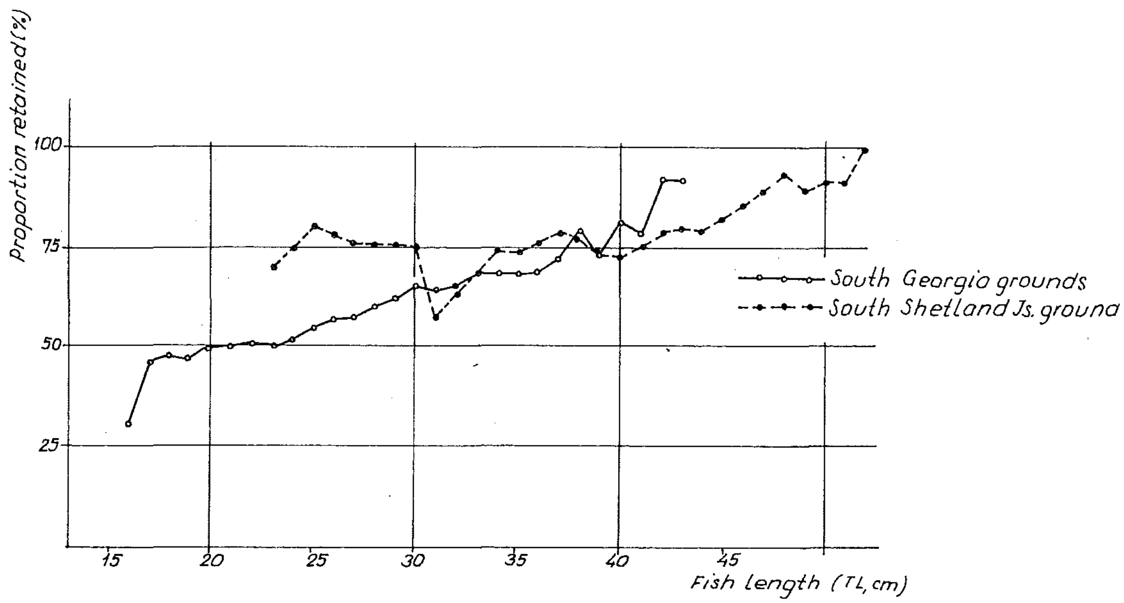

Figure 10 Twine codend (mesh 120 mm) selectivity ogive for mackerel icefish.

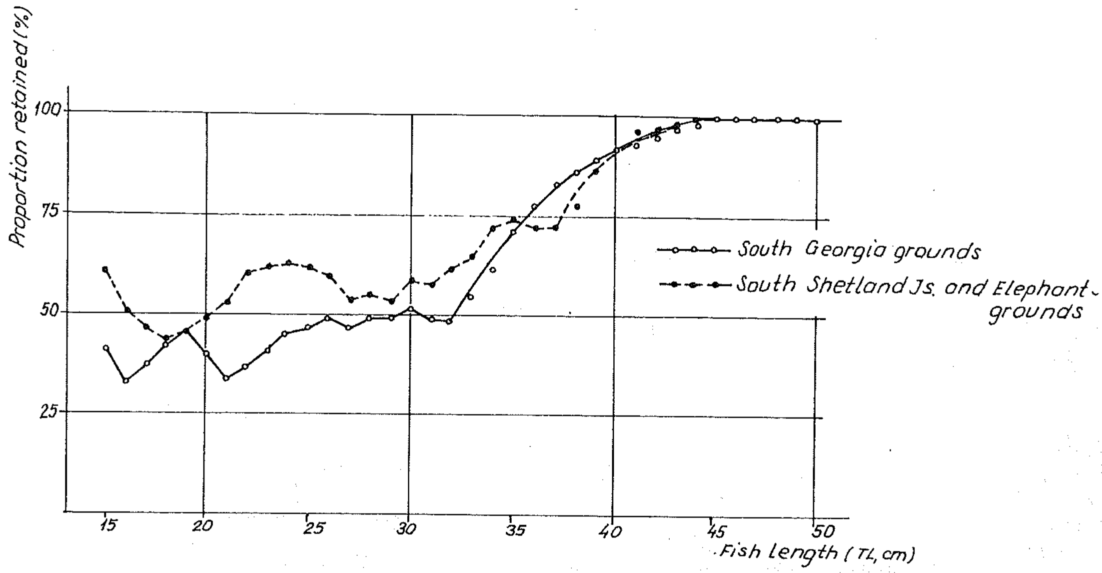

Figure 11 Twine codend (mesh 120 mm) selectivity ogive for bumphead Notothenia.

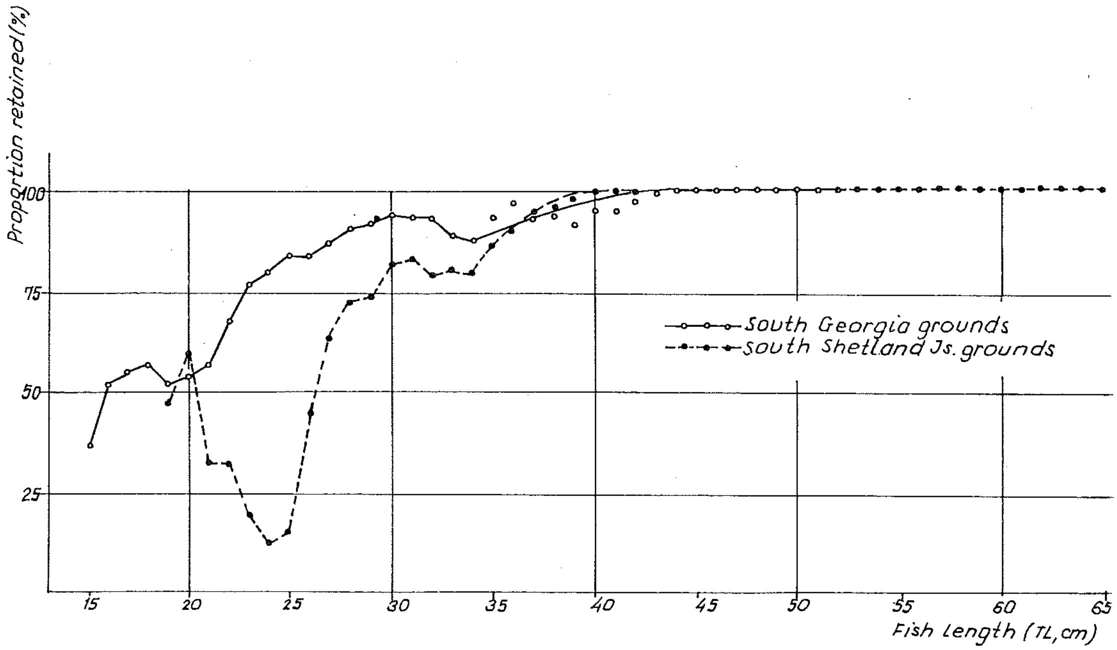

Figure 12 Twine codend (mesh 120 mm) selectivity ogive for Scotia Sea icefish.

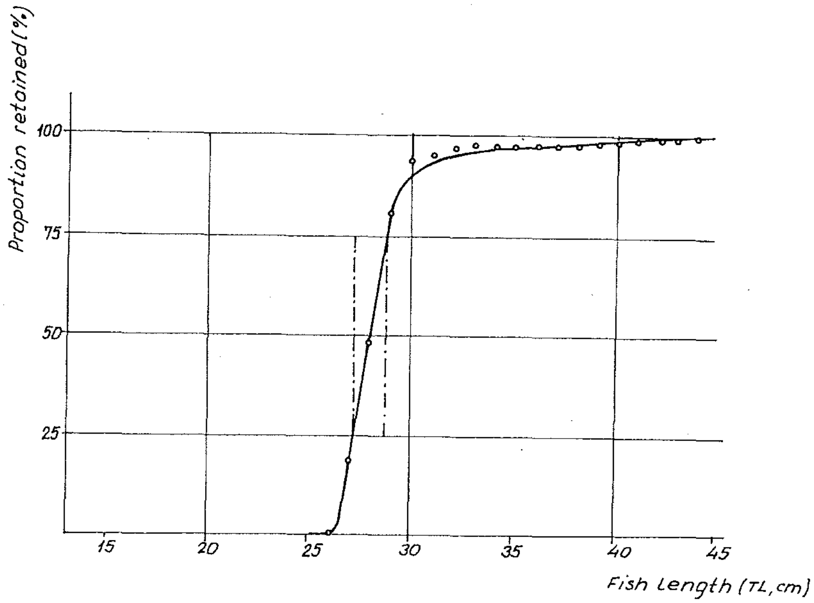

Figure 13 Twine codend (mesh 120 mm) selectivity ogive for ocellated icefish.

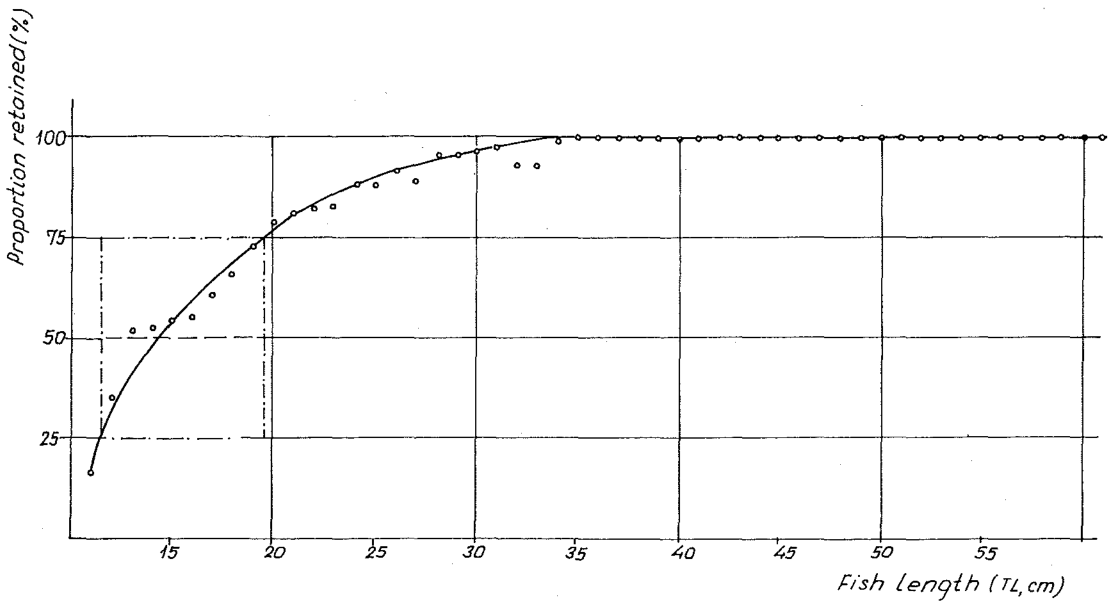

Figure 14 Twine codend (mesh 120 mm) selectivity ogive for Patagonian toothfish.

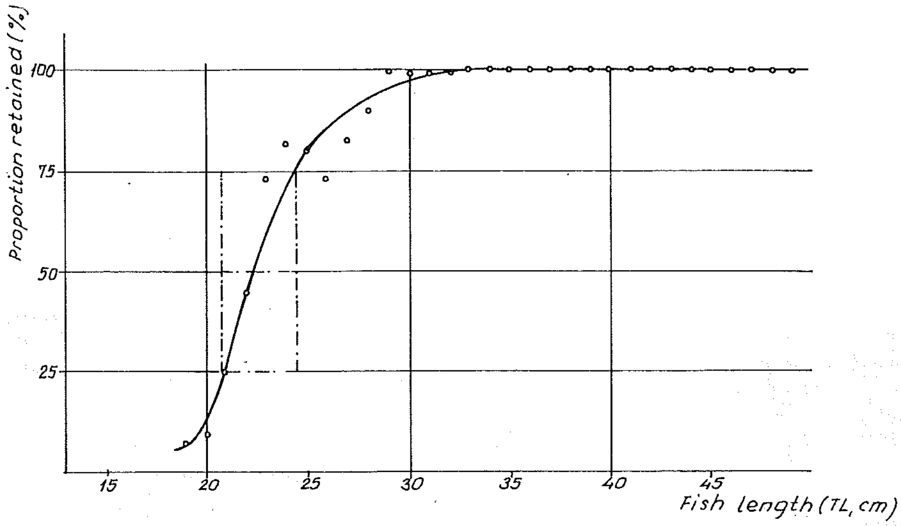

Figure 15 Tape codend ("60") selectivity ogive for mackerel icefish on Antarctic Peninsula grounds.

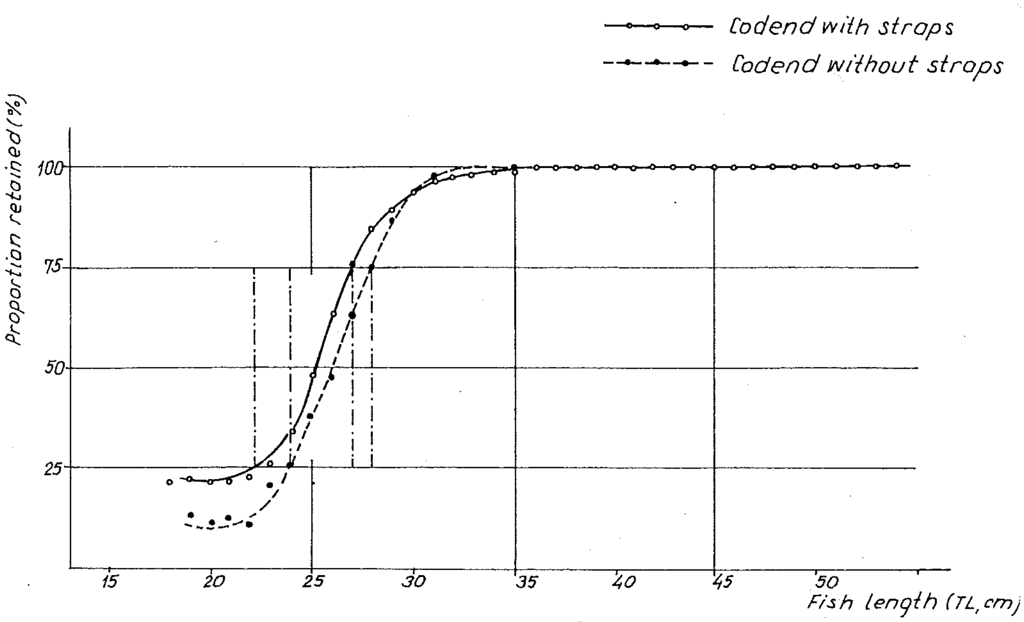

Figure 16 Tape codend ("60") selectivity ogive for bumphead Notothenia on Antarctic Peninsula grounds.

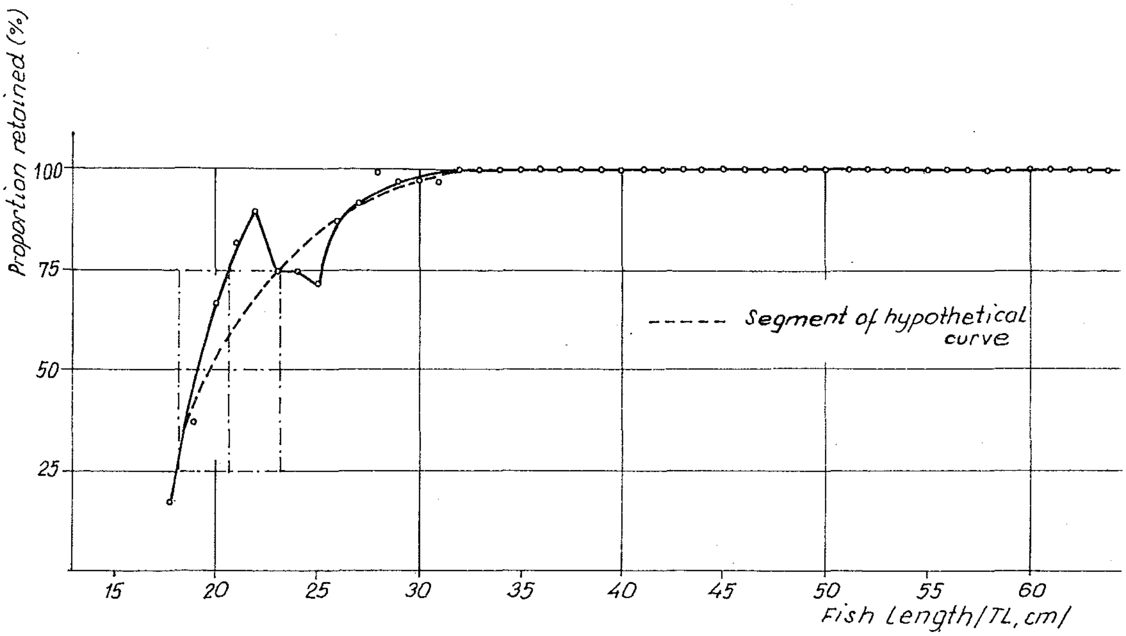

Figure 17 Tape codend ("60") selectivity ogive for Scotia Sea icefish on Antarctic Peninsula grounds.

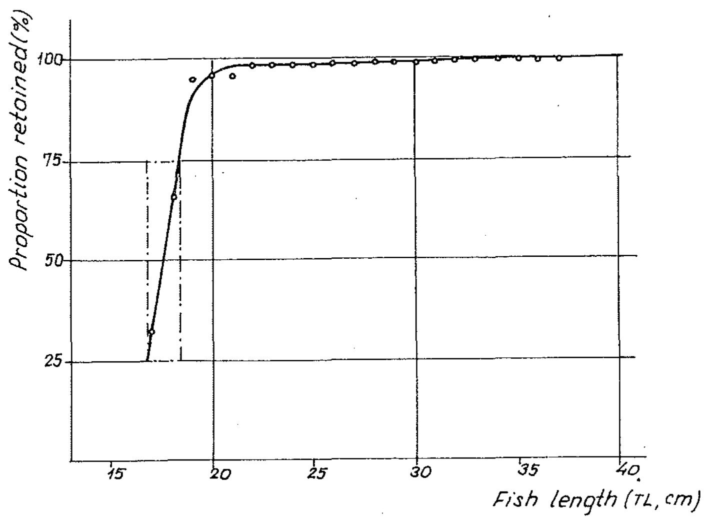

Figure 18 Tape codend ("60") selectivity ogive for spiny icefish on Antarctic Peninsula grounds.

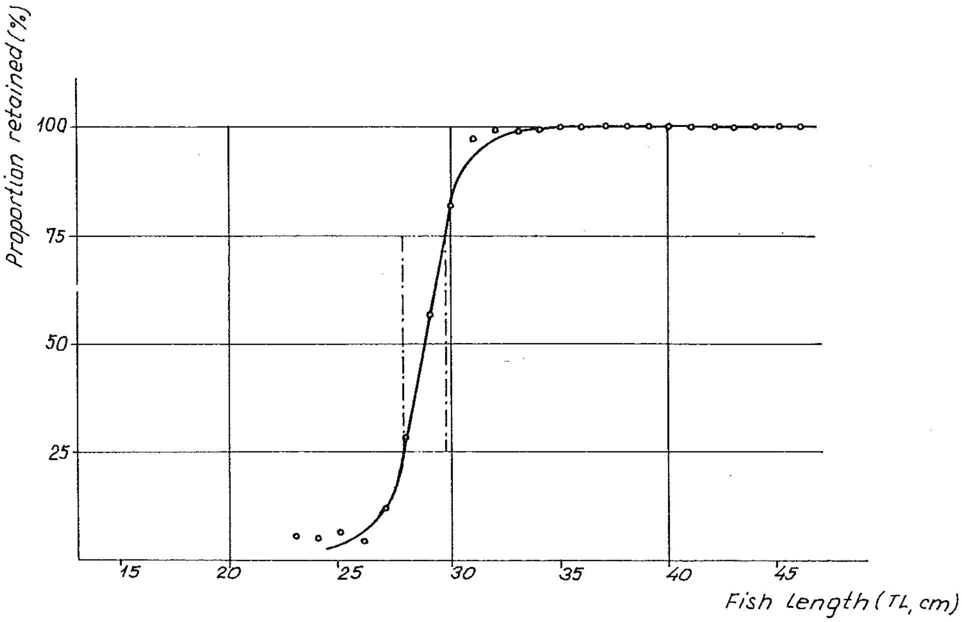

Figure 19 Tape codend ("60") selectivity ogive for ocellated icefish on Antarctic Peninsula grounds.

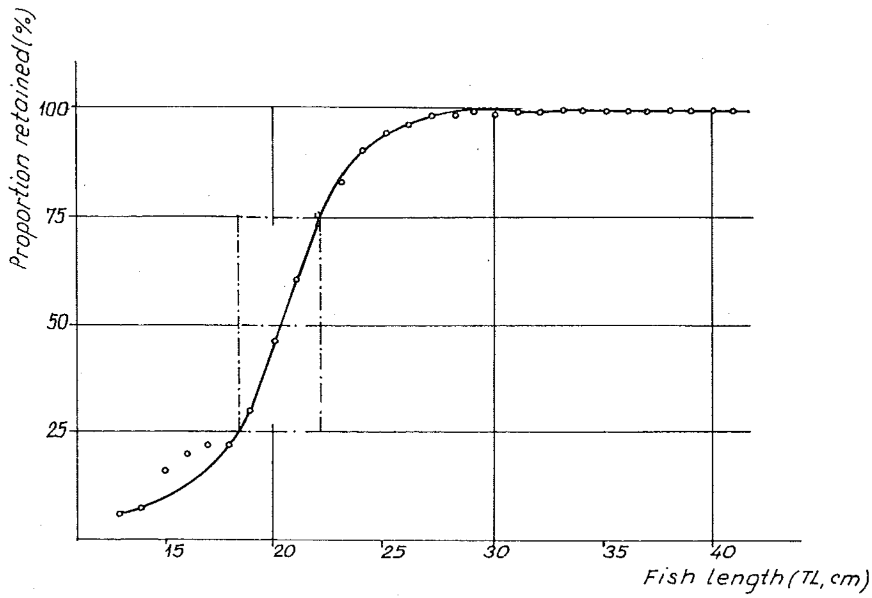

Figure 20 Tape codend ("60") selectivity ogive for <u>Notothenia kempi</u> on Antarctic Peninsula grounds.

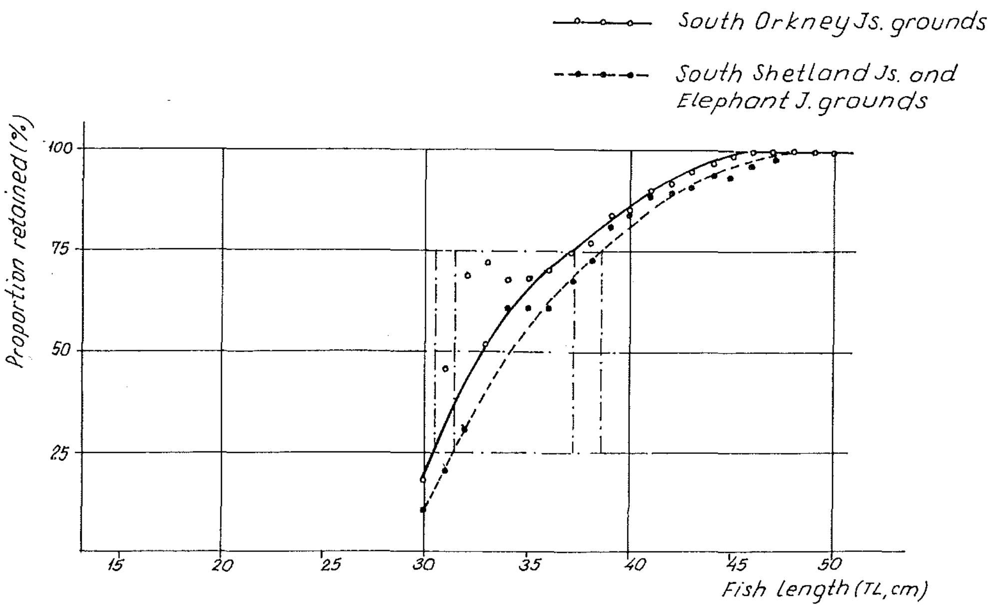

Figure 21 Tape codend ("100") selectivity ogive for mackerel icefish.

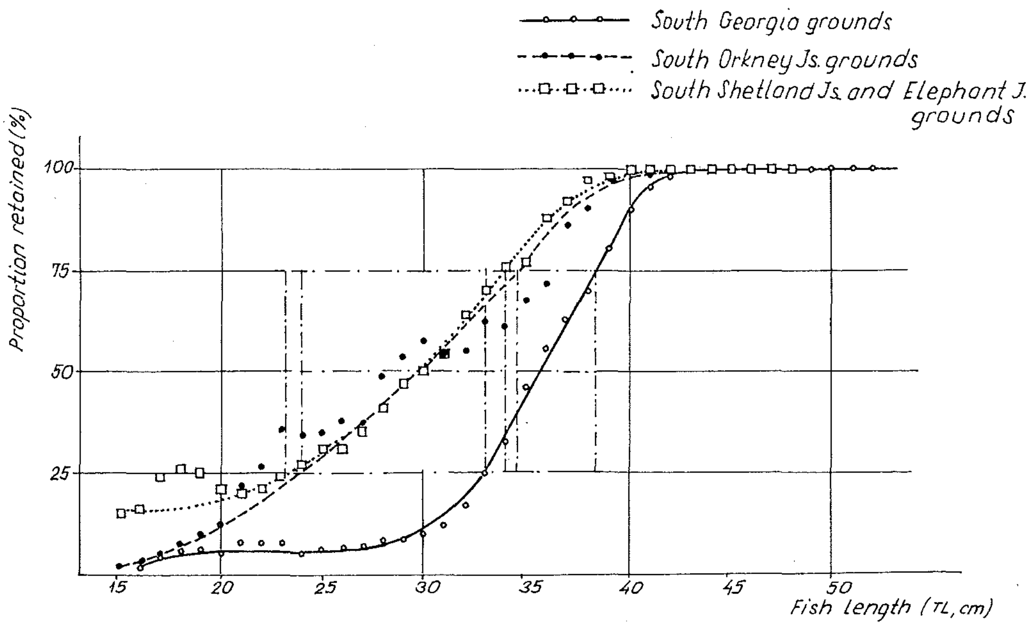

Figure 22 Tape codend ("100") selectivity ogive for bumphead <u>Notothenia</u>.

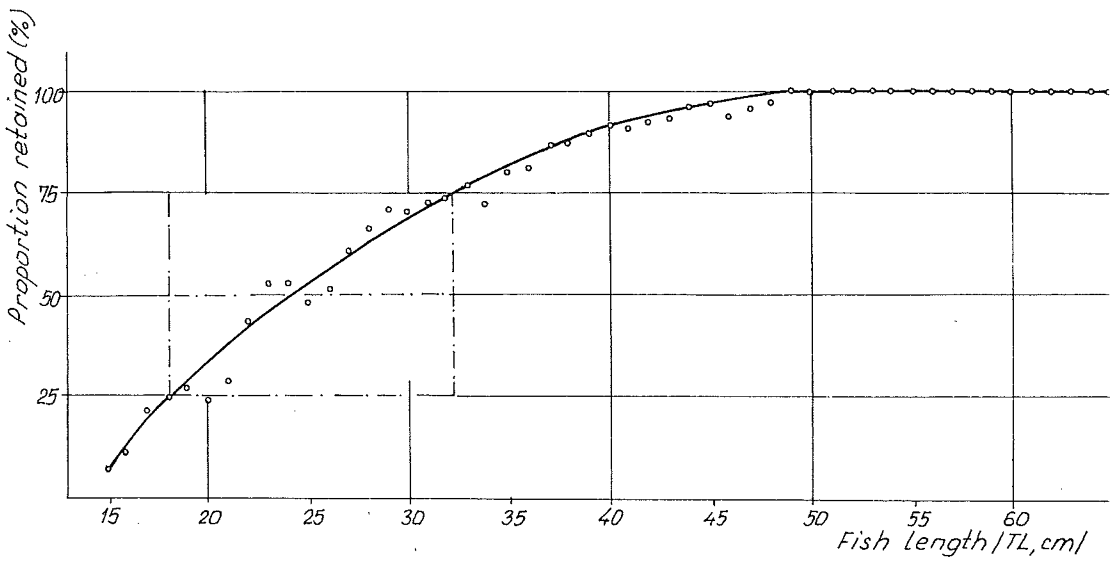

Figure 23 Tape codend ("100") selectivity ogive for Scotia Sea icefish on South Georgia grounds.

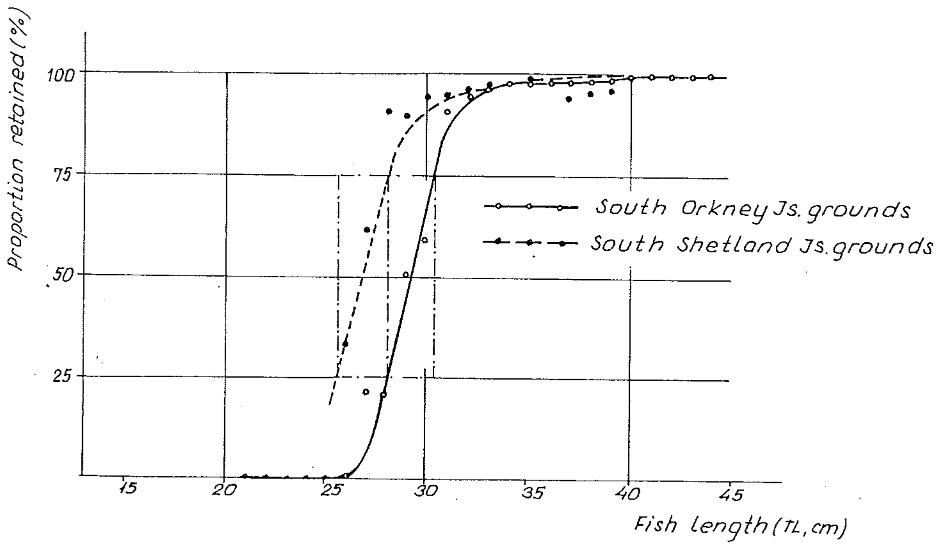

Figure 24 Tape codend ("100") selectivity ogive for ocellated icefish.

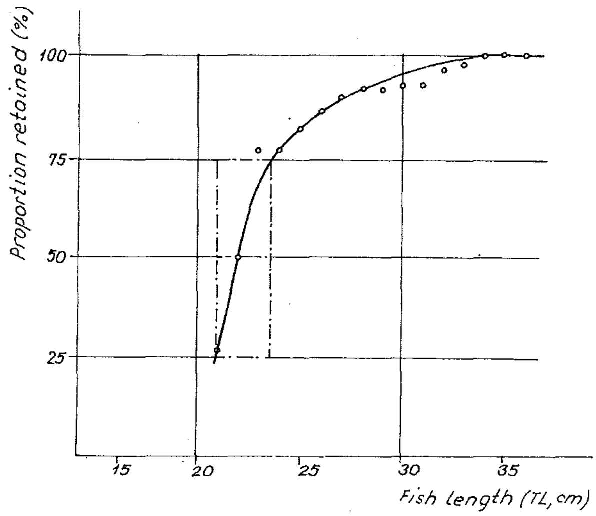

Figure 25 Tape codend ("100") selectivity ogive for spiny icefish on South Shetland grounds.

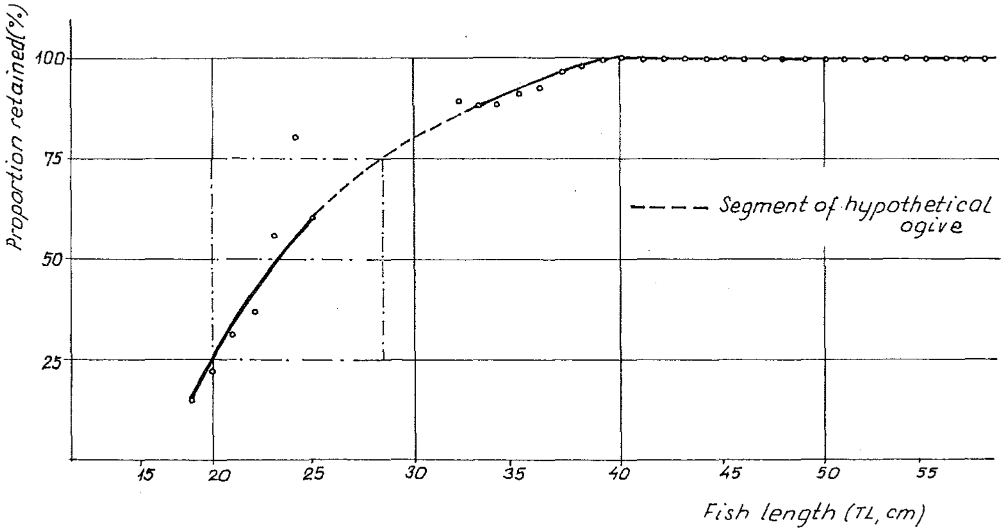

Figure 26 Tape codend ("100") selectivity ogive for South Georgia icefish on South Georgia grounds.

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Légendes des figures

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Tabla 4 — Datos para los estudios de selectividad de una malla de corona de cinta de capa simple (luz de malla de 60 mm), recopilados en el área de la Península Antártica.

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Figura 2 — Plano de construcción del arrastre de fondo 32/36.

Figura 3 — Plano del equipamiento del arrastre de fondo 32/36.

Figura 4 — Plano de la corona de cinta con un forro superior de malla fina y una inserción de malla fina en la parte inferior de la corona.

Figura 5 — Plano del equipamiento estándar de la corona (versión I).

Figura 6 — Plano del equipamiento modificado de la corona de cinta (versión II).

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Figura 8 — Ojiva de selectividad de la malla de corona de doble capa (luz de malla de 120 mm) para Notothenia gibberifrons (bumphead notothenia).

Figura 9 — Ojiva de selectividad de la malla de corona de doble capa (luz de malla de 120 mm) para el pez de hielo del Mar de Scotia en zonas de Georgia del Sur.

Figura 10 — Ojiva de selectividad de la malla de corona de hilo trenzado (luz de malla de 120 mm) para el pez de hielo caballa.

Заголовки к таблицам

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Таблица 2 Информация для изучения селективности двуслойного кутка (размер ячей - 120 мм).

Таблица 3 Информация для изучения селективности однослойного веревочного кутка (размер ячей - 120 мм).

Таблица 4 Информация для изучения селективности однослойного ленточного кутка (размер ячей - 60 мм), собранная в районе Антарктического полуострова.

Таблица 5 Информация для изучения селективности однослойного ленточного кутка (размер ячей - 100 мм).

Таблица 6 Изменения в размере ячей (в мм) ленточного кутка "60".

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Рисунок 9 Огива селективности двуслойного кутка (ячея - 120 мм) для ледяной рыбы моря Скотия в районе Южной Георгии.

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Рисунок 17 Огива селективности ленточного кутка ("60") для ледяной рыбы моря Скотия в районе Антарктического полуострова.

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Рисунок 21 Огива селективности ленточного кутка ("60") для ледяной скумбрии.

Рисунок 22 Огива селективности ленточного кутка ("100") для зеленой нототении.

Рисунок 23 Огива селективности ленточного кутка ("100") для ледяной рыбы моря Скотия в районе Южной Георгии.

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SC-CAMLR-VI/BG/31

AREAS OF SEABED WITHIN SELECTED DEPTH RANGES IN THE SOUTH-WEST ATLANTIC AND ANTARCTIC PENINSULA REGIONS OF THE SOUTHERN OCEAN

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Abstract

Data were tabulated for FAO sub-areas : 48.1 (East), 48.1 (West), 48.2, 48.3, 48.4, 48.5 and 88. Total areas and sea areas were given for these categories. Areas estimated from admiralty charts were expressed as percentages for the following depth ranges : 0-50, 50-100, 150-250, 250-500 and >500m; 0-150, 0-250, 0-500, >50, >150, and >500m. Extra detailed information was presented for subdivisions 50, 51, and 52 of sub-area 48.3.

Résumé

Les données ont été présentées sous forme de tableau pour les sous-zones de la FAO : 48.1 (Est), 48.1 (Ouest), 48.2, 48.3, 48.4, 48.5 et 88. Les zones totales et les régions marines ont été données pour ces catégories. Les régions estimées à partir des cartes marines ont été exprimées en pourcentages pour les gammes de profondeur suivantes : 0-50, 50-100, 150-250, 250-500 et >500m; 0-150, 0-250, 0-500, >50, >150, et >500m. D'autres renseignements détaillés ont été présentés pour les subdivisions 50, 51, et 52 de la sous-zone 48.3.

Resumen

Se tabularon datos para las siguientes sub-áreas FAO : 48.1 (Oriental), 48.1 (Occidental), 48.2, 48.3, 48.4, 48.5 y 88. Se dieron áreas totales y áreas de mar para estas categorías. Las áreas estimadas en base a cartas de almirantazgo fueron expresadas como porcentajes para los siguientes rangos de profundidad : 0-50, 50-100, 150-250, 250-500 y >500m; 0-150, 0-250, 0-500, >50, >150, y >500m. Se presentó información detallada adicional para las subdivisiones 50, 51 y 52 de la sub-área 48.3.

Резюме

Сведены в таблицы данные по следующим подрайонам ФАО: 48.1 (восточная часть), 48.1 (западная часть), 48.2, 48.3, 48.4, 48.5 и 88. По каждому из них даны общая площадь и площадь акватории. Площади, определенные по адмиралтейским картам, даны в процентном выражении для следующих диапазонов глубин: 0-50, 50-100, 150-250, 250-500 и >500 м, 0-150, 0-250, 0-500, >50, >150 и >500 м. По подучасткам 50, 51 и 52 подрайона 48.3 дана дополнительная подробная информация.

AREAS OF SEABED WITHIN SELECTED DEPTH RANGES IN THE SOUTH-WEST ATLANTIC AND ANTARCTIC PENINSULA REGIONS OF THE SOUTHERN OCEAN

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INTRODUCTION

During the first meeting of the Fish Biology Working Party of the SCAR/SCOR/IABO/ACMRR Group of Specialists on Living Resources of the Southern Ocean it was recognised that in order to facilitate stock assessment studies it would be advantageous to have information on areas of seabed between selected depth contours. This paper provides this information for the Antarctic Peninsula and the Scotia Arc regions (Figure 1). This paper was originally published as I. Everson (1984)*. This is a revised and corrected version of that paper.

METHODS

Contours at 50, 150, 250 and 500 metres depth were drawn on Admiralty Charts covering the whole area. The FAO sub-areas were then marked in and each sub-area divided into rectangles for the area analyses. Where an area was present on more than one chart the rectangle used was that on the largest scale chart. Areas were estimated using transparent millimetre graph paper and the areas converted to square kilometers by reference to the scale at the relevant latitude. The results are set out in Tables 1 - 15. The co-ordinates are those of the northern, southern, eastern and western limits of each rectangle. All latitudes are in degrees south, all longitudes in degrees west. In several instances these include rectangles from larger scale charts although the areas have been treated separately, (i.e. there is no overlap in the area measured).

* I. Everson, Areas of Seabed within Selected Depth Ranges in the South-West Atlantic and Antarctic Peninsula Regions of the Southern Ocean, British Antarctic Survey, Cambridge, 1984.

Table 1 Summary of areas of seabed between specified depth ranges. Where no number is entered, the area has been incorporated into the next deepest range.

FAO sub-area	Area of sea (km^2) within depth range (m)					Total	Table numbers
	0-50	50-150	150-250	250-500	>500		
48.1 (East)						218 101	2, 9
48.1 (West)						572 070	3, 10
48.2	–	3 404	4 255	17 020	826 318	850 997	4, 11
48.3	1 342	10 733	22 808	12 075	1 296 055	1 341 672	5, 12
48.4	–	–	–	847	846 250	847 097	6, 13
48.5	–	–	–	209 598	1 973 713	2 183 316	7, 14
88 (70°– 92°W)	–	19 275	3 401	40 817	1 070 314	1 133 807	8, 15

Table 2 FAO Subarea 48.1 (East).

Subdivision	Coordinates				% Sea area in depth range (m)					Area (km^2)	
	N	S	E	W	0-50	50-150	150-250	250-500	>500	Sea	Total
1	62°00'	62°20'	59°30'	60°00'	–	2.2	8.7	44.6	44.6	956	957
2	62°00'	62°20'	58°30'	59°30'	–	91.6	2.9	3.7	1.8	1359	1934
3	62°00'	62°20'	57°30'	58°30'	–	27.6	6.4	12	54	1500	1934
4	62°20'	62°40'	57°30'	58°30'	–	0	0	0	100	1898	1898
5	62°20'	62°40'	58°30'	59°30'	–	9.5	2.7	3.2	84.5	1809	1898
6	62°20'	62°40'	59°30'	60°00'	–	63.3	8.7	9.7	18.4	772	949
7	62°40'	63°05'	59°00'	60°00'	–	0.3	0.3	2.6	96.7	2350	2352
8	62°40'	63°05'	58°00'	59°00'	–	4.6	3.4	22.7	69.3	2352	2352
9	62°40'	63°05'	57°30'	58°00'	–	95.3	2	2.7	0	1176	1176
10	60°00'	61°00'	50°00'	60°00'	–	0.6	1.2	2.6	95.6	60850	60850
11	61°00'	63°00'	50°00'	53°00'	0	0	0	0	100	34819	34819
[12	58°00'	60°00'	50°00'	58°00'	0	0	0	0	100	101837	101837]*
13	61°00'	62°00'	57°30'	60°00'	–	6.6	4.3	20.4	68.8	14417	14740
14	61°00'	62°00'	56°00'	57°30'	–	1.5	2.4	28.4	67.4	8843	8843
15	61°00'	62°00'	53°00'	56°00'	–	11.6	2.8	12.1	73.5	17110	17686
16	62°00'	63°00'	56°00'	57°30'	–	14.4	11.1	12.9	61.6	8539	8555
17	62°00'	63°00'	53°00'	56°00'	–	2	18	41.8	38.2	17109	17109
18	63°05'	64°00'	57°30'	60°00'	–	31.7	5.8	16.5	45.9	5136	12587
19	63°00'	64°00'	56°00'	57°30'	–	15.4	3.6	7.2	73.8	6279	8268
20	63°00'	64°00'	50°00'	56°00'	–	4.5	1.8	86.1	7.5	30827	33082
Total for sub-area 48.1 (East)					–	5.6	3.2	11.6	79.6	218101	226989

*Subdivision 12 is outside of Subarea 48.1

Table 3 FAO Subarea 48.1 (West).

	Coordinates				% Sea area in depth range (m)					Area (km^2)	
Subdivision	N	S	E	W	0-50	50-150	150-250	250-500	>500	Sea	Total
21	62°00'	62°20'	60°30'	61°10'	-	2.2	8.7	44.6	44.6	1284	1284
22	62°20'	62°40'	60°30'	61°10'	-	85.7	7.7	6.6	0	964	1266
23	62°40'	63°05'	60°30'	61°10'	-	24.7	27.4	44	3.9	1476	1565
24	62°40'	63°05'	60°00'	60°30'	-	7.3	5.5	9.6	77.6	1036	1174
25	62°20'	62°40'	60°00'	60°30'	-	95.2	2.1	2.8	0	564	947
26	62°00'	62°20'	60°00'	60°30'	-	54.1	17.8	19	9.1	961	961
27	60°00'	64°00'	64°00'	70°00'	0	0	0	3.4	96.6	371299	371299
28	60°00'	61°00'	60°00'	64°00'	0	0	0	0	100	24340	24340
29	64°00'	66°00'	68°00'	70°00'	-	0.4	-	49.2	50.4	20886	20886
30	66°00'	67°00'	68°00'	70°00'	-	3.9	3.1	67.9	25.1	9226	9850
31	67°00'	68°00'	68°00'	70°00'	-	51.8	12.7	25	10.5	6607	9456
32	68°00'	69°00'	68°00'	70°00'	-	19.2	6	61.4	13.5	9049	9054
33	66°00'	67°00'	66°00'	68°00'	-	22.1	23.4	49.7	4.8	8110	9850
34	67°00'	68°00'	66°00'	68°00'	-	36.6	17.2	37.6	8.6	2261	9456
35	68°00'	69°00'	66°00'	68°00'	-	53.4	23	23.6	0	3555	9054
36	61°00'	62°00'	61°10'	64°00'	0	0	0	0	100	16703	16703
37	62°00'	63°00'	61°10'	64°00'	-	15.9	5	6.8	72.3	15952	16159
38	63°00'	64°00'	61°10'	64°00'	-	19.2	12.9	36.2	31.7	14894	15617
39	61°00'	62°00'	60°00'	61°10'	-	0	0	3.2	96.8	6877	6877
40	63°05'	64°00'	60°00'	61°10'	-	22.3	5.2	9.2	63.3	5586	5874
41	65°00'	66°00'	66°00'	68°00'	-	13.9	23	50.9	12.2	10085	10245
42	64°00'	65°00'	66°00'	68°00'	0	0	2.4	67.1	30.5	10637	10637
43	64°00'	65°00'	64°00'	66°00'	-	15.3	7.2	43	34.5	10407	10637
44	65°00'	66°00'	64°00'	66°00'	-	42.2	42.2	11.2	4.4	8685	10245
45	66°00'	67°00'	64°00'	66°00'	-	5.6	5.6	1	0	1196	9850
46	64°00'	65°00'	62°00'	64°00'	-	35.9	35.9	16	12.1	6744	10637
47	64°00'	65°00'	61°00'	62°00'	-	33.7	33.7	18.4	14.2	2686	5319
	Total for sub-area 48.1 West				-	10.4	6.1	18.6	64.9	572070	609242

Table 4 FAO Subarea 48.2.

	Coordinates				% Sea area in depth range (m)					Area (km^2)	
Subdivision	N	S	E	W	0-50	50-150	150-250	250-500	>500	Sea	Total
73	60°21'	60°40'	44°10'	45°00'	–	10.8	7.8	15.9	65.5	1601	1603
74	60°40'	61°00'	44°10'	45°00'	–	27.6	61.4	11	0	1930	2008
75	60°40'	61°00'	45°00'	46°00'	–	19	29	52	0	1927	2008
76	60°40'	61°00'	46°00'	47°00'	–	11.2	70.8	18	0	2008	2008
77	60°00'	64°00'	30°00'	50°00'	0	0	0	4.5	95.5	452647	452647 *
78	57°00'	60°00'	30°00'	50°00'	0	0	0	0	100	387430	387430
79	60°21'	60°40'	46°00'	47°00'	–	65	10.7	5	19.3	1919	1926
80	60°21'	60°40'	45°00'	46°00'	–	29.2	16	18.1	36.6	1535	1926
	Total for sub-area				0	0.4	0.5	2	97.1	850997	851556

* Excludes areas 73-76, 79, 80.

Table 5 FAO Subarea 48.3.

	Coordinates				% Sea area in depth range (m)					Area (km²)	
Subdivision	N	S	E	W	0-50	50-150	150-250	250-500	>500	Sea	Total
48	50°00'	53°00'	30°00'	46°00'	0	0	0	0	100	369297	369297
49	56°00'	57°00'	30°00'	46°00'	0	0	0	0	100	109136	109136
50	53°00'	56°00'	40°00'	46°00'	-	0.9	1.7	0.7	96.7	344470	344486
51	53°00'	56°00'	35°00'	40°00'	-	1.9	5.2	1.9	91	70190	70190 *
52	53°00'	56°00'	30°00'	35°00'	-	0.6	0.9	0.7	97.8	322942	322954
53	50°00'	57°00'	46°00'	50°00'	0	0	0	0	100	92322	92322
54	53°40'	54°00'	38°00'	38°50'	1.4	21	40.6	31.6	5.4	2023	2025
55	53°40'	54°00'	37°00'	38°00'	2.1	55.2	24.8	17.9	0	2414	2430
56	53°40'	54°00'	36°00'	37°00'	0	1.8	30.6	56.6	11	2430	2430
57	53°40'	54°00'	35°10'	36°00'	0	0	3.1	12	84.9	2025	2025
58	54°00'	54°30'	38°00'	38°50'	0.7	4.8	92.8	1.7	0	2994	3007
59	54°00'	54°30'	37°00'	38°00'	9.4	34.1	41	15.5	0	2732	3608
60	54°00'	54°30'	36°00'	37°00'	7.6	40.3	31.6	20.6	0	1487	3608
61	54°00'	54°30'	35°10'	36°00'	0	4.1	53.4	18.5	24	3006	3007
62	54°30'	55°05'	35°10'	36°00'	2.6	47.7	25.7	23.9	0.2	3262	3454
63	54°30'	55°05'	36°00'	37°00'	7	26.9	39.2	20.5	6.3	3347	4144
64	54°30'	55°05'	37°00'	38°00'	0.1	6.4	25.6	36.1	31.8	4141	4144
65	54°30'	55°05'	38°00'	38°50'	0	0	25.6	11.4	63	3454	3454
	Total for sub-area				0.1	0.8	1.7	0.9	96.6	1341672	1345721

* Excludes area included in 54-65.

NOTE:

A more detailed analysis of subdivisions 50, 51, & 52 is given in tables 17 & 18.

Table 6 FAO Subarea 48.4.

	Coordinates				% Sea area in depth range (m)		Area (km^2)	
Subdivision	N	S	E	W	0-500	>500	Sea	Total
66	56°00'	60°00'	24°00'	29°30'	0.9	99.1	143782	144073
67	50°00'	53°00'	26°00'	30°00'	0	100	92322	92322
68	53°00'	56°00'	26°00'	30°00'	0	100	86121	86121
69	60°00'	64°00'	24°00'	30°00'	0	100	139235	139235
70	56°00'	60°00'	29°30'	30°00'	0	100	13097	13097
71	50°00'	56°00'	20°00'	26°00'	0	100	267758	267758
72	56°00'	60°00'	20°00'	24°00'	0	100	104782	104782
	Total for sub-area				0.1	99.9	847097	847388

Table 7 FAO Subarea 48.5.

	Coordinates				% Sea area in depth range (m)		Area (km²)	
Subdivision	N	S	E	W	0-500	>500	Sea	Total
81	65°00'	70°00'	50°00'	66°00'	50	50	313029	378286
82	64°00'	65°00'	50°00'	60°00'	51.6	48.4	49890	53196
83	64°00'	65°00'	30°00'	50°00'	0	100	106396	106396
84	65°00'	70°00'	30°00'	50°00'	0	100	472858	472858
85	64°00'	78°00'	20°00'	30°00'	9.9	90.1	507572	563141
86	70°00'	78°00'	30°00'	62°00'	15.8	84.2	733571	871718
	Total for sub-area				9.6	90.4	2183316	2445595

Table 8 FAO Subarea 88.

	Coordinates				% Sea area in depth range (m)					Area (km^2)	
Subdivision	N	S	E	W	0-50	50-150	150-250	250-500	>500	Sea	Total
87	60°00'	66°00'	70°00'	92°00'	0	0	0	0	100	740541	740541
88	66°00'	70°00'	70°00'	92°00'	-	4.6	0.8	10.1	84.4	393266	407327
	Total for sub-area 88				0	1.7	0.3	3.6	94.4	1133807	1147868

Table 9 FAO Subarea 48.1 (East).

	Coordinates				% Sea area in depth range (m)							Total Sea
Subdivision	N	S	E	W	0-150	0-250	0-500	>50	>150	>250	>500	area (km^2)
1	62°00'	62°20'	59°30'	60°00'	2.2	10.8	55.4	100	97.8	89.2	44.6	956
2	62°00'	62°20'	58°30'	59°30'	91.6	94.5	98.2	100	8.4	5.5	1.8	1359
3	62°00'	62°20'	57°30'	58°30'	27.6	34	46	100	72.4	66	54	1500
4	62°20'	62°40'	57°30'	58°30'	0	0	0	100	100	100	100	1898
5	62°20'	62°40'	58°30'	59°30'	9.5	12.2	15.5	100	90.5	87.8	84.5	1809
6	62°20'	62°40'	59°30'	60°00'	63.3	71.9	81.6	100	36.7	28.1	18.4	772
7	62°40'	63°05'	59°00'	60°00'	0.3	0.7	3.3	100	99.7	99.3	96.7	2350
8	62°40'	63°05'	58°00'	59°00'	4.6	8	30.7	100	95.4	92	69.3	2352
9	62°40'	63°05'	57°30'	58°00'	95.3	97.3	100	100	4.7	2.7	0	1176
10	60°00'	61°00'	50°00'	60°00'	0.6	1.8	4.4	100	99.4	98.2	95.6	60850
11	61°00'	64°00'	50°00'	53°00'	0	0	0	100	100	100	100	34819
[12	58°00'	60°00'	50°00'	58°00'	0	0	0	100	100	100	100	101837]*
13	61°00'	62°00'	57°30'	60°00'	6.6	10.8	31.2	100	93.4	89.2	68.8	14417
14	61°00'	62°00'	56°00'	57°30'	1.5	3.8	32.2	100	98.5	96.2	67.8	8843
15	61°00'	62°00'	53°00'	56°00'	11.6	14.4	26.5	100	88.4	85.6	73.5	17110
16	62°00'	63°00'	56°00'	57°30'	14.4	25.5	38.4	100	85.6	74.5	61.6	8539
17	62°00'	63°00'	53°00'	56°00'	2	20	61.8	100	98	80	78.2	17109
18	63°05'	64°00'	57°30'	60°00'	31.7	37.6	54.1	100	68.3	62.4	45.9	12587
19	63°00'	64°00'	56°00'	57°30'	15.4	19	26.2	100	84.6	81	73.8	6279
20	63°00'	64°00'	53°00'	56°00'	4.6	6.4	92.5	100	95.4	93.6	7.5	30827
	Total for sub-area 48.1 (East)				5.6	8.8	20.4	100	94.6	91.5	80.3	218101

* Subdivision 12 is outside of Subarea 48.1

Table 10 FAO Subarea 48.1 (West).

	Coordinates				% Sea area in depth range (m)							Total Sea
Subdivision	N	S	E	W	0-150	0-250	0-500	>50	>150	>250	>500	area (km^2)
21	62°00'	62°20'	60°30'	61°10'	2.2	10.8	55.4	100	97.8	89.2	44.6	1284
22	62°20'	62°40'	60°30'	61°10'	85.7	93.4	100	100	14.3	6.6	0	964
23	62°40'	63°05'	60°30'	61°10'	24.7	52.1	96.1	100	75.3	47.9	3.9	1476
24	62°40'	63°05'	60°00'	60°30'	7.3	12.9	22.4	100	92.4	87.1	77.6	1036
25	62°20'	62°40'	60°00'	60°30'	95.2	97.2	100	100	4.8	2.8	0	564
26	62°20'	62°20'	60°00'	60°30'	54.1	71.9	90.9	100	45.9	28.1	9.1	961
27	60°00'	64°00'	64°00'	70°00'	0	0	3.4	100	100	100	96.6	371299
28	60°00'	61°00'	60°00'	64°00'	0	0	0	100	100	100	100	24340
29	64°00'	66°00'	68°00'	70°00'	0.4	0.4	49.6	100	96.6	96.6	50.4	20886
30	66°00'	67°00'	80°00'	70°00'	3.9	7	74.9	100	96.1	93	25.1	9226
31	67°00'	68°00'	68°00'	70°00'	51.8	64.5	89.5	100	48.2	35.5	10.5	6607
32	68°00'	69°00'	68°00'	70°00'	19.2	25.2	86.5	100	80.8	74.8	13.5	9049
33	66°00'	67°00'	66°00'	68°00'	22.1	45.5	45.2	100	77.9	54.5	4.8	8110
34	67°00'	68°00'	66°00'	68°00'	36.6	53.8	91.4	100	63.4	46.2	8.6	2261
35	68°00'	69°00'	66°00'	68°00'	53.4	76.4	100	100	46.6	23.6	0	3555
36	61°00'	62°00'	61°10'	64°00'	0	0	0	100	100	100	100	16703
37	62°00'	63°00'	61°10'	64°00'	15.9	20.9	27.7	100	84.1	79.1	72.3	16159
38	63°00'	64°00'	61°10'	64°00'	19.2	32.1	68.3	100	80.8	67.9	31.7	15617
39	61°00'	62°00'	60°00'	61°10'	0	0	3.2	100	100	100	96.8	6877
40	63°05'	64°00'	60°00'	61°10'	22.3	27.5	36.7	100	77.7	72.5	63.3	5586
41	65°00'	66°00'	66°00'	68°00'	13.9	37	87.8	100	86.1	63	12.2	10085
42	64°00'	65°00'	66°00'	68°00'	0	2.4	69.5	100	100	97.6	30.5	10637
43	64°00'	65°00'	64°00'	68°00'	15.3	22.5	65.5	100	84.7	77.5	34.5	10407
44	65°00'	66°00'	64°00'	66°00'	42.2	84.4	95.6	100	57.8	15.6	4.4	8685
45	66°00'	67°00'	64°00'	66°00'	5.6	11.2	12.1	100	94.4	88.8	87.9	1196
46	64°00'	65°00'	62°00'	64°00'	35.9	71.9	87.9	100	64.1	28.1	12.1	6744
47	64°00'	65°00'	61°00'	62°00'	33.7	67.4	85.8	100	66.3	32.6	14.2	5319
	Total for sub-area 48.1 (West)				10.0	15.4	33.8	100	90	84.1	66.2	575633

Table 11 FAO Subarea 48.2.

	Coordinates				% Sea area in depth range (m)							Total Sea
Subdivision	N	S	E	W	0-150	0-250	0-500	>50	>150	>250	>500	area (km^2)
73	60°21'	60°40'	44°10'	45°00'	10.8	18.6	34.5	100	89.2	81.4	65.5	1601
74	60°40'	61°00'	44°10'	45°00'	27.6	89	100	100	72.4	11	0	1930
75	60°40'	61°00'	45°00'	46°00'	19	48	100	100	81	52	0	1927
76	60°40'	61°00'	46°00'	47°00'	11.2	82	100	100	88.8	18	0	2008
77	60°00'	64°00'	30°00'	50°00'	0	0	4.5	100	100	100	95.5	452647*
78	57°00'	60°00'	30°00'	50°00'	0	0	0	100	100	100	100	387430
79	60°21'	60°40'	46°00'	47°00'	65	75.7	80.7	100	35	24.3	19.3	1919
80	60°21'	60°40'	45°00'	46°00'	29.2	45.2	63.4	100	70.8	54.8	36.6	1535
	Total for sub-area 48.2.3				0.4	0.8	2.9	100	99.6	99.2	97.1	850997

Excludes areas 73-76, 79-80

Table 12 FAO Subarea 48.3.

	Coordinates				% Sea area in depth range (m)							Total Sea
Subdivision	N	S	E	W	0-150	0-250	0-500	>50	>150	>250	>500	area (km^2)
48	50°00'	53°00'	30°00'	46°00'	0	0	0	100	100	100	100	369297
49	56°00'	57°00'	30°00'	46°00'	0	0	0	100	100	100	100	109136
50	53°00'	56°00'	40°00'	46°00'	0.9	2.6	3.3	100	99.1	96.4	96.7	344470
51	53°00'	56°00'	35°00'	40°00'	1.9	7.1	9	100	98.1	92.9	91	70190*
52	53°00'	56°00'	30°00'	35°00'	0.6	1.5	2.2	100	99.4	98.5	97.8	322942
53	50°00'	53°00'	46°00'	50°00'	0	0	0	100	100	100	100	92322
54	54°00'	54°00'	38°00'	38°50'	22.4	63	94.6	98.6	77.6	87	5.4	2023
55	53°40'	54°00'	37°00'	38°00'	57.4	82.1	100	100	97.9	42.6	17.9	2414
56	53°40'	54°00'	36°00'	37°00'	1.8	32.4	89	100	98.2	67.6	11	2430
57	53°40'	54°00'	35°10'	36°00'	0	3.1	15.1	100	100	96.9	84.9	2025
58	54°00'	54°30'	38°00'	38°50'	5.5	98.3	100	99.3	94.5	1.7	0	2994
59	54°00'	54°30'	37°00'	38°00'	43.5	84.5	100	90.6	56.6	15.5	0	2732
60	54°00'	54°30'	36°00'	37°00'	47.9	79.4	100	92.4	52.1	20.6	0	1487
61	54°00'	54°30'	35°10'	36°00'	4.2	57.6	76	100	95.8	42.4	24	3006
62	54°30'	55°05'	35°10'	36°00'	50.3	76	99.8	97.4	49.7	24	0.2	3262
63	54°30'	55°05'	36°00'	37°00'	34	73.2	93.7	93	66	26.8	6.3	3347
64	54°30'	55°05'	37°00'	38°00'	6.4	32	68.2	99.9	93.6	68	31.8	4141
65	54°30'	55°05'	38°00'	38°50'	0	25.6	37	100	100	74.4	63	3454
	Total for sub-area 48.2.1				1.0	2.8	3.8	99.9	99.0	97.2	96.2	1341672

* Excludes area included in 54-65

Table 13 FAO Subarea 48.4.

	Coordinates				% Sea area in depth range (m)		Total sea
Subdivision	N	S	E	W	0-500	>500	area (km^2)
66	56°00'	60°00'	24°00'	29°30'	0.9	99.1	143782
67	50°00'	53°00'	26°00'	30°00'	0	100	92322
68	53°00'	56°00'	26°00'	30°00'	0	100	86121
69	60°00'	64°00'	24°00'	30°00'	0	100	139235
70	56°00'	60°00'	29°30'	30°00'	0	100	13097
71	50°00'	56°00'	20°00'	26°00'	0	100	267758
72	56°00'	60°00'	20°00'	24°00'	0	100	104782
	Total for sub-area 48.2.2				0.1	99.9	847097

Table 14   FAO Subarea 48.5.

	Coordinates				% Sea area in depth range (m)							Total Sea
Subdivision	N	S	E	W	0-150	0-250	0-500	>50	>150	>250	>500	area (km^2)
81	65°00'	70°00'	50°00'	66°00'			50		50		50	313029
82	64°00'	65°00'	50°00'	60°00'			48.4				45.4	49890
83	64°00'	65°00'	30°00'	50°00'							100	106396
84	65°00'	70°00'	30°00'	50°00'							100	472858
85	64°00'	78°00'	20°00'	30°00'	0		9.9	100			90.1	507572
86	70°00'	78°00'	30°00'	62°00'			15.8				84.2	733571
	Total for sub-area 48.3						9.6	100			90.4	2183316

Table 15 FAO Subarea 88.

	Coordinates				% Sea area in depth range (m)							Total Sea
Subdivision	N	S	E	W	0-150	0-250	0-500	>50	>150	>250	>500	area (km^2)
87	60°00'	66°00'	70°00'	92°00'	0	0	0	100	100	100	100	740541
88	66°00'	70°00'	70°00'	92°00'	4.6	5.5	15.6	100	95.4	94.5	84.4	393266
	Total for sub-area 88				1.7	2.0	5.6	100	98.3	96.3	94.4	1133807

Table 16 UK Admiralty Charts used to estimate the areas of seabed.

Chart		Subdivision Reference Numbers					
Number	Title	sub-area 48.1	sub-area 48.2	sub-area 48.3	sub-area 48.4	sub-area 48.5	sub-area 88
1775	South Orkney Islands		73-76,79,80				
1776	Livingston Island to King George Island	1-9,21-26					
3175	Approaches to Graham Land	10,11,27-29	77			81-83	85,86
3200	Falkland Islands to Graham Land	12-20	78	53	69-72		
3205	South Shetland Islands and Bransfield Strait	36-40					
3570	Brabant Island to Adelaide Island	41-47					
3571	Lavoisier Island to Alexander Island	30-35					
3593	South Sandwich Islands				66		
3596	Approaches to South Georgia			48-52	67,68		
3597	South Georgia			54-65			
3176	Weddell Sea					84	

Table 17 Detail analysis of Subdivisions 50, 51 and 52 in FAO Subarea 48.3 (Data derived from "Bathymetric Chart of the Approaches to South Georgia" Edition 1. Compiled by R.B. Heywood and L.S. Allen, British Antarctic Survey. BAS (Misc) 4 Edition 1 1984).

	Boundary				% Sea Area in Depth Range					Area (km²)	
	Lat (°S)		Long (°W)								
Subdivision	N	S	E	W	0-50	50-150	150-250	250-500	>500	Sea	Total
* 50	53°00'	56°00'	40°00'	46°00'	0	0	0	0	100	322193	322193
89	53°00	54°00'	40°00'	43°00	0.7	5.6	11.0	7.2	74.1	22286	22293
51	55°40'	56°00'	34°00'	40°00'	0	0	0	0	100	13809	13809
52	53°00'	56°00'	30°00'	34°00'	0	0	0	0	100	85940	85940
90	53°00'	53°40'	38°50'	40°00'	0	0	0	0	100	5780	5780
91	53°00'	53°40'	38°00'	38°50'	0	0	2.4	0.9	96.7	4128	4128
92	53°00'	53°40'	37°00'	38°00'	0	0	2.9	4.8	92.3	4954	4954
93	53°00'	53°40'	36°00'	37°00'	0	0	2.5	3.5	94.0	4954	4954
94	53°00'	53°40'	35°10'	36°00'	0	0	0	0	100	4128	4128
95	53°00'	53°40'	34°10'	35°10'	0	0	0	0	100	5780	5780
96	53°40'	54°30'	38°50'	40°00'	0	0.5	35.3	15.1	49.1	7157	7157
97	54°30'	55°05'	38°50'	40°00'	0	0	0	0.5	99.5	4904	4904
98	53°40'	54°30'	34°00'	35°10'	0	0	0	0	100	7157	7157
99	54°30'	55°05'	34°00'	35°10'	1.4	10.0	11.5	13.5	63.6	4896	4904
100	55°05'	55°40'	38°50'	40°00'	0	0	0	0	100	4814	4814
101	55°05'	55°40'	38°00'	38°50'	0	0	0	0	100	3439	3439
102	55°05'	55°40'	37°00'	38°00'	0	0	0	0	100	4126	4126
103	55°05'	55°40'	36°00'	37°00'	0	0	7.8	3.0	89.2	4126	4126
104	55°05'	55°40'	35°10'	36°00'	0	17.5	40.8	18.3	23.4	3439	3439
105	55°05'	55°40'	34°00'	35°10'	0	5.7	13.0	5.4	75.9	4814	4814

Table 18 Detail analysis of Subdivisions 50, 51 and 52 in FAO Subarea 48.3. (Data derived from "Bathymetric Chart of the Approaches to South Georgia" Edition 1. Compiled by R.B. Heywood and L.S. Allen, British Antarctic Survey. BAS (Misc) 4 Edition 1 1984).

	Boundary				% Sea Area in Depth Range							Area (km²)
	Lat (°S)		Long (°W)									
Subdivision	N	S	E	W	0-150	0-250	0-500	>50	>150	>250	>500	Total Sea
* 50	53°00'	56°00'	40°00'	46°00'	0	0	0	100	100	100	100	322193
89	53°00'	54°00'	40°00'	43°00'	6.3	17.3	24.6	98.0	92.4	81.4	74.1	22286
51	55°40'	56°00'	34°00'	40°00'	0	0	0	100	100	100	100	13809
52	53°00'	56°00'	30°00'	34°00'	0	0	0	100	100	100	100	85940
90	53°00'	53°40'	38°50'	40°00'	0	0	0	100	100	100	100	5780
91	53°00'	53°40'	38°00'	38°50'	0	2.4	3.3	100	100	97.6	96.7	4128
92	53°00'	53°40'	37°00'	38°00'	0	2.9	7.6	100	100	97.1	92.4	4954
93	53°00'	53°40'	36°00'	37°00'	0	2.6	6.0	100	100	97.5	94.0	4954
94	53°00'	53°40'	35°10'	36°00'	0	0	0	100	100	100	100	4128
95	53°00'	54°40'	34°10'	35°10'	0	0	0	100	100	100	100	5780
96	53°40'	54°30'	38°50'	40°00'	0.5	35.7	50.8	100	99.6	64.3	49.2	7157
97	54°30'	55°05'	38°50'	40°00'	0	0	0.5	100	100	100	99.5	4904
98	53°40'	54°30'	34°00'	35°10'	0	0	0	100	100	100	100	7157
99	54°30'	55°05'	34°00'	35°10'	11.4	22.9	36.9	98.6	88.6	77.1	63.6	4896
100	55°05'	55°40'	38°50'	40°00'	0	0	0	100	100	100	100	4814
101	55°05'	55°40'	38°00'	38°50'	0	0	0	100	100	100	100	3439
102	55°05'	55°40'	37°00'	38°00'	0	0	0	100	100	100	100	4126
103	55°05'	55°40'	36°00'	37°00'	0	7.8	10.8	100	100	92.2	89.2	4126
104	55°05'	55°40'	35°10'	36°00'	17.5	58.3	76.6	100	82.5	41.7	23.4	3439
105	55°05'	55°40'	34°00'	35°10'	5.7	18.7	24.1	100	94.3	81.3	75.9	4814

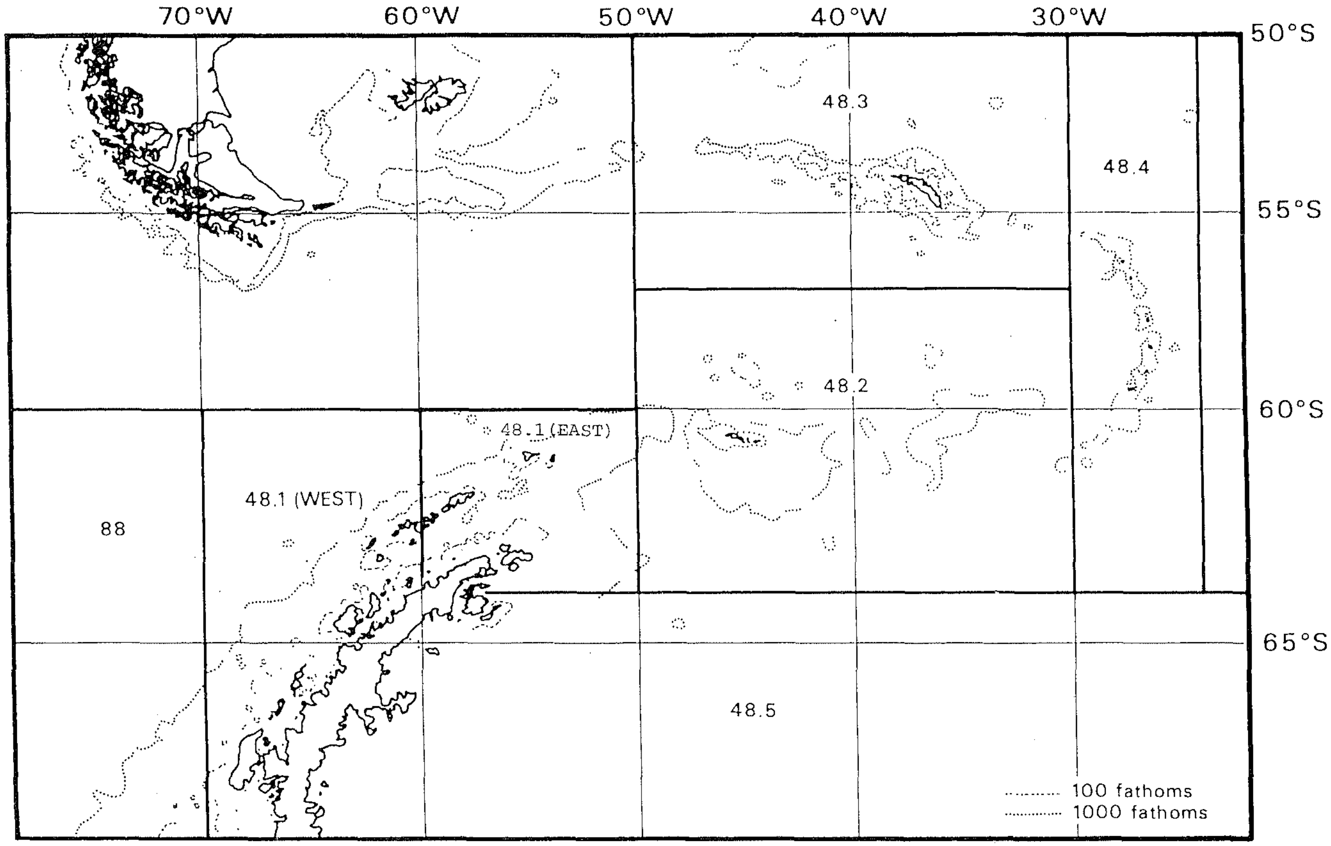

Figure 1 Subareas designated by FAO in the south-west Atlantic Ocean.

Légendes des tableaux

Tableau 1	Récapitulation des zones de fond marin au sein d'échelles de profondeur spécifiées. L'absence de chiffre indique que la zone a été incorporée dans l'échelle de plus grande profondeur voisine.
Tableau 2	Sous-zone FAO 48.1 (Est).
Tableau 3	Sous-zone FAO 48.1 (Ouest).
Tableau 4	Sous-zone FAO 48.2.
Tableau 5	Sous-zone FAO 48.3.
Tableau 6	Sous-zone FAO 48.4.
Tableau 7	Sous-zone FAO 48.5.
Tableau 8	Sous-zone FAO 88.
Tableau 9	Sous-zone FAO 48.1 (Est).
Tableau 10	Sous-zone FAO 48.1 (Ouest).
Tableau 11	Sous-zone FAO 48.2.
Tableau 12	Sous-zone FAO 48.3.
Tableau 13	Sous-zone FAO 48.4.
Tableau 14	Sous-zone FAO 48.5.
Tableau 15	Sous-zone FAO 88.
Tableau 16	Cartes de la marine du Royaume-Uni utilisées pour estimer les zones de fond marin.
Tableau 17	Analyse détaillée des subdivisions 50, 51 et 52 dans la sous-zone FAO 48.3 (Données tirées de "Bathymetric Chart of the Approches to South Georgia" Edition 1. Compilées par R.B. Heywood et L.S. Allen, British Antarctic Survey. BAS (Misc) 4 Edition 1 1984).
Tableau 18	Analyse détaillée des subdivisions 50, 51 et 52 dans la sous-zone FAO 48.3. (Données tirées de "Bathymetric Chart of the Approaches to South Georgia" Edition 1. Compilées par R.B. Heywood et L.S. Allen, British Antarctic Survey. BAS (Misc) 4 Edition 1 1984).

Légende de la figure

Figure 1	Sous-zones désignées par la FAO dans le sud-ouest de l'océan Atlantique.

Encabezamientos de las Tablas

Tabla 1	Resumen de las áreas del lecho marino entre rangos de profundidad especificados. Donde no figura ningún número, el área ha sido incorporada al rango que le sigue en profundidad.
Tabla 2	Subárea FAO 48.1 (Este).
Tabla 3	Subárea FAO 48.1 (Oeste).
Tabla 4	Subárea FAO 48.2.
Tabla 5	Subárea FAO 48.3.
Tabla 6	Subárea FAO 48.4.
Tabla 7	Subárea FAO 48.5.
Tabla 8	Subárea FAO 88.
Tabla 9	Subárea FAO 48.1 (Este).
Tabla 10	Subárea FAO 48.1 (Oeste).
Tabla 11	Subárea FAO 48.2.
Tabla 12	Subárea FAO 48.3.
Tabla 13	Subárea FAO 48.4.
Tabla 14	Subárea FAO 48.5.
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SC-CAMLR-VI/BG/16

BRIEF REPORT OF THE JOINT SOVIET-AUSTRALIAN EXPEDITION OF THE USSR FRV PROFESSOR MESYATSEV TO THE AUSTRALIAN FISHING ZONE AROUND THE TERRITORY OF HEARD AND MCDONALD ISLANDS, MAY-AUGUST, 1987

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Abstract

The results of the first joint Soviet-Australian expedition to the AFZ around Heard and McDonald Islands are briefly reported. Environmental conditions of the shelf area of Heard were favourable for the formation of commercial aggregations of Champsocephalus gunnari during the austral winter. Stability of the aggregation is discussed in relation to the environmental conditions. The unique character of Heard's population of C. gunnari was determined according to a number of biological and morphological parameters. A preliminary stock assessment of the detected aggregation of C. gunnari is given.

Résumé

Le compte rendu des résultats de la première expédition conjointe URSS-Australie dans la zone de pêche australienne aux alentours du territoire des îles Heard et McDonald est brièvement présenté. Les conditions du milieu sur le plateau continental de Heard étaient favorables à la formation de concentrations commerciales de Champsocephalus gunnari durant l'hiver austral. La stabilité de la concentration est examinée par rapport aux conditions du milieu. Le caractère unique de la population de C. gunnari à Heard a été déterminé d'après un certain nombre de paramètres biologiques et morphologiques. Une évaluation préliminaire du stock de la concentration détectée de C. gunnari est donnée.

Resumen

Se informa brevemente sobre los resultados de la primera expedición conjunta soviético-australiana a la Zona Pesquera Australiana alrededor de las islas Heard y MacDonald. Las condiciones del medio ambiente del área de la plataforma de Heard fueron favorables para la formación de concentraciones comerciales de Champsocephalus gunnari durante el invierno austral. Se trata la estabilidad de la concentración en relación a las condiciones del medio ambiente. El carácter único de la población de C. gunnari de Heard fue determinado de acuerdo a un número de parámetros biológicos y morfológicos. Se presenta una evaluación de reserva preliminar de la concentración de C. gunnari que fuera detectada.

Резюме

Кратко излагаются результаты первой совместной советско-австралийской экспедиции в рыболовную зону Австралии вокруг островов Хёрд и Макдональд. Условия среды на шельфе острова Хёрд были благоприятны для образования промысловых скоплений щуковидной белокровки (ледяной Гуннара) зимой Южного полушария. Обсуждается стабильность скопления щуковидной белокровки в связи с условиями среды. Показано своеобразие популяции щуковидной белокровки о.Хёрд по ряду биологических и морфологических параметров. Дана предварительная оценка величины биомассы обнаруженного скопления щуковидной белокровки.

BRIEF REPORT OF THE JOINT SOVIET-AUSTRALIAN EXPEDITION OF THE USSR FRV **PROFESSOR MESYATSEV** TO THE AUSTRALIAN FISHING ZONE AROUND THE TERRITORY OF HEARD AND MCDONALD ISLANDS, MAY-AUGUST, 1987

Annotation

This is a brief report on the outcome of the investigations in the Australian Fishing Zone around Heard and McDonald Islands; its purpose is to present concisely the results and a preliminary analysis of these results in order to facilitate planning and coordination of the research to be conducted during the next phase of the program.

As agreed in the conditions of the joint research, a full report on the research will be forwarded as soon as possible to the Australian contact through diplomatic channels. The Australian observer onboard the Professor Mesyatsev has obtained, as was agreed, copies of all the raw data resulting from the research.

INTRODUCTION

The Australian Commonwealth and the USSR have shown mutual interest in studying the fish stocks of the Australian Fishing Zone around the territory of Heard and McDonald Islands by sending to this area the USSR SRV Professor Mesyatsev during the austral winter of 1987. Research within the Australian waters was carried out during two periods : the first from 10 May until 27 June and the second from 24 July until 2 August. The Soviet Union was represented by 12 scientists, and Australia, by one observer.

The research program to be conducted in Australian waters was designed and proposed by Soviet scientists and totally agreed to by the Australian side provided a number of operational procedures were adhered to.

Soviet scientists believe that before rational management decisions about fish stocks can be made an assessment not only of the abundance of the objects of fishing but also the oceanological conditions which the fish inhabit must be studied in detail. The research program was therefore designed to investigate and assess the fish stocks of the Australian Fishing Zone and to simultaneously conduct a comprehensive study of the oceanological condition of the area. Where accumulations of fish were encountered an intensive study of the oceanological conditions was to be made. The research included hydrographic, geologic, oceanographic, hydrobiological (plankton) and ichthyological investigations. Ichthyological investigations included acoustic and trawling surveys, followed by a detailed biological analysis of the catches.

General Outline of Research Conducted during the Expedition:

1. Acoustic survey of the sea-bed and an investigation of the acoustic dispersing layers in the water column.

2. Complex oceanological studies were conducted at 83 stations. At these stations, samples were taken from the water column to determine salinity, dissolved oxygen, phosphates and silicic acid. Water temperature was also measured. Additional water samples were taken so that phytoplankton and suspended sediments could be studied. At a further 37 stations hydrological studies were carried out.

   The methods used in the above determination were described in detail in the research proposal submitted to the Australian side by the USSR, and will only be briefly mentioned in this report.

   Water samples were taken using Nansen water bottles (BM-48), salinity was determined using a Yeokal salinometer 601 Mark III. Phosphates and silicic acid were determined using a photoelectric calorimeter with microprocessor KPhK-2MP.

Zooplankton samples were taken from various strata in the water column using closing conically reverse JOM and Juday nets. Macroplankton was collected from selected horizons in the water column using a towed BMS-3 net (closing model). Ichthyoplankton collections were made with a drifting PNS-1 net.

3. The bottom was sampled at some shallower stations using a grab (Ocean 50) and a core sampling tube.

4. Midwater and Bottom trawls were carried out to study the fish of the shelf and sea mount areas.

   Trawls used were : Bottom Trawl 39.6/41.7 and midwater trawl 70/370. (Detailed plans of the nets and cod ends used were made available to and copied by the Australian observer).

   A detailed analysis of a sample from each catch was carried out. Analysis included:

   a) measurement of standard length/total length
   b) determination of weight
   c) collection of otoliths and scales for age determination
   d) determination of sex and sexual maturity
   e) description of stomach contents and degree of fullness of stomach
   f) state of digestion of food items
   g) state of fatness.

   A total of 805 fish representing seven species were tagged and released.

5. Observations of the distribution and abundance of sea birds and marine mammals were conducted.

RESULTS

The main results of the expedition are briefly reported below, taking into account the suggestions made by the Australian observer (Mr P. Ensor) that in this brief report, emphasis should be placed on the outcome of the ichthyological studies.

NOTE : the method of calculating the estimate of fish stocks is given in detail. Charts and figures are not attached to this report but were copied by the Australian observer and will be available to the Australian side. A detailed chart resulting from the hydrographic surveys will be forwarded as part of the full report on the cruise.

I. Hydrographic and Geological Investigations

The upper surface of the Kerguelen Ridge to the north of Heard Island, within the AFZ, presents itself as a plateau incorporating the shelf of Heard Island and a number of submarine mountains in the form of truncated cones or greatly dissected sea mountains evidently of volcanic origin.

The above mentioned sea mountains are situated to the north and west of Heard Island and are orientated for the most part E-W and N-S. The sea mountains (Banks) have the following names:

1. Youznays (Southern)
2. Shrednaya (Middle)
3. Zapadnaya (Western)
4. Shootchaya (Pike)
5. Vostochnaya (Eastern)
   and further to the east
6. Novaya (New)

According to our hydrographic survey Bank 3 is almost entirely in the French Fishing Zone, with the exception of the Southern slope and it is located further to the west than the previously charted position.

Bank 4 also appeared to be shifted to the NW and the border between the AFZ and the French FZ divides it in half. The other Banks are situated within the AFZ and their precise positions were charted during the cruise.

The fishing ground to the east of Heard Island is an extrusion of the morphologic, tectonic block forming the shelf of Heard Island. The west side of the fishing ground is bordered by a submarine valley and the slope into the valley is steep and dissected. On the eastern side of the border of the fishing ground is a broad basis with gentle slopes.

The relief of the tops of the Banks 1-5 and that of the fishing ground are considered suitable for bottom trawling. The relief of Bank 6 is not very suitable for bottom trawling and the echo sounder must be constantly monitored during trawls.

II. Oceanographic Investigations

Results obtained during the course of these investigations must be analysed more thoroughly because some conclusions are ambiguous, but it is possible to make some preliminary conclusions.

1. The thermohaline and hydrochemical structure of the waters of the investigated area are determined to a considerable degree by the location of the Antarctic convergence and the main stream of the circumpolar Antarctic current.

2. According to the complex survey data during May and June the investigated area was in the zone of mixing of Antarctic and sub-Antarctic waters. According to the survey, the northern and north-eastern streams, when approaching Heard Island and its shallow plateau-life shelf, divided into two streams which rounded the shelf on the eastern and western sides. The eastern stream was more intensive. The main frontal area of the Antarctic convergence was most likely in the southern part of the French Fishing Zone.

The vergencies of the streams and their meanderings which were influenced by the bottom relief produced in the investigated area a number of whirls of different scales, cyclonic and anticyclonic in nature, the most part of which have a complex thermohaline structure.

3. In May-June, the area was characterised by summer modification of the Antarctic water structure. Everywhere around the plateau, a cold, sub-surface layer was detected and correspondingly the season thermocline was detected.

   Over the plateau the cold sub-surface layer was absent. It was modified by the presence of the formation of warm whirls over the plateau. In surface layers the whirl was characterised by increased salinity and increased concentration of biogenic salts, but in deep layers (more than 150m) the salinity and concentration of biogenic salts decreased. This whirl was most probably formed by Antarctic and sub-Antarctic surface waters and deep water Antarctic water in the ratio of approximately 2:2:1.

4. During the second cruise the structure of the waters of the area was of a winter character. Cold sub-surface layers and the seasonal thermocline correspondingly were absent as a result of intensive cooling of the surface waters during autumn-winter convection.

   The surface water temperature decreased from 2.3-2.6°C (during the first cruise) to 1.3-1.8°C (during the second cruise).

5. According to the mesoscale and microscale oceanographic investigations in the area of aggregation of Champsocephalus gunnari a cyclonic whirl was detected. The whirl was 25-30 miles in diameter and incorporated 2-3 smaller (7-10 miles diameter) ellipsoidal cyclonic whirls separated by

anticyclonic streams of the current. Their formation is related to meandering of the stream of the current passing in the south-eastern part of the area. The location of the aggregation of C. gunnari was related to the position of the south most of this cyclonic whirl during the first and second cruises. The water of the whirl was warmer and more saline and contained a higher concentration of biogenic salts. The whirl was most distinct in the layer deeper than 120m.

Low catches at the end of July are related to the destruction or movement of this whirl from the area when the velocity of the winds sharply increased.

6. It is considered worthwhile to recommend the discovered area of aggregations of C. gunnari for commercial exploration bearing in mind the abiotic conditions favourable for the formation of fish aggregations were quasi-stationary (they remain stable at the same position or location).

III. Hydrobiological Investigations (Plankton)

According to the results of the complex survey conducted from May to June there was an uneven distribution of meso and macroplankton over the surveyed area. The biomass of the mesoplankton was within the range 8–176 mg/m^3 (mean 63.7 mg/m^3) and macroplankton ranged from 1–166 mg per 10 minutes of trawling with the BMS-3 net (mean 33.7g/10 min of trawl). The least productive areas were to the north east from Heard Island and over Bank Youznaya (southern), (Biomass of mesoplankton was less than 50 mg/m^3, macroplankton less than 20g/10 min of trawling). The most productive areas were the area of aggregation of C. gunnari; Banks Shrednaya (middle), Vostochnaya (eastern) and Schootchya (Pike) (Mesoplankton was greater than 100 mg/m^3 and macroplankton 50-100g/10 min of trawling).

In May–June the catches of mesoplankton in the conically reverse nets consisted mainly of Copepoda and Ostracoda.

In samples of macroplankton Euphausia vallentini was dominant and only occasionally were found E. triacantha and Parathemista gaudichaudi.

In July, sub-adult Euphausids predominated in the macroplankton forming the acoustic dispersing layer. E. vallentini and P. gaudichaudi were caught only occasionally. E. triacantha was absent from the catches.

In July the vertical development of the sound dispersing layer was considerably less than in May and June.

IV. Ichthyological Studies and Estimation of Stocks of Fish

In this part of the program 62 successful trawls were made (16 midwater and 46 bottom trawls). Location of the trawls is shown on the chart. Eleven bottom trawls were made on the Bank Novaya (New Bank), one bottom trawl was made on the Bank Vostochnaya (East Bank), and 26 bottom trawls were made in an area on the Heard Island shelf where an accumulation of Champsocephalus gunnari (Lomberg : Channichthyidae) was located; three bottom trawls were made on the slopes at the shelf edge surrounding the area of aggregation. A number of trawls were made in the area between Heard Island and the area of accumulation of C. gunnari.

I. Bank Novaya :

Accumulations of fish were not detected on the Bank Novaya during research in this area on 26-27 July. Acoustic surveys revealed no trace of fish and catches in the 11 trawls were low. Catches ranged from several kg to 300 kg. At depths from 250 to 480m Notothenia squamifrons (Gunther, Notothenidae) prevailed. Only one catch from the north-western part of the bank consisted entirely of C. gunnari.

Analysis of hydrological data showed the absence of conditions necessary for the accumulation of fish.

The fish resources of Bank Novaya should not, however, be regarded as not promising since accumulations of C. gunnari and N. squamifrons were found here in autumn and spring 1975 and in spring 1976 by Soviet fishing operations. Further studies should be conducted in this area in the future.

The most common species in the catches were Dissostichus eleginoides (Smitt) (90.9% of catches), Notothenia squamifrons (90.9%) and Channichthys rhinoceratus (81.8%) and C. gunnari (81.8%).

By weight of fish in the catches, N. squamifrons dominated (63.3%) followed by C. gunnari (23.9%).

A. Notothenia squamifrons :

Notothenia squamifrons was caught over the whole range of trawled depths. Specimens varied in length from 5 to 50cm (mean TL = 24.4cm) and in weight from 4.7 to 1224g (mean weight = 237.6g). Some increase in size with depth was detected. Immature, never spawned fish prevailed (females 80%, males 90%).

GSI females = $\frac{0.3\text{–}1.0}{0.5}$ %, GSI males = $\frac{0.2\text{–}0.5}{0.4}$ %

(GSI = Gonadosomatic Index)

A very small proportion of fish had gonads with signs of long past spawning (not less than half a year ago) (females 1.3%, males 7.8%).

GSI females = $\frac{3.1\text{–}10.2}{7.3}$ %, GSI males = $\underline{1.3}$ %

Out of the analysed fish 82% had food present in their stomachs. The average degree of stomach fullness (on a subjective scale from 0-4) was 1.6 and the mean weight ratio was $101.5^{\circ}/_{\circ\circ\circ}$.

The most frequent prey items recorded in the stomach contents were : Hyperiidae : Parathemists gaudichaudi (in 25.7% of stomachs with food) and Euphausiidae : E. vallentini and E. triacantha (in 26.2% of stomachs with food).

By weight, Ctenophora and P. gaudichaudi represented 55.3% and 22.2% of the food, respectively.

In other areas of the Southern Ocean (Indian Sector) N. squamifrons has also a characteristically high diversity in its diet (Chechoon, 1984). We have recorded not less than 17 groups and species of organisms in the stomachs of N. squamifrons. The most common food items were macroplankton organisms (in 78.4% of stomachs with food). Benthic organisms were recorded in 10% of stomachs with contents. Fish, (Krefftichthys anderssoni and fry of C. gunnari) were present in 4.4% of stomachs containing food.

B. Chamsocephalus gunnari

The length frequency of Champsocephalus gunnari was represented by fish from 9 to 41cm (TL). Within this range, three distinct size groups of fish were recognised :

1. TL length $\frac{9-13}{11.2}$ cm mean weight 5.4g

2. TL length $\frac{21-27}{22.8}$ cm mean weight 63.9g

3. TL length $\frac{33-41}{36.4}$ cm mean weight 235.1g

Large fish dominated the catches (more than 95% by weight).

Sex of individuals of the smallest size group could not be visually determined. Gonads of fish of the second group were of the stage II classification, characterised by protoplasmic growth. Gonads of the third group were in the resting stage, a considerable time after spawning (spawning had apparently occurred not less than two months previously). The maturity of these fish was assigned to stage VI-III for females and stage VI-II for males. GSI for these after spawning stages of development is 1.4% for females and 0.3% for males.

Of the analysed fish, 80% had food present in their stomach. The mean degree of stomach fullness was 1.9, (80.3°/ooo by weight ratio). [Ratio of sum of all stomach contents to sum of weight of all analysed fish, including ones with empty stomachs (total weight with intestines)].

The diet of C. gunnari was less diverse than that of N. squamifrons. Only five groups of food items were found : E. triacantha, E. vallentini, P. gaudichaudi and fry of C. gunnari and K. anderssoni. The dominant food items were E. vallentini, E. triacantha and P. gaudichaudi represented in respectively 47.8%, 41.3% and 4.3% of stomachs with food. These prey species represented, respectively. 40.1%, 36.6% and 14.2% of the weight of food.

Fry of C. gunnari were recorded in 4.3% of all stomachs with food and they represented 8.7% of the total weight of food.

C. Other species

Species other than N. squamifrons and C. gunnari were only occasionally recorded in the catches from Bank Novaya. The small number individuals of other species available for analysis was insufficient for a detailed discussion of their biology to be made.

Assessment of the stocks of fish in the area were not made because fish aggregation on the Bank Novaya were not detected and only trawling surveys were made.

II. Bank Vostochnaya :

On the Bank Vostochnaya no aggregations of fish were detected. The catch from the one bottom trawl in the area (238-250m depth) amounted to only 36.6kg. Traces of sound dispersing layers were identified as aggregation of planktonic organisms (P. gaudichaudi and E. vallentini). The results of previous cruises, by soviet vessels into this area (before the establishment of the AFZ), show the possibility of conditions favourable for fish aggregations to occur.

III. Heard Island Shelf :

Major trawls were made in May-June and July-August in the eastern shelf of Heard Island. Depth of trawls varied from 144m to 500m. C. gunnari dominated in the bottom and midwater catches. In catches in May-June, three size groups of C. gunnari may be discerned.

1. TL $\frac{5\text{-}10}{6.8}$ cm mean weight 1.14g

2. TL $\frac{15\text{-}24}{18.9}$ cm mean weight 28.3g

3. TL $\frac{28\text{-}42}{34.9}$ cm mean weight 233.2g

The first group is made up of fish of the present year (age group 0+). This group was detected in the water adjacent to the territorial waters east of Heard Island. Fish of the second group were distributed over a vast area to the east and north-east from Heard Island.

The eastern boundary of pelagic aggregations consisting mainly of fish of this size group coincides approximately with the 74°30′ meridian. During the whole period of the investigations, dense vertically stretched aggregations of food organisms and of fish of this size were detected by echosounder EK-120S and CVS-881B.

In bottom trawls, on the shelf east of Heard Island during May-June when this aggregation of fish was first detected, fish of the third size group were present (depths from 218-265m). The aggregation was within the area bounded by 52°27′S, 74°48′E; 52°22′S, 75°09′E; 52°39′S, 75°38′E; 52°38′S, 75°12′E. In midwater trawls fish of the second and third size groups were present. It was also noted that the number of fry in the catches decreased with depth while the number of mature fish increased.

In July-August only bottom trawls were performed in this area where aggregations were discovered during the present cruise. It appeared that in the larger part of this area (to the west for the line running North-South between approximately 75°02′ to 75°12′) only large fish were present in the catches

(TL = $\frac{26-40}{34.8}$ cm; mean weight = 246g)

To the east of the above mentioned line, as well as fish of the large size group, smaller fish

(TL = $\frac{17-24}{19.9}$ cm; mean weight = 35.1g)

amounted to 5-36% of the catch by weight. Thus the available data allow us to make the general conclusion that the adult, mature part of the population occupies areas other than those occupied by immature fish. Substantial numbers of immature fish inhabit the western waters of the Heard Island Shelf on the eastern side of the island and adjacent to the boundary of the territorial waters of Heard Island. Immature fish also inhabit the waters to the east of the aggregation of mature fish and are also present in pelagic waters within the aggregation.

Sex of the smallest size group of fish caught on the shelf could not be visually determined. Gonads of the second size group were at stage II (stage of protoplasmic growth) during the whole period of the investigation. For fish of the third size group, significant changes were detected while comparing the stage of maturity of the gonads during the following three periods (25 May-9 June, 13 June-26 June, 26 July-1 August). For the purposes of this discussion, research during May-June was divided into two periods, since between 9 June and 13 June no trawls were made. Eight percent of females caught between 25 May and 9 June had gonads with signs of the previous spawning (not less than six months previously). Eighty-six percent of females were characterised by a low intensity trophoplasmatic growth of ova. The mean GSI of females during this period was

$$\frac{0.5\text{–}10.9\%}{1.8}$$

During the period between 25 May and 9 June, active spermatogenesis, as determined visually, had begun in only 42.9% of males. The mean GSI of males was

$$\frac{0.3\text{–}1.3\%}{0.8}$$

During the second period, 13 June-26 June, the processes of ripening of ova and sperm accelerated considerably. Mean GSI increased markedly and were

$$\frac{1.6\text{–}13.3\%}{3.4} \text{ for females and } \frac{0.3\text{–}3.75\%}{1.7} \text{ for males}$$

The differences in the degree of ripeness of sexual products are especially conspicuous when comparing the first and second periods with the third period. By 26 July-1 August, evidently, all fish capable of participating in the next spawning (possibly during the austral spring) are characterised by active processes of trophoplasmatic growth. Perhaps, it is possible to say that only 3.9% of females and 8.3% of males of the total population will not participate in the next spawning, i.e. : they are immature. All other fish were characterised by active processes of ova - and spermatogenesis. During this period the mean GSI for mature females varied from 7.2% to 31.1%. GSI for all females was

$$\frac{0.4\text{–}31.1\%}{7.50}$$

The mean GSI for mature males varied from 2.9% to 3.2%. GSI for all males was

$$\frac{0.1\text{–}5.2\%}{2.9}$$

According to these data the gonads of males and females have increased considerably in weight in comparison with the first and second periods.

Marked differences in the degree of fullness of stomachs of fish, and in the range of food items present, were also evident between the three periods.

During the first period (25 May-9 June) only bottom trawls were carried out. All fish in the catches were of the third size group. The degree of stomach fullness was very low (mean stomach fullness 0.5 or 11.1°/ooo). Only 36% of all analysed fish had food in their stomachs. The most frequent prey item was E. vallentini (present in 90.5% of stomachs containing food). P. gaudichaudi, fish fry and calanoida were present, in respectively, 6.3%, 7.9% and 1.6% of stomachs with food. By weight of stomach contents E. vallentini comprised 58.7%, P. gaudichaudi 29.3% and fish fry 11.8%.

During the second period (13 June-26 June), trawls were performed with the midwater trawl. Fish of the third size group were caught near the bottom. Out of all analysed fish, 55.3% had food in their stomachs. The degree of stomach fullness was higher (1.1 or 30.2°/ooo). The frequency of occurrence of E. vallentini was lower (76.4% of stomachs with food), but that of P. gaudichaudi and calanoida had increased (22.5% and 12.4% respectively). During this time the proportion of P. gaudichaudi in the stomach contents increased and represented 52.0% by weight and that of E. vallentini had decreased to 45.7%.

During the third period the degree of stomach fullness increased to 71.1% (mean 1.42) and 80.9 of analysed fish had food in their stomachs.

The range of food items was more similar to that found in the first period. The third period was charactrised by the appearance of E. triacantha as a prey item. E. vallentini was found in 94.2% of stomachs with food, E. triacantha (14.0%) calanoida (11.1%), P. gaudichaudi (5.5%), Myctophidae (K. anderssonii) (6.1%). By weight of food E. vallentini, E. triacantha, P. gaudichaudi, K. anderssonii and calanoida represented respectively 77.7%, 5.6%, 5.1%, 10.7% and 0.7%. The percentage by weight of P. gaudichaudi had decreased by an order of magnitude.

An extremely interesting observation was that during May-June a diurnal migration of C. gunnari was observed. During night time this species migrated into the water column. At the end of June bottom aggregations were practically not seen. The composition of food in stomachs was similar to the composition of macroplankton sampled by the BMS-3 net.

In July-August, furcilia of Euphausids, which predominated in the acoustic dispersing layers, from the surface to 130m, were not present in the fish stomachs. The concentration of aggregations of fish decreased slightly but the aggregation remained near the bottom. It follows that during this period, the Euphausids E. vallentini and E. triacantha were present not far above the bottom. The behaviour of C. gunnari was primarily controlled by the distribution of food organisms.

The distribution of food organisms was, in turn, determined by considerable alterations in the structure of the water masses resulting from the range of summer structure to winter (the seasonal pycnocline practically disappeared).

The feeding of fish of the first and second size groups was considered peculiar. Fish of the first size groups were caught only in June, in midwater trawls and the degree of fullness of their stomachs was extraordinarily high 925.5°/ooo. Stomach contents were composed entirely of sub-adult euphausids (furcilia). During the second period fish of the second size group were caught with the midwater trawl but during the third period with the bottom trawl.

During the second period the degree of fullness of their stomachs was, on the contrary, very low. Mean degree of stomach fullness was 0.6 (12.5°/ooo). Among the food items were found P. gaudichaudi (in 77.5% of stomachs with food and representing 81.8% of food by weight). E. vallentini and Calanoida were present in respectively 70.5% and 5% of stomachs with food and represented 15.9% and 2.3% of the weight of food.

Late in July and at the beginning of August the composition of food of fish of the third size group changed even more markedly than that of fish of the second size group. P. gaudichaudi was not found among the food items which consisted of E. vallentini , E, triacantha and Calanoida and which were found in 85.3%, 23.5% and 32.4% of stomachs with food respectively and by weight of food these species represented respectively 82.5%, 7.0% and 10.5%.

Biological data, in particular the time of possible spawning, the size of fish at sexual maturity (females minimum length 29-30cm TL and males 27-28cm TL) and also results of the morphometric analysis demonstrate that the population of C. gunnari from the Heard Island Shelf is possibly discrete from the population of the same species of the shelf of the Kerguelen archipelago.

Thus, it is possible to determine the assessment of stocks and the sustainable yield for each of these areas separately.

It should be pointed out that, in general, the population dynamics of C. gunnari of the Heard Island Shelf area must be different from that of C. gunnari from the shelf of the Kerguelen archipelago. Prior to exploitations of the fish stocks of the Kerguelen Shelf, Notothenia rossii played the major role in regulating the population level of C. gunnari (Chechoon 1984, Kokos, pers comm). The results of the present and previous expeditions show that the population of N. rossii, on the Heard Island Shelf, is not large.

Large aggregations of D. eleginoides, the second largest carnivore of the sub-antarctic shelf waters, have not yet been detected in the Heard Island Shelf area. The population level of C. gunnari may be possibly influenced by predation by fur seals which were observed on the area of accumulation of C. gunnari and on Bank Novaya. But, all the same, it is clear that the principles regulating the Heard Island Shelf population of C. gunnari are unique and different from those regulating the Kerguelen Shelf population. A more precise answer will be obtained when some results of the tagging of 614 specimens of C. gunnari are obtained.

Evaluation of stocks :

Aggregation of C. gunnari were detected on the shelf area of Heard Island using a Simrad EK120S echosounder (working frequency 120 kHz and impulse duration 1 ms). Aggregations were also detected with a Koden 881B Fish-finder with a colour video display (working frequency 200 kHz). The attempt to use the Simrad integrater was not successful because of unfavourble conditions and the resulting weak signal strength of echo was lower than the threshold of the echo integrator QM-MkII. In the future an attempt will be made to evaluate the biomass with the help of the Soviet integrator SIORS with higher technical capabilities. The swept area method was therefore applied to determine the stock of C. gunnari in the area of the aggregation on the Heard Island Shelf. Traces recorded by the echosounder EK12) were also considered when determining the boundary of the aggregation.

Not many trawls were made on the area of aggregation during May and June (seven bottom trawls and eight midwater trawls) because hydrographic and oceanological investigations were conducted during the same period and because of worsening weather conditions after 10 June.

In general, traces of C. gunnari were recorded over the territory of about $123nm^2$. The central part of the aggregation, with catches up to 24+ per trawl, occupied an area of about $40nm^2$. The stock of the core of the aggregation was evaluated to be 25.7 $\pm$ 17.6 thousand tonnes and in the area, in general, 47.8 ± 46.0 thousand tonnes. Such a large error in stock assessment (46.0 thousand tonnes) was a result of few trawls.

From 26 July to 1 August 19 bottom trawls were made and this enabled the boundaries of the aggregation to be more accurately defined and to speak with more assurance about the assessment of fish stocks and the level of sustainable yield.

The swept area method for assessing stocks assumes that the fish are distributed evenly over the area of trawling. The amount of fish in the aggregation (irrespective of the catchability of the trawl) may be represented by

$$Q = \frac{F}{f} (\overline{x} \pm \varepsilon)$$

where F = the determined area of the aggregation
f = the swept area of one trawl
x = average catch per trawl
ε = error in determination (Udovich 1974)

It is assumed that trawls have equal duration and that the density of aggregation (CPE) is constant during the time of the survey, if, within the determined area, there is a high variance in catches. Stocks should be separately calculated for areas with different catches, and then the results summed.

During the survey it was not always possible to follow all of the above mentioned conditions. Because trawls were not always of exactly the same duration, the catches were recalculated into catch per hour of trawl. Due to the considerable differences in the weight of catches the whole survey area (130.55 nm^2) was divided into areas where catches were high (50.64 nm^2) and areas where catches were low [(≤ 1 tonne), 79.99 nm^2].

The swept area for one hour of trawling is equal to S = a.
where a = horizontal opening of the net (bottom trawl a = 29.5 m)
= distance swept in one hour of trawl.

For areas with density aggregations - 6.90km and in areas of lower density = 6.74km and the swept areas were $0.21km^2$ and $0.20km^2$ respectively.

Average catch per trawling ($x \pm \sigma$) in the area of dense aggregation was 8.01 ± 6.11 tonnes and in the area of lower density was 0.603 ± 0.688 tonnes.

The error in determination $\varepsilon = t\beta \frac{\sigma}{\sqrt{n}}$

where $t\beta$ = students coefficient

For the area with dense aggregations

$$\varepsilon = 1.812 \frac{6.11}{\sqrt{11}} = \pm 3.34 \ (P \geq 0.90)$$

For the area with lower density

$$\varepsilon = 1.812 \frac{0.688}{\sqrt{8}} = \pm 0.452 \ (P \geq 0.90)$$

therefore : the values of mean catch for the areas are :

high density area x = (8.01 ± 3.34) tonnes
lower density area x = (0.603 ± 0.452 tonnes

the area of the dense aggregation occupied an area of $173.7km^2$

the value of the ratio of $\frac{F}{f} = 827.143$

the area of the low density region was $274.1km^2$

$$\frac{F}{f} = 1370.5$$

Q high density area = (6625 ± 2763) tonnes
Q low density area = (826.4 ± 619.5) tonnes.

But as mentioned above, the catchability of the trawl was not considered.

For the trawl of the given type and the given fishing object (C. gunnari) the practically determined catchability was previously determined as approximately 0.3. This value was obtained through studying the dynamics of catch in relation to the speed of trawling, which allows determination of the rate of evasion of fish from the trawl.

Therefore :

Q high density area = (22085 ± 9209) tonnes

Q low density area = (2755 ± 2065 tonnes)

and the total stock of fish for the area equals 24840 ± 11274 tonnes.

Since the parameters of the equation of growth of the Heard Shelf population of C. gunnari are unknown as yet, and it is impossible to build a model of rational exploitation we have to use the value of the sustainable yield calculated in Azcherniro according to the Baranoff, Beverton and Holt model for the Kerguelen Archipelago Shelf population of C. gunnari which equals 30% from the commercial stock.

Considering that in the Heard Island Shelf population of C. gunnari the entire aggregation was composed of mature fish, the total population may be regarded as commercial stock. Taking into account the above statements, the sustainable yield of the investigated aggregation is (7452 ± 3382) tonnes (or approximately 7.5 ± 3.4 thousand tonnes). Bearing in mind that the dynamics of abundance of the Heard population of C. gunnari are not studied, we consider it possible to yield annually 6000 tonnes at the beginning of commercial exploration.

Because of the short research period and the resultant low number of trawls, catches from night trawls were also included in the calculations (although daytime catches exceeded night catches by two to three times), and we think the stocks of fish are considerably under estimated.

It should also be considered that while the vessel was moving out of the AFZ a prolonged bottom trace was recorded on the Simrad EK120S to the North-West of the aggregation of C. gunnari which was investigated. This additional trace had the characteristics of mature C. gunnari.

Thus it is recommended in the first stage of commercial fishing in the AFZ around Heard Island to yield annually 6000 tonnes of C. gunnari without damage to the population. In the future, as our knowledge of the fishing resource grows, this value will most probably increase.

V. Seabirds and Marine Mammals

Visual observations of seabirds and marine mammals were conducted from the Professor Mesyatsev in the Australian Fishing Zone.

Systematic 10 minute counts of seabirds were conducted in accordance with the methods recommended by the Scientific Committee on Antarctic Research.

Between 10 May and 27 June, 164 counts were conducted and 24 species were recorded; during the shorter second period of research (24 July-2 August) 13 species were recorded during 23 counts.

A high abundance of seabirds was observed over the Shelf waters of Heard Island on several occasions during the first period of research. The area of high abundance of seabirds which covered more than 20 square n miles was dominated by the following species : Daption capense, Fulmarus glacialoides, Pachyptila sp and Halobaena caerulea. Large numbers of the birds in this area were in small flocks on the water surface and they were observed actively feeding.

The area of high abundance of birds coincided, each time that it was observed, with the area of highest catches of C. gunnari. In this area, and especially where the birds were feeding, there were well defined sound dispersing layers, characteristic of planktonic organisms, in the upper and middle strata of the water column.

Fur seals are rarely seen at sea away from their breeding areas and so it was very interesting to record 215 fur seals during the time in the Australian waters.

During the May and June period of research 158 seals were seen. The sightings were most frequent within the localised area of the Heard Island Shelf where catches of C. gunnari were highest and where large feeding aggregations of seabirds were observed.

Observations included three sightings of about 30 seals, near the same location, on separate days over a one week period (possibly resightings of the same group). On three occasions in this area individual fur seals were observed. These seals were at the surface of the water holding relatively large fish in their mouths.

A total of 57 seals were seen during the second period of research (24 July–2 August). Almost all of these were again recorded over the shelf area of Heard Island where they were frequently observed during May and June, but several were recorded on Bank Novaya.

CONCLUSION

As a result of the complex investigation during the cruise of the USSR SRV Professor Mesyatsev, it was found that during the Austral winter, an aggregation of C. gunnari is present on the shelf of Heard Island.

These data differ with the previously described distribution of fish resources in the Australian Fishing Zone. During the winter season the aggregation of C. gunnari occupied a stable position during a prolonged period of investigation of the area under study.

On the basis of a number of morphological and biological data a conclusion was made on the unique character of the population of C. gunnari of the shelf of Heard Island. It was also concluded that this population was distinct from the population occupying the shelf area of the Kerguelen Archipelago. It was found that the hydrological conditions, favourable for the formation of food plankton and fish aggregation, are quasi-stationary.

The general picture of the circulation of water masses and peculiarities in the distribution of planktonic organisms in the investigated area were determined precisely enough.

It was shown that fish aggregations may form on some sub-marine mountains in the Kerguelen ridge under certain conditions.

Seabirds and fur seals were detected in the areas of the increased concentration of plankton and fish.

The location of the submarine mountains and the character of the relief of the submarine Kerguelen Ridge, within the AFZ were more precisely determined.

All the above mentioned results give basis to speak about relatively high biological productivity (including fish productivity) of the investigated area and allow us to regard this area as having potential for commercial fishing.

Table 1. Species composition by frequency and by weight + 0.01% by weight

	Shelf of Heard Island Ulenscp O. Xepg				New Bank Bareka Hobar	
	Bottom trawls		Midwater trawls		Bottom trawls	
	% freq occ	% by weight	% freq occ	% by weight	% freq occ	% by weight
	2	3	4	5	6	7
Lamnidae						
Lamna nasus (Bonnaterre, 1788)	2.9	0.1	11.8	0.5	–	–
Rajidae						
Bathyraja eatonii (Gunther, 1876)	32.4	0.2	–	–	36.4	3.4
B. murrayi (Gunther, 1880)	23.5	+	–	–	18.2	+
B. irrasa Hureau a. OzoufCostaz, 1980	2.9	+	–	–	9.1	0.8
Bathyraja sp.1	14.7	+	–	–	9.1	0.1
Bathyraja sp.2	2.9	+	–	–	–	–
Myctophidae						
Electrona antarctica (Gunther, 1878)	5.9	+	23.5	+	9.1	+
Gymnoscopelus braueri (Lohnberg, 1905)	–	–	–	–	9.1	+
G nicholsi (Gilber, 1911)	8.8	+	5.9	+	18.2	+
G. opisthopterus Fraser-Bruhner,1949	2.9	+	–	–	–	–
Krefftichthys anderssonii (Lohnberg, 1905)	2.9	+	–	–	18.2	+
Protomyctophum tenisoni (Norman, 1930)	2.9	+	–	–	–	–
Muraenolepididae						
Muraenolepis marmoratus (Gunther, 1880)	11.8	+	–	–	45.5	0.1
Macrouridae						
Macrourus carinatus (Gunther, 1878)	2.9	+	–	–	–	–
Macrourus sp. c.f. whitsoni	2.9	+	–	–	–	–

	Shelf of Heard Island Ulenscp O. Xepg				New Bank Bareka Hobar	
	Bottom trawls		Midwater trawls		Bottom trawls	
	% % freq occ	% % by weight	% % freq occ	% % by weight	% % freq occ	% % by weight
	2	3	4	5	6	7
<u>Congiopodidae</u>						
Zanclorhynchus spinifer (Gunther, 1880)	–	–	–	–	45.5	0.1
<u>Nototheniidae</u>						
Notothenia rossii rossii (Richardson, 1844)	8.8	+	–	–	–	–
N. squamifrons (Gunther,1880)	26.5	+	–	–	90.9	63.3
N. acuta (Gunther, 1880)	32.4	+	–	–	–	–
N. mizops (Gunther, 1880)	8.8	+	–	–	63.6	0.1
Dissostichus eleginoides (Smitt, 1889)	61.8	0.8	–	–	90.9	6.7
<u>Harpagiferidae</u>						
Harpagifer sp. cf. spinosus	–	–	5.9	+	–	–
<u>Channichthyidae</u>						
Chamsocephalus gunnari (Lomberg, 1905)	91.2	96.5	82.4	99.5	81.8	23.9
Channichthys rhinoceratus (Richardson, 1844)	85.3	2.4	47.1	+	81.8	1.5
<u>Tempylidue</u>						
Paradiplospinus antarcticus Andriashev	5.9	+	5.9	+	9.10	+
<u>Bothidae</u>						
Mancopsetta maculata antarctica (Kothylar, 1978)	–	–	–	–	54.5	+

Légende du tableau

Tableau 1 Composition des espèces par fréquence et par poids + 0,01% par poids.

Encabezamiento de la Tabla

Tabla 1 Composición de las especies por frecuencia y por peso + 0.01% por peso.

Заголовок к таблице

Таблица 1 Видовой состав по частоте встречаемости и по весу + 0,01%.

WG-FSA-87/16

DISTRIBUTION OF FISH LARVAE AT SOUTH GEORGIA : HORIZONTAL, VERTICAL, AND TEMPORAL DISTRIBUTION AND EARLY LIFE HISTORY RELEVANT TO MONITORING YEAR-CLASS STRENGTH AND RECRUITMENT

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Abstract

Four studies on the early life history stages of Antarctic fish at South Georgia are reported. In winter and summer fish larvae and early juveniles were present over the continental shelf and abundant near the coast, but rare in oceanic waters. During winter in the 265 m deep fiord of Cumberland East Bay the early stages of many species were found throughout the water column. In summer only four species of larvae were abundant, they were found in the upper 100 m of the water column, especially the top 2 m layer at certain times of day. In both seasons some species showed daily vertical migration.

The findings are discussed in relation to surveys for sampling the early stages of fish at South Georgia, with special reference to the early life history of Champsocephalus gunnari.

Résumé

Quatre études sur les premiers stades de la vie des poissons de l'Antarctique en Géorgie du Sud font l'objet d'un compte rendu. En hiver et en été, des larves de poissons et des juvéniles précoces étaient présents sur le plateau continental et abondants près de la côte, mais rares dans les eaux océaniques. Au cours de l'hiver, on a trouvé dans le fjord d'une profondeur de 265 m de la Baie Est de Cumberland les premiers stades de la vie de nombreuses espèces dans toute la colonne d'eau. En été, seulement quatre espèces de larves étaient abondantes; elles se trouvaient dans les 100 mètres supérieurs de la colonne d'eau, surtout dans la couche des 2 mètres supérieurs à certains moments de la journée. Au cours des deux saisons, une migration verticale quotidienne a été observée chez certaines espèces.

Les conclusions sont examinées relativement aux prospections d'échantillonnage des premiers stades de la vie des poissons en Géorgie du Sud, en particulier les premiers stades de Champsocephalus gunnari.

Resumen

Se presentan cuatro estudios sobre las primeras etapas del historial de vida de los peces antárticos en Georgia del Sur. En invierno y verano había larvas de peces y peces jóvenes en su primera etapa de vida presentes en la plataforma continental y los mismos abundaban cerca de la costa, pero escaseaban en las aguas océanicas. Durante el invierno, en el fiordo de 265 m de profundidad de la bahía de Cumberland East, las primeras etapas de varias especies fueron halladas a través de toda la columna de agua. En verano abundaron sólo cuatro especies de larvas, las cuales fueron halladas en los 100 m superiores de la columna de agua, especialmente en la capa superior de 2 m, a ciertas horas del día. En ambas temporadas algunas especies mostraron una migración vertical diaria.

Se discuten los resultados en relación a las prospecciones para el muestreo de peces en su primera etapa en Georgia del Sur, con especial referencia a las primeras etapas del historial de vida de <u>Champsocephalus gunnari</u>.

Резюме

Сообщается о четырех исследованиях ранних стадий жизненного цикла антарктических рыб в районе Южной Георгии. Зимой и летом наблюдалось присутствие личинок рыбы и молоди на ранних стадиях развития в районе континентального шельфа и в большом количестве - у берега, но очень редко - в открытом океане. Зимой в фиорде залива Камберланд Ист-бей, глубиной в 265 м, по всему водяному столбу было обнаружено присутствие особей многих видов на ранних стадиях жизненного цикла. Летом в изобилии были личинки только четырех видов; они были обнаружены в верхних 100 м водяного столба, особенно в верхних 2 м - в определенное время суток. В течение обоих времен года у некоторых видов наблюдалась ежесуточная вертикальная миграция.

Результаты этих наблюдений рассматриваются в связи со съемками, нацеленными на взятие образцов рыбы на ранних стадиях развития у Южной Георгии; особое внимание уделяется ранним стадиям жизненного цикла <u>Champsocephalus gunnari</u>.

DISTRIBUTION OF FISH LARVAE AT SOUTH GEORGIA: HORIZONTAL, VERTICAL, AND TEMPORAL DISTRIBUTION AND EARLY LIFE HISTORY RELEVANT TO MONITORING YEAR-CLASS STRENGTH AND RECRUITMENT

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INTRODUCTION

British Antarctic Survey has undertaken seven cruises using RRS John Biscoe to investigate the Antarctic marine ecosystem, around South Georgia. The island is an important breeding area for higher predators which are also studied by shorebased research at Bird Island. During these cruises fish biologists under the guidance of Martin White have studied small fish, including the early stages of the Notothenioidei and other common coastal species, and the midwater fishes (mainly Myctophidae).

The purpose of this paper is to communicate information on fish biology gained from these studies of relevance to CCAMLR, especially to item 4 of the agenda of the Meeting of the Ad Hoc Working Group on Fish Stock Assessment, (Hobart 19 - 23 October, 1987), "surveys of early life history stages".

1. WINTER SOUTH GEORGIA ZONE SURVEY, 28 JULY TO 21 AUGUST, 1983

Methods

The study was a grid survey around South Georgia (Figure 1). There were 26 oceanic stations (depth >2000 m), 11 shelf edge stations (depth <2000, >200 m) and 5 shelf/neritic stations (depth <200 m). A multiple rectangular midwater trawl of 8 m^2 and 4.5 mm mesh (MRMT8) was used to sample discrete depth strata of 0-250 m, 250-500 m and 500-1000 m depth depending on bathymetry. The shallower depth strata were sampled at all stations. Only one sample at each depth interval was taken at each station. The results are plotted for each separate net fished, as number of specimens per 10^5 m^3 of water filtered, with no discrimination according to depth. The key to abundance represented by filled circles in the Figures 2-17 follows Figure 1. For most hauls a single specimen caught would give a calculated value of about 5 per 10^5 m^3 volume filtered. Information on fish standard length is also given; this includes data from a study in the fiord of Cumberland East Bay during 20 September to 5 October, 1983, approximately one month after the zone survey.

Results

Eggs of either Notothenia rossii or Notothenia neglecta (probably not both) were found in the surface waters over the shelf and in Cumberland East Bay at densities of about 2 000 per 10^5 m^3. The highest catches were not using the MRMT8 net but were from the Foredeck Net (FNet) towed in the upper 2 m of water column alongside the foredeck of the ship. This suggests that the eggs were not adequately sampled by MRMT8 nets, so their vertical distribution is included later under part 3. (Figure 19).

Chamsocephalus gunnari larvae of 12-32 mm standard length (SL) occurred at only four of the stations over the continental shelf and in none of the oceanic stations (Figure 2). However, one month later they were abundant in Cumberland East Bay (Figure 20).

Pagothenia hansoni larvae of 23-54 mm SL occurred at all depths fished on a single station near to the coast (Figure 3). They were abundant one month later in Cumberland East Bay.

Nototheniops larseni larvae of 15-55 mm SL occurred only over the shelf (Figure 4), at abundances of 7-600 per 10^5 m^3 where present. They were abundant one month later in Cumberland East Bay.

Notothenia kempi larvae 21-25 mm SL were found mostly over the shelf except for a single specimen just off the shelf to the south of South Georgia (Figure 5).

Pseudochaenichthys georgianus larvae of 12-30 mm SL were found on the shelf near the north-east coast of South Georgia (Figure 6), and they were moderately abundant one month later in Cumberland East Bay.

Chaenocephalus aceratus larvae were absent from the survey although they were moderately abundant in Cumberland East Bay about one month later when they were 10-30 mm SL.

Psilodraco breviceps larvae of 11-27 mm SL occurred at two stations near to the coast (Figure 7).

Larvae and early juveniles of the eel-cod Muraenolepis microps 45-71 mm SL were found mostly over the shelf or near the edge of the shelf (Figure 8).

Larvae of the midwater barracudina (Paralepididae) Notolepis coatsi 16-77 mm SL occurred at many oceanic stations (Figure 9). They were found mostly beyond the shelf but also over the shelf near the middle of the north-east coast of South Georgia.

Conclusions

The early stages of the order Notothenioidei and the family Muraenolepididae occurred over the continental shelf of South Georgia. Many species were abundant or common in the fiord of Cumberland East Bay on the north coast of the island even when they had been caught at few of the 42 stations around the island. In contrast the early stages of Notolepis coatsi were common at oceanic stations beyond the shelf although they also occurred over part of the shelf.

2. SUMMER, PREDATOR PREY CRUISE: RADIAL TRANSECTS AROUND BIRD ISLAND, SOUTH GEORGIA, 4 FEBRUARY TO 5 MARCH, 1986

Methods

Samples were taken using the MRMT8 along radial transects extending to the north and south of Bird Island (Figure 10). Samples were mostly to 100 m depth and some to 500 m depth; these have been combined. Figures are plotted for each net fished as number of specimens per 10^5 m^3 volume filtered by the 8 m^2, 4.5 mm mesh net. The total number of specimens caught (n) and the range of their standard length (SL) is given for each species for all stations combined (normally only including data from specimens less than 80 mm SL).

Results

No significant catches of pelagic fish eggs were made.

Champsocephalus gunnari larvae of 40-54 mm (and one of 15 mm) SL (n=33) were found mainly over the continetal shelf to the south of Bird Island (Figure 11).

Notothenia gibberifrons larvae of 21-38 mm SL (n=229) were abundant over the continental shelf to the north and south of Bird Island, but were absent at the stations beyond the shelf (Figure 12).

Nototheniops larseni larvae of 18-35 mm SL (n=83) and early juveniles of 50-80 mm SL (n=45) were abundant over the shelf to the north and south of the island (Figure 13).

Nototheniops nudifrons larvae and early juveniles of 27-50 mm (and one of 70 mm) SL (n=109) were most abundant over the shelf (Figure 14).

Pseudochaenichthys georgianus juveniles of 79 and 93 mm SL were caught at separate stations over the shelf (Figure 15).

Chaenocephalus aceratus larvae/early juveniles 51-77 mm SL (n=6) were only found over the shelf (Figure 16).

Muraenolepis microps larvae 26-45 mm SL, (n=21) and one 61 mm were most abundant over the shelf to the north of Bird Island. They were also present at most shelf stations but at only one oceanic station (Figure 17).

Conclusions

Although this was a simple survey that did not cover an extensive geographical area it supports the conclusions of the previous study. These are also supported by further unpublished observations by the British Antarctic Survey that found fish larvae to be very abundant in summer within 15 n. miles of the north-east coast of South Georgia. Therefore in summer and winter the early stages of the Notothenioidei and Muraenolepis microps are most abundant over the continental shelf at South Georgia, and rare or absent in oceanic waters beyond the shelf.

3. DIURNAL VERTICAL DISTRIBUTION OF FISH LARVAE IN CUMBERLAND EAST BAY, SOUTH GEORGIA, DURING WINTER, 20 SEPTEMBER TO 5 OCTOBER, 1983.

Methods

A single station along the fiord of Cumberland East Bay (Figure 18) was sampled during four periods of the day at four depth strata with six replicates of most samples. The surface 0-2 m depth was sampled by horizontal tows of 30 minutes duration using a Foredeck Net (FNet) (1 m^2, 4.5 mm mesh) fished alongside the foredeck of the ship in surface waters undisturbed by the ship's wake. A multiple rectangular midwater trawl net of 8 m^2 and 4.5 mm mesh (MRMT8) was used to sample from near the bottom of the fiord (265 m depth) to the surface by upward oblique hauls at discrete depth strata. These net hauls were at 250-150, 150-70 and 70-2 m depth, each for 30 minutes duration towed at 2.5 knots. The results were calculated assuming the net was 100% efficient. Catches from the Foredeck

Net (1 m^2) were multiplied by 8 to complement those of the MRMT8 (8 m^2). The results are expressed as total number from all replicates of each sample combined, to give number of specimens per $12x10^4$ m^3 of water filtered by the net. Some samples were missed or ruined due to bad weather, emergency, or jellyfish; in such cases the totals were adjusted by an appropriate proportion to given numbers per standard total volume filtered. The number of replicates per time and depth combination is given in Table 1. The length range (SL) of the species was given in part 1.

Results

Eggs 4.7 mm in diameter of either Notothenia rossii or N. neglecta (probably only one species) were most abundant in the upper 2 m of the water column at all times of the day (Figure 19). Numbers for the pre-sunset period appear to be lower than at other times of day.

Champsocephalus gunnari larvae after sunset were most abundant in the upper 70 m layer and at 2-150 m depth before dawn (Figure 20). In the light period after dawn they were at 0-70 m depth, and later before sunset at 2-70 m, but not in the upper 2 m surface layer. There is an upwards vertical migration during sunset from 2-70 m depth to the upper surface layer, followed by a downwards migration during dark from the surface layer. During winter larvae were mostly in the upper 150 m, although at all observed periods of the diurnal cycle some were found from the surface down to 250 m depth. During the light period the nets caught less specimens than during the period of darkness. This suggests significant net avoidance by this species at only 12-32 mm standard length.

Nototheniops larseni larvae after sunset were most abundant in the surface 0-2 m depth layer and moderately abundant at 2-70 m depth (Figure 21). Before the dawn they were most abundant at 2-70 m and moderately abundant in the upper 2 m depth layer. During the light period they were caught in much lower numbers but were most abundant at 2-70 m depth. None were caught in the surface 2 m when it was light. Nototheniops larseni larvae migrate up to the surface 2 m layer after dark, then down to 2-70 m depth during daylight, although at all parts of the diurnal cycle some larvae were caught at all depths.

Pseudochaenichthys georgianus larvae were absent from the upper 2 m except after dawn (Figure 22). They were most abundant at 70-250 m depth before dawn and at 2-70 m depth after sunrise, when they were also moderately abundant at 150-250 m depth. The catches during daylight periods show that much fewer specimens were taken before sunset (and none at the surface) compared to after sunrise. After sunset they were most abundant at 70-150 m depth. At all times of the day larvae were present in the lower 150-250 m depth layer. Low catches during the pre-sunset period could be due to a migration close to the sea-bed, and this is worth further study.

Chaenocephalus aceratus larvae were never caught in the upper 2 m layer (Figure 23). They were most abundant before sunset at 2-70 m depth. After dark they migrated to deeper water at 70-250 m depth, most to 150-250 m depth, then before dawn up to the 70-150 m depth layer. After dawn they were most abundant at 150-250 m, rare at 70-150 m and moderately abundant at 2-70 m depth. This suggests a dawn migration either to the surface or to deep water and a movement during the day to the 2-70 m layer, then a downward migration at sunset, then upwards to 70-150 m depth during the night.

Parachaenichthys georgianus larvae of 11-35 mm SL were absent from the upper 2 m layer before and after sunset but were found in that layer before and after dawn (Figure 24). At all times of the day they were most abundant at 2-70 m depth and generally did not migrate deeper, although a few were found deeper at all times of the day. Catches before sunset were lower than at other times of the day. Vertical migration seemed limited to some movement up to the surface during the dark, and down from the surface during the day.

Electrona antarctica early stages of about 7-25 mm SL were never found in the upper 2 m (Figure 25). They were most abundant in the 70-250 m depth layer and moderately abundant at 2-70 m. There is some evidence for a downward migration during daylight followed by upward migration during the dark.

Conclusions

In winter there are significant numbers of the early stages of fish in Cumberland East Bay, South Georgia. Several species were found at all depths during most periods of the diurnal cycle. Eggs were most abundant in the surface 2 m depth layer. This upper 2 m depth layer is avoided completely by some species (Chaenocephalus aceratus, Electrona antarctica), whereas others migrate to the surface at particular periods of the diurnal cycle (Champsocephalus gunnari, Nototheniops larseni, Pseudochaenichthys georgianus, Parachaenichthys georgianus). Most species were generally more abundant in the upper 150 m of the water column at most times though Chaenocephalus aceratus, Pseudochaenichthys georgianus and Electrona antarctica were abundant near the bottom of the fiord at certain periods of the diurnal cycle. Many species showed evidence of vertical migration during the diurnal cycle (Champsocephalus gunnari, Nototheniops larseni, Pseudochaenichthys georgianus, Chaenocephalus aceratus).

To estimate the abundance of fish larvae at South Georgia in winter, it is necessary to sample the whole water column, and to sample during darkness to reduce net avoidance.

4. DIURNAL VERTICAL DISTRIBUTION OF FISH LARVAE IN CUMBERLAND EAST BAY, SOUTH GEORGIA DURING SUMMER, 4-14 JANUARY, 1987

Methods

A single station along Cumberland East Bay was sampled at seven depth strata during six periods of the day (Figure 26). The Foredeck Net was fished as described in part 3, with six replicates per sample. The MRMT8 was fished by downward oblique hauls at discrete depth strata: 2-20, 20-60, 60-100, 100-140, 140-180 and 180-220 m; each net was fished for 20 minutes at 2.5 knots with three replicates per sample. The results were calculated assuming the nets were 100% efficient and are expressed as an average number of specimens (n=3) per 13.3×10^3 m^3 of water filtered by the net.

Results

Champsocephalus gunnari migrated from the surface after sunset to 70-100 m depth by midnight (Figure 26). Before sunrise many had moved from 60-100 m to the surface 0-2 m and after dawn all had moved to the surface. By midday there was some migration from the surface to 2-100 m but before sunset most had returned to the upper 2 m, and many to 2-20 m depth. After sunset most were still in the upper 2 m though some had migrated down to 20-100 m, and by midnight most were at 60-100 m depth. Overall distribution varied with season, in winter they were found throughout the water column, but in summer they were only in the upper 100 m of the 265 m deep fiord (cf Figures 20 and 26).

Notothenia gibberifrons were always most abundant in the epipelagic 0-2 m surface layer at all periods of the diurnal cycle (Figure 28). However, catches at midnight and before sunrise seem low. There was a lot of variation in the numbers caught in the surface nets, which probably indicates that the larvae form shoals. It is possible, by chance, if the larvae form shoals that the midnight and pre-sunrise samples underestimated their abundance. The average abundance at the surface is likely to be somewhere between the highest and lowest average catches, probably about 5 per 10^6 m^3.

Nototheniops larseni were mainly at 2-20 m depth except after sunset when they were abundant in the upper 2 m (Figure 29). Moderate numbers were found in the upper 100 m during all times of the day. In winter they were found throughout the water column but in summer few were found deeper than 100 m (cf Figures 21 and 29).

Pagothenia hansoni was interesting because the smaller larvae were in the upper water layers and the larger larvae in deeper water. But this observation is provisional and awaits statistical analysis before it can be fully ratified. At night the smaller larvae were found mostly in the upper 2 m of the water column whereas during daylight they were caught in lower numbers and were most abundant in the upper 20 m (Figure 30). The larger larvae/late larvae were found mostly at 60-220 m depth and in lower numbers than the smaller larvae. The larger larvae showed some evidence of vertical migration from 100–180 m after sunrise to 60–100 m at midday, then back to 100–180 m before sunset. Some came up to 20–100 m after sunset and remained there until after midnight. Before sunrise most were at 60–100 m, and then migrated down to 100–180 m depth during sunrise. This observation of vertical separation with size is provisional pending further analysis.

Pelagic eggs were not found during the fiord in the summer although eggs that were probably of Pagothenia hansoni were found in the stomachs of some benthic feeding adult fish.

Conclusions

In summer there were several species of fish larvae that were abundant in the upper 100 m of the fiord of Cumberland East Bay and few were present between 100–220 m depth at all periods of the diurnal cycle, although the bottom 45 m of the 265 m deep fiord was not sampled. In summer there was vertical migration in many species including Champsocephalus gunnari and Nototheniops larseni. The upper 2 m depth layer was important for the larvae of Chaemsocephalus gunnari, Notothenia gibberifrons, Nototheniops larseni and Pagothenia hansoni. Therefore in summer the upper 150 m of the water column, especially the upper 2 m, contains the highest densities of fish larvae in the fiord. The effect of strong winds on the surface water layer in relation to the distribution of epipelagic fish larvae is worthy of further study.

5. DISCUSSION OF THE SPATIAL AND TEMPORAL DISTRIBUTION, AND EARLY LIFE HISTORY RELEVANT TO SAMPLING FISH LARVAE AT SOUTH GEORGIA

Where to sample? From these studies in winter and summer the fish larvae of the commercially exploited Notothenioidei are found over the continental shelf, especially in the neritic near-coastal waters within 20 n. miles of the coast such as the fiord of Cumberland East Bay.

How many stations to sample? This depends on the distribution of the target species. To evaluate their general distribution it would first be necessary to sample a stratified random grid over the area to be surveyed. A grid of a minimum of about 40 stations would be necessary for the continental shelf of South Georgia. This would be followed by sampling using a more intensive grid within the areas of high abundance of the target species. This all depends on how the target species are distributed. If the species spawns near the coast the larvae may be concentrated fairly evenly within perhaps 10 n. miles of the coast, in which case, after the initial survey, a further 10 near coastal stations may be enough to make a reasonably confident estimate of the abundance. Obviously this is partly a statistical problem, and a statistician should be consulted on the results of the initial survey to plan the subsequent smaller survey(s).

Is the abundance of fish larvae in Cumberland East Bay an index of the status of the stocks? A short-cut method of determining the relative success of the youngest year-class of the fish species around the island would be to determine their abundance each year, at the same time of year, in Cumberland East Bay. This rests on the assumption that each species in the bay is representative of the whole stock. This may be true for some species. For example, the adult *Champsocephalus gunnari* which spawn in the bay are probably subject to the same fishing and natural mortalities, feeding success, and growth, etc., as the rest of the stock, and their reproductive success, and larval survival and growth, may be the same as at other localities around the island. If these assumptions were satisfied then an intensive survey in the bay during one week each December could be used as an index of the year class strength of the youngest age class of the population. It would also be pertinent to measure the wind strength and direction in the bay during August to January, because this may affect the abundance of larvae in any year.

What depth to sample? From the studies on vertical distribution the depths sampled depends on the target species and the time of the year. For example *Champsocephalus gunnari* was most abundant in the upper 150 m in summer. Therefore for this species it may be sufficient to sample the upper 150 m of the water column. To make quantitative surveys of the species it would be necessary to include samples of the undisturbed near surface layers (undiluted by the mixing effect of the wake of a ship). For some species it may be necessary to sample the layer just above the sea-bed and further investigations to evaluate this are necessary.

What time of the day to sample? From the studies in part 3 and 4 there was evidence of reduced numbers of fish larvae in daylight samples. Therefore, for quantitative studies it would be best to sample during darkness.

What sampling gear to use? Rectangular Midwater Trawl Net of 8 m^2 and 4.5 mm mesh and a Foredeck Net of 1 m^2 and 4.5 mm mesh seemed to give reasonable and comparable results. However, it is likely that smaller fish larvae can pass through the 4.5 mm mesh in significant quantities because the smallest relevant dimension (body depth) for many species is only about 1-3 mm. Therefore, experiments on mesh selectivity should be performed to evaluate the optimum mesh size for target species. A mesh of 2 mm may be better but this would clog more easily, especially with other plankton, and may result in a reduced filtering efficiency. Optimum mesh size is worth further study. In the meantime MRMT8 (and Foredeck Net) seems a reasonable net to use as it is used by several nations and the results of several co-operating countries could be directly compared.

How many replicates at each station of each sample? This depends on the volume of water filtered per sample in relation to how evenly the target species is distributed. Experience using either six replicates (winter) or three replicates (summer) suggests that for 30 minute tows using MRMT8 nets, three is a minimum and six replicates is reasonable. There was evidence that for some species (Notothenia gibberifrons in summer) six replicates by the Foredeck Net may sometimes be inadequate in species whose larvae form shoals. Therefore Foredeck Net samples may require about 10 replicates if tows are of 20 minutes duration, or longer tows with less replicates, (say six tows of 40 minutes duration) may be enough to make a reasonable quantitative estimate of the abundance of fish larvae.

What time of the year to sample? This depends on the early life cycle and growth rate of the target species. Many species spawn over a period of several weeks, with the larvae hatching over two or more months. Spawning may be localised in the fiords, or near trenches on the continental shelf of South Georgia. If the eggs are benthic the distribution of early larvae will be localised down-current of the spawning grounds. If the eggs are pelagic the larvae will be more evenly and widely dispersed. Larvae grow and become more widely distributed with time in general but on a smaller scale they become more patchily distributed by a combination of shoaling and diurnal vertical migration. When larvae metamorphose into early juveniles they often change their pelagic habit and become demersal. This makes them much less accessible to gear such as the MRMT8 net which is susceptible to damage by the sea-bed. In any case as they grow they can avoid the net more easily, and the MRMT8 net catches few Notothenioidei more than 60 mm total length. Taking these aspects of the life cycle into account the optimum time to undertake quantitative sampling is when the larvae are about 25 to 45 mm in total length (23-41 SL), when they are fairly evenly dispersed and mortality factors have had time to influence the year-class strength of the cohort. For example Champsocephalus gunnari hatch at about 12.5 mm total length in August to October. An average growth rate of 0.35 mm per day was observed during late November to mid January (1981/82), from a total length of 31.2 to 52.0 mm (n=1135, r^2 0.99). Mortality reduces their numbers throughout the larval period. In Cumberland East Bay at their depths of maximum abundance during darkness, in winter (1983) there were about 1 000 per $12x10^4$ m^3, whereas, in summer (early 1987) about 300 per $13.3x10^3$ m^3; a ratio of 30:1. Although these data are not strictly comparable it illustrates the point that abundance in terms of numbers is reduced as the cohort gets older. The optimum time to conduct a survey of this species is after all the larvae have hatched and are accessible to the sampling gear, and towards the end of their larval period when mortalities have made a significant impact on the year class strength. For Champsocephalus gunnari the period of mid-November to January may be a reasonable time of year with mid-December the optimum in an average year.

ACKNOWLEDGEMENTS

Thank you to: M.G. White, I. Everson, R.B. Heywood, V. Woodley, P. Ward, D. Bone, J. Warren, R.A. Coggan, M. Pilcher, M. Roscoe, L. Holmes and the rest of the Offshore Biological Programme team who worked many days of long hours during the research cruises; W. Slosarczyk for valuable work during our last cruise; the Officers and Crew of RRS John Biscoe for sterling co-operation and service; A.G. Wood who prepared software which greatly assisted data analysis for parts 1 and 2; and to other colleagues at British Antarctic Survey for their useful discussion following a presentation of the results. Special thanks to R.A. Coggan who made useful suggestions on the manuscript.

Table 1. Number of replicates

Time of day	Predawn	Postdawn	Predusk	Postdusk
Net depth m				
0–2	5	6	6	6
0–70	5	6	5	6
70–150	5	6	5	6
150–250	4	6	5	6

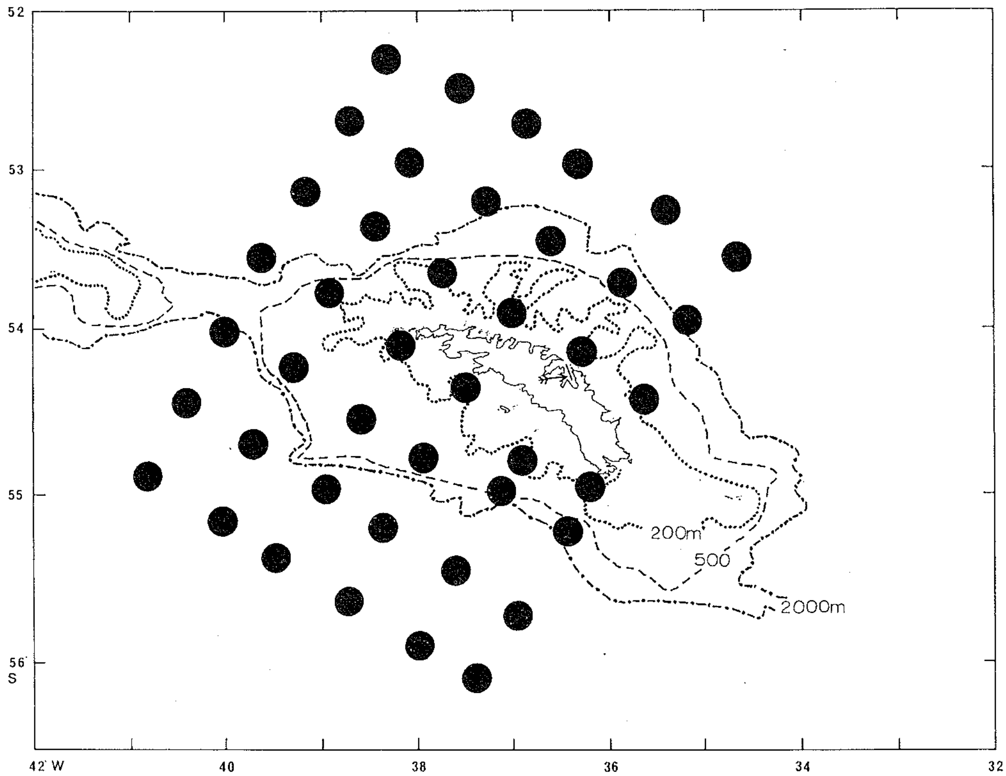
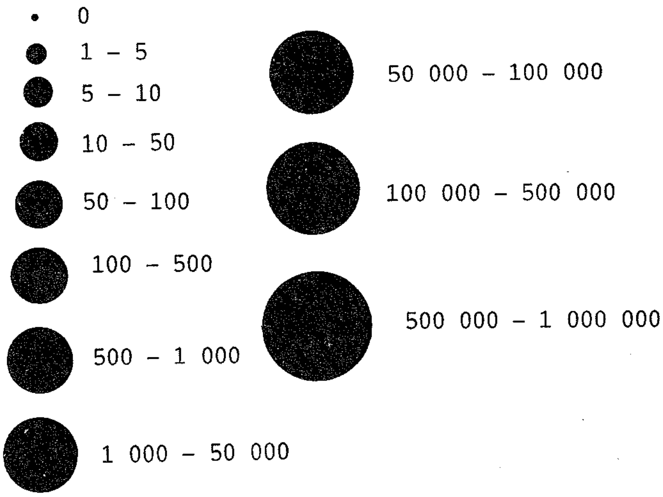


Figure 1   South Georgia zone survey, stations sampled.



Key to Figures 2 - 17. Number per 10^5 m^3 volume filtered.

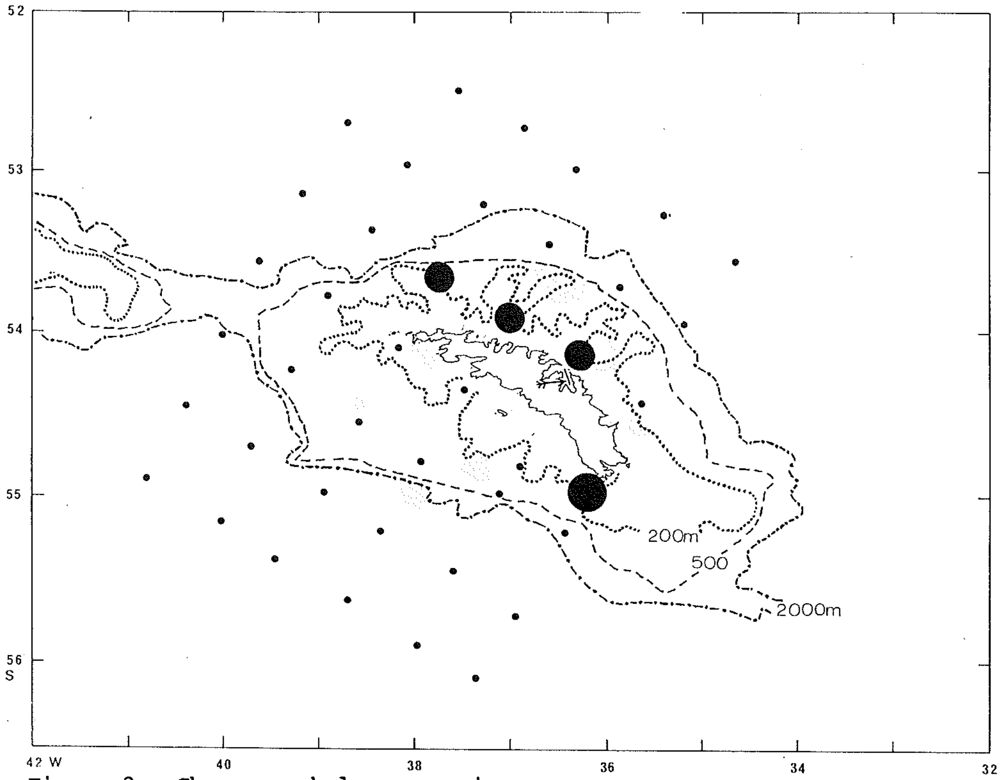


Figure 2 Champsocephalus gunnari.

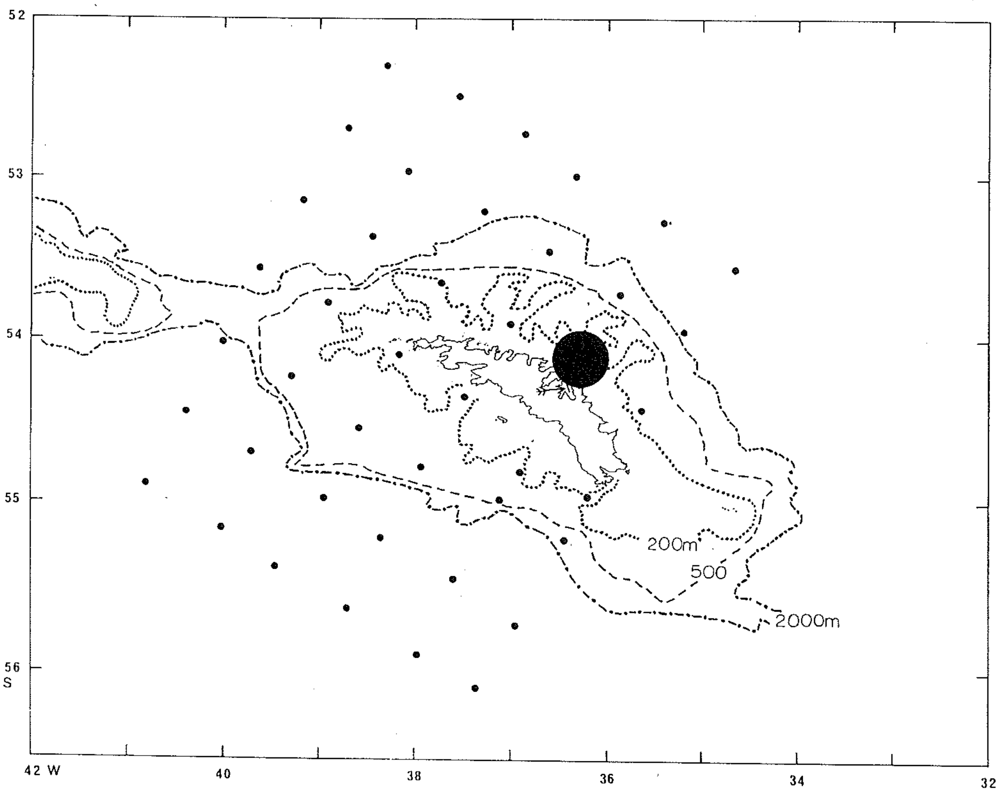


Figure 3 Pagothenia hansoni.

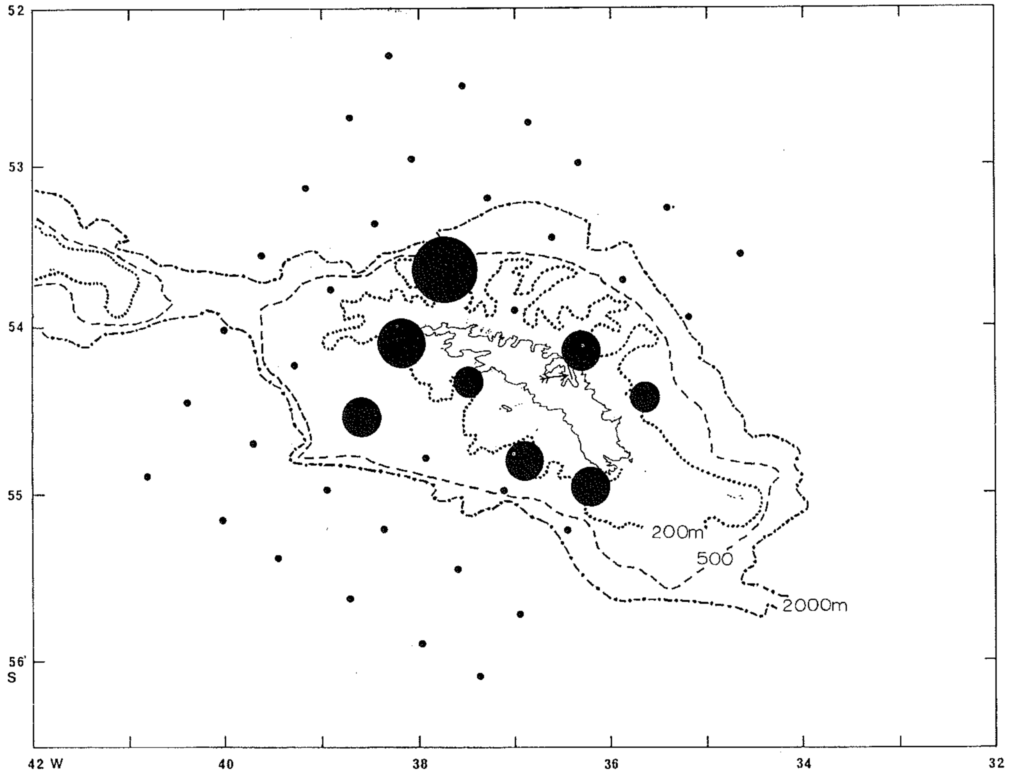


Figure 4 Nototheniops larseni.

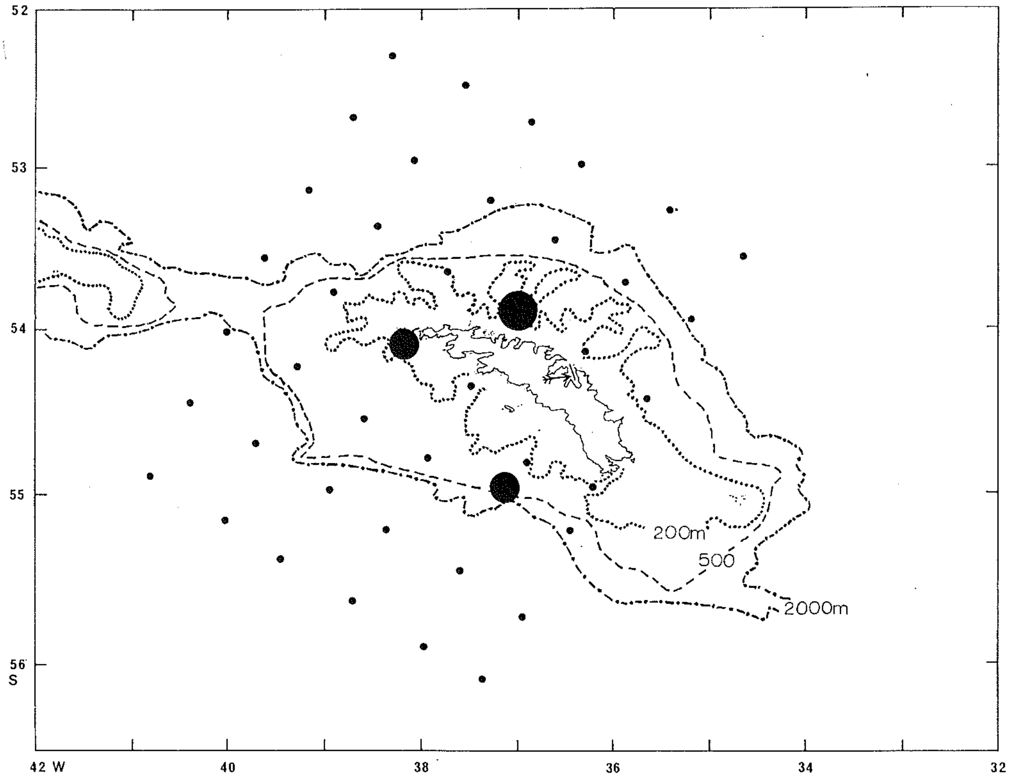


Figure 5 Notothenia kempi.

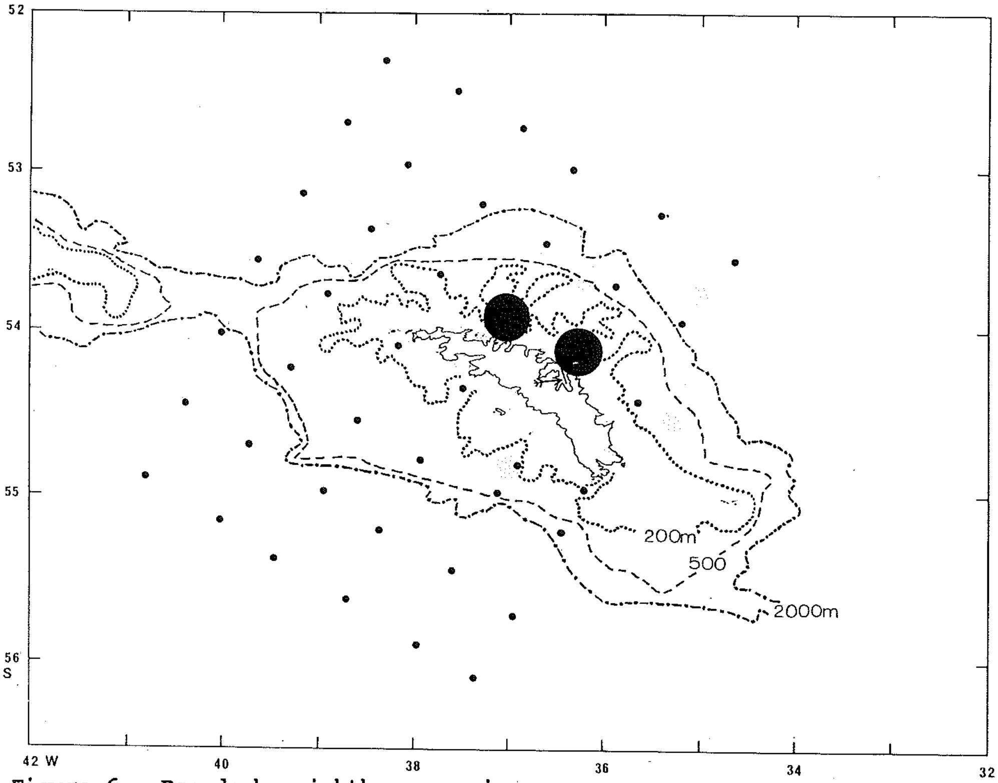


Figure 6 Pseudochaenichthys georgianus.

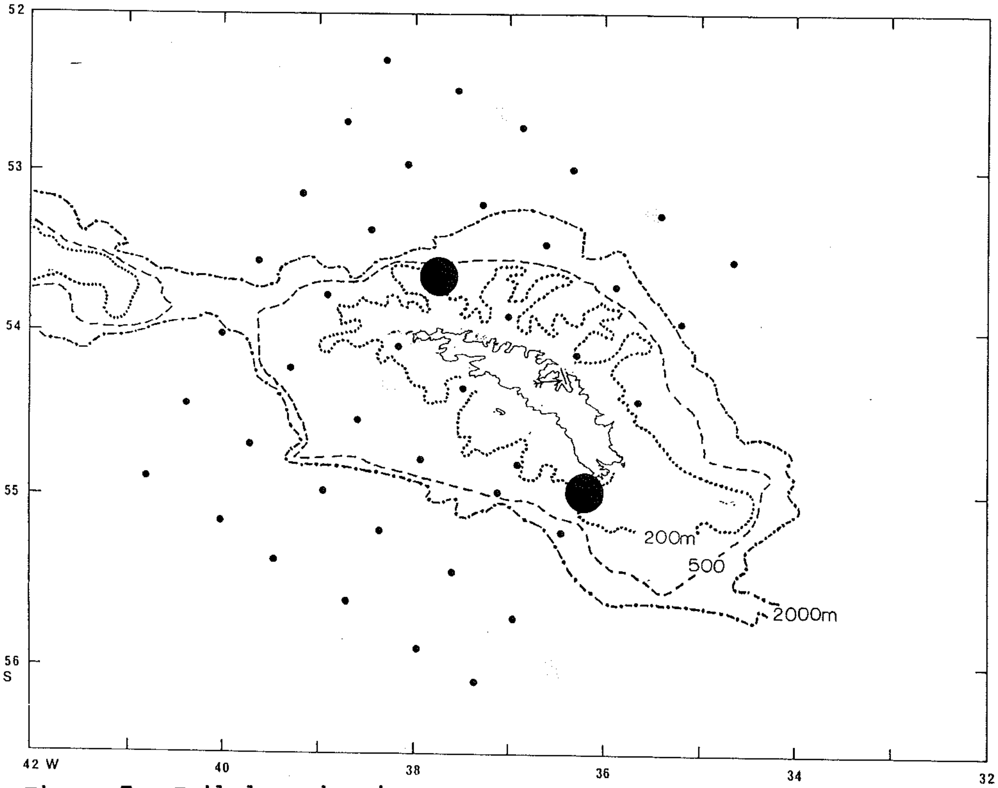


Figure 7 Psilodraco breviceps.

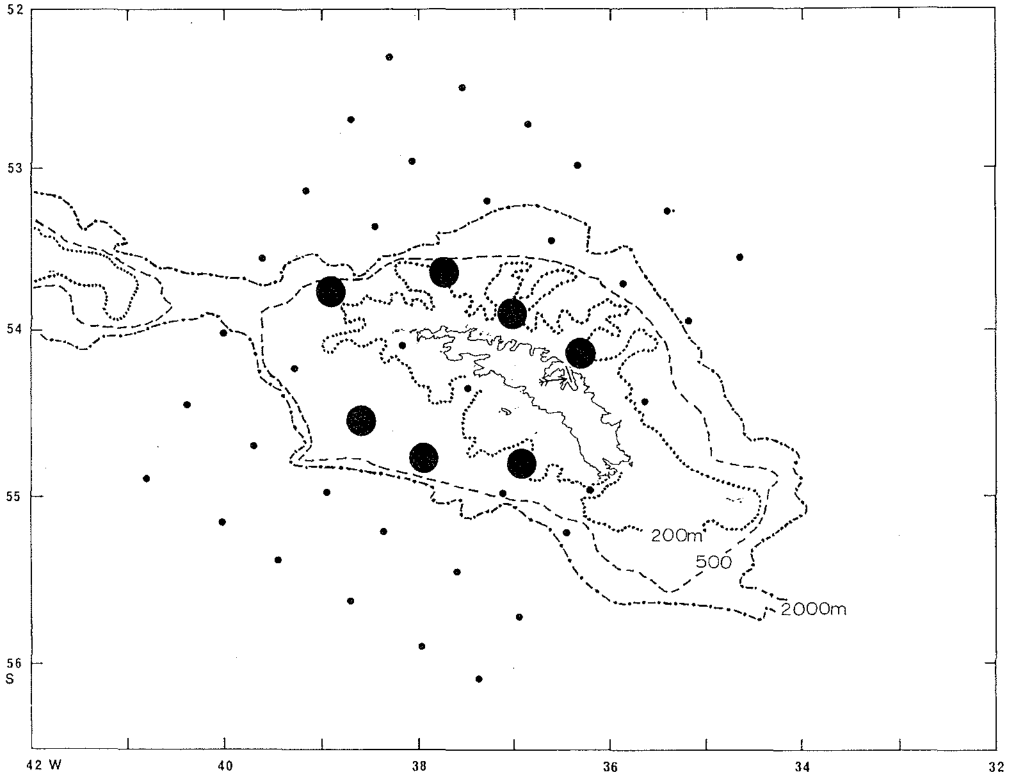


Figure 8 Muraenolepis microps.

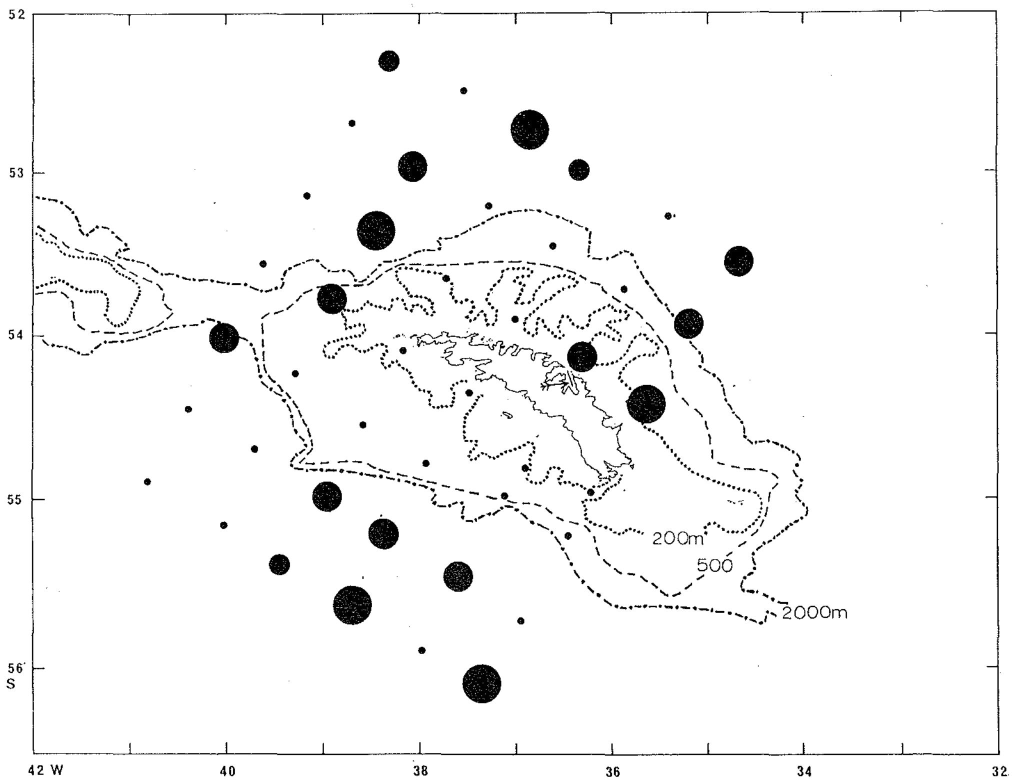


Figure 9 Notolepis coatsi.

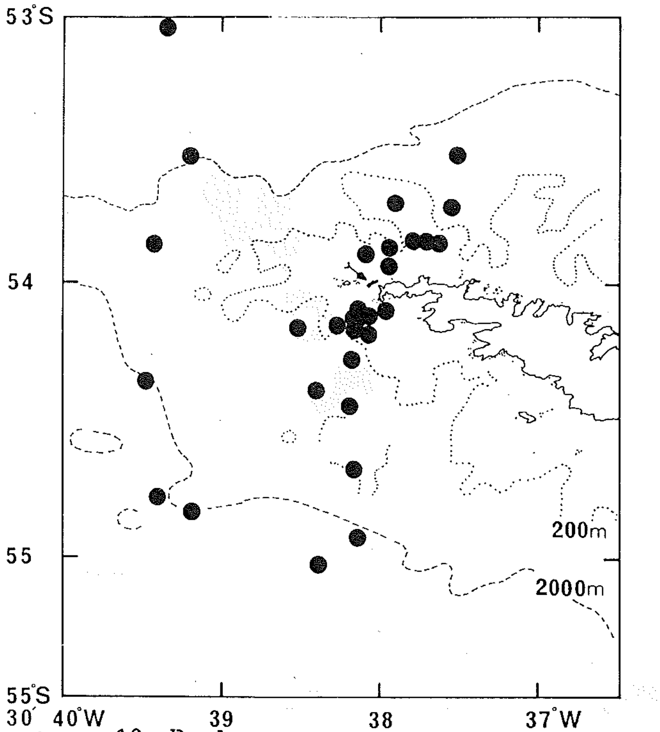


Figure 10 Predator-prey cruise, stations sampled.

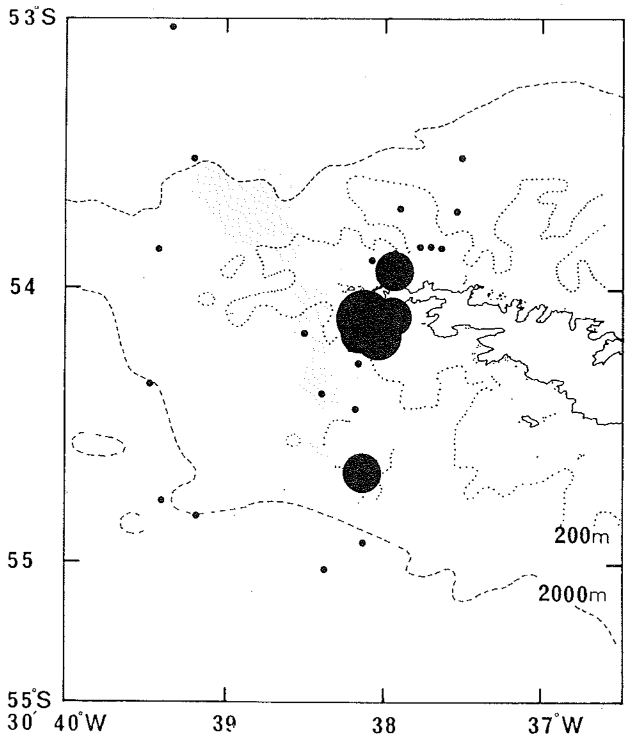


Figure 11 Champsocephalus gunnari.

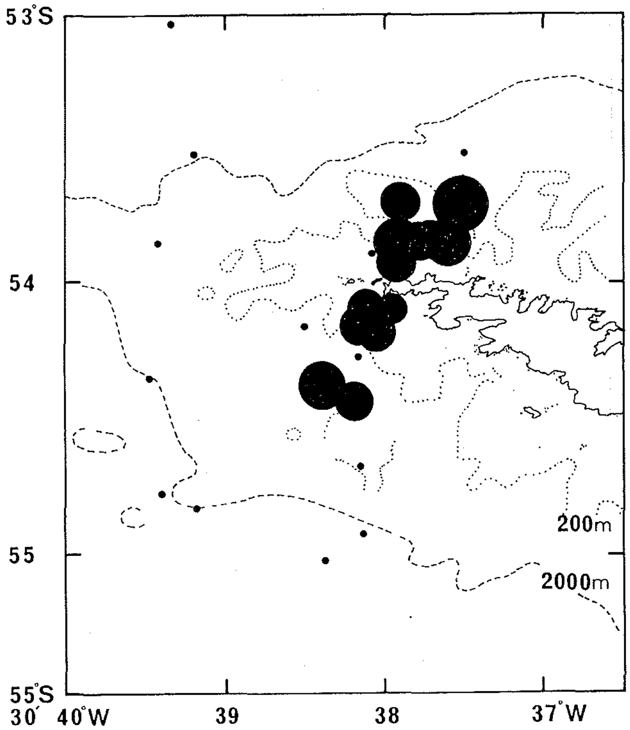


Figure 12 Notothenia gibberifrons.

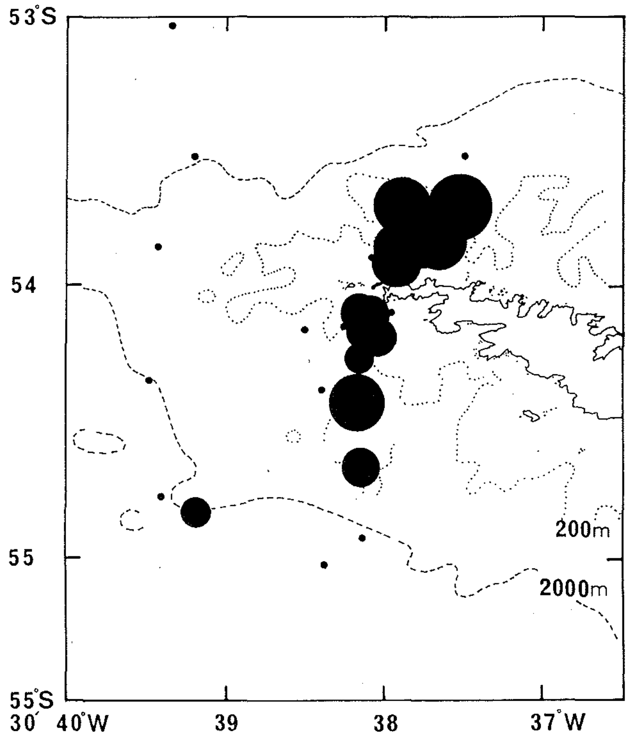


Figure 13 Nototheniops larseni.

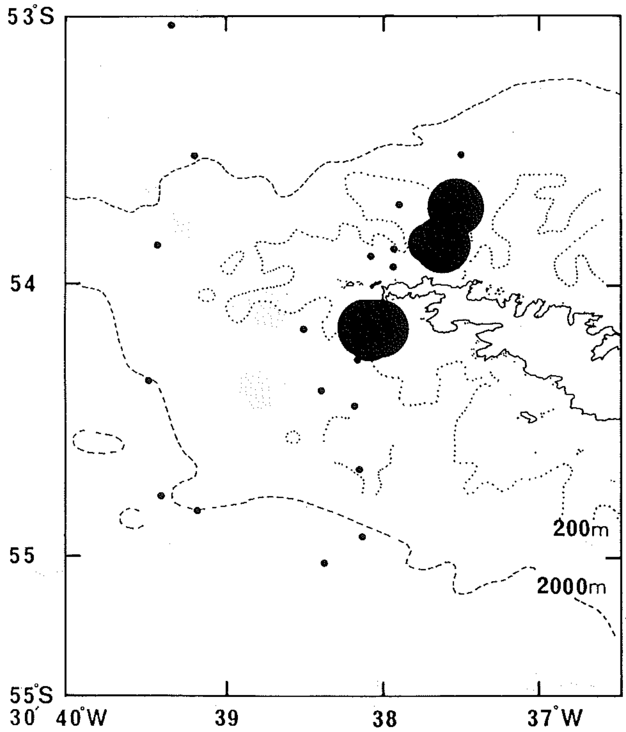


Figure 14 Nototheniops nudifrons.

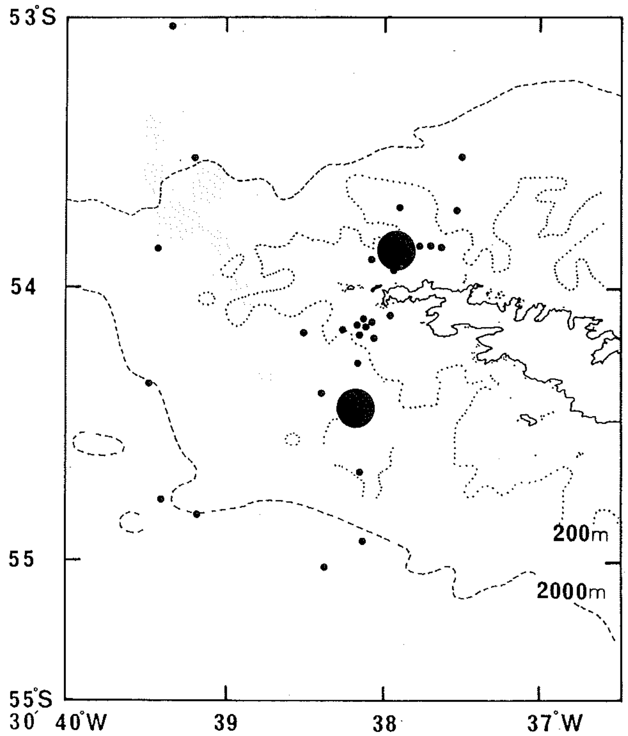


Figure 15 Pseudochaenichthys georgianus.

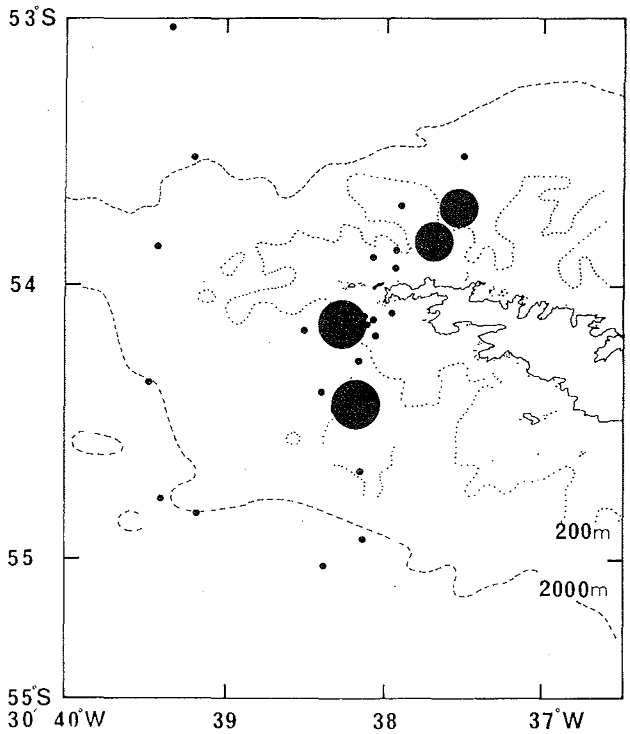


Figure 16 Chaenocephalus aceratus.

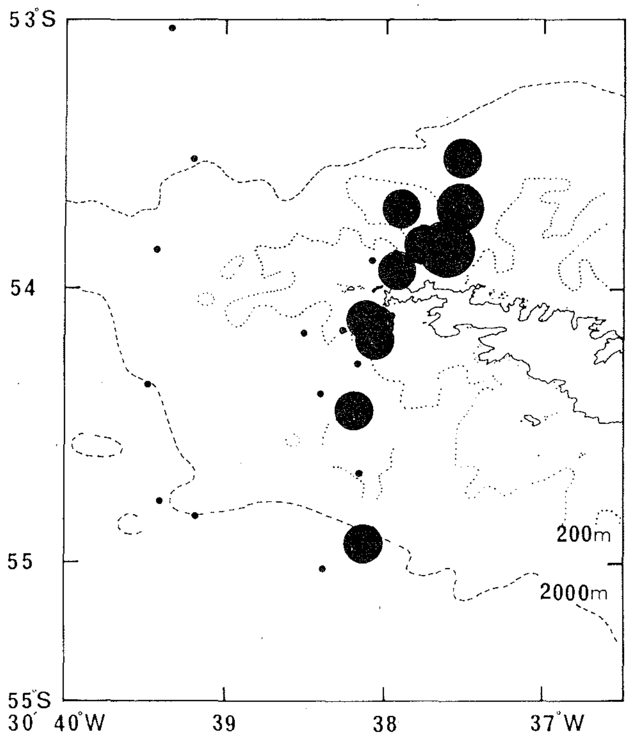


Figure 17 Muraenolepis microps.

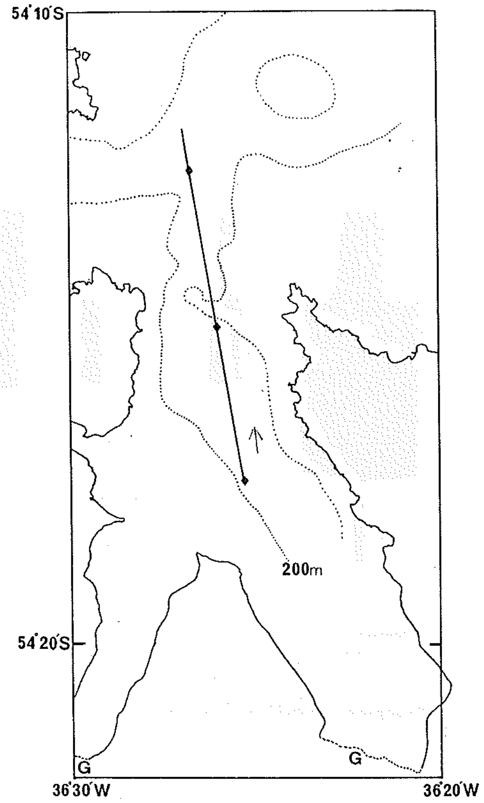


Figure 18 Cumberland East Bay, samples along line of station indicated.

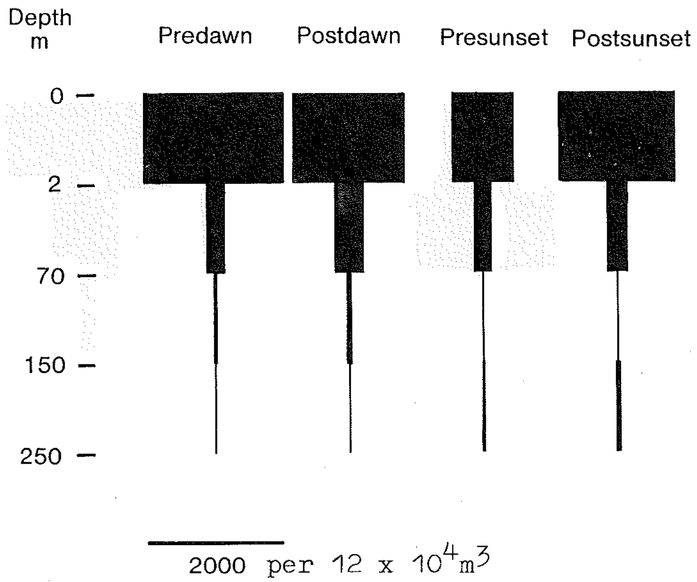


Figure 19 <u>Notothenia</u> sp. eggs.

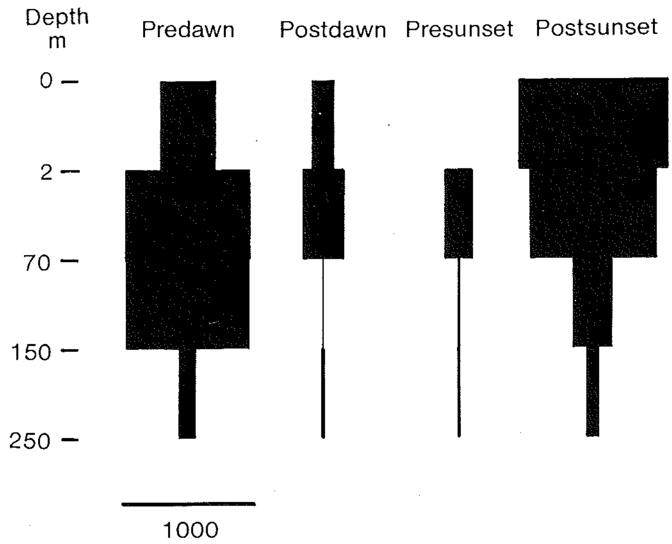


Figure 20 Champsocephalus gunnari.

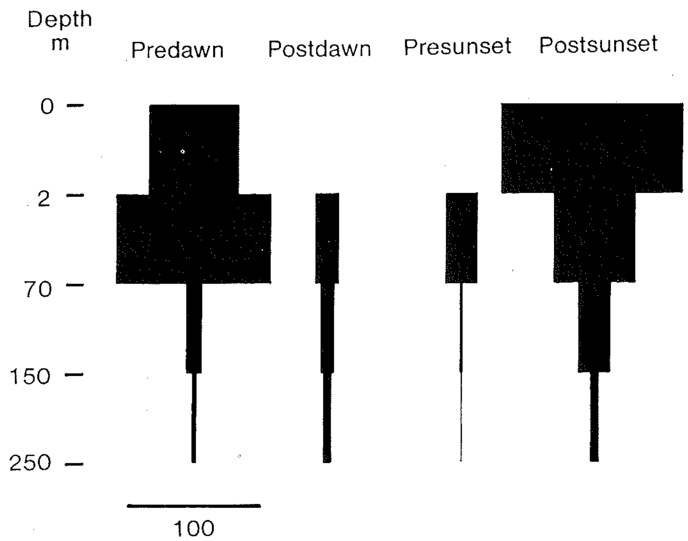


Figure 21 Nototheniops larseni.

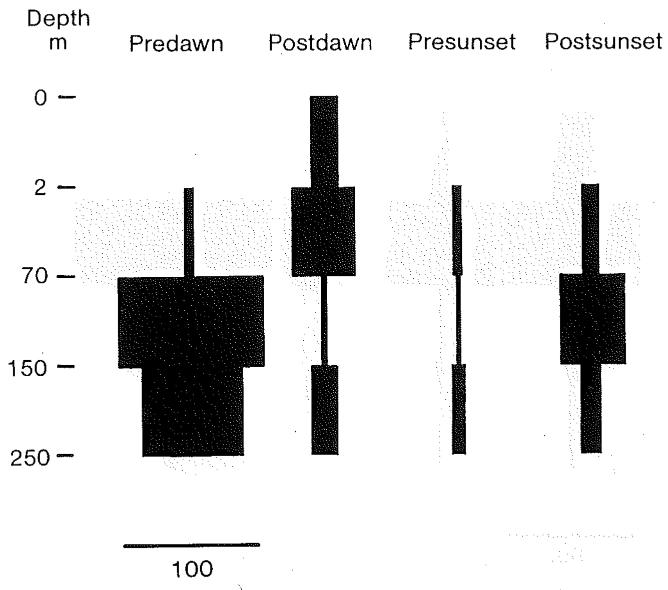


Figure 22 Pseudochaenichthys georgianus.

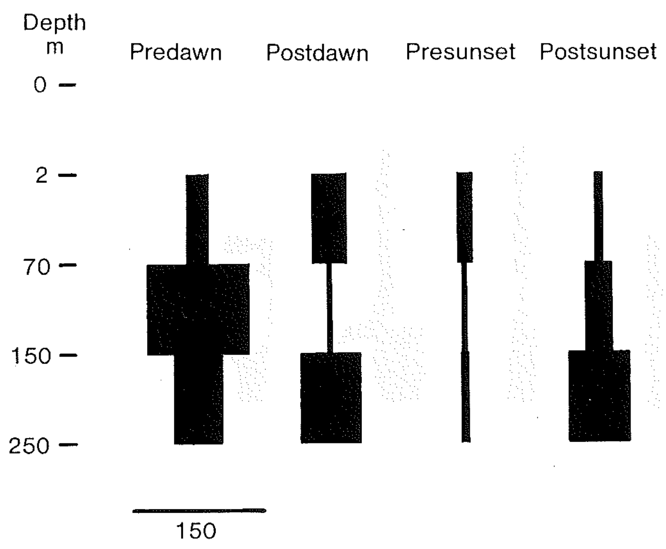


Figure 23 Chaenocephalus aceratus.

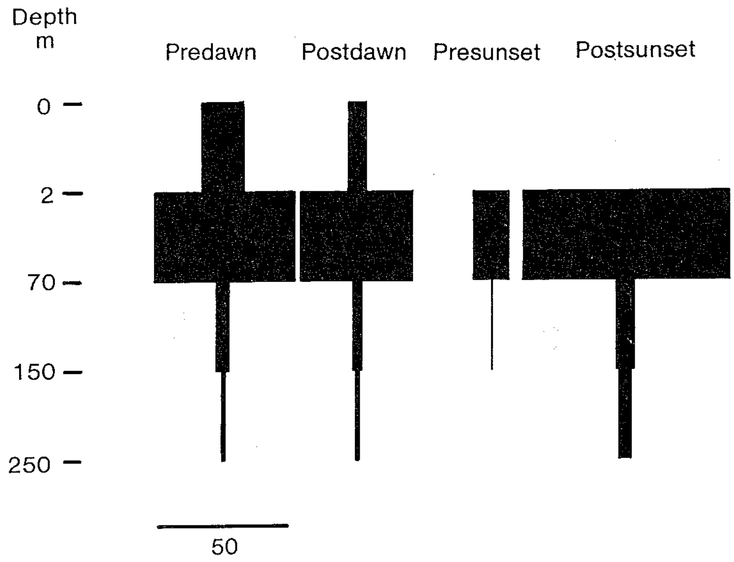


Figure 24 Parachaenichthys georgianus.

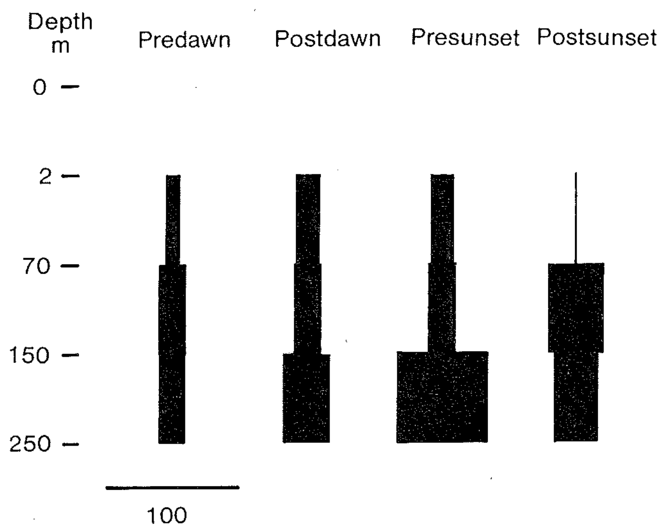
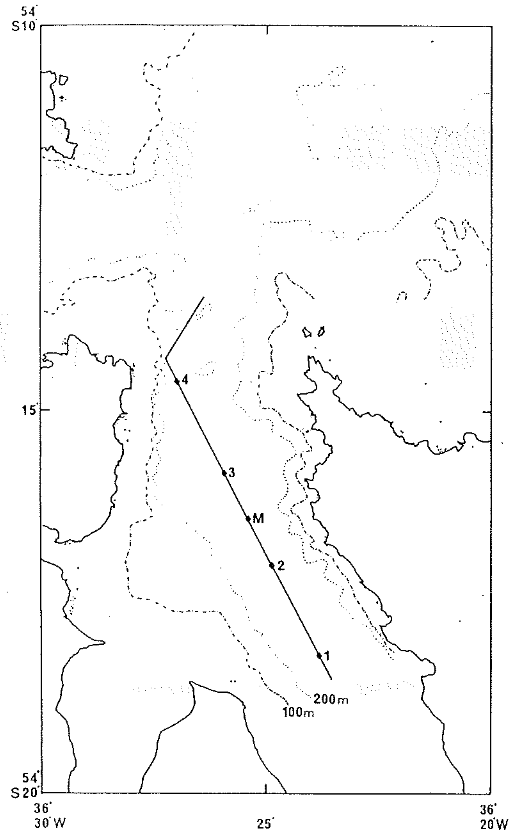
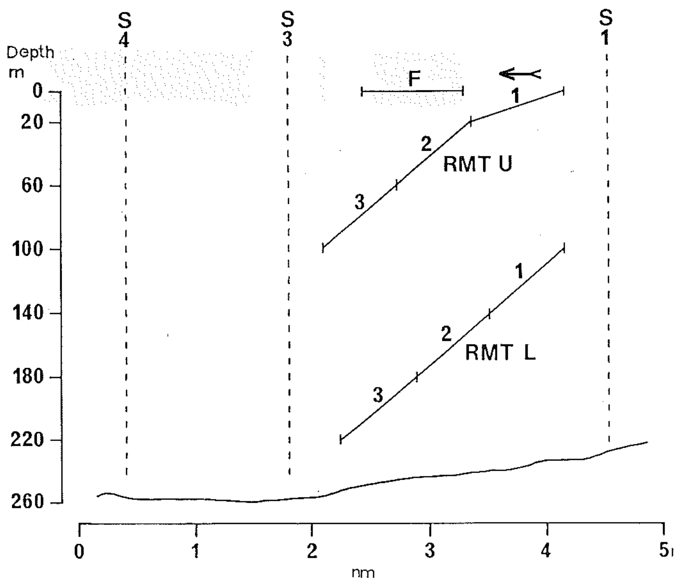


Figure 25 Electrona antarctica.



(a) Location



(b) Vertical section.

Figure 26 Cumberland East Bay, station sampled along 1-3.

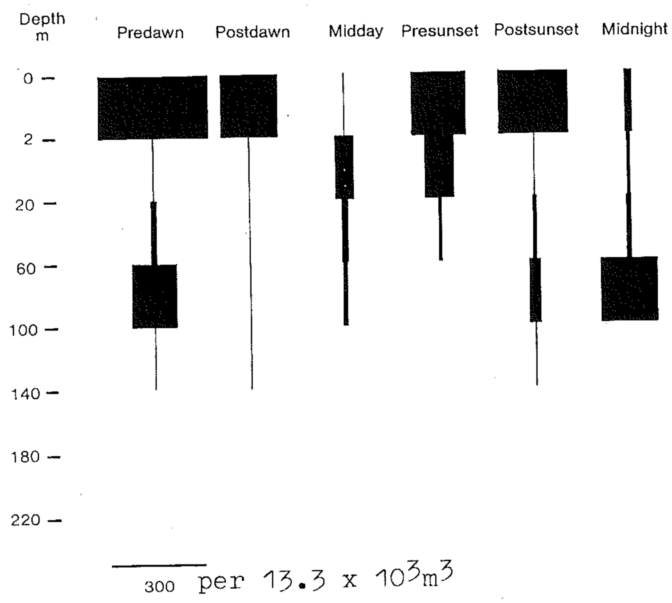


Figure 27 Champsocephalus gunnari.

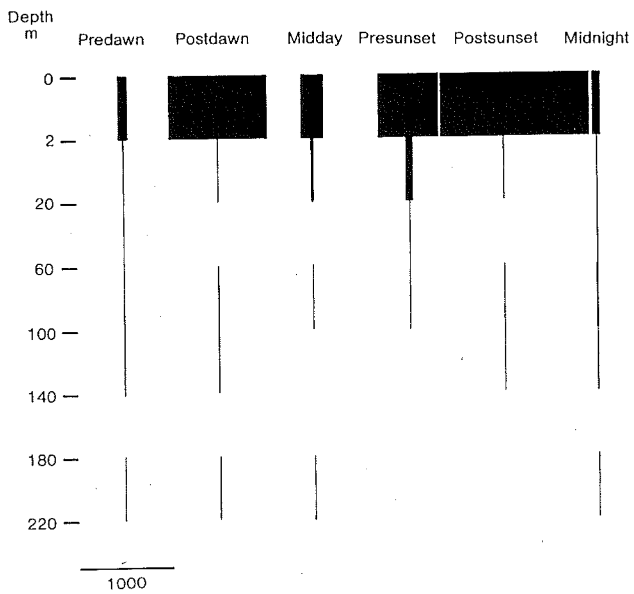


Figure 28 Notothenia gibberifrons.

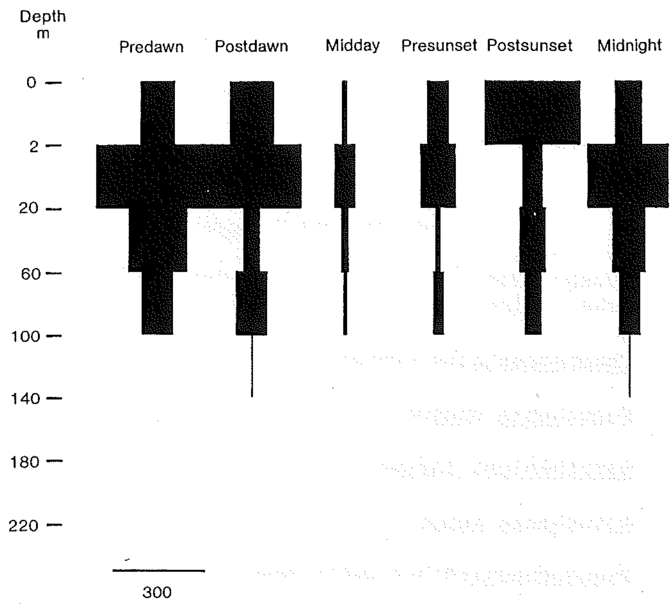
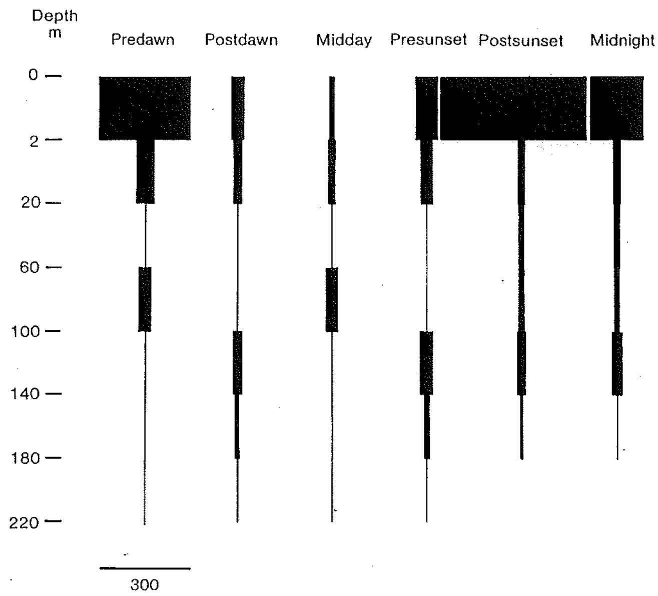


Figure 29 Nototheniops larseni.



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SC-CAMLR-VI/BG/12 Rev.1

RESULTS OF FISH STOCK ASSESSMENT SURVEY, SOUTH GEORGIA REGION, NOVEMBER - DECEMBER 1986

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Abstract

Biomasses and length compositions of eight stocks from South Georgia are described based on results of a stratified random bottom trawl survey. A total of 124 tows was undertaken between 29 November and 17 December 1986 by the R.V. Professor Siedlecki using a Polish B-454 otter trawl. Biomass was estimated based on stratified swept-area calculations. Estimates of biomass of Notothenia rossii and Patagonotothen brevicauda guentheri were an order of magnitude lower than observed by Kock in 1985. Abundance of Dissostichus eleginoides and Pseudochanichthys georgianus appeared lower in 1986/87 than 1984/85, although not by an order of magnitude. Abundances of Notothenia gibberifrons and Chaenocephalus aceratus as estimated by this study and Kock were roughly equal. Abundance estimates of Chamsocephalus gunnari were larger in 1986/87 than 1984/85, probably due to good recruitment of 1983/84 and 1984/85 year classes. Coefficients of variation ranged from 67.9% (Notothenia squamifrons) to 12.6% (C. aceratus).

Résumé

Les biomasses et les compositions en longueurs de huit stocks de la Géorgie du Sud sont décrites à partir des résultats obtenus au cours d'une prospection stratifiée au chalut de fond effectuée au hasard. Entre le 29 novembre et le 17 décembre, le navire de recherche Professeur Siedlecki a effectué un total de 124 traits au moyen d'un chalut à panneaux polonais B-454. La biomasse a été estimée à partir de calculs portant sur une aire balayée stratifiée. Les estimations de la biomasse de Notothenia rossii et de Patagonotothen brevicauda guentheri étaient nettement inférieures à celles observées par Kock en 1985. L'abondance de Dissostichus eleginoides et de Pseudochaenichthys georgianus est apparue moindre en 1986/87 qu'en 1984/85, pas à un degré important cependant. En ce qui concerne l'abondance de Notothenia gibberifrons et de Chaenocephalus aceratus, cette étude et celle entreprise par Kock ont abouti à des estimations sensiblement égales. Les estimations d'abondance de Champsocephalus gunnari étaient plus élevées en 1986/87 qu'en 1984/85, probablement à cause d'un bon recrutement des classes d'âge 1983/84 et 1984/85. Les coefficients de variation allaient de 67,9% (Notothenia squamifrons) à 12,5% (C. aceratus).

Resumen

Se describen las composiciones por biomasas y por tallas de ocho reservas de Georgia del Sur, en base a los resultados de una prospección de arrastre de fondo aleatoria estratificada. El buque de investigación Professor Siedlecki emprendió un total de 124 remolques entre el 29 de noviembre y el 17 de diciembre de 1986 usando un arrastre con puertas polaco B-454. La biomasa fue estimada en base a cálculos estratificados de área barrida. Las estimaciones de la biomasa de Notothenia rossii y Patagonotothen brevicauda guentheri fueron menores en un orden de magnitud que las observadas por Kock en 1985. La abundancia de Dissostichus eleginoides y Pseudochaenichthys georgianus parecieron ser menores en 1986/87 que aquellas de 1984/85, aunque no en un orden de magnitud. Las abundancias de Notothenia gibberifrons y Chaenocephalus aceratus, tanto las estimadas en este estudio, como aquellas estimadas por Kock resultaron aproximadamente iguales. Las estimaciones de la abundancia de Champsocephalus gunnari fueron mayores en 1986/87 que aquellas de 1984/85, probablemente debido a un buen restablecimiento de las clases-año de 1983/84 y 1984/85. El rango de los coeficientes de variación fue de 67.9% (Notothenia squamifrons) a 12.6% (C. aceratus).

Резюме

Биомасса и состав по длине для восьми запасов в районе Южной Георгии даются на основе результатов послойных выборочных съемок с помощью донного трала. Всего в период с 29 ноября по 17 декабря 1986 г. НИС "Профессор Сидлецки" было произведено 124 траления польским оттертралом "В-454". Биомасса оценивалась на основе расчетов по послойно протраленным площадям. Оценки биомассы Notothenia rossii и Patagonotothen brevicauda guentheri были на порядок ниже, чем таковые по наблюдениям Кока в 1985 г. Численность Dissostichus eleginoides и Pseudochaenichthys georgianus оказалась меньше в 1986/87 г., чем в 1984/85 г., хотя и не на порядок. Оценки численности Notothenia gibberifrons и Chaenocephalus aceratus, полученные в данной работе и Коком, были приблизительно одинаковы. Оценки численности Champsocephalus gunnari были выше для 1986/87 г., чем для 1984/85 г., - возможно, в связи с успешным пополнением запаса годовыми классами 1983/84 и 1984/85 г.г. Коэффициент вариативности колебался от 67,9% (Notothenia squamifrons) до 12,6% (C. aceratus).

RESULTS OF FISH STOCK ASSESSMENT SURVEY, SOUTH GEORGIA REGION, 24 NOVEMBER - 17 DECEMBER 1986

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INTRODUCTION

The decline of groundfish stocks since the late 1970's in the South Georgia region has been documented for several years (e.g., Kock et al. 1985). Of the major finfish resources, the decline in abundance of Notothenia rossii has been the most pronounced; by 1985, Kock (1985a) estimated stock size of N. rossii to be less than 10% of its original unexploited level. Declines in abundance of other species were estimated to be substantial between 1975/76 and 1980/81 (Kock et al. 1985).

Regulation of the South Georgia groundfish fisheries was established in 1984 when the Commission for the Conservation of Antarctic Marine Living Resources adopted measures to rebuild stocks of N. rossii. Those measures included prohibition of commercial fishing within 12 miles of the island of South Georgia, implementation of a 12 mm minimum mesh size in fisheries directed toward N. rossii and Dissostichus eleginoides and implementation of a minimum mesh size of 80 mm in fisheries direction toward Notothenia gibberifrons, Notothenia kempi, Notothenia squamifrons, and Champsocephalus gunnari. The mesh measures were to become effective September 1985. In 1985, the Commission also recommended minimization of by-catch of N. rossii in other fisheries.

1 Colleagues Dr Jozef Sosinski, Sea Fisheries Institute, Gdynia, Poland and Dr Krzysztof Skora, Marine Field Laboratory at Hel, Institute of Oceanography, Gdansk University Poland have not had the opportunity to review the content of this draft, but should be affiliated as authors because of their substantial past and future involvement and contribution.

The objective of this paper is to evaluate the current status of groundfish stocks, based on comparisons of estimates of stock biomass and length composition from research vessel surveys in 1984/85 (Kock 1985a, Kock 1985b) and 1986/87.

METHODS

Sampling was based on a stratified random survey design, in which stations were allocated to 100 m depth strata (stratum 1: 50-150 m, stratum 2: 151-250 m, stratum 3: 251-500 m) roughly in proportion to the area within each stratum (Everson 1984). Within each stratum, stations were randomly assigned. (The design of Kock (1985a,b) is most similar, and consequently will serve as the basis for most of the comparisons here.)

Thirty minute tows were made by the R.V. Profesor Siedlecki using a Polish B-454 otter trawl equipped with 80 mm mesh and a 20 mm liner. Distance between wing nets averaged 20.6 m, and headrope height was approximately 4 m. (Zaucha pers. comm.). Distance over bottom was recorded to the nearest tenth of a nautical mile (0.18532 km).

A total of 124 tows were accomplished between 29 November and 17 December 1986. Of 111 tows performed along the South Georgia coast, 95 were considered standard (e.g., relatively little or no gear damage) (Figure 1). In the Shag Rocks region, 13 tows were made without a liner, of which 11 were considered standard. Sampling density was 1 successful tow/384 km^2 along the South Georgia region and 1 tow/482 km^2 in the Shag Rocks region. Of the 58 possible division/depth combinations described by Everson (1984), 11 were unsampled, (9.8% of the total area between 50-500 m). Total trawlable biomass was estimated based on stratified swept-area calculations (SURVAN program, Kramer MS).

RESULTS

Notothenia rossii

Notothenia rossii occurred in 28 out of 95 hauls (26%) near South Georgia, primarily along the southeast and northern portions of the island (Figure 2). Eleven tows consisted of only one specimen, and 22 of the 28 hauls contained three individuals or less. A single relatively large haul (457.6 kg) northeast of Cumberland fjords (stratum 2) accounted for over 65% of the total biomass caught. Catch per tow (kg) and total biomass (mt) was lowest in stratum 1 (Table 1).

In light of the relatively large proportion of zero catches and the similarity to a log-normal distribution of the non-zero catches, biomass was estimated based on the delta distribution (Pennington, 1983) and normal distribution (Table 2), to develop more precise estimators.

From the survey data, N. rossii biomass was estimated to be 4 500 mt (from the normal distribution) and 2 400 mt (from the delta distribution). These values are 35% and 19%, respectively, of the 1984/85 estimates. Specimens ranged in length from 27-68 cm, with a mean length of 47.1 cm, and few fish below 40 cm (Figure 3).

Notothenia gibberifrons

Notothenia gibberifrons occurred at 97% of the South Georgia stations and 73% of the Shag Rock stations. Largest catches were obtained north and southeast of South Georgia (Figure 4), with the single largest catch (204.8 kg) contributing 9% of total catch.

Total biomass near South Georgia was estimated at approximately 13 500 mt, over half of which was estimated to occur between 151-250 m, and about one third occurring between 251-500 m (Table 1). Mean lengths of 17.9, 21.3 and 32.0 were observed in strata 1-3, respectively, with an overall mean length of 22.3 cm. Depending on the age-length schedule used, modes at 8, 16 and 20 cm (Figure 5) would correspond to age groups 1-3, respectively; a mode expected near 26 cm (age 4) is not evident; and the peak at 38 cm would correspond to age 8 fish (1978/79 year class) (Boronin and Frolkina 1976, Shust and Pinskaya 1978, as tabulated in Kock et al. 1985). If alternate age-length schedules are used (e.g., Skora 1980, in Kock et al. 1985), the 21-23 cm values would probably represent age 3-5 fish, with relatively few age 6-8 year olds (25-29 cm). The peak at 37-38 cm would then correspond to age 12 fish, the 1974/75 year class. Biomass at Shag Rocks was relatively low (400 mt), primarily found between 50-150 m. Mean length in stratum 1 was estimated at 34.0 cm and 33.6 cm overall (age 9 under schedule of Skora, 1980; age 6 otherwise), and probably reflects the larger mesh size used there (Figure 6).

Notothenia squamifrons

Notothenia squamifrons occurred at relatively few South Georgia stations (31%) but contributed to some of the largest hauls in the survey (5 226 kg and 2 355 kg/30 min. tow, division 65) (Figure 7). Catch per tow was highest between 251-500 m (on the west/southwest coast) and between 200-250 m (on the northeast coast). The two largest hauls contributed 98% of the total biomass caught of this species. The species also occurred at Shag Rocks, but at much lower densities (Tables 1,2).

Biomass estimates based on a delta distribution were an order of magnitude lower than those based on a normal distribtion, 9 000 vs. 40 000 mt, respectively (Table 2); and the former estimate appears more realistic, as distribution of haul values is described by the delta distribution much more accurately than the normal. Specimen lengths range from 10 to 49 cm (Figure 8), with overall mean length of 35.0 cm and modes at 14 cm, 29 cm and 40-42 cm. Patterns at Shag Rocks were less regular (Figure 9), based on only the 45 specimens caught in that region.

Patagonotothen brevicauda guentheri

This species occurred only in the Shag Rocks region (division 89, Everson 1984) in the two shallowest strata (Table 1). All observed lengths fell between 9 -22 cm, except for a single specimen at 27 cm. Modes were observed at 13 and 17 cm in both strata; however, the 13 cm mode was more pronounced at shallower stations (between 50-150 m) (Figure 10). Biomass estimates appear unrealistically low, below recent reported catch levels and an order of magnitude lower than previous survey estimates (Kock, 1985b) (Table 2).

Dissostichus eleginoides

Catches of Dissostichus eleginoides were largest at stations between 251-500 m in South Georgia and between 151-250 m at Shag Rocks (Table 1, Figure 11). The species occurred at 37% of the stations from South Georgia at catch rates between 0.1-86.0 kg/tow. At Shag Rocks, the species was ubiquitous, occurring at ten out of eleven of the stations, at catch rates between 1.0-32.0 kg/tow.

Total biomass was estimated at 2 600 mt, with about one third of the biomass contributed by the Shag Rocks region (Table 2). Mean lengths of 16.6, 32.4 and 48.8 cm were observed from South Georgia strata 1-3, with an overall mean of 44.7 cm (Figure 12). At Shag Rocks, overall mean length was estimated at 38.3 cm (Figure 13). Length frequency distributions from both areas showed modes around 16-17 cm, 27 cm, 37-38 cm, 44-47 cm and 52-53 cm, with only a few individuals greater than 55 cm.

Champsocephalus gunnari

Champsocephalus gunnari was ubiquitous throughout the survey region, occurring at all stations at South Georgia and nine out of eleven stations st Shag Rocks (Figure 14). Catch per tow ranged from 0.2-879.5 kg/30 min tow. Most biomass was concentrated between 151-250 m (Table 1).

Biomass estimates of 61 000 mt in 1986/87 are comparable to below median levels observed between 1978-80 from virtual population analysis. The overall coefficient of variation of the biomass estimate (17.6%) is below the average for survey indices for Northwest Atlantic demersal species (NEFC, MS). Mean fish length by stratum increased with depth from 22.4 to 26.5 and 27.5 cm in strata 1-3 (South Georgia), respectively, averaging 25.2 cm overall (Figure 15). Modes at 14, 22 and 26 cm correspond to fish aged 1, 2 and 3. The shift in the length frequency distribution to a mode at 24 cm on Shag Rocks (Figure 16) may reflect differential distribution of the year class by size, and more likely, the use of unlined 80 mm mesh in that area.

Pseudochaenichthys georgianus

Highest catch rates of Pseudochaenichthys georgianus were obtained from stations on the eastern side of South Georgia, at depths greater than 151 m (Figure 17, Table 1). The species occurred at 79% of the South Georgia stations at catch rates between 0.1-58.0 kg/tow.

Total biomass was estimated at 5 200 mt, slightly over half of which was concentrated between 151-250 m. Overall mean length was 37.2 cm, with a strong mode at 33-34 cm, probably representing age 3 fish (Figure 18). The upper mode(s) (48-51 cm) probably include fish aged 6-7 or 8 (depending on published curve used) (Kock et al. 1985).

Chaenocephalus aceratus

Chaenocephalus aceratus was most abundant in the eastern and southeastern shelf of South Georgia (Figure 19), primarily at depths between 151-250 m (Table 1). The species was observed at 84% of the South Georgia stations; maximum catch in a single haul was 162.4 kg.

Total biomass was estimated at 11 700 mt. Observed lengths ranged between 13-76 cm, with an overall mean length of 34.2 cm (Figure 20). In contrast to most patterns of increasing fish size with depth, mean length in this case decreased with depth, from 49.8 to 34.8 and 32.3 cm in strata 1-3, respectively. A combined series of three adjacent stations north of Clerke Rocks between 250-500 m produced 19% of the total number of individuals estimated caught, with a strong mode at 25 cm. Seventy-one fish were measured from stations in stratum 1, representing almost the entire catch from the stratum; 89% of those fish were 40 cm or above. Successive modes in the length frequency distribution of 15, 25, 34, 42 and 50 cm correspond to published mean lengths at ages 1, 2, 3, 5 and likely 6 (Kock et al 1985); an expected mode corresponding to age 4 fish between 36-40 cm was not present. Length at 50% maturity has been estimated at around 46-47 cm (approximately age 6) and 95% maturity between 52-57 cm approximately age 7 (Kock et al. 1985). Consequently, it appears that about 10% of the population is between 50-95% mature (e.g. 46-51 cm) and only 12% of the current population is fully sexually mature (e.g. ≥52 cm).

DISCUSSION

Even though biomass estimates of N. rossii by Kock (1984a) and this study have relatively large associated variances, it is far more likely that the stock has continued to decline in recent years rather than stabilizing or rebuilding. The two largest single hauls in this study were both only 10% of the two largest hauls observed in 1984/85. The mean length (47.1 cm) was almost 3 cm smaller than observed in 1984/85 (49.9 cm), and was close to the length at 50% maturity for females (Kock 1986a); the mode has also shifted downward from 50 to 44 cm. (It remains to be investigated if length at sexual maturity has continued to decrease since 1984/85 (Kock 1985a)).

Biomass estimate for N. gibberifrons of 15 800 mt in 1984/85 and 14 000 mt in 1986/87 are not significantly different given the variability of the estimates. Based on length frequency distributions from South Georgia, recruitment appeared to be declining in recent cohorts in the

25-29 cm length range : the peak at 38 cm is consistent with the large 1974/75 year class identified in previous virtual population analyses, when consistent age/length schedules are used. Relatively large numbers of pre-recruits (<25 cm) may provide some opportunity to improve the status of this stock in the near future.

The extremely low biomass estimate for P. b. guentheri likely reflects the use of bottom trawl to sample a semi-pelagically distributed species. In that case, the difference in headrope height between this survey (approximately 4 m.) and the Federal Republic of Germany survey (6 m.) may also contribute to the lower estimate. Modes in the length frequency observed in this study are consistent with those observed by Kock (1985b), if interpreted using a growth curve developed by Soviet investigaotrs (Anon. 1984). In that case, modes observed in 1984/85 at 10 and 15 cm in January/February would correspond to fish ages 2 and 3 (1982/83 and 1981/82 year classes) (Figure 21). Modes observed here (November) at 13 and 17 would correspond to fish ages 3 and 4 (1983/84 and 1982/83 year classes), while the shoulder at 19 cm would correspond to fish age 5 (1981/82 year class). In that context, the low proportion of individuals greater than 16 cm observed by Naumov et al. (1983) in February 1978/79 may reflect low abundance of fish above age 3, or poor recruitment in year classes before 1976/77. This would be consistent with reports of no commercial catches of P. b. guentheri before 1978/79.

The estimated biomass of Dissostichus eleginoides is about 70% lower than in 1984/85 (Kock 1985b). Length frequency distributions contain few individuals over 55 cm, in contrast to 1984/85, when a significant proportion of fish were between 55-70 cm. Currently, nearly all of the population is likely to be sexually immature (Kock et al., 1985).

The 1987 estimate of C. gunnari biomass is three to four times that found by the 1985 Federal Republic of Germany survey (Kock 1985b, Table 2). Biomass estimates for this species are conservative : a) additional fish were observed using hydroacoustic gear at heights above the headrope during trawling and b) additional individuals on Shag Rocks may have been present but not retained by the mesh. The increase appears to be due to the relatively strong presence of age 2 fish. Part of this cohort is already vulnerable to the fishery, based on length frequency results from 80 mm mesh used on Shag Rocks. The 1985/86 year class looks relatively small, however.

Biomass estimates of Ps. georgianus have dropped by about a third since 1984/85 (Kock 1985b). Length frequency distributions indicate a relatively strong 1983/84 year class that would be expected to reach length of 50% maturity by the end of 1987/88 or the beginning of 1988/89.

Although estimates of biomass of C. aceratus have been relatively constant over time (10 013 mt, 1982/83 (Slosarczyk et al. 1984); 11 542 mt, 1984/85 (Kock 1985b); 11 742 mt 1986/87), the age structure of the population appears to have changed markedly, even since 1984/85. When length frequencies 30 cm or greater are considered, in 1984/85 about half the fish were at or above length of 95% maturity and a quarter of fish were below length of 50% maturity (Kock 1985b). By 1986/87, the situation was reversed : half the fish were below length of 50% maturity and about a quarter were at or above length of 95% maturity. Thus, although biomass estimates appear stable, the fraction of the biomass that is sexually mature seems to be decreasing, with the attendant increasing risk of recruitment overfishing.

ACKNOWLEDGEMENTS

We are especially grateful for the long hours by the participating scientists from the Sea Fisheries Institute and the deck crew of the R.V. Profesor Siedlecki during this cruise; as well as volunteer assistance by personnel from the British Antarctic Survey, Smithsonian Institute, Southeast Fisheries Center, University of Hawaii and Moss Landing Marine Laboratory.

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Table 1 Estimates of mean trawlable biomass and coefficients of variation by depth strata, November-December 1986/87.

	Stratum							
	50 - 150 m.		151 - 250 m.		251 - 500 m.		Combined	
	Minimum biomass (mt)	Coef. var. (%)	Minimum biomass (mt)	Coef. var. (%)	Minimum biomass (mt)	Coef. var. (%)	Minimum biomass (mt)	Coef. var. (%)
N. rossii								
South Georgia	131	38.7	3636	83.9	761	95.1	4528	69.2
N. gibberifrons								
Shag Rocks	349	54.4	51	46.5	-	-	400	47.9
South Georgia	1920	47.7	7567	15.8	4057	33.0	13544	14.9
N. squamifrons								
Shag Rocks	-	-	22	64.0	15	99.8	37	55.6
South Georgia	3	99.6	59	52.1	39930	76.3	39991	76.2
P. b. guentheri								
Shag Rocks	119	94.6	224	48.4	-	-	343	45.5
D. eleginoides								
Shag Rocks	202	40.7	433	57.1	335	99.8	969	43.7
South Georgia	5	85.7	50	36.4	1546	35.2	1601	34.0
C. gunnari								
Shag Rocks	5551	87.4	4992	60.8	-	-	10543	54.3
South Georgia	10224	62.7	32634	18.5	7556	29.5	50414	18.0
Ps. georgianus								
South Georgia	483	44.4	3253	20.2	1503	25.1	5240	15.0
Ch. aceratus								
South Georgia	551	40.2	7659	16.2	3533	21.7	11743	12.6
Number of hauls								
Shag Rocks	3		6		2		11	
South Georgia	19		47		29		95	

Table 2 Comparisons of estimates of mean trawlable biomass, standard deviation and coefficient of variation based on normal and delta distributions, November-December 1986/87, and relative to estimates by Kock (1985), January-February 1984/85.

	Shag Rocks			South Georgia			Combined		
	Minimum biomass (mt)	Std. dev.	Coef. var. (%)	Minimum biomass (mt)	Std. dev.	Coef. var. (%)	Minimum biomass (mt)	Std. dev.	Coef. var. (%)
N. rossii	-	-	-	4528	3134	69.2	4528	3134	69.2
Delta	-	-	-	2384	994	41.7	2384	994	41.7
Kock (1985)							12781	12768	99.9
N. gibberifrons	400	191	47.9	13544	2018	14.9	13944	2027	14.5
Kock (1985)							15762	4476	28.4
N. squamifrons	37	21	55.6	39991	30468	76.2	40028	30468	76.1
Delta	39	23	59.0	8997	6133	68.2	9036	6132	67.9
P. b. guentheri	343	156	45.5	-	-	-	343	156	45.5
Kock (1985)							7256	3417	47.1
D. eleginoides	969	423	43.7	1601	545	34.0	2570	690	26.8
Kock (1985)							8159	6242	76.5
C. gunnari	10543	5723	54.3	50414	9073	18.0	60957	10727	17.6
Kock (1985)							15821	16042	101.4
Ps. georgianus	-	-	-	5240	787	15.0	5240	787	15.0
Kock (1985)							8134	2684	33.0
Ch. aceratus	-	-	-	11743	1478	12.6	11743	1478	12.6
Kock (1985)							11542	4686	40.6

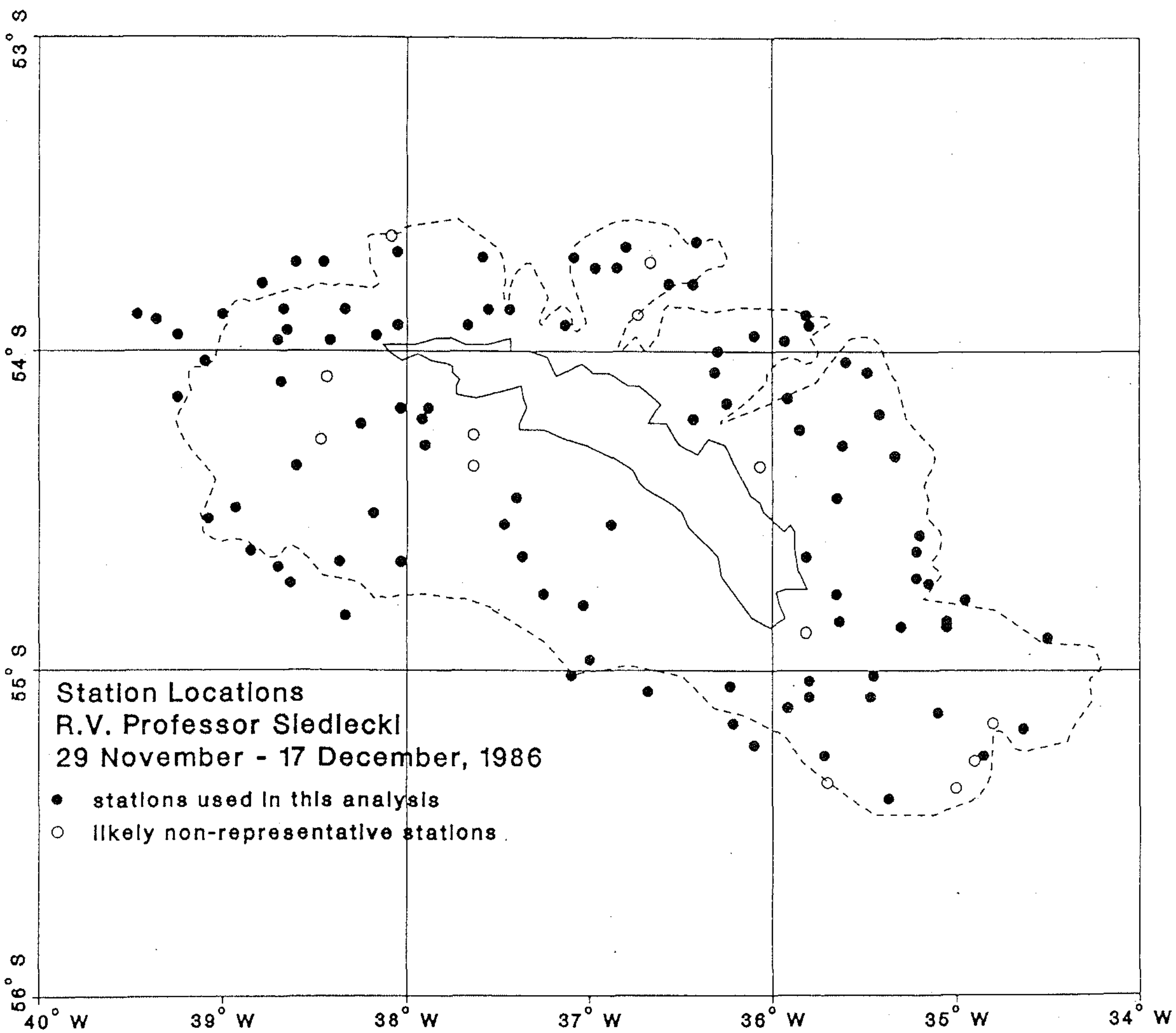

Figure 1. Station locations, South Georgia, R.V. Profesor Siedlecki, 29 November - 17 December 1986.

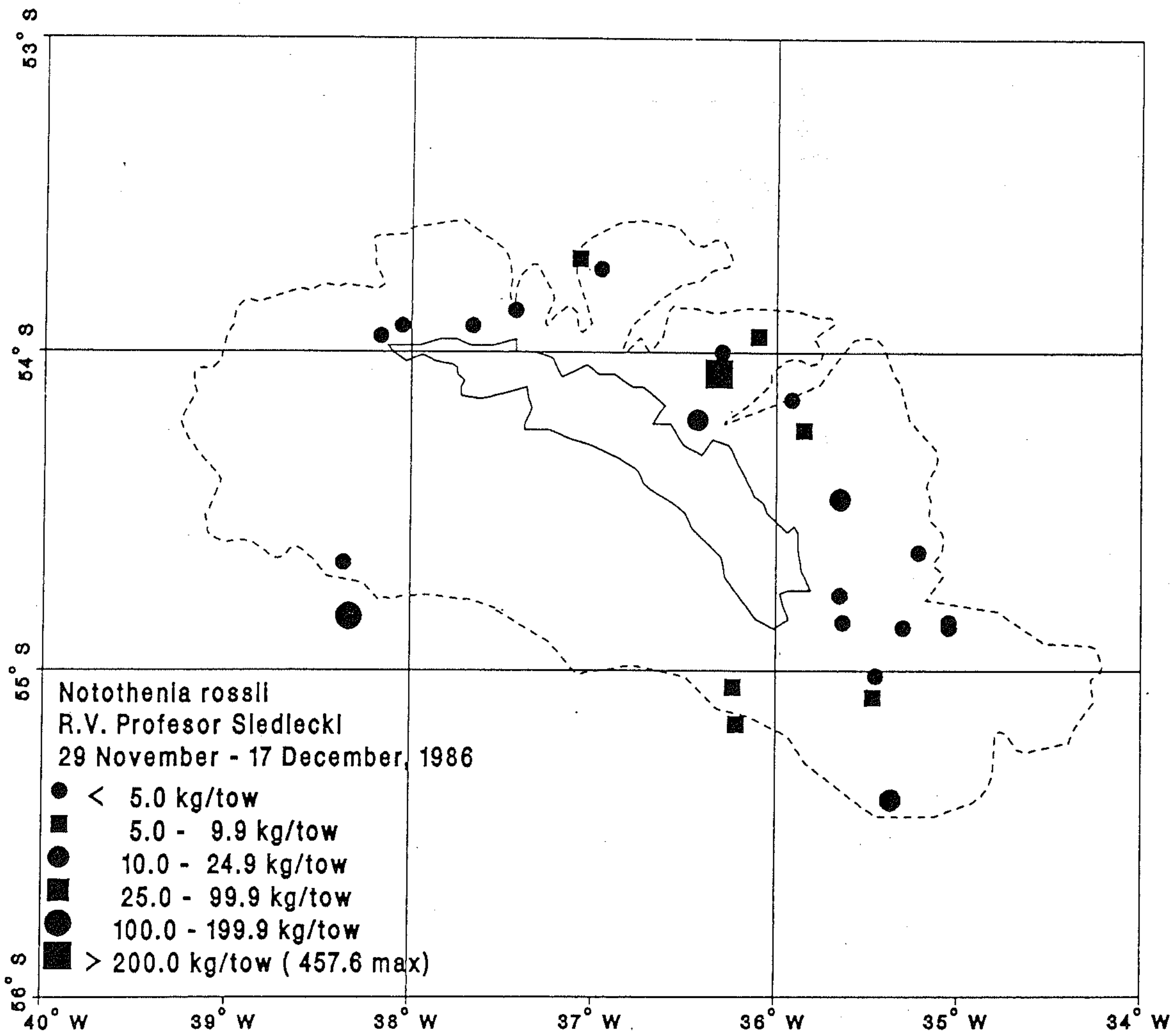

Figure 2. Distribution of catch per tow, Notothenia rossii, South Georgia.

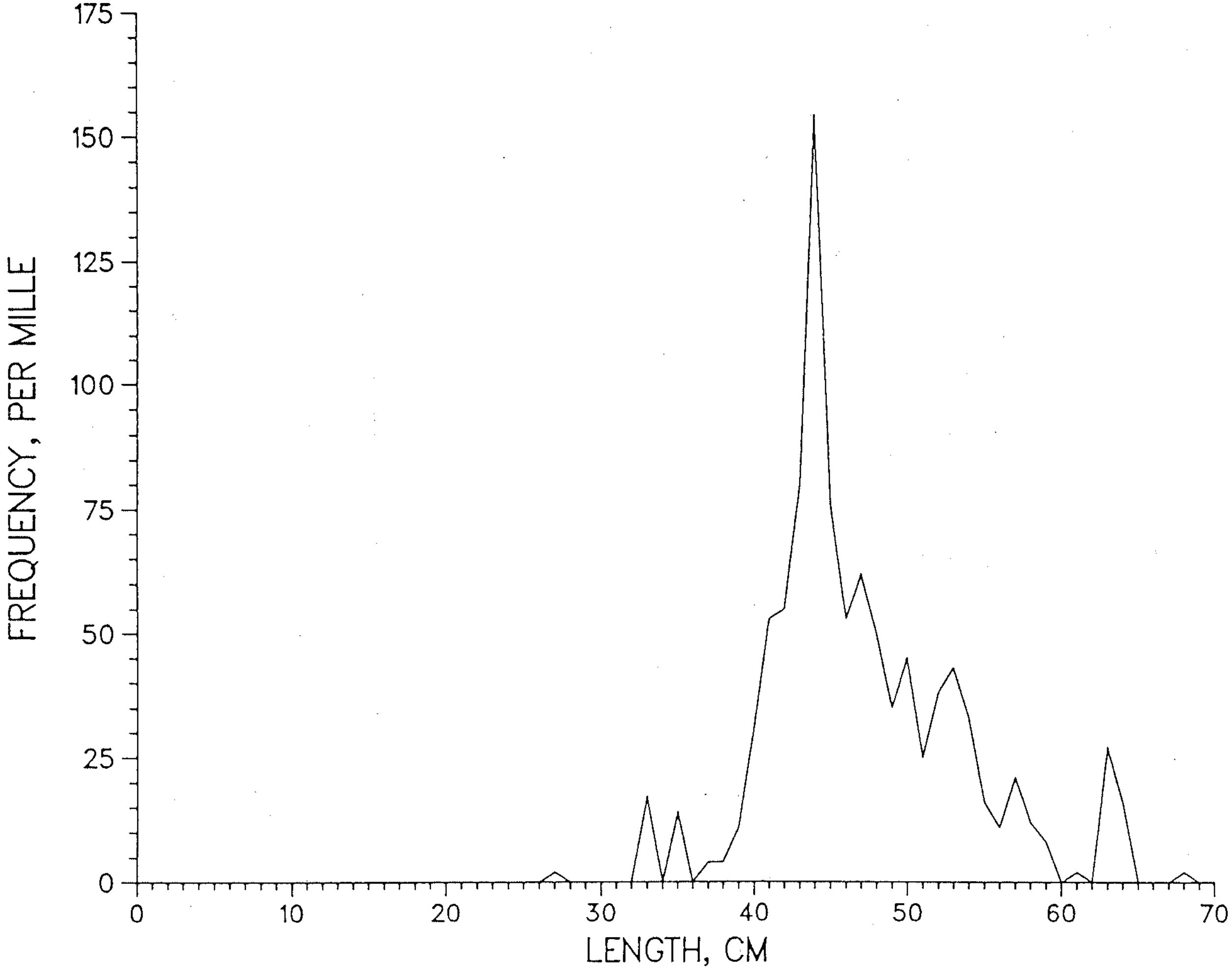

Figure 3. Length frequency distribution, N. rossii, South Georgia.

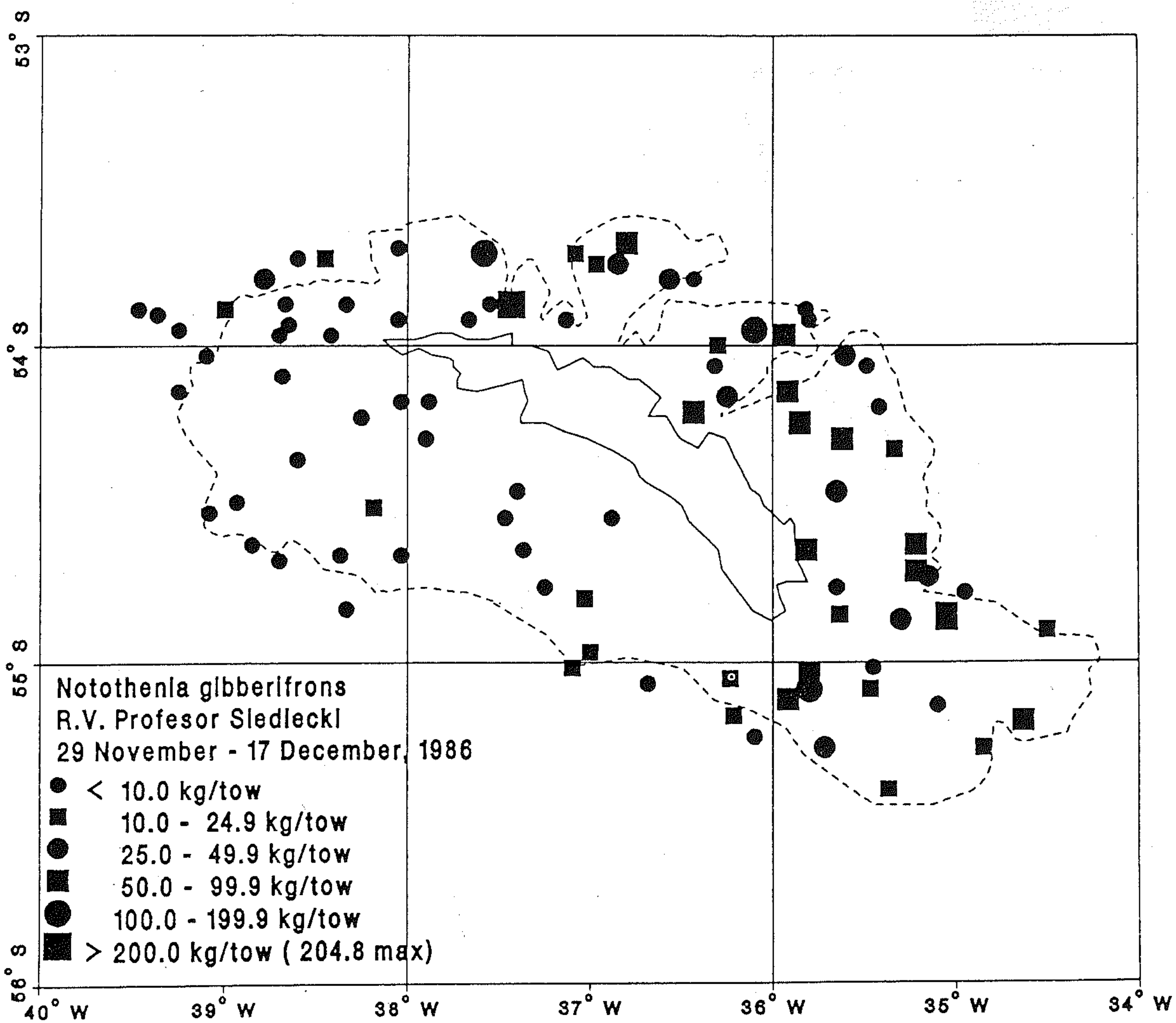

Figure 4. Distribution of catch per tow, Notothenia gibberifrons, South Georgia.

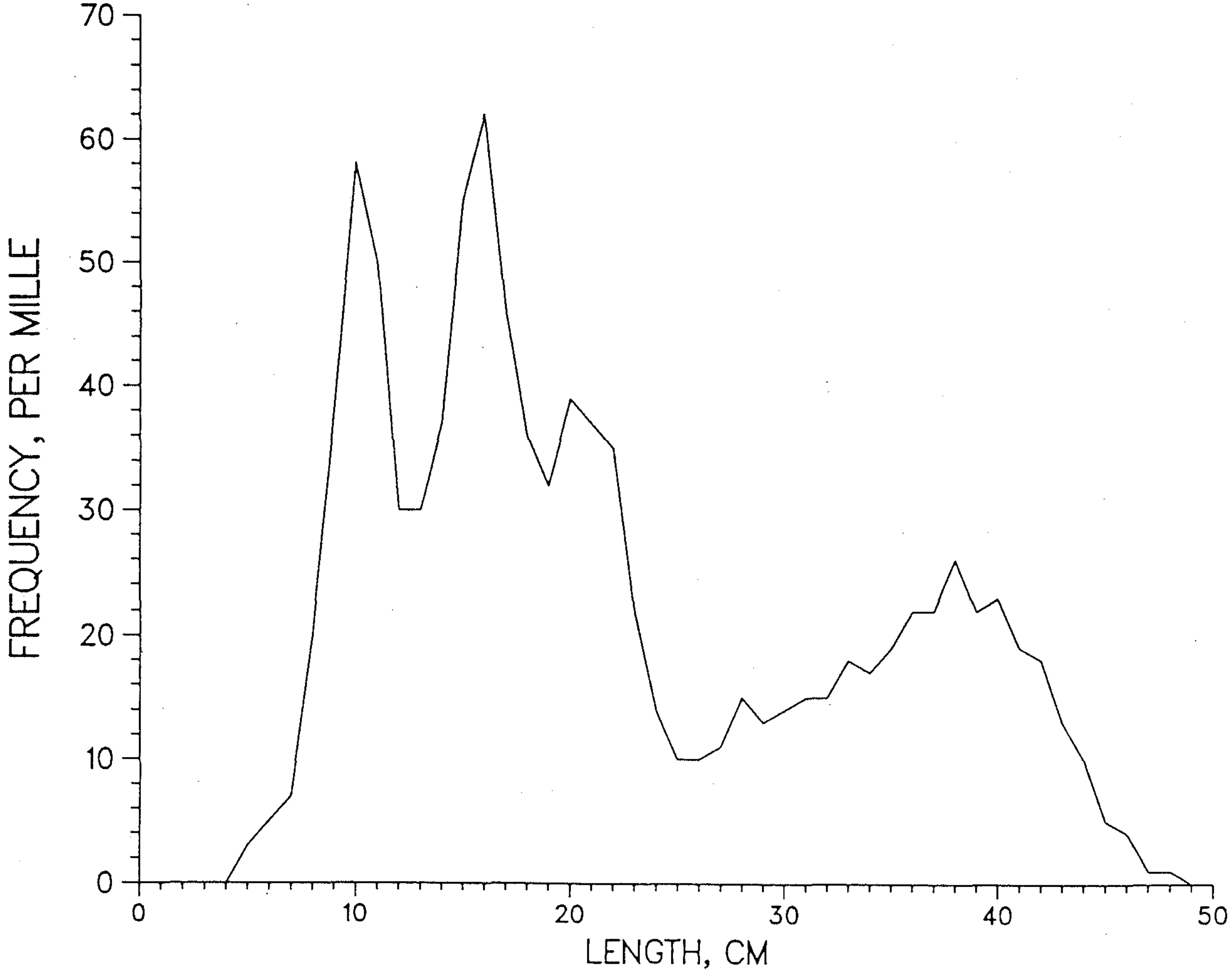

Figure 5. Length frequency distribution, N. gibberifrons, South Georgia.

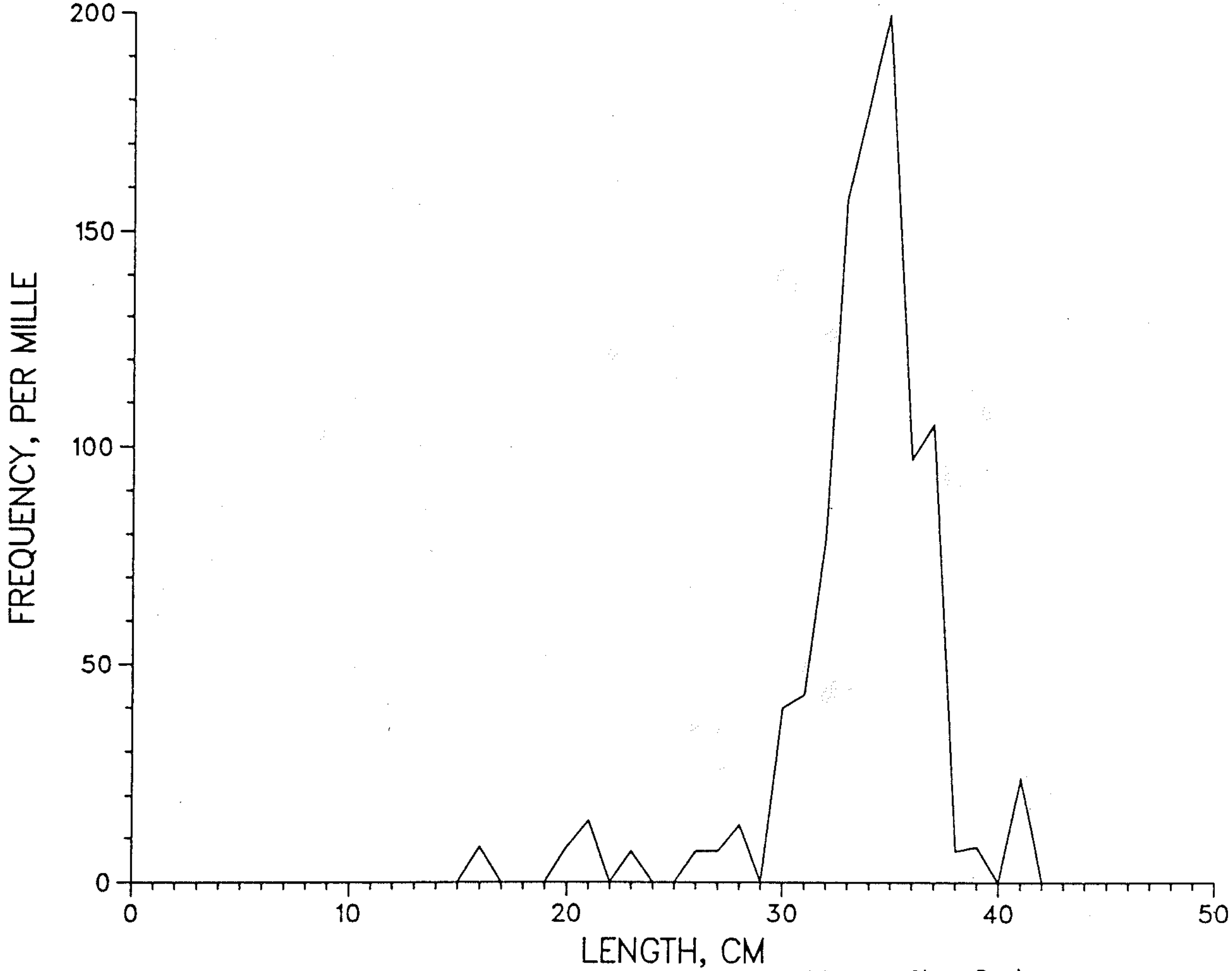

Figure 6. Length frequency distribution, N. gibberifrons, Shag Rock.

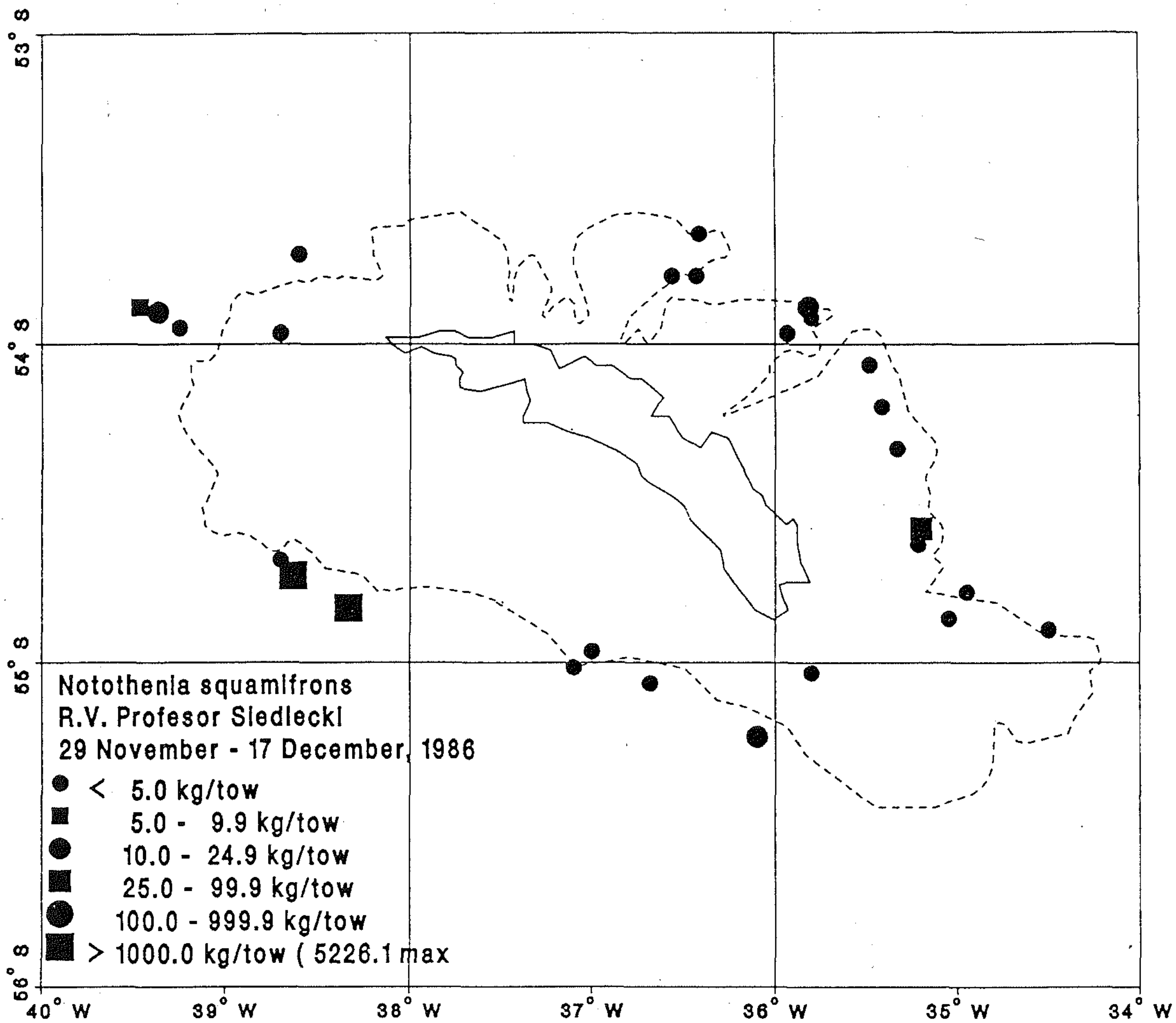

Figure 7. Distribution of catch per tow, Notothenia squamifrons, South Georgia.

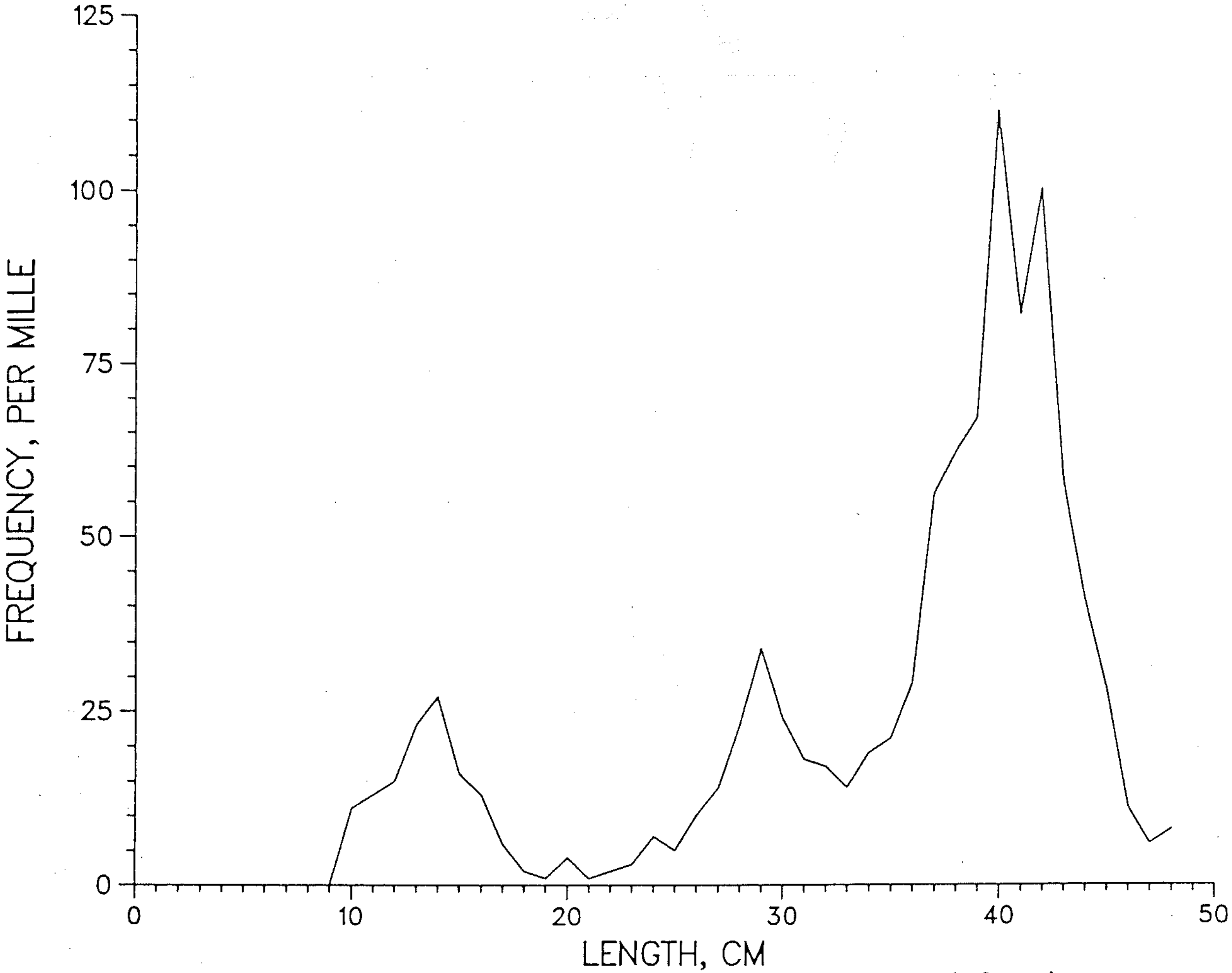

Figure 8. Length frequency distribution, N. squamifrons, South Georgia.

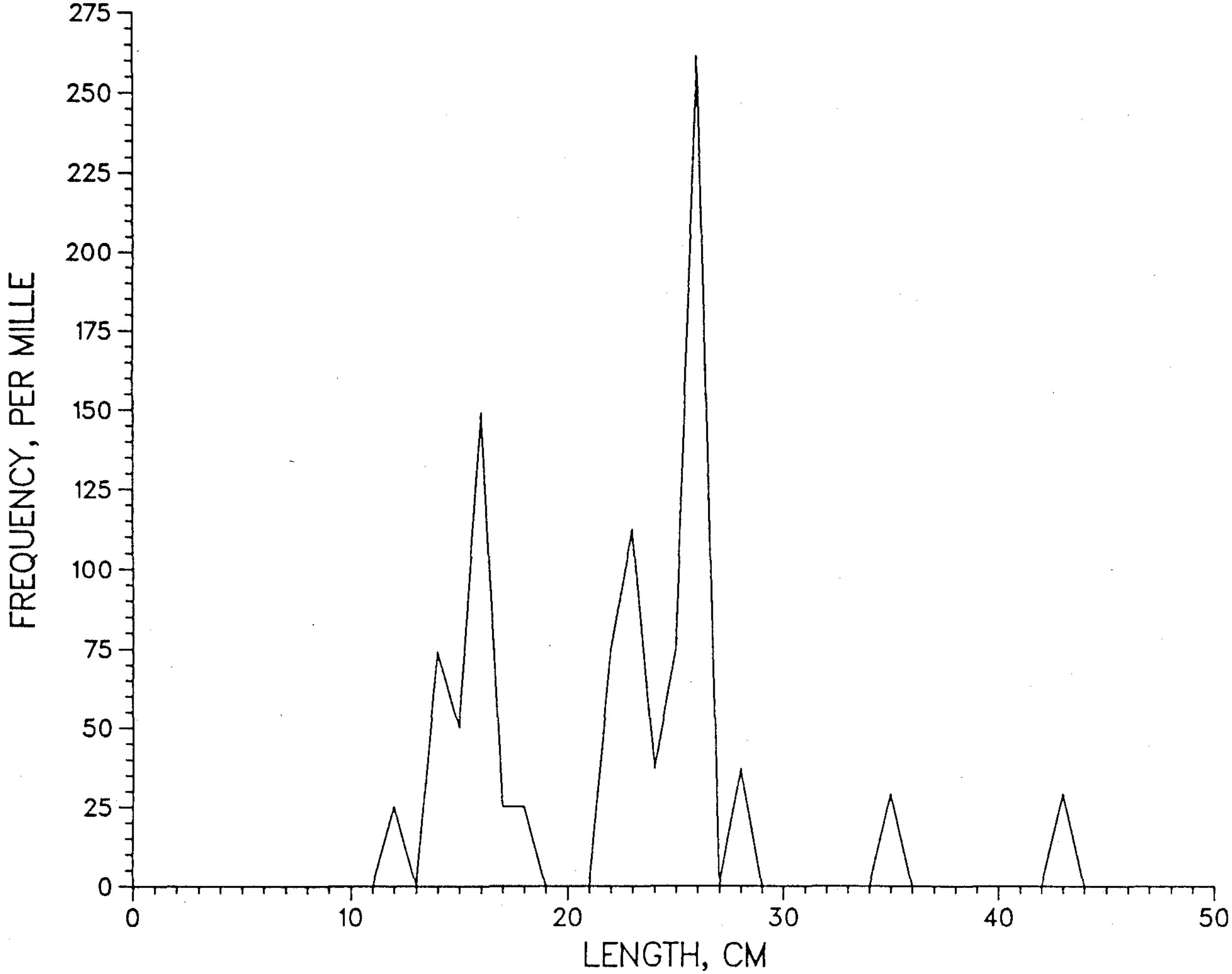

Figure 9. Length frequency distribution, N. squamifrons, Shag Rocks.

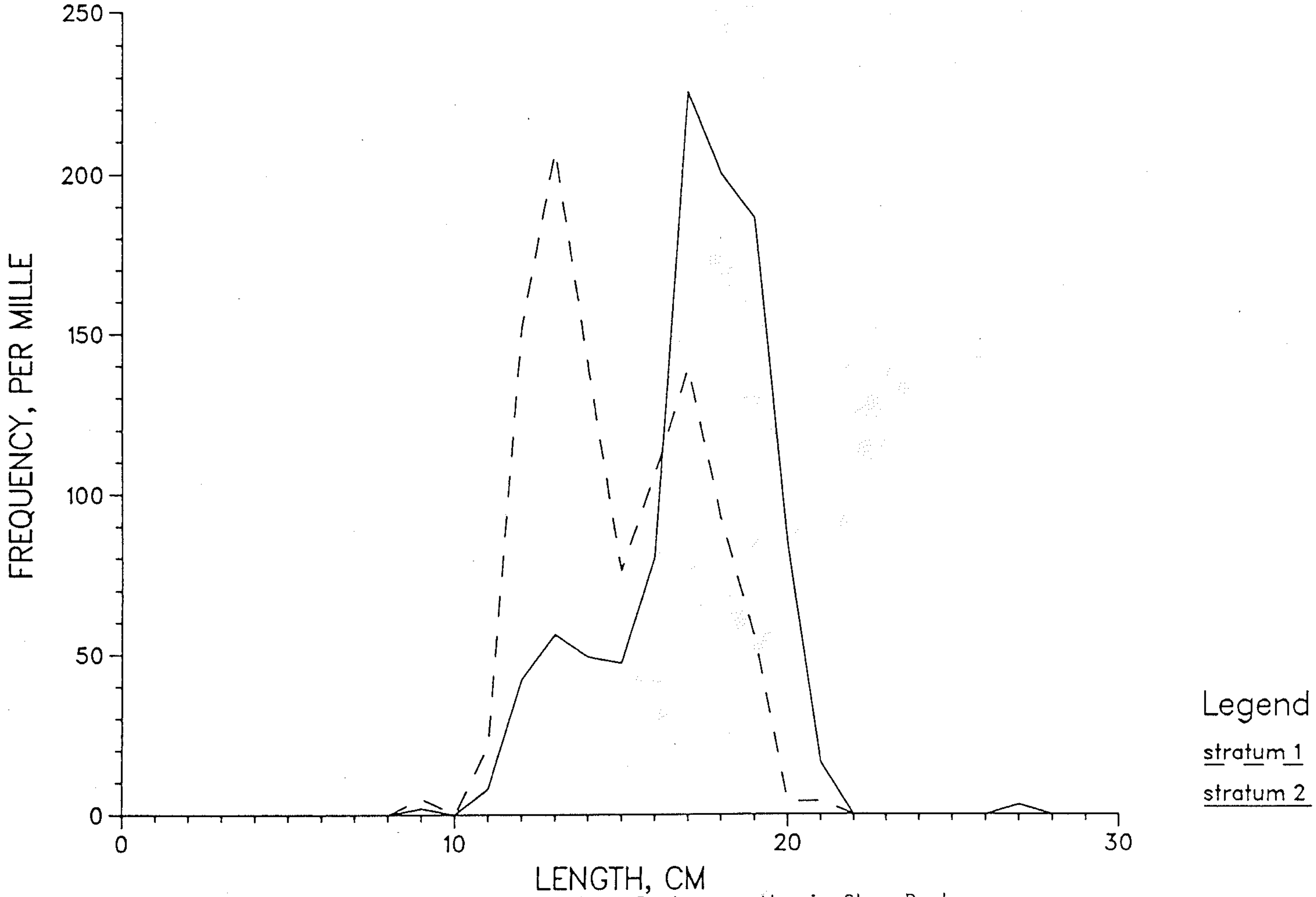

Figure 10. Length frequency distribution, *P. b. guentheri*, Shag Rocks.

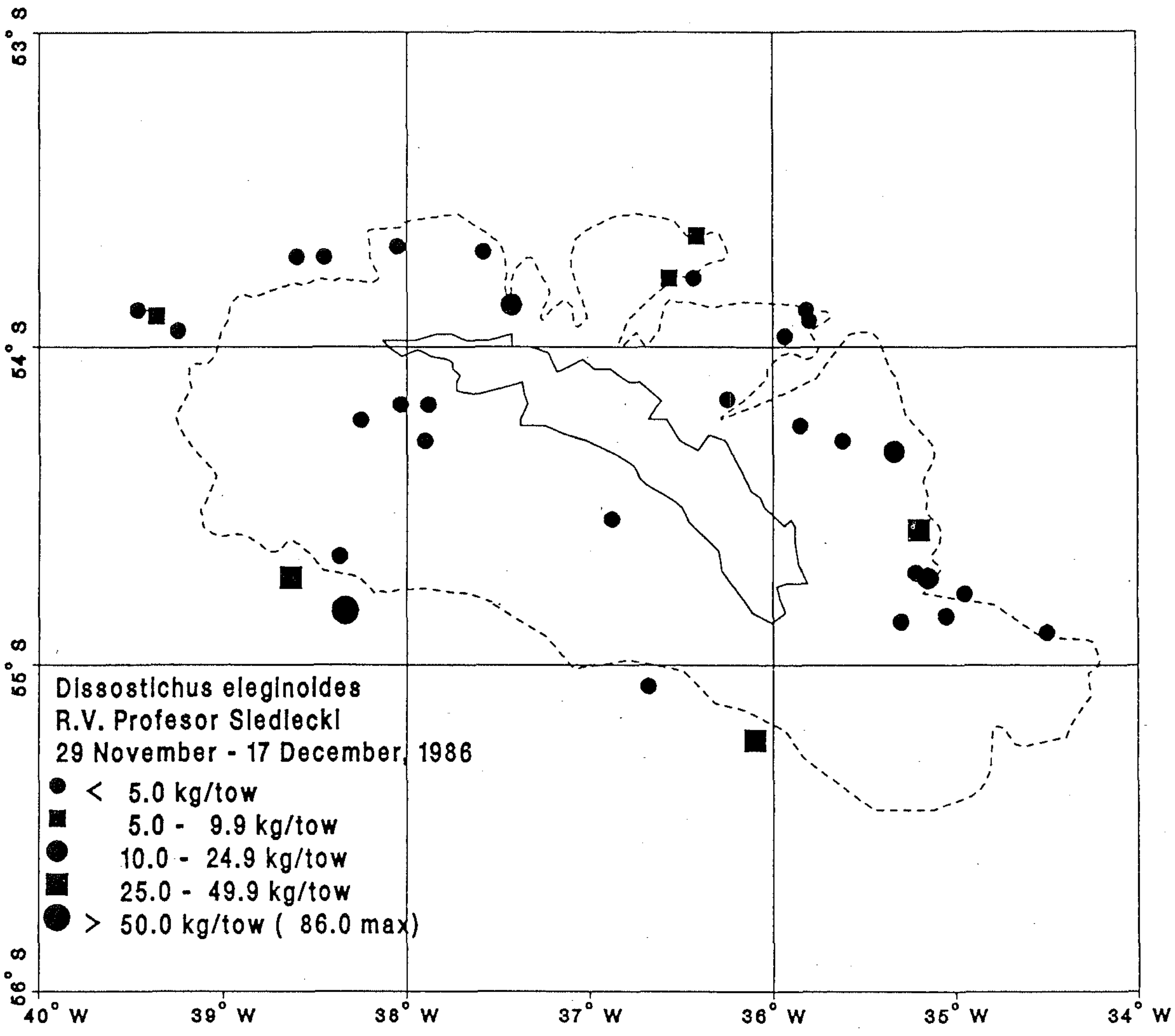

Figure 11. Distribution of catch per tow, Dissostichus eleginoides, South Georgia.

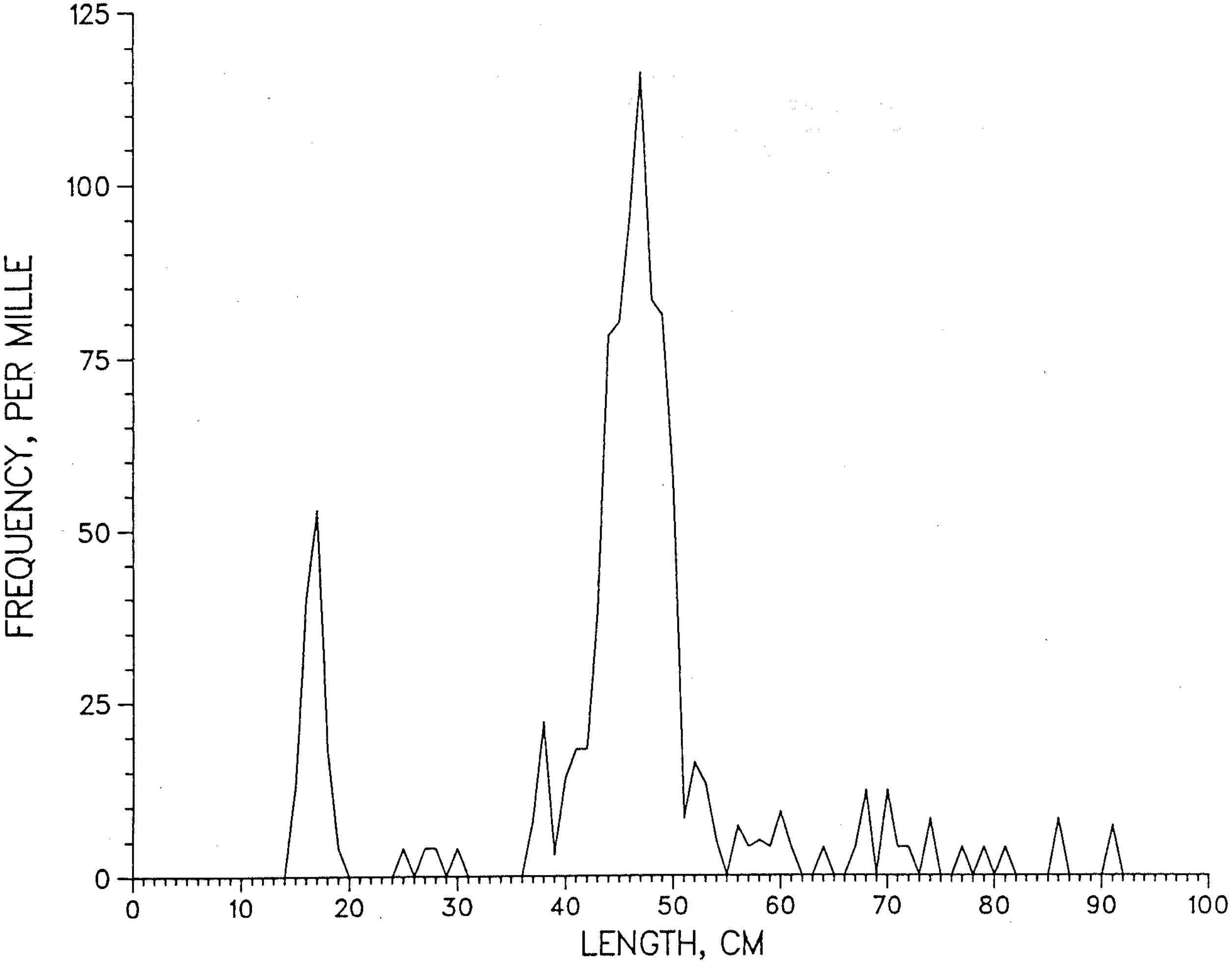

Figure 12. Length frequency distribution, D. eleginoides, South Georgia.

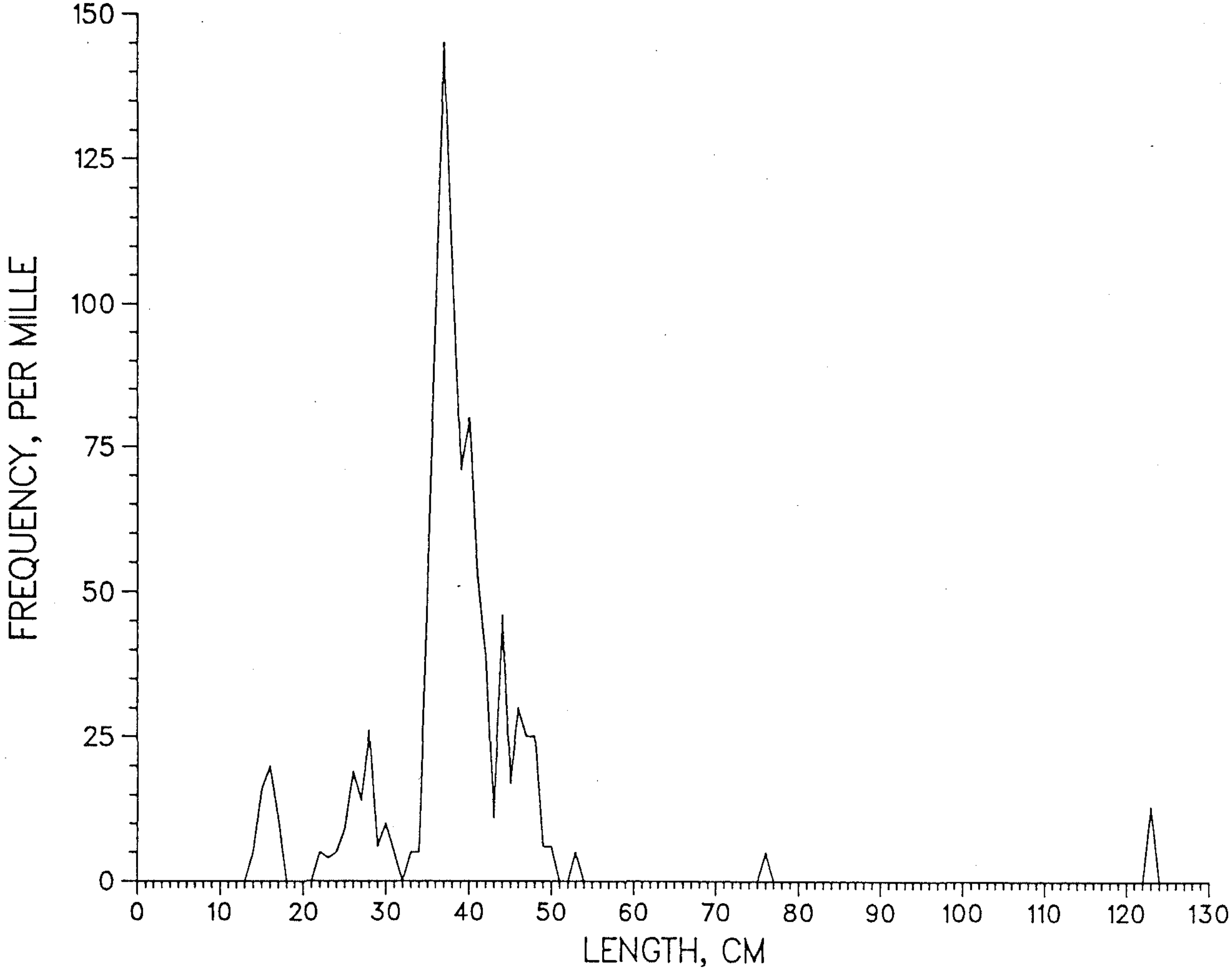

Figure 13. Length frequency distribution, D. eleginoides, Shag Rocks.

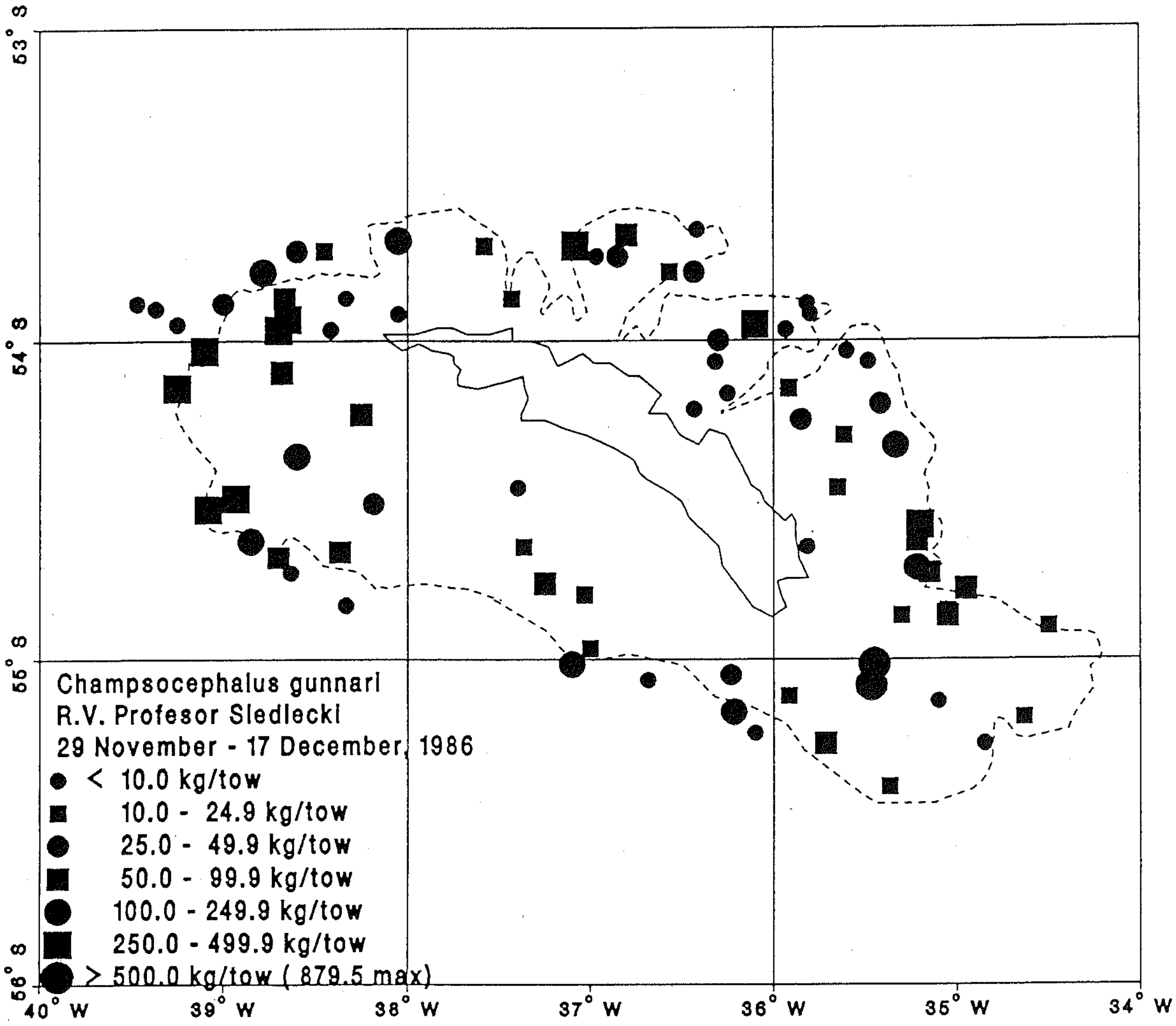

Figure 14. Distribution of catch per tow, Champsocephalus gunnari, South Georgia.

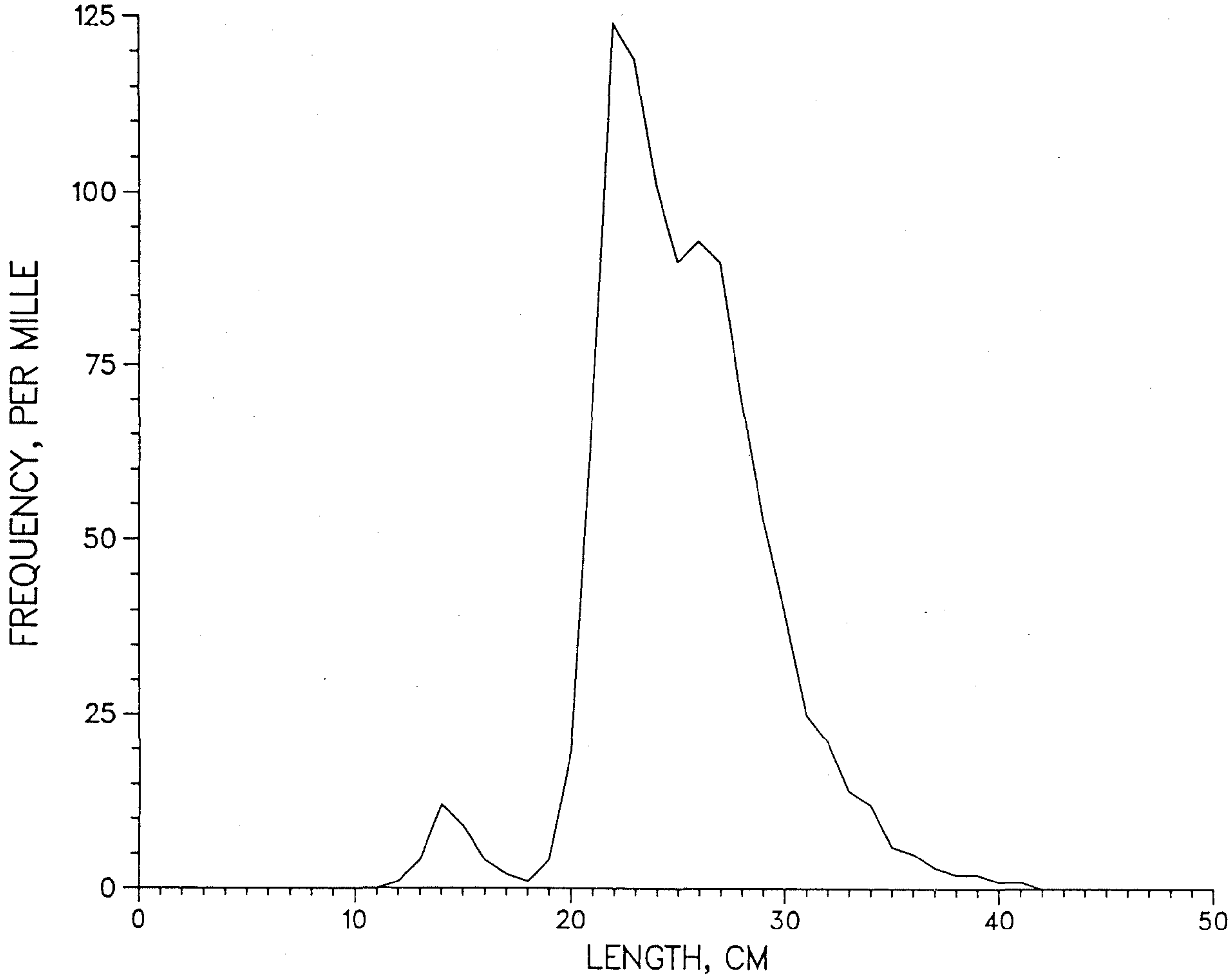

Figure 15. Length frequency distribution, C. gunnari, South Georgia.

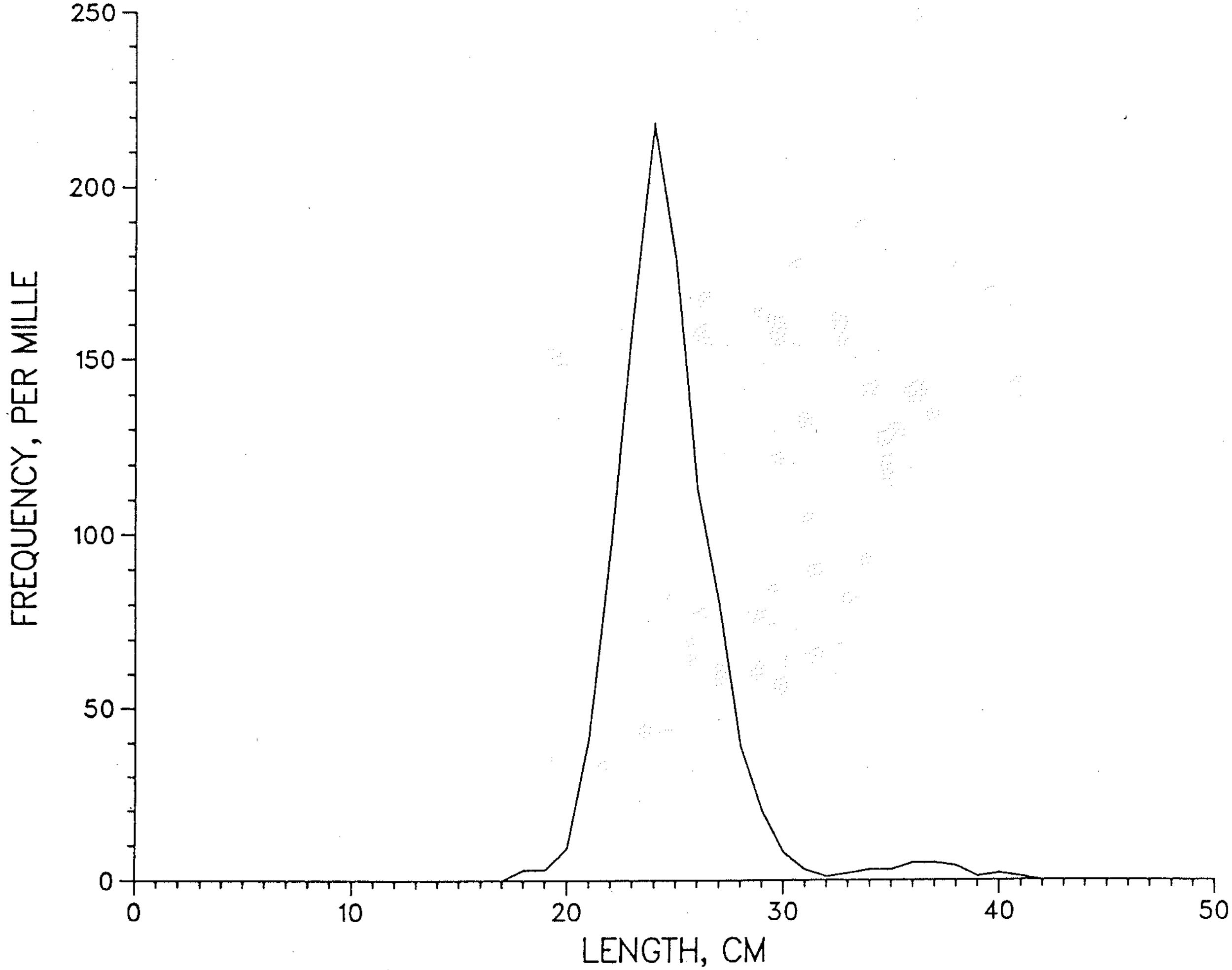

Figure 16. Length frequency distribution, C. gunnari, Shag Rocks.

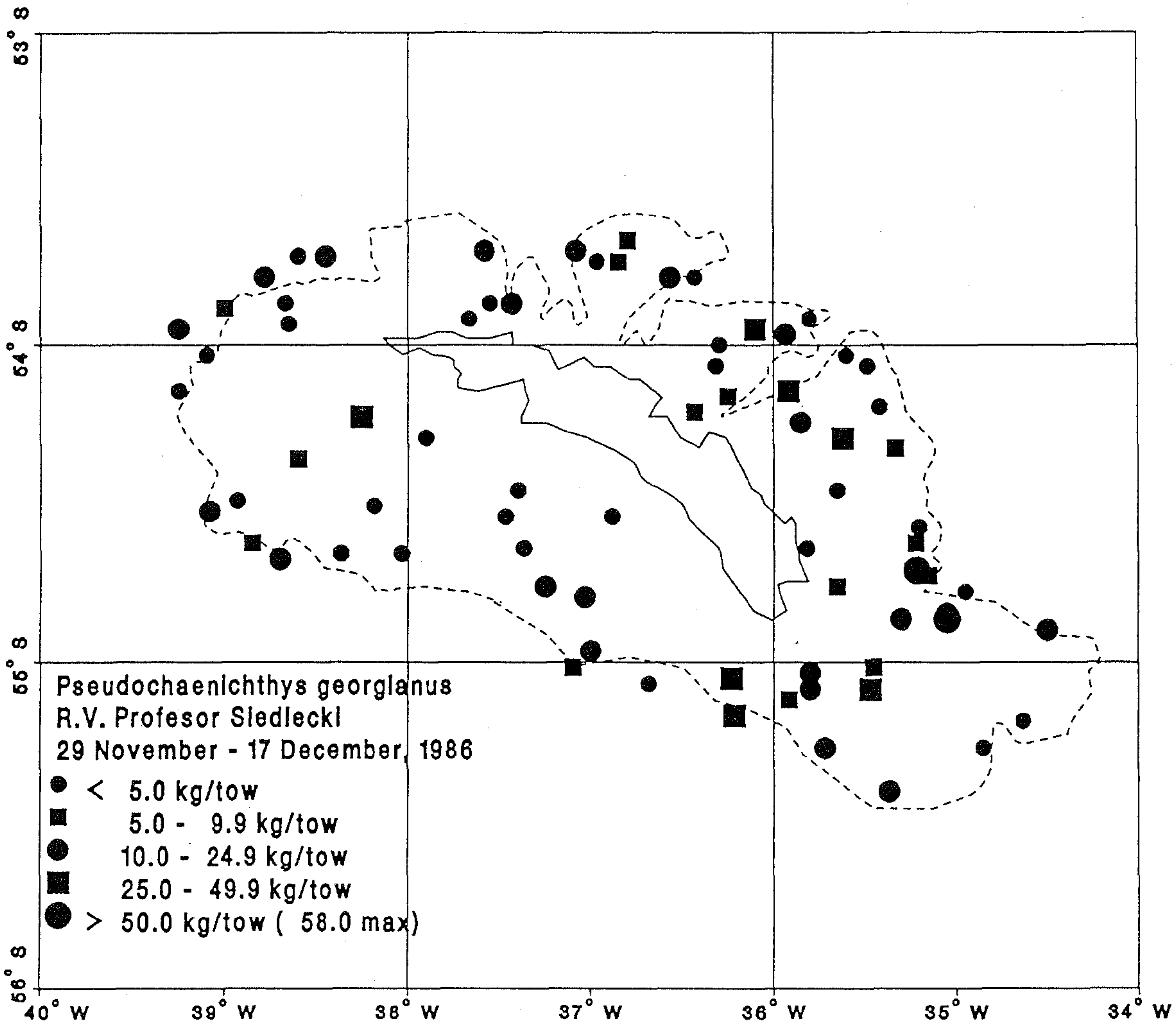

Figure 17. Distribution of catch per tow, Pseudochaenichthys georgianus, South Georgia.

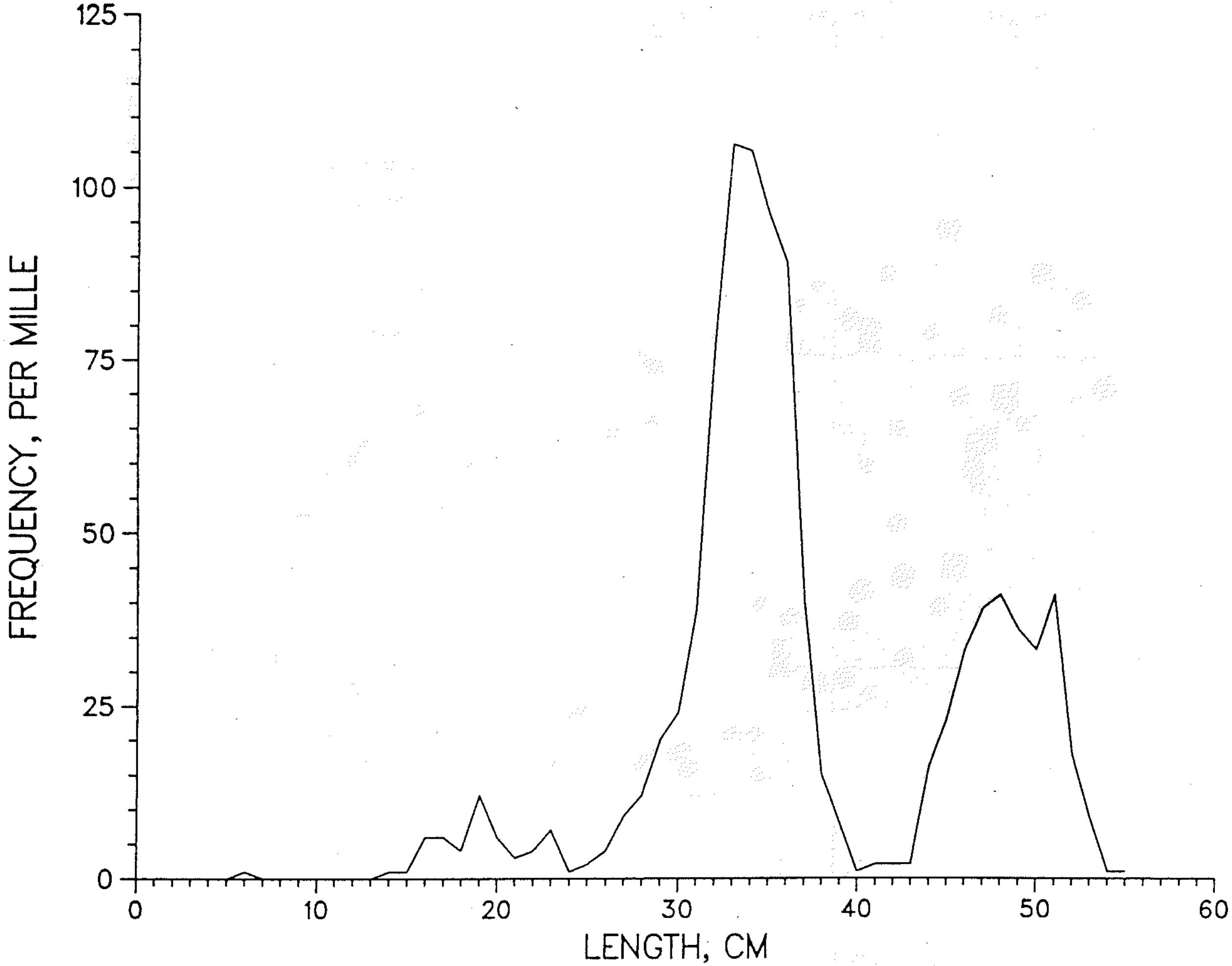

Figure 18. Length frequency distribution, Ps. georgianus, South Georgia.

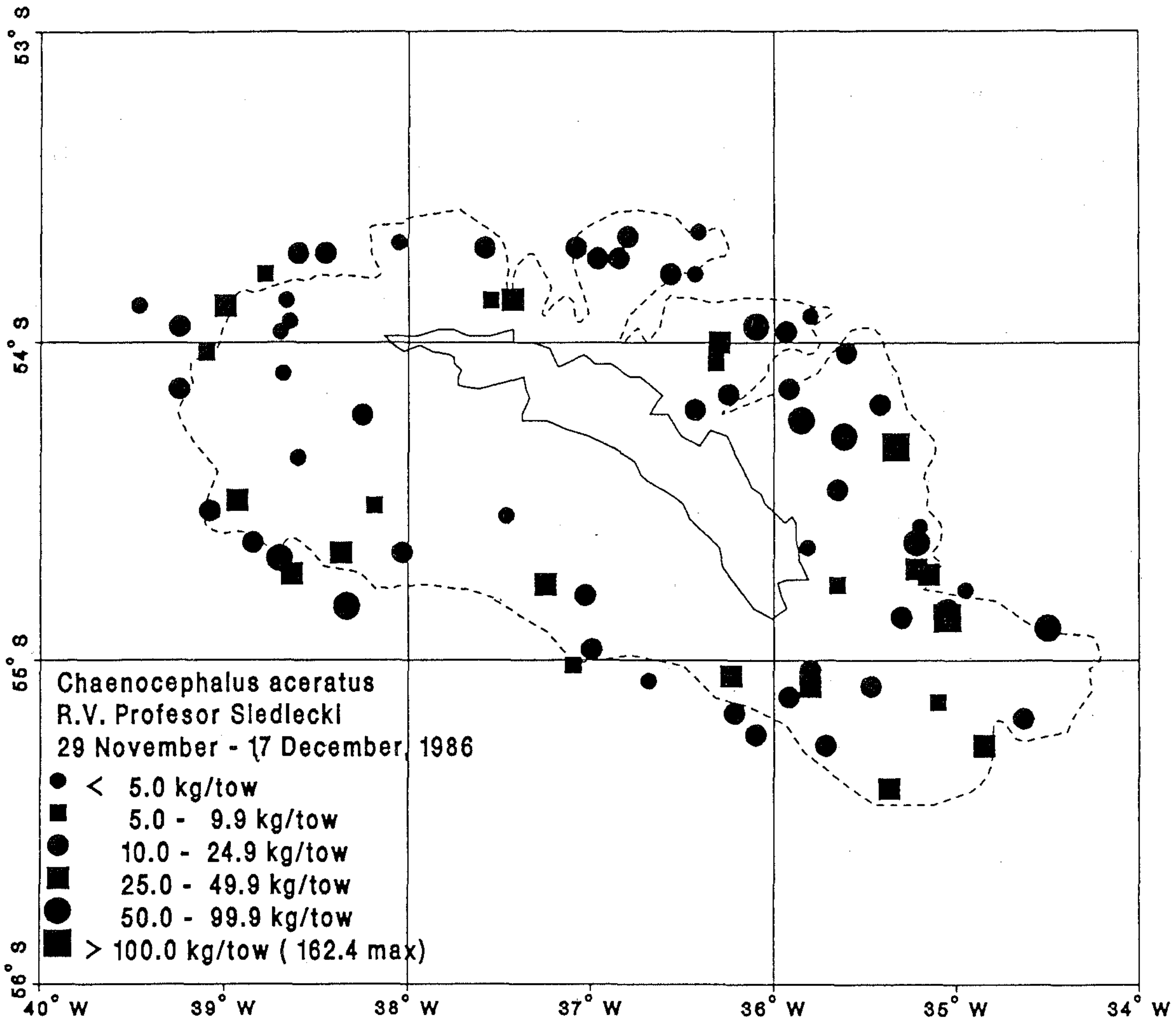

Figure 19. Distribution of catch per tow, Chaenocephalus aceratus, South Georgia.

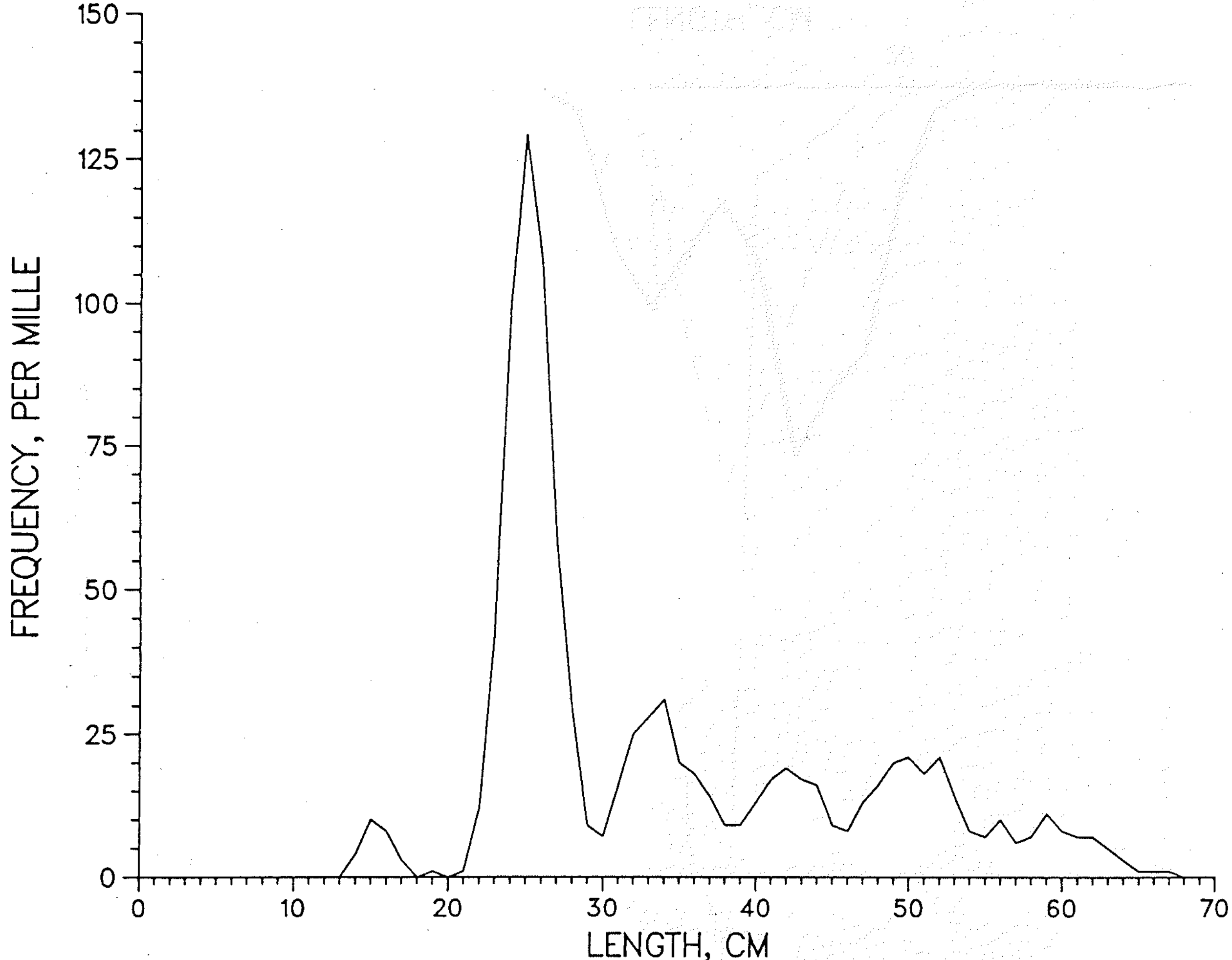

Figure 20. Length frequency distribution, Ch. aceratus, South Georgia.

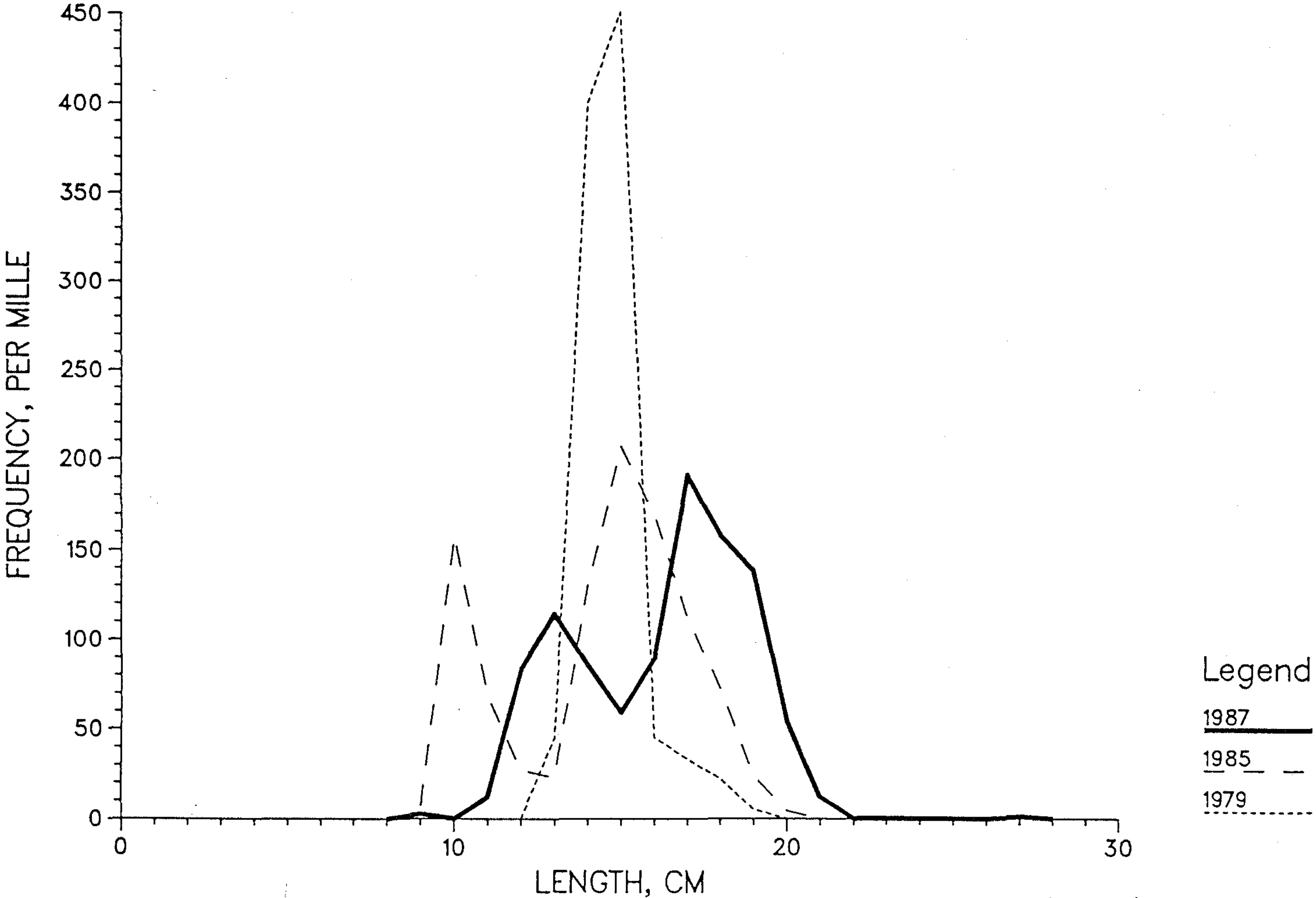

Figure 21. Comparison of length frequency distributions, P. b. guentheri, Shag Rocks, described by Naumov et al. 1979, Kock 1985 and this study.

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SC-CAMLR-VI/BG/40
(WG-FSA-87/10)

ANALYSIS OF CHANGES IN BIOMASS OF FISH STOCKS IN THE SOUTH GEORGIA AREA IN 1976/77-1986/87

M. Mucha and W. Ślósarczyk
(Poland)

Abstract

The swept area method was used to estimate biomass density changes in the stocks of five fish species (Champsocephalus gunnari, Chaenocephalus aceratus, Pseudochaenichthys georgianus, Notothenia gibberifrons and Notothenia rossii marmorata) in the South Georgia area in the seasons 1976/77-1986/87. In most of the seasons analysed, the estimates covered a near-bottom layer in about 1/6 of the area of the island shelf.

Assessment results point to considerable variations in fish biomass density, in the studied period. Estimates of fish stocks biomass ranged from 43 to 158 thousand tons. The changes in the biomass level are first of all a result of periodical fluctuations in the biomass density of C. gunnari stock. High biomass density appeared with 2-4 year intervals after recruiting an abundant year-class to the exploited stock. The biomass of other bottom species is more stable, especially in the case of N. gibberifrons. Recently, an increase in the C. aceratus stock has been observed and, at the same time, there has been a gradual decline in the P. georgianus stock.

Résumé

La méthode de l'aire balayée a été utilisée pour estimer les changements de densité de la biomasse dans les stocks de cinq espèces de poissons (Champsocephalus gunnari, Chaenocephalus aceratus, Pseudochaenichthys georgianus, Notothenia gibberifrons et Notothenia rossii marmorata) dans la zone de la Géorgie du Sud au cours des saisons 1976/77-1986/87. Dans la plupart des saisons analysées, les estimations portaient sur une couche proche du fond et couvraient environ 1/6 de la superficie du plateau de l'île.

Les résultats d'évaluation indiquent des variations considérables dans la densité de la biomasse ichtyologique pour la période étudiée. Les estimations de la biomasse des stocks ichtyologiques variaient de 43 000 à 158 000 tonnes. Ces variations sont tout d'abord le résultat de fluctuations périodiques dans la densité de la biomasse du stock de C. gunnari. Une forte densité de la biomasse est apparue à des intervalles de 2-4 ans après le recrutement d'une abondante classe d'âge dans le stock exploité. La biomasse des autres espèces de fond est plus stable, surtout dans le cas de N. gibberifrons. Une augmentation du stock de C. aceratus a récemment été remarquée alors que le stock de P. georgianus a connu une baisse graduelle.

Resumen

Se usó el método del área barrida para estimar los cambios en la densidad de la biomasa en las reservas de cinco especies de peces (Champsocephalus gunnari, Chaenocephalus aceratus, Pseudochaenichthys georgianus, Notothenia gibberifrons y Notothenia rossii marmorata) en el área de Georgia del Sur en las temporadas de 1976/77-1986/87. En la mayor parte de las temporadas analizadas, las estimaciones cubrieron una capa cercana al fondo en alrededor de 1/6 del área de la plataforma de la isla.

Los resultados de la evaluación apuntan a considerables variaciones en la densidad de la biomasa de los peces en el período estudiado. Las estimaciones de la biomasa de las reservas de peces variaron de 43 a 158 miles de toneladas. Los cambios en el nivel de la biomasa son ante todo el resultado de las fluctuaciones periódicas en la densidad de la biomasa de la reserva de C. gunnari. Una alta densidad de biomasa apareció con intervalos de 2-4 años luego de restablecer una abundante clase-año a la reserva explotada. La biomasa de las otras especies de fondo es más estable, especialmente en el caso de N. gibberifrons. Recientemente se ha observado un aumento en la reserva de C. aceratus y, al mismo tiempo, ha habido una gradual declinación en la reserva de P. georgianus.

Резюме

Для оценки изменений в плотности биомассы запасов пяти видов рыбы (Champsocephalus gunnari, Chaenocephalus aceratus, Pseudochaenichthys georgianus, Notothenia gibberifrons и Notothenia rossii marmorata) в районе Южной Георгии в сезоны 1976/77-1986/87 гг. использовался метод протраленных площадей. В течение большинства проанализированных сезонов проведенная оценка охватывала придонный слой примерно на 1/6 площади островного шельфа.

Результаты оценки указывают на существенные вариации в величине плотности биомассы рыбы в рассматриваемый период. Оценки биомассы рыбных запасов варьировались от 43 до 158 тысяч тонн. Изменения величины биомассы являются в первую очередь результатом периодических флуктуаций в

плотности биомассы запаса C. gunnari. Высокая плотность биомассы возникала с интервалом в 2-4 года после вхождения многочисленного годового класса в промысловый запас. Величина биомассы других придонных видов более постоянна, особенно в случае N. gibberifrons. Недавно наблюдалось увеличение запаса C. aceratus, и в то же время происходило постепенное сокращение запаса P. georgianus.

ANAYLSIS OF CHANGES IN BIOMASS OF FISH STOCKS IN THE SOUTH GEORGIA AREA IN 1976/77-1986/87

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1. INTRODUCTION

Beginning with the second half of seventies, a number of biomass estimates of fish in the Antarctic appeared in print. Three independent methods of calculation may be generally distinguished : (1) based on annual production of fish biomass in a selected area (Everson 1977) as well as on annual consumption of fish by Antarctic birds and mammals (Laws 1977), (2) based on swept area (Hureau 1979; Kock 1981, 1985; Mucha 1982; Ślósarczyk et al. 1985) and (3) based on Virtual Population Analysis (Anon. 1985, 1986). The swept area methods, widely-used, especially on fishing grounds exploited by the fishery, yield acceptable biomass estimates (Kock, Duhamel and Hureau 1985). This method was used to estimate the biomass of five species of fish caught by the Polish fishery in selected subdivisions of the South Georgia shelf in the 1976/77-1986/87 seasons. The present study is a follow-up to an earlier paper by Ślósarczyk et al. (1985) and, at the same time, offers a repeated analysis of these investigations from the 1976/77-1986/87 period. The authors' objective was to examine the changes in the stocks of fish inhabiting the near-bottom zone located in five statistical subdivisions (56, 57, 60-62 acc. to Everson 1984), exploited regularly by the Polish fishery, in the 11 years of observations (Figure 1).

2. MATERIAL AND METHOD

The biomass estimates of fish stocks in the 1983/84-1986/87 period were prepared, just like in the earlier period, on the basis of data collected by observers from the Sea Fisheries Institute on board the trawlers Taurus (1983/84 and 1984/85) and Carina (1985/86) as well as the analysis of fishing logs of the F.V. Manta (1986/87), supplemented by observations from R.V. Professor Siedlecki (1986/87) (Table I).

Due to the fact that the results of sample hauls of our research vessel are available for only two fishing seasons (1978/79 and 1986/87), only catch results of fishing vessels were used here. On the one hand, this reduces the range of possible conclusions from calculations based on such material, on the other it enables a comparison of changes in the size and structure of fish biomass in eight out of eleven fishing seasons in the period studied. Catch results of the research vessel Professor Siedlecki could not be used in this analysis because of distinctly lower CPUE's attained by this vessel as compared with a standard trawler of similar tonnage, engine power and trawl dimensions. This was especially visible in the 1986/87 season, when catch results of a trawler were much higher although both vessels fished at the same time and on the same fishing grounds. It was partly a result of the more extensive fishing experience of the trawler's master and a better knowledge of the local fishing grounds.

Fish stock biomass was estimated in three depth zones : 50-150, 150-250 and 250-500 m. Mean relative biomass density was calculated without additional density stratification, for each depth zone, separately in each statistical subdivision. This means that in comparison with our earlier estimates (Mucha 1982; Ślósarczyk et al 1985) our assumptions were more cautious when estimating the biomass, which was calculated only for those depth zones within the subdivisions, for which CPUE was known; the results were not extrapolated for a wider comparable area of the shelf. In most of the seasons analysed, the estimates covered about 1/6 of the area (6.3 thousand km^2) of the whole shelf of the island, where the majority of fishing grounds traditionally exploited by Polish fishermen are located and from which the results of our long-term observations come (Figure 1). Only results of catches made with a bottom trawl, a length of headline of 32 or 36 m and a horizontal opening of 17.5 or 24 m were used in the calculations (Table I). Hauls made with a midwater trawl, even towed near the bottom, were disregarded, since estimates based on those data are not comparable with the calculations based on bottom trawl hauls (Ślósarczyk et al. 1985, Annex 1). Because detailed published information about the catching efficiency of the bottom trawls is not available, a catchability coefficient of C = 1 was assumed.

3. RESULTS AND DISCUSSION

There has been a number of attempts to estimate the biomass of fish stocks off South Georgia with the swept area method (Anon. 1980; Kock 1981, 1985; Mucha 1982; Ślósarczyk et al. 1985). These estimates are in most cases incomparable with each other because of some differences in method used, the kind of information serving as the basis of calculations (research or commercial fishery catches) as well as differences in the interpretation of the results obtained. The present study attempts to evaluate the extent of changes in the size of fish stocks off South Georgia, calculated by the swept area method in the past eleven years, on the basis of homogeneous data coming from one type of vessel, one type of gear and one method of fishing.

According to our estimates, the size of the biomass of fish in the near bottom water layer of the South Georgia shelf, in the depth zone of 50-500 m, in subdivisions 56, 57, 60-62 fluctuated in 1977-1987 period from 43 to 158 thousand tons (Table II, Figure 2).

In the seasons of 1978/79, 1979/80 and 1982/83, from which information for calculations was not available, the size of the biomass could have been lower or higher than the range of values given above, judging by the level of total catches of fish on the South Georgia grounds (Anon. 1986). Our previous estimates of fish biomass from that area (Ślósarczyk et al. 1985) also exceed the 43-158 thousand tons range. This is a result of the fact that those estimates were based on a larger shelf area (over 12 thousand km^2) as well as a different extrapolation method of biomass density on the surface of individual depth zones.

Champsocephalus gunnari

Substantial influence on the results of biomass estimates for this species and total biomass was exerted by great changes in biomass density of C. gunnari in some subdivisions and some depth zones, as a result of which three distinct peaks of its biomass (Table III, IV; Figures 3,4) were observed within the past eleven fishing seasons. Most probably there was a fourth peak in the 1982/83 season, because of very large catches of C. gunnari (128.2 thousand tons) in this area (Anon. 1986). A decisive factor in the high estimate of total biomass in the 1976/77 season was the high biomass density of C. gunnari in subdivision 56, in the 150-250 m zone (94.2 t/km^2) as well as equally high density values in subdivision 57, depth zones of 150-250 and 250-500 m (Table IV, Figure 4). In the 1980/81 season relatively high density values for C. gunnari uniformly distributed in the wide zone of shallow waters (50-150 m) of subdivision 62 had a decisive influence on the size of total fish biomass (Table IV, Figure 4). Similarly, in the 1986/87 season, the high biomass density of C. gunnari in the shallow-water area (50-150 m), in subdivision 62, as well as relatively high density in the wide 150-250 m zone of subdivisions 61 and 62 (Table IV, Figure 4) influenced the high result of the total fish biomass estimate, as compared with the previous seasons.

In the 1976/77 season, when the first peak biomass level of C. gunnari was observed, the catches were composed mainly of fish belonging to age-groups IV-VIII, with a length of 35-42 cm. The structure of the exploited C. gunnari stock in two later seasons characterized by high biomass densities was quite different. In both of them, 3-year old fish predominated - with a length of 22-33 cm in 1980/81 (December-February, fish length measurement on board the fishing vessel), and a length of 21-30 cm in 1986/87 (November-December, data from research catches).

The periods of relatively low biomass of C. gunnari in our study comprise seasons 1977/78-1978/79, 1981/82 and 1983/84-1985/86. In the first period, this is an indirect result of the finding of abundant fishing grounds for C. gunnari and other Channichthyidae in the southern part of the Scotia Arc. and a decline in interest of the fleet in a search for concentrations of fish in the South Georgia area. It is thus likely that a sudden drop in the biomass level in our study between the 1976/77 and 1978/79 seasons was not exclusively caused by intensive catches in the first season. Low biomass estimates in relation to the size of world catches in the eighties result from the fact that our biomass estimate is based solely on bottom hauls (in order to render the data comparable in the whole period under study), while a substantial part of the catches of this species came from mid-water trawls, more efficient in taking fish out of reach of a bottom trawl. These differences are visible most of all in the 1981/82 and 1983/84 seasons (of Anon. 1986). A trial biomass estimate of the C. gunnari stock by the swept area method on the basis of data from a mid-water trawl, made in the 1983/84 season (Ślósarczyk et al. 1985, Annex 1) showed that such an estimate may be 2.5-3 times higher than a biomass estimate of C. gunnari based on bottom trawl data.

Chaenocephalus aceratus

Estimate results point to a gradual increase in the biomass of this species from a level of 3 thousand tons in the 1977/78 season to 18.5 thousand tons in the last season (Table III, Figure 3). A distinct increase in biomass density in most of the subdivisions was especially visible after the 1981/82 season (Table IV, Figure 5). This is reflected in the twofold increase of the estimated biomass between the 1981/82 and 1983/84 seasons (Table III). Only to a small degree could this be a result of new fishing tactics used. Both in the pre-1982/83 seasons (Ślósarczyk et al. 1985) and in the 1983/84-1986/87 period, fishing operations were directed mainly at C. gunnari. In the seasons in which mixed catches prevailed (1977/78 and 1984/85), when higher CPUE of C. aceratus could have been expected, higher biomass density may be observed only in the latter season (Table IV). In the first of them, despite high CPUE of P. georgianus and N. gibberifrons, occurring in the fishing ground along with C. aceratus, the CPUE of the latter was low and the level of the estimated biomass, the lowest among those observed in the eleven seasons (Table III).

Prior to the 1977/78 seaons, large fish with lengths of 30-65 cm, age-groups III-IX, predominated in the catch. In the 1978/79-1981/82 period the stock was visibly rejuvenated; strong year classes of 1976, 1977, and 1978 were recruited to the stock. At that time young fish, age-groups II-IV, with lengths below 45 cm, predominated in the catch. In the 1983/84 season, when the biomass density of C. aceratus increased distinctly, no fish below 30 cm in length were found in the catch

(Kompowski, unpublished). It consisted of large fish with lengths of 42-65 cm, mostly from age-groups V and VI (year classes of 1977 and 1978). Higher biomass density in 1984/85 may be a result of recruitment to the exploited stock of relatively strong year classes of 1981-1983, which appeared in the catch alongside fully exploited, abundant year classes of 1976-1978.

Pseudochaenichthys georgianus

In the 1976/77 and 1977/78 seasons, when the biomass of P. georgianus was estimated at a high level of 11.3 and 25 thousand tons (Table III, Figure 3), large fish (exceeding 45 cm and belonging to age-groups V through XII) were mostly observed in the catch. In the following season (1978/79) an increased share of young fish (age-groups I-III) was observed in sample hauls of the R.V. Professor Siedlecki (Anon. 1978). In the 1980/81 season, the percentage of young fish with lengths of 32-40 cm was still quite high in the catch (no data from the 1979/80 season). Biomass densities in both the 1978/79 (Ślósarczyk et al. 1985) and 1980/81 seasons (Table IV, Figure 6) were among the lowest observed. In the following season, biomass density increased while a decrease in the share of youngest fish and a simultaneous increase of fish 41-49 cm in length in the catch structure was observed. In the period between 1983/84 and 1986/87 this process was repeated. In the first season of that period very high biomass densities of P. georgianus (Table IV, Figure 6) were noted, accompanied by a large share of older fish (similar to the 1976/77 season). The biomass estimate in the 1983/84 season was the highest of the whole study period (Table III, Figure 3) despite the small area of the shelf covered by fishing operations and estimates, as well as the fact that operations were directed at C. gunnari. In subsequent seasons biomass densities of P. georgianus generally decreased; at the same time, beginning with 1985/86, young fish with lengths of 34-40 cm reappeared in the catch. In the last season (1986/87) the above-mentioned species was not found in the analysed catches of F.V. Manta so we could speak of zero biomass density. However, P. georgianus was at the same time second in quantity (8.2%) component of C. gunnari by-catch on the second Polish fishing vessel on the South Georgia grounds. It was also observed at that time in sample hauls of the R.V. Professor Siedlecki on the same fishing grounds (Figure 3). It is thus difficult to evaluate to what degree a density and biomass estimate based on observations from a single vessel reflects the actual state of P. georgianus stock. When large concentrations of C. gunnari appear, the interest of fishermen in other species of demersal fish declines. This might apply to catches of P. georgianus in 1986/87 in the case of F.V. Manta, when the main species sought was C. gunnari.

Notothenia gibberifrons

N. gibberifrons is characterized by the most stable biomass density indices (Table IV, Figure 7). As a result, with the exception of the 1983/84 season, the results of biomass estimate of this species usually range between 9 and 11 thousand tons (Table III, Figure 3). The estimate made in the 1983/84 season is approximately two times lower than the remaining ones, because the shelf area covered by fishing operations and biomass calculation in that season was also two times smaller (Table III).

However, some changes in the biological structure of the N. gibberifrons stock were observed during the study period. In the first two seasons (1976/77 and 1977/78) 10-year old fish and older predominated in the catch. Their share gradually decreased in later years while the percentage of younger fish increased (Ślósarczyk et al. 1985). In the eighties, the highest frequency was observed in age-groups VIII-X (Skóra, unpublished). Mean lengths of fish dropped from 37 cm in 1976/77 to 32 cm in 1981/82 (Ślósarczyk et al. 1985), and then increased to 36 cm in 1984/85 (Skóra) and 38 cm in 1985/86 (Kreft and Szynaka, 1986). An increase in mean length of fish in the last season could have been affected by the closing for the fishery of the shallow-water near-shore zone, mostly inhabited by small fish, below a length of 30 cm.

Notothenia rossii marmorata

Differences in biomass estimates of this species are generally a result of its uneven distribution over the shelf. Most likely, only the localization of new concentrations of N. rossii accounts for the high biomass density indices in some seasons, among others in the 250-500 depth zone in subdivisions 56 and 60 in the 1981/82 season, in the 150-250 m zone in subdivision 60, and in the 250-500 m zone in subdivisions 60-62, in the 1984/85 season (Table IV, Figure 8). High biomass densities gave in effect high biomass estimates in those seasons (Table III, Figure 3), which - most likely - were not a result of very large one-time recruitment. Beginning with the 1985/86 season, a decline in the biomass level, estimated on the basis of catches of fishing vessels might be apparent only due to the introduction of first catch regulatory measures for this species.

In the second half of the seventies, a large share of young fish belonging to age-groups III-V was observed in Polish catches; it often exceeded 50% of the catch (in numbers of fish). Mean lengths of fish in catches gradually decreased at that time from 59 cm in 1976/77 to 43 cm in 1980/81 (Ślósarczyk et al. 1985), age-groups V-VIII began to predominate in catches. This is connected with a simultaneous, sudden increase of CPUE in the deeper zone (250-500 m) and may indicate that new concentrations of fish of this species were discovered. Another increase in the mean length of fish from 46.2 cm in 1983/84 to 48 cm in 1984/85 could also be related to the very high, unobserved earlier increase in biomass density in the deep water zone (250-500 m). Further increase in mean length of fish to 50.5 cm in the following season could only be a result of catch regulatory measures for N. rossii, most of all the closing by the CCAMLR of near-shore waters for the fishery.

4. MANAGEMENT ADVICE

In the majority of analysed seasons of the 1976/77-1986/87 period, C. gunnari constituted the basis of catches off South Georgia and it seems that this early-maturing species might maintain such a status in the future, provided numerous year classes are recruited to the exploited stock. In a period of predominance of age-group II fish in the catches, they appeared with 2-4 year intervals and until 1984 kept catches at a high level, each time for two subsequent seasons : the year class of 1978 (Ślósarczyk et al. 1985) in the 1980/81 and 1981/82 seasons (Anon. 1986), and the year class of 1980 in 1982/83 and 1983/84 (Anon. 1986). The abundant year class of 1984, observed in great numbers as age-group I in sample hauls taken in the 1985/86 season (Kreft and Szynaka 1986), brought about very high biomass density values in the 1986/87 season. It seems that, similarly to the previous years, this year class might keep catches in the 1986/87 and the following season at a high level. To reduce, however, fishing in the 1987/88 season on the first spawning 1984 year-class, catches should be limited, depending on the total catch in the previous season.

Turning our attention to other species, the biomass and stock structure of C. aceratus has been improving recently and limiting the catches of this species appears unnecessary. The situation of the P. georgianus stock is not clear and requires confirmation by an estimate made by a different method. The biomass of the N. gibberifrons stock is stable and it seems unlikely that catches should be limited. What is worth doing is improving its structure by restrictions on the catch of juvenile fish. Latest tendencies in the structure and biomass of the N. rossii stock cannot be discussed on the basis of the results of commercial catches because of severe restrictions imposed on its fishery.

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Table I Information on time and location of catches, swept area and fishing gears.

Season	Month	Vessel	Place of capture /Division No.after Everson 1984/	Depth range /m/	Swept area /km²/	No.of hauls	Gear type	Horizontal openning of trawl/m/	Speed of trawling /knots/
1976/77	I-V	m/t"Gemini"	56,57,60,61,62	150-500	6 142	277	P-36/39	24.0	3.8
1977/78	XII-IV	m/t"Gemini"	56,57,60,61,62	150-500	6 737	218	P-32/36 P-36/39	17.5 24.0	3.8
1978/79									
1979/80									
1980/81	X-II	m/t"Libra"	56,57,60,61,62	50-500	9 302	464	P-32/36	17.5	3.2-4.0
1981/82	XI-II	m/t"Neptun"	56,57,60,61	50-500	4 686	285	P-32/36	17.5	3.6-3.8
1982/83									
1983/84	XI-I	m/t"Taurus"	56,57,60,61,62	50-500	3 665	96	P-32/36	17.5	3.8
1984/85	X-XI	m/t"Taurus"	56,57,60,61,62	50-500	7 147	154	P-32/36	17.5	3.5
1985/86	XI-I	m/t"Carina"	56,57,60,61,62	50-500	6 434	232	P-32/36	17.5	3.2
1986/87	XI-I	m/t"Manta"	56,61,62	50-500	6 246	73		17.5	3.0

Table II Fish stock biomass off South Georgia, within subdivisions 56, 57 and 60-62, in the near-bottom water layer estimated by the "swept area" method.

Seasons	Depth range /m/	Subdivisions					
		56	57	60	61	62	Total
1976/77	50-150						
	150-250	73 136	2 905	7 238	17 014		100 293
	250-500	30 388	16 695	1 989	4 615	4 134	57 821
	Total	103 524	19 600	9 227	21 629	4 134	158 114
1977/78	50-150						
	150-250	4 463	864	1 739	11 236	6 537	24 839
	250-500	9 352		1 224	4 115	3 510	18 201
	Total	13 815	864	2 963	15 351	10 047	43 040
1978/79							
1979/80							
1980/81	50-150	586		7 968	2 633	33 298	44 485
	150-250	8 482	536	5 358	13 643	7 124	35 143
	250-500	7 701	1 410	1 714	3 225	4 524	18 574
	Total	16 769	1 946	15 040	19 501	44 946	98 202
1981/82	50-150				1 809		1 809
	150-250	5 803	630	3 666	16 051		26 150
	250-500	17 877		3 979			21 856
	Total	23 680	630	7 645	17 860		49 815
1982/83							
1983/84	50-150	457			1 316		1 773
	150-250	9 672	820		31 458		41 950
	250-500			2 845		7 020	9 865
	Total	10 129	820	2 845	32 774	7 020	53 588
1984/85	50-150	237			1 685		1 922
	150-250	4 539	567	5 734	20 385	8 296	39 521
	250-500	6 463	1 337	6 120	9 675	7 566	31 161
	Total	11 239	1 904	11 854	31 745	15 862	72 604
1985/86	50-150	696			2 275		2 971
	150-250	8 109	2 992		22 311	12 906	46 318
	250-500	5 227		1 438	3 392	6 786	16 843
	Total	14 032	2 992	1 438	27 978	19 692	66 132
1986/87	50-150	542			1 218	51 504	53 264
	150-250	8 630			22 150	17 011	47 791
	250-500				4 226	5 304	9 530
	Total	9 172			27 594	73 819	110 585
Area /km^2/	50-150	44		599	123	1 556	2 322
	150-250	744	63	470	1 605	838	3 720
	250-500	1 375	243	306	556	780	3 260
	Total	2 163	306	1 375	2 284	3 174	9 302

Table III Fish stock biomass off South Georgia by year, subdivision and species.

Seasons	Species*	Subdivisions 56	57	60	61	62	Total
1976/77	ANI	90 710	19 130	261	111		110 212
	SSI	2 216	86	247	667	468	3 684
	SGI	2 624	49	6 426	1 724	468	11 291
	NOG	5 499	262	1 209	2 223	1 716	10 909
	NOR	1 650		945	15 292	1 092	18 979
	MZZ	825	73	139	1 612	390	3 039
	Total	103 524	19 600	9 227	21 629	4 134	158 114
1977/78	ANI	212	13	31	538	503	1 297
	SSI	773	6	155	1 185	815	2 934
	SGI	8 190	800	1 660	9 342	5 025	25 017
	NOG	3 729	13	698	2 884	2 961	10 285
	NOR	911	32	419	1 402	743	3 507
	MZZ						
	Total	13 815	864	2 963	15 351	10 047	43 040
1978/79							
1979/80							
1980/81	ANI	11 627	1 131	12 168	13 814	38 566	77 306
	SSI	1 004	160	581	1 290	1 515	4 550
	SGI	1 141	208	612	1 414	1 827	5 202
	NOG	1 622	392	1 373	2 711	2 798	8 896
	NOR	1 100	49	245	111	156	1 661
	MZZ	275	6	61	161	84	587
	Total	16 769	1 946	15 040	19 501	44 946	98 202
1981/82	ANI	4 340	353	2 123	10 452		17 268
	SSI	1 283	69	529	1 840		3 721
	SGI	2 183	120	760	3 136		6 199
	NOG	5 631	88	1 588	2 432		9 739
	NOR	10 243		2 645			12 888
	MZZ						
	Total	23 680	630	7 645	17 860		49 815
1982/83							
1983/84	ANI	1 799	145	581	12 036	1 014	15 575
	SSI	1 238	101	520	5 999	312	8 170
	SGI	6 146	498	734	12 394	4 680	24 452
	NOG	565	44	459	2 345	1 014	4 427
	NOR	381	32	551			964
	MZZ						
	Total	10 129	820	2 845	32 774	7 020	53 588
1984/85	ANI	481	6	769	383	1 060	2 699
	SSI	2 428	543	1 489	7 204	2 751	14 415
	SGI	1 792	932	1 917	8 812	1 635	15 088
	NOG	1 582	423	1 098	4 070	4 164	11 337
	NOR	4 956		6 581	11 276	6 252	29 065
	MZZ						
	Total	11 239	1 904	11 854	31 745	15 862	72 604
1985/86	ANI	7 357	2 457	673	14 267	2 722	27 476
	SSI	3 570	214	214	4 710	1 959	10 667
	SGI	316	13	61	2 438	6 978	9 806
	NOG	1 992	176	245	4 420	4 308	11 141
	NOR	74			661	2 748	3 483
	MZZ	723	132	245	1 482	977	3 559
	Total	14 032	2 992	1 438	27 978	19 692	66 132
1986/87	ANI	6 790			22 000	51 551	80 341
	SSI	884			2 939	14 753	18 576
	SGI						
	NOG	1 498			2 655	7 203	11 356
	NOR					312	312
	MZZ						
	Total	9 172			27 594	73 819	110 585
Area /km^2/		2 163	306	1 375	2 284	3 174	9 302

* ANI - Champsocephalus gunnari, SSI - Chaenocephalus aceratus, SGI - Pseudochaenichthys georgianus, NOG - Notothenia gibberifrons, NOR - Notothenia rossii marmorata, MZZ - other marine fishes.

Table IV Biomass density of fish stocks off South Georgia by year, subdivision, depth zone and species.

Seasons	Species*	Subdivisions														
		56			57			60			61			62		
	/m/	50-150	150-250	250-500	50-150	150-250	250-500	50-150	150-250	250-500	50-150	150-250	250-500	50-150	150-250	250-500
1976/77	ANI		94.2	15.0		45.6	66.9		0.1	0.7			0.2			
	SSI		1.5	0.8		0.2	0.3		0.2	0.5			1.2			0.6
	SGI		0.2	1.8			0.2		12.5	1.8			3.1			0.6
	NOG		2.4	2.7		0.3	1.0		1.4	1.8		0.9	1.4			2.2
	NOR			1.2					1.1	1.4		8.8	2.1			1.4
	MZZ			0.6			0.3		0.1	0.3		0.9	0.3			0.5
1977/78	ANI		0.1	0.1		0.2				0.1		0.3	0.1		0.6	
	SSI		0.3	0.4		0.1			0.2	0.2		0.6	0.4		0.6	0.4
	SGI		3.8	3.9		12.7			2.1	2.2		4.4	4.1		4.6	1.5
	NOG		1.5	1.9		0.2			0.9	0.9		1.0	2.3		1.3	2.4
	NOR		0.3	0.5		0.5			0.5	0.6		0.7	0.5		0.7	0.2
	MZZ															
1978/79																
1979/80																
1980/81	ANI	11.3	9.6	2.9	20.0	6.0	3.1	11.3	9.6	2.9	20.0	6.0	3.1	20.0	6.0	3.1
	SSI	0.4	0.4	0.5	0.4	0.6	0.5	0.4	0.4	0.5	0.4	0.6	0.5	0.4	0.6	0.5
	SGI	0.4	0.4	0.6	0.5	0.6	0.7	0.4	0.4	0.6	0.5	0.6	0.7	0.5	0.6	0.7
	NOG	1.2	1.0	0.6	0.5	1.2	1.3	1.2	1.0	0.6	0.5	1.2	1.3	0.5	1.2	1.3
	NOR			0.8			0.2			0.8			0.2			0.2
	MZZ			0.2		0.1				0.2		0.1				
1981/82	ANI		3.8	1.1	11.9	5.6			3.8	1.1	11.9	5.6				
	SSI		0.8	0.5	0.6	1.1			0.8	0.5	0.6	1.1				
	SGI		0.9	1.1	0.7	1.9			0.9	1.1	0.7	1.9				
	NOG		1.1	3.5	1.5	1.4			1.1	3.5	1.5	1.4				
	NOR		1.2	6.8					1.2	6.8						
	MZZ															
1982/83																
1983/84	ANI	2.0	2.3		2.0	2.3				1.9	3.9	7.2				1.3
	SSI	1.1	1.6		1.1	1.6				1.7	1.8	3.6				0.4
	SGI	6.1	7.9		6.1	7.9				2.4	4.2	7.4				6.0
	NOG	1.0	0.7		1.0	0.7				1.5	0.8	1.4				1.3
	NOR	0.2	0.5		0.2	0.5				1.8						
	MZZ															
1984/85	ANI	1.3	0.2	0.2	14.5	0.1			0.4	1.9	0.5	0.2			0.8	0.5
	SSI	0.5	1.2	1.1	0.5	0.9	2.0		1.8	2.1	4.1	3.1	3.1		1.7	1.7
	SGI		1.3	0.6	2.2	6.3	2.2		1.8	3.5	7.8	4.2	2.0		1.3	0.7
	NOG	0.3	1.0	0.6	0.1	1.7	1.3		1.1	1.9	1.2	1.3	3.3		3.2	1.9
	NOR	3.3	2.4	2.2	3.3				7.1	10.6	0.1	3.9	9.0		2.9	4.9
	MZZ															
1985/86	ANI	10.4	6.5	1.5	81.5	39.0				2.2	11.8	7.5	1.4		1.2	2.2
	SSI	2.8	2.6	1.1	6.6	3.4				0.7	3.3	2.3	1.1		1.5	0.9
	SGI	0.4	0.4		0.1	0.2				0.2	1.0	1.2	0.7		6.0	2.5
	NOG	1.4	1.3	0.7	4.8	2.8				0.8	1.7	2.0	1.8		3.0	2.3
	NOR		0.1								0.1	0.3	0.3		3.0	0.3
	MZZ	0.8		0.5	2.4	2.1				0.8	0.6	0.6	0.8		0.7	0.5
1986/87	ANI	8.9	8.6								8.7	11.1	5.6	24.3	15.0	1.5
	SSI	1.5	1.1								0.3	1.6	0.6	6.1	3.3	3.2
	SGI															
	NOG	1.9	1.9								0.9	1.1	1.4	2.7	2.0	1.7
	NOR															0.4
	MZZ															
Area /km²/		44	744	1375	-	63	243	599	470	306	123	1605	556	1556	838	780

*ANI - Champsocephalus gunnari, SSI - Chaenocephalus aceratus, SGI - Pseudochaenichthys georgianus, NOG - Notothenia gibberifrons, NOR - Notothenia rossii marmorata, MZZ - other marine fishes.

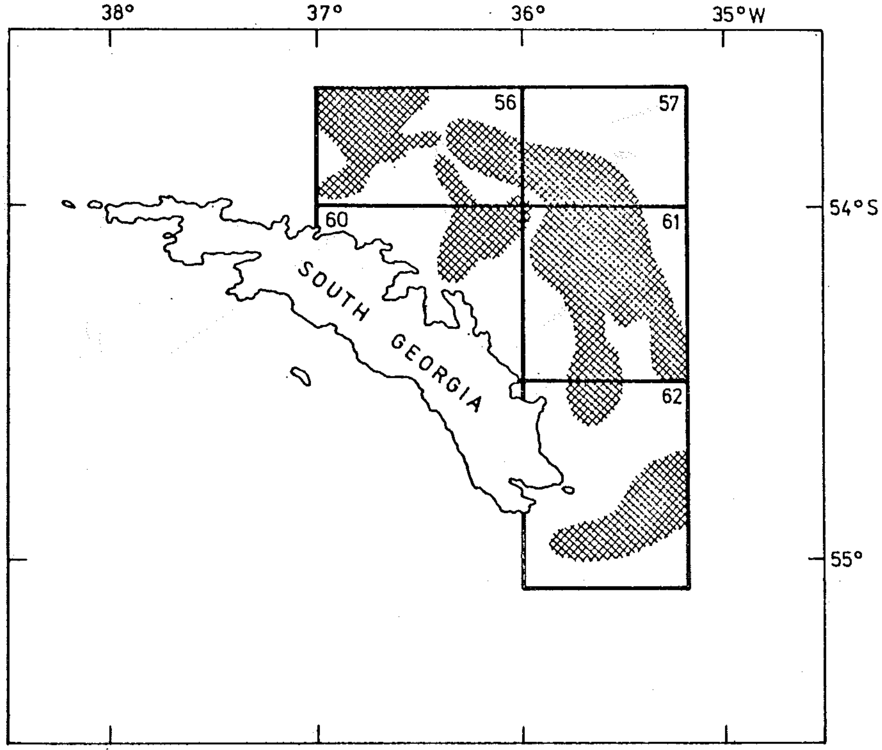


Figure 1 Area exploited regularly by the Polish fishery in the period 1977-1987 within statistical subdivisions 56, 57 and 60-62 (after Everson 1984).

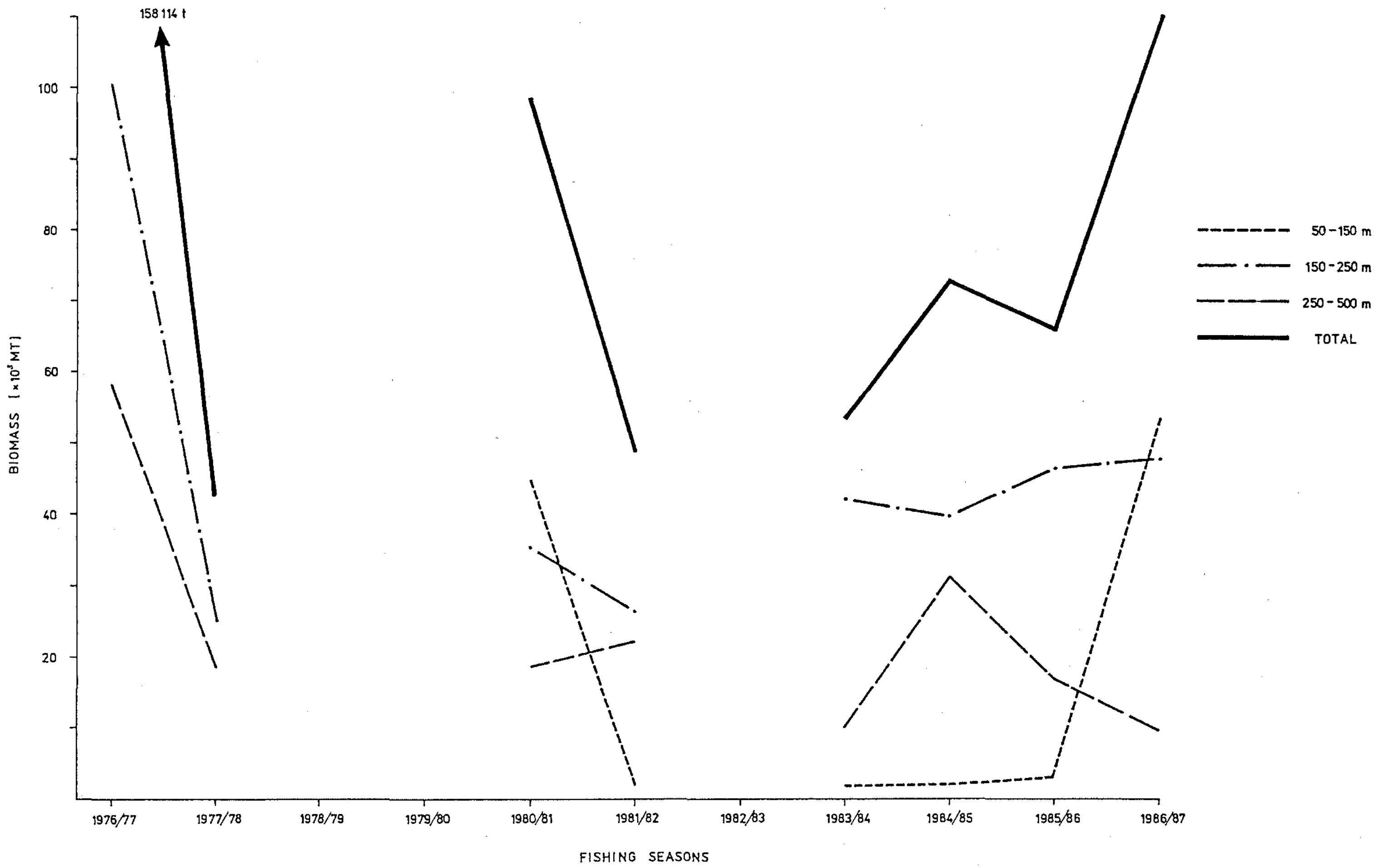


Figure 2 Changes in bottom fish biomass off South Georgia in 1977-1987 within subdivisions 56, 57 and 60-62, in three depth zones, estimated by the "swept area" method.

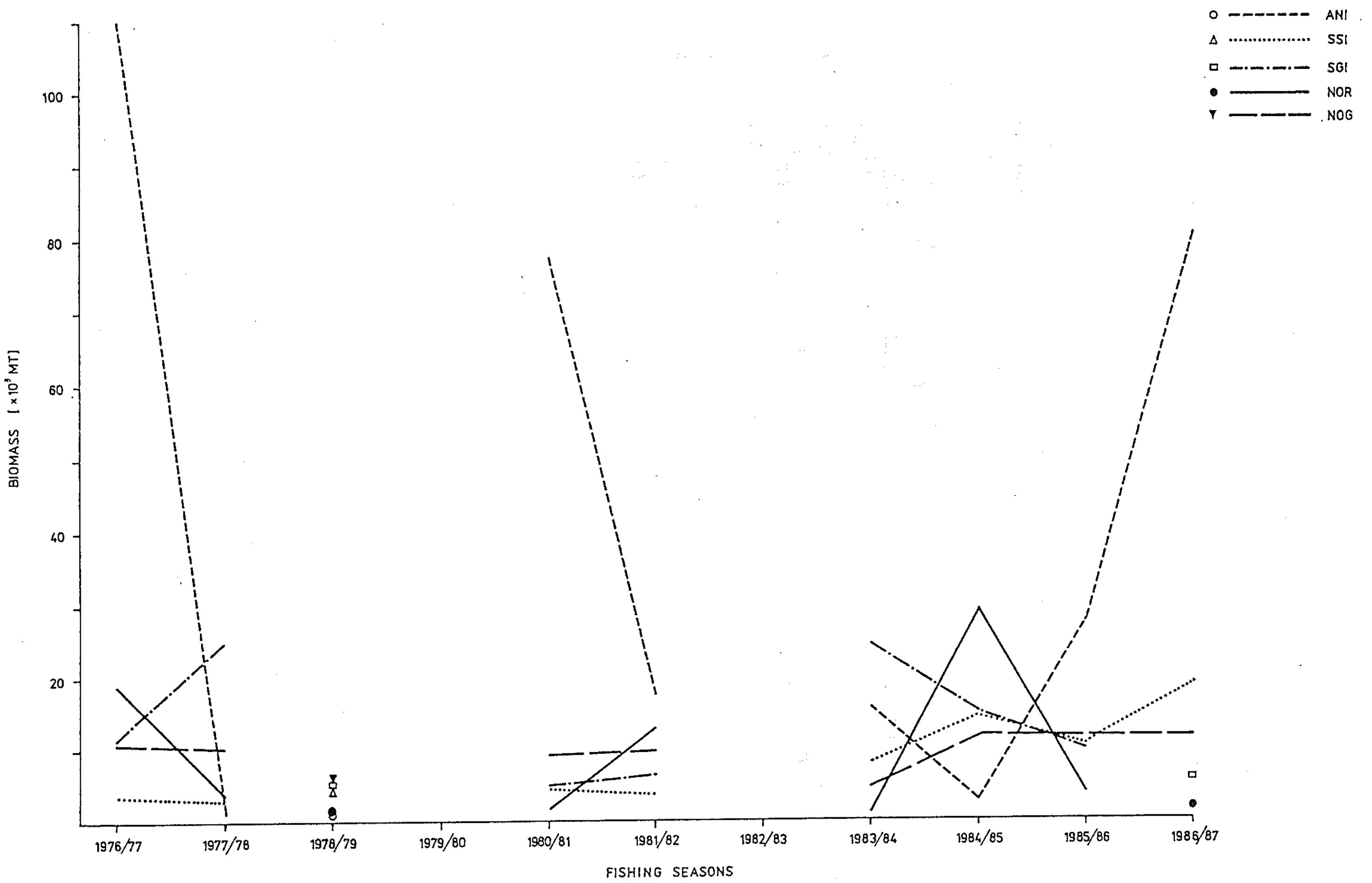


Figure 3 Changes in fish stocks biomass off South Georgia in 1977–1987 (ANI – Champsocephalus gunnari, SSI – Chaenocephalus aceratus, SGI – Pseudochaenichthys georgianus, NOR – Notothenia rossii marmorata, NOG – Notothenia gibberifrons).

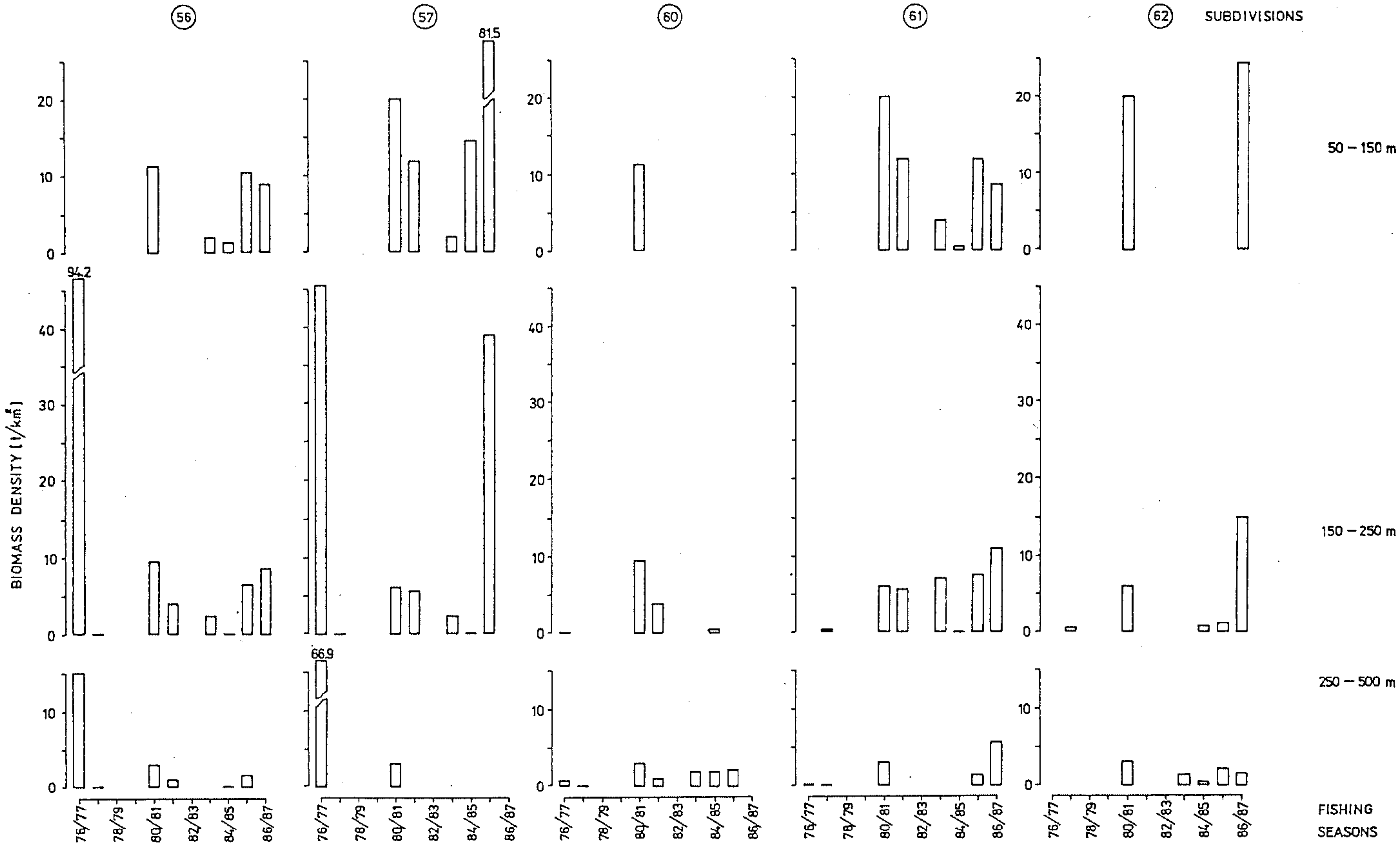


Figure 4   Biomass density of <u>Champsocephalus gunnari</u> by year, subdivision and depth zone.

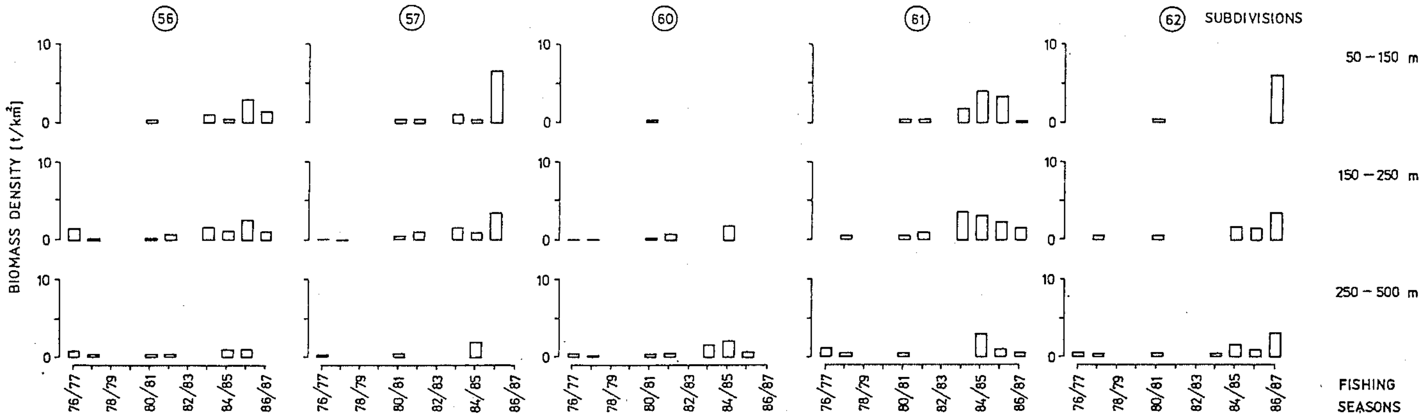


Figure 5 Biomass density of Chaenocephalus aceratus by year, subdivision and depth zone.

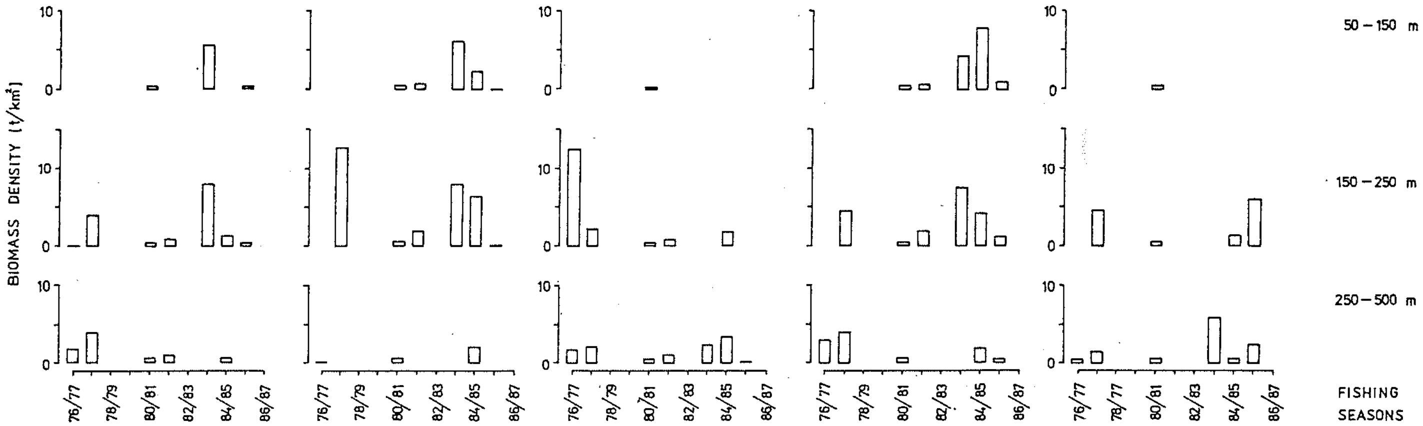


Figure 6 Biomass density of Pseudochaenichthys georgianus by year, subdivision and depth zone.

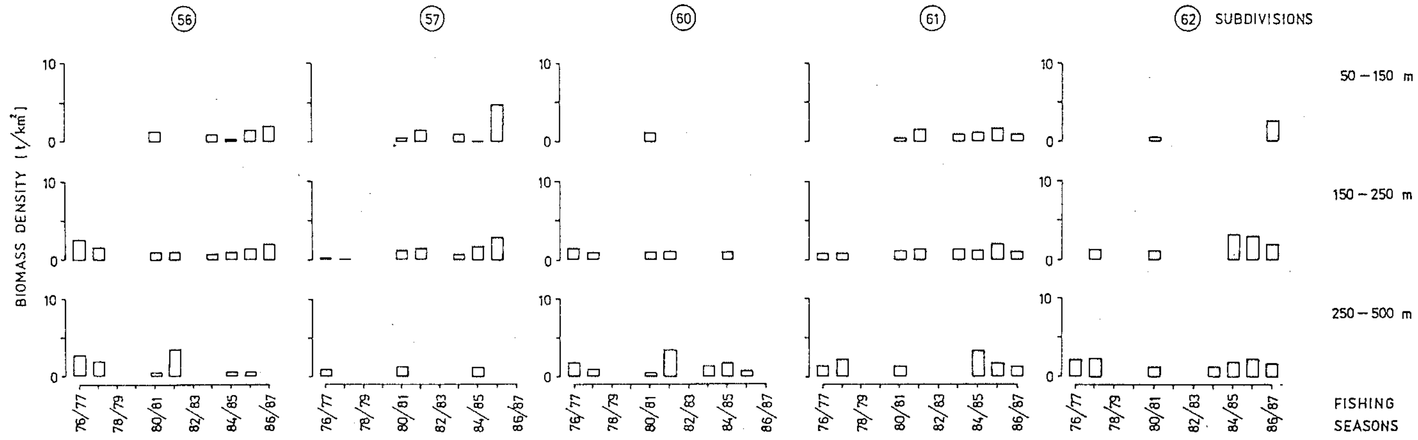
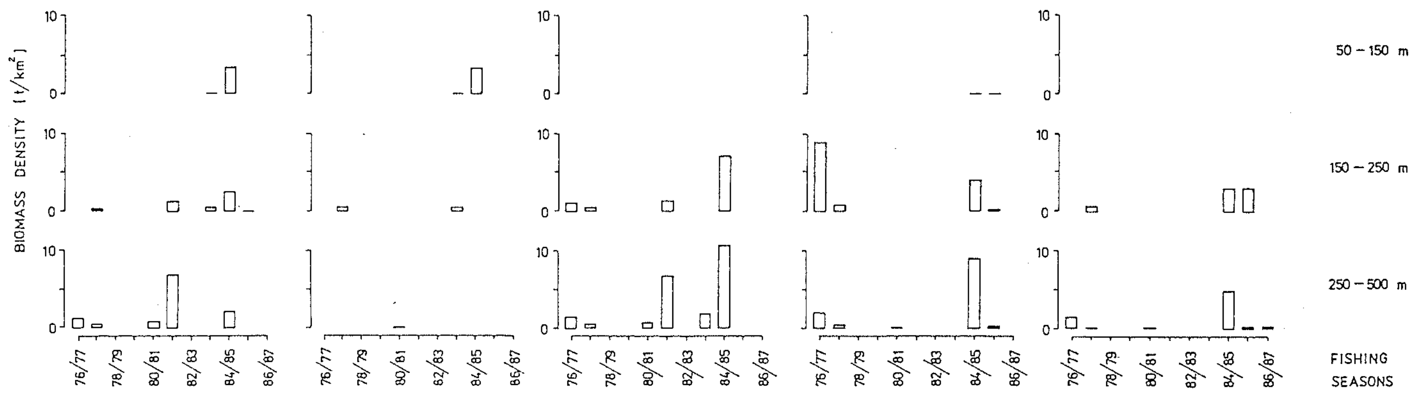


Figure 7 Biomass density of Notothenia gibberifrons by year, subdivision and depth zone.



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SC-CAMLR-VI/BG/39

THE ERROR OF THE BIOMASS ESTIMATE AS A FUNCTION OF SURVEY PARAMETERS AND THE STATISTICS OF A DENSITY FIELD OF KRILL AGGREGATIONS

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Abstract

Simple relationships expressing the dependence of relative sampling error in a biomass estimate (from a survey) on the statistical characteristics of the fish concentration density field and on parameters of the survey itself, have been derived with the help of mathematical statistics and methods of calculus of probabilities. The biomass estimate is determined as the product of the average density for the region under examination and the area of this region. For a hydroacoustic survey, the anisotropy parameters correlation radius along transects and coefficient of variation serve as field characteristics on which the error depends. The direction of the survey with respect to the axis of the correlation ellipse and the frequency of transects (sections) serve as survey parameters. The relationships described here can be used in practice for both a posteriori estimation of the error made when calculating the biomass, and for survey planning on the basis of a priori estimates of the statistical characteristics of the concentration density field. These might provide a basis for the operative control of surveys.

Résumé

La statistique mathématique et les calculs de probabilités ont permis d'établir des relations simples exprimant la dépendance de l'erreur relative d'échantillonnage dans l'estimation de la biomasse (à partir d'une prospection) sur les caractéristiques statistiques du champ de densité des concentrations de poissons et sur les paramètres de la prospection même. L'estimation de la biomasse est déterminée comme étant le produit de la densité moyenne pour la région examinée et la superficie de cette région. Pour une prospection hydroacoustique, les paramètres d'anisotropie, le rayon de corrélation le long des transects et le coefficient de variation servent de caractéristiques de terrain dont dépend l'erreur. La direction de la prospection quant à l'axe de l'ellipse de corrélation et la fréquence des transects (sections) servent de paramètres de prospection. Les relations ici décrites peuvent être utilisées en pratique à la fois pour une estimation a posteriori de l'erreur faite en calculant la biomasse et pour la préparation de prospections sur la base d'estimations a priori des caractéristiques statistiques du champ de densité des concentrations. Elles peuvent fournir une base pour le contrôle opératoire des prospections.

Resumen

Se han deducido correlaciones simples que expresan la dependencia del error relativo de muestreo en la estimación de biomasa (obtenida de una prospección) de las características estadísticas del campo de densidad de las concentraciones de peces y de los parámetros de de la prospección en sí, utilizándose la estadística matemática y los métodos de cálculo de probabilidades. La estimación de biomasa se determina como el producto de la densidad promedio para la región bajo estudio y el área de esta región. Para una prospección hidroacústica, los parámetros de anisotropía, el radio de correlación a lo largo de secciones transversales y el coeficiente de variación sirven como características de campo de las cuales depende el error. La dirección de la prospección con respecto al eje de la elipse de correlación y la frecuencia de las secciones transversales sirven como parámetros de prospección. Las relaciones aquí descriptas pueden ser usadas en la práctica para una estimación a posteriori del error cometido al calcular la biomasa, así como para la planificación de una prospección sobre la base de estimaciones a priori de las características estadísticas del campo de densidad de las concentraciones. Las mismas podrían proporcionar una base para el control operativo de las prospecciones.

Резюме

Простые соотношения, выражающие зависимость относительной ошибки выборки при оценке биомассы (по данным съемки) от статистических характеристик поля плотности концентраций рыбы и от параметров самой съемки, были выведены с помощью математической статистики и метода расчетов с учетом теории вероятностей. Оценка биомассы определяется как произведение средней плотности по рассматриваемому району и площади этого района. В случае гидроакустической съемки параметры анизотропии, радиус корреляции вдоль разрезов и коэффициенты вариативности служат характеристиками поля, от которых зависит ошибка. Направление съемки по отношению к оси корреляционного эллипса и частота разрезов (секций) служат параметрами съемки. Описанные здесь соотношения могут на практике использоваться как для последующего определения ошибки, сделанной при вычислении величины биомассы, так и для планирования съемок на основе предварительной оценки статистических характеристик поля плотности концентрации. Это может стать основой для оперативного контроля при проведении съемок.

THE ERROR OF THE BIOMASS ESTIMATE AS A FUNCTION OF SURVEY PARAMETERS AND THE STATISTICS OF A DENSITY FIELD OF KRILL AGGREGATIONS

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1. Introduction

Estimates of fishing objects biomass are the main result of hydroacoustic and trawl surveys. Since these estimates cause a certain effect on making decisions which very often have a considerable economic and ecological meaning, it is necessary to supply them with confidence intervals indicating the limits of possible errors with desired probability. Thus, it is important to find out on which parameters of survey and statistical characteristics of fishing objects the error of the obtained biomass estimate might depend and how this dependence can be expressed mathematically with account for the probability nature of the estimate in question.

If such a dependence has been revealed, it would be possible to solve an inverse and quite important from the practical point of view problem of determining parameters of optimal survey allowing us to estimate biomass, the error of which does not exceed the defined level with desired probability.

This paper is devoted to all these problems.

2. Basic relationships

Let us at first confine to the easiest and most widespread method of estimating biomass B in a region under consideration:

$B=\bar{\rho}S$, where S is region area, and $\bar{\rho}$ is average surface density of concentartions in it, determined using materials obtained through "instant" (i.e. rather short in time) regular survey. In this case, if not to consider the so-called errors of measurement (which can be assumed as known) introduced by the method of obtaining initial information, one should regard relative error δ of estimate B as a sampling relative error of the estimate of average density $\bar{\rho}$. In case of hydroacoustic survey, neither B, nor δ do depend on integration interval (if using an echointegrator). That is why in this context echo surveys can be considered similarly to trawl surveys, assuming that in case of both these types of survey the choice of information is performed in knots (intersections) of a regular rectangular grid covering the region under examination, with steps h_x and h_y, along coordinate axes x and y, connected with direction of survey (for short, these points will be called knots). The difference between them lies in the fact that in case of trawl survey steps h_x and h_y are usually close to each other in their values $(h_x \sim h_y)$, while in case of echo survey one of the steps (further on h_x), corresponding to the distance covered by a vessel between two successive echo pulses, is much less that the other one (h_y) which represents a distance between transects (sections): $h_x \ll h_y$.

In the majority of cases fishing objects concentration density fields have a typical patch-like structure, at the same time certain patches with a higher density have irregular shapes, are arranged in disorder (they can get rearranged in big aggregations or drift apart at distances considerably exceeding their own sizes);

density within one patch, as well as its shape, are subject to random perturbations. Thus when speaking about "instant" survey of a large aquatorium, in the first approximation one can consider concentration density ρ as a stationary, i.e. independent on time, homogeneous random field.

Isotropic fields

Let us at first assume that field $\rho(x,y)$ is an isotropic one. This is typical of concentrations density fields in open ocean regions, far from shelves, jet currents, equator and other physio-geographical factors which can give rise to the existing specified directions. Homogeneous isotropic field ρ has got one and the same dispersion $\mathcal{D}_\rho$ for all its points, and its normalized correlation function A, characterizing statistical interdependency of ρ values in any two points, depends itself only on distance r between them: $A=A(r)$. Correlation radius R, the minimum distance at which correlation between density values becomes negligible, is a vivid characteristic of field correlation properties (i.e. of the function A). In the general case, this radius depends on direction, but for isotropic field $R=const$, so all points in which density correlates with density in a fixed point, are in fact concentrated within the circle of radius R (called correlation circle) with its centre in this fixed point. We shall need two more values besides R :

$$a_1=\frac{1}{\pi R^2}\iint\limits_{\omega} A(r)\,dx\,dy=\frac{2}{R^2}\int_0^R r\,A(r)\,dr, \qquad (1)$$

$$a_2=\frac{1}{R}\int_0^R A(r)\,dr. \qquad (2)$$

These values represent integral average values of A over correlation circle ω and correlation radius, respectively. Finally, we shall assume values h_x, h_y and R to be small enough as compared to the size of region under examination (in reality, it is exactly the situation). This will allow us to consider all knots as "equal in rights", neglecting differences between internal points and those belonging to boundary strip.

According to a relation, well-known in mathematical statistics, dispersion $\mathcal{D}_{\bar{\rho}}$ of the estimate of average density $\bar{\rho} = \sum_{i=1}^{N} \rho_i / N$ calculated for all knots (N is the general number of knots), is expressed by the double sum

$$\mathcal{D}_{\bar{\rho}} = \frac{1}{N^2} \sum_{i=1}^{N} \sum_{j=1}^{N} K_{ij} , \qquad (3)$$

where $K_{ij} = \mathcal{D}_\rho A(r_{ij})$ are correlation moments of field ρ for the i-th and j-th knots, r_{ij} is the distance between these knots. One can replace $N = S / h_x h_y$ in (3) (note that in case of arbitrary configuration of the region under examination, this relationship is, generally speaking, approximate, though it is as accurate as smaller the steps h_x and h_y are). Taking into account "equality in rights" of all knots one can fix any internal knot with number i ; then using the fact that the field ρ is isotropic, the formula (3) can be rewritten in a different form:

$$\mathcal{D}_{\bar{\rho}} = \frac{\mathcal{D}_\rho}{S} h_x h_y \sum_{j=1}^{N} A(r_{ij}) . \qquad (4)$$

In case of trawl survey stations are usually installed far-between, thus, by the order of magnitude grid steps are no less than the correlation radius: $h_x \gtrsim R$, $h_y \gtrsim R$. In this case

$A(r_{ii})=1$ (as $r_{ii}=0$), and at $i \neq j$ all values of $A(r_{ij})$ are practically zero, so from (4) we obtain:

$$\mathcal{D}_{\bar{\rho}} = \mathcal{D}_{\rho}\, h_x h_y / S. \tag{5}$$

This relatioship written in the form $\mathcal{D}_{\bar{\rho}} = \mathcal{D}_{\rho}/N$ is well-known and often used when processing independent experiments (see, for example, Venttsel, 1962).

In the other limiting case which seems to be not ever rea lized in practice and which, however, is very important for understanding the main results of the work, when $h_x \ll R$ and $h_y \ll R$, expression $h_x h_y \sum_{i=1}^{N}\sum_{j=1}^{N} A(r_{ij})$, being a part of (4), can be replaced with high accuracy by integral of A over correlation circle. In other words, using (1), the equality (4) can be rewritten in the form:

$$\mathcal{D}_{\bar{\rho}} = \pi a_1 \mathcal{D}_{\rho} R^2 / S. \tag{6}$$

Hydroacoustic survey occupies an intermediate position between the two abovedescribed cases: now $h_x \ll R$, $h_y \gtrsim R$, and thus, density in the i-th knot correlates only with density in knots located on the same track at a distance no more than R. That is why, when replacing expression $h_x \sum_{j=1}^{N} A(r_{ij})/2$ by the integral of A over correlation radius, we obtain out of (1) and (4) :

$$\mathcal{D}_{\bar{\rho}} = 2 a_2 \mathcal{D}_{\rho} R h_y / S. \tag{7}$$

Since estimate of average density $\bar{\rho}$ is a random value distributed according to a normal law (N is large), its absolute error ε depends on confidence probability β and

$\sigma_{\bar{\rho}} = \sqrt{D_{\bar{\rho}}}$ which is a standard deviation of $\bar{\rho}$:

$$\varepsilon = t_{\beta}\,\sigma_{\bar{\rho}}\,. \tag{8}$$

In (8) $t_{\beta} = \sqrt{2}\,\Phi^{-1}(\beta)$ and $\Phi^{-1}(\beta)$ is Laplace's inverse function of defined confidence probability β ; tables of values t_{β} depending on β can be found in any book on mathematical statistics.

Thus, passing from ε to relative error $\delta = \varepsilon/\bar{\rho}$, from (5) - (8) we obtain the following relationships:

at $h_x \gtrsim R$, $h_y \gtrsim R$ (trawl survey)

$$\delta = t_{\beta}\, v \sqrt{h_x h_y / S}\,, \tag{9}$$

at $h_x \ll R$, $h_y \ll R$ ("superfrequent" survey)

$$\delta = t_{\beta}\, b v R / \sqrt{S}\,, \tag{10}$$

at $h_x \ll R$, $h_y \gtrsim R$ (hydroacoustic survey)

$$\delta = t_{\beta}\, c v \sqrt{R h_y / S}\,, \tag{11}$$

where $b = \sqrt{\pi a_1}$, $c = \sqrt{2 a_2}$ and $v = \sigma_{\rho}/\bar{\rho}$ is the variation coefficient of density field ρ . Note that, if correlation properties of fields under examination are similar, i.e. when reduced to normalized argumant, r/R , their correlation functions coincide, then b and c are universal constants.

From (9) - (11) it is clear that the minimum possible error is practically obtained in case of steps (h_x and h_y for trawl survey or h_y - for hydroacoustic survey) of the order of R (or some less); "superfrequent" survey is inefficient because in this case (expression (10)) the error does not depend on h_x and h_y , i.e. it does not decrease with the growth of the number of knots.

Expressions (9) - (11) represent desired dependences of biomass estimate error on survey parameters and isotropic field statistical characteristics. Consequently, when resolving equality (9) relative to $h_x h_y$, and (11) - relative to h_y , we can obtain mathematical basis for survey optimal planning. Thus, if it is necessary to estimate biomass of fishing objects in a certain region of the open ocean with the help of hydroacoustic survey with such accuracy that relative error should not exceed defined level Δ with probability β , and if a priori estimate of $\mathcal{V}$ is accurate enough, then distance between transects h_y is to be taken from the following condition:

$$h_y \leqslant \left(\frac{\Delta}{t_\beta c \mathcal{V}}\right)^2 \frac{S}{R}. \qquad (12)$$

Anisotropic fields

Up to now we have been discussing isotropic density fields. However, quite simple geometric considerations allow us to apply results obtained to anisotropic fields in which one can specify two mutually perpendicular directions in such a way that along one of them correlation radius is maximum, and along the other one - it is minimum. Such a situation occurs, for example, when survey is being carried out in shelf waters where medium, and, correspondingly, concentration characteristics change insignificantly along the shelf, and change considerably - in perpendicular direction. In this case, correlation circle gets deformed and becomes an ellipse, large and small radii of which we shall denote as R_M and R_m. It is clear that now error δ can depend on anisotropy index $k=R_M/R_m \geq 1$ and survey direction which we shall define by angle α between axis x and the large axis of correlation ellipse. Introducing symbols $R_x = R_M/\sqrt{k^2 \sin^2\alpha + \cos^2\alpha}$ and $R_y = R_M/\sqrt{k^2\cos^2\alpha + \sin^2\alpha}$ for correlation radii in directions of x- and y- axes, as well as $H_x = R_M R_m/R_y$ and $H_y = R_M R_m/R_x$ for the sizes of a rectangle with sides being parallel to axes x and y and embracing this ellipse, similarly to the abovedescribed we obtain three variants of survey: $h_x \gtrsim H_x$ and $h_y \gtrsim H_y$, $h_x \ll H_x$ and $h_y \ll H_y$, $h_x \ll H_x$ and $h_y \gtrsim H_y$. At the same time relationship (9) does not change, constants b and c remain the same, and R in (10) is replaced by $\sqrt{R_M R_m}$. For hydroacoustic survey (the third variant) we have instead of (11) and (12):

$$\delta = t_\beta c v \sqrt{R_x h_y/S}, \qquad h_y \leq (\Delta/t_\beta c v)^2 S/R ,$$

Thus when determining the accuracy of biomass estimate one has to know correlation radius only along transects Since it depends on k and α, error δ and allowed distance between transects h_y also depend on this parameters. For example, when h_y is defined, the minimum error can be obtained if $\alpha = 90°$; correspondingly, the maximum distance between transects providing for desired accuracy with defined probability, corresponds to such a direction of survey when $\alpha = 90°$.

3. Discussion

One can also present some other generalizations of the abovedescribed approach, and, in particular, for non-homogeneous fields which can be expanded into sum of deterministic component (for short, we shall call it a trend) and homogeneous random component (noise). However, such a generalization demands more complex mathematical constructions, since, formally, in this case, the sampling error, that has already been mentioned here, is connected only with the random component, and, consequently, does not characterize the whole error in biomass estimate completely enough. Thus, if noise were small as compared to trend, the first place would be occupied by the error caused by the approximate method of estimating biomass (in this case - by substituting a final sum for double integral of trend). Fortunately, as it has already been mentioned, in practice there usually takes place an inverse relation between deterministic and random components.

Results of numerical (computer) experiments on simulating surveys of various isotropic fields of one size $\ell = \sqrt{S} = const$ with one and the same step along transects $h_x = const$ (Kalikhman et al., 1986, fig. 2), allow us to realize that dependences derived here are quite universal; these model fields are represented by 50x50 numerical matrices and in general have weak autocorrelation. When analysing these data, it is convenient to use relative distance between transects h_y/ℓ instead of h_y.

Survey carried out with the help of this discrete model can be interpreted as hydroacoustic or trawl survey with stations installed frequent along transects - from the abovesaid it is clear that it depends on correlation properties of fields being simulated. However, in any case, if error δ in biomass estimate obeys dependence (9) or (11), then (since S and h_x are constant) values $\xi = \delta/v\sqrt{h_y/l}$, corresponding to each experiment , should be proportional to t_β with coefficient of proportion constant for every field; in this case empirical probability β is defined as a ratio n_ξ/n of the number n_ξ of experiments in which ξ does not exceed the given level, and the total number n of experiments. Check-up with the help of these data showed that it is true (see fig.1). Moreover, from the fig.1 it is clear that relationship $\xi = q\, t_\beta$ or(which is the same) $\delta = q\, t_\beta v\sqrt{h_y/l}$, where $q \approx 0.15$, is satisfied with food accuracy. Thus, coefficient of proportion is actually the same for all model fields, despite the fact that they have different (in some cases rather significant) trend.

Also note, that in data used (Kalikhman et al., 1986) value δ represents an average error for several methods of estimating B , including via expression $B = \bar{p} S$, and this means that relationships similar to those derived in this paper, are valid for other methods of estimating biomass.

4. Conclusion

Results mentioned here can be used in practice both for a posteriori estimation of relative error in biomass estimate by means of survey matherials and for survey optimal planning, i.e. determining its parameters by already known estimates of field statistical characteristics, allowed error and desired confidence probability. In last case, if there are not enough a priori data of this kind, one can use the method of operative control, when all the necessary field characteristics are being determined and gradually checked in the course of survey itself. According to them, on the basis of dependences offered, survey parameters are chosen and detailed, and survey is gradually being transformed into an optimal regime. In this case, however, one should take into account the fact that if this process takes too long and survey is transformed into optimal regime too late (or does not have time at all to get transformed into it), then biomass estimate error might turn out to be higher than that desired for defined confidence probability.

References

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List of Symbols

A - normalized correlation function of the field ρ

B - biomass or its estimate

D_ρ - dispersion of the field ρ

$D_{\bar{\rho}}$ - dispersion of $\bar{\rho}$

h_x, h_y - grid steps along axes x and y

k - anisotropy index

K_{ij} - correlation moment

l - size of a model field

N - number of the grid knots (size of a sample)

R - correlation radius of an isotropic field

R_M, R_m - large and small correlation radii

R_x - correlation radius in the direction of tracks

S - area of the region under survey

v - variation coefficient

x, y - coordinate axes (the survey transects are parallel to x-axis)

α - angle between axis x and the large axis of the correlation ellipse

β - confidence probability

δ - relative sampling error of biomass estimate

Δ - desired relative accurancy of a survey

ε - absolute sampling error of biomass estimate

ρ - surface density of concentrations

$\bar{\rho}$ - average density (over the region under survey)

$\sigma_{\bar{\rho}}$ - standard deviation of $\bar{\rho}$

$\Phi^{-1}(\beta)$ - Laplace's inverse function on β

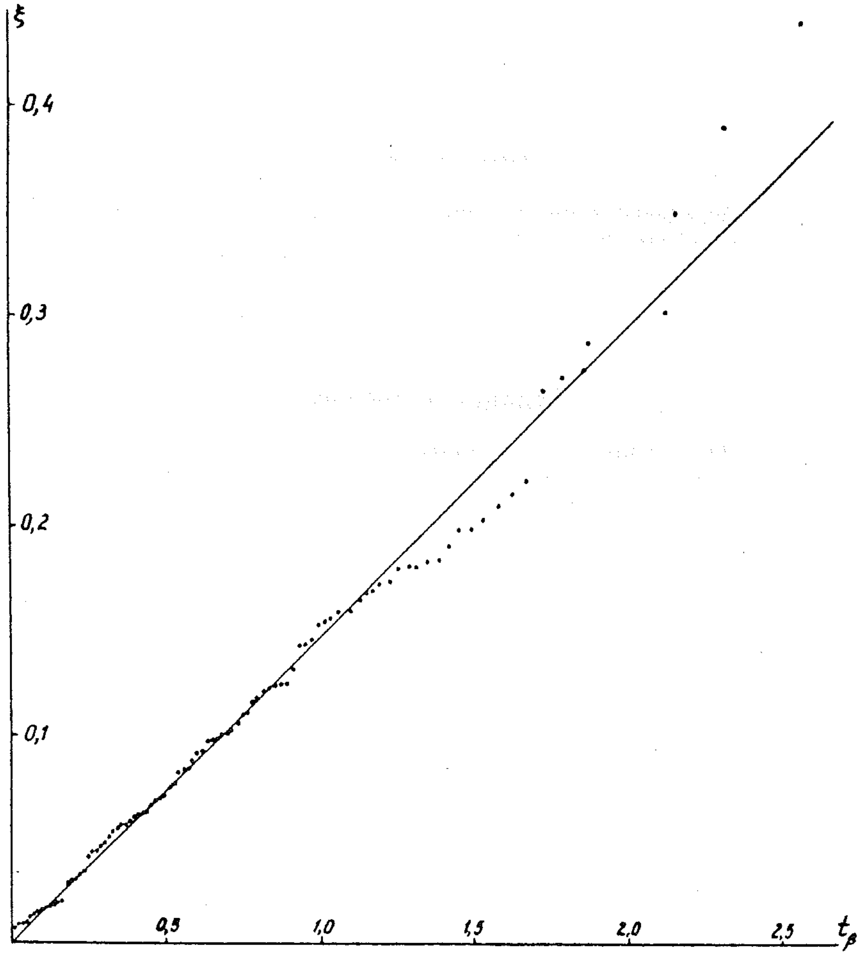

Fig.1. Dependence of value $\xi = \delta / v\sqrt{h_y / l}$ on t_β : points are experimental data, straight line is the graph of equation $\xi = 0.15\, t_\beta$

Légende de la figure

Figure 1 Dépendance de la valeur $\xi = \delta / v\sqrt{h_y/l}$ sur t_β : les points correspondent à des données expérimentales, la ligne droite est le graphe de l'équation $=0,15t$.

Leyenda de la Figura

Figura 1 Dependencia del valor $\xi = \delta / v\sqrt{h_y/l}$ de t_β : los puntos corresponden a datos experimentales, la línea recta es el gráfico de la ecuación $=0.15t$.

Подпись к рисунку

Рисунок 1 Зависимость величины $\xi = \delta / v\sqrt{h_y/l}$ от t_β : точки - данные экспериментов, прямая линия - график уравнения $= 0,15t$.

(WG-FSA-87/8 Rev.1
and WG-FSA-87/15)

SIMULATION OF RECOVERY RATES OF FISH STOCKS IN THE SOUTH GEORGIA AND KERGUELEN ISLANDS AREAS

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Abstract

The benefits of conservation measures are generally based on the rebuilding of the depleted stocks and improvement in yields. It is desirable that such measures be based on the expected rate of recovery relative to rates of fishing.

A simulation model based on a probabilistic recruitment function was developed to provide long-term projections of the magnitude and rate of recovery of important fish stocks. While annual recruitment is the primary factor affecting recovery, the age of first recruitment is also an important consideration.

The simulated yields correspond, on the average, with the past observations. The simulations may prove useful in comparing observed performance of regulations to the expected outcomes from the simulations.

Résumé

Les avantages des mesures de conservation sont généralement basés sur la reconstitution des stocks dépeuplés et l'amélioration des rendements. Il est souhaitable que de telles mesures soient basées sur le taux prévu de repeuplement par rapport aux taux d'exploitation.

Un modèle de simulation basé sur une fonction de recrutement probabiliste a été mis au point afin de fournir des projections à long terme sur la magnitude et le taux de repeuplement des stocks de poissons importants. Bien que le recrutement annuel soit le principal facteur affectant le repeuplement, l'âge au premier recrutement est aussi une considération importante.

Les rendements simulés correspondent dans l'ensemble aux observations antérieures. Les simulations peuvent s'avérer utiles si l'on compare la performance observée de la réglementation aux résultats prévus des simulations.

Resumen

Los beneficios de las medidas de conservación se basan generalmente en la reconstrucción de las reservas agotadas y el mejoramiento en los rendimientos. Es deseable que tales medidas estén basadas en la tasa esperada de recuperación relativa a las tasas de pesca.

Se desarrolló un modelo de simulación basado en una función probabilística de restablecimiento para proporcionar proyecciones a largo plazo de la magnitud y tasa de recuperación de importantes reservas de peces. Mientras que el restablecimiento anual es el principal de los factores que afectan la recuperación, la edad de primer restablecimiento es también una consideración importante.

Los rendimientos simulados guardan correspondencia, en el promedio, con las observaciones pasadas. Las simulaciones pueden resultar útiles para comparar el desempeño observado de los reglamentos con los resultados esperados de las simulaciones.

Резюме

Польза мер по сохранению заключается в основном в восстановлении истощенных запасов и увеличении вылова. Желательно, чтобы эти меры основывались на ожидаемых величинах темпов восстановления по отношению к интенсивности промысла.

С целью получения долгосрочных прогнозов относительно уровня и темпа восстановления важных рыбных запасов была разработана имитационная модель, основанная на вероятностной функции пополнения. В то время, как ежегодное пополнение является основным фактором, влияющим на процесс восстановления, также очень важно учитывать и возраст при первом вхождении в облавливаемый запас.

Полученные с помощью имитационной модели величины уловов в среднем соответствуют сделанным ранее наблюдениям. Эти имитационные модели могут оказаться полезными при сравнении наблюдаемых результатов применения мер с ожидаемыми результатами, полученными с помощью имитационных моделей.

SIMULATION OF RECOVERY RATES OF FISH STOCKS IN THE SOUTH GEORGIA AND KERGUELEN ISLANDS AREAS

I. INTRODUCTION

The Fish Stock Assessment Working Group concluded from analysis completed at its 1986 meeting that the stocks at South Georgia Island (Subarea 48.3) and Kerguelen Island (Subarea 58.5) have been depleted by heavy fishing (Report of the Fifth Meeting of the Scientific Committee, 1986). N. rossii was deemed severely depleted, and the Commission agreed that only small, unavoidable by-catches should be taken. The group also estimated that the stock could be expected to increase at an approximate rate of 30% per year with no fishing on it. C. gunnari and N. gibberifrons around South Georgia Island were also deemed to have been reduced to low enough stock sizes to cause concern.

The Scientific Committee recommended that the Commission take steps to ensure recovery of the fish stocks. Several options for action with respect to C. gunnari and N. gibberifrons were put forward which included a range from no fishing to limiting catch to the 85-86 season level. None of the options proved acceptable.

This paper presents projections of the stocks and catch over the next 20 years for the major species of concern at different fishing mortalities. These projections provide estimates of the expected annual rate of change of the stock sizes and yield.

Recruitment of new cohorts to the stock is the most important factor determining the rate of recovery of the stocks. The 1986 Fish Stock Working Group analysis provided some estimates of the sizes of past recruiting year classes. The time series for estimates is rather short, and the data upon which they were based rather poor. The effect of factors such as stock size and environment on the size of recruiting year classes is not known.

The simulations provide a measure against which the actual results of any recovery program can be compared.

II. METHODS

Because of the state of available data, we have taken a data-based modeling approach. Annual recruitment is estimated from a probablistic model. This is used in a simulation model which is otherwise deterministic. The projections, in effect, represent samples from some rather large universe of possibilities from which expected rates of recovery and measures of variability are obtained.

In the model for projecting future fish stock size, natural mortality and growth parameters may be assumed to not change much over time, at least relative to the effects of recruitment. With these fixed parameters, the recruitment and structure, stock size and yield for the next year are calculated using the Murphy catch equation. The size of the recruiting year class affects the future stock size far more than the growth and mortality factors, except for fishing.

1. Recruitment Function

The approach used in this paper is to fit a mixture of lognormal distributions by a modified kernel method to recruitment data and to use this distribution to generate observations for recruitment. The nonparametric method employed is a variation of the kernel technique. The distribution to be estimated is approximated by a mixture of lognormal distributions. There is one lognormal (known as a Kernel) for each available observation. Each kernel is "centred" so that its geometric mean is located at the corresponding observation. The logarithmic standard deviation of the various kernels is known as the bandwidth. The bandwidth was taken to be proportional to the geometric mean; i.e., the coefficient of variation was constant.

The central theme in application of kernel methodology is determination of suitable bandwidth. Overly small bandwidths yield estimated pdf's whose graphs have a rough, jagged appearance. Excessively large bandwidths smooth the probability mass over a wide interval, losing most of the local features of the data. There is extensive literature on kernel methods (Wertz and Schneider, 1979) and we will not here dwell upon the technical aspects except to point out that bandwidth determination was done through cross-validation.

A universal recruitment model was fitted to pooled data consisting of recruitment series for 18 fish stocks from various parts of the world (Hennemuth et al., 1982). The pooled data were scaled to normalize magnitudes which varied among species, and combined into a single large data set consisting of 325 observations. The histogram of the combined data set is shown in Figure 1. Superimposed is the fitted kernel estimate. The kernel fit, while generally acceptable, does exhibit a leftward bias for small year classes. We have been able to remove most of this bias by using variable bandwidths. As noted, recruitment data for the South Georgia and Kerguelen Islands area stocks are limited and could not be used for direct fitting.

In order to use this method of generating recruitment for the present study, the recruitment curve was adjusted to the arithmetic mean of the size of recruiting year classes of the South Georgia stocks. Figure 2 displays some of the frequency distributions of the size of annual recruitment generated for the various simulation runs.

2. Age of First Recruitment

The age of first recruitment to the fishery stock was determined by analyzing the instantaneous fishing mortality rates from the VPA for each year. The mortality rates of each age within a year were scaled from the age of maximum mortality rate within that year to the lowest age of fish caught. The estimated fishing mortality at age was rather variable from year to year. The age of first recruitment was chosen based on the most consistent significant catches of the younger age groups. The age of first recruitment generally corresponds to 10% of full F. Table 1 displays the initial age and average size in numbers of recruitment for each species. The arithmetic mean of the size of the recruit was used to adjust the scale of the generalized recruitment function. The arithmetic mean of all years was used as the average of the size of the recruiting age groups. The age of first recruitment derived from the VPA data was also used for the survey analysis of one year's data.

3. Simulation Model

The simulation model calculates, using the Murphy catch equation, a time-series of catch and remaining stock sizes given various levels of fishing and natural mortality, initial stock size, and recruitment. Recruitment was generated by the kernel method described in the preceding paragraphs. The starting parameters used in this analysis are displayed in the data section.

The output of the model includes stock size (numbers) and biomass, catch numbers, and weight; averages and standard errors are also produced for each of the 20-year runs. For each set of parameters, ten simulation runs were made. The average of the ten runs for each year was also calculated to show major trends. This average is not, however, a valid measure of the expected yearly simulated values.

III. DATA

1. South Georgia

The VPA's used by the CCAMLR Fish Working Group (see Working Group Report, SC-CAMLR-V/4), which included fisheries for *N. rossii*, *N. gibberifrons*, and *C. gunnari* in South Georgia Island waters, were used as one data base for age composition, recruitment, fishing and natural mortality rates, initial stock size, and biomass. A second estimate of initial stock size, biomass, and age composition was based on 1987 US/Polish research vessel survey data, where biomass estimates were based on swept-area calculations (Gabriel, 1987, SC-CAMLR-VI/BG/12, Rev.1).

Estimates of initial stock composition (numbers at age) were calculated by averaging years 1983 and 1984 for all three species in the VPA's. SURVAN, a groundfish survey analysis program, processed the 1987 research vessel survey data into biomass estimates and population estimates by length. K.-H. Kock's age/length table for N. rossii from South Georgia in January/February, 1985 (SC-CAMLR-IV/BG/12) was applied to convert the research vessel survey length data to population estimates by age. Split-year Polish age/length tables from fishery catch samples were available for N. gibberifrons : 76/77, 77/78, 78/79, 80/81, 81/82; and C. gunnari : 76/77, 77/78, 78/79, 80/81, 81/82 and 83/84. The annual age/length keys for each of the two species were combined and normal curves of ages were fit within each length interval to obtain estimates of population numbers at age. A von Bertalanffy age/length equation was used when the age/length keys did not cover the range of lengths. The parameter estimates for von Bertalanffy's equation came from the BIOMASS Scientific Series No. 6, 1985, by K.-H. Kock, G. Duhamel, and J.-C. Hureau.

The terminal-year fishing mortality coefficients in the VPA's were used for the fully recruited age groups. A vector of partial fishing mortality rates was developed from a multiplicative analysis of variance model (ln F = ln age + ln year) incorporating year and age effects which was fit to a matrix of log F's from the 1980-1984 VPA's. The retransformed vectors of age-specific coefficients were used as the partial recruitment vector. The coefficient of determination (R^2) for the models for N. rossii, N. gibberifrons, and C. gunnari was 0.897 and 0.599, and 0.740, respectively.

Table 2 displays the final format of the data.

2. Kerguelen

The VPA's estimated by Duhamel (1987, PhD. unpublished), for N. rossii and N. squamifrons fisheries on the Kerguelen Island shelf, were used to obtain the parameters for simulation (Table 3).

Estimates of initial stock composition (numbers at age) were calculated averaging years 1982 and 1983 for N. rossii, and 1985 and 1986 for N. squamifrons in the VPA's. The coefficient for determination (R^2) for the models for N. rossii and N. squamifrons was 0.878 and 0.496, respectively.

IV. RESULTS

Graphs of the ten stock size projections and the mean for the various species and fishing mortalities are presented in Figures 3 to 18 for South Georgia stocks and 19 to 22 for Kerguelen stocks. The averages of the ten 20-year projections for the stock size and catch in numbers and weight are given in Table 4 (South Georgia) and Table 5 (Kerguelen). It may be useful to reiterate here that the higher F is the terminal F value used in last year's VPA's, and the lower is half that excepting N. rossii at South Georgia where the highest F of 0.5 is taken from Saila et al. (MS) (see SC-CAMLR-VI/3) analysis. The SURVAN projections are in units relating to the Polish research vessel catchability factor which is obviously less than that of the commercial vessels. One can compare only the relative rates of change.

1. Stock Recovery Rates

1.1 N. rossii

1.1.1 South Georgia

For the VPA-based projections at F = 0.089, the stock size increases steadily to its peak at about 2.5 times the starting value in seven years; it doubles in five years. For F = 0.177, the stock size increases to its peak again at about 2.5 times the starting point in about 12 years; doubling in about seven years. For F = 0.55, the stock does not exhibit any trend of recovery.

With the survey data, the stock declines by a third or more for all F values in from six to eight years, after which it stabilizes at the lower size.

1.1.2 Kerguelen

The VPA-based projections indicate that at F = 0.38 the stock increases by a factor of 2 in about five years; however, the recovery is only 1.7 times the initial size with F = 0.76.

1.2 N. gibberifrons (South Georgia)

The VPA-based projections indicate that at F = 0.071 the stock increases to about 2.8 times the initial size in ten years; it doubles in about five years. At F = 0.142, the stock peaks at about 2.5 times the initial size in 15 years and doubles in 11 years. For the survey data base, the stock increases slowly by about 50% over the 20 years at F = 0.071. For F = 0.142, the stock does not change significantly.

1.3 C. gunnari (South Georgia)

The projections for this stock do not indicate any recovery at any of the fishing mortality coefficients for either of the data sets. The mortalities are higher than those applied to other species, as is the magnitude of stock size (note the different ordinal scale on the plots).

1.4 N. squamifrons (Kerguelen)

At F = 0.36, the stock almost doubles in five years and increases slowly but continuously over the 20 years. For the VPA-based projection at F = 0.72, the stock size increases to about 2.3 times the initial value in five years.

2. Biomass and Yield Changes

The projections of stock biomass and yield for the same data sets used to describe stock size trends are portrayed in Figures 23-29 (South Georgia) and 30-31 (Kerguelen); the data are contained in Tables 4 and 5.

2.1 South Georgia

2.1.1 N. rossii

The trends in stock biomass are, of course, similar to those of stock numbers, but the biomass doubles in less time than it takes for the numbers of fish to do so. This results from the increasing numbers of older fish compared to the initial age composition. For the VPA data set at F = 0.55, the catch peaks in about five to nine years at a level double the initial yields; thereafter it declines slowly. At F = 0.177, the yield rises slowly, peaking in 15 years at about 5 times the initial yield. At F = 0.089, the yield peaks at ten years at 6 times the initial yield.

The survey data set indicates continuously declining yields at F = 0.55, while at the lower fishing mortalities the yield increases slightly at first, but does not change significantly over the projection period.

2.1.2 N. gibberifrons

As with N. rossii, the trends in stock biomass have a pattern similar to that of stock numbers but with the biomass doubling in less time.

The yields increase steadily to about 4 times the initial yield at the end of the 20-year simulation, doubling in four years for both mortalities.

For the SURVAN data set, the yields do not change.

2.1.3 C. gunnari

Projections from the VPA data set indicate immediate drop in yields at both fishing mortality levels, followed by increases in the 4-10-year period and further decreases thereafter. Projections from the survey data base illustrate highly variable changes in yield, but no long-term trend at F = 3.5; a short-term increase by 2X in six years, decreasing thereafter at F = 1.75; a doubling in yield in 11 years at F = 0.875.

2.2 Kerguelen

2.2.1 N. rossii

The trends in stock biomass show a similar pattern to the stock numbers. For the VPA data set at F = 0.76, the yield peaks in six years at double the initial level; thereafter, it declines slowly. At F = 0.38, the catch peaks in ten years at about 4.2 times the initial yield and is followed by a small decline.

2.2.2 N. squamifrons

The trends in stock biomass again show a similar pattern to the stock numbers. The yields increase by a factor of 4 for F = 0.72 and by 6 for F = 0.36 at the end of the 20 years simulated.

3. Summary of Trends

3.1 South Georgia

The entries in Table 6 summarize the points of reference for the various projections. In general, for N. rossii and N. gibberifrons, the stock size recoveries were larger for the lower F's used, and indicated recovery to over double the initial size in from 8 to 15 years. Recovery of stock biomass was relatively larger and faster. The survey-data-based projections indicated recovery only for C. gunnari at lower F's. N. gibberifrons indicated no significant changes, while N. rossii yields and population decreased at high F and did not recover at lower F's. The differences are likely due to the fact that only the one year's point was available for determinig recruitment year-class size in the survey catchability units. The accuracy is unknown. This applies as well to the numbers at age for the initial population, but this is of less concern since the simulation will tend to equilibrate after a few years.

The situation for C. gunnari is obviously different. The stock does not recover but rather declines, except for the lowest mortality in the SURVAN data set. The relatively high fishing mortality is likely responsible. Another factor is that the full mortality is applied from the age of recruitment, which corresponds to the pattern observed in the data. Perhaps a marginally significant increase in yield would occur at F = 0.875.

3.2 Kerguelen

The entries in Table 7 summarize the points of reference for various projections. In the Kerguelen area, the stock size recoveries are larger for the lower F's. At F = 0.38, the stock size for N. rossii doubles in five years. Note that for N. squamifrons, the higher F doubles in four years and the lower F in ten years. However, the stock population over 20 years remains relatively low and constant. If the maximum increase factor for the high F is compared with the low F, there is a relatively smaller change in stock size, but a significantly larger change in the yield. The larger change in yield would be due to the shift in the age composition.

V. DISCUSSIONS AND CONCLUSIONS

The results have defined, under the constraints of the fishing mortality rates applied, the probable recovery rates of the stocks. It has been demonstrated for the simulations based on the VPA data set for N. rossii, N. gibberifrons, and N. squamifrons, that recovery within a reasonable time period might indeed be expected. For C. gunnari, this is not the case. With the initial stock size and age composition taken from the 1987 US/Polish research cruise data, the stock simulations indicated less and slower recovery; some declined.

The major factors affecting the results are the recruitment and fishing--both the level of F and the age at which it is applied.

1. Recruitment

The probability density function used, and the random year-by-year selection from it, assume that the past average recruitment will continue, and that the frequency distribution of various sizes of the recruiting year class follow the "universal" set of data. In the simulation, stock size is not a directly dependent variable, but the historical set of observations from which the pdf is derived would implicitly account for the influence of the various factors. Use of the usual stock and recruitment relations, however, would not much affect the results of the relative recovery rate.

2. Fishing Mortality

The F applied to the terminal year of the VPA's (1985) was derived from the Federal Republic of Germany's 1985 survey results for the South Georgia stocks. The VPA indicated considerably higher F's in previous years. Higher fishing mortality rates would certainly reduce the amount and rate of recovery illustrated in the analysis. This is demonstrated for N. rossii if the higher 1986 mortality rate in Saila et al. is applied. Another aspect of fishing mortality is the distribution over the young ages. This is demonstrated in the simulations for C. gunnari, where the full F was applied to the recruiting year class. The stock declined and both the stock size (and biomass) and yield illustrated large changes from year to year; they were highly dependent on the size of the annually recruiting year class. Past data indicate that for some years the other stocks also had high mortalities on younger age classes.

The lack of data about the Kerguelen stocks before the establishment of an Exclusive Economic Zone (1978) must be pointed out, but from the beginning of exploitation (1970) to this date, high levels of catch were reported and, hence, probably also mortality. The current fishing rates have been reduced following the conservation measures (lower F level or F = 0) and now the rate of recovery must be close to the simulation model results.

3. Yields

The magnitude and pattern could change markedly from those simulated, depending on the pattern of fishing. It may be noted that the fluctuating yields of C. gunnari simulated here tend to be similar to past observations.

The application of a constant F and partial recruitment over the years in the simulations is not what has been observed in the past fisheries. Also observed is that fishing mortality is increased on large recruiting year classes. The yield and population is most likely higher in the simulations than in practice, because a constant F is the more optimal method for longer-term yields.

The magnitudes of average annual yields from the simulations (VPA-based) compared to the reported catches are given in Table 8.

The close correspondence of average simulated yield to average observed catch cannot be used simplistically to validate the simulations, nor to judge the correct magnitude of F. Because the simulations were based on the VPA's which are calculated from fishery data, the average reported catches are not independent of the simulated yields. However, it does provide an indication that if the input parameters are suitably scaled to the commercial fishing practices, the recruitment model and the simulations provide results which can be used to judge probable future realizations.

The simulated yields point out the important result that the yield per unit F is higher, particularly for C. gunnari, for the lower fishing rates.

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Table 1. Initial age and numbers in millions of individual recruits

	South Georgia Age	South Georgia Average Recruitment VPA	South Georgia Average Recruitment Survey	Kerguelen Age	Kerguelen Average Recruitment VPA
N. rossii	4	4.152	0.151	5	1.725
N. squamifrons				7	1.189
N. gibberifrons	8	15.132	3.322		
C. gunnari	3	228.540	260.218		

Table 2. Parameters used for simulation model (South Georgia)

Age	Initial Stock Size (millions) VPA	SURVAN	F Vector	Biomass (kg)
		N. rossii		
4	-	-	0.3036	0.735
5	3.235	1.033	0.5228	1.526
6	2.299	0.903	0.6501	2.382
7	1.071	0.535	0.9664	3.090
8	0.285	0.255	1.0000	3.808
9	0.091	0.127	1.0000	4.430
10	0.071	0.051	1.0000	5.013
11	0.023	0.022	1.0000	5.586
12+	0.006	0.029	1.0000	6.077
		N. gibberifrons		
8	-	-	0.4496	0.331
9	9.220	3.603	0.5807	0.433
10	4.102	3.598	0.6695	0.522
11	2.391	2.939	0.8597	0.578
12	1.651	2.070	1.0000	0.659
13	1.006	1.361	1.0000	0.708
14	0.877	0.769	1.0000	0.784
15	0.304	0.409	1.0000	0.877
16	0.000	0.214	1.0000	0.923
17	0.000	0.093	1.0000	0.999
18	0.000	0.037	1.0000	1.079
19+	0.012	0.022	1.0000	1.124
		C. gunnari		
3	-	-	1.0000	0.132
4	60.985	20.844	1.0000	0.256
5	35.113	7.196	1.0000	0.359
6	8.853	2.432	1.0000	0.435
7	2.918	1.152	1.0000	0.480
8	0.836	0.745	1.0000	0.534
9	0.418	0.282	1.0000	0.582
10+	0.626	0.191	1.0000	0.665

Table 3. Parameters used for simulation model (Kerguelen)

Age	Initial Stock Size (millions)	F Vector	Biomass (kg)
	N. rossii (Kerguelen)		
5	-	0.1978	0.988
6	0.959	0.3662	1.490
7	0.483	1.0000	2.058
8	0.172	1.0000	2.672
9	0.121	1.0000	3.319
10	0.103	1.0000	3.975
11	0.051	1.0000	4.632
12	0.038	1.0000	5.271
13+	0.028	1.0000	5.897
	N. squamifrons (Kerguelen)		
7	-	0.0979	0.245
8	0.640	0.2278	0.349
9	0.420	0.3061	0.457
10	0.241	0.3210	0.549
11	0.118	0.4674	0.707
12	0.043	0.6418	0.846
13	0.012	1.0000	0.991
14+	0.001	1.0000	1.142

Table 4. Average of the Ten 20-Year Projections for Stock Size in Numbers (X 10^{-6}) and Weight (X 10^{-3})

Year	Stock Weight	Catçh Weight	Stock (No's)	Catch (No's)
		N. rossii VPA F = 0.177		
1985	18.935	2.006	11.441	0.990
1986	26.454	3.122	13.346	1.319
1987	34.053	4.293	15.532	1.624
1988	42.097	5.497	18.590	1.968
1989	48.721	6.558	18.741	2.146
1990	55.269	7.513	21.162	2.367
1991	59.713	8.295	21.869	2.542
1992	64.645	8.699	25.625	2.746
1993	67.412	9.223	24.601	2.859
1994	69.213	9.468	25.111	2.893
1995	71.749	10.103	25.581	3.040
1996	73.570	10.228	26.417	3.055
1997	76.771	10.381	30.624	3.288
1998	81.222	11.151	28.672	3.380
1999	80.340	11.248	26.452	3.259
2000	80.181	11.625	26.671	3.312
2001	74.125	10.669	24.071	3.004
2002	75.144	10.603	25.678	2.991
2003	73.373	10.395	24.555	2.949
2004	74.520	10.228	27.455	3.027
AVE	63.380	8.570	23.110	2.640
		N. rossii VPA F = 0.089		
1985	18.930	1.041	11.433	0.511
1986	28.540	1.737	14.891	0.742
1987	38.203	2.544	16.552	0.937
1988	49.001	3.414	20.325	1.163
1989	60.182	4.326	23.028	1.375
1990	70.416	5.126	24.443	1.514
1991	79.099	5.838	27.372	1.685
1992	84.242	6.279	27.913	1.772
1993	86.570	6.485	27.245	1.775
1994	86.589	6.560	27.554	1.793
1995	85.008	6.511	25.561	1.733
1996	86.274	6.626	25.336	1.702
1997	80.869	6.256	23.762	1.612
1998	79.120	5.964	25.561	1.589
1999	79.855	5.959	25.842	1.617
2000	75.118	5.556	23.865	1.530
2001	73.395	5.579	22.618	1.519
2002	74.454	5.666	24.119	1.548
2003	71.571	5.411	22.508	1.477
2004	75.960	5.636	25.292	1.546
AVE	69.170	5.130	23.260	1.460

Table 4 (continued) N. rossii SURVAN F = 0.177

Year	Stock Weight	Catch Weight	Stock	Catch
1987	7.56	.96	3.08	.35
1988	8.28	1.16	2.80	.36
1989	8.50	1.29	2.54	.36
1990	8.22	1.26	2.18	.31
1991	7.59	1.16	1.91	.27
1992	6.65	1.02	1.59	.22
1993	5.34	.81	1.29	.18
1994	3.75	.55	1.05	.13
1995	2.34	.33	.80	.09
1996	2.35	.33	.79	.09
1997	2.28	.32	.80	.09
1998	2.22	.31	.81	.09
1999	2.32	.32	.87	.10
2000	2.34	.32	.85	.10
2001	2.41	.34	.82	.10
2002	2.42	.34	.82	.10
2003	2.37	.33	.84	.10
2004	2.42	.34	.86	.10
2005	2.50	.34	.92	.10
2006	2.49	.35	.85	.10
AVE	4.22	.61	1.33	.17

N. rossii SURVAN F = 0.089

Year	Stock Weight	Catch Weight	Stock	Catch
1987	7.58	.50	3.10	.18
1988	8.79	.65	2.87	.20
1989	9.55	.77	2.68	.21
1990	9.88	.80	2.50	.19
1991	9.73	.79	2.34	.17
1992	9.08	.73	2.10	.15
1993	7.65	.61	1.80	.13
1994	5.32	.42	1.35	.09
1995	2.95	.22	.93	.06
1996	2.94	.22	.93	.06
1997	3.05	.23	.94	.06
1998	3.06	.23	.93	.06
1999	2.99	.23	.92	.06
2000	2.94	.22	1.02	.06
2001	2.99	.22	1.02	.06
2002	2.98	.22	1.01	.06
2003	3.11	.23	1.02	.07
2004	3.16	.24	.98	.07
2005	3.14	.24	.94	.06
2006	3.13	.24	.97	.06
AVE	5.20	.40	1.52	.10

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock (No's)	Catch (No's)
		N. rossii VPA F = 0.55		
1985	18.858	5.472	11.336	2.745
1986	26.184	7.401	17.758	3.963
1987	30.838	9.321	16.803	4.381
1988	33.217	10.475	16.459	4.422
1989	33.894	11.416	16.400	4.576
1990	33.904	11.168	16.684	4.475
1991	34.029	11.119	16.688	4.474
1992	35.353	11.336	18.325	4.731
1993	34.201	11.418	15.242	4.410
1994	32.387	10.945	14.535	4.097
1995	29.177	10.187	12.725	3.744
1996	28.656	9.391	14.484	3.730
1997	28.126	9.254	13.461	3.686
1998	27.530	8.987	12.991	3.529
1999	26.704	8.979	12.595	3.502
2000	26.331	8.645	13.033	3.466
2001	26.038	8.494	12.816	3.445
2002	26.918	8.662	13.729	3.582
2003	29.244	9.176	16.152	4.035
2004	32.566	10.043	17.973	4.506
AVE	29.710	9.600	15.010	3.980
		N. rossii SURVAN F = 0.55		
1987	7.56	2.57	3.08	.96
1988	6.25	2.31	2.13	.74
1989	4.77	1.88	1.51	.55
1990	3.39	1.33	1.01	.36
1991	2.38	.91	.72	.24
1992	1.75	.65	.62	.19
1993	1.36	.47	.56	.16
1994	1.10	.37	.48	.13
1995	.96	.31	.47	.13
1996	.96	.32	.47	.13
1997	.94	.31	.44	.12
1998	.89	.30	.40	.11
1999	.82	.28	.35	.10
2000	.78	.26	.38	.10
2001	.78	.25	.40	.10
2002	.79	.25	.39	.10
2003	.82	.26	.42	.11
2004	.84	.27	.42	.11
2005	.85	.27	.42	.11
2006	.89	.29	.47	.12
AVE	1.94	.69	.76	.23

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock (No's)	Catch (No's)
		N. gibberifrons VPA F = 0.142		
1985	17.174	1.418	40.381	3.078
1986	21.613	1.908	46.180	3.831
1987	25.930	2.421	52.258	4.580
1988	30.901	3.037	60.974	5.564
1989	33.582	3.493	61.779	6.002
1990	35.877	3.804	63.821	6.302
1991	38.629	4.141	67.991	6.728
1992	42.955	4.544	76.376	7.364
1993	46.307	4.872	81.429	7.834
1994	48.705	5.181	83.243	8.149
1995	49.209	5.378	80.894	8.214
1996	50.043	5.500	82.831	8.398
1997	49.611	5.427	83.242	8.381
1998	50.822	5.519	85.244	8.497
1999	54.902	5.790	96.273	9.195
2000	55.450	5.909	94.855	9.301
2001	56.689	6.100	95.166	9.459
2002	55.146	6.136	88.785	9.251
2003	53.200	6.044	83.521	8.893
2004	51.814	5.839	83.075	8.663
AVE	43.430	4.620	75.420	7.380
		N. gibberifrons VPA F = 0.071		
1985	15.462	0.674	35.211	1.416
1986	20.984	0.958	44.784	1.905
1987	27.036	1.297	55.052	2.457
1988	33.705	1.699	66.247	3.092
1989	40.309	2.111	75.969	3.679
1990	43.829	2.417	76.385	3.951
1991	47.727	2.708	80.267	4.253
1992	51.993	2.999	85.626	4.579
1993	54.968	3.205	87.174	4.723
1994	59.540	3.429	94.869	5.012
1995	63.316	3.649	99.761	5.274
1996	64.760	3.743	100.560	5.360
1997	64.440	3.735	100.259	5.376
1998	64.600	3.785	99.347	5.405
1999	64.770	3.789	100.325	5.429
2000	63.308	3.718	97.342	5.317
2001	62.102	3.655	95.011	5.203
2002	63.148	3.732	95.686	5.251
2003	63.700	3.748	97.148	5.277
2004	64.991	3.762	101.551	5.380
AVE	51.730	2.940	84.430	4.420

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock	Catch
	N. gibberifrons SURVAN F = 0.142			
1987	9.83	1.01	18.30	1.75
1988	10.65	1.13	19.13	1.88
1989	11.36	1.23	19.84	1.98
1990	11.63	1.28	19.40	1.99
1991	11.58	1.30	18.51	1.94
1992	11.86	1.32	19.13	1.97
1993	11.96	1.33	19.28	1.97
1994	11.86	1.31	19.03	1.93
1995	11.58	1.28	18.51	1.89
1996	11.26	1.25	18.10	1.85
1997	10.62	1.19	16.82	1.75
1998	10.46	1.16	16.97	1.73
1999	10.38	1.15	16.89	1.72
2000	10.54	1.14	17.63	1.74
2001	10.54	1.14	17.69	1.75
2002	10.87	1.17	18.36	1.81
2003	11.33	1.21	19.32	1.89
2004	11.99	1.26	21.11	2.02
2005	12.17	1.29	20.98	2.05
2006	12.40	1.33	21.11	2.09
AVE	11.24	1.22	18.80	1.89
	N. gibberifrons SURVAN F = 0.071			
1987	9.99	.52	18.77	.91
1988	11.73	.63	21.49	1.07
1989	12.52	.71	21.07	1.12
1990	12.98	.76	20.38	1.14
1991	13.36	.81	20.21	1.15
1992	14.24	.85	21.83	1.20
1993	15.32	.88	24.17	1.26
1994	15.42	.89	23.45	1.25
1995	15.02	.88	22.14	1.22
1996	14.47	.87	21.38	1.20
1997	13.80	.83	20.44	1.15
1998	13.30	.79	19.80	1.10
1999	13.49	.78	21.04	1.12
2000	13.15	.76	20.76	1.10
2001	14.24	.80	23.27	1.19
2002	15.52	.87	25.68	1.30
2003	15.96	.91	25.41	1.33
2004	16.00	.91	25.71	1.36
2005	15.96	.92	26.11	1.39
2006	16.77	.96	27.31	1.44
AVE	14.16	.82	22.52	1.20

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock (No's)	Catch (No's)
		C. gunneri VPA F = 3.50		
1985	63.974	60.159	332.466	312.642
1986	23.855	22.433	169.194	159.105
1987	21.781	20.482	160.517	150.946
1988	30.620	28.794	227.841	214.255
1989	33.554	31.553	248.388	233.577
1990	38.627	36.324	286.269	269.199
1991	27.488	25.849	200.916	188.936
1992	40.957	38.515	305.074	286.883
1993	32.151	30.234	235.800	221.739
1994	48.264	45.386	359.549	338.109
1995	29.094	27.359	211.253	198.656
1996	40.695	38.268	302.790	284.735
1997	21.303	20.033	153.665	144.502
1998	30.969	29.123	230.588	216.839
1999	32.756	30.803	242.277	227.830
2000	19.392	18.235	140.696	132.306
2001	32.989	31.022	246.247	231.564
2002	35.396	33.285	261.890	246.274
2003	27.711	26.058	203.218	191.101
2004	39.052	36.723	290.595	273.268
AVE	33.530	31.530	140.460	226.120
		C. gunneri VPA F = 1.75		
1985	61.785	48.866	315.884	249.832
1986	50.357	39.827	317.556	251.155
1987	38.416	30.384	237.343	187.714
1988	48.015	37.975	322.742	255.256
1989	64.018	50.632	433.245	342.653
1990	52.485	41.511	328.525	259.829
1991	62.267	49.247	415.551	328.659
1992	64.380	50.918	420.677	332.712
1993	49.896	39.463	308.802	244.231
1994	56.795	44.919	376.959	298.136
1995	31.391	24.827	176.700	139.752
1996	31.758	25.117	207.375	164.012
1997	31.839	25.181	207.129	163.819
1998	46.686	36.924	319.490	252.684
1999	57.766	45.687	387.180	306.220
2000	43.099	34.087	264.218	208.969
2001	56.082	44.355	378.849	299.631
2002	43.013	34.019	265.390	209.897
2003	33.798	26.731	210.090	166.160
2004	36.546	28.904	240.772	190.426
AVE	48.020	37.980	306.720	242.590

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock	Catch
		C. gunnari SURVAN F = 3.5		
1987	52.92	49.77	356.34	335.09
1988	58.26	54.78	431.47	405.74
1989	42.99	40.43	314.66	295.89
1990	43.46	40.87	321.09	301.95
1991	30.01	28.22	219.07	206.01
1992	25.15	23.65	184.84	173.82
1993	44.15	41.52	329.70	310.04
1994	28.98	27.25	211.13	198.54
1995	28.87	27.15	213.26	200.54
1996	34.95	32.87	259.32	243.86
1997	40.45	38.04	299.80	281.92
1998	30.12	28.33	220.53	207.38
1999	75.40	70.90	565.47	531.75
2000	43.62	41.02	316.12	297.27
2001	32.15	30.24	235.34	221.31
2002	36.31	34.15	269.01	252.97
2003	53.07	49.90	395.15	371.59
2004	61.10	57.45	452.79	425.79
2005	43.05	40.49	314.58	295.82
2006	36.52	34.34	268.51	252.50
AVE	42.08	39.57	308.91	290.49
		C. gunnari SURVAN F = 1.75		
1987	40.21	31.80	260.06	205.68
1988	38.56	30.50	249.15	197.06
1989	48.10	38.04	323.05	255.50
1990	70.33	55.62	480.95	380.38
1991	60.19	47.61	380.01	300.55
1992	73.30	57.97	490.79	388.16
1993	62.72	49.61	396.21	313.36
1994	49.47	39.13	307.61	243.29
1995	46.64	36.88	300.46	237.63
1996	40.39	31.95	256.02	202.48
1997	49.24	38.95	329.81	260.84
1998	52.90	41.84	347.70	275.00
1999	48.33	38.22	309.20	244.55
2000	46.38	36.68	299.57	236.93
2001	31.03	24.54	185.28	146.54
2002	35.57	28.13	236.47	187.02
2003	42.34	33.48	282.45	223.39
2004	61.37	48.54	419.31	331.63
2005	55.90	44.21	357.19	282.50
2006	39.36	31.13	238.20	188.39
AVE	49.62	39.24	322.47	255.04

Table 4 (continued)

Year	Stock Weight	Catch Weight	Stock	Catch
		C. gunnari VPA F = 0.875		
1985	69.54	38.50	374.60	207.41
1986	66.57	36.86	330.57	183.03
1987	63.27	35.03	313.54	173.60
1988	64.18	35.53	328.69	181.99
1989	65.86	36.47	338.89	187.64
1990	59.99	33.21	289.82	160.47
1991	58.01	32.12	290.63	160.92
1992	62.67	34.70	330.40	182.94
1993	57.55	31.86	279.20	154.59
1994	66.59	36.87	361.41	200.10
1995	82.80	45.85	460.15	254.78
1996	78.04	43.21	382.38	211.72
1997	74.27	41.12	368.17	203.85
1998	73.35	40.61	371.08	205.46
1999	76.83	42.54	399.35	221.11
2000	76.81	42.53	389.75	215.80
2001	70.35	38.95	341.13	188.88
2002	72.60	40.20	375.39	207.85
2003	71.67	39.68	361.92	200.39
2004	87.57	48.49	484.68	268.36
AVE	69.93	38.72	358.59	198.54
		C. gunnari SURVAN F = 0.875		
1987	50.61	28.02	338.82	187.60
1988	79.98	44.28	475.56	263.31
1989	80.07	44.33	402.47	222.84
1990	86.85	48.09	457.53	253.33
1991	94.42	52.28	497.99	275.73
1992	92.41	51.16	463.36	256.55
1993	85.26	47.21	415.22	229.90
1994	79.82	44.19	392.73	217.45
1995	79.79	44.18	406.31	224.97
1996	79.44	43.98	403.01	223.14
1997	70.61	39.09	336.67	186.41
1998	112.48	62.28	677.18	374.94
1999	108.83	60.26	538.82	298.34
2000	88.71	49.12	400.09	221.52
2001	76.00	42.08	357.03	197.68
2002	76.84	42.55	395.07	218.75
2003	73.63	40.77	366.12	202.71
2004	61.03	33.79	278.89	154.42
2005	64.60	35.77	338.64	187.50
2006	64.99	35.98	331.56	183.58
AVE	80.32	44.47	413.65	229.03

Table 5. Average of the Ten 20-Year Projections for Stock Size in Numbers (x 10-6) and Weight (x 10-3)

Year	Stock Weight	Catch Weight	Stock	Catch
	N. rossii, Kerguelen F = 0.76			
1984	5.79	2.04	3.47	.96
1985	6.25	2.17	3.86	1.09
1986	7.05	2.48	4.43	1.27
1987	7.96	2.76	5.03	1.42
1988	9.74	3.25	6.40	1.73
1989	10.57	3.72	6.47	1.91
1990	10.54	4.18	5.98	2.03
1991	10.27	3.98	5.92	1.88
1992	9.26	3.64	5.03	1.67
1993	8.89	3.56	4.97	1.64
1994	8.10	3.11	4.48	1.42
1995	8.45	3.15	5.05	1.51
1996	8.30	3.04	4.82	1.46
1997	8.30	3.23	4.77	1.55
1998	8.18	3.08	4.78	1.47
1999	8.71	3.13	5.31	1.54
2000	8.83	3.25	5.19	1.59
2001	9.17	3.47	5.43	1.69
2002	9.44	3.43	5.67	1.68
2003	9.21	3.53	5.23	1.69
AVE	8.65	3.21	5.11	1.56
	N. rossii, Kerguelen F = 0.38			
1984	5.84	1.18	3.52	.54
1985	7.13	1.54	4.08	.71
1986	8.97	2.02	5.15	.93
1987	10.92	2.41	6.15	1.08
1988	12.55	2.94	6.67	1.28
1989	14.22	3.44	7.36	1.45
1990	15.91	3.80	8.14	1.56
1991	16.52	4.15	7.82	1.65
1992	18.65	4.53	9.59	1.83
1993	18.15	4.52	8.24	1.74
1994	17.88	4.97	7.71	1.88
1995	16.72	4.43	7.12	1.57
1996	15.79	4.15	6.73	1.46
1997	15.27	3.97	6.67	1.42
1998	14.70	3.77	6.52	1.37
1999	14.49	3.67	6.70	1.37
2000	14.62	3.66	6.81	1.38
2001	14.57	3.59	7.14	1.42
2002	14.81	3.75	6.87	1.45
2003	15.26	3.89	7.23	1.50
AVE	14.15	3.52	6.81	1.38

Table 5 (continued)

Year	Stock Weight	Catch Weight	Stock	Catch
1987	.84	.15	2.15	.33
1988	1.18	.21	3.05	.44
1989	1.44	.29	3.46	.57
1990	1.77	.36	4.20	.69
1991	2.06	.44	4.80	.81
1992	2.25	.51	4.87	.90
1993	2.31	.55	4.75	.93
1994	2.28	.59	4.43	.93
1995	2.29	.60	4.51	.92
1996	2.35	.60	4.95	.94
1997	2.28	.60	4.59	.95
1998	2.27	.56	4.75	.91
1999	2.28	.55	4.81	.91
2000	2.35	.57	4.88	.95
2001	2.39	.59	4.91	.97
2002	2.35	.61	4.67	.96
2003	2.46	.60	5.23	.97
2004	2.41	.60	4.96	.99
2005	2.49	.62	5.15	1.01
2006	2.48	.61	5.16	1.00
AVE	2.13	.51	4.51	.85

1987	1.03	.09	2.90	.20
1988	1.41	.14	3.50	.29
1989	1.80	.21	4.02	.38
1990	2.15	.27	4.47	.46
1991	2.50	.35	4.91	.55
1992	2.78	.42	5.24	.62
1993	2.90	.48	5.20	.67
1994	2.96	.49	5.28	.67
1995	2.86	.46	5.25	.65
1996	2.90	.47	5.26	.66
1997	3.16	.49	6.29	.70
1998	3.17	.50	5.90	.73
1999	3.15	.50	5.72	.72
2000	3.13	.49	5.62	.70
2001	3.51	.54	6.82	.77
2002	3.58	.57	6.72	.82
2003	3.77	.61	7.23	.87
2004	3.84	.59	7.20	.85
2005	3.68	.55	6.77	.82
2006	3.83	.62	6.74	.87
AVE	2.91	.44	5.55	.65

Table 6. Summary of standard reference points for projections (South Georgia stocks)

Species	Data Set F	Stock Size 1	Stock Size 2	Stock Size 3	Yield 1	Yield 2	Yield 3
N. rossii	VPA 0.55	1.6	7	-	2.1	4	4
	0.177	2.7	12	7	5.8	15	2
	0.089	2.4	7	4	6.4	11	4
	SUR 0.55	**			**		
	0.177	**			*		
	0.089	**			*		
N. gibberifrons	VPA 0.142	2.4	14	8	4.3	16	3
	0.071	2.9	11	4	5.6	11	3
	SUR 0.142	*			*		
	0.071	1.5	20+	-	*		
C. gunnari	VPA 3.5	**			**		
	1.75	*			*		
	0.875	*			*		
	SUR 3.5	*			*		
	1.75	*			2	11	11
	0.875	*			2	11	11

1 Maximum increase factor
2 Time to reach maximum--years
3 Time to reach 2X increase--years
* No increase
** Actual decrease

Table 7. Summary of standard reference points for projections (Kerguelen)

Species	Data Set	F	Stock Size 1	Stock Size 2	Stock Size 3	Yield 1	Yield 2	Yield 3
N. rossii	VPA	0.76	1.7	6	*	2.1	6	*
		0.38	2.7	8	5	4.2	10	3
N. squamifrons	VPA	0.72	2.3	9	4	4.0	8	3
		0.36	2.5	16	10	6.8	16	2

1 Maximum increase factor
2 Time to reach maximum--years
3 Time to reach 2X increase--years
* No increase

Table 8. Comparison of simulated and past reported yields.

Stock		F	Average Simulated Yield	Years	Average Reported Catch
N. rossii	S. Georgia	0.550	9.6		
		0.177	8.6	72-85	4.3
		0.089	5.1	76-85	5.7
	Kerguelen	0.770	3.2	80-86	0.9
		0.380	3.5		
N. gibberifrons		0.142	4.6	76-85	4.7
		0.071	2.9		
N. squamifrons		0.720	0.5	79-86	5.3
		0.380	0.4		
C. gunnari		3.500	31.5	72-85	30.2
		1.750	38.0	76-85	41.9
		0.875	38.7		

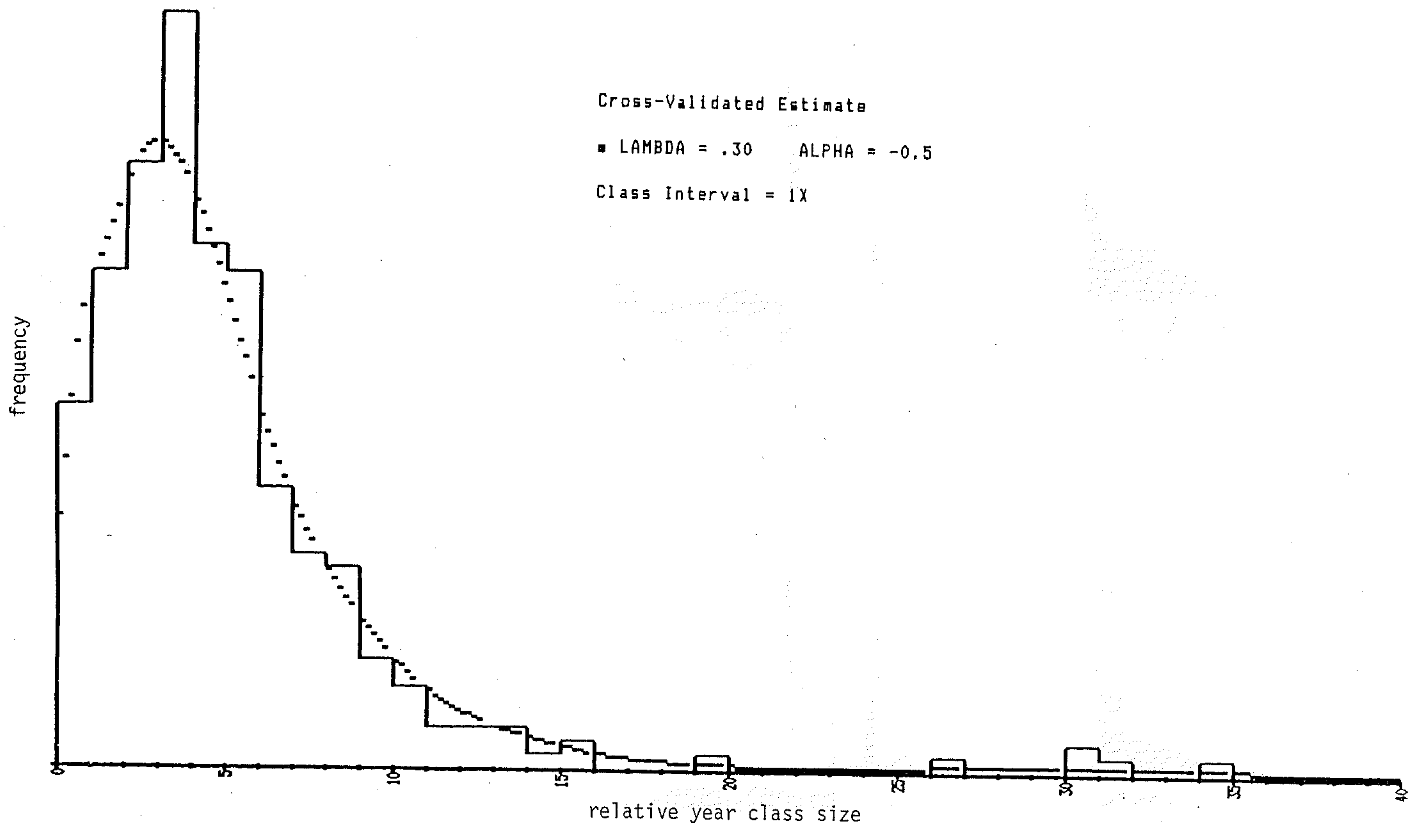

Figure 1. Universal recruitment probability density function used in simulation

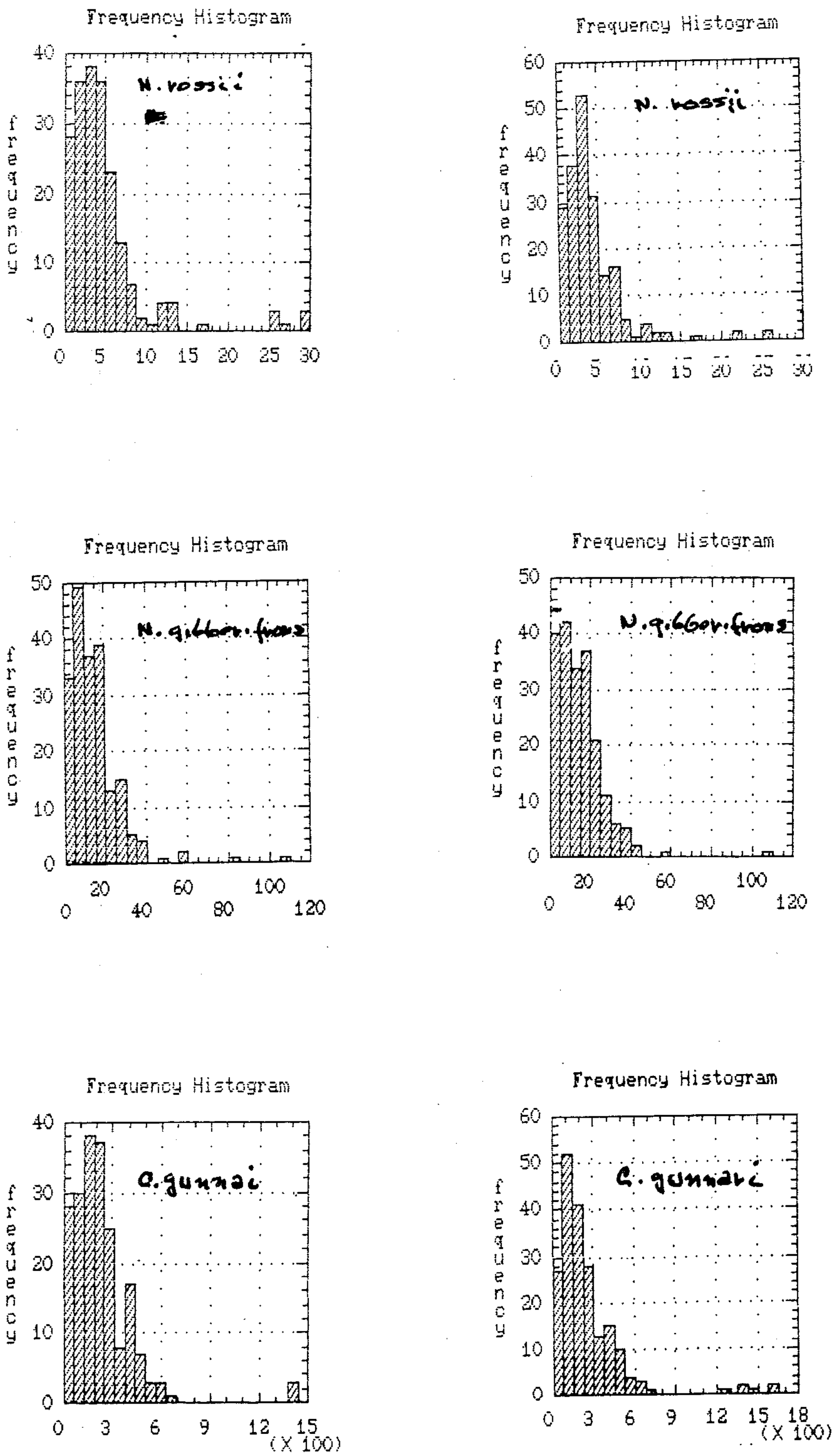

Figure 2. Randomly generated recruitment frequencies (no's fish x 10^{-6}).

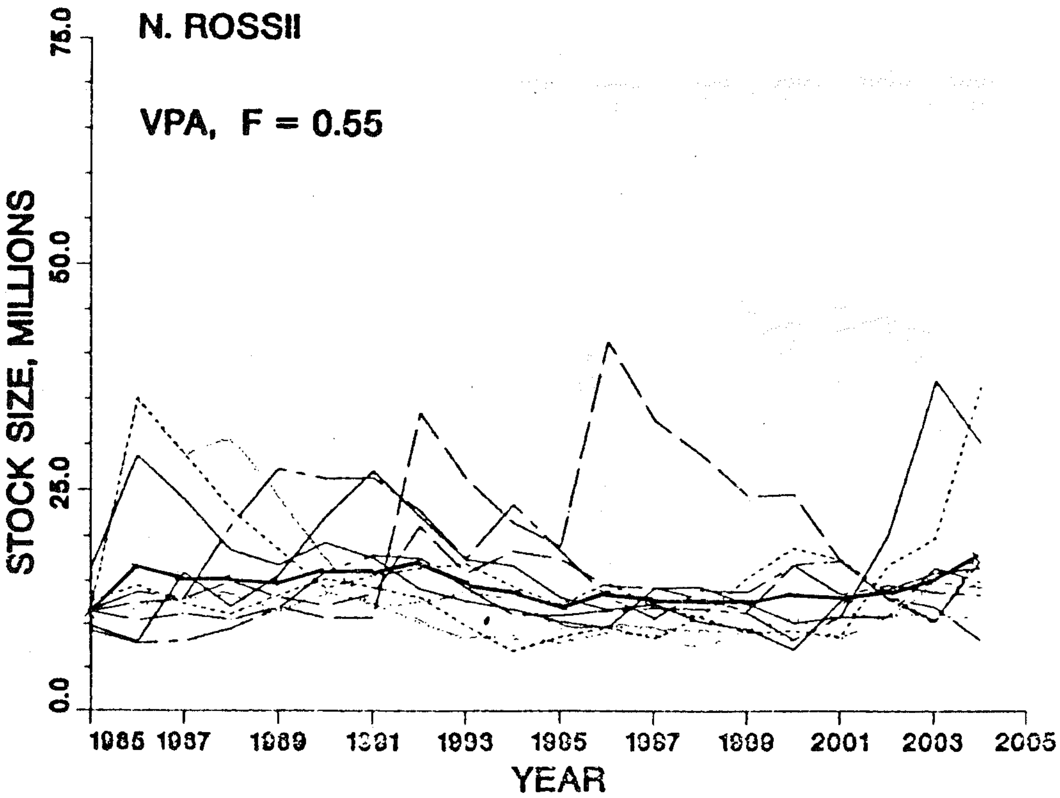

Figure 3. Simulations of stock size (millions of fish) of N. rossii, South Georgia subarea, F=0.55, based on VPA.

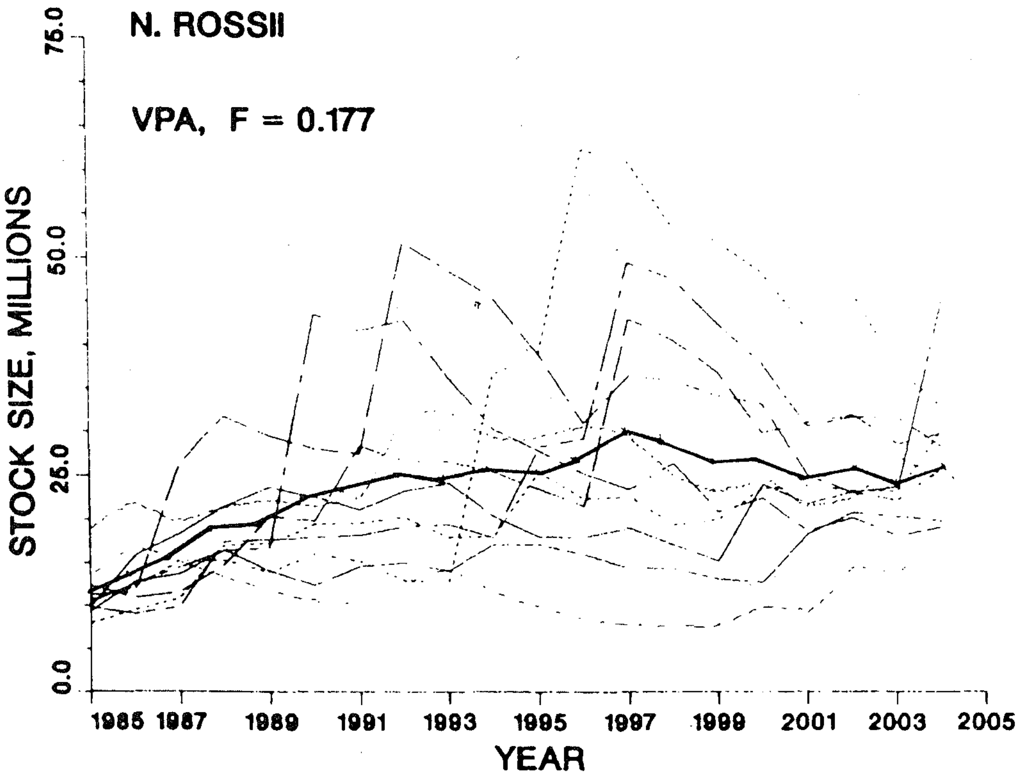

Figure 4. Simulations of stock size (millions of fish) of <u>N. rossii</u> South Georgia subarea, F=0.177, based on VPA.

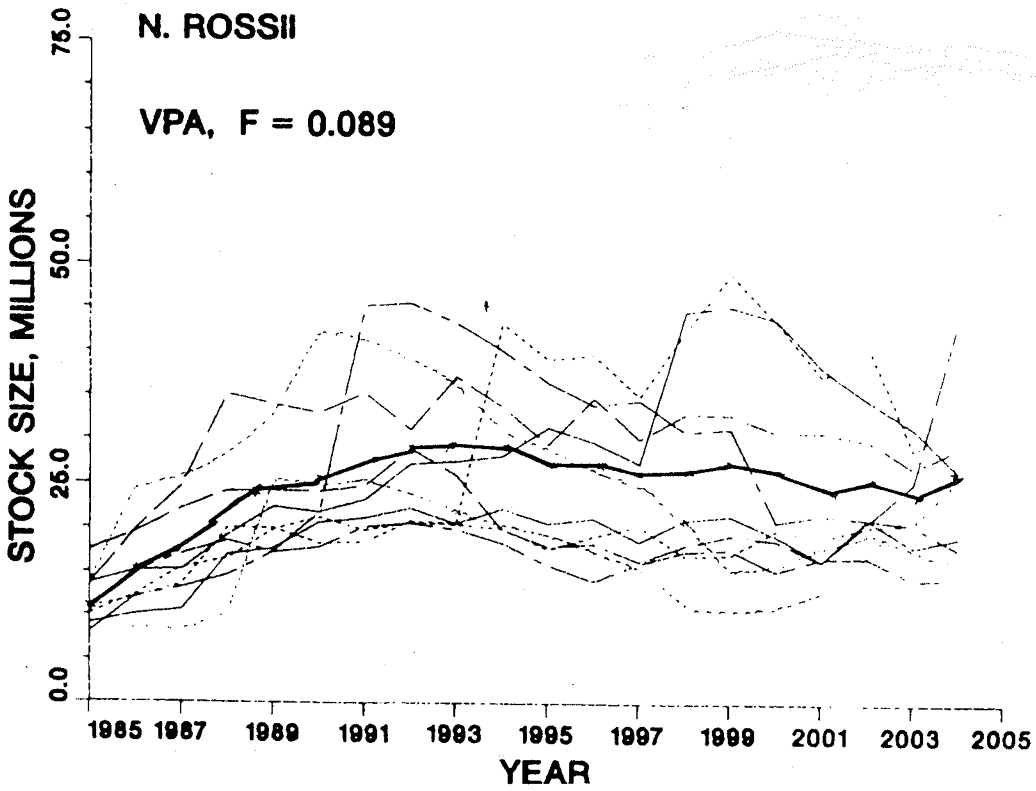

Figure 5. Simulations of stock size (millions of fish) of <u>N. rossii</u> South Georgia subarea, F=0.089, based on VPA.

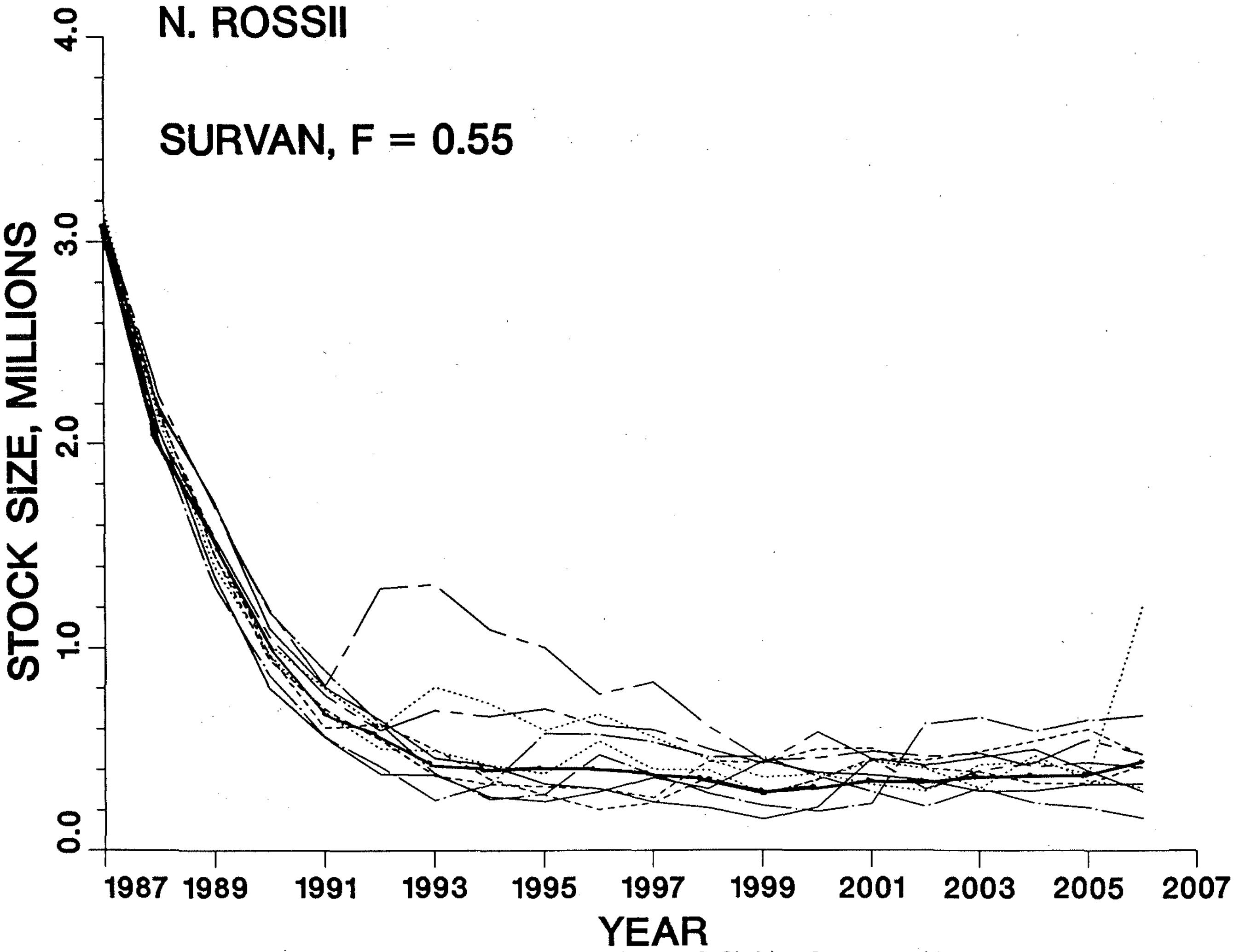

Figure 6. Simulations of stock size (millions of fish) of N. rossii, South Georgia subarea, F=0.55, based on SURVAN.

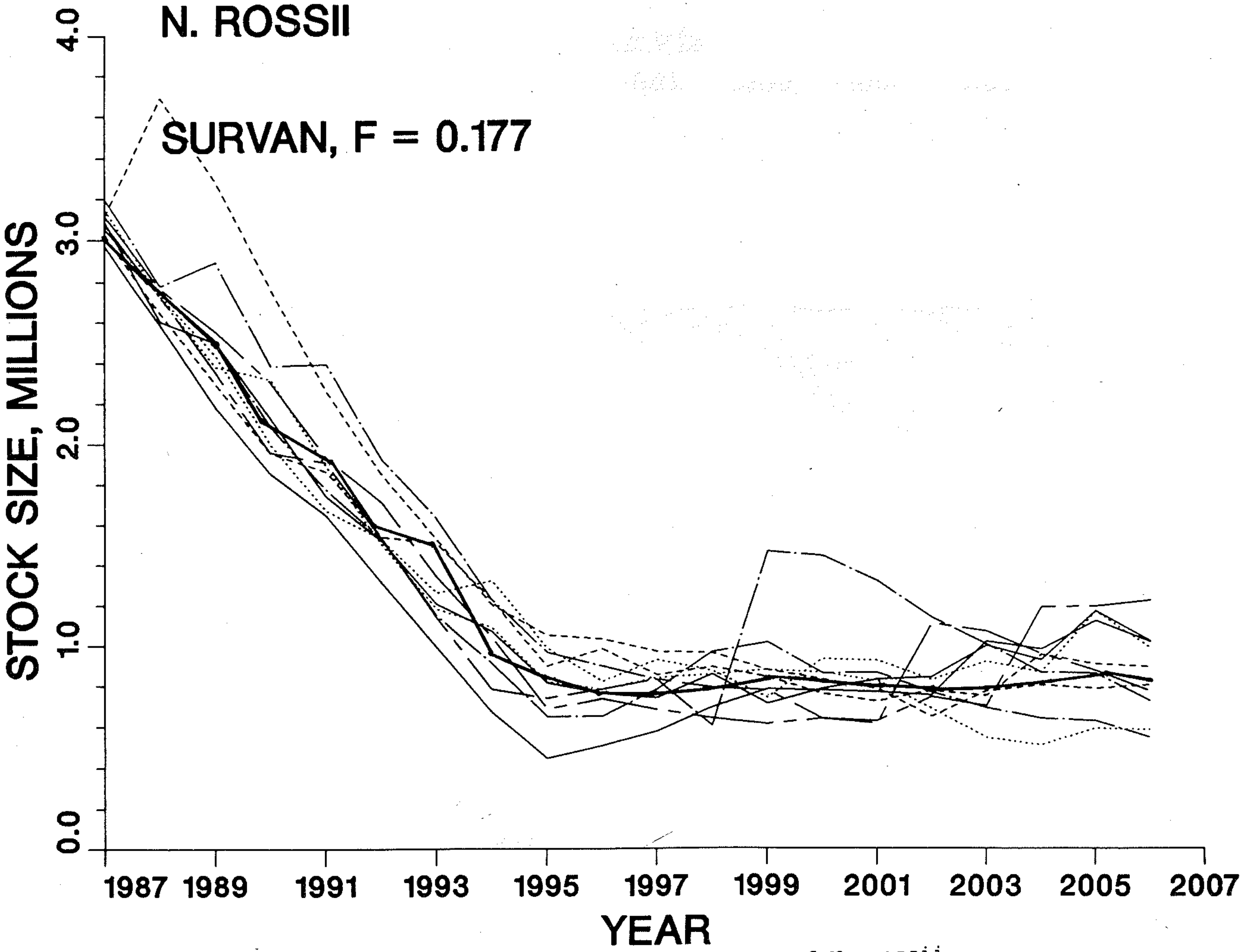

Figure 7. Simulations of stock size (millions of fish) of N. rossii, South Georgia subarea, F=0.177, based on SURVAN.

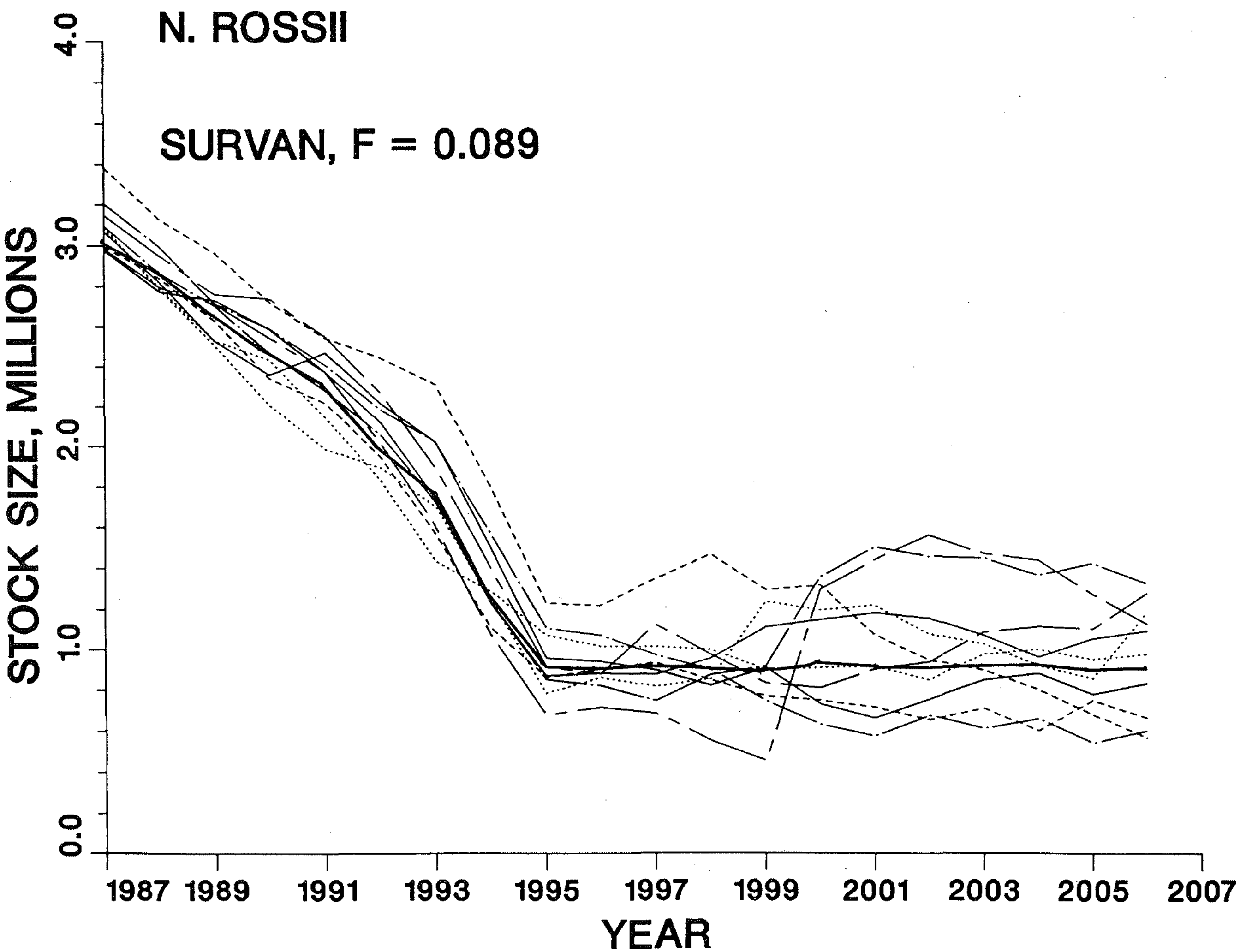

Figure 8. Simulations of stock size (millions of fish) of N. rossii, South Georgia subarea, F=0.089, based on SURVAN.

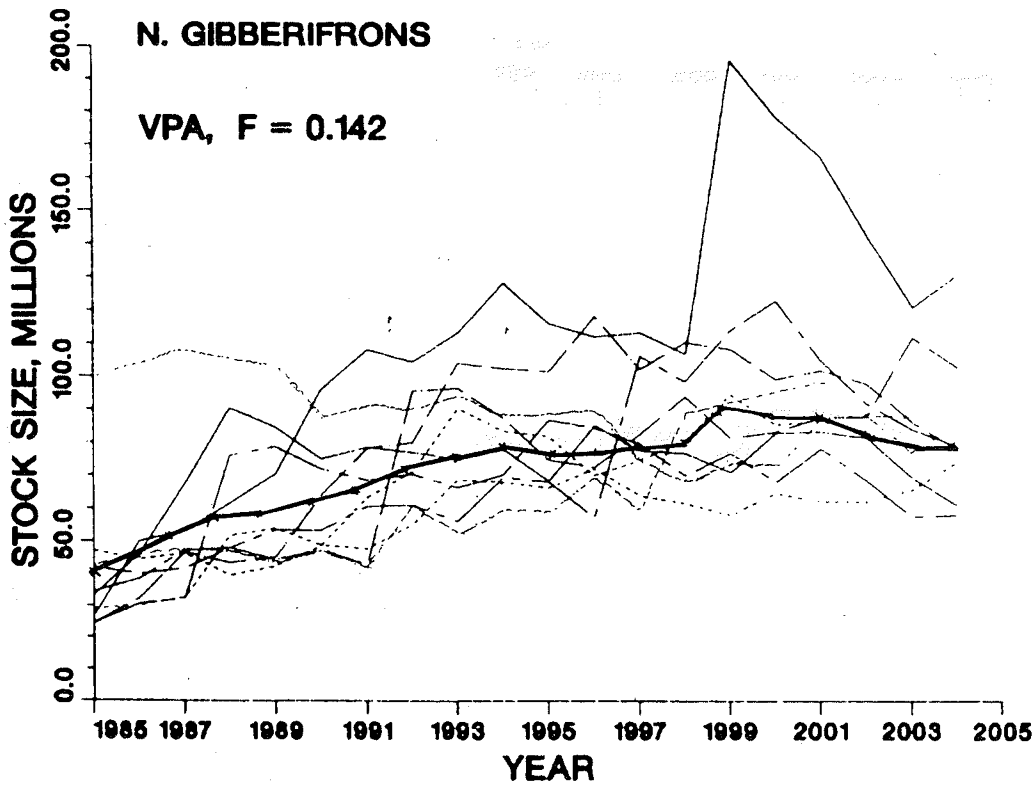

Figure 9. Simulations of stock size (millions of fish) of N. gibberifrons, South Georgia subarea, F=0.142, based on VPA.

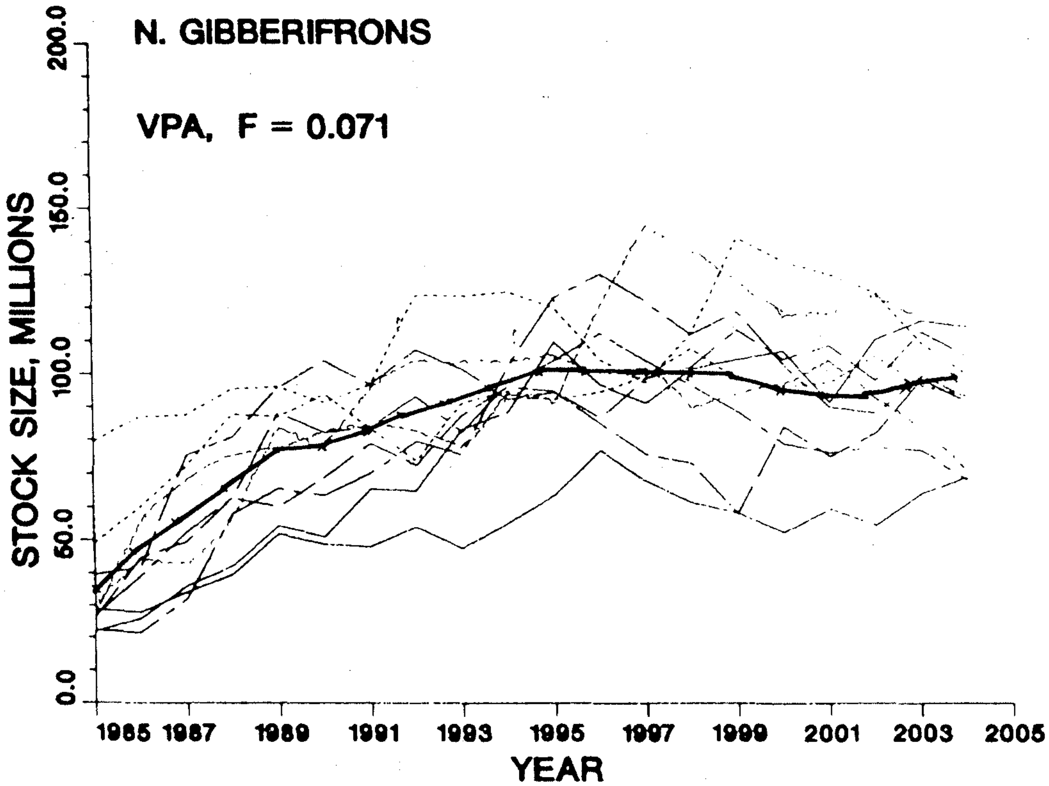

Figure 10. Simulations of stock size (millions of fish) of N. gibberifrons, South Georgia subarea, F=0.071, based on VPA.

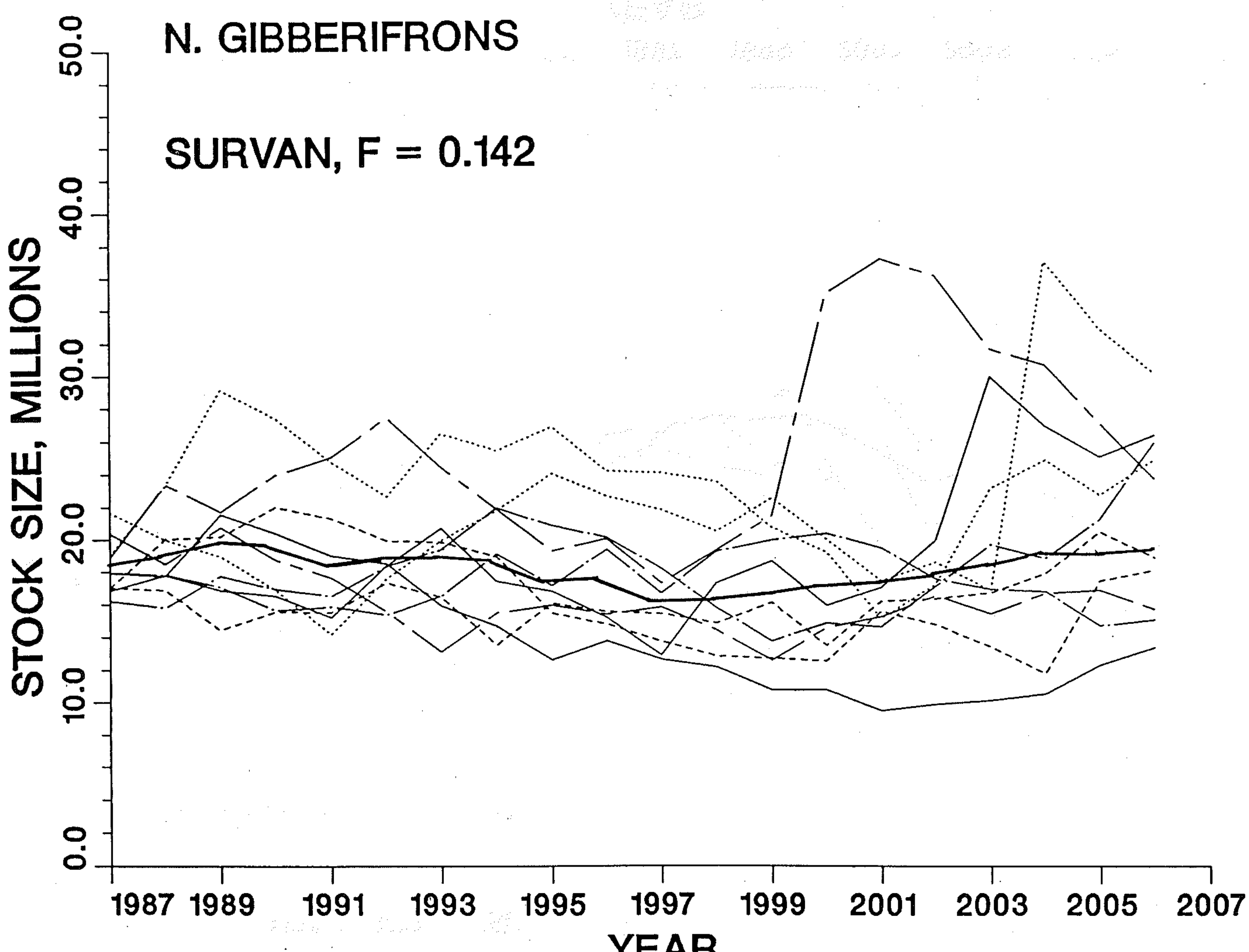

Figure 11. Simulations of stock size (millions of fish) of <u>N. gibberifrons</u>, South Georgia subarea, F=0.142, based on SURVAN

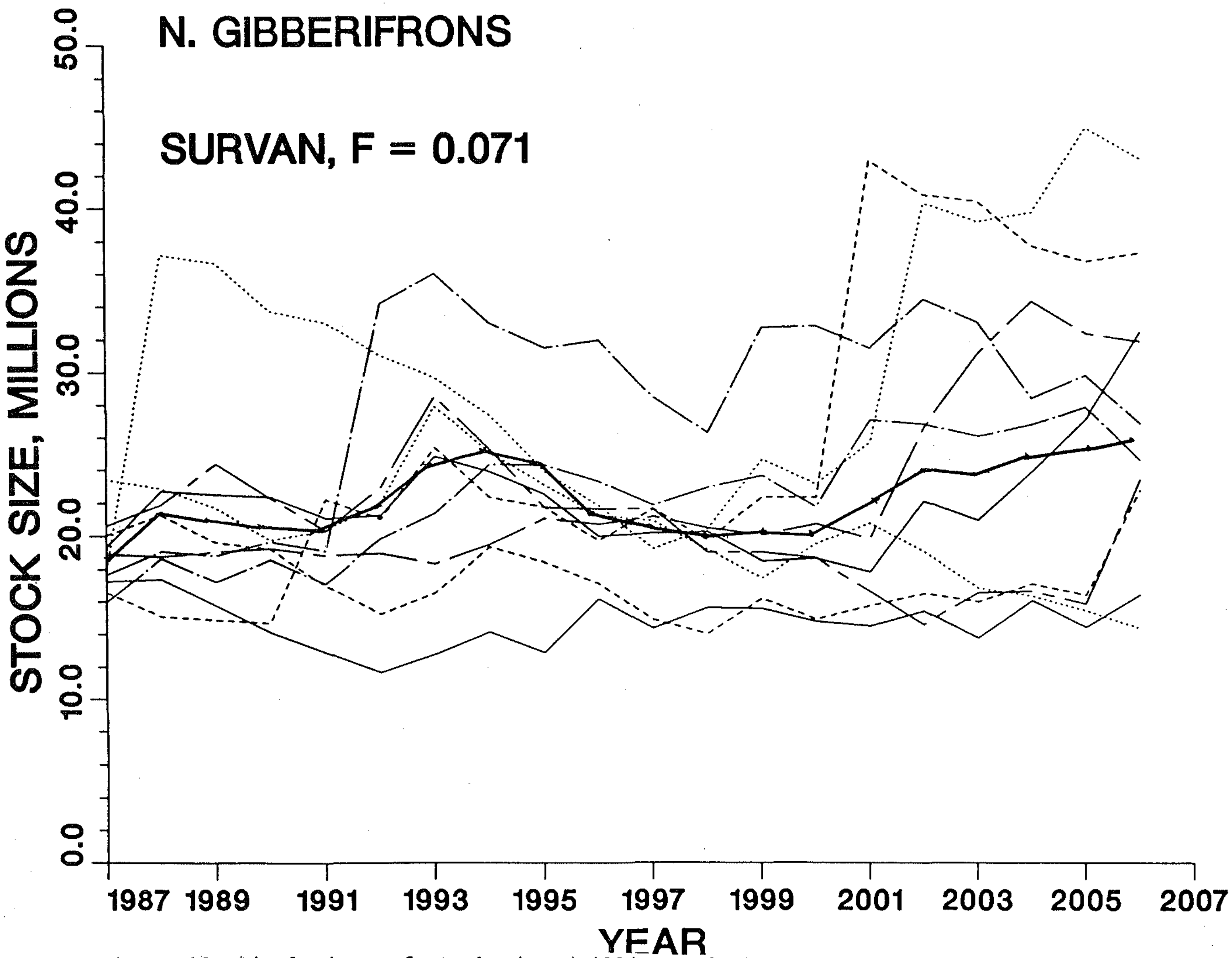

Figure 12. Simulations of stock size (millions of fish) of N. gibberifrons, South Georgia subarea, F=0.071, based on SURVAN.

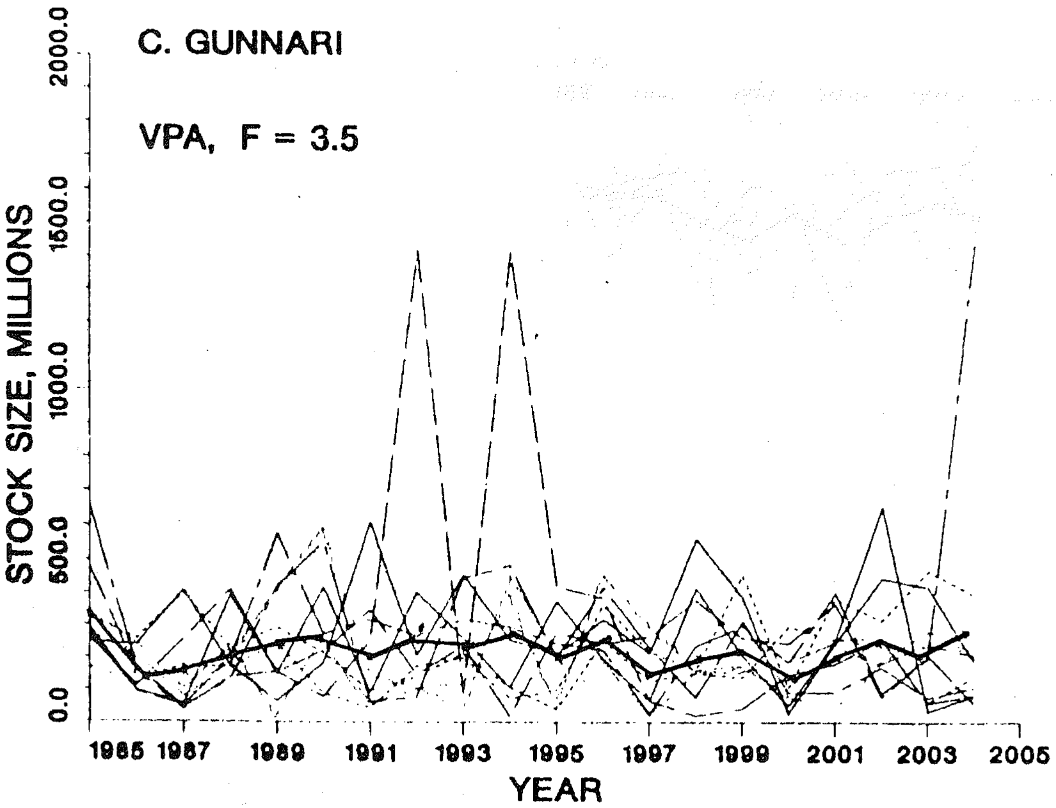

Figure 13. Simulations of stock size (millions of fish) of C. gunnari, South Georgia subarea, F=3.5, based on VPA.

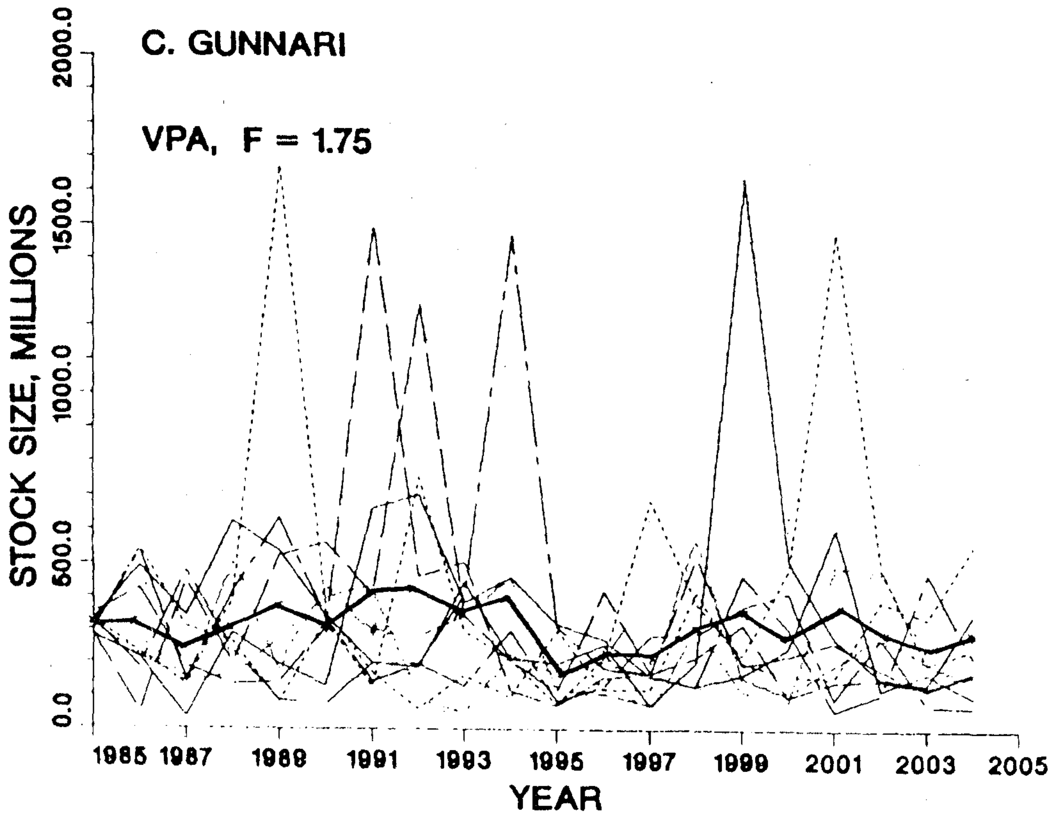

Figure 14. Simulations of stock size (millions of fish) of <u>C. gunnari</u>, South Georgia subarea, F=1.75, based on VPA.

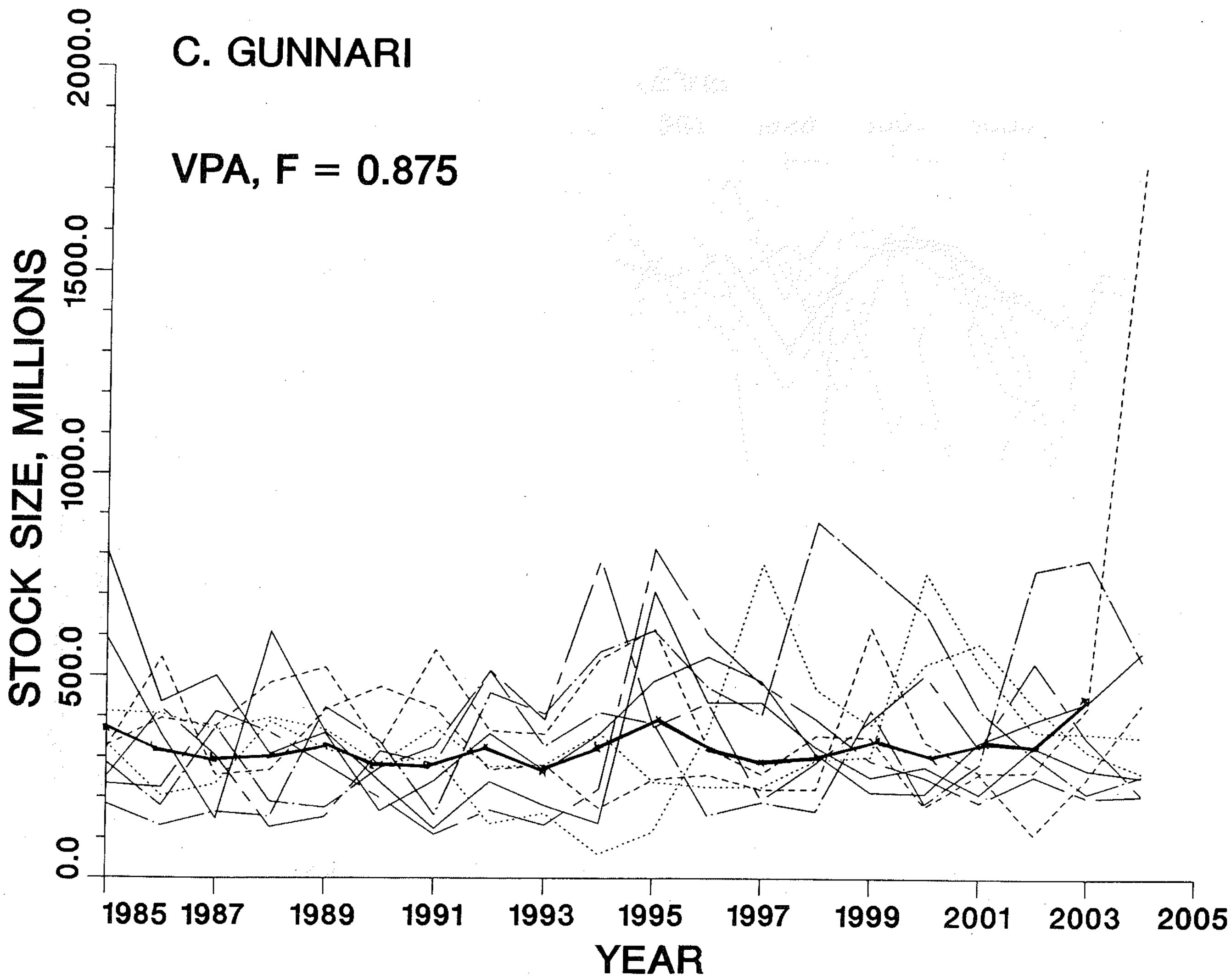

Figure 15. Simulations of stock size (millions of fish) of C. gunnari, South Georgia subarea F=0.875. based on VPA.

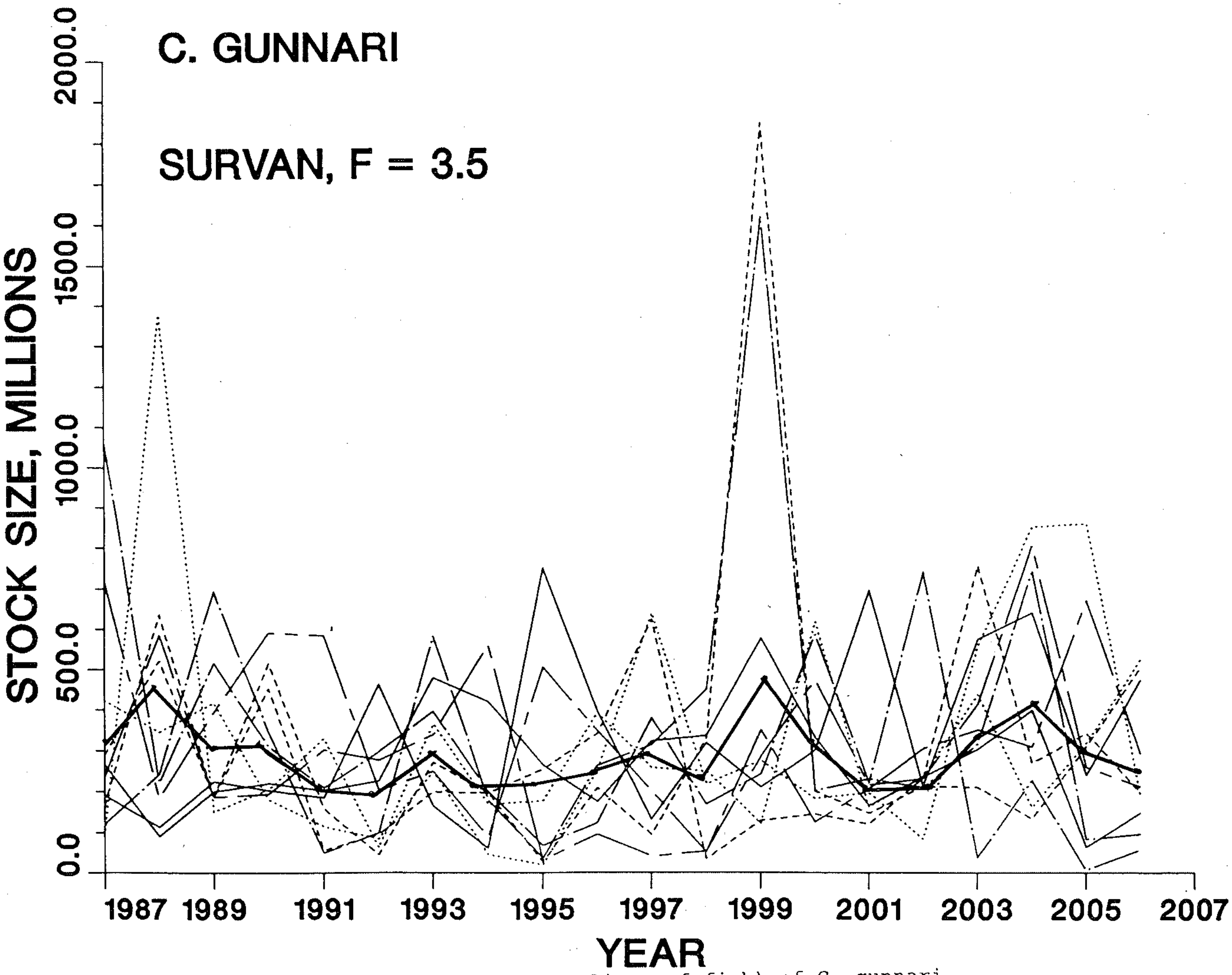

Figure 16. Simulations of stock size (millions of fish) of C. gunnari, South Georgia subarea, F=3.5, based on SURVAN.

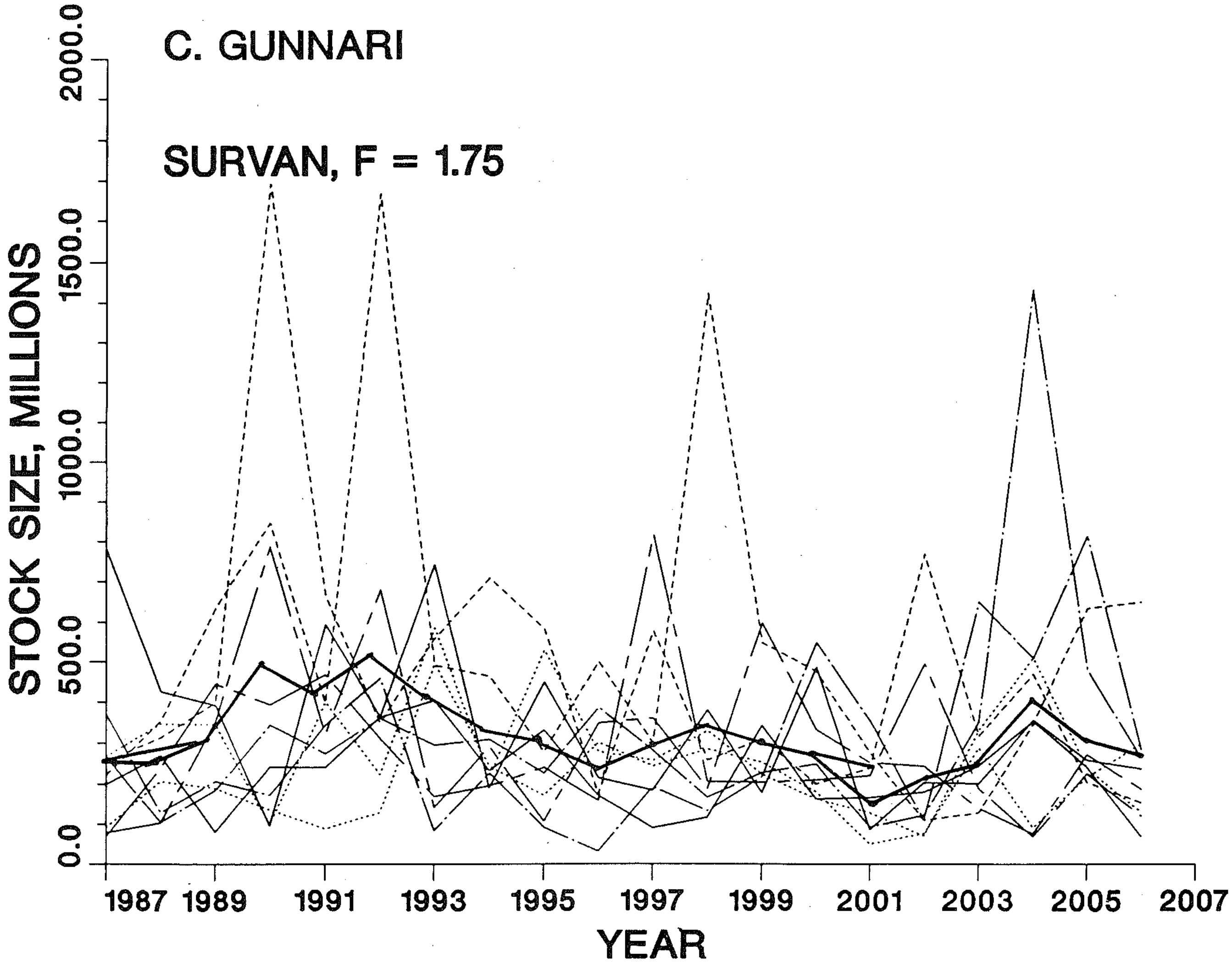

Figure 17. Simulations of stock size (millions of fish) of C. gunnari, South Georgia subarea, F=1.75, based SURVAN.

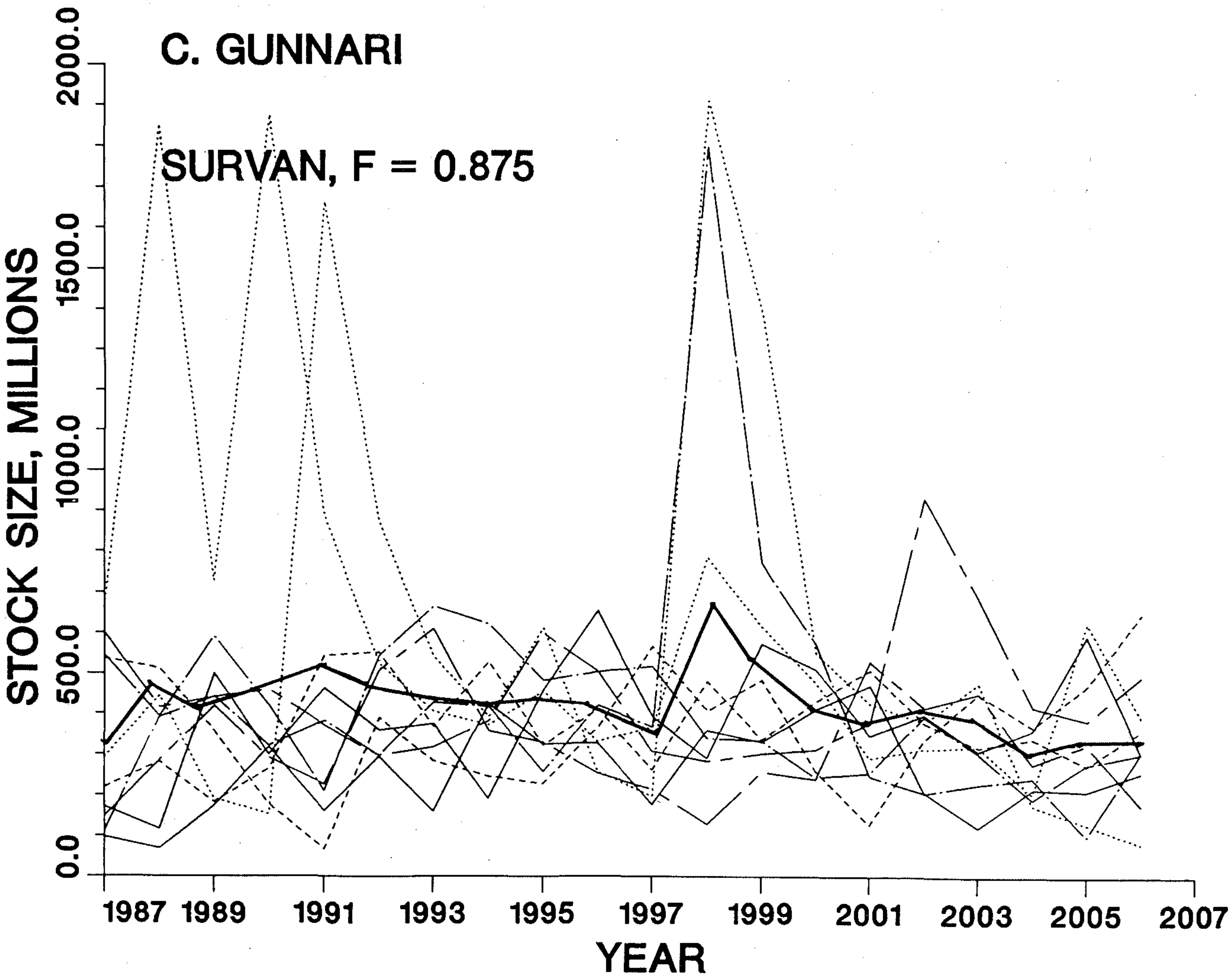

Figure 18. Simulations of stock size (millions of fish) of C. gunnari, South Georgia subarea, F=0.875, based on SURVAN.

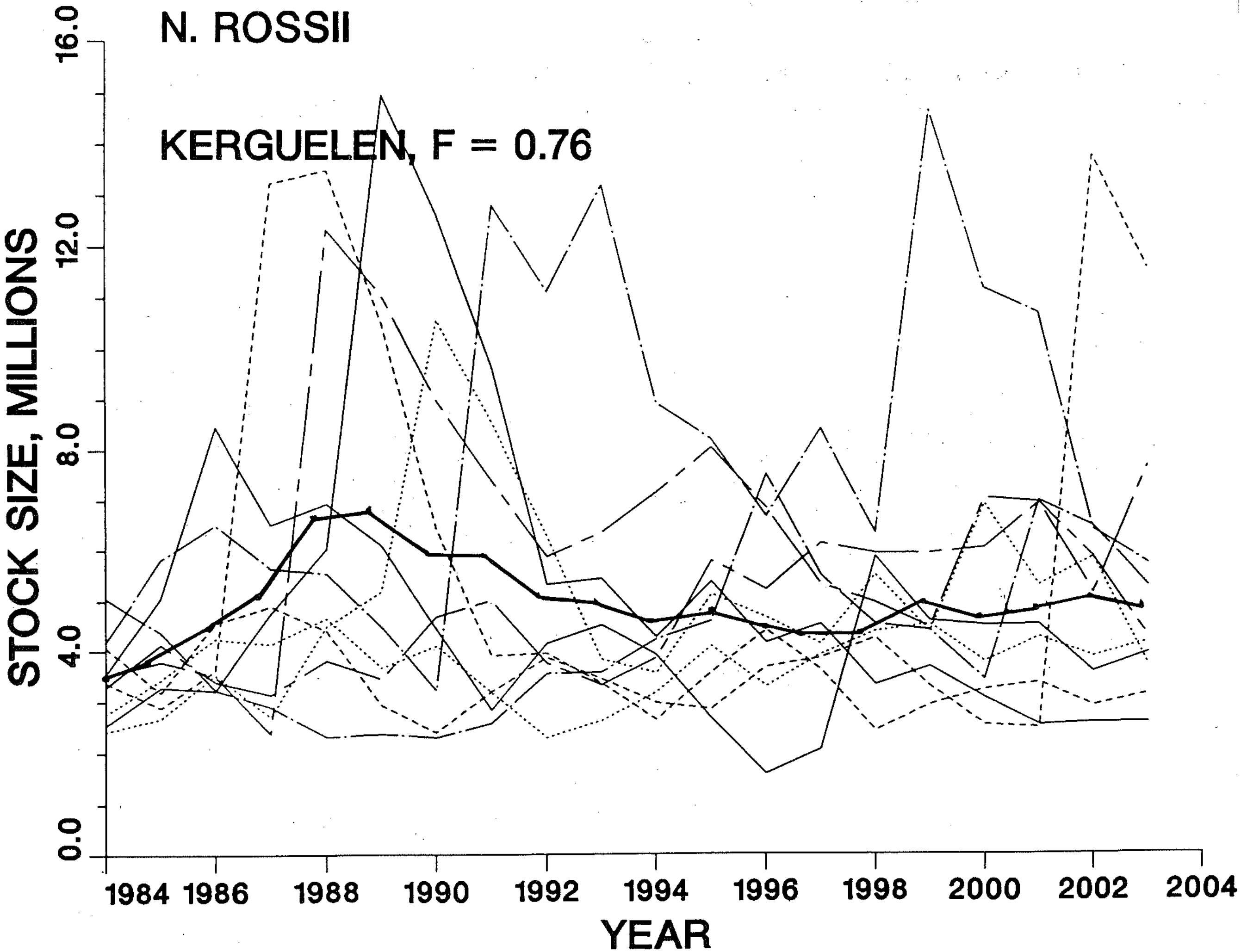

Figure 19. Simulations of stock size (millions of fish) of <u>N. rossii</u>, Kerguelen Island Shelf, F=0.76, based on VPA.

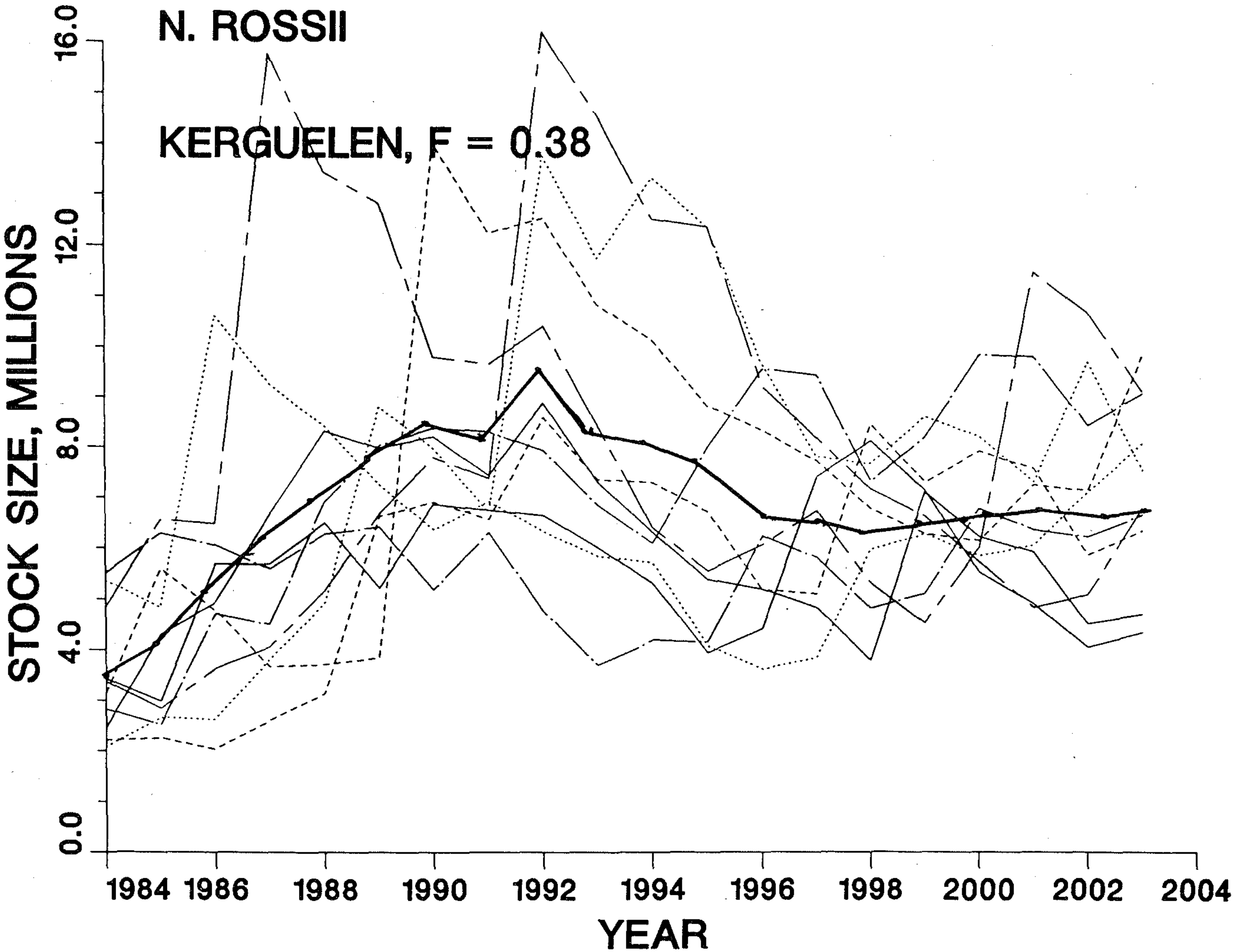

Figure 20. Simulations of stock size (millions of fish) of N. rossii, Kerguelen Island Shelf, F=0.38, based on VPA.

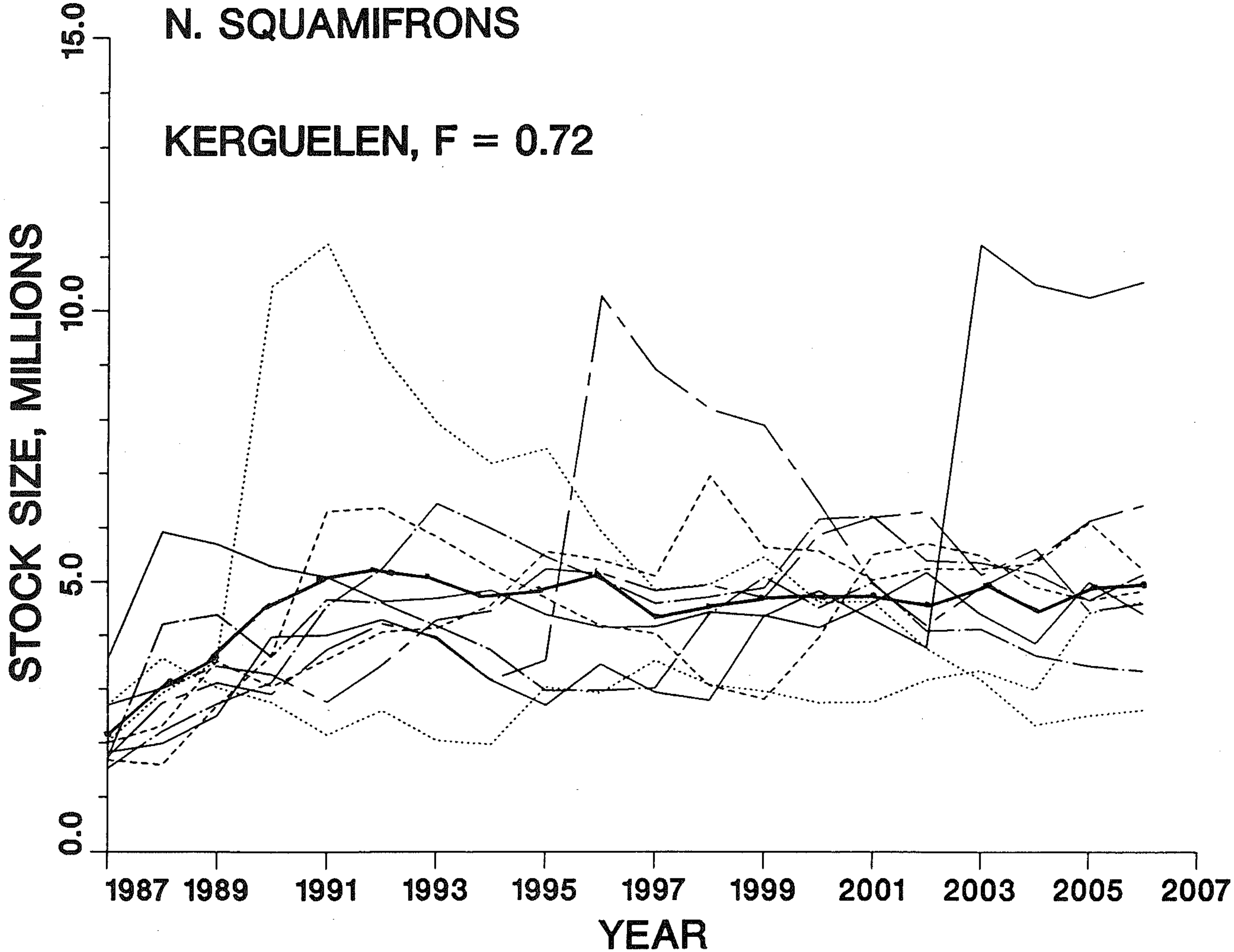

Figure 21. Simulations of stock size (millions of fish) of N. squamifrons, Kerguelen Island Shelf, F=0.72, based on VPA.

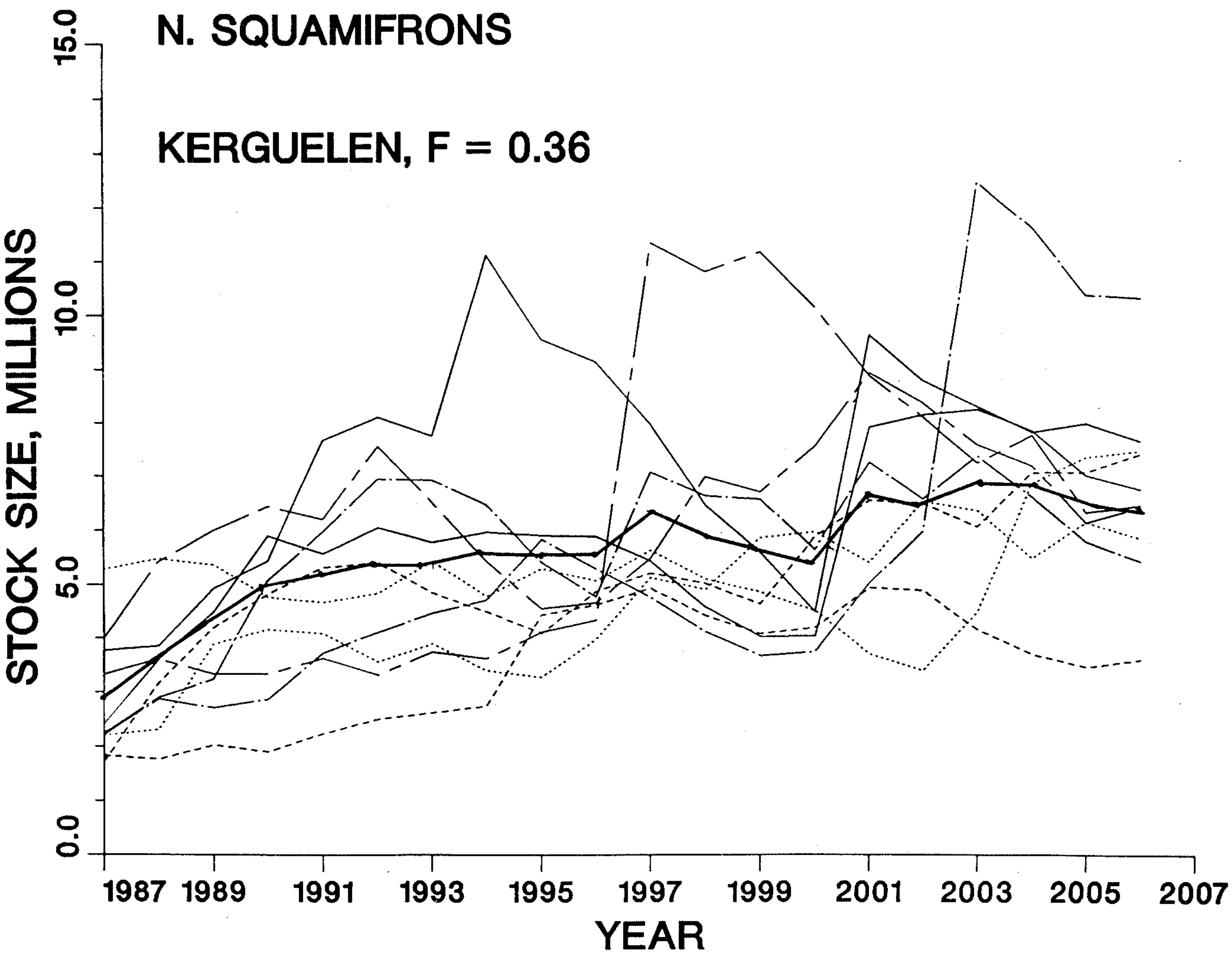

Figure 22. SImulations of stock size (millions of fish) of N. squamifrons, Kerquelen Island Shelf, F=0.36, based on VPA.

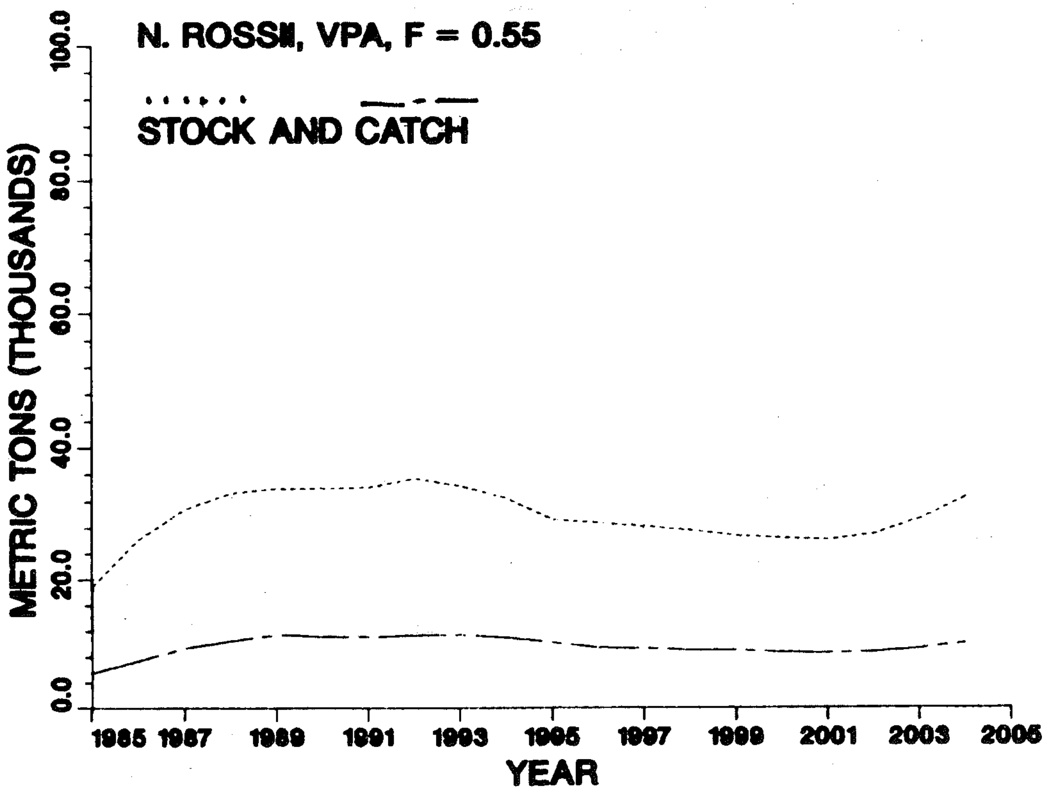

Figure 23. Simulations of weight of stock and catch for N.rossii, South Georgia subarea, F=0.55, based on VPA.

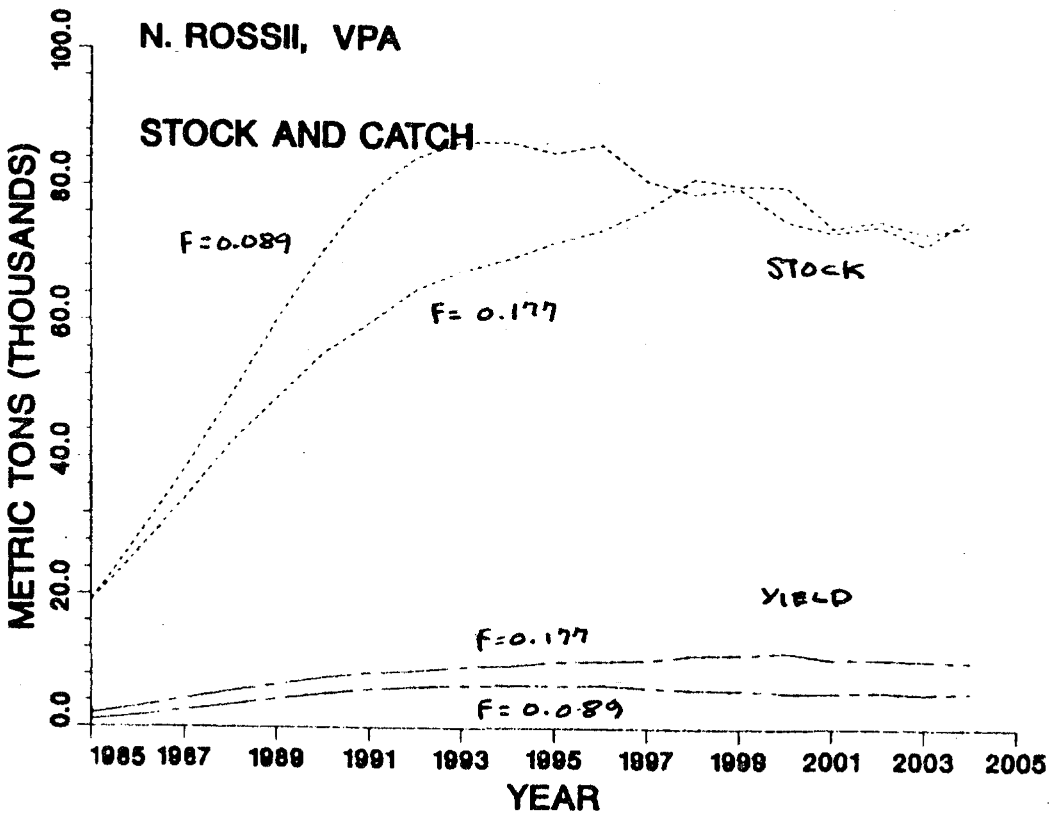

Figure 24. Simulations of weight of stock and catch for N. rossii, South Georgia subarea, based on VPA.

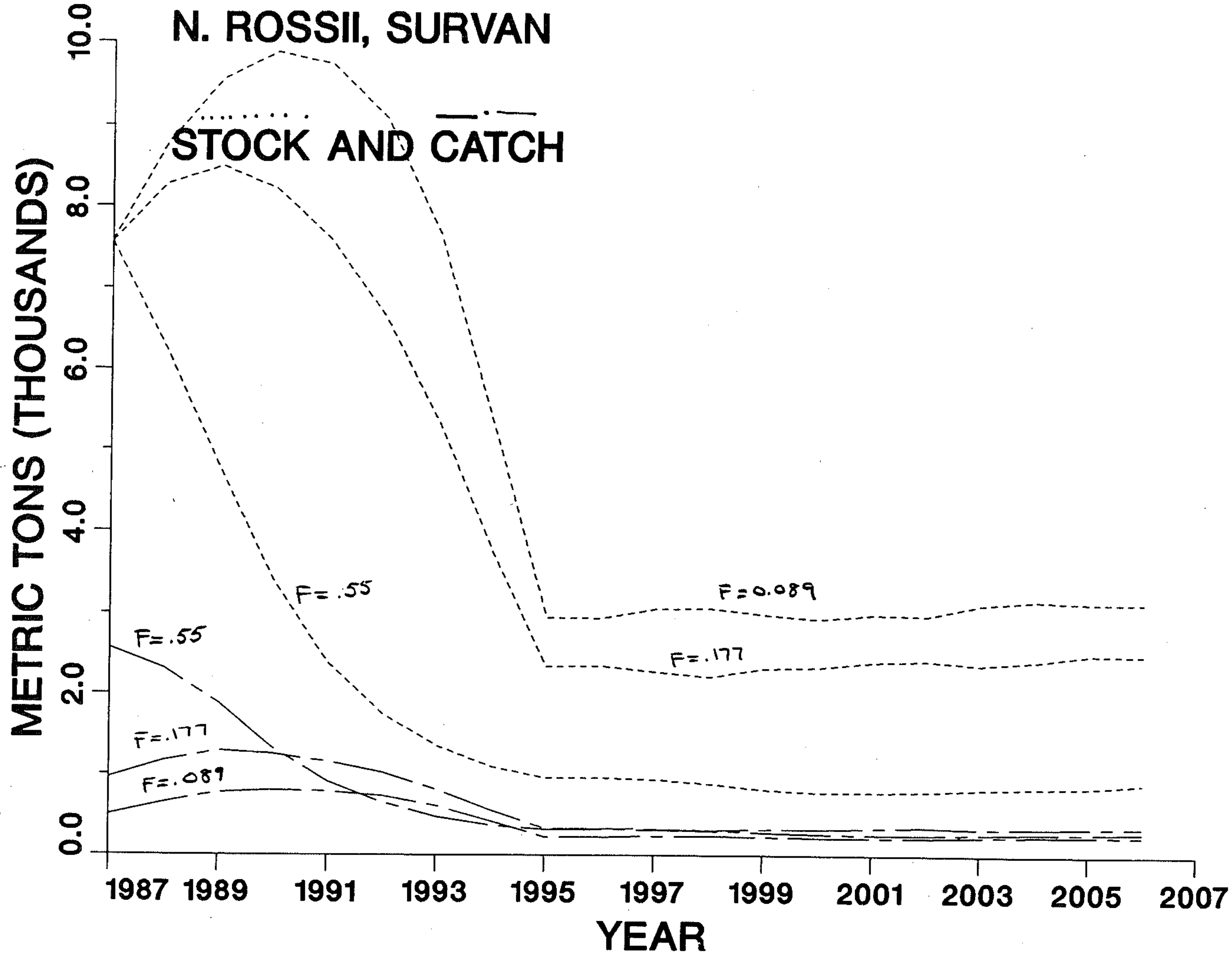

Figure 25. Simulations of weight of stock and catch for N. rossii, South Georgia subarea, based on SURVAN.

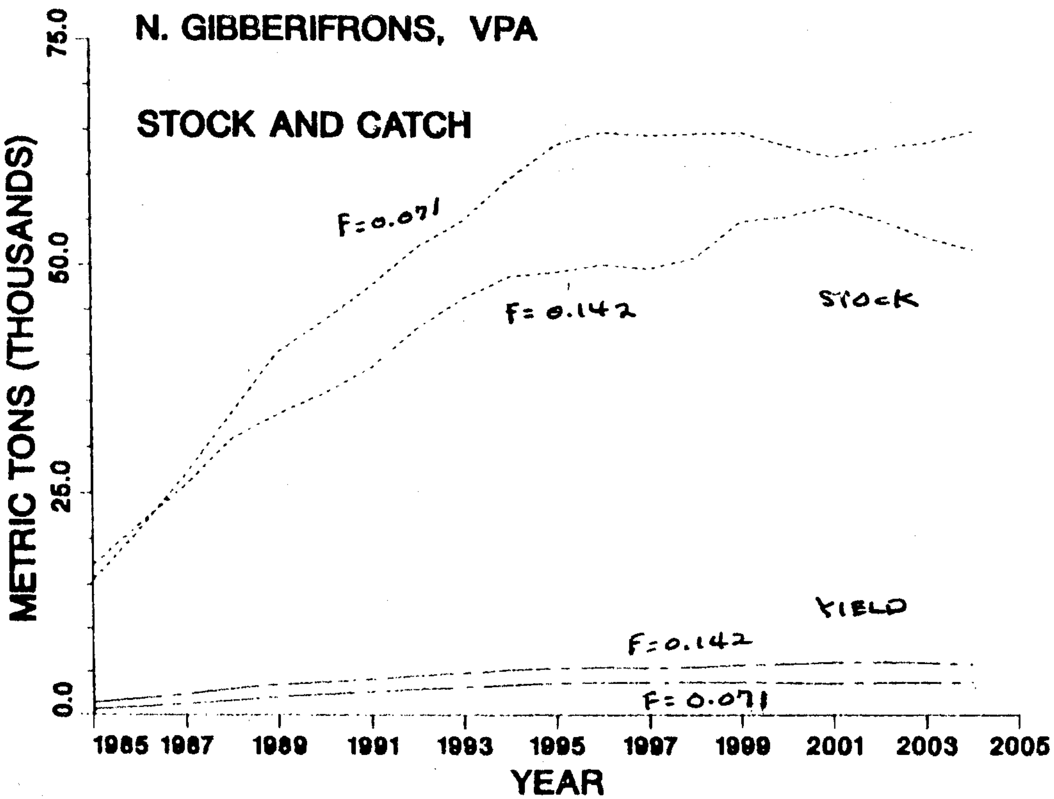

Figure 26. Simulations of weight of stock and catch for N. gibberifrons, South Georgia subarea, based on VPA.

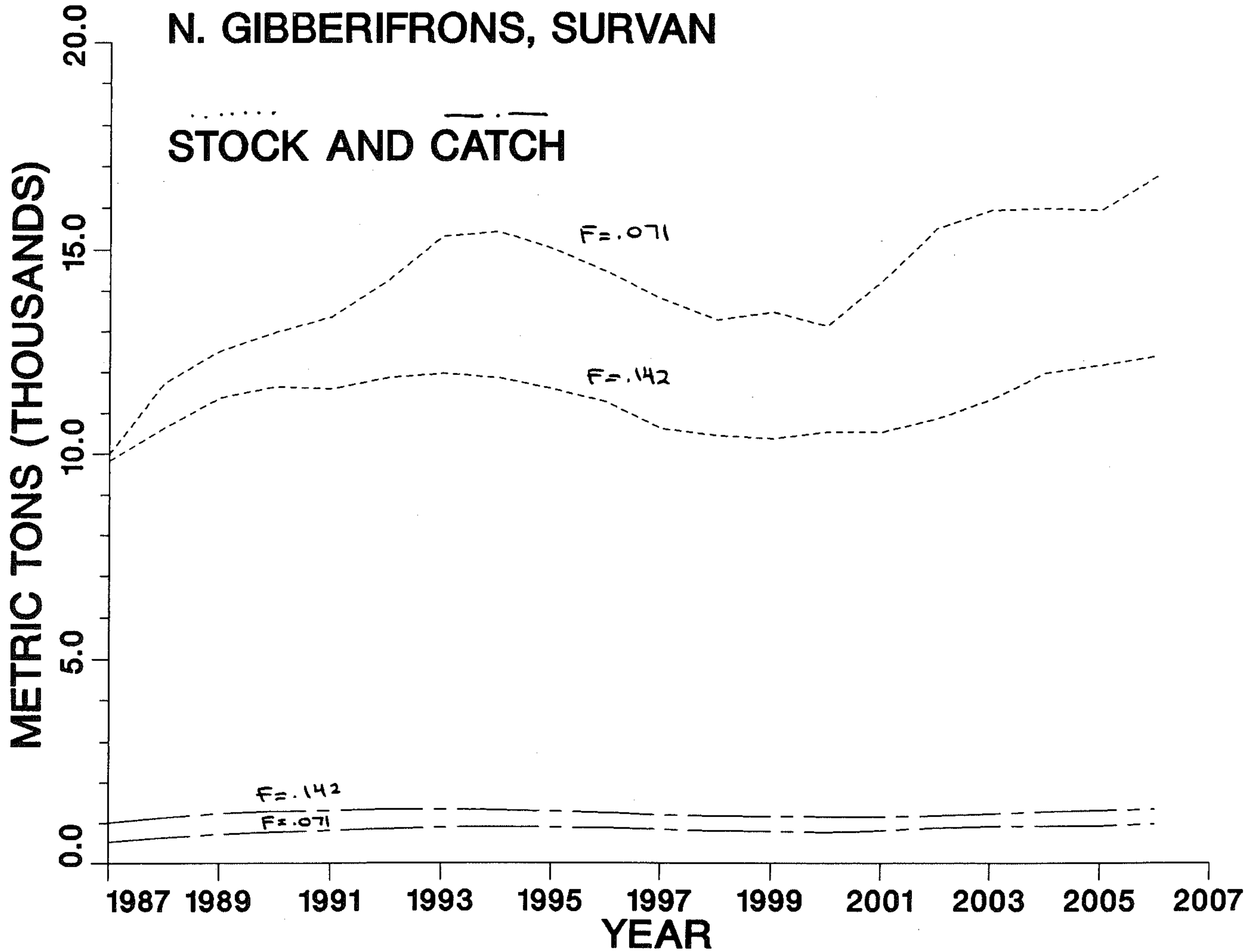

Figure 27. Simulations of weight of stock and catch for N. gibberifrons, South Georgia subarea, based on SURVAN.

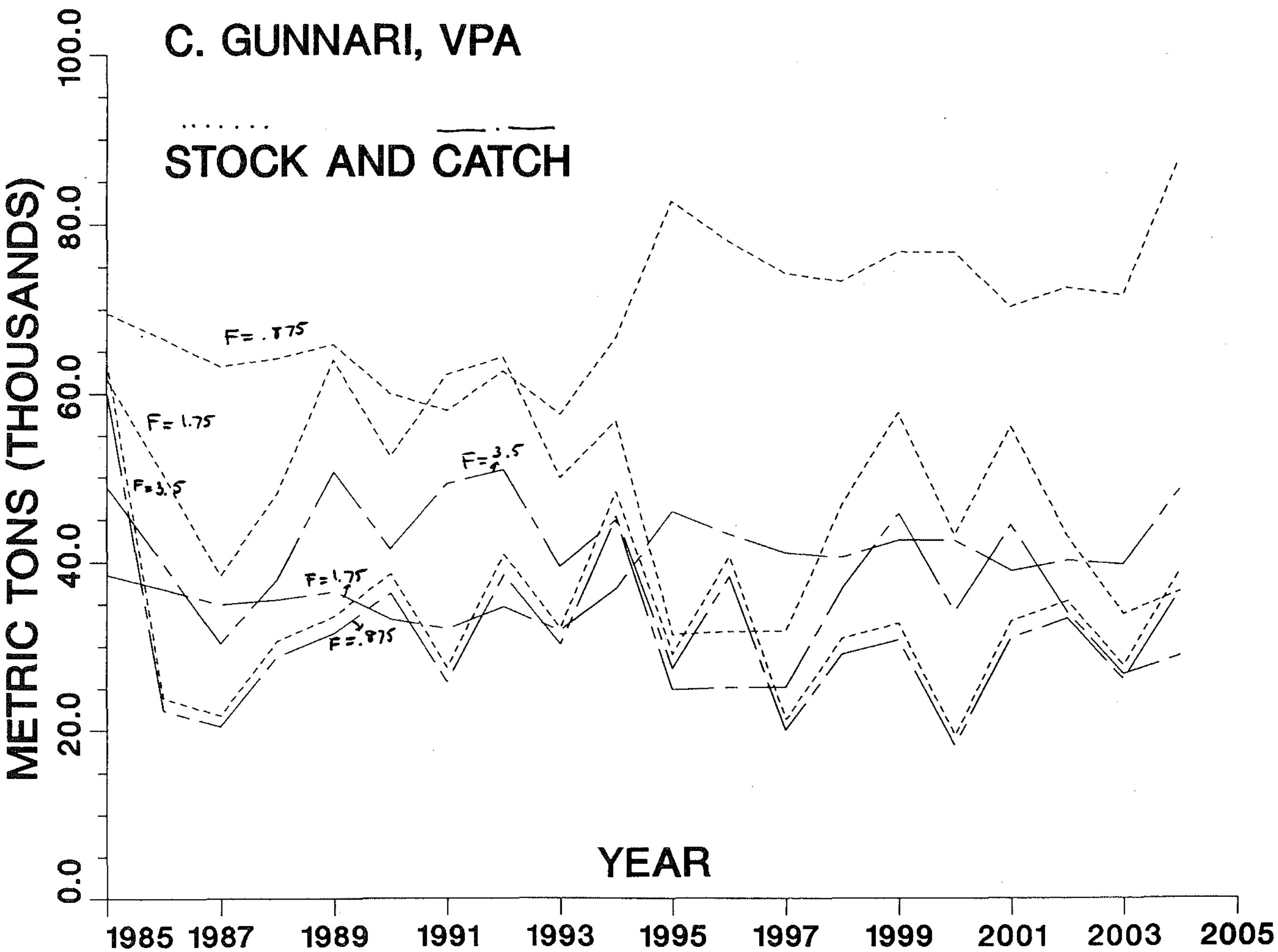

Figure 28. Simulations of weight of stock and catch for C. gunnari, South Georgia subarea, based on VPA.

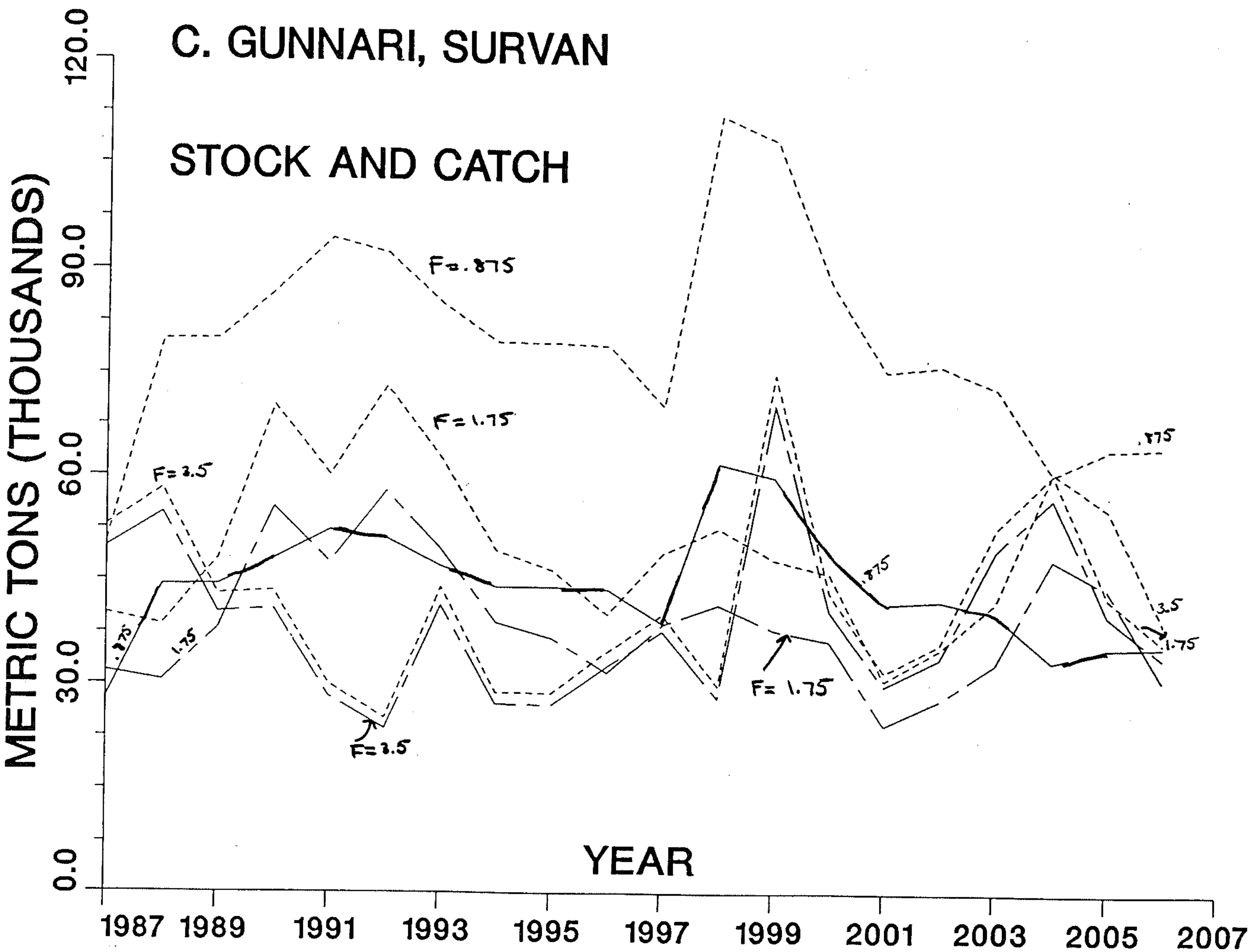

Figure 29. Simulations of weight of stock and catch for C. gunnari South Georgia subarea, based on SURVAN.

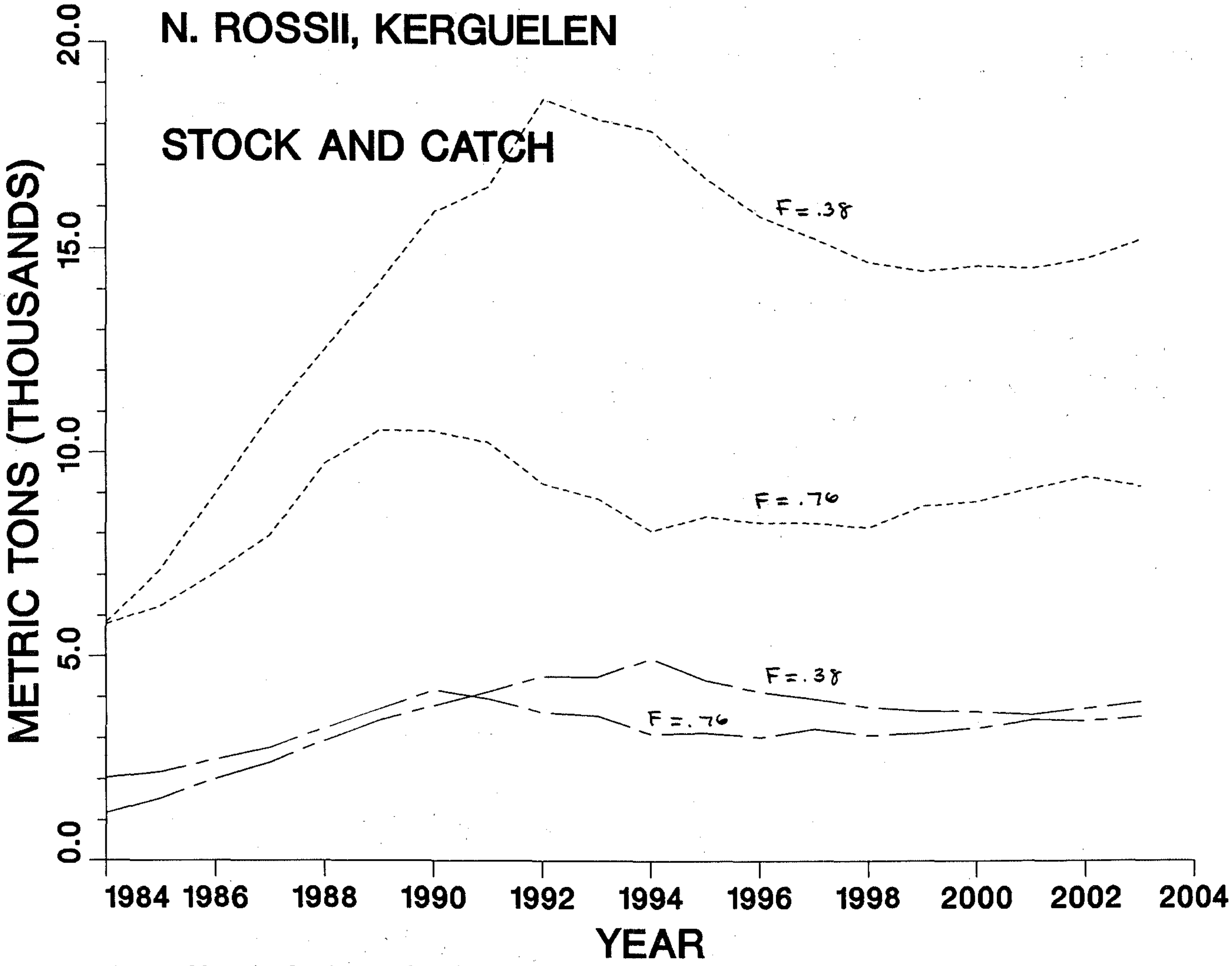

Figure 30. Simulations of weight of stock and catch for N. rossii, Kerguelen Island Shelf, based on VPA.

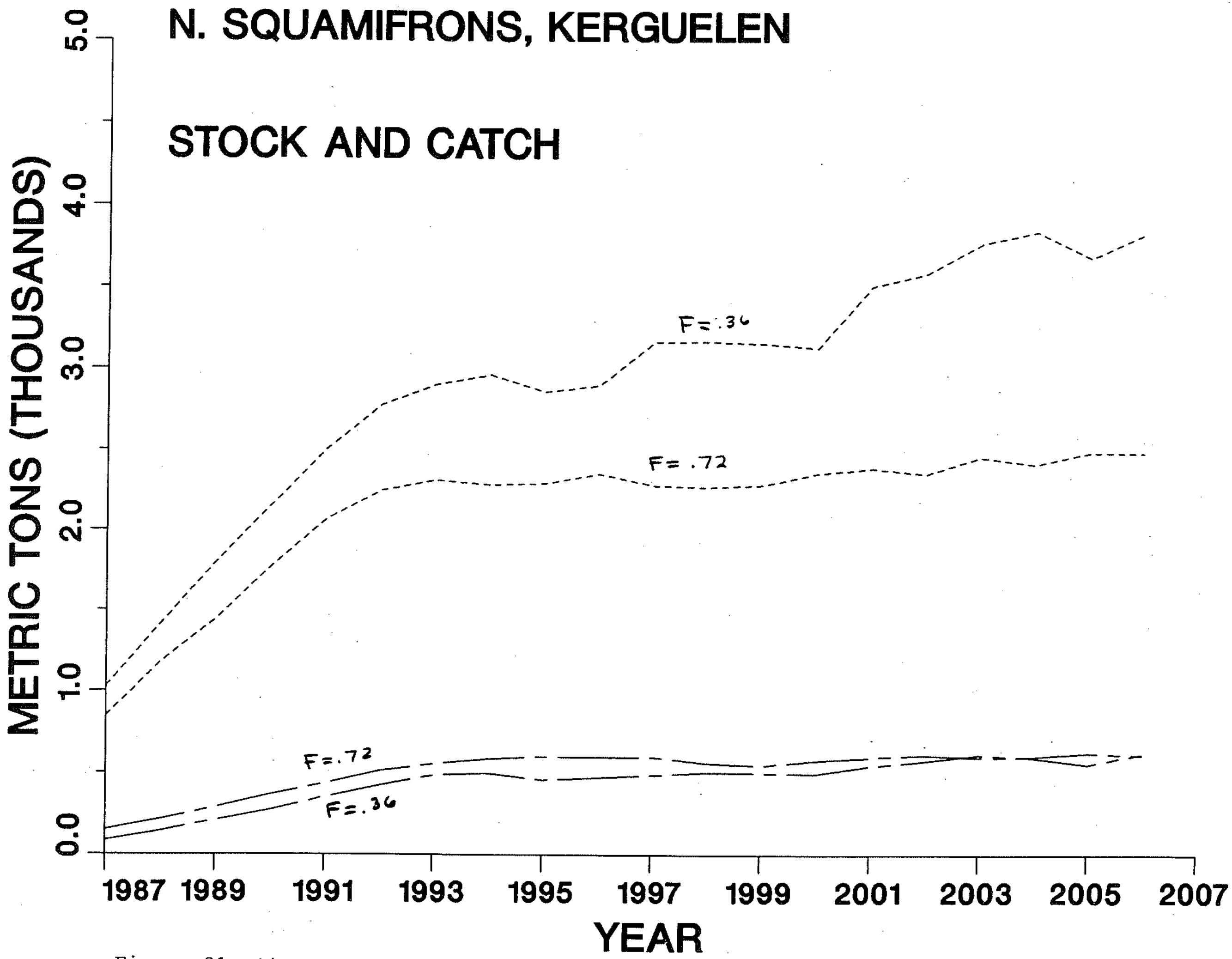

Figure 31. Simulations of weight of stock and catch for N. squamifrons, Kerguelen Island Shelf, based on VPA.

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Tableau 2 — Paramètres utilisés pour le modèle de simulation (Géorgie du Sud).

Tableau 3 — Paramètres utilisés pour le modèle de simulation (Kerguelen).

Tableau 4 — Moyenne des dix projections sur 20 ans concernant la taille du stock en nombre d'individus (x 10^{-6}) et en poids (x 10^{-3}).

Tableau 5 — Moyenne des dix projections sur 20 ans concernant la taille du stock en nombre d'individus (x 10^{-6}) et en poids (x 10^{-3}).

Tableau 6 — Récapitulatif des points de référence standard pour les projections (stocks de la Géorgie du Sud).

Tableau 7 — Récapitulatif des points de référence standard pour les projections (Kerguelen).

Tableau 8 — Comparaison des rendements simulés et des rendements déclarés au cours des années passées.

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Figure 1 — Fonction de densité universelle de probabilité de recrutement utilisée dans la simulation.

Figure 2 — Fréquences de recrutement générées au hasard (nombre de poissons x 10^{-6}).

Figure 3 — Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,55, basées sur la VPA.

Figure 4 — Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,177, basées sur la VPA.

Figure 5 — Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,089, basées sur la VPA.

Figure 6 — Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,55, basées sur SURVAN.

Figure 7 Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,177, basées sur SURVAN.

Figure 8 Simulations de la taille du stock (millions de poissons) de N. rossii, sous-zone de la Géorgie du Sud, F=0,089, basées sur SURVAN.

Figure 9 Simulations de la taille du stock (millions de poissons) de N. gibberifrons, sous-zone de la Géorgie du Sud, F=0,142, basées sur la VPA.

Figure 10 Simulations de la taille du stock (millions de poissons) de N. gibberifrons, sous-zone de la Géorgie du Sud, F=0,071, basées sur la VPA.

Figure 11 Simulations de la taille du stock (millions de poissons) de N. gibberifrons, sous-zone de la Géorgie du Sud, F=0,142, basées sur SURVAN.

Figure 12 Simulations de la taille du stock (millions de poissons) de N. gibberifrons, sous-zone de la Géorgie du Sud, F=0,071, basées sur SURVAN.

Figure 13 Simulations de la taille du stock (millions de poissons) de C. gunnari, sous-zone de la Géorgie du Sud, F=3,5, basées sur la VPA.

Figure 14 Simulations de la taille du stock (millions de poissons) de C. gunnari, sous-zone de la Géorgie du Sud, F=1,75, basées sur la VPA.

Figure 15 Simulations de la taille du stock (millions de poissons) de C. gunnari, sous-zone de la Géorgie du Sud, F=0,875, basées sur la VPA.

Figure 16 Simulations de la taille du stock (millions de poissons) de C. gunnari, sous-zone de la Géorgie du Sud, F=3,5, basées sur SURVAN.

Figure 17 Simulations de la taille du stock (millions de poissons) de C. gunnari, sous-zone de la Géorgie du Sud, F=1,75, basées sur SURVAN.

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WG-CSD-87/12

BEYOND MSY : A CONSIDERATION OF DEFINITIONS OF MANAGEMENT OBJECTIVES

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Abstract

The concept of "Maximum Sustainable Yield" (MSY) has provided a useful guideline for resource management under the assumptions of a simple population model and simple objectives. This paper explores different guidelines under more realistic population models, taking account of the objectives set out in Article II of the CCAMLR Convention. The criteria will depend on whether the main concern is with recruitment or growth overfishing. Account also needs to be taken of the uncertainties associated with any assessment. Suggestions are made for the provision of advice to the Commission for the finfish and krill fisheries.

Résumé

Le concept de "production maximale équilibrée" (PME) a fourni un principe directeur utile pour l'aménagement des ressources dans l'hypothèse d'un modèle de population simple et d'objectifs simples. Ce document explore différentes lignes directrices d'après des modèles de population plus réalistes, tenant compte des objectifs exposés à l'Article II de la Convention de la CCAMLR. Les critères varieront selon que l'intérêt principal portera sur le recrutement ou la surexploitation au détriment de la croissance. Il faudra également tenir compte des incertitudes liées à toute évaluation. Certaines propositions sont avancées en ce qui concerne la présentation de suggestions à la Commission concernant les pêcheries de poissons à nageoires et de krill.

Resumen

El concepto de "Máximo Rendimiento Sostenible" (MSY) ha provisto una pauta útil para la administración de recursos bajo las suposiciones de un modelo sencillo de población y de objetivos simples. Este documento explora diferentes pautas bajo modelos de población más realistas, tomando en cuenta los objetivos establecidos en el Artículo II de la Convención de CCAMLR. Los criterios dependerán en si la mayor inquietud se encuentra en la sobrepesca de las poblaciones en restablecimiento o en aumento. También debe tomarse en cuenta las incertidumbres asociadas con toda evaluación. Se dan sugerencias para la provisión de asesoramiento a la Comisión para las pesquerías de pez aleta y de krill.

Резюме

Концепция "максимального устойчивого вылова" (MSY) являлась полезным руководящим принципом управления ресурсами - при наличии исходных посылок, присущих простым популяционным моделям и простым целям. В данной работе разрабатываются другие руководящие принципы при принятии более реалистичных популяционных моделей, учитывая цели, изложенные в Статье II Конвенции АНТКОМа. Критерии будут зависеть от того, что вызывает большее беспокойство: перелов особей пополнения или перелов молоди. Также надо учитывать и неопределенности, присутствующие в любых оценках. Делаются предложения по представлению Комиссии рекомендаций по промыслу плавниковых рыб и криля.

BEYOND MSY : A CONSIDERATION OF DEFINITIONS OF MANAGEMENT OBJECTIVES

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INTRODUCTION

The traditional one-phrase definition of the objective of resource management has been the Maximum Sustained Yield (MSY). This has several advantages: simplicity, ease of comprehension, and reasonable correspondence to the behaviour of resources under exploitation. In the 1950s and 1960s it served a very useful purpose in bringing an understanding of the broad principles of resource management to administrators and industry. In later years it has come under increasing criticism. Economists have felt that it does not take enough account of economic and social factors, and have proposed alternatives such as Maximum Economic Yield (MEY). Biologists have felt that it uses too simplistic a concept of how natural populations behave, and that not enough account is taken of interactions between species and variability.

A number of alternative formulations have been offered. One with considerable practical implications is contained in the Convention for the Conservation of Antarctic Marine Living Resources. This gives, as an objective of the Commission, ensuring that the population does not fall below the level giving the greatest net annual increase (GNAI). Under the simplest conditions i.e. with all factors other than the direct impact of exploitation remaining constant, GNAI would probably be the same as MSY, and both provide clear guidance on the need for management. If the population is below the level giving MSY or GNAI, or which in the simple case is the same condition, if the amount of fishing is above the MSY or GNAI level, then management is needed. Under more realistic conditions they will differ. Also the criteria for management is less simple, because there is no longer a simple one to one relation between the amount of fishing and population abundance or between either and the rate of increase in the population.

I. GENERAL CONSIDERATIONS

Recruitment Overfishing

A fish population is usually thought of in two parts. For the first few months or years of life, as eggs, larvae or juveniles, the fish are too small to be caught by normal fishing gear, and these fish are not included in the stock as commonly thought of. At some point, the age of recruitment, the fish become big enough, or change their distribution or behaviour, and become accessible to fishing. Though the point of recruitment is not always clear cut, and the boundary between pre-recruits and recruits is somewhat subjective and can change if there are big changes in fishing practice, the distinction is an important one that exists for all fish except perhaps for a few sharks and rays that are large at birth. Except where explicitly stated otherwise this paper will be concerned only with the exploited stock.

Following Russell (1942) the change in the population can be written as R+G–M–C, where

R is the recruits to the stock,

G is the growth put on by the fish that have already recruited

M is the losses due to natural mortality

and C is the catch.

In this formulation all quantities are expressed as weight i.e. the use of M is different from its normal use as a coefficient. In the normal usage the losses due to natural mortality can be written as M*P, where P is the population biomass. In the steady state, the change in population is zero, i.e. R+G–M–C=0, or C=R+G–M. In this familiar expression it is clear that net natural increase and sustainable yield are the same, and the MSY and GNAI points are identical. To explore how they may differ in more complex situations the components of the right hand side need to be examined separately.

R is not affected by current events in the recruited stock, but will depend on the size of the adult stock (which will be related to, but not necessarily identical to, the recruited stock) some time previously when the fish recruiting were spawned, and also on events in the pre-recruit stage. There are substantial arguments, and an equally substantial literature, on the relation between recruitment and adult stock. It is generally agreed that the relation between the abundance of adults and the average or expected recruitment from that stock can be described by a curve similar to those of Ricker (1954) or Beverton and Holt (1957) (Figure 1), but that there is great variation about the average curve. The main arguments concern the position of a given stock on the curve and the relative attention that should be given to the roles of stock size and environmental factors in determining recruitment.

The Ricker curve has a maximum, but this will rarely be the point corresponding to MSY or GNAI. The difference is most easily seen for the simple case of salmon, in which recruitment, catching, spawning, and death follow in quick succession, with no appreciable influence of growth, or of natural death until after spawning. In this case the net increase per generation, or sustainable yield from a brood, will be the difference between the recruitment and the parent stock i.e. the difference between the stock-recruit curve in Figure 1 and the straight line of equal stock and recruitment. Provided that the recruitment is greater that S_{opt}, the spawning stock corresponding to this maximum, the objective of GNAI will be met by taking an amount $R-S_{opt}$, so that the escapement (i.e. recruitment less catch) will equal S_{opt}. If environmental conditions vary, so that recruitment varies, even when stock is maintained at S_{opt}, then catches will vary. It can be argued that they are not being sustained, and that MSY is equal to the minimum catch, occurring after poor environmental conditions. It may also be noted that the policy corresponding to GNAI is uniquely defined in terms of stock size, i.e. escapement should be maintained at S_{opt}, but if environmental conditions are varying there is no unique rate of fishing that gives GNAI. Good recruiting year-classes can be fished harder than weak ones.

Growth Overfishing

These last conclusions, that GNAI can be determined in terms of biomass but not fishing rate, are reversed in the case of a fish stock like some North Sea demersal stocks, where it appears that, to a first approximation, recruitment is independent of adult stock, and management is a matter of achieving the right balance between growth and natural mortality. For a period after a brood of young fish recruits, the growth of the individuals exceeds losses due to natural mortality, and in the absence of fishing the total biomass of the brood will increase. As the fish get older, growth slows down, and at some point - the critical age of Ricker (1948) - losses will exceed growth, and having reached a maximum, the total biomass of the brood will decline. The net natural rate of growth (which may be positive or negative) will depend on its age structure. A stock with mostly young fish will tend to increase and one with mostly old fish will decrease.

If recruitment does not vary, then the age structure will be determined by the level of fishing. The effect of fishing on the natural rate of increase can be derived from the earlier equations in the form $C = R + G - M$, or in terms of yield per recruit (recruitment in this case being measured as total weight of recruits) $C/R = 1 + (G-M)/R$.

Calculation of yield per recruit as a function of the growth and natural mortality coefficients, and as function of the two main characteristics of the fishery - the age at first capture (which may be greater than the age of recruitment if selective gear is used) and the fishing mortality - is a standard procedure (Beverton and Holt 1957). Typical results for North Sea plaice for two ages of first capture are shown in Figure 2. Apart from a constant, these curves are identical with the curves of $(G-M)/R$. For low age at first capture there is a clear maximum, which under conditions of constant recruitment corresponds to MSY and GNAI, and under these conditions will also correspond to specific values of fishing mortality and stock biomass. If recruitment varies due to environmental factors then to a close approximation this value of fishing mortality will, if sustained, give a greater yield than any other sustained fishing mortality, and can be considered as giving GNAI (but not strictly MSY because the yield is not sustained at the same level). However the corresponding stock size will vary in proportion to changes in recruitment. A more accurate calculation will show that the long term yield can be achieved by a fishing mortality that varies about the constant recruitment optimum, being lower when a strong year-class has just recruited and higher when it is old. This will bring the average age of the fish caught closer to the critical age, but the practical difference is likely to be small.

More Complex Situations

Few stocks present cases of pure recruitment or growth overfishing. Even when there is little indication of stock size affecting recruitment over the range of stock sizes so far observed, it is clear that if stock is sufficiently reduced, there will be a fall in recruitment. Thus the absence of a maximum in the yield per recruit curve of Figure 2 for a high age at first capture does not reflect the behaviour of the total yield (or net natural increase) which will fall off at sufficiently high values of fishing mortality.

If environmental conditions are constant, the two approaches are readily combined. The yield per recruit approach can be used to determine the adult stock that will result from a given recruitment under any given fishing pattern (fishing mortality and age at first capture). The resulting lines, giving stock as a function of recruitment, can be plotted in a stock and recruitment diagram (Figure 3). The point where the line for a given fishing pattern cuts the stock-recruit line gives the equilibrium recruitment and stock for that fishing pattern, and hence, by multiplying the yield per recruit by the equilibrium recruitment, the total yield. The fishing pattern that gives the maximum yield is then readily determined. Under these constant conditions, and ignoring the possibility of changing the age at recruitment, unique values of stock size and fishing mortality can be determined corresponding to this maximum, which corresponds to MSY and GNAI. The necessary steps in this have been set out in more detail by Sissenwine and Shepherd (1987).

In practice the recruitment will vary, possibly quite greatly, independently of any changes in adult stock. The difficulties that this causes in determining the underlying relation between mean recruitment and adult stock are well known. In addition it invalidates any simple application of the concepts of GNAI or MSY. The greatest yield that can be sustained is one corresponding to full exploitation of the weaker year-classes - but a much less than full exploitation of the stronger ones. The net natural increases may be negative, even in the absence of fishing when strong year-classes are being replaced by weak ones. Conversely, the stock may increase when a strong year-class recruits, even when it is being heavily exploited.

In the simplest form of this situation, in which the stock-recruit relation is known, it is possible to work out optimum strategies according to various economic or other criteria (see Clark 1985 Chapter 6). Unfortunately these procedures do not in general satisfy criteria such as those of CCAMLR, nor do they deal with sources of uncertainty other than those that Clark refers to as "gambler's uncertainty", i.e. to take a simple example, the uncertainty as to the value that next year's recruitment will take from a (known) probability distribution about a (known) stock-recruit relation.

Possible Criteria Under Variability and Uncertainty

The previous section suggests that if a stock could suffer from both recruitment and growth overfishing, and its recruitment varies considerably, it is not easy to define, still less determine, policies that would satisfy general conservation criteria such as those demanded by CCAMLR. A possible way forward might be to apply separately the criteria relevant to the two types of overfishing, i.e. to ensure that the fishing mortality does not rise above the level causing growth overfishing (or a reduced yield per recruit), and the adult stock does not fall below the point where recruitment begins to fall appreciably.

Considerations of this kind lay behind the original concept of objectives such as $F_{0.1}$ (Gulland and Boerema 1973). These give a point on the yield per recruit curve which is objectively defined, and can be estimated reasonably precisely. In the conditions of the north Atlantic in the early 1970s, with consensus being vital, but countries seeing their interests corresponding to very different levels of fishing, $F_{0.1}$ enabled the scientists in ICNAF to give clear advice on target levels of fishing mortality. This was not possible using MSY, because it gave either an unreasonably high value (if recruitment effects were ignored, and only the yield per recruit curve was used) or could not be estimated (if recruitment effects were taken into account).

As Shepherd (in press) points out, $F_{0.1}$ does not take stock-recruitment effects explicitly into account, and thus, he suggests, sweeps this problem under the carpet. This is only partly true. One of the objectives of the original proponents was to make it less likely that the adult stock declined to the point at which recruitment might be affected seriously. In the case of most ICNAF stocks this was probably achieved, but, although using $F_{0.1}$ can make recruitment overfishing less likely, it is neither a sufficient nor a necessary condition for doing this. It may also be noted that because recruitment effects are not dealt with, $F_{0.1}$ may not necessarily be the point based on economic criteria that it is often supposed to be. That is, unless recruitment is not affected, the marginal yield (as opposed to marginal yield per recruit) will not be exactly 10% of the marginal yield at very light fishing.

Despite these shortcomings $F_{0.1}$ does provide one leg of a management policy that will satisfy conservation criteria of e.g. CCAMLR. Ensuring the F does not exceed $F_{0.1}$ will prevent growth overfishing and discourage recruitment overfishing. What is needed is a second leg that goes further in preventing recruitment overfishing. This will chiefly be a matter of maintaining an adequate adult stock, which has been the top priority in managing marine mammals.

Because of their low fecundity and low mortality in the pre-recruit phase (perhaps 50% compared with 99.999% or more for fish) recruitment among marine mammals is more nearly proportional to adult stock than is the case for fish. Also, though the determination of the stock-recruit relation is not easy, some estimate of its general form and hence of the form of the relation between stock and net recruitment can be obtained. From this, the point of maximum net recruitment (MNR, which will be equivalent to GNAI or MSY) can be determined. If net recruitment rate (i.e. net recruitment as proportion of adult stock) declines linearly from a maximum at very low stocks to zero when the stock is at the carrying capacity of the environment, then MNR will occur when the stock is at 50% of the maximum. There is a belief, with some observational support, mostly from large terrestrial mammals (Fowler 1981) that the recruitment rate is fairly constant until the stock comes close to carrying capacity. In that case MNR or MSY will occur at a population size of more than 50% of maximum.

Where there are formal commitments in terms of MSY or similar criteria, e.g. in the International Whaling Commission, or under the U.S. Marine Mammal Protection Act, there have been considerable discussions over the precise location of the maximum. The IWC has used a value of 60%. In the U.S. the requirement of Optimum Sustained Population (OSP) has been interpreted as being a range of population sizes from that giving MSY (usually taken as 60-70% of maximum) upwards.

For fish, there is as yet no simple rule of thumb about how big the stock should be, though it is clear that for many stocks MNR occurs at population levels well below the unexploited level. For example MNR for the four stocks illustrated in Figure 12 of Cushing (1977) lie between about 50% (for salmon) and 25% (for cod) of the largest stock in the data series, the MNR for plaice being indeterminate but certainly less than 30% of the biggest observed stock. Bearing in mind that all these stocks have been heavily fished so that, with due reservations for the temporary effects of the occasional very large year-class, the observed levels of abundance are well below the original, unexploited, levels, it appears that keeping these stocks at 50 or 60% of the unexploited level would be unnecessarily cautious.

In practice, fisheries management has often erred in the opposite direction. Lacking any general guidance on what size of adult stock is needed, controls on fishing with the aim of preventing recruitment overfishing have not generally been introduced until enough data has been accumulated to determine empirically the stock-recruit curve for the stock in question. This determination usually requires observations at low levels of stock and of recruitment, i.e. the onset of the recruitment overfishing which a good management policy should prevent. Though scientists have warned about the possible onset of recruitment failure e.g. in relation to several herring stocks in the 1970s (Saetersdal 1980), or to the Peruvian anchovy just before the collapse (Anon 1972), these were seldom acted on. This failure was mainly because the recruitment collapses were possibilities or probabilities, rather than certainties, and the management practices of those times did not call for action until the need for action was fully proven. The relative scarcity of serious cases of recruitment overfishing is not due to good management, but because in many fisheries the fishing effort has not reached the critical level for economic reasons (the fishery ceases to be profitable) or because controls are applied to control the more easily demonstrable growth overfishing.

A better awareness of the risks, and new management principles, such as the CCAMLR Convention, have reduced some of the difficulties of acting on probabilities without conclusive proof, but the scientific problems of knowing when action is becoming desirable (i.e. when the stock is likely to fall, in the absence of action, below the MNR level), remain. There is little chance, for the typical stock with considerable natural variation in recruitment, that the level of MNR can be determined purely by the manipulation of data (principally of pairs of values of adult stock size and resulting recruitment) from that stock until there are some values for stock sizes less than MNR.

One approach to this problem is to recognize that there appear to be fairly consistent patterns in the stock-recruitment curves of different stocks within a taxonomic group. Thus for flatfish it is often difficult to detect any change in mean recruitment over a wide range of populations, and MNR occurs at a population that is a small proportion of the unfished stock. Small pelagic fish (herrings, anchovies etc) on the other hand seem prone to recruitment collapses. In individual cases it may be difficult to disentangle possible effects of overfishing from those of environmental changes to which these stocks also seem to be sensitive (Murphy 1977) but the records of collapses closely following periods of heavy fishing are too long to doubt the importance of fishing.

From these records it is possible to make rough estimates of the stock level at which recruitment starts to decline appreciably, expressed as a percentage of the unfished stock. A superficial examination of some of the available data, chiefly those presented at the 1983 FAO meeting in Costa Rica (Csirke and Sharpe 1984) suggests that MNR for clupeoid species occurs at stock sizes some 30-50% of the unexploited level. If further analyses confirm this suggestion, these values and similar values for other groups of species could be used for determining management measures.

Another approach is that being developed in the north Atlantic in terms of a replacement fishing mortality or fishing pattern (Anon 1985, Sissenwine and Shepherd 1987). This is based on a plot of observed values of adult stock, S, and subsequent recruitment, R, but no attempt is made to fit an explicit stock-recruit function. Instead it is noted that any fishing pattern (i.e. vector of fishing mortality at age) will correspond to a straight line in this diagram giving the adult stock that would arise from a given steady recruitment under that fishing pattern. Any points that lie above the line correspond to year-classes that would, under that pattern, do more than replace themselves. The proportion of points that lie above the line for any given pattern therefore gives an indication of the probability that the stock will increase under that pattern, i.e. that the yield is sustainable or better.

Using this approach, several possible target values of fishing pattern (or of F, if possible changes in age at first capture are not of concern) can be determined. Sissenwine and Shepherd propose the use of the median line, i.e. that with equal number of points above and below it, designated by F_{rep}, as likely to be best in practice. This could, if the mean value of R/S changes appreciably with stock size, be somewhat conservative. They point out that, (using the terms of this paper), MNR would probably be better estimated by putting greater weight on the observations at low stock sizes, and Shepherd (1982) suggested the line that had only 10% of the points above it. With this value of F, or with F_{high} in ICES terms (Anon 1986), it is known that the stock can sometimes replace itself, but these occasions may be so rare that over a period, replacement is not possible. Thus a value of F that will certainly avoid overfishing, but is not too restrictive cannot be determined without better knowledge of the underlying relationship. Nevertheless the various values noted here do give some guidance, with F_{rep} probably being the best if it is preferred to make any error on the safe side.

II. TOWARDS A POLICY FOR CCAMLR

The Problems of Providing Advice

One aim in preparing this note was to find some objectively definable quantities that the Scientific Committee of CCAMLR could use in advising the Commission in order that it could fulfil the objectives set out in the Convention. This was not entirely successful, and defining policies that will achieve GNAI (or MSY), even for single species, remains difficult for fish, and even more for krill so long as the true stock-recruit relation is cloudy. Some guidance can be given in terms of either fishing mortality or stock size, the presumption being that action is called for if either measure falls into the danger zone.

For krill, the problem is made more difficult by the need to take into account "associated and dependent" species. It is probably too early to hope to establish a policy for krill that can be put into quantitative terms, and the main consideration here will be given to the fish stocks.

The Fish Stocks

Limits on fishing mortality might be proposed in order to prevent either recruitment or growth overfishing. For the latter, F_{max}, the value giving maximum yield per recruit, is the extreme upper limit, but for most purposes, including that of improved economic performance, $F_{0.1}$ will be the more satisfactory. Similarly, F_{rep} is probably the better limit to use for avoiding recruitment overfishing. If these can be accepted as strategic objectives, then tactical advice can be framed in terms of preventing the actual value of F exceeding the lower of these two values. Consideration of limits on stock size, however, are likely to arise only through concern about recruitment overfishing.

The limits proposed here, whether to F or biomass, provide useful criteria for management only if it is possible to determine, with reasonable reliability, when the limits are being approached. The experience of the IWC has shown how doubts about the values of population parameters can be used, by different groups at different times, to achieve particular objectives. The general uncertainties surrounding the other Antarctic stocks are certainly no less than those surrounding whales. However by focussing on those parameters that are relatively well known, and by addressing explicitly the implications of uncertainty, it may be possible to determine procedures that will enable the Commission to reach definite conclusions on what to do.

For most fish stocks there are fairly good estimates of the biological parameters (growth, natural mortality, age at maturity etc) needed to construct yield per recruit curves and similar functions of fishing pattern, in fact, because age-composition data are available for several stocks from the time that exploitation began, the estimates of natural mortality for these stocks is probably better than for most other stocks. It is therefore possible to calculate for most stocks values of $F_{0.1}$ and also of the value of F that would prevent the spawning biomass per recruit falling below any desired percentage (say 30%) of that in the unexploited stock. Further, the nature of the uncertainties in the parameter estimates are such that it would not be unreasonable to ask the

Scientific Committee for lower limits to these F values, i.e. the lower limit to the possible values of $F_{0.1}$, taking into account uncertainties in growth, natural mortality etc.

The Commission could then set strategic policy objectives in terms of target Fs (based on the information on $F_{0.1}$, spawning biomass per recruit, etc. and the central and lower bounds of these figures). It might also determine a safety net in terms of lower bound to the absolute level of the spawning stock i.e. the level below which the fishery should be closed for a time to allow rebuilding, regardless of the value of F. This would give the following decision tree.

1. Is the spawning stock below the safety level?
   Yes; close the fishery.
   No; go to 2.
2. Is the value of F in the next season likely to reach the target F if no measures are applied?
   Yes; apply measures to keep F to the target level.
   No; allow unrestricted fishing for the next season.

For the purposes of taking decisions, an uncertain answer to either question should be treated as a Yes (i.e. the fishery should be closed unless it is clear that the spawning stock is not dangerously low, and measures should be introduced unless it is clear that F will not reach the target level).

A problem still remains, if measures are called for, in determining what measures, in an understandable and enforceable form, will ensure that the target F is not exceeded. Assuming that mesh regulations and similar measures have been taken as far as is practicable and have been taken into account in calculating yield per recruit and the target F, and that closed areas and closed seasons will not provide a sufficiently sensitive control, two types of controls remain - on catches and on fishing effort.

Catch quotas have been the standard method in the traditional fishery commissions, principally because they used a measure (tons of fish) which was immediately comparable between countries. Experience has shown that they can raise difficulties in enforcement and lead to uncertainties in the reported catch statistics, and, for some stocks, very serious problems in estimation. If next year's quota is to ensure a predetermined level of fishing mortality, i.e. have the hoped for effect on the stock, it must take account of the size of next year's stock. For long-lived stocks which are not subject to much natural variation e.g. whales, this is no problem. For most fish, including most North Atlantic fish subject to quotas, the work of calculating next year's quota is considerable. It involves two parts, determining (usually from catch records) the size of this year's stock, and how much of it will be present next year, and how many young recruits will enter the fishery next year (either from pre-recruit surveys or by assuming that recruitment will be average). Neither process is very accurate.

For Antarctic stocks it might be reasonable to hope that meaningful quotas be calculated for Notothenia rossii (once the stocks are rebuilt to the point at which fishing would be possible). For Champsocephalus however, the carry over of old fish is small, and the recruitment is so variable that controls by quota seems impracticable. If recruitment is strong, the opportunity for good catches may be lost, while if it is weak the stock may be severely over-fished.

Control by effort limitation may be easier. A serious objection, if no regular adjustments are made, is that improvements in fishing efficiency can mean that a control (e.g. that no more than 20 trawlers can fish) that may be satisfactory in 1987 can allow the actual value of F in say 1990 or 1995 to greatly exceed the target F. The worst of such dangers could be avoided by setting fresh limits on nominal effort each year, based on the values of F and fishing effort in the most recent years.

Since some fish stocks cannot, on the arguments presented here, be managed by catch quotas, but could be managed by effort control, the question arises whether effort controls should be applied to all stocks. This should be possible. The chief problem would seem to be that of determining when effort is directed at a species, and the question of incidental catches. This might be dealt with by counting activities (operations of a vessel for a season or a day) towards the effort limit for a species unless the catches of that species are below some acceptably low level.

KRILL

For krill much the same considerations apply, so far as constructing a yield per recruit curve or similar relations is concerned. The population parameters are not quite so well known (doubts surround the exact growth pattern, and it may be necessary to use a relatively wide range of parameter values). On the other hand F is clearly negligible at the moment, and any estimate of total mortality will also be an estimate of natural mortality. The difference comes in selecting a target, or limiting value of F. Clearly the value of $F_{0.1}$, or other target based on single-species considerations will correspond to very high levels of catch, (at least if applied to the Antarctic as a whole), and concern will almost certainly arise over the possible impact on other species before such target Fs are approached.

Knowledge of the interactions between krill and other species is still far from enabling a target F to be set that would, for example, offer no threat to penguins. On the other hand information is being obtained on the degree of natural variation in local krill abundance that can occur, and its impact on associated species. From this it may be possible to determine boundaries to the extent of change in mean krill abundance that could be accepted without risk to other stocks - perhaps a decline of 10%. From calculations similar to those of yield per recruit it would be possible to determine what level of F on krill would be associated with such declines in krill abundance (assuming constant recruitment), thus giving a preliminary target for the maximum allowable F for krill (for the Antarctic as a whole, or for smaller areas) based on multi-species considerations.

Translating these target Fs, which might be adopted as medium term Commission strategic objectives, into specific measures will be more difficult than in the case of fish. At the time that such measures are first considered it is likely that no direct estimates of F on krill will be available. However estimates of krill biomass have been made from acoustic surveys, appeals to consumption rates by predators etc. These are highly variable, but they do allow lower bounds to be set to the biomass, in the whole Antarctic, or for particular regions. The fact that such bounds may differ substantially from the true biomass (perhaps by an order of magnitude) is not important. The point is that the use of the relation Catch = F x mean biomass, will allow catch limits to be set that will ensure that the krill fishery does not harm other species. It will only be when these conservative limits become substantive obstacles to further development to the krill fishery that better estimates of biomass, or of current F, will become important.

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ACKNOWLEDGEMENTS

My thanks are due to John Beddington, John Heap and Inigo Everson for productive discussions and for comments on drafts of this paper.

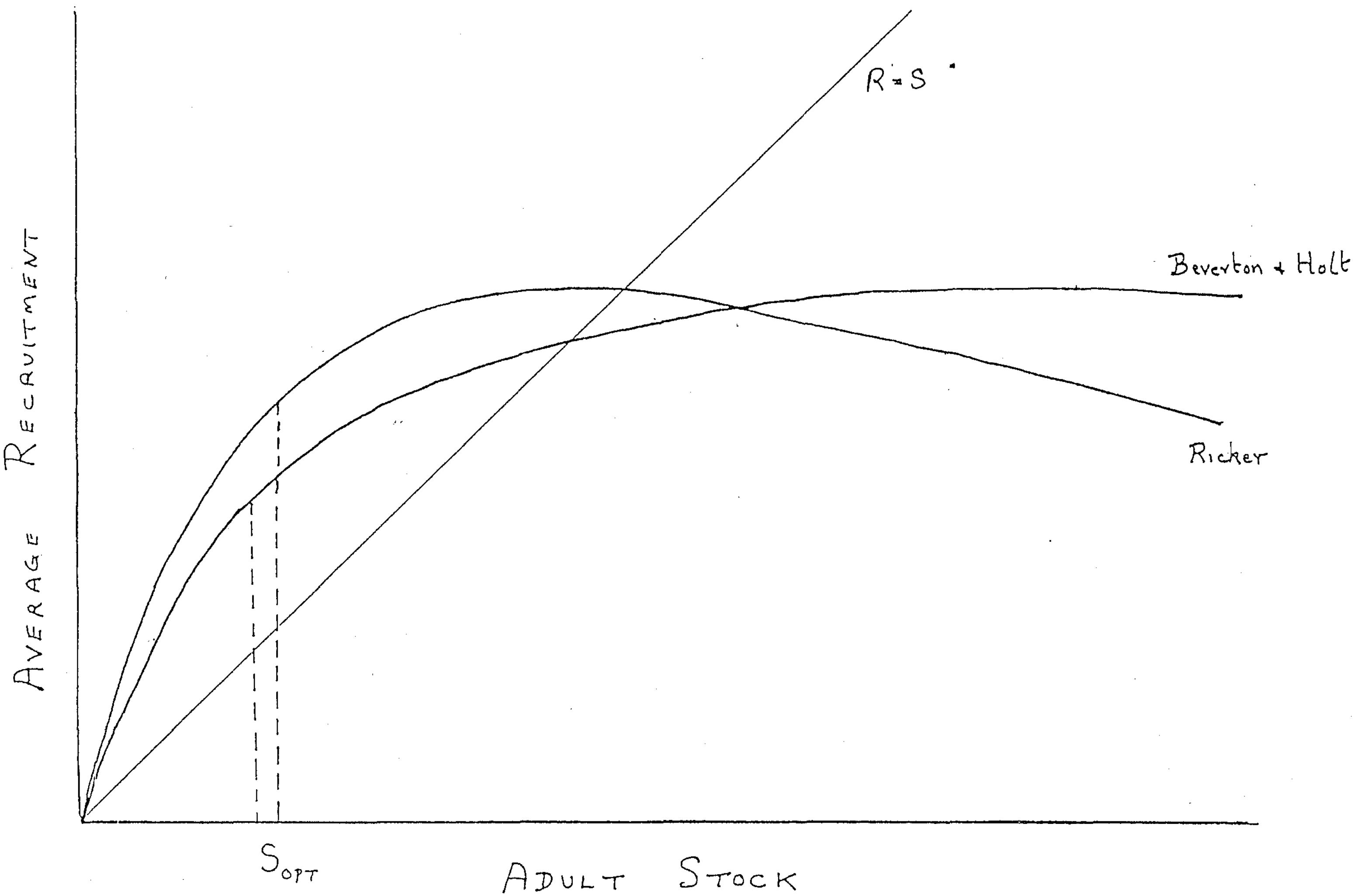

Figure 1 Typical curves relating average recruitment to the abundance of the adult stock for the Ricker and Beverton and Holt equations. S_{OPT} denotes the value of adult stock that results in the maximum difference between parent stock and subsequent recruitment.

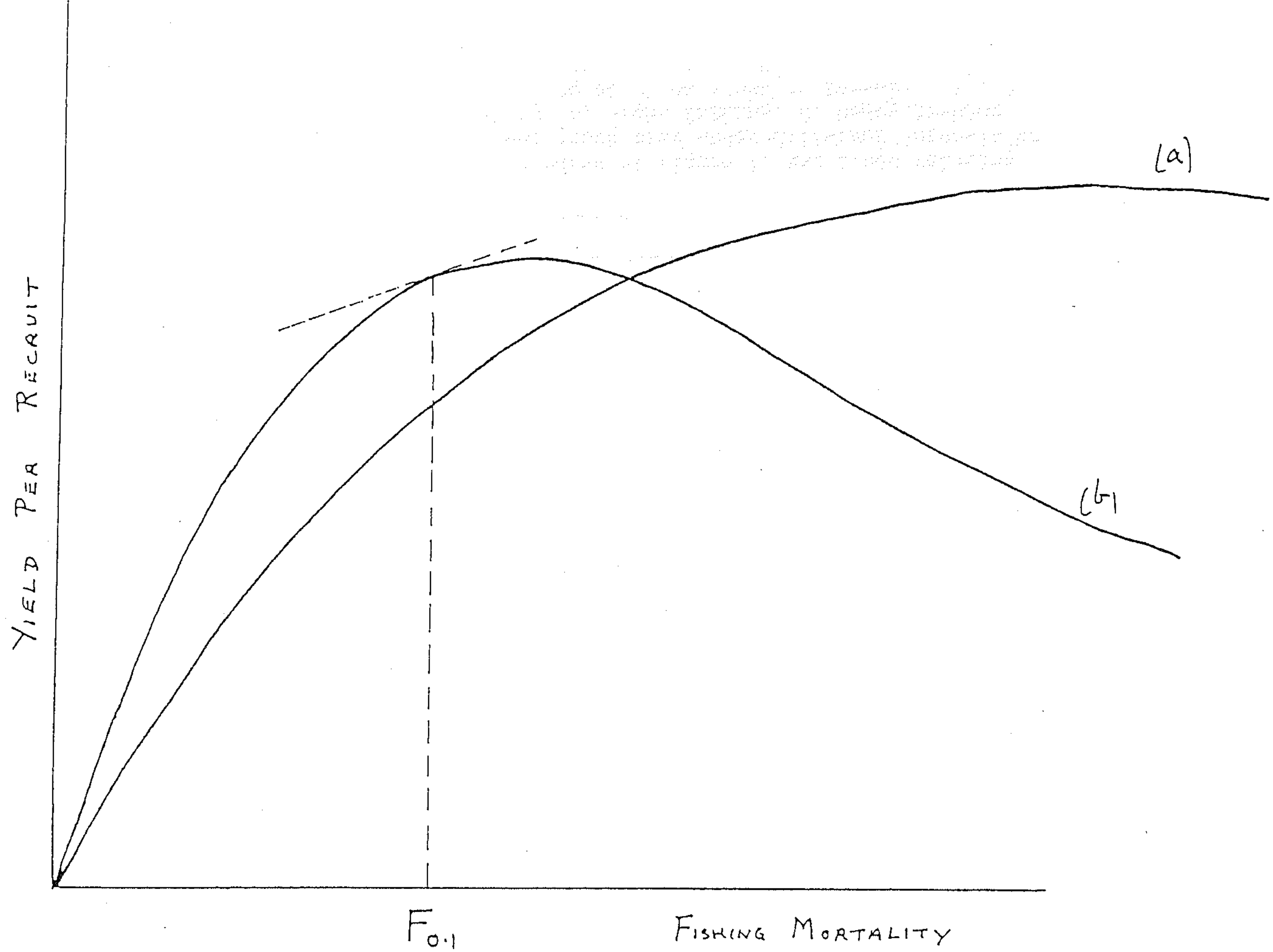

Figure 2 Typical yield per recruit curves for high and low sizes at first capture (curves (a) and (b) respectively). $F_{0.1}$ denotes, for curve (b), the value of F at which the slope of the curve is one-tenth of that at the origin.

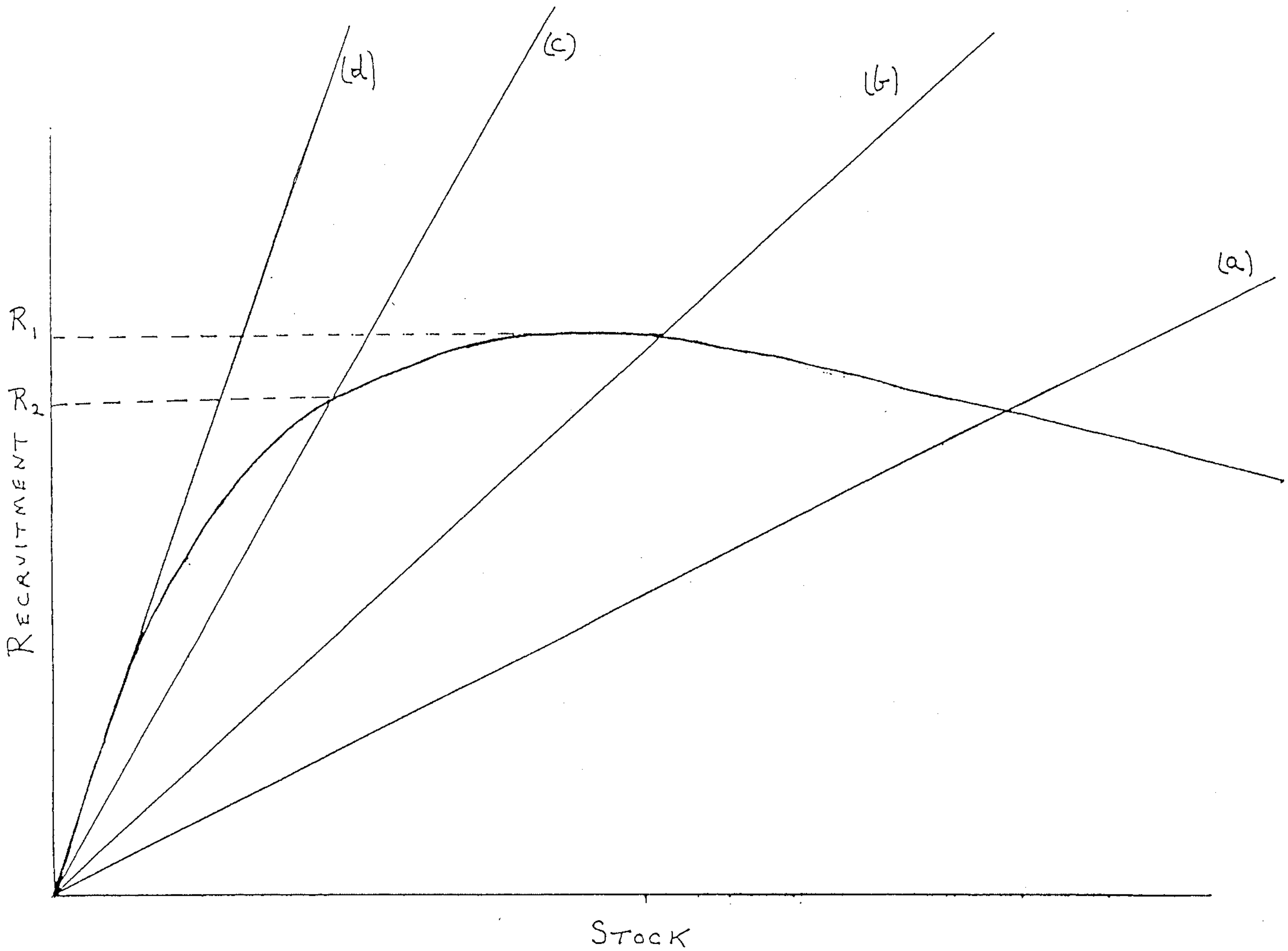

Figure 3 The Ricker stock-recruit curve of Figure 1, and lines relating recruitment to subsequent stock size under different intensities of fishing (a, no fishing, b, light fishing, c, heavy fishing, d, limiting value of fishing at which stock collapses). R_1 , R_2 denotes equilibrium recruitments under light and heavy fishing.

Légendes des figures

Figure 1 Courbes typiques mettant en relation le recrutement moyen et l'abondance du stock adulte pour les équations de Ricker et de Beverton et Holt. S_{OPT} indique la valeur du stock adulte qui mène à la différence maximale entre le stock parental et le recrutement subséquent.

Figure 2 Courbes typiques de rendement par recrue pour les tailles élevées et basses à la première capture (courbes (a) et (b) respectivement). $F_{0.1}$ indique, pour la courbe (b), la valeur de F à laquelle la pente de la courbe est égale au dixième de la pente à l'origine.

Figure 3 Courbe de Ricker stock-recrue de la Figure 1, et lignes mettant en relation le recrutement et la biomasse subséquente en fonction de différentes intensités de pêche (a, aucune pêche, b, pêche d'intensité légère, c, de forte intensité, d, valeur limite de la pêche à laquelle le stock s'effondre). R_1, R_2 indiquent des recrutements d'équilibre dans les cas de pêche légère et intense.

Leyendas de las Figuras

Figura 1 Curvas típicas que correlacionan el restablecimiento promedio con la abundancia de la población adulta para las ecuaciones de Ricker y de Beverton y Holt. S_{OPT} indica el valor de la población adulta que resulta en la diferencia máxima entre la población progenitora y el restablecimiento subsiguiente.

Figura 2 Curvas típicas de rendimiento por restablecimiento para tamaños altos y bajos en la primera captura (curvas (a) y (b) respectivamente). $F_{0.1}$ indica, para la curva (b), el valor de F donde la pendiente de la curva es una décima parte de la pendiente en el origen.

Figura 3 La curva de población-restablecimiento de Ricker de la Figura 1, y las líneas que correlacionan el restablecimiento con el tamaño de la población subsiguiente bajo diferentes intensidades de pesca (a, pesca nula, b, pesca ligera, c, pesca intensa, d, valor límite de pesca que provoca el colapso de la reserva). R_1, R_2 indican los restablecimientos de equilibrio bajo pesca ligera e intensa.

Подписи к рисункам

Рисунок 1 — Типичные кривые, связывающие величины среднего пополнения с размером запаса взрослых особей в уравнениях Риккера и Бевертона и Хольта. S_{OPT} – величина объема запаса взрослых особей, полученная как результат максимальной разницы между родительским запасом и последующим пополнением.

Рисунок 2 — Типичные кривые "вылова на особь пополнения" при больших и малых размерах при первом вылове /кривые (a) и (b) соответственно/. $F_{0,1}$ – для кривой (b) дает величину F, при которой наклон кривой равняется одной десятой такового у начала координат.

Рисунок 3 — Кривая "запас/особь пополнения" - Риккера, данная на Рисунке 1, и кривые, связывающие пополнение с последующим размером запаса при различных уровнях интенсивности промысла (a - отсутствие промысла, b - небольшой промысел, c - интенсивный промысел, d - предельная величина интенсивности промысла, при которой запас истощается). R_1, R_2 - величины пополнения при небольшом и интенсивном промысле, дающие равновесное состояние.

CEPHALOPOD RESEARCH IN THE ANTARCTIC

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Abstract

Cephalopods are a major component of the Antarctic marine food web and it seems inevitable that they will be the subject of future commercial exploitation. Research is being carried out at BAS on the species composition and distribution of Antarctic cephalopods, their production and biomass, population dynamics and trophic relations. However, there is insufficient information at present for CCAMLR to formulate effective policy for management of Antarctic cephalopods. In view of the rapidity that cephalopod fisheries can develop there is need for co-ordinated international research effort. Any commercial fishing for cephalopods should be fully monitored, research should be concentrated on population biology and trophic relations of cephalopods, and a central reference collection of Antarctic cephalopods should be established. The Cephalopod International Advisory Council (CIAC) should receive the support of CCAMLR.

Résumé

Les céphalopodes forment un élément majeur de la chaîne trophique marine en Antarctique et il paraît inévitable qu'ils feront à l'avenir l'objet d'une exploitation commerciale. Des recherches se poursuivent actuellement au BAS (British Antarctic Survey) sur la composition et la répartition des céphalopodes antarctiques, leur production et leur biomasse, leur dynamique démographique et leurs relations trophiques. Faute d'informations suffisantes, la CCAMLR n'est cependant pas en mesure pour l'instant d'énoncer une politique efficace sur l'aménagement des céphalopodes antarctiques. La rapidité avec laquelle peut se développer l'exploitation des céphalopodes impose un effort de recherches coordonnées sur le plan international. Il serait nécessaire de contrôler toute exploitation commerciale des céphalopodes, de concentrer les recherches trophiques des céphalopodes, et d'établir une bibliothèque centrale de référence sur les céphalopodes antarctiques. Le Conseil Consultatif International sur les Céphalopodes (CIAC) devrait bénéficier du soutien de la CCAMLR.

Resumen

Los cefalópodos constituyen un importante componente de la red alimenticia marina antártica y parece inevitable que fueren objeto de una explotación comercial futura. Se está llevando a cabo una investigación en la Prospección Antártica Británica (BAS) sobre la composición de las especies y la distribución de los cefalópodos antárticos, su producción y biomasa, la dinámica de sus poblaciones y sus relaciones tróficas. Sin embargo, no existe actualmente información suficiente que permita a CCAMLR formular una política efectiva para la administración de los cefalópodos antárticos. En vista de la rapidez que pueden desarrollar las pesquerías de cefalópodos, existe la necesidad de un esfuerzo de investigación internacional coordinado. Toda pesca comercial de cefalópodos debería ser totalmente controlada, la investigación debería concentrarse en la biología de las poblaciones y las relaciones tróficas de los cefalópodos, y debería establecerse una colección de referencia central de cefalópodos antárticos. El Consejo Internacional de Asesoramiento sobre Cefalópodos (CIAC) debería recibir el apoyo de CCAMLR.

Резюме

Головоногие - одна из основных составляющих антарктической морской трофической цепи, и представляется неизбежным, что в будущем они явятся объектом коммерческой эксплуатации. В BAS (Британском управлении антарктической съемки) в настоящее время проводятся исследования по видовому составу и распределению антарктических головоногих, их продуктивности и биомассе, динамике популяции и трофическим связям. Тем не менее, имеющейся в настоящее время информации недостаточно для выработки АНТКОМом эффективной стратегии управления запасами головоногих Антарктики. Ввиду того, что промысел головоногих может возникнуть очень скоро, имеется потребность в скоординированной международной исследовательской деятельности. Любой коммерческий промысел головоногих должен полностью находиться под контролем; исследования должны быть сконцентрированы на биологии популяций и трофических связях головоногих, а также должна быть создана реферативная коллекция антарктических головоногих. Международный консультативный совет по головоногим (CIAC) должен получить поддержку АНТКОМа.

CEPHALOPOD RESEARCH IN THE ANTARCTIC

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INTRODUCTION

The Southern Ocean is known to contain large stocks of cephalopods, especially squid, which form an important component of the diet of several species of whales, seals and birds (Roper, 1981; Clarke, 1983). Important commercial fisheries for squid currently exist in sea areas adjacent to the Antarctic - around New Zealand and the Falkland Islands - and there has been at least one exploratory squid-fishing expedition, south of the Antarctic Polar Front, in the vicinity of South Georgia. There is an expanding world market for squid and squid products and it is inevitable that, in the future, Antarctic squid stocks will come under pressure of commercial exploitation. Recent experience has shown that squid fisheries can rapidly become very large. It is therefore important that the Commission for the Conservation of Antarctic Living Marine Resources (CCAMLR) should be preparing plans for an effective management strategy before large scale fishing commences.

The effective management of stocks of Antarctic cephalopods will depend upon knowledge of :

1. The species composition and distribution of the Antarctic cephalopod fauna

2. Production and biomass

3. Demography and population dynamics

4. Trophic relations - role of cephalopods as predators and prey in the Southern Ocean ecosystem.

This paper considers the current state of knowledge for each of these topics in order to highlight key areas for research.

CURRENT STATUS OF ANTARCTIC CEPHALOPOD RESEARCH

Species Composition and Distribution

The Antarctic cephalopod fauna is poorly known because much of the material available to science has been the semi-digested remains from the gut contents of vertebrate predators. The approximate geographical range of the major species of the Antarctic is given by Fischer and Hureau (1985) but this list is not exhaustive (see Clarke, 1980) and there is almost no information about the relationships between species and particular water masses or current systems or their relationships with the continental shelf or island groups.

A cephalopod sampling programme, using a RMT25, was initiated by the British Antarctic Survey (BAS) during the 1986-87 Antarctic season. This net was fished open and produced an important collection of squid from the vicinity of the South Georgia shelf break. The collection, together with Antarctic collections from the 'Discovery' expeditions and from the 'Walther Herwig', 'Polarstern' and 'Professor Siedlecki' cruises, is being examined by the author at BAS. Considerable progress could be made by further sampling for cephalopods with large mid-water and bottom trawls and possibly with commercial jigging gear.

The distribution of the early-life phases of three common species of squid, in relation to the vertical structure of the Southern Ocean, has been examined at BAS by Rodhouse and Clarke (1985, 1986) and Rodhouse (in press a). These data, although very limited, suggest distinct patterns of distribution in relation to the hydrological structure of the ocean. Further sampling with opening/closing nets is needed to obtain information on vertical distribution of other species and at different geographical locations.

Production and Biomass

A considerable body of data has been collected by BAS, in collaboration with the Marine Biological Association of the UK (MBA), on the consumption of cephalopods by homeothermic vertebrate predators (Clarke et al., 1981; Clarke and McLeod, 1982a, b; Clarke and Prince, 1981; Croxall and Prince, 1982; Rodhouse et al., 1987; Rodhouse, in press b). These data have enabled Clarke (1983) to estimate the total cephalopod consumption in the Southern Ocean, and Croxall et al. (1985) to estimate consumption in the Scotia Sea. The estimates, 34.2 million tonnes and 3.7 million tonnes per year respectively, demonstrate the importance of squid in the ecosystem and, in the absence of any information on total production, highlight the need for prudent management plans.

Using currently available data it is impossible to estimate the standing stock of Antarctic cephalopods. It is unlikely that much progress in estimating stocks of Antarctic cephalopods can be made until commercial scale fishing operations commence. Stock assessment of target species will clearly be of the highest priority following the onset of commercial exploitation.

Demography and Population Dynamics

Cephalopod populations differ from other commercially exploited fish populations in a number of respects and provide special problems for management (Caddy, 1983; Amaratunga, 1987). There are no life-history data for any species of Antarctic cephalopod. Indeed the life histories of very few cephalopod species are known (Boyle, 1983). Data will be required on the biological parameters - growth, mortality, life span, fecundity and migrations - upon which population management models are based.

The author is currently engaged in research on the life cycles and growth of two species of cool temperate myopsid squid species, *Alloteuthis subulata* and *Loligo gahi*, from the UK and the Falklands Islands respectively, and the cool temperate oegopsid squid *Illex argentinus* from the Falkland Islands fishery. Data are being collected on growth, maturation and the morphometric, histological and biochemical changes associated with these processes. The resulting analyses will be an important contribution to fundamental knowledge of cephalopod life cycles and will be valuable for comparative purposes as information from Antarctic species becomes available.

It is known that cephalopods generally have high growth rates and growth efficiencies. However, until recently, population studies have been hampered by lack of reliable methods of estimating age. Recent advances in validating the daily nature of micro-growth increments in the cephalopod statolith (Dawe et al., 1985; Hurley et al., 1985; Lipinski, 1986; Yang et al., 1986) now enable age to be determined with reasonable confidence. Studies at BAS on size at age for the species from the Falkland Islands fishery are being carried out and techniques for preparation and reading of statolith growth increments are being refined.

At BAS, cephalopod growth is also being studied using an index calculated from the ratio in the tissues of RNA to DNA. This index is based on the hypothesis that, within a living cell, nuclear DNA content is fixed, provided it is not dividing, but RNA content varies with protein synthesis rate. The RNA/DNA ratio may thus provide a means of assessing rate of metabolic turnover. This information can then be used to assess nutritional status and comparative growth rates of cephalopods caught in the field. A protocol for the assay of nucleic acids in cephalopod tissue has been developed and a growth experiment has been run with Sepia officinalis, fed at a range of food rations and temperatures. This material is being used to validate the nucleic acid ratio as an index of growth rate in cephalopods. If successful, the technique has the potential for enabling the assessment of nutritional status and comparative growth rate of juvenile cephalopods from net hauls in the Antarctic. This type of data in turn may be useful, in the future, for predicting year class strength of exploited species prior to recruitment.

Factors associated with mortality in cephalopods are poorly understood. Clearly, predation by vertebrates is a major factor in the Southern Ocean but the contribution to total mortality is not known. In many species of cephalopod for which the life history is known, life span is approximately one year; spawning occurs once and is quickly followed by death. Size frequency distributions of the cephalopod prey of Antarctic predators (cf. Rodhouse et al., 1987), estimated from beak size distributions, suggest that populations of most species consist of a single year class. However, this may reflect selective feeding by the predators and further information from other sampling methods is required before firm conclusions can be drawn about the life span of Antarctic cephalopods.

Fecundity of cephalopods from temperate and tropical seas tends to be relatively low (Caddy, 1983) and the eggs are usually large. The evolution of semelparity in the group suggests that juvenile mortality is generally low. There is evidence that the evolution of life history patterns in marine organisms has been influenced by latitude (A. Clarke, 1983) and so it is possible that there are differences between high latitude species and those from warmer waters.

Knowledge of seasonal patterns of migration in relation to life history is often important for the management of exploited cephalopod populations. Data are entirely lacking for Antarctic species.

Trophic Relations

Research on the role of cephalopods as prey for Southern Ocean homeothermic vertebrate predators continues at BAS and includes studies on Southern Elephant Seals (*Mirounga leonina*) and Wandering, Grey-headed and Black-browed Albatrosses (*Diomedea exulans*, *D. chrysostoma* and *D. melanophris*). Information from this research will be essential if cephalopod stocks are to be managed with due consideration for the conservation of those species of birds, whales and seals which consume cephalopods as a major part of their diet. Predation by fish has not been researched but this is also a question which should be addressed. Total allowable catch will have to be set in any future fishery so that the yield to predators is maintained at a level which ensures their stable recruitment.

It is also important that, in the future, some emphasis should be placed on elucidating the role of squid as predators in the Southern Ocean's pelagic/meso-pelagic community. In this context BAS is collaborating with the Zoology Department at the University of Aberdeen, through a Natural Environment Research Council (NERC) CASE postgraduate award, to explore the use of serological methods to analyse the gut contents of Antarctic cephalopods.

Antibodies to Antarctic krill (Euphausia superba) have been successfully raised in rabbits and testing is being carried out for cross reactions with other pelagic species which are putative prey items of Antarctic cephalopods. When these tests are complete, the gut contents of three species of squid, collected by BAS during the 1986/87 season, will be tested for the presence of Euphausia superba. In addition to the serology programme, research is also being carried out on the functional morphology of the beaks of Antarctic squid.

Future research will also include more conventional analyses of cephalopod gut contents such as the use of eye remains to identify prey species and estimate their size (see Nemoto et al., 1985)

International Co-ordination of Cephalopod Research

Cephalopod research is in progress at several institutes world-wide. The Cephalopod International Advisory Council (CIAC) sponsors symposia, workshops and scientific publications relating to the Cephalopoda as well as publishing a newsletter. It provides an international forum for scientific exchange on matters of cephalopod biology.

CONCLUSIONS

The Southern Ocean contains large, unexploited stocks of squid which potentially have a high commercial value. Two major fisheries for squid exist adjacent to the Southern Ocean, in the south-east Pacific and South Atlantic. It is almost inevitable that attention will soon turn to

Southern Ocean stocks. Experience elsewhere, notably in the Falkland Islands fishery, has shown that squid fisheries can develop very rapidly. If this were to happen in the Antarctic, without adequate management, there would be potentially serious consequences for the squid stocks and for the predator populations - birds, whales and seals - for which squid are a major food resource.

Current knowledge of the biology of Antarctic squid stocks is inadequate for CCAMLR to formulate effective management policy. There is therefore a pressing need for international effort in this field. This could be achieved by concentrated effort on the following topics :

1. Co-ordination of research effort so as to pool resources and information. It is particularly important to increase our knowledge of the species composition and distribution of the Antarctic cephalopod fauna.

2. Any commercial cephalopod fishing in the Antarctic should be monitored fully and scientific information from such activities should be maximised. Catch and effort data, based on a meaningful effort index, are clearly of prime importance for making stock estimates. However, given the state of knowledge of the Antarctic cephalopod fauna, the value of obtaining specimens from commercial catches should be emphasized. Considerable benefit to science and commerce would be derived from placing scientific personnel aboard commercial vessels fishing for cephalopods in the Antarctic.

3. Increasing research effort into the population dynamics of Southern Ocean cephalopods; in particular ensuring uniformity of criteria and methodology used in age determination.

4. Investigations of the trophic relations of cephalopods, both as predators and prey.

5. Establishment of a central reference collection of Antarctic cephalopod material.

6. The Cephalopod International Advisory Council (CIAC) is the international organization for professional cephalopod workers. Where its activities are relevant to the Antarctic it should receive the support of CCAMLR.

ACKNOWLEDGEMENTS

I thank Drs I. Everson and J.P. Croxall for their advice and criticism. The Institute of Oceanographic Sciences (NERC) has made the cephalopod material from the 'Discovery' collections available to me. Drs K.-H. Kock and V. Siegel arranged for the loan of cephalopod material from the Antarctic cruises of the 'Polarstern' and 'Walther Herwig'. Dr K.E. Skora arranged for the loan of cephalopod material from the Antarctic cruises of the 'Professor Siedlecki'. Dr M.R. Clarke and Mr P.L. Pascoe, at the MBA, and Dr A. Clarke at BAS, are collaborating with the nucleic acid ratio experiments. Research on cephalopods from the Falkland Islands Fishery is being funded by the Falkland Islands Government.

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SC-CAMLR-VI/BG/35

OBSERVATIONS OF FISHING OPERATIONS ON A KRILL TRAWLER AND DISTRIBUTIONAL BEHAVIOUR OF KRILL OFF WILKES LAND DURING THE 1985/86 SEASON

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Abstract

Japanese krill fishing operations were observed on board a commercial vessel and the actual operation described in detail. "Fish-finder" was mose useful in detecting swarms, while sonar was used to judge the towing direction. The size of fished swarms ranged from 100 m to 10 km with different distributions occurring in different fishing areas. While catch per towing time reflects within-swarm density, catch per day was thought to be a good index to measure abundance of a concentration. Comparison of such an index across time and space may prove difficult due to problems of standardization when data from different vessels are to be used.

Résumé

Les opérations de pêche de krill japonaises ont été observées à bord d'un navire commercial et les opérations proprement dites ont été décrites dans le détail. Le "détecteur de poissons" a été très utile pour détecter les bancs, alors que le sonar a servi à estimer la direction de chalutage. La taille des bancs pêchés allait de 100 m à 10 km, la répartition variant selon le secteur de pêche. Alors que la prise par temps de chalutage reflète la densité au sein du banc, la prise par jour semblait un bon indice pour mesurer l'abondance d'une concentration. La comparaison de cet indice sur le plan temporel et spatial pourra s'avérer difficile étant donné les problèmes de standardisation lorsque doivent être utilisées les données provenant de différents navires.

Resumen

Se observaron operaciones pesqueras de krill japonesas a bordo de una nave comercial y se describió en detalle la operación en sí. El "Fish-finder" ("Localizador de peces") fue de gran utilidad en la detección de cardúmenes, mientras que el sonar fue usado para decidir la dirección de remolque. El tamaño de los cardúmenes pescados varió de 100 m a 10 km, observándose diferentes distribuciones en distintas áreas pesqueras. Mientras que la captura por tiempo de remolque refleja la densidad dentro del cardúmen, se pensó que la captura por día era un buen índice para medir la abundancia de una concentración. La comparación de tal índice a través del tiempo y el espacio puede resultar difícil debido a los problemas de estandarización cuando deban utilizarse datos de diferentes embarcaciones.

Резюме

С борта коммерческого судна велось наблюдение за японскими промысловыми операциями при промысле криля, и дается детальное описание этих операций. "Рыбоискатель" оказался наиболее полезным при обнаружении скоплений, в то время как гидролокатор использовался при определении направления траления. Размеры обловленных скоплений варьировались от 100 м до 10 км с различным распределением на разных промысловых участках. Величина "улов на время траления" отражает плотность внутри скопления; считалось, что величина "улов за день" является хорошим показателем для определения численности концентрации. Сравнение таких показателей по временной и пространственной шкале может оказаться нелегким делом, т.к. при использовании данных с различных судов возникают трудности с их стандартизацией.

OBSERVATIONS OF FISHING OPERATIONS ON A KRILL TRAWLER AND DISTRIBUTIONAL BEHAVIOUR OF KRILL OFF WILKES LAND DURING THE 1985/86 SEASON

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1. INTRODUCTION AND MATERIALS

It is now becoming a necessity to develop stock assessment of krill not only to manage the stock but also to monitor and manage the Antarctic ecosystem as a whole. The usefulness of CPUE (catch per unit effort) data as an index of krill abundance is now under investigation in the "Krill Simulation Studies of CPUE" by the Scientific Committee of CCAMLR. This study desperately needs information on fishing operational strategies and aggregation behaviour of krill.

This document summarizes information collected on board a commercial vessel, including information on the fishing strategies and actual operation and on the distributional behaviour of krill necessary for the interpretation of CPUEs.

Information utilized in this report was collected on board Zuiyo Maru No. 2 (3 023 tons, Hakodate Kokai Gyogyo Co.) throughout the 1985/86 season off Wilkes Land. The operational features may not necessarily be the most representative of the Japanese krill fishery in the past there, or at present in the Scotia Sea.

2. THE FISHING STRATEGIES

2.1 Favorite Krill Quality

Three types of products were produced by Zuiyo Maru No. 2 : fresh-frozen krill (for fishing bait and food in fish culture), boiled-and-frozen krill (for human consumption), and meal (for food in fish culture). In addition to these products, Japanese vessels produce peeled krill meat (for human consumption), and more than half the total Japanese catch is used for direct human consumption. Processing constraints differ according to the product. Fresh-frozen and boiled-and-frozen krill must be processed within 3 hours of capture, whereas meal can be processed much later.

The major products of Zuiyo Maru No. 2 were fresh-frozen and boiled-and-frozen krill. The determining factors were as follows :

1. "Greenness"

   "Green" krill were commonly found during January off Wilkes Land. They have a green hepatopancreas as a result of intensive feeding on phytoplankton and were avoided because of their dirty appearance, unfavorable smell and inferiority in taste. Processing options were affected by krill greenness (Table 1). Of the three types of above products, fresh-frozen krill is the most sensitive to greenness.

2. Size

   Although instructions for reporting size of krill in the logbook required categorization of the krill by body length, this vessel took body height as well into consideration in the categorization : LL (larger than 45 mm, and 7.3 mm in average height), L (between 35 and 45 mm in length, and 6.5 mm in average height), and M (below 35 mm in length, and 4.3 mm in average height). Generally the largest size category is the most preferable to the fishery. The smaller classes are less valuable due to marketing competition with the smaller euphausid species, *Euphausia pacifica*, fished off northern Japan.

   But the smaller sized krill, on the other hand, tend to be less green and they are caught preferentially if only green krill are available to the fishery.

3. Gravid females

   Gravid females were sought especially when green krill were unavoidable because egg diminishes the green appearance and adds tastiness.

4. Body color
Transparent krill (called "white") are firm and look delicious, while brick red/pink krill (called "pink") are flaccid and easy to crush. This grading has come to be adapted following that used for shrimps. White are more valuable than pink.

2.2 Macroscale Ground Selection

The krill fishery has not been a self-sustaining operation economically and hence a combination with other bottom trawling operations was sought. Historical fishing grounds used by Japanese krill expeditions are divided geographically into three regions : off Enderby Land, off Wilkes Land (including George V Land), and the Scotia Sea.

In earlier years, the trawlers operated in the fishing grounds off Enderby and Wilkes Lands. This is partly due to the survey on the feasibility of a krill fishery started off Enderby Land by the Japan Marine Fishery Resources Research Center (JAMARC) and partly due to the least transit times to Japan and fishing grounds of demersal fish off Africa. In recent years, the through-year activity of the trawlers has come to be incorporated into the fish and squid-harvesting off South America and New Zealand and almost all the vessels operate in the Scotia Sea. Only one or two vessels operate off Wilkes Land and none operates off Enderby Land.

Besides this logistic/economic advantage, the Scotia Sea ground has other desirable factors, e.g. the better catch rates and the higher proportion of the LL sized krill, which are indispensable for the recently developed technology used in producing peeled krill meat. Another advantage is the geographical feature which diminishes worry about cargo work.

In contrast, the quality of krill of Wilkes Land is better than that in the Scotia Sea (Table 2). For example, catches may be kept for processing fresh-frozen products for about three hours, one hour longer than in the Scotia Sea. Flaccid krill have become a problem since the Scotia Sea became the main operating area.

Zuiyo Maru No. 2, in 1985/86, chose the ground off Wilkes Land, although she had to engage in squid fishing off the Falkland Islands afterwards. The reason was that the quality of krill off Wilkes Land had been extremely good (white krill, the largest size class and high percentage of gravid females) in the previous season and similar quality was expected based on information from vessels of another company that had already been operating there. Unfortunately there was no white krill by the time the vessel reached there, but it was decided to operate in this ground.

2.3 Searching for Krill Concentrations

Krill distribution is too patchy to be able to come across harvestable concentrations by a random "walk-search" method, so the vessel made use of various information. In Table 3 are shown frequencies of causes of major shifts of Zuiyo Maru No. 2 in search of a new fishing ground during the season.

The most important information was the historical distribution of good harvesting areas. Such areas tend to occur in rather limited areas, possibly linked to oceanographic features such as submarine rises, the eddying effect around the tips of glaciers or the Antarctic Divergence. These features may hold krill in that area for a prolonged period. The best fishing area operated by Zuiyo Maru No. 2 in 1985/86 season was within the area of good harvesting in the past.

During operations, the crew collected data along the expedition route on the quality and quantity of krill and water temperature. These data were utilized to forecast a change in biological and fishing conditions to determine whether to return to the areas previously found but abandoned successively.

Communication with other fishing vessels and sometimes with the cargo ship were made to enhance the ability to find high density areas.

Minke whales were not a useful cue, as usual. They were seen in low krill density areas as frequently as in high density areas. This was partly because fishing areas were far away from the pack ice edge where minke whales feed on krill. Icebergs were not useful to find krill concentrations. Within concentrations, however, they could sometimes be useful to detect swarms until they moved away with the current in a day or so.

The vessel was very experienced and eager to find high density areas. She increased frequency of directional changes immediately after detecting low density krill to find her way into density areas.

2.4 Detection of Swarms

Once the vessel succeeded in finding areas of high krill density (concentrations), detection of individual swarms was the basic activity of the operation. The fishing vessel tended to select the larger sized swarms to tow. The distribution of swarms thus selected and actually towed varied in size from 100 m to 10 km (Figure 1). Extremely large swarms extended over 5 km with very low density.

In Table 4 are shown the relative frequencies of cues used in detecting swarms on which tows were made. Fish-finder was the most important cue throughout the season. In high density areas, the number of swarms per unit area was so high that there was little need to rely on sonar which gave a wider horizontal effective search width. Also in areas where swarms exceeded more than 3-4 km length/diameter but their densities were too low for being detected by sonar, fish-finder was the only method on which to rely.

When swarms were small and scattered (generally in the beginning of the season), sonar was indispensable in detecting them. It could detect krill swarms at ranges of 300-400 meters when swarms were dense and well below the surface. (Krill swarms are generally denser in the Scotia Sea and the detectable range may extend up to 800 meters.) Although fish-finder can detect swarms at any depth just below the vessel, sonar could miss dense swarms because of its narrow vertical range of detection. The main usage of sonar in the high season was to detect the direction of extension in order to judge the direction of towing.

Surface swarms, which usually occurred only in the half-light period after sunset, were difficult to detect by sighting. Another vessel which had crews experienced in whale sightings seemed to use sighting to some extent.

3. FISHING AREAS

3.1 Fishing Areas in the 1985/86 Season Off Wilkes Land

As a result of operations by Zuiyo Maru No. 2, the characteristics of six fishing areas (Figure 2) are summarized in Table 5. In those areas, operations were continued more than three days. Among them, areas H2 and J met best with the requirement of production where a constant daily catch of over 50 tons was attained. In the best harvestable area H2, which had been a good fishing area in the past as well, the vessel's maximum capacity of daily catch of 100 tons was reached. Area H1 may correspond to the periphery of the concentration H2, judging from the similarity in length frequency histograms. Area J, which was found based on the information from the cargo ship, seemed to correspond to the Antarctic Divergence.

Other areas such as F, D and B were less dense, although area D and B provided a fairly good yield of white krill in the previous season. In those offshore areas, the concentrations may vary from year to year.

3.2 High Yielding Fishing Area for the Past Four Years

Around area H2, there have been good yielding areas for the past four seasons except in the 1984/85 season when vessels were concentrated on white krill found offshore (Figure 3). The spatial scale of this good concentration was 100-300 km from east to west and 30-50 km from north to south and corresponds to meso-scale aggregations according to the diagram of Haury et al. (1977). Submarine rises seemed to hold krill in this area. Krill abundance surveys by research vessels should be designed in such a way as not to miss this scale of concentrations.

4. CATCH RATES

4.1 The Utility of Catch Per Day and Catch Per Haul in Juding the Worth of Fishing Areas

When the vessel moved to a new area, catch per haul of the first few hauls gave a base to determine whether to stay or to leave. If krill quality was bad in the first haul, the vessel left irrespective of the catch per haul. A level of about three tons of catch per haul was used as the criterion.

The decision to leave areas where they had kept on operating was made on the basis of catch per day. If catch per day was less than 50 tons, the vessel left the area and moved to new areas.

4.2 Interpretation and Usefulness of CPUE

Data obtained from individual operations are catch and towing time. Accumulated catch and number of hauls by day can be calculated easily. Thus catch per day, catch per haul and catch per towing time are major CPUEs from the krill fishery.

Catch per towing time seems to be a good index of the within-swarm density when towing was made on a small number of swarms or on swarms in clumps. But when more than several swarms were fished in one towing, such density would obviously be underestimated due to inter-swarm paucity. When swarms were very dense and large, hauls were made on a single swarm alone and so catch per towing time indexed more accurately within-swarm density. Figure 4 shows the chart of the net recorder when the haul was made on the highest density swarm in the season. The absolute density of this swarm was estimated as 40 g/m^3 under the assumption of filtering rate equals 1.0.

Catch per haul may not be used as an index of within-swarm density or concentration density. During the operation of Zuiyo Maru No. 2, catch was kept to 7-10 tons per haul at the maximum in order to maintain freshness. The captain paid great attention to maintaining this level through making use of the net recorder chart and adjusting towing time (or number of swarms fished). As shown in Figure 5 this adjustment was made successfully up to a certain level of catch per towing time, but above this, there seems to be a tendency to increase catch per haul as a failure.

Catch per day, on the other hand, seems to be a good index of abundance in concentration. This is because of the strategy of the fishery to continue to take daily catches as close to its maximum processing capacity. Once a vessel finds a concentration of krill suitable for more than several days operation, it continues 24 hours operation in order to maximize the daily catch. The number of hauls and towing time are adjusted, under constratints of desired level of catch per haul, based on swarm density and within-swarm density. Such processes form a kind of Operations Research which is not explicitly stated by the captain but is practised in actual operation based on his experience.

There are, however, several problems associated in utilizing catch per day as an index of abundance. When catch per day reaches the maximum processing capacity, it may not be a sensitive index any further. Areas of green krill within a concentration may be avoided as well as small sized swarms, which obviously causes underestimation of abundance (although greenness or size composition seem to be properties of the concentration rather than swarms wihtin the concentration). The proportion of small sized swarms, in contrast to the fishable ones, within a concentration is closely connected with the swarming behaviour of krill and is not well known to date.

Catch per day, however, may be useful in detecting yearly changes in relative abundance of krill in a concentration. The area of such a concentration may be measured easily based on the extension of the operated position. Change in the formation of concentrations in geographical location, area and density (catch per day) as well as length composition seems to be a possible means of detecting yearly changes in krill biomass in that area. Comparison of such an index across time and space may prove difficult when data from different vessels are to be used because of problems in standardization.

4.3 Difficulty in Measuring Searching Time

Searching time may be useful for estimating the density of swarms within a concentration or measuring abundance in a much wider area. Searching time is almost equivalent to the duration between the completion of one haul and the start of the next in low density areas, and may be measurable. On the other hand, searching time is very short and difficult to define in high density areas, where constraints are imposed mainly by food processing capacity. For example, in high density area H2, the vessel did not have to be so serious about searching any longer. While newly caught krill were being processed, the vessel moved around to pass time and detected many swarms here and there. As the time for the next towing approached, the vessel shot at a swarm/swarms just encountered. When no swarm was found in the vicinity of the vessel at that time, the vessel returned to the swarms previously detected and marked on the chart. In such a situation, searching time may be recorded as almost nil and thus be of no use for any index. Sometimes the captain could not resist the temptation to haul high density swarms the vessel just encountered and so had to keep the net in the water until processing of the catch from the previous tow was completed.

Table 6 shows the time budget measured on board Zuiyo Maru No. 2. Searching time consists of primary searching effort and confirmation to keep in contact with previously found swarms; it was quite difficult to distinguish the two.

5. TEMPORAL CHANGES IN CATCH RATES

5.1 Diurnal Migration of Krill and Change in Catch Rates

Diurnal changes in the vertical distribution of krill and density were exhibited through the results of operation. In mid-summer (first half of January), under conditions of permanent daylight, krill maintained a fairly constant vertical distribution (Figure 6). When a period of darkness appeared (latter half of January), krill exhibited a diurnal vertical migration to surface at night. Catch per towing time tended to be a little higher during the half-light period after sunset. In late-summer (latter half of February), when the period of darkness became longer, krill went through a regular cycle of condensation - aggregating in dense swarms during the daytime and migrating to the surface after sunset then quickly dispersing in density and vertical distribution, which resulted in a big drop in catch rates by night. In March, when night time extended as long as seven hours, swarms dispersed so perfectly at night that the vessel had to spend many hours searching.

5.2 Longer Temporal Scale Change

Catch per towing time was not stable in each fishing area. In dense area H2, where operations took place for about a month, catch per towing time fluctuated greatly not only from day to night but also over longer temporal scales (Figure 7). The period of operation in area H2 is divided into three decades ; from mid-February to end-February (period I, 80 hauls in total), from end-February to early-March (period II, 90 hauls in total) and from early-March to mid-March (period III, 72 hauls in total). Catch per towing time in period II was twice as high as that in periods I and III although there was hardly any difference in catch per day and catch per haul between them. Since the operation in each period was done almost entirely on the same concentration, the change in catch per towing time may reflect temporal changes in within-swarm density in the concentration. Nothing is known about changes in krill abundance between these periods. Note that this concentration did not move although icebergs moved with the current, usually northwestward.

6. LENGTH FREQUENCY DISTRIBUTION OF KRILL

6.1 Congruence of Length Frequency Distribution Between Samples from Different Parts of the Net

Length measurements of samples from the catch were made in order to investigate whether the length frequency distribution of samples from one part of the catch can be regarded as representative. One set comprises two samples from the same haul each containing 150 individuals of krill, one sample taken from the mouth of the net and the other from the end of net. After the comparison of paired samples from 30 sets of measurements, it was concluded that krill were well mixed in the net and sampling from one part of the catch might be a good representative.

6.2 Variations in Size Compositions Between Sequential Hauls

In areas such as area O (Figure A-4) where the overall length frequency distribution was unimodal, the size composition of catch of sequential hauls was constant throughout the operations (Figure 8). Samples of over 40 mm in length were sexed by eye and are represented as the shadowed part in the figure.

In areas such as H2, where the overall length frequency distribution was bimodal, the proportion of large and small sizes often varied between sequential hauls with fairly stable modes (Figure 8). It may indicate, therefore, that the proportion differs swarm by swarm. Since swarms were many in number and their locations kept changing, the vessel could not select swarms which contained mainly large sizes.

6.3 Overall Size Composition in the 1985/86 Season

The size composition off Wilkes Land tends to differ year to year in contrast to the rather stable proportion of LL sizes in the Scotia Sea. This season was characterized by a bimodal length frequency distribution, lacking a mode at 40 mm (Figure 9). Whether this paucity of the 40 mm size class was due to changes in year class strength or due to water movement carrying these sizes away is unknown.

7. CONCLUSIONS

The fishing vessels search effectively for krill concentrations over a wide area where experience indicates several concentrations may be found. Since the vessels move to, and remain in, high density areas, CPUE seems to be less likley to reflect annual variation in large scale krill abundance. Detailed information on large spatial scale from research vessels is also required for estimating variability in krill abundance on such a large scale.

This distribution and distributional behaviour of krill shows significant spatial and temporal changes. High concentrations tend to occur in rather limited areas, based on the accumulated data of fishing expeditions. Thus by investigating the properties of these concentrations, such as spatial scales, within-swarm densities and size compositions, it may be possible to obtain useful information on what distributional parameters of krill accurately reflect the annual change in large scale krill abundance.

ACKNOWLEDGEMENTS

The author thanks Captain Nishimuta and his crew for their help with these research activities during the krill fishing cruise 1985/86 aboard the fishing vessel Zuiyo Maru No. 2. He also thanks Dr Y. Shimadzu, Far Seas Fisheries Reasearch Laboratory for constructive advice on the manuscript.

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HAURY, L.R., J.A. MCGOWN, and P.H. WIEBE. 1978. Patterns and processes in the time-space scales of plankton distributions. In : Steele, J.H. (ed.) Spatial pattern in plankton communities. Plenum press, New York, p. 277-328.

Table 1. Utility of krill in different feeding condition

feeding condition	utility
non-feeding	for all processing options; especially fresh-frozen krill
moderately feeding	for all processing options; especially boiled-and-frozen krill
intensively feeding ("green")	for processing into peeled meat and fish meal

Table 2. Comparison of krill qualities off Wilkes Land and in the Scotia Sea

	off Wiles Land	in the Scotia Sea
feeding condition	less "green"	"green"
shell	strongly built	easy to crush
body color	white	pink
texture	firm	soft and flaccid
by-catch	negligible	salps may cause problem

Table 3. Causes of shift of vessel in search for a new fishing area

causes	frequency
Good area in past:	6
Return to areas previously used/found during season (in hope of quality improvement):	4
Communication with other vessels:	4
Ice condition:	2
Iceberg with sea birds on it:	2

Table 4. Relative frequencies of cues used in detecting swarms (%)

cue	month January	February	March
fish finder	59	86	76
sonar	39	14	23
sighting	2	0	1

n = 641 in total

Table 5. Characteristics of each fishing area

Fishing area	Period	Catch/day (tons)	Catch/haul (tons)	Catch/time (tons/min.)	Main cue for locating area	Reason for leaving area	By-catch
F	1-4 Jan.	25	2.6	0.14	Communication with other vessels	Poor catch	None
D	6-9 Jan.	43	4.3	0.11	Return to area in hope of quality improvement	Poor catch	None
B	11-14 Jan.	33	3.9	0.05	Return to area in hope of quality improvement	Poor catch	None
J	15-31 Jan.	65	5.6	0.12	Communication with other vessels	Drop in ratio of gravid females	Fish (Paralepididae) by a negligible amount
H1	5-10 Feb.	67	5.4	0.14	Good harvesting area in past	Drop in catch	Fish (Channichthyidae) by a negligible amount
H2	11 Feb.- 14 Mar.	99	9.2	0.35	Good harvesting area in past	Finish of the operation	Fish (Channichthyidae) by a negligible amount

Table 6. Time budget of Zuiyo Maru No.2 in 1985/86 off Wilkes Land

Item	Month First Jan.	Latter Jan.	First Feb.	Latter Feb.	First Mar.
Searching	56 %	31	40	35	35
Towing	28	42	37	24	21
Net handling	13	20	16	14	15
Idling	0	0	0	15	4
Cargo work	3	7	7	12	22
Drifting	0	0	0	0	3

Searching; the time between finishing one haul and starting the next, i,e, primary searching effort + confirmation to keep in contact with the swarms
Net handling; entry to and withdrawal from water
Idling; due to bad weather, engine kept going
Drifting; engine stopped

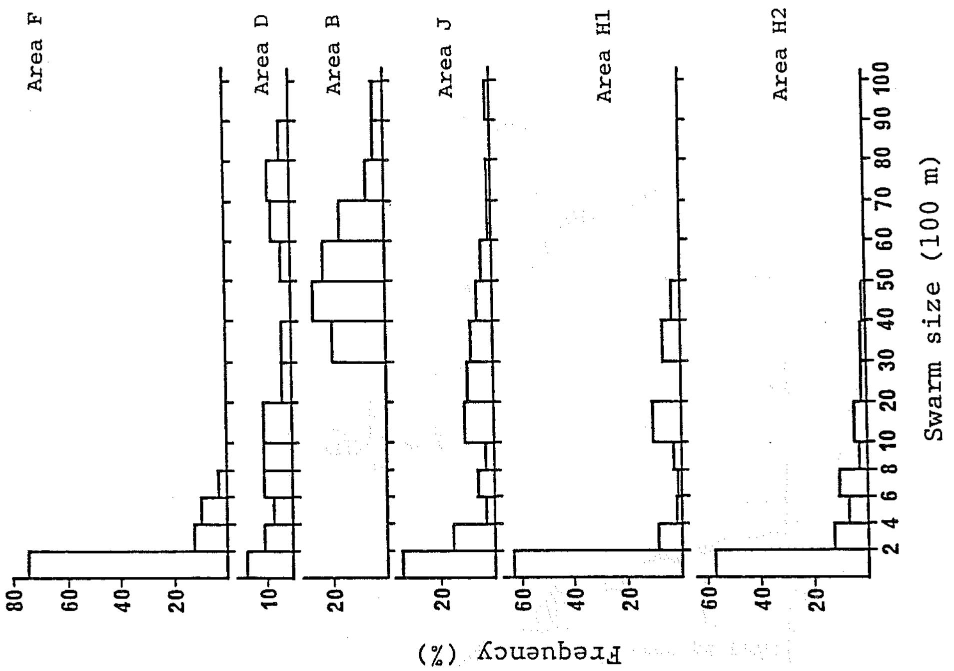

Fig. 1. Frequency distributions of swarm sizes towed in each fishing area

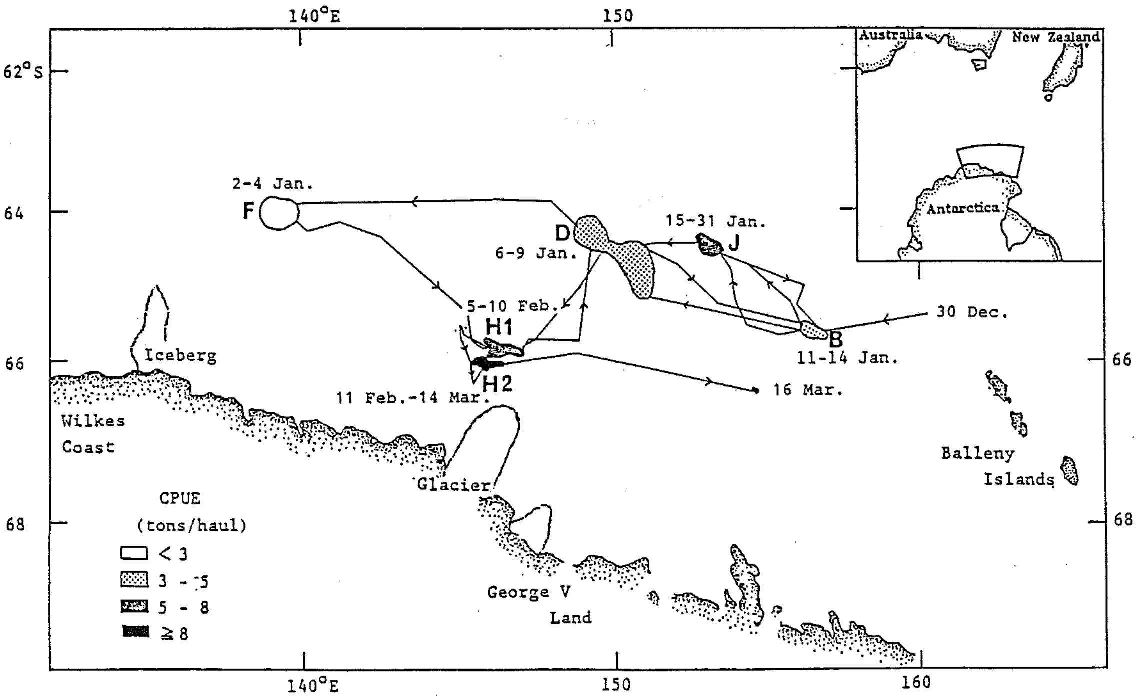

Fig. 2. The cruise track of Zuiyo Maru No.2 in the 1985/86 season.
Range of fishing grounds are encircled

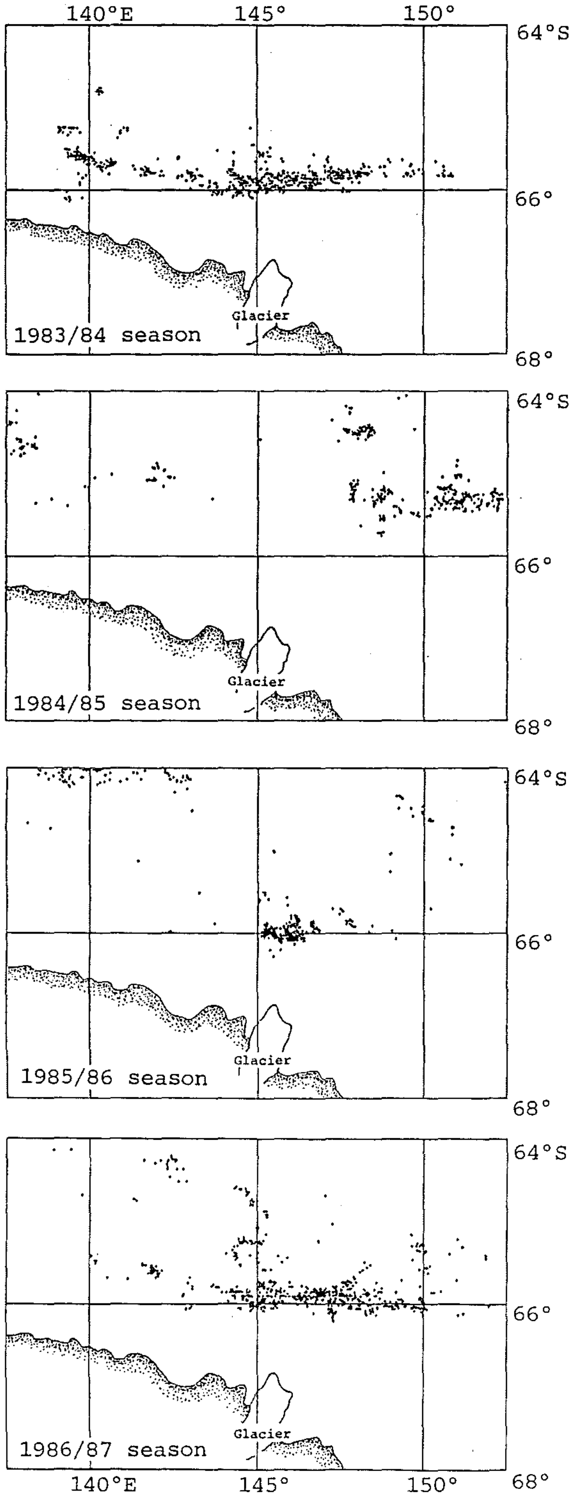

Fig. 3. Operated area around area H2 by Japanese krill fishery from 1983/84 to 1986/87 seasons.
• shows starting position of individual towing.

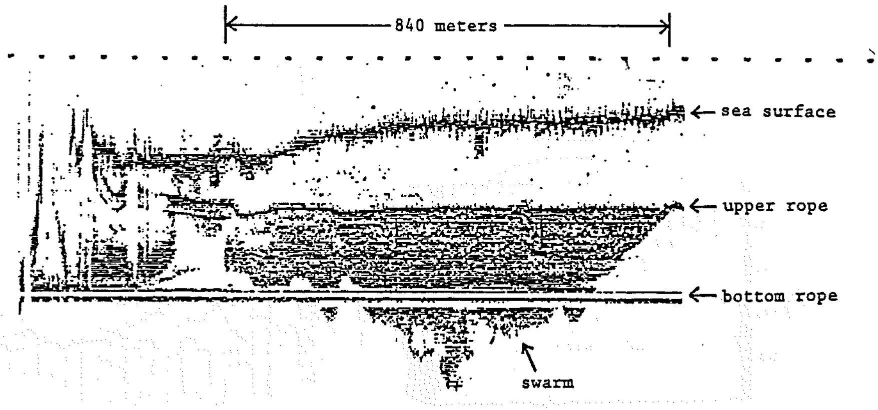

Fig. 4. Chart of net recorder when the densest swarm was fished . 20 tons of krill was caught in 14 min. of towing. Absolute density was estimated as 40 g/m³

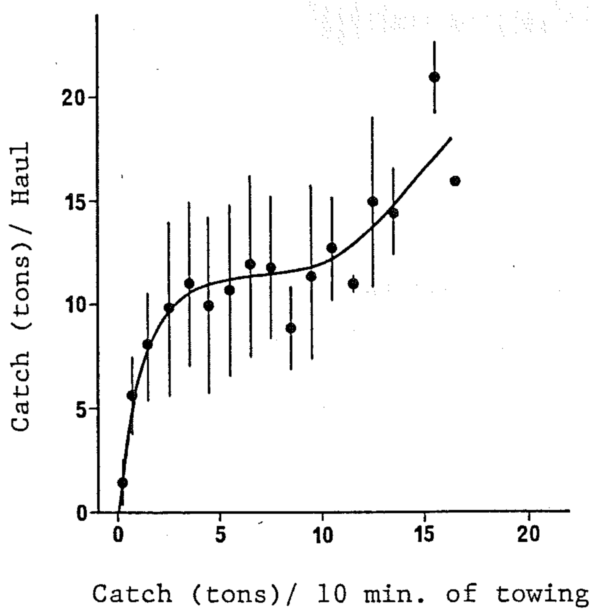

Fig. 5. Catch per haul against catch per towing time. Vertical bars show ± standard deviations

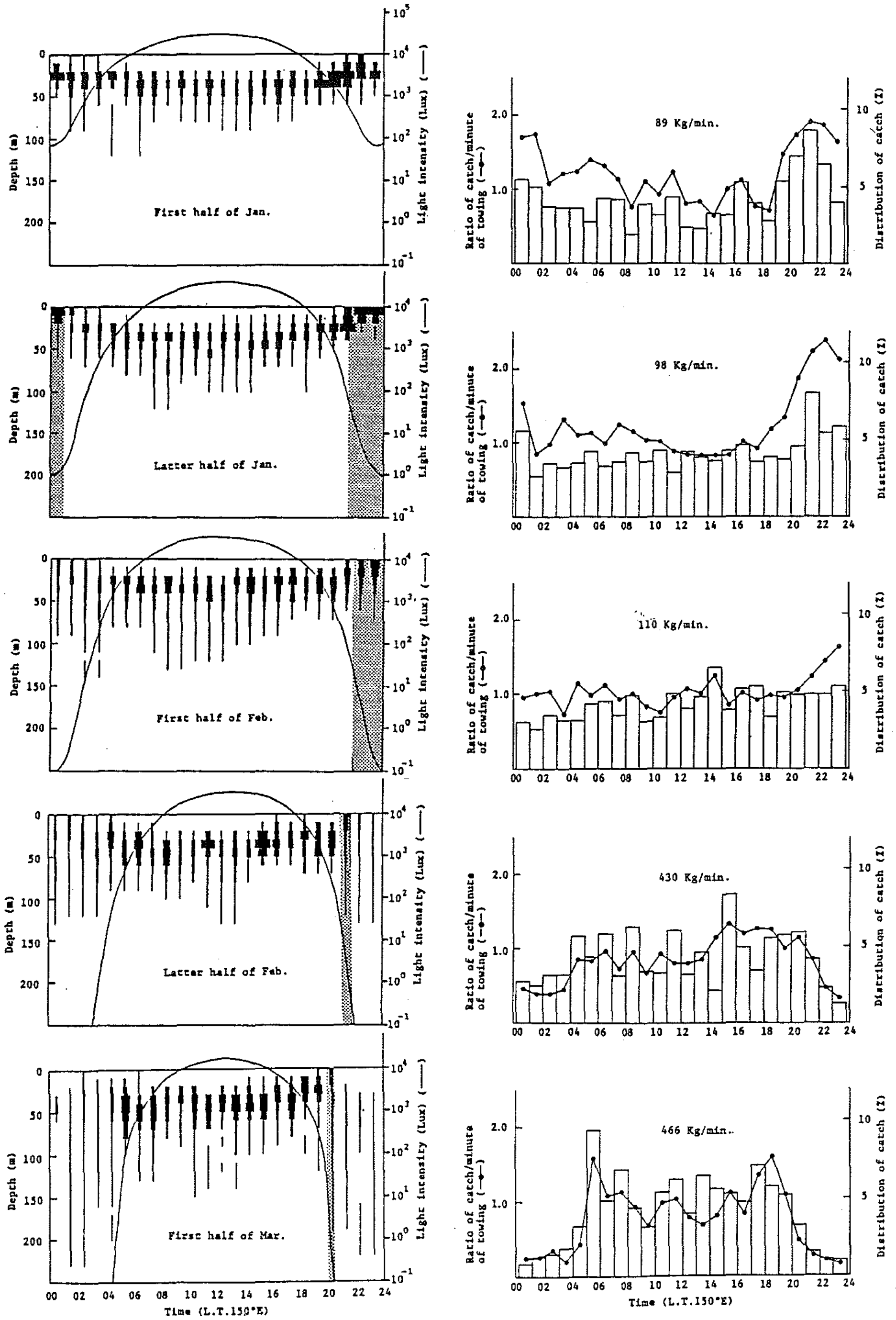

Fig. 6. Profiles of diurnal variations of mean light intensity, vertical distribution of krill, catch per haul and catch per towing time. Catch per towing time is standardized to mean catch per towing time during daytime (06:00-18:00) which is shown in right figure. Shading indicates the period of frequent occurrence of surface swarms.

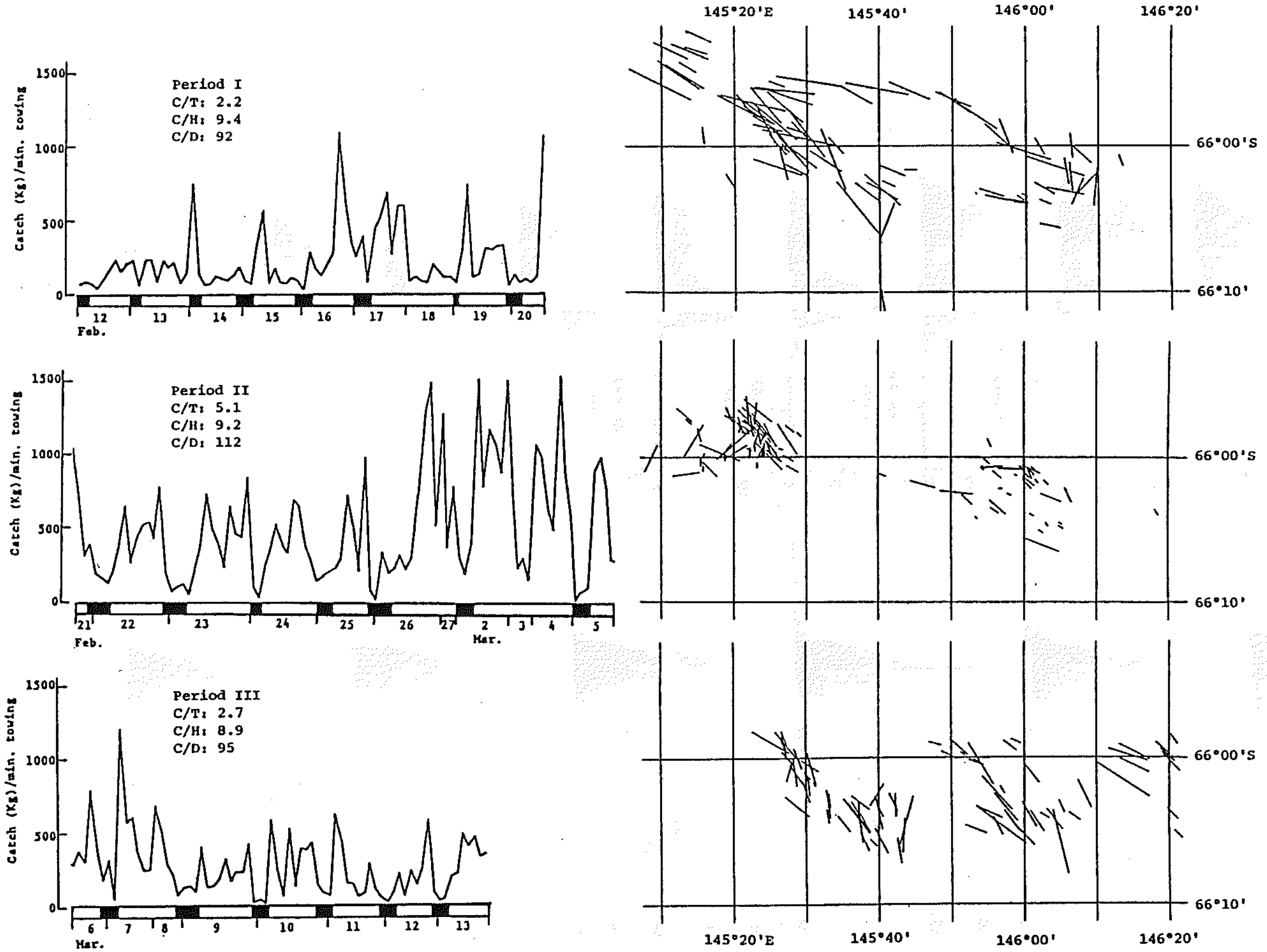

Fig. 7. Catch per towing time and towed tracks for three successive periods in area H2.

C/T: catch (tons) per 10 min. of towing
C/H: catch (tons) per haul
C/D: catch (tons) per day

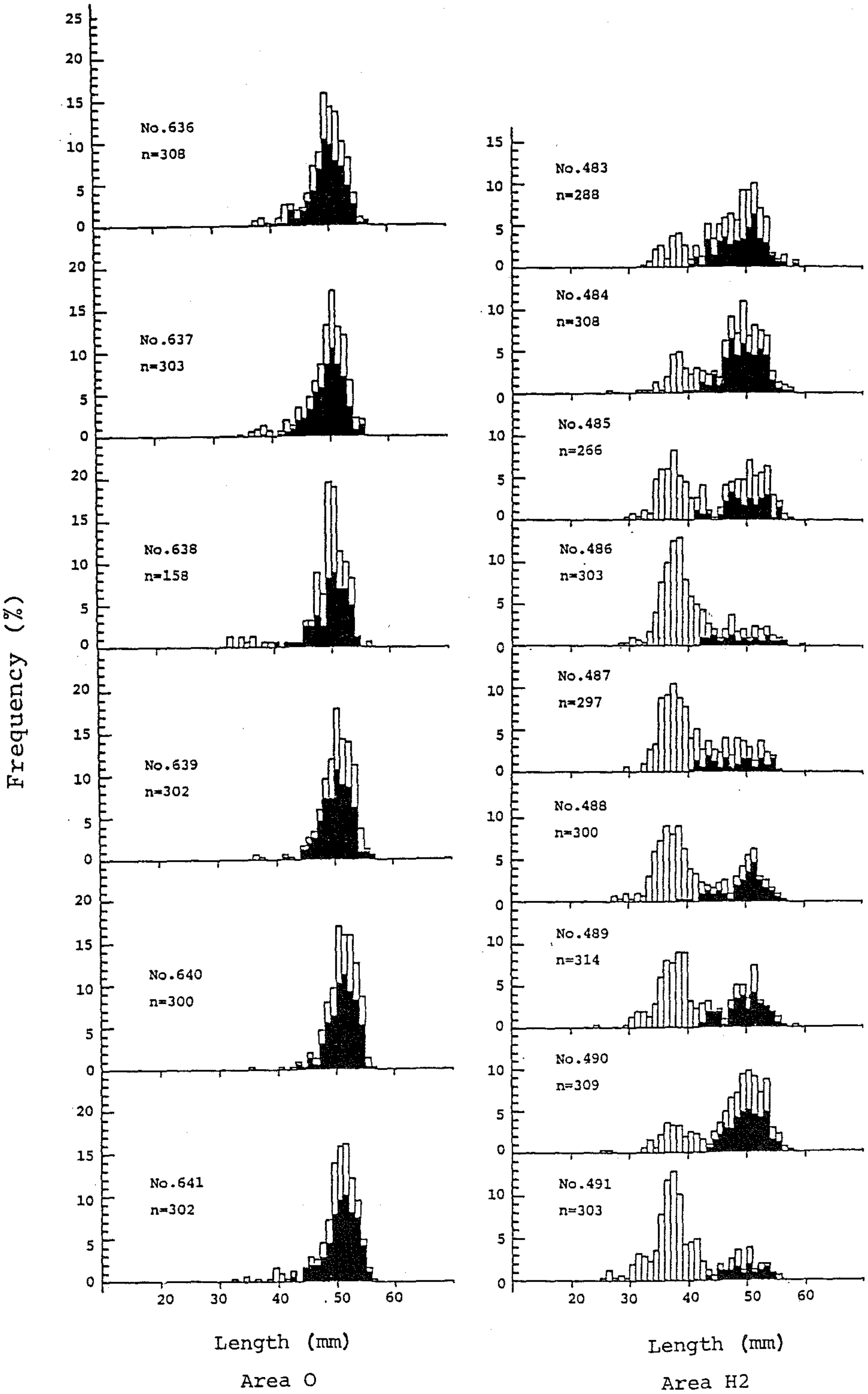

Fig. 8. Variations in size composition between sequential hauls.
Shadowed part of each histograms represents the proportion of females (see text). Area O is shown in Fig. A-4.

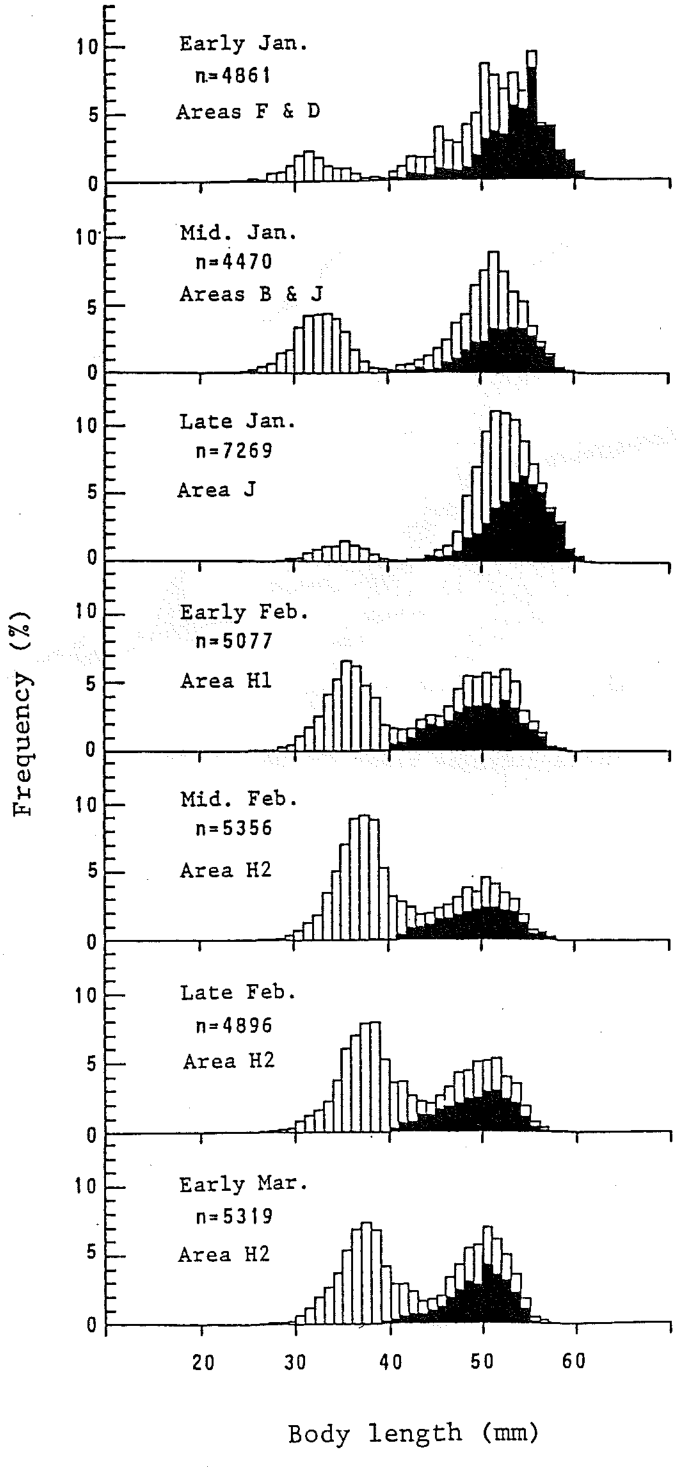

Fig. 9. Length frequency histograms during the season.
Shadowed part represents the proportion of females (see text).

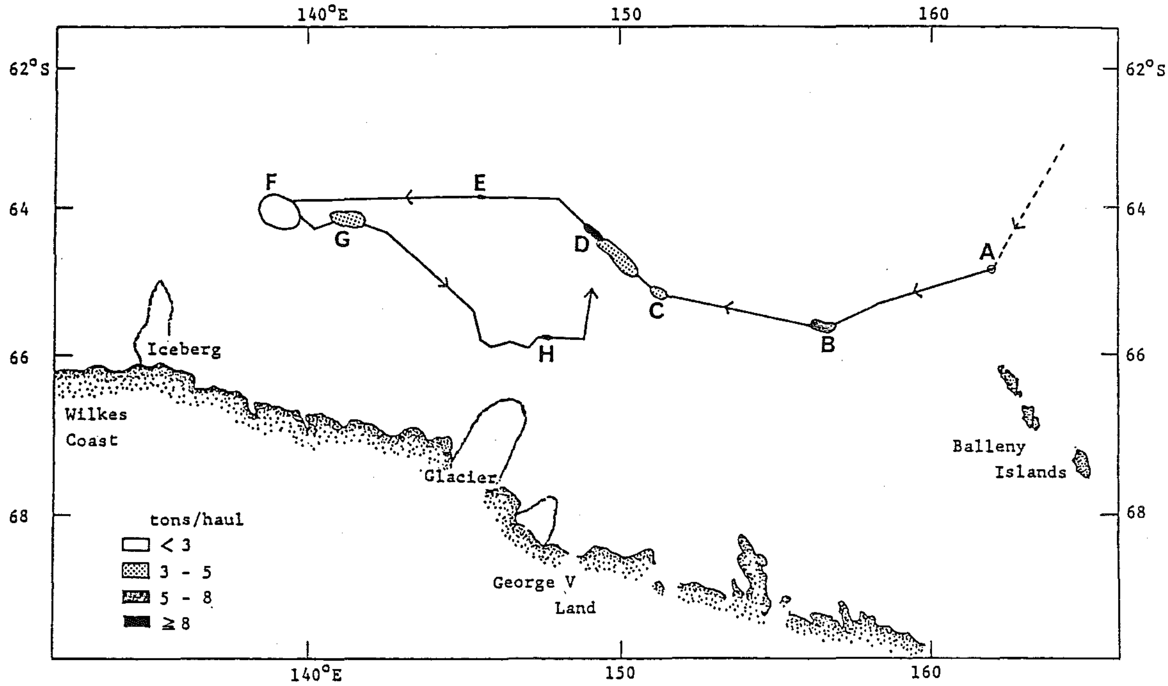

Fig.A-1.Cruise track [30 Dec.-6 Jan.]

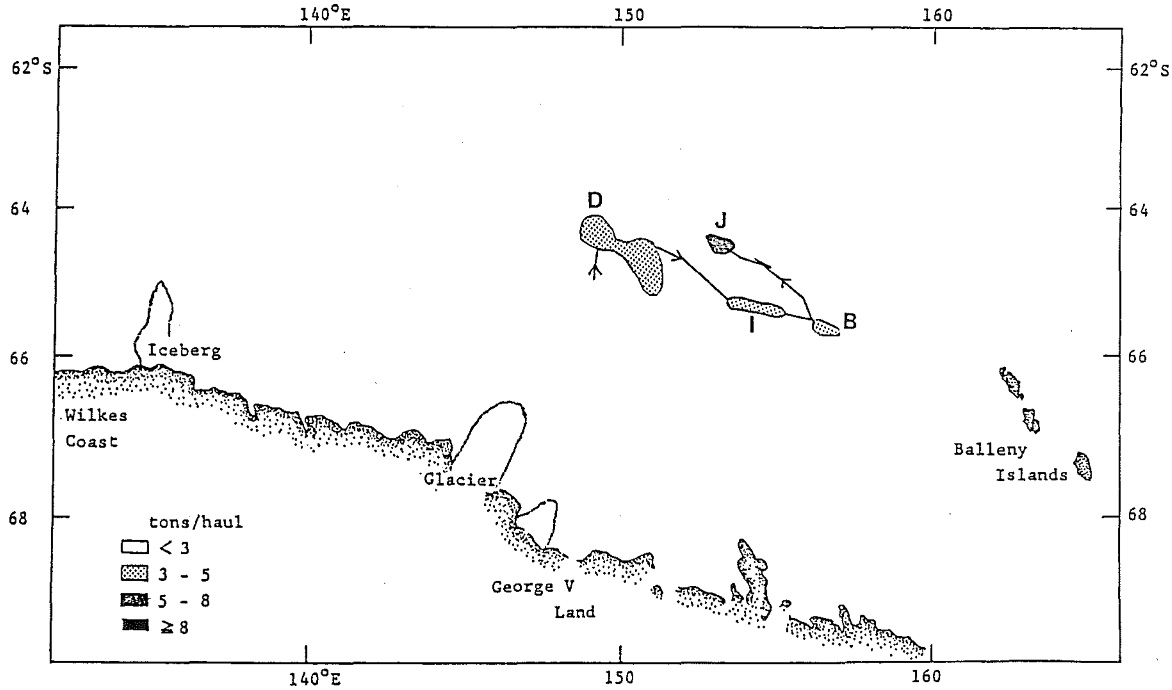

Fig. A-2. Cruise track [6-31 Jan.]

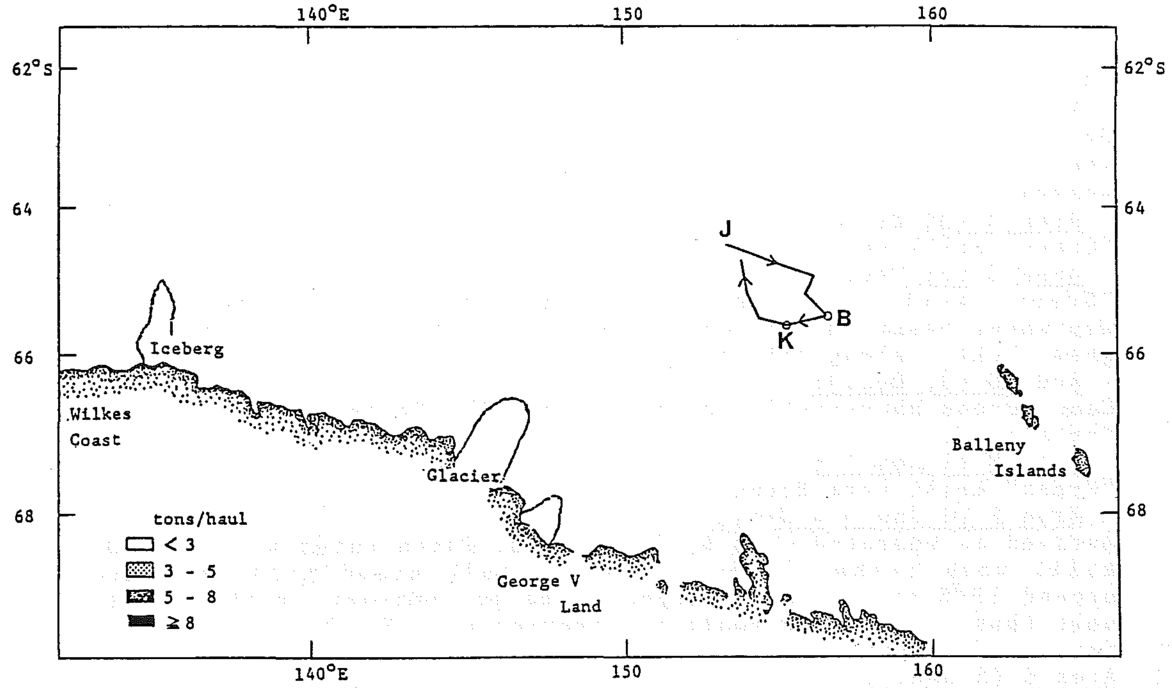

Fig. A-3. Cruise track [31 Jan.-1 Feb.]

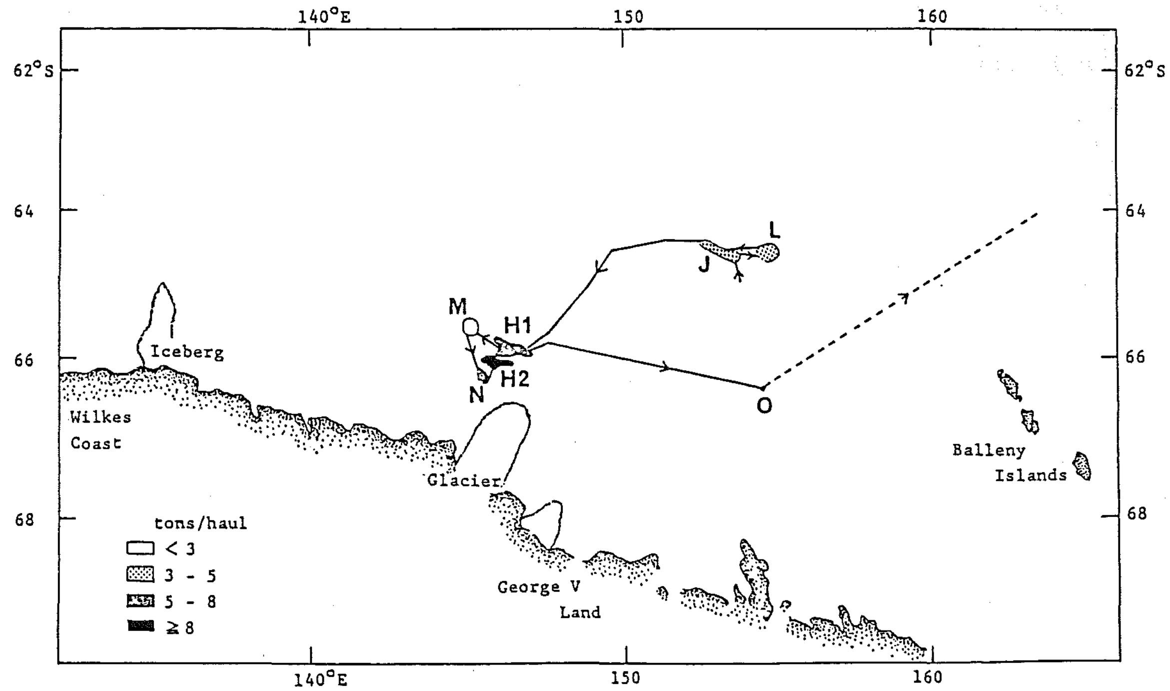

Fig. A-4. Cruise track [2 Feb.-16 Mar.]

APPENDIX

Cruise track and detail explanation of operation

30 Dec.- 6 Jan. (Fig.A-1)

Area A (30 Dec.):

Operation started. Headed to Ehiko Maru at area F, along 65°S, where a good catch of "white" krill was gained in the previous season.

Area B (30 Dec.):

"Green" krill were detected and moved west.

Area C (31 Dec.):

"Green" Krill were detected (not abundant). Turned north-westwards based on information that Ehiko Maru was fishing "less" green krill along 64°S.

Area D (31 Dec.):

Came across harvestable concentration, but "green" krill. So left for area F.

Area E (1 Jan.) :

"Green" krill were found (not abundant).

Area F (2 Jan.- 4 Jan.) :

Arrived in operated area by Ehiko Maru. Catch rates were poor and krill were rather "green". Also small sized krill appeared around 139°E and it was thought to be predominant further to the west (based on the accumulated experience). So turn east heading for area H where a good yield was obtained in past.

Area G (5 Jan.):

On the way to Area H, less abundant area was found.

Area H (6 Jan.):

"Green" krill were found, so left in a hurry. Decided to return to harvestable area D located previously on 31 Dec. in the hope of quality improvement by this time.

6-31 Jan. (Fig.A-2)

Area D (6 - 9 Jan.):

Dense swarms found on 31 Dec. were disappeared. "Greenness" was improved but catch rates were poor, so moved toward area B where "green" krill were detected on 30 Nov. in the hope of quality improvement.

Area I (10-11 Jan.):

On the way to area B, "green" and small krill were detected (not abundant).

Area B (11-14 Jan.):

Low catch rates and low percentage of gravid females with little improvement of "greenness". Moved to the mushroomed shaped swarms at 64°40'S and 154°40'E informed by the cargo ship on 12 Jan. Accumulated information said that krill were scare further to the east except in the vicinity of Balleny Islands where krill were dark "green".

Area J (15-31 Jan.):

A fairly good harvestable area was located to the north-west of the informed position of the mushroomed swarms. Ehiko Maru joined to Zuiyo Maru No.2 on 17 Jan. and operated together afterwards.

31 Jan. - 1 Feb. (Fig.A-3)

Area J (15-31 Jan.):

Catch per haul kept on going fairly good, but toward the end of January the percentage of gravid females decreased, that made krill look "green". So left for area B again in the hope of quality and quantity improvement.

Area B (31 Jan.):

No krill. So moved to area K(65°30'S,155°00'E) where "white" krill were fished in the previous season.

Area K (31 Jan.):

No krill. So returned to area J.

Area J (1 Feb.):

Not only the percentage of gravid females but also catch rates were low. On the other hand Ehiko Maru was fishing gravid females at area L, so moved to area L.

2 Feb. - 16 Mar. (Fig.A-4)

Area L (2 Feb.):

The percentage of gravid females was high, but catch rates were extremely poor. So returned to area J.

Area J (3 Feb.):

There seemed to be little hope in the quality and quantity improvement any more in this area. And the company requested to take 500 tons of M-sized krill. So gave up this area where LL-sized krill were dominant and headed for area H (near to pack ice edge) where L and M sized krill tend to be dominant according to the accumulated experience.

Area H1 (5-10 Feb.):

M-sized krill were dominant and catches were good at first. But it did not last, so Zuiyo Maru No.2 had to move.

Area M (11 Feb.):

Catch rates were very poor, so turned south to pack ice edge where krill tend to be abundant.

Area N (11 Feb.):

Krill were abundant but "green". Also scattered ices were seen and it was felt dangerous for operation. So turned to the north.

Area H2 (11 Feb.-14 Mar.):

At last found the way into the best fishing area in that season. Krill were less "green" or "white", and L or M in size. Catch rates were so good that the processing rate reached the saturation. In mid-March icing began and catch rates declined gradually. The production goal was almost accomplished on 14 Mar., a very stormy day, left for the port in Chile.

Area O (16 Mar.):

Came across dense swarms around good yielding area in past. Size was LL. Operations for the 1985/86 season was completed after 12 hours' fishing there.

Légendes des tableaux

Tableau 1 — Utilité du krill dans différentes conditions alimentaires.

Tableau 2 — Comparaison de la qualité du krill au large de la Terre de Wilkes et dans la Mer de Scotia.

Tableau 3 — Causes du déplacement des navires à la recherche d'une nouvelle zone de pêche.

Tableau 4 — Fréquences relatives des procédés utilisés pour détecter les bancs (%).

Tableau 5 — Caractéristiques de chaque zone de pêche.

Tableau 6 — Utilisation du temps du Zuiyo Maru N° 2 en 1985/86 au large de la Terre de Wilkes.

Légendes des figures

Figure 1 — Répartitions des fréquences de tailles des bancs pêchés au trait dans chaque zone de pêche.

Figure 2 — Trajet de l'expédition du Zuiyo Maru N° 2 pendant la saison 1985/86. Les différents secteurs de pêche sont entourés.

Figure 3 — Zone couverte autour de H2 au cours des opérations de pêche au krill par le Japon des saisons 1983/84 à 1986/87. • indique la position de départ de chaque trait.

Figure 4 — Graphique de l'enregistreur du chalut au moment où le banc le plus dense a été pêché. Vingt tonnes de krill ont été prises en 14 minutes de chalutage. La densité absolue a été estimée à 40 g/m^3.

Figure 5 — Prise par trait par opposition à la prise par temps de chalutage. Les barres verticales indiquent les écarts types $\pm$.

Figure 6 — Profils des variations diurnes de l'intensité moyenne de la lumière, de la répartition verticale du krill, de la prise par trait et de la prise par temps de chalutage. La prise par temps de chalutage est standardisée pour signifier la prise moyenne par temps de chalutage durant la journée (06.00-18.00 h) indiquée dans la figure de droite. Les hachures indiquent la période d'occurrence fréquente de bancs de surface.

Figure 7 — Prise par temps de chalutage et trajets des traits au cours de trois périodes successives dans la zone H2. C/T = prise (tonnes) pour 10 minutes de chalutage; C/H = prise (tonnes) par trait; C/D = prise (tonnes) par jour.

Figure 8 Variations dans la composition en longueurs entre des traits séquentiels. La partie foncée de chaque histogramme représente la proportion de femelles (voir texte). La zone O est indiquée à la Figure A-4.

Figure 9 Histogrammes des fréquences de longueurs pendant la saison. La partie foncée représente la proportion de femelles (voir texte).

Figure A-1 Trajet de l'expédition (30 décembre - 6 janvier).

Figure A-2 Trajet de l'expédition (6 - 31 janvier).

Figure A-3 Trajet de l'expédition (31 janvier - 1 février).

Figure A-4 Trajet de l'expédition (2 février - 16 mars).

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Tabla 1 Utilidad del krill en diferentes condiciones de alimentación.

Tabla 2 Comparación de la calidad del krill aguas afuera de la Tierra de Wilkes y en el Mar de Scotia.

Tabla 3 Causas del desplazamiento de los buques en busca de una nueva zona de pesca.

Tabla 4 Frecuencia relativa de los indicadores usados en la detección de cardúmenes (%).

Tabla 5 Características de cada zona de pesca.

Tabla 6 Distribución del tiempo del Zuiyo Maru N° 2 en 1985/86 aguas afuera de la Tierra de Wilkes.

Leyendas de las Figuras

Figura 1 Distribución de las frecuencias de los tamaños de los cardúmenes remolcados en cada zona de pesca.

Figura 2 Trayectoria de la expedición del Zuiyo Maru N° 2 en la temporada de 1985/86. Las extensiones de las zonas de pesca se indican con círculos.

Figura 3 Area alrededor de H2 explotada por la pesquería de krill japonesa desde la temporada de 1983/84 hasta la de 1986/87. • indica la posición de partida de cada remolque.

Figura 4 Carta del registrador de red cuando se pescó el cardumen más denso. Se capturaron veinte toneladas de krill en 14 minutos de remolque. La densidad absoluta fue estimada en 40 g/m^3.

Figura 5 Captura por lance contra captura por tiempo de remolque. Las barras verticales indican las desviaciones estándar ±.

Figura 6 Perfiles de las variaciones diurnas de la intensidad de luz media, distribución vertical del krill, captura por lance y captura por tiempo de remolque. La captura por tiempo de remolque está estandarizada a la captura media por tiempo de remolque durante las horas del día (0600-1800 hrs), lo cual se presenta en la figura de la derecha. El sombreado indica el período de presencia frecuente de cardúmenes superficiales.

Figura 7 Captura por tiempo de remolque y trayectorias remolcadas en el transcurso de tres períodos sucesivos en el área H2. C/T = captura (toneladas) por 10 minutos de remolque; C/H = captura (toneladas) por lance; C/D = captura (toneladas) por día.

Figura 8 Variaciones en la composición de tallas entre lances consecutivos. El área sombreada de cada histograma representa la proporción de hembras (véase el texto). El área O se indica en la figura A-4.

Figura 9 Histogramas de frecuencia de tallas durante la temporada. El área sombreada representa la proporción de hembras (véase el texto).

Figura A-1 Trayectoria de la expedición (30 de diciembre - 6 de enero).

Figura A-2 Trayectoria de la expedición (6 - 31 de enero).

Figura A-3 Trayectoria de la expedición (31 de enero - 1° de febrero).

Figura A-4 Trayectoria de la expedición (2 de febrero - 16 de marzo).

Заголовки к таблицам

Таблица 1 Возможные способы обработки криля после различных режимов питания.

Таблица 2 Сравнение качественных характеристик криля из района Земли Уилкса с крилем моря Скотия.

Таблица 3 Причины перемены курса судна в поисках новых промысловых районов.

Таблица 4 Относительная частота использования того или иного метода обнаружения скоплений (в %).

Таблица 5	Данные по каждому промысловому району.
Таблица 6	График работы "Зуйо-мару №2" в районе Земли Уилкса, 1985/86 г.

Подписи к рисункам

Рисунок 1 Частотное распределение размеров скоплений, облавливавшихся в каждом промысловом районе.

Рисунок 2 Маршрут плавания "Зуйо-мару №2" в сезоне 1985/86 г. Очерчены границы промысловых участков.

Рисунок 3 Район вокруг Н2, где с сезона 1983/84 г. по сезон 1986/87 г. производился вылов криля японскими промысловиками. ● указывает исходную позицию при каждом тралении.

Рисунок 4 Схема, полученная сетевым регистратором в момент облова скопления самой высокой плотности. За 14 минут траления было выловлено двадцать тонн криля. Абсолютная плотность была оценена в 40 г/м^3.

Рисунок 5 Кривая величин соотношения "улов за траление"/"улов за определенное время траления". Вертикальные линии указывают ± стандартное отклонение.

Рисунок 6 Профили суточных изменений в средней интенсивности света, вертикальном распределении криля, величине "улов за траление" и "улов за определенное время траления". Величины "улова за определенное время траления" соотнесены со средними величинами "улова за определенное время траления в течение дня" (06.00-18.00), что показано на рисунке справа. Штриховка указывает на период времени, когда часто встречались поверхностные скопления.

Рисунок 7 Улов за определенное время траления и маршруты траления для трех последовательных промежутков времени в районе Н2. C/T - улов (в тоннах) за 10 минут траления, C/H - улов (в тоннах) за траление, C/D - улов (в тоннах) за день.

Рисунок 8 Изменения в размерном составе между последовательными тралениями. Заштрихованные участки каждой гистограммы указывают на относительное количество особей женского пола (см. текст). Район О показан на Рисунке А-4.

Рисунок 9 Гистограммы ассортимента длин за сезон. Заштрихованный участок указывает на относительное количество особей женского пола (см. текст).

SC-CAMLR-VI/BG/24

AGE AND GROWTH OF ANTARCTIC EUPHAUSIACEA (CRUSTACEA) UNDER NATURAL CONDITIONS*

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Abstract

Five species of Antarctic euphausiid crustaceans were studied from the Antarctic Peninsula and the south-eastern Weddell Sea. Life spans range from two years for Euphausia frigida to six years for the krill Euphausia superba. Growth in length and weight was calculated by non-linear regressions. No difference in growth of krill was observed between the Antarctic Peninsula area and the eastern Weddell Sea. Former opinions that differ are discussed. Seasonal growth was re-analyzed for the species Euphausia triacantha, and a three-year life span proposed. Male Euphausia crystallorophias have a shorter life span than females, while their growth rate is similar. A short description of the life cycle and generation time of each species is given. In general, Antarctic euphausiids seem to remature and spawn at least twice and in some cases three times during their life, except for E. frigida which spawns only once.

* published in Marine Biology 96 : 483-495 (1987)

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Résumé

Cinq espèces de crustacés euphausiacés antarctiques provenant de la Péninsule Antarctique et du sud-est de la mer de Weddell ont été étudiées. La fourchette de longévité est comprise entre deux ans pour Euphausia frigida et six ans pour le krill Euphausia superba. La croissance en longueur et en poids a été calculée par régressions non-linéaires. Aucune différence de croissance du krill n'a été observée entre la région de la Péninsule Antarctique et l'est de la mer de Weddell. Certaines opinions émises précédemment et différentes font l'objet d'une discussion. La croissance saisonnière a été réanalysée pour l'espèce Euphausia triacantha et une longévité de trois ans a été proposée. L'Euphausia crystallorophias mâle a une longévité inférieure à celle de la femelle, alors que leur taux de croissance est identique. Le cycle d'évolution et la durée d'une génération pour chaque espèce sont brièvement décrits. De façon générale, les euphausiacés antarctiques semblent arriver à maturité et frayer au moins deux fois et parfois trois au cours de leur vie, à l'exception de E. frigida qui ne fraie qu'une seule fois.

* publié dans Marine Biology 96 : 483-495 (1987)

Resumen

Se estudiaron cinco especies de crustáceos eufáusidos antárticos de la península antártica y el Mar de Weddel sud-oriental. Los períodos de vida varían de dos años para Euphausia frigida, a seis años para el krill Euphausia superba. El crecimiento en talla y peso fue calculado por regresiones no lineales. No se observaron diferencias en el crecimiento del krill entre el área de la península antártica y el Mar de Weddel oriental. Se discuten opiniones anteriores que difieren. Se analizó nuevamente el crecimiento estacional para las especies Euphausia triacantha y se propuso un período de vida de tres años. El macho de la especie Euphausia crystallorophias tiene un período de vida más corto que el de la hembra, mientras que su tasa de crecimiento es similar. Se da una breve descripción del ciclo de vida y del tiempo de generación de cada especie. En general, los eufáusidos antárticos parecen remadurar y desovar por lo menos dos veces y en algunos casos tres veces durante su vida, a excepción de E. frigida, que desova solo una vez.

* publicado en Marine Biology 96 : 483-495 (1987)

Резюме

Изучалось пять видов антарктических ракообразных-эуфаузиид Антарктического полуострова и юго-восточной части моря Уэдделла. Продолжительность жизни варьируется от двух лет у Euphausia frigida до шести лет у криля Euphausia superba. Рост в длину и увеличение веса вычислялись по нелинейной регрессии. Не было замечено разницы в росте криля района Антарктического полуострова и криля восточной части моря Уэдделла. Обсуждаются предыдущие - отличные от этой - точки зрения. Был заново проанализирован сезонный рост для вида Euphausia triacantha, и сделано предположение о продолжительности жизни в три года. У особей мужского пола вида Euphausia crystallorophias продолжительность жизни короче, чем у самок, в то время как темп роста почти такой же. Дается краткое описание жизненного цикла и времени генерации каждого вида. В общем представляется, что антарктические эуфаузииды заново созревают и мечут икру по крайней мере два, а в некоторых случаях и три раза в течение жизни, за исключением E. frigida, которая мечет икру только один раз.

* опубликовано в Marine Biology 96 : 483-495 (1987)

SC-CAMLR-VI/BG/33

AN ASSESSMENT OF THE MERITS OF LENGTH AND WEIGHT MEASUREMENTS OF ANTARCTIC KRILL EUPHAUSIA SUPERBA.*

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Abstract

Published relationships of various length measurements as predictors of wet or dry weight in Antarctic krill Euphausia superba Dana are standardised with new data on the relationships of three length measurements to wet and dry weight as functions of sex, maturity stage and moult stage. The range of coefficients and exponents for these relationships are examined and an example given to indicate the potential such variation has for introducing error into estimates of biomass based on acoustic data. An alternative approach is examined in which length and additional biological data are assessed in terms of decreases in the residual variance of relationships. We have identified key sources of variability where relatively small increases in the effort of analysis result in large improvements in the precision of prediction. Surprisingly, the stage of the moult cycle of the animal has little effect upon length-weight relationships. The use of categories of sex and maturity stage, however, has marked effect upon the residual variance. Again surprisingly, the simple division of krill into male and female categories is of little practical use in improving the precision of any prediction of mass. However, the separation of gravid females, either from male or non-gravid female krill or, from adult male and other krill does result in a marked improvement in the precision of prediction. Example equations are provided.

* In press : British Antarctic Survey Bulletin No. 79 (May 1988).

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Résumé

Les relations publiées des différentes mesures de longueur en tant qu'indicateurs du poids vert ou sec du krill antarctique Euphausia superba Dana sont standardisées avec les nouvelles données sur les relations entre trois mesures de longueurs et le poids sec et vert en tant que fonctions du sexe, du stade de la maturité et du stade de la mue. L'éventail des coefficients et des exposants pour ces relations est examiné et un exemple est donné qui permet d'indiquer le potentiel d'une telle variation à l'égard de l'incorporation de l'erreur dans les estimations de la biomasse basées sur les données acoustiques. Une autre approche examinée dans le document consiste à évaluer la longueur et des données biologiques supplémentaires en fonction des diminutions de la variance résiduelle des relations. Nous avons identifié les sources-clés de la variabilité où une intensification relativement faible de l'effort d'analyse aboutit à une précision de prédiction bien supérieure. Contrairement à ce qu'on pourrait attendre, le stade du cycle de la mue de l'animal a peu d'effet sur les relations longueur-poids. Par contre, l'utilisation de catégories pour le sexe et le stade de maturité a un effet prononcé sur la variance résiduelle. Autre surprise : la division simple du krill en mâles et en femelles ne sert guère à améliorer la précision de toute prédiction portant sur la masse. Cependant, si l'on sépare les femelles gravides, soit des mâles ou des femelles non-gravides, soit des mâles adultes et de l'autre krill, il en résulte une nette amélioration quant à la précision de la prédiction. Des exemples d'équations sont fournis.

* Sous presse : British Antarctic Survey Bulletin No. 79 (May 1988).

<u>Resumen</u>

Las correlaciones publicadas de las distintas mediciones de talla como pronosticadores del peso en fresco o seco del krill antártico <u>Euphausia superba</u> Dana son estandarizadas con datos nuevos sobre las correlaciones de tres mediciones de talla al peso en fresco y seco como funciones de sexo, etapa de madurez y etapa de muda. Se examina el rango de los coeficientes y los exponentes para estas correlaciones y se da un ejemplo para indicar el potencial que tal variación tiene para introducir error en las estimaciones de la biomasa basadas en datos acústicos. Se examina un enfoque alternativo en el cual se evalúan talla y datos biológicos adicionales en términos de las disminuciones en la varianza residual de las correlaciones. Hemos identificado fuentes clave de variabilidad en las que los aumentos relativamente pequeños en el esfuerzo de los análisis resultan en grandes mejoras en la precisión de la predicción. Sorpendentemente, la etapa del ciclo de muda del animal tiene poco efecto sobre las correlaciones de talla-peso. El uso de las categorías de sexo y etapa de madurez tiene, sin embargo, un marcado efecto sobre la variación residual. Nuevamente resulta sorprendente que la simple división del krill en las categorías de macho y hembra es de poco uso práctico en el mejoramiento de la precisión de cualquier predicción de masa. Sin embargo, la separación de las hembras grávidas, ya sea del krill macho o del krill hembra no grávido o, de los machos adultos y de otros krill, resulta de hecho en un marcado mejoramiento en la precisión de la predicción. Se proveen ejemplos de ecuaciones.

* En prensa : British Antarctic Survey Bulletin No. 79 (May 1988).

Резюме

Опубликованные ранее соотношения, связывающие различные данные по длине с сырым и сухим весом антарктического криля Euphausia superba Dana, приведены в соответствие с новыми данными по взаимозависимостям трех измерений по длине и сырого и сухого веса как функции от пола, стадии половозрелости и стадии линьки. Рассматривается весь диапазон коэффициентов и экспонентов для этих уравнений и приводится пример, иллюстрирующий то, что при таком разбросе имеется возможность возникновения ошибки в оценках биомассы, полученных на основе акустических данных. Разбирается альтернативный подход, при котором данные по длине и дополнительные биологические данные рассматриваются с точки зрения уменьшения остаточной дисперсии в соотношениях. Мы выявили те ключевые источники появления разброса, где при относительно небольшом увеличении усилий при анализе можно существенно повысить точность предсказаний. На удивление, стадия цикла линьки организма играет незначительную роль в соотношении "длина-вес". Однако использование категорий пола и степени половозрелости существенно влияет на остаточную дисперсию. Опять же, на удивление, простое разделение криля на категории особей мужского и женского пола практически дает очень немного для повышения точности любых предсказаний массы. При этом отделение икряных особей либо от особей мужского пола и неикряных особей женского пола либо от взрослых особей мужского пола и прочего криля дает в результате существенное повышение точности предсказаний. Даются примеры уравнений.

В периодике: British Antarctic Survey Bulletin No. 79 (May 1988).

SC-CAMLR-VI/BG/13
(WG-CEMP-87/19)

CAN WE SATISFACTORILY ESTIMATE VARIATION IN KRILL ABUNDANCE?*

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Abstract

Knowledge of abundance and rates of change of abundance are basic requirements for fisheries models. Catch per unit effort (CPUE) has traditionally been used in demersal fisheries assessments as an estimator of abundance. It is less satisfactory for pelagic fisheries. Evidence is given that CPUE estimated from data reported to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) does not provide a realistic index of krill abundance.

Recognising that there is a large natural year to year variation in krill abundance it is important that this be quantified and separated from fishery induced variation. The timescale for such information is discussed in the light of the needs of fishery management.

* In press in : Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

1. British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, UK.

Résumé

Il est essentiel de connaître l'abondance et les taux de changement de l'abondance si l'on veut établir des modèles d'exploitation. La prise par unité d'effort (PUE) a traditionnellement été utilisée dans les évaluations des pêches démesales en tant que paramètre d'abondance. Elle convient moins bien aux pêches pélagiques. Il est démontré que la PUE estimée à partir de données déclarées à la Commission pour la Conservation de la Faune et la Flore Marines de l'Antarctique (CCAMLR) ne fournit pas un indice réaliste de l'abondance du krill.

Vu qu'il existe une grande variation interannuelle naturelle dans l'abondance du krill, il est important de la quantifier et de la distinguer des variations dues à la pêche. Un calendrier pour l'obtention de ces informations est présenté à la lumière des besoins relatifs à l'aménagement des pêches.

* Sous presse dans : Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

Resumen

El conocimiento de la abundancia y de las tasas de variación de la abundancia son requisitos básicos para los modelos de pesquerías. La captura por unidad de esfuerzo (CPUE) ha sido usada tradicionalmente en las evaluaciones de pesquerías demersales como un estimador de la abundancia. Este índice es menos satisfactorio para las pesquerías pelágicas. Se presenta evidencia de que la CPUE estimada en base a aquellos datos presentados a la Comisión para la Conservación de los Recursos Vivos Marinos Antárticos (CCAMLR) no provee un índice realista de la abundancia de krill.

Reconociendo que existe una gran variación natural de un año a otro en la abundancia de krill, es importante que esta variación sea cuantificada y separada de la variación inducida por la actividad pesquera. Se trata la escala de tiempo para dicha información a la luz de las necesidades de la administración de las pesquerías.

* En prensa en : Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

Резюме

Знание численности и темпов изменения ее – основное требование при построении моделей промысла. Величина улова на единицу усилий (CPUE) традиционно используется как показатель численности при промысле демерсальной рыбы. С меньшим успехом она применяется при пелагическом промысле. Даются доказательства того, что величины CPUE, полученные на основании данных, представленных Комиссии по сохранению морских живых ресурсов Антарктики (АНТКОМ), не дают реалистического показателя количества криля.

Учитывая то, что межгодовые естественные изменения в количестве криля велики, важно, чтобы они были определены количественно, и чтобы было проведено различие между ними и изменениями, вызванными промыслом. В свете требований управления промыслом обсуждается график получения информации такого рода.

* В периодике в: Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

SC-CAMLR-VI/BG/8

PREY MONITORING SURVEYS. A DISCUSSION OF THE CHARACTERISTICS NECESSARY IN PREY SURVEYS

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Abstract

The CCAMLR Ecosystem Monitoring Programme requires information on prey distribution to relate to changes in predator demography. The paper discusses the constraints imposed on such surveys and outlines some possible designs.

Résumé

Le Programme de contrôle de l'écosystème de la CCAMLR demande que les informations sur la répartition des proies soient relatives aux changements dans la démographie des prédateurs. Le document examine les contraintes qu'imposent de telles prospections et indique brièvement quelques types de prospections possibles.

Resumen

El Programa de CCAMLR de Control del Ecosistema requiere información acerca de la distribución de las especies presa para relacionar con los cambios en la demografía de los depredadores. Este documento trata los constreñimientos impuestos sobre tales prospecciones y reseña algunos diseños posibles.

Резюме

Программе АНТКОМа по мониторингу экосистемы требуется информация о распределении потребляемых видов для соотнесения ее с изменениями в демографии хищников. В работе обсуждаются ограничения, налагаемые на такие съемки, и описываются возможные схемы их проведения.

PREY MONITORING SURVEYS. A DISCUSSION OF THE CHARACTERISTICS NECESSARY IN PREY SURVEYS

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INTRODUCTION

The CCAMLR Ecosystem Monitoring Programme (CEMP) has developed to the point where the implementation of monitoring of several predator parameters is believed to be praticable. Evaluation of the cause of changes in the values of these parameters is dependent on information being available on the availability of krill to the predators either before or during the monitoring period. This places an immediate constraint on the timing and duration of the prey monitoring studies.

The predator parameters may also be used to help define the geographical limits for the prey survey. Furthermore the diving ability of the selected predators defines the vertical stratum covering the amount of prey that is available to the predators. This is not synonymous with the total prey available as a significant amount, perhaps even all of the prey may be beyond the diving range of the selected predators at certain times. It is important to be able to distinguish between these two characteristics of prey distribution.

SURVEY CONSTRAINTS IMPOSED BY THE PREDATOR PARAMETERS

a. Predator Parameters

Eight penguin monitoring parameters have been identified and these are listed in Table 1 along with comments regarding the implied requirements for prey surveys. Three of the parameters (foraging trip duration, chick fledging weight and chick diet) identify a restricted period during which an effect due to prey availability is likely to be recognised.

The remaining parameters require information on the availability of krill in an undefined region during a poorly specified period of time which includes part, at least, of the winter. These parameters, adult weight on arrival at breeding colony, length of first incubation shift, annual trend in size of breeding population, demography (annual survivorship, age at first reproduction, cohort strength) and breeding success, are therefore not suitable for comparison for interpretative purposes with quasi-instanteous surveys of krill abundance.

b. Survey Area

During the chick and pup rearing periods the predators are restricted to a relatively small area of the ocean. Precise information on foraging range is not available although from a knowledge of swimming speed, activity budgets and foraging trip duration a reasonable estimate can be made of the maximum radius of the 'foraging circle' relative to the breeding colony. Current best estimates are as follows :

Adelie Penguin	50 - 80 km (Max 100 km)
Chinstrap Penguin	40 - 60 km
Macaroni Penguin	50 - 100 km
Fur Seal	approx 100 km
Black-browed Albatross	approx 200 km

(Croxall pers comm.)

Taking the predator study colonies as the centre then prey surveys covering a radius of 100 km from the site should provide adequate coverage for penguins and fur seals while a 200 km radius may cover black-browed albatross foraging areas.

c. Depth Ranges

Fur seal and penguin diving activity patterns are concentrated within the range 0 to 100 metres from the surface. Albatrosses are unable to dive deeper than about 2 metres. These values indicate two sampling depth strata; further layers within these are desirable. It is also desirable to sample over the full depth range of krill.

INTEGRATED STUDY AREAS

a. Antarctic Peninsula Region

The area is indicated in Figure 1. The arcs of circles are of radius equivalent to 100 km and are centred on the study sites indicated in Table 1 of the report of the CCAMLR Ecosystem Monitoring Programme 1987.

The area to the south of Anvers Island contains a lot of foul ground and small islands and is unsuitable for establishing a survey. This area could form as much as half of the area available to foraging predators. Since such a large proportion of the area is unsuitable for survey further consideration needs to be given as to whether to continue to include this site as a primary monitoring site.

The sea areas close to the remaining sites are relatively free from foul ground and it would therefore be possible to undertake surveys in them. The timing of such surveys is constrained by the predator foraging periods; these are :

Adelie Penguin	23 Nov-13 Dec (guarding) or 2 Jan (creche)
Chinstrap Penguin	20 Dec-13 Jan (guarding) or 21 Feb (creche)

'Guarding' is the period when at least one adult of the pair is in attendance with the chicks. 'Creche' is when one or both of the adults are collecting food and chicks from the colony congregate into creches.

Although there is some overlap between the species the total period is about three months. In practical terms this is probably too long for a single survey, it is more likely that no more than one month is likely to be available. Some compromise may therefore need to be sought between the start of the Adelie and the end of the Chinstrap periods. A suitable compromise might be from 13 Dec to 13 Jan. Such a compromise would reduce the effectiveness of comparisons involving Chinstrap Penguin fledging weight. Any compromise decisions on the timing and duration of the survey can only be made on the advice of experts in the field of predator monitoring.

b. South Georgia

This is considered to be synonymous with Bird Island. The key predators are Macaroni Penguin, Fur Seal and Black-browed Albatross. A map showing the limits of the study area with circles of radius 100 and 200 km is shown in Figure 2. Very little of the area is unsuitable for survey.

Appropriate periods for predator monitoring are :

Macaroni Penguin	26 Dec - 19 Jan (guard) or 1 Feb (creche)
Fur Seal	12 Dec to 12 Jan

Rather than survey throughout this period a compromise of from about 20 Dec to 20 Jan would probably cover both species adequately. This would however raise the same compromise situation regarding comparison with chick weight at fledging.

c. Prydz Bay

It is not clear from the Report of the Working Group precisely where the predator monitoring sites are to be established. It is assumed that the main focus will be at Davis Station and this is indicated in Figure 3.

The main species identified for study is the Adelie Penguin which in this region begins feeding chicks about 13 Dec, the guarding phase is completed by about 2 Jan and creche phase by about 21 Jan. A survey timed to last for a month prior to 20 Jan would permit comparison with chick fledging weight but be less suitable for the early chick growth period.

SURVEY DESIGN

The primary aim of the survey is to determine how much krill is available to the predators during a defined critical period and within a defined range of the study colony. The area of the survey may therefore be considered to be contained within an arc. Seen in this way the study colony is effectively a point location from which foraging predators will search radially up to a distance of about 100 km. By analogy with predator foraging activity, the transects could be located along radii. Such a situation is shown in Figure 4 for a survey of ten transects.

It is likely that there will be some form of coastal water flow which could introduce systematic errors into the sampling. To overcome this the transects could be surveyed in pairs in a random sequence. If the pairs were selected so as to start at the study colony end then the time taken to travel between pairs would be minimised.

Assuming a constant survey speed of 10 knots (18.5 km/hr) for the hours of daylight (the time when krill are likely to be absent from the surface layer and hence be undetected) and that surveying closer than about 15 km to the colony is impractical, then about three transects per day could be surveyed. This would permit a set of 10 transects to be surveyed in about four days leaving the hours of darkness free for net sampling to determine the species composition in the zooplankton for predator dietary comparisons to be made.

Concentrating the survey phase during the hours of daylight reduces the likelihood of large amounts of krill being present in the near surface layer. Much predator feeding does however take place after dark so that some consideration needs to be given to krill night depth based on daytime surveys. On balance it is probably better to survey during the day and apply such a correction than to continue at night using different techniques.

This survey is not suitable for Black-Browed Albatross due to the larger area and also because it requires estimation of krill at the surface. Further research on krill vertical migration may allow factors to be determined which convert daytime krill availability to that of surface availability during the day and night.

Several such surveys could be completed within a month and also allow some time between surveys in which to undertake additional studies aimed at investigating water circulation and the krill distribution outside this primary survey region.

No account has been taken of the likely effects of sea ice on the effectiveness of the survey. At South Georgia this is likely to be minimal. The South Shetland Island area is also generally free of ice during the December/January period. The Prydz Bay area is often congested with ice and this may mitigate completely against a survey of this type.

The above is only one of the several options that could be employed and is primarily aimed at purely predator/prey interactions. Alternative designs that are as efficient for this purpose but more efficient for determining specific properties associated with krill are also possible. Before deciding on a particular survey it is essential that expert statistical advice is sought to refine the survey and take due consideration of the analyses to be undertaken on the resultant data.

CONCLUDING COMMENTS

The proposals outline a framework that could be used to monitor krill abundance locally and compare it with specific predator parameters. The area covered by such surveys and the level of interaction is only a small proportion of the total Southern Ocean. The level of coverage in the

South Shetland Island and South Georgia regions may be adequate for a monitoring exercise in those regions because the shore-based sites are sited in areas likely to be sensitive to variation over a wider area. This is not definite particularly if we wish to make comparisons involving integrated estimates of abundance over the year. The Prdyz Bay region is much more poorly known and for that region it may be advisable to undertake a coastal monitoring survey covering several study colonies.

Essentially, the unfortunate conclusion is that we have methods for monitoring prey locally but the logistics of mounting large scale surveys on an annual basis currently preclude direct estimation over the wider area. The difference between the few hundred square kilometres contained within the surveys described above and the 35 million square kilometres of the Southern Ocean is too great for simple extrapolation to apply.

ACKNOWLEDGEMENTS

I am grateful Dr J. Croxall for comments on an early draft of this manuscript.

Table 1. Consideration of predator parameters and the implied requirements from prey surveys

Predator Parameter	Required Prey Survey Characteristics	
	Duration and Timing	Area
Adult Arrival Weight	Unspecified duration during winter	Unknown but large
First incubation shift length	Unspecified duration early spring	Unknown may be large
Population Size	Unspecified duration	Unknown may be large
Demography	Unspecified duration during year	Unknown but large
Foraging trip duration	Approx one month in summer	Max 100 km from colony
Breeding success	Unspecified duration during year. Main survey in Spring and Summer	Unknown but may be large
Chick fledging weight	Approx two months during summer	Max 100 km range from colony
Chick diet	Approx one month	Max 100 km range from colony

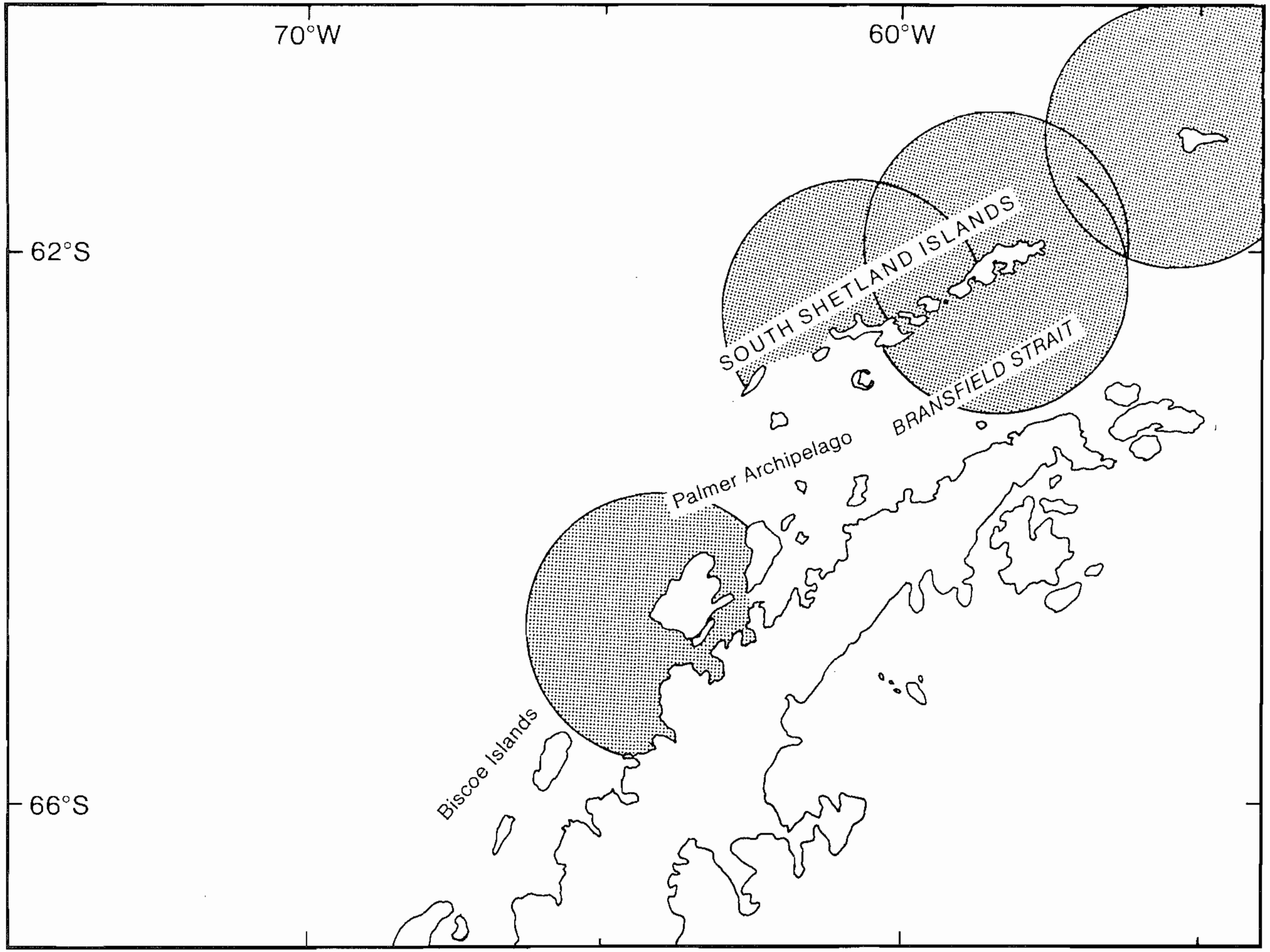

Figure 1 Peninsula Area. The shaded areas are approximately 100 km from the study sites.

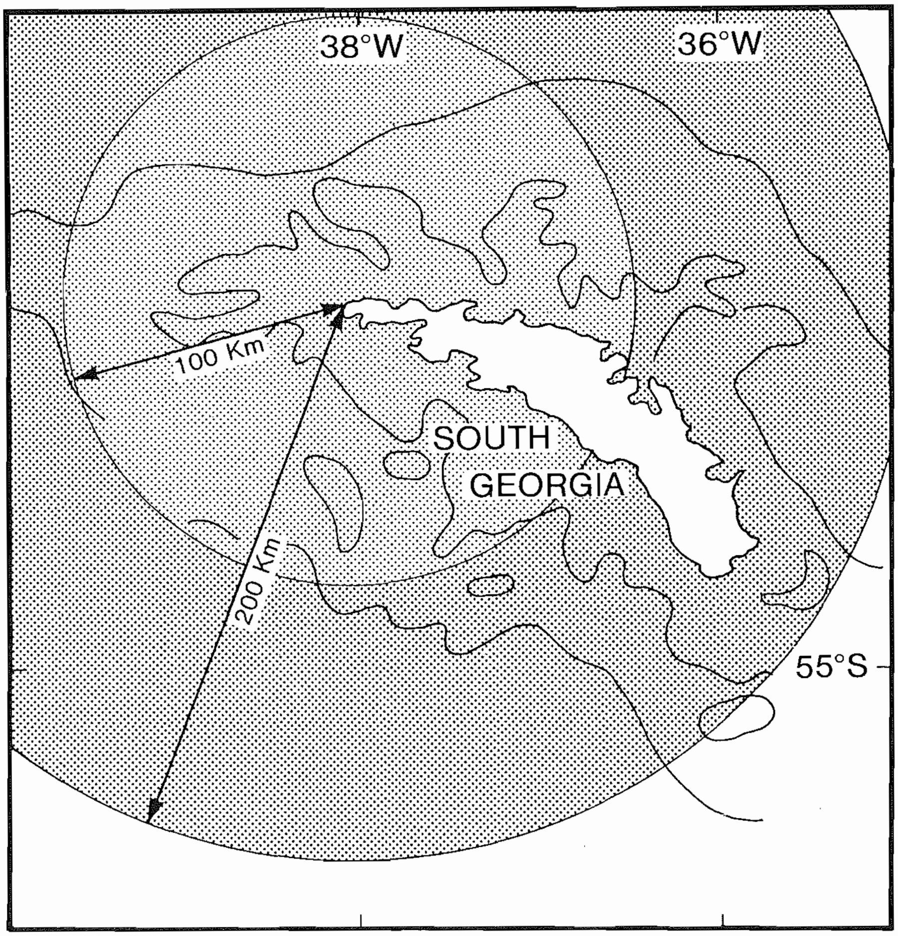

Figure 2 South Georgia Region. Circles represent 100 and 200 km from Bird Island.

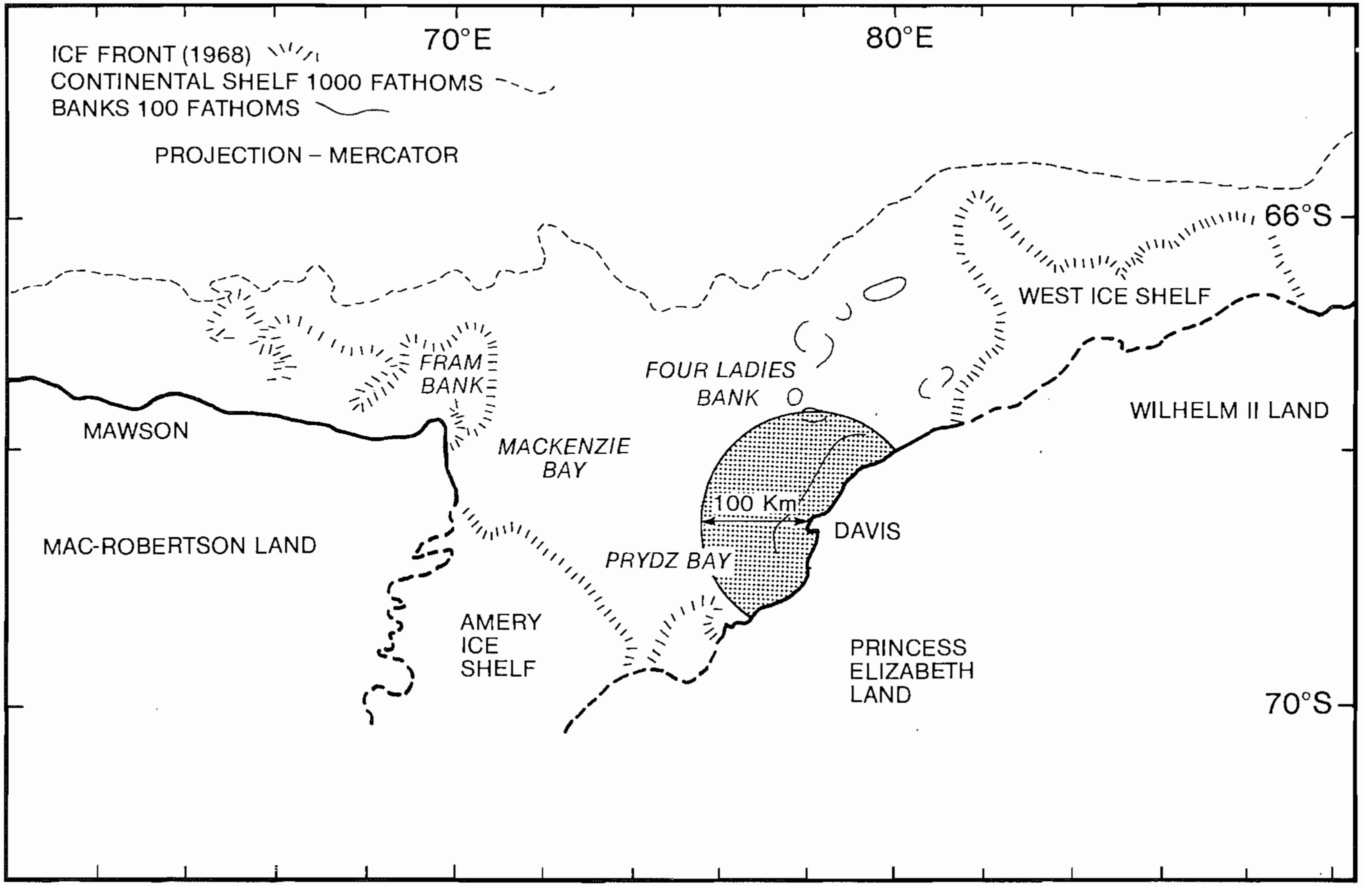

Figure 3 Prydz Bay Region. (Map reproduced from ANARE Research Notes No. 7, reprinted May 1985).

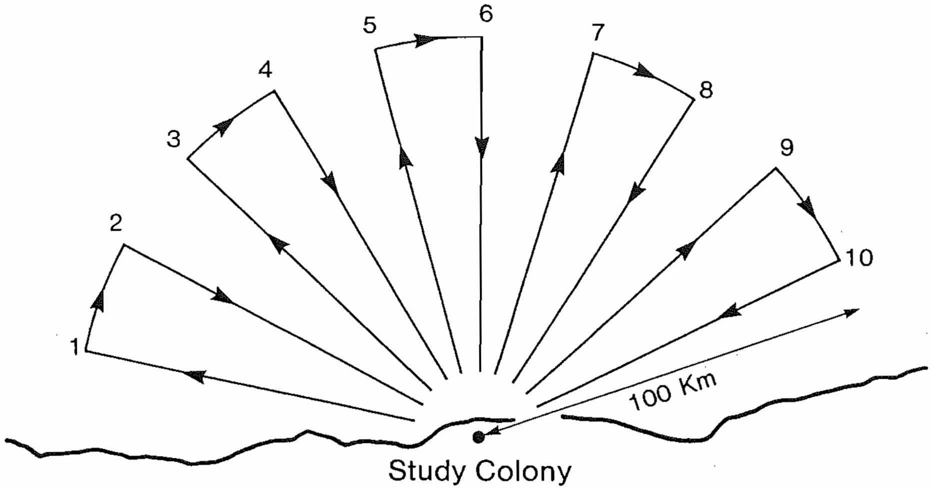

Figure 4 Radial transect survey design. The outer limit of each transect would be 100 km from the study colony. The length of each transect would therefore be between 85 and 90 km. Pairs of transects could be surveyed in random order so as to minimise bias, e.g. 9+10, 5+6, 1+2, 3+4, 7+8.

Légende du tableau

Tableau 1 — Considération des paramètres des prédateurs et impératifs implicites relatifs aux prospections des proies.

Légendes des figures

Figure 1 — Zone de la Péninsule. Les régions hachurées se trouvent à environ 100 km des sites d'étude.

Figure 2 — Région de la Géorgie du Sud. Les cercles représentent 100 et 200 km à partir de l'Ile Bird.

Figure 3 — Région de la Baie Prydz. (Carte reproduite d'après ANARE Research Notes No. 7, réimpression mai 1985).

Figure 4 — Modèle de prospection par sections transversales radiales. La limite extérieure de chaque transect se trouverait à 100 km de la colonie étudiée. La longueur de chaque transect serait donc de 85 à 90 km. Les paires de transects seraient prospectées au hasard afin de minimiser tout biais, par ex. 9+10, 5+6, 1+2, 3+4, 7+8.

Encabezamientos de las Tablas

Tabla 1 — Consideración de los parámetros de los depredadores y los requerimientos que sugirieron las prospecciones de las especies presa.

Leyendas de las Figuras

Figura 1 — Area de la Península. Las áreas sombreadas se encuentran aproximadamente a 100 km de los sitios de estudio.

Figura 2 — Región de Georgia del Sur. Los círculos representan 100 y 200 km desde la Isla Bird.

Figura 3 — Región de la Bahía Prydz. (Mapa reproducido de las Notas de Investigación ANARE N^{o} 7, reimpresas en mayo de 1985).

Figura 4 — Diseño de prospecciones de secciones transversales radiales. El límite exterior de cada sección transversal estaría a 100 km de la colonia de estudio. Por lo tanto, cada sección transversal tendría entre 85 y 90 km de longitud. Podrían prospectarse pares de secciones transversales en orden aleatorio a fin de minimizar el sesgo, por ejemplo 9+10, 5+6, 1+2, 3+4, 7+8.

Заголовки к таблицам

Таблица 1 Обсуждение параметров хищников и вытекающие из этого требования к съемкам потребляемых видов.

Подписи к рисункам

Рисунок 1 Антарктический полуостров. Заштрихованные районы находятся примерно в 100 км от изучаемых участков.

Рисунок 2 Регион Южной Георгии. Окружности - расстояние в 100 и 200 км от острова Берд.

Рисунок 3 Регион залива Прюдс. (Карта переснята из "ANARE Research Notes" №7, переиздано в мае 1985 г.)

Рисунок 4 Схема съемки по радиальным разрезам. Внешняя граница каждого разреза в 100 км от изучаемой колонии. Таким образом, длина каждого разреза - между 85 и 90 км. Чтобы свести к минимуму погрешность измерений, съемки пар разрезов могут производиться в произвольном порядке, напр., 9+10, 5+6, 1+2, 3+4, 7+8.

WG-CEMP-87/9

THE UTILIZATION OF SEABIRD CENSUSES FOR KRILL MONITORING

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Abstract

The possibility of using bird observations made at sea as a means of monitoring krill in the Antarctic ocean is explored. No variation source directly linked with krill was identified by means of correspondence analysis. Contour plotting, profile analysis and tests for equality of covariance matrices proved capable of detecting changes in bird abundance and/or species composition, associated with three levels of krill abundance.

A vector close to multi-normality was obtained, thus suggesting that refinements of the technique will allow the discrimination of krill levels by means of bird counts thereby providing an efficient tool for statistical tests of significance. The most promising approach seems to be the application of discriminant analysis.

Further developments of the method are possible only with greater databases, calling for international cooperation on the subject.

Résumé

Est explorée la possibilité d'utiliser les observations sur les oiseaux faites en mer pour contrôler le krill dans l'océan Austral. Aucune source de variation liée directement au krill n'a été identifiée au moyen d'une analyse de correspondance. Les levés de contour, les analyses de profil et les tests d'égalité des matrices de covariance se sont avérés capables de détecter des changements dans l'abondance des oiseaux et/ou la composition des espèces, liés à trois niveaux de l'abondance de krill.

Un vecteur proche de la multi-normalité a été obtenu, suggérant ainsi qu'un affinement de la technique permettra de distinguer les niveaux de krill par les dénombrements d'oiseaux, ce qui fournira un outil efficace pour les tests statistiques de signification. L'approche la plus prometteuse semble être l'application de l'analyse discriminante.

La méthode ne connaîtra de nouveaux développements que grâce à des bases de données plus importantes, ce qui suppose une collaboration internationale en la matière.

Resumen

Se estudia la posibilidad de utilizar las observaciones de aves hechas en el mar como un medio de controlar el krill en el océano antártico. No se identificó ninguna fuente de variación ligada directamente con el krill por medio de análisis de correspondencia. El trazado de contornos, el análisis de perfiles y las pruebas para detectar la igualdad de las matrices de covarianza demostraron ser capaces de detectar cambios en la abundancia de las aves y/o composición de las especies, asociados con tres niveles de abundancia de krill.

Se obtuvo un vector cercano a la multinormalidad lo cual, por lo tanto, sugiere que los refinamientos de esta técnica permitirá la discriminación de los niveles de krill por medio de recuentos de aves, proveyendo de este modo una herramienta eficaz para pruebas estadísticas significativas. El enfoque más promisorio parece ser la aplicación del análisis discriminante.

Los desarrollos ulteriores del método son sólo posibles con mayores bancos de datos, lo que requiere una cooperación internacional en el tema.

Резюме

Рассматривается возможность применения результатов проведенных в море наблюдений морских птиц в качестве одного из средств мониторинга криля в Антарктическом океане. Анализ совпадений не выявил никаких непосредственно связанных с крилем источников отклонений. Оказалось, что с помощью вычерчивания контуров, профильного анализа и проверки равнозначности ковариантных матриц можно выявить изменения в численности птиц и/или видовом составе, связанном с тремя уровнями численности криля.

Был получен вектор, близкий к мультинормальному, что дает основания предположить, что усовершенствованный метод позволит определить различные уровни количества криля при помощи подсчета птиц, что, таким образом, явится эффективным средством для получения статистических критериев значимости. Наиболее обещающим кажется применение дискриминантного анализа.

Дальнейшее развитие этого метода возможно только при наличии больших баз данных, что требует международного сотрудничества в этом вопросе.

THE UTILIZATION OF SEABIRD CENSUSES FOR KRILL MONITORING

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INTRODUCTION

Man-induced changes in the Antarctic ecosystem will first appear as changes in biological parameters of the species suffering the pressure of fisheries. It was the case with whales, seals, fishes, etc. While the mentioned species are more or less suitable for direct observation, at the present state of the art it is economically impossible to keep track of biological parameters of krill populations on a regional basis by means of direct measurements. This represents a significant shortcoming in our capability to provide in time the advice needed by the Commission and calls for indirect measures of krill population status.

Ecosystem monitoring in the open ocean represents an important and difficult task. It is a necessary complement to the land-based monitoring programs being developed by CCAMLR members and can provide information on areas not reached by indicators when studied in their reproductive sites but crucial to ecosystem evolution and management.

For monitoring purposes it is necessary to define a sampling unit where measurements can be taken regularly, which is more difficult in the open ocean due to the high variability of the abiotic component of the marine ecosystem. It is impossible to sample the same spot under the same conditions in two consecutive years.

Moreover, other parameters of value to the ecosystem are still less suitable for sampling : rates, variations in zooplankton abundances and composition, etc. calling for indirect estimators.

Bird observations made from ships are an inexpensive and simple methodology which can be performed with a minimum of training, thus allowing the utilization of practically any platform. Observations give information on factors governing distribution and abundances. The rationale behind the present exploratory work is that the vector composed by the bird counts per species will show differences associated with krill, either in its position measures or in other distributional properties. Such changes will be more efficiently detected if parametric statistics can be applied.

In the Reports of previous meetings of the Working Group on Ecosystem Monitoring a list of interesting variables and parameters was identified. As well as minke whales and penguins, bird populations will reflect changes in abundance of krill in a given area.

On the other hand, if changes detected are to be used by administrators, it is necessary to make every effort to obtain a measure of statistical significance associated with every statement produced.

The present paper is the result of exploring the possibility of using bird observations made at sea, for the purpose of krill abundance monitoring. Bearing in mind the concept of the CCAMLR Working Group on Ecosystem Monitoring that recommends the survey of parameters and variables easily obtained and sensitive to changes in the actual object of the monitoring program, this possibility was considered worthy of being investigated. It is to be noted that bird observations can be carried out from any ship operating in the area, thus becoming an inexpensive way of monitoring krill abundances over great areas, least as accurate as any of the already proposed indicators (seals, minke whales, etc.), and not tied to the operations of a fishing fleet as is the case with catch per unit effort.

To this end, 72 bird observations made during FIBEX (1981) cruise of R/V Dr Eduardo L. Holmberg taken together with acoustic records of krill abundance were studied by some multivariate techniques. The main objective was to identify which bird species can be used as indicators of krill abundance and to outline the methodology of data analysis in order to obtain parametric exact tests for hypothesis testing.

The same data set has been analysed by Visbeek and Fontana (1983) from the viewpoint of the autecology of bird species. This analysis has proven the sensitivity of the bird variates to slight variations in abiotic conditions and was based on an ANOVA approach to profile analysis developed by Gneisser and Greenhouse (1958) followed by planned contrasts according to Bonferroni.

MATERIAL AND METHODS

Along the January-February 1981 cruise of R/V Dr Eduardo L. Holmberg, realised as part of the FIBEX exercise, birds within 500 m of the sides of the ship were recorded in the 10-minute Seabird Record Cards. The area sampled lies between 57 and 62 degrees South and 42 and 48 degrees West; more details on the methods are to be found in Visbeek and Fontana (1983).

From the records of a Simrad EK120 echosounder, five levels of krill abundance have been determined associated with each bird observation. It should be noted that the fifth level is several orders of magnitude greater than the fourth.

The statistical methodology employed was selected in order to obtain :

- Graphic displays purporting dimensionality reduction, readily understandable in biological terms.
- Methods allowing hypothesis testing with the material at hand.
- Methods that can be used for comparison with other data sets, thus allowing for monitoring of different parameters. For the sake of clarity, the methods applied will be briefly described :

Correspondence Analysis

Descriptions of the method can be found in Lebart, Morineau and Fenelon (1979).

The method is closely related to principal components; it is based on the eigenanalysis of the moment of inertia of the given set of points. Masses are allocated as total birds observed when considering the sighting-points in the p-space of bird species; or as the total number of birds of a given species when species-points in the n-space of observations are considered. These two representations of the set of observations are reduced in dimensions by considering only those eigenvectors associated with a high contribution to total inertia. It can be shown that the eigenvectors are the same and that representations in both spaces (birds and observations) are equivalent. This allows the representation in a single plot of bird and sighting points, providing good insight on the interrelations of species and localities of observation.

The main output is formed by a table of eigenvalues and percentages of total inertia explained, and bidimensional plots of the points using as coordinates the projections on the directions of eigenvectors.

Contour Plotting

This method is due to Andrews (1972) and also described in Gnanadesikan (1977). Given a vector (x) in a p-dimensional space, a bidimensional representation is obtained defining a set of directions in the p-space and projecting the interesting points on these. Useful sets of directions are generated by means of the vector of parametric orthogonal functions :

(1) $a'(t) = (1/\sqrt{2}\ ), \sin t, \cos t, \sin 2t, \cos 2t, \ldots)$

the parameter t is kept between pi and minus pi.

The projections are calculated as a linear function of t for the point x :

(2) $Fx(t) = a'(t) \cdot x$,

and the values of Fx(t) represented as ordinates of the abscissa (t). In that way, each point will be replaced by a curve, allowing for graphic comparisons. Those directions where differences occur can be identified for ulterior investigation by the values taken by a'(t).

The representations obtained are not unique, in the sense that the order of the variates in the p-space determines the coefficients associated with each variate. Each permutation purports a strict association of variates and coefficients defined in (1) (each permutation might be considered as a different definition of space orientation), thus permutations provide different insights into data structure.

At variance with discriminant analysis this method is not aimed to obtain a direction where differences between treatments are maximal, but to obtain a picture of the directions where the differences occur.

Two applications of the method will be developed in the sequel :

1. Quantile contour plotting :

   On each of the directions generated by (1), F(t) functions are calculated for the 72 observations according to (2). These 72 values are ordered and First Decile (D1), First Quartile (Q1), Median (M), Third Quartile (Q3) and Ninth Decile (D9) evaluated. Then quantiles are plotted against t values and the ratios : (D1-M)/(Q1-M) and (D3-M)/(Q3-M) calculated and listed. The plot will give information on the presence of multimodality and highly correlated variates, while the ratios should be approximately equal to 1.9 if joint normality of the variates is assumed.

   It is to be noted that quantile contour plotting is not a formal test for multinormality, but will give an idea of the distributional properties of data, which is sufficient with the data set at hand.

2. Function contour plotting :

   Taking the centroids of different treatments and treatment levels as the points in p-space to be analysed, function contour plotting as described above provides a method of classification which permits clustering (provided number of points is kept low). At variance with conventional clustering methods based in the definition of ultrametrics, it allows the inclusion or not of a point in some of the clusters formed as well as identifying directions that result in similarities or differences in the plot. Furthermore, as a consequence of the selection of orthogonal functions as components of vector a'.

3. As $\int_{-\pi}^{\pi}$ [fi(t)-fj(t)]^2 dt

   is proportional to the euclidean distance defined between points xi and xj, closeness of the curves might be considered as closeness in the original p-space.

Comparison of Covariance Matrices

A Chi-square statistic is constructed as an extension of Bartlett's test (Morrison, 1977), to provide an exact test of the null hypothesis of equality of several covariance matrices. The statistic is also highly sensitive to non-normally distributed variables and not defined if one or more of the matrices is singular, thus precluding the inclusion of variates not observed in one of the data subsets.

Profile Analysis

Given a set of groups of p-dimensional data, with non-singular covariance matrices (not necessarily equal), we can define the profile of one of the groups as the values of the mean vector of the group. This technique, fully detailed in Morrison (1977), allows the construction of a test for the profile parallelism hypothesis and tests for group mean level and variate levels, the last two only if the first test resulted non-significant.

Fortran source programs for correspondence analysis are those published in Lebart, Morineau, Fenelon (1979). Other methods were run utilizing Fortran programs developed by authors on IBM PC-XT 640K.

RESULTS AND DISCUSSION

Bird sightings have been used by fishermen and sailors as indicators of fishing targets and geographical features for many years. Our goal should be to translate this fact into a mathematically tractable form, defining a model to be applied in hypothesis testing. Results given by each of the methods used will be discussed prior to general evaluation of results.

Correspondence Analysis

Table I. presents the percentage of inertia associated with each of the eigenvalues obtained considering all variates and krill related variates (as per literature information) alone.

Data dimensionality can be sensibly reduced applying this method, but neither of the new coordinate axes obtained can be attached to the variables of our interest (figs. 1-4). This approach might prove to be significant to the biology of avian communities, but to our present purpose they show that krill influence is at least correlated with other factors. Thus a methodology allowing for specific representation of interesting directions in the space defined by the bird variates is necessary.

Contour Plotting

Figs. 5-9 show the application of the method to raw and log-transformed data, with and without considering the *Pygoscelis* spp. variate. From the comparison it results that log transformed data are more stable, both representations showing not only the differences between treatments, but also the fact that without penguins their discrimination is still possible.

From Figure 5 and other permutations of variates (random, according to food regime and abundances) several directions where treatments show differences have been identified. The next step was the identification of the coefficients associated to each variate in these directions. The analysis showed clearly the influence of Pygoscelis spp., Pagodroma nivea and Pachyptila spp. in treatment discrimination. Results were not so clear for Daption capense.

Krill treatments resulted in different curves that can be grouped:

1) Sightings where krill was highly abundant
2) Sightings where krill was abundant
3) Sightings where krill was scarce or absent.

In the sequel, only these three levels will be considered. Figs. 8 and 9 present the results obtained applying the method to the species considered as possible krill feeders with and without penguins.

Contour plotting in the space defined by indicators identified here was not attempted because the same set of data provided the selection of species and the representation.

Profile Analysis

Due to the fact that under the assumptions of this method all groups to be compared must possess a non-singular covariance matrix, we were restricted to the use of following species (present under all krill levels) :
Diomedea exulans + D.epomophora, Daption capense, Pagodroma nivea, Pachyptila spp. and Oceanites oceanicus.

Results of the test were significant at the .01 level, thus indicating that the species considered react differentially to the presence of krill. A simple inspection of the profiles shown in Figure 10 indicates that it is Pagodroma nivea and to a lesser extent Pachyptila spp. that can be used as krill indicators.

Equality of Covariance Matrices

In all cases tested and with the transformations (raw data, square root and log) used, covariance matrices were significantly different. It is impossible to decide with the evidence at hand, whether this result is due to an inequality of covariances or to non-normality of data. Anyhow any of the origins of the significant difference will lead to a useful insight : if it is non-normality, data can be transformed in order to get a multinormal set of variates thus allowing for a highly efficient test of hypothesis. If the matrices are essentially different, this inequality can be used to detect variations in krill abundance and comparisons from year to year. Contour plotting of the position measures for treatments 1 and 2, (log transformed data) shown in Figures 12 and 13, as well as their quotients, strongly suggest the possibility of obtaining a normalized variable by means of the log transformation or a related one. These plots also show that if non-normality actually exists it is not very great. Further work should be devoted to this approach.

Based on the above results, we can now develop a line of analysis :

I. From the correspondence analysis of the whole set of data, no major axis can be extracted with a high correlation with krill abundance. This means that the general linear model (purporting a regression) will be of little use until a set of interesting contrasts is defined. Krill appears always correlated with other factors, thus calling for a line of analysis enabling the selection of specifically interesting directions.

II. Contour plotting is strictly descriptive in nature, no significance can be attached to the graphics obtained, but they showed that the method is sensible to krill presence, that penguins are not essential for discrimination, but only three levels of abundance were detected. It must be noted that the plots are scaled to make full use of a 130 spaces printer, so curves coming from different plots should be compared with caution after rescaling the drawings.

Plots made on 3 or 5 krill levels identified the species responsible for the discrimination between treatments. These species might be considered as sensitive to krill presence, but not considered as good indicators until further validation is done.

III. A Vector was constructed with all species present at different krill levels and latitudes. This restriction is needed if non-singular covariance matrices are to be obtained in each treatment level. Covariances at three different krill levels and four latitudes were found to be significantly different. Significant results might be the outcome of a non-normally distributed variable, or of differences in covariance matrices. In either case, a multivariate general linear model cannot be fitted if probability levels are to be used outside the present body of data.

IV. With the same subsets defined for krill and latitude treatments in III, profile analysis was performed. Significant results prove that species do not react homogenously to changes in latitude or krill abundance. Direct inspection of profiles showed that Pagodroma nivea and Pachyptila spp. are the variates responsible for the non parallelism of profile of the third treatment.

V. A vector of variates supposed to be sensitive is constructed and analysed with the same methods with the following summary of results :
- No krill regression on species is worth trying (correspondence analysis).
- Highly different contours resulted.
- Significantly different covariance matrices have been found as well as profiles resulted non-parallel.

VI. Quantile Contour Plotting was performed on the vector of sensitive variates showing minor deviations from normality.

This result strongly suggests the possibility that covariance matrices comparison results are rather due to actual differences in covariances and not to the lack of joint normality. This leaves open the possibility of finding a set of treatments that leaves multinormally distributed residuals. In that case a conservative degree of freedom ANOVA, as developed by Geissen and Greenhouse (1958) and described in Morrison (1977) and Winer (1971), can be applied. This will give a powerful tool for monitoring by means of the formulation of adequate contrasts, and eventually to obtain regression curves. No such method is attempted here, because of the fact that directions to be tested are defined from the same set of data.

CONCLUSIONS

1. The present analysis has been developed mainly on a Fibex data set restricted to the summer 1981 north of South Orkneys Islands. Its results cannot be extrapolated to other areas and years, until the analysis is validated by subjecting other data sets where krill and birds have been registered simultaneously, to the same or refined statistical techniques. Moreover, the exploratory work performed does not preclude the application of other methodologies not used (discriminant analysis, canonical correlation, non-parametric statistics, etc.).

2. A set of sensitive bird species has been identified. This set would allow either :

   a) detection of krill concentrations by means of classical discriminant analysis. This will be possible if normality analysis and comparisons with other data sets allow for the restrictions of the method (mainly normality) and the analysis made under different well-identified conditions;

   b) detection of krill concentrations by means of univariate ANOVA under the conservative degrees of freedom formulation;

c) detection of krill concentrations by associating to its presence a certain covariance structure. Thus intensive cruising of a certain region will provide a data set to be compared with those where krill has been independently evaluated. Comparisons can be tested by means of covariance matrices comparisons or profile analysis.

3. If the univariate approach is tenable, the possibility of constructing a regression line of krill abundance on the bird variates should be considered and carefully tested. Such an approach will directly yield an estimation of krill abundance from bird sightings under different affecting factors.

4. A monitoring minimum approach can be outlined :

   i) To identify areas where bird observations (with or without simultaneous krill evaluations) are carried out by ships not necessarily commited to research;

   ii) to decide the methodology to be used for krill detection by means of bird sightings (parametric statistics, covariance matrices comparison, profile analysis or non-parametric tests);

   iii) weights should be allocated providing a compensation for the total Record Cards obtained by a given cruise in the area;

   iv) numbers of bird cards indicative of krill presence can be taken as a measure of krill abundance in the area considered.

5. Due to the amount of information necessary, this monitoring development can be fruitfully envisaged only under a cooperative international basis, allowing the use of BIOMASS and CCAMLR data bases, which will provide the background for the simultaneous analysis of other factors not included in the present paper because of the insufficient number of observations (e.g. time, depth of krill patches, latitude, meteorological conditions, etc.).

Acknowledgements : Authors are grateful to Dr Aldo P. Tomo and Lic. Diego Gru, who recorded krill abundance.

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Table 1. Eigenvalues obtained from correspondence analysis

	Krill related variates			All variates		
	EIGENVALUE	PERCENT.	ACCUMUL	EIGENVALUE	PERCENT.	ACCUMUL
2	.72307	35.14	35.14	.71822	28.75	28.75
3	.61801	30.03	65.18	.56255	22.52	51.27
4	.48580	23.61	88.79	.46305	18.54	69.81
5	.17237	8.38	97.16	.30425	12.18	81.99

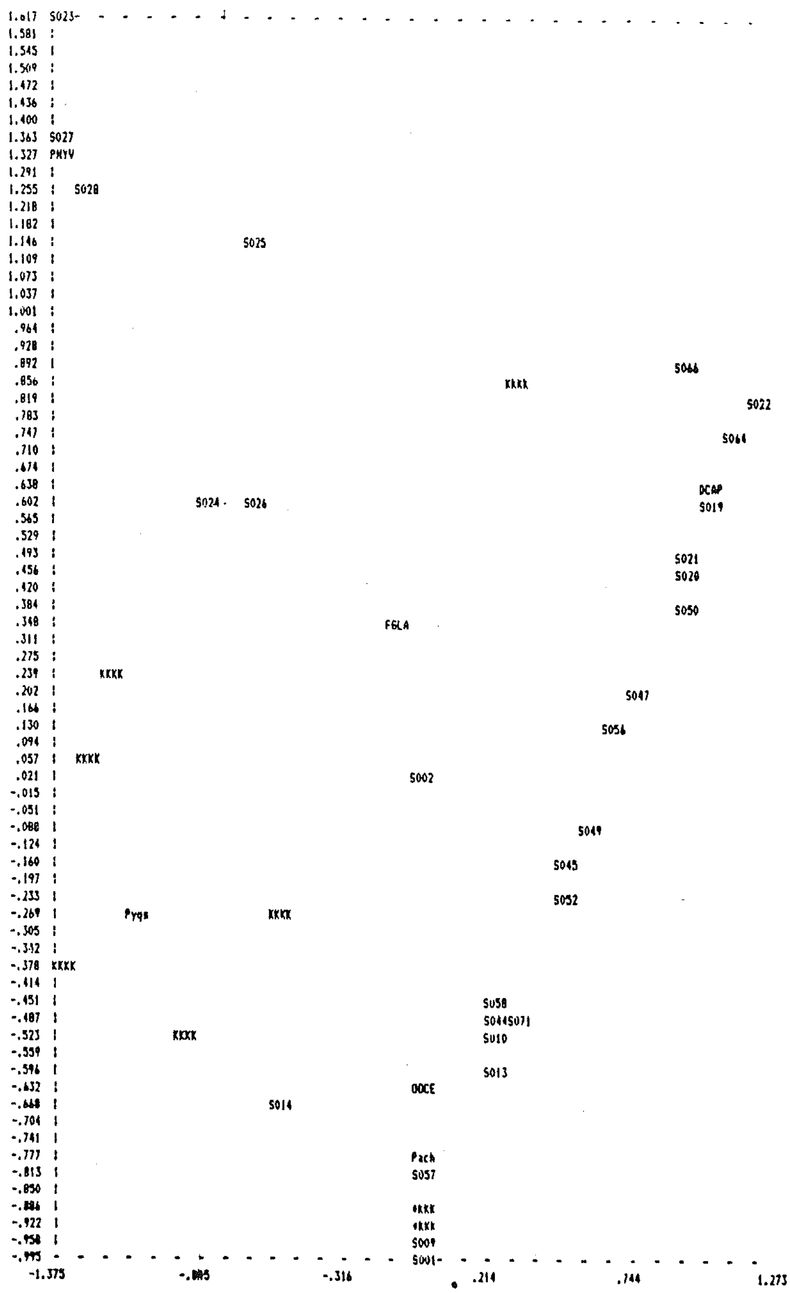

Figure 1 Correspondence analysis of krill related variates. Projection on axis 1 (horizontal) and 2 (vertical). Stations where krill was highly abundant are represented by KKKK or *KKK if stations without krill have same coordinates. Points marked with ! are out of scale. Pachyptila spp = Pach; Pygoscelis spp = Pygs; Oceanites oceanicus = OOCE; Pagodroma nivea = PNYV; Fulmarus glacialoides = FGLA; Daption capense = DCAP; Macronectes spp = Macr; Diomedea exulans ± Diomedea epomophora = Derr; Diomedea melanophris = DMEL; Phoebetria palpebrata = PPAL.

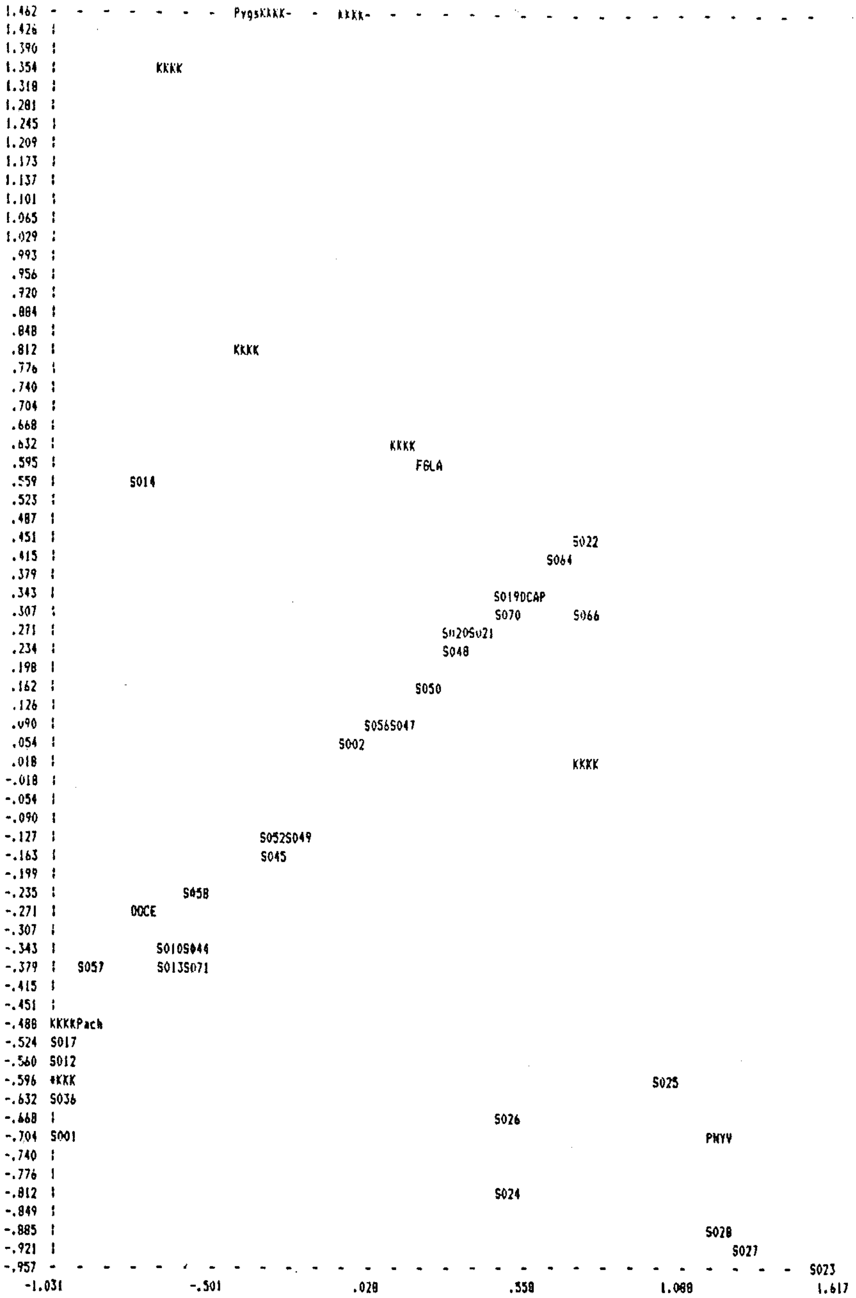

Figure 2 Correspondence analysis of krill related variates. Projection on axis 2 (horizontal) and 3 (vertical). Captions as per Figure 1.

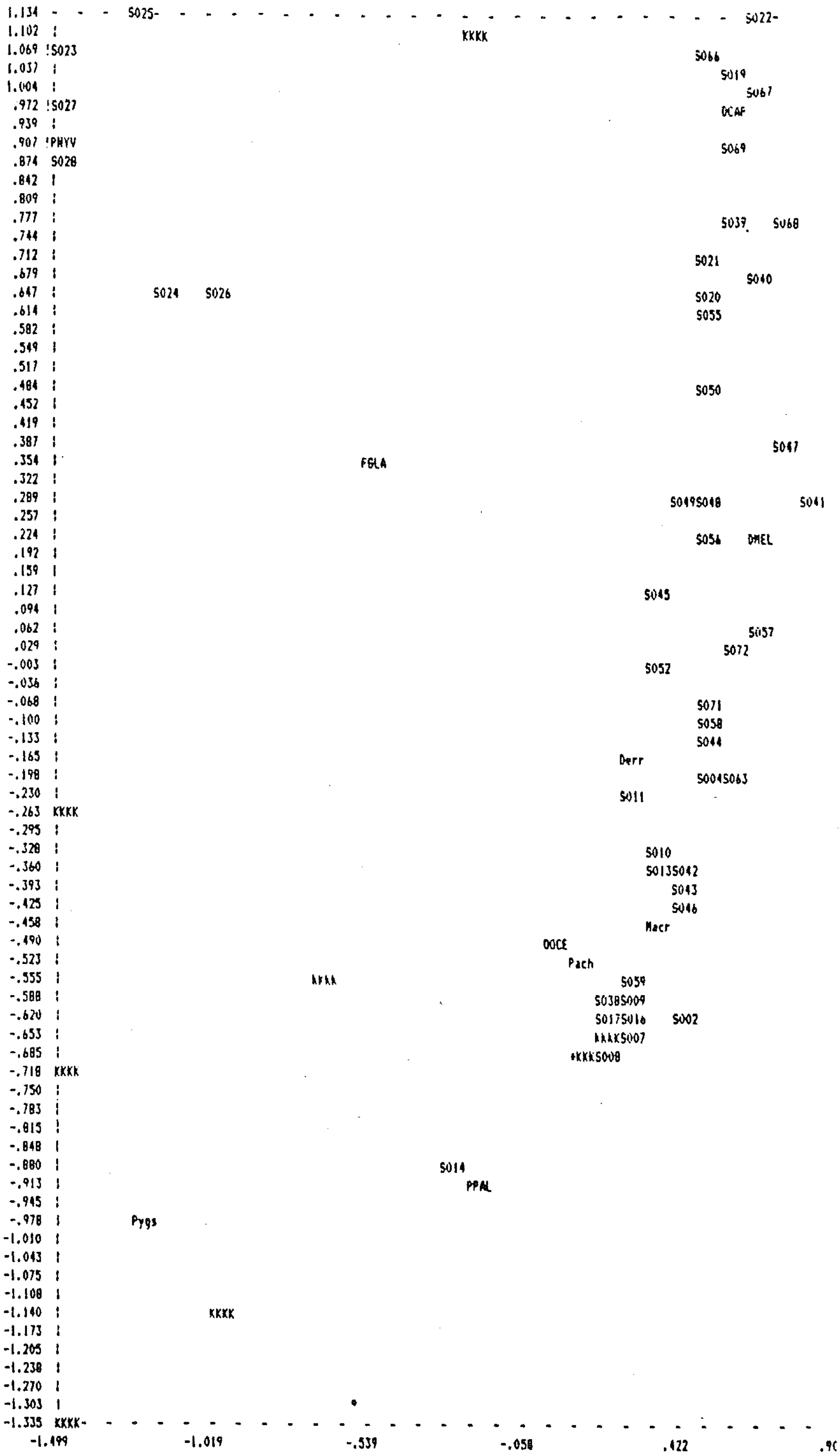

Figure 3 Correspondence analysis of all variates. Projection on axis 1 (horizontal) and 2 (vertical). Captions as per Figure 1.

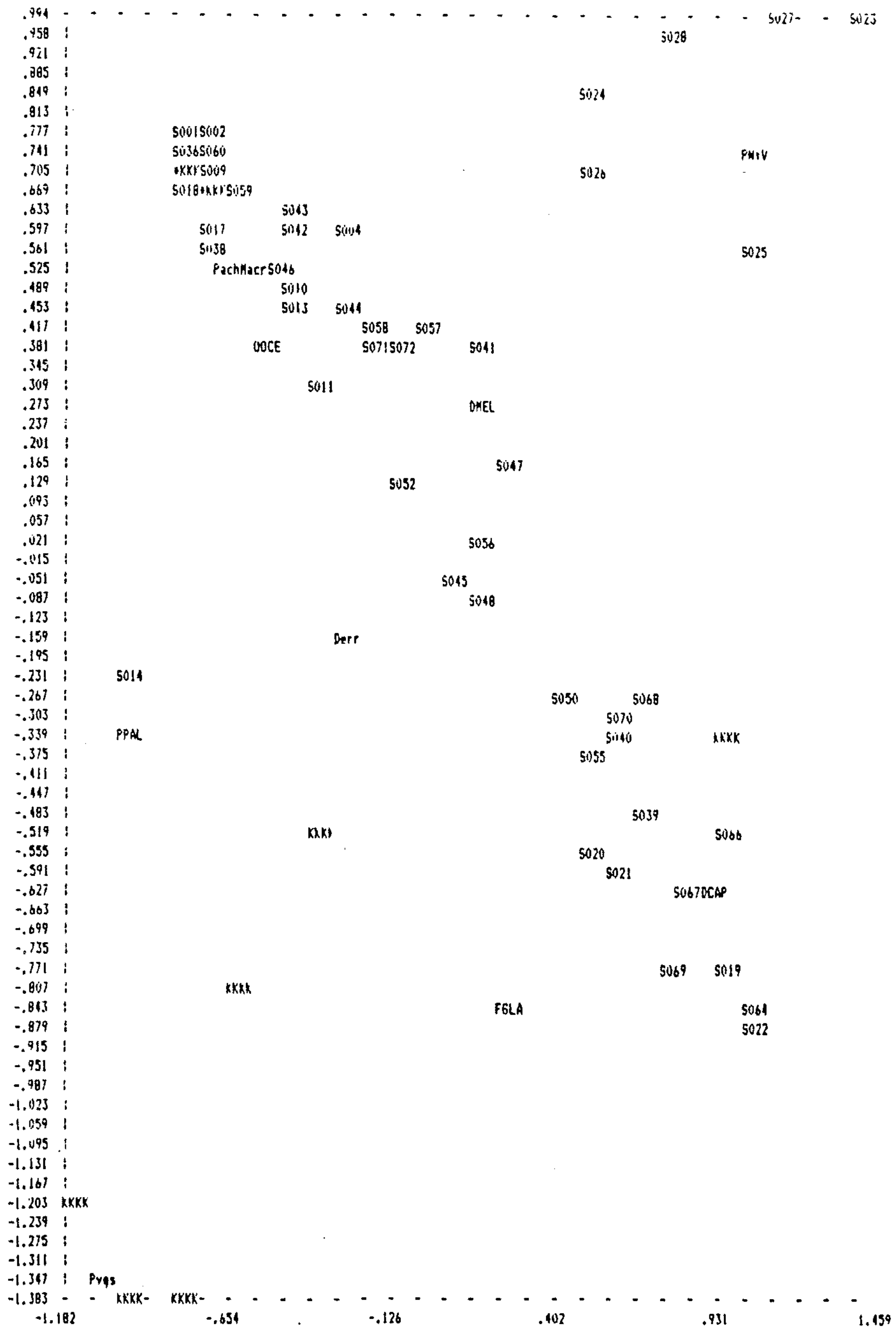

Figure 4 Correspondence analysis of all variates. Projection on axis 2 (horizontal) and 3 (vertical). Captions as per Figure 1.

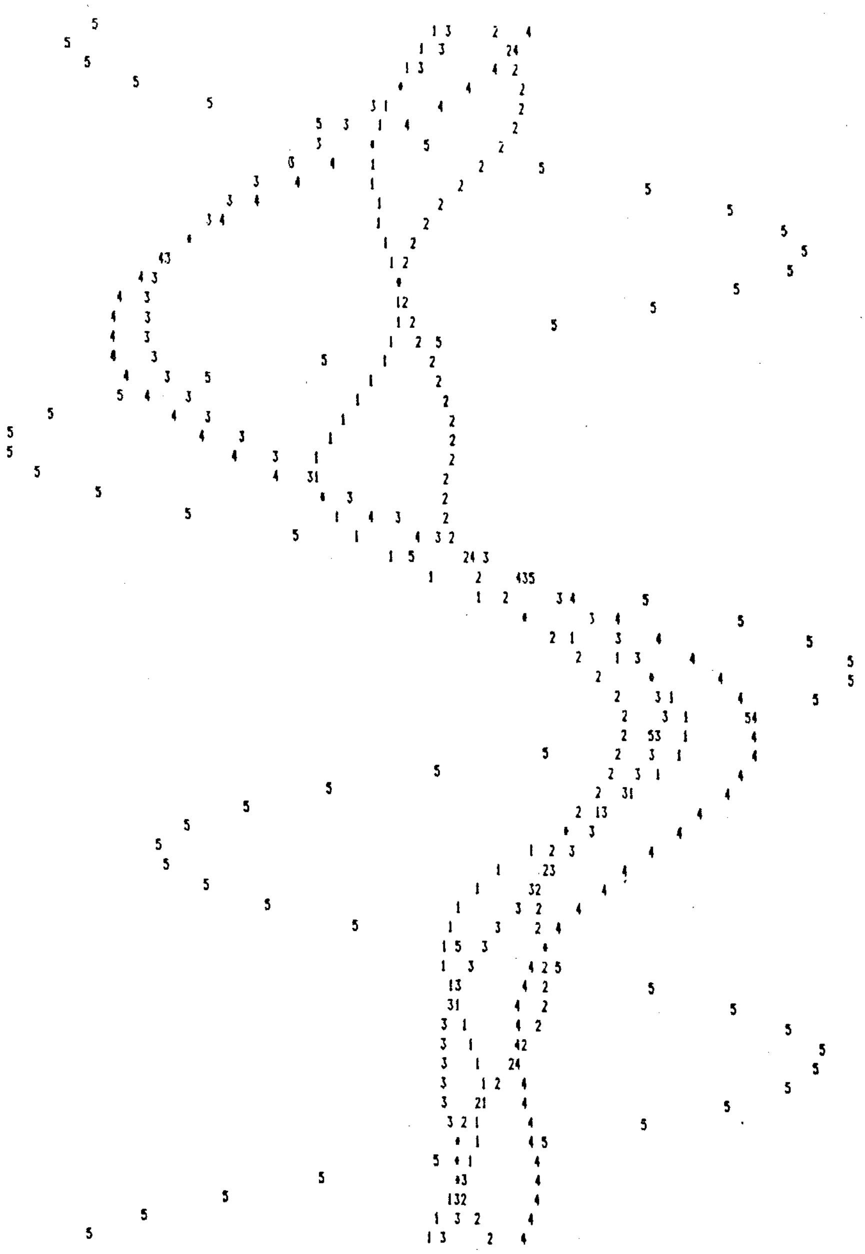

Figure 5 Contour plot of the centroids of five krill levels in the space defined by the 10 variates in decreasing order. Raw data.

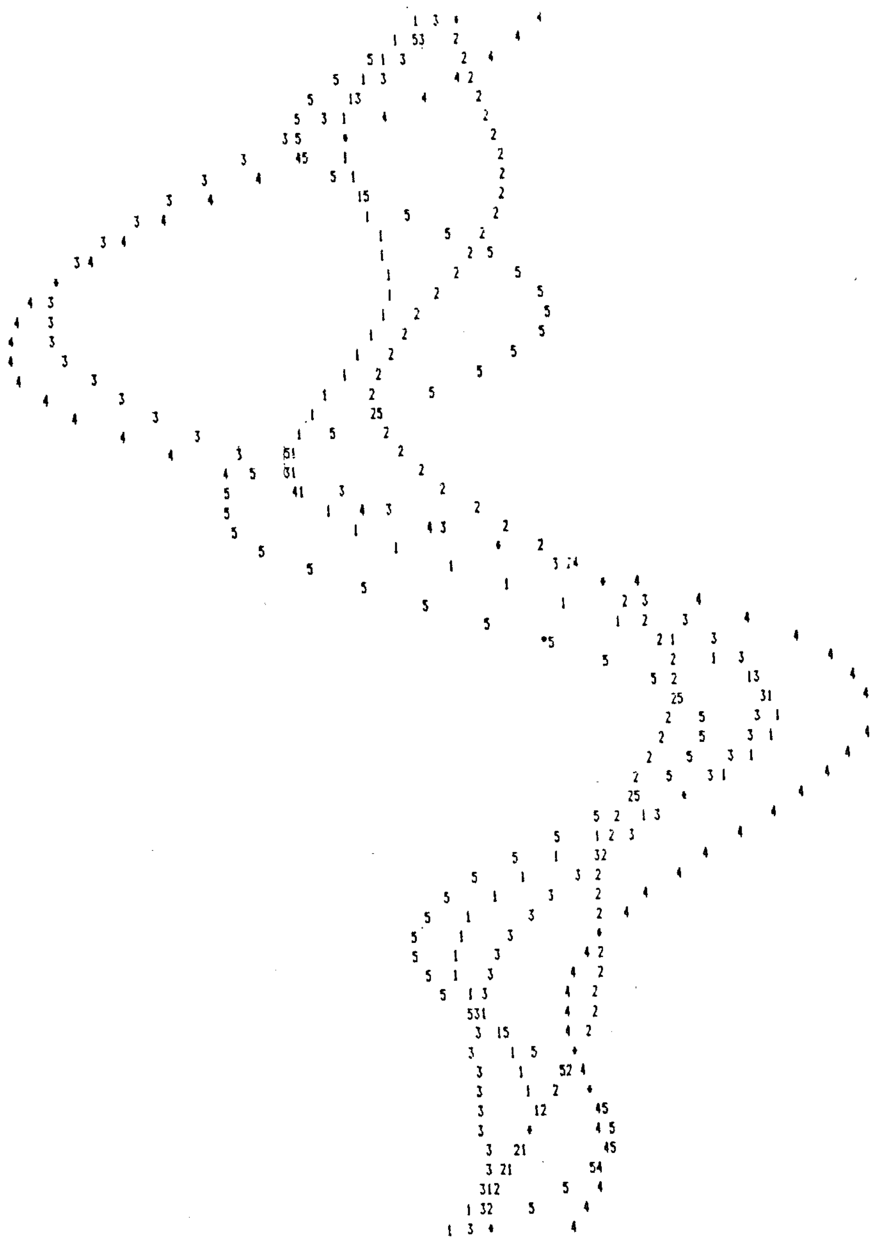

Figure 6 Contour plot of the centroids of five krill levels in the space defined by all variates except Pygoscelis spp. in decreasing order. Raw data.

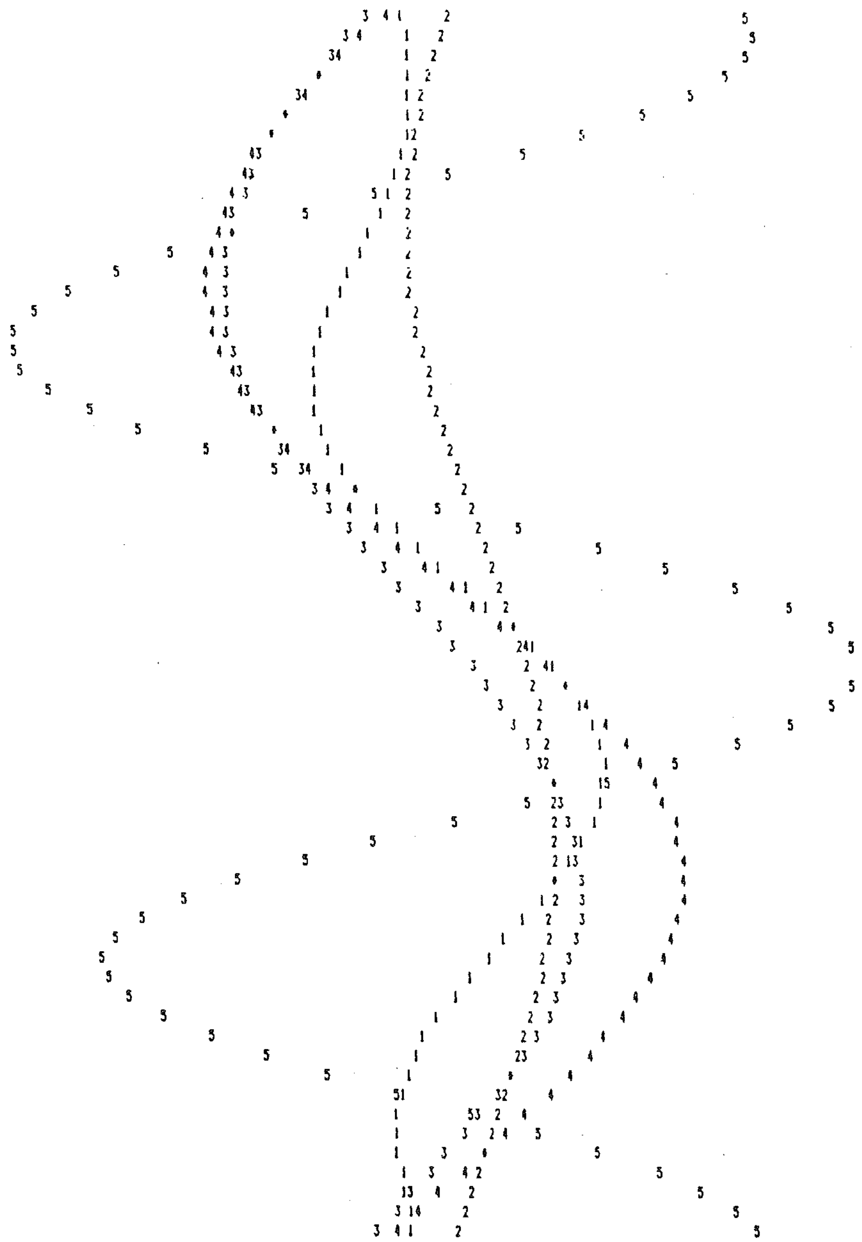

Figure 7 Contour plot of the centroids of five krill levels in the space defined by sensitive (from literature data) variates in decreasing order. Raw data.

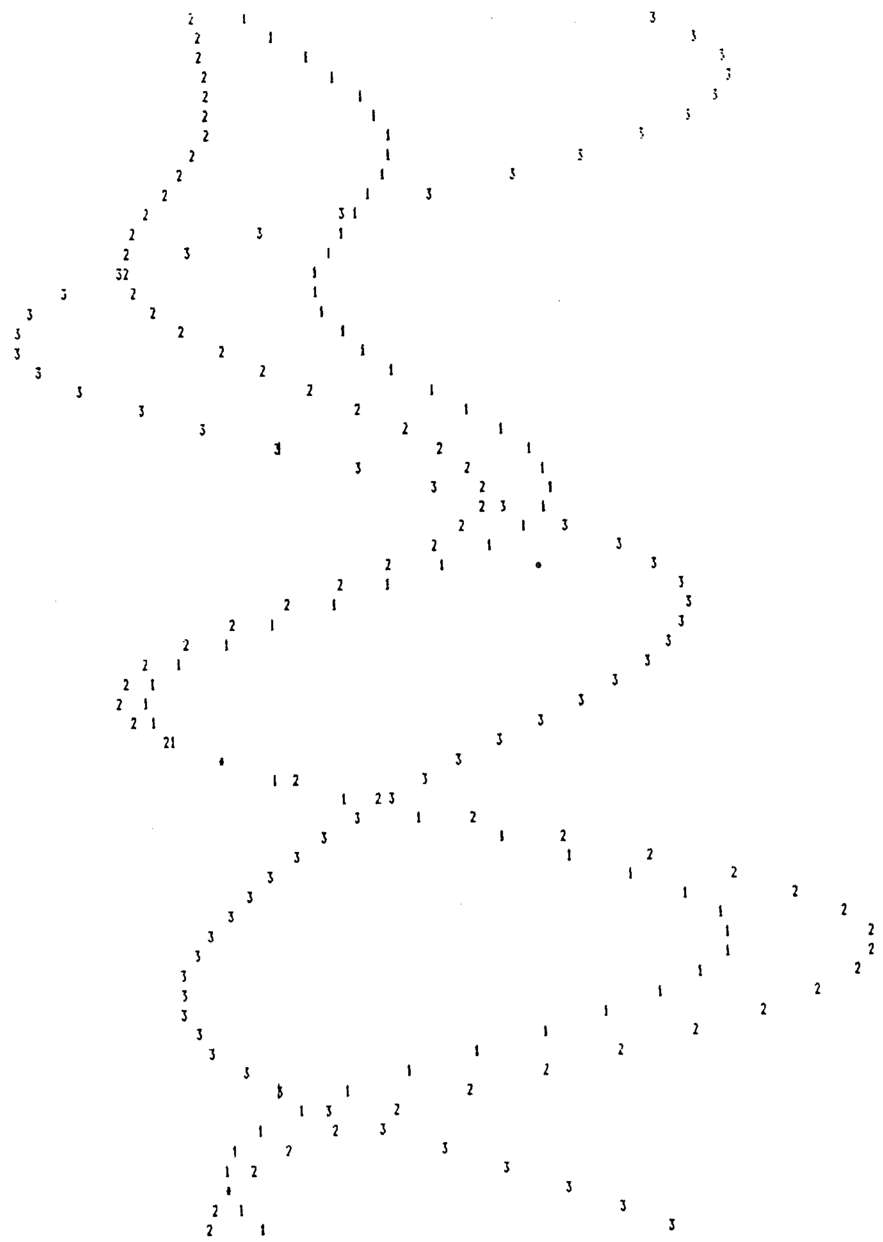

Figure 8 Contour plot of the centroids of three krill levels in the space defined by all sensitive variates in decreasing order. Log transformed data.

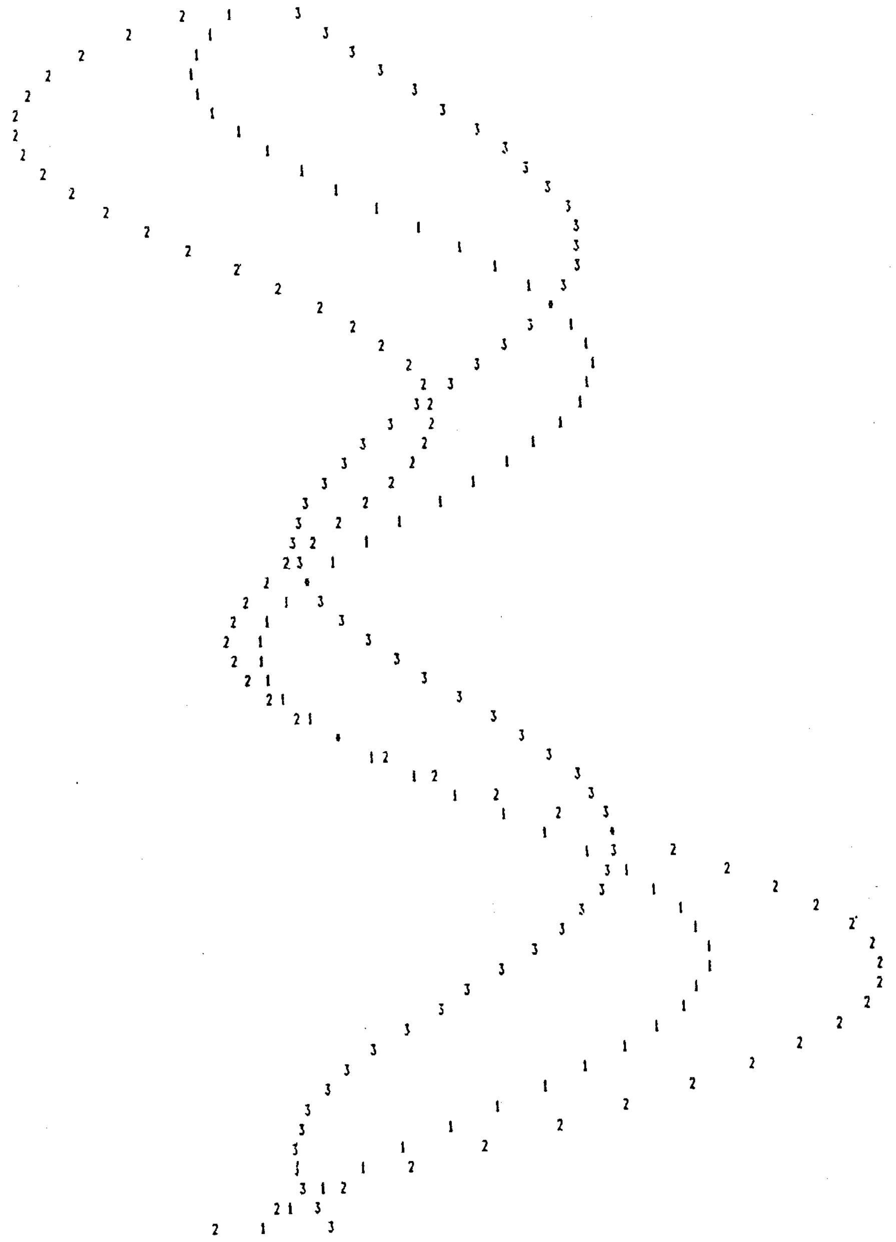

Figure 9 Contour plot of the centroids of three krill levels in the space defined by all sensitive variates except Psygoscelis spp. in decreasing order. Log transformed data.

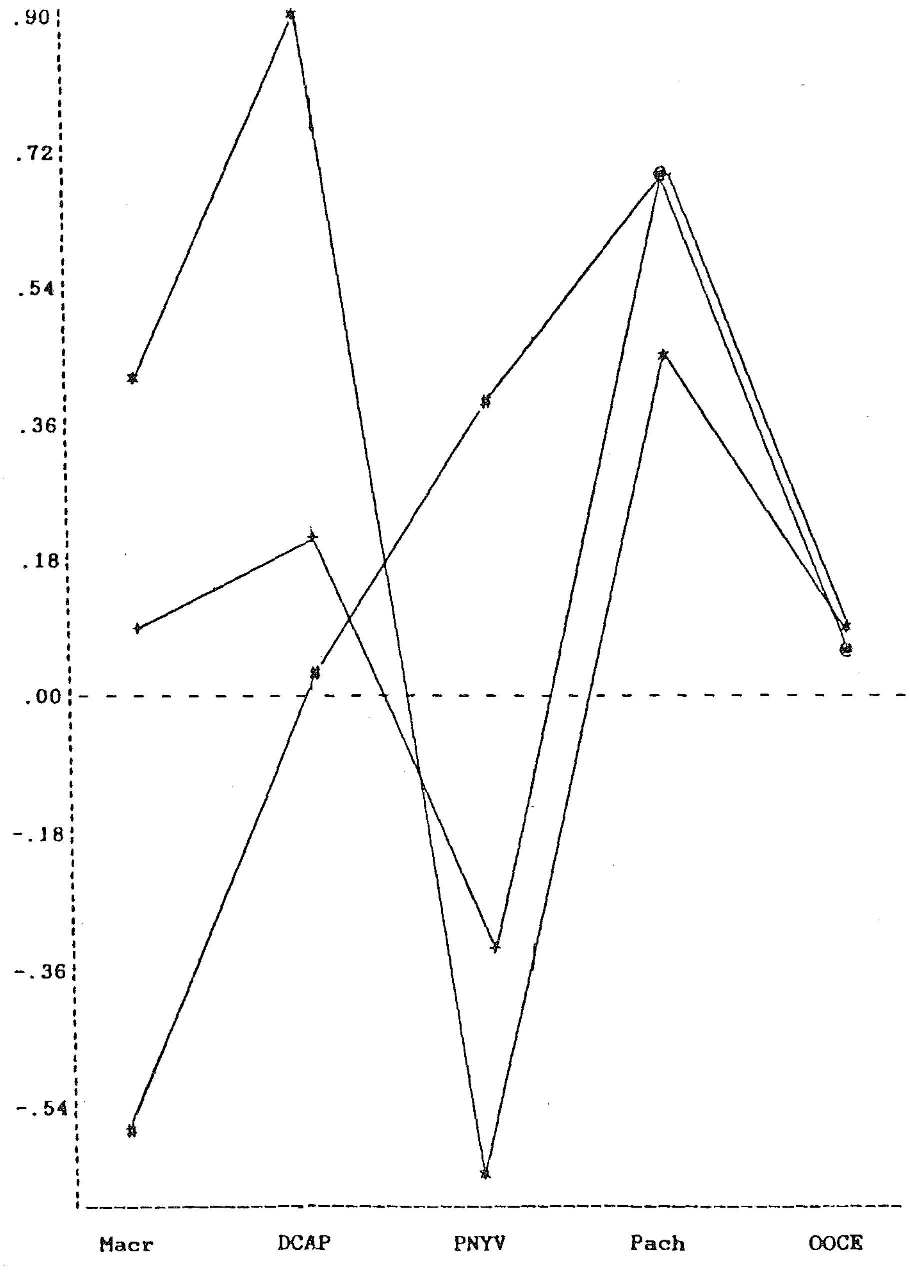

Figure 10 Profiles of the means of three levels of krill abundance. Log transformed data. (+ = scarce or absent, * = present or abundant, # = highly abundant).

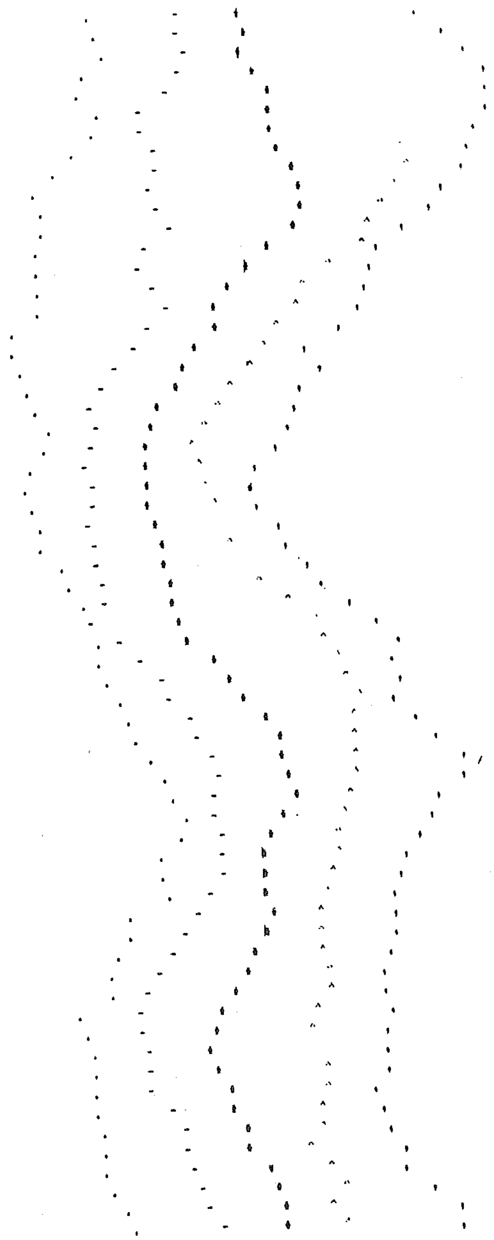

Figure 11 Quantile Contour Plot for the position measures of treatment 1 (scarce or no krill). 1st Decile (.), 1st Quartile (-), Median (*), 3rd Quartile (^) and 9th Decile (,). Log transformed.

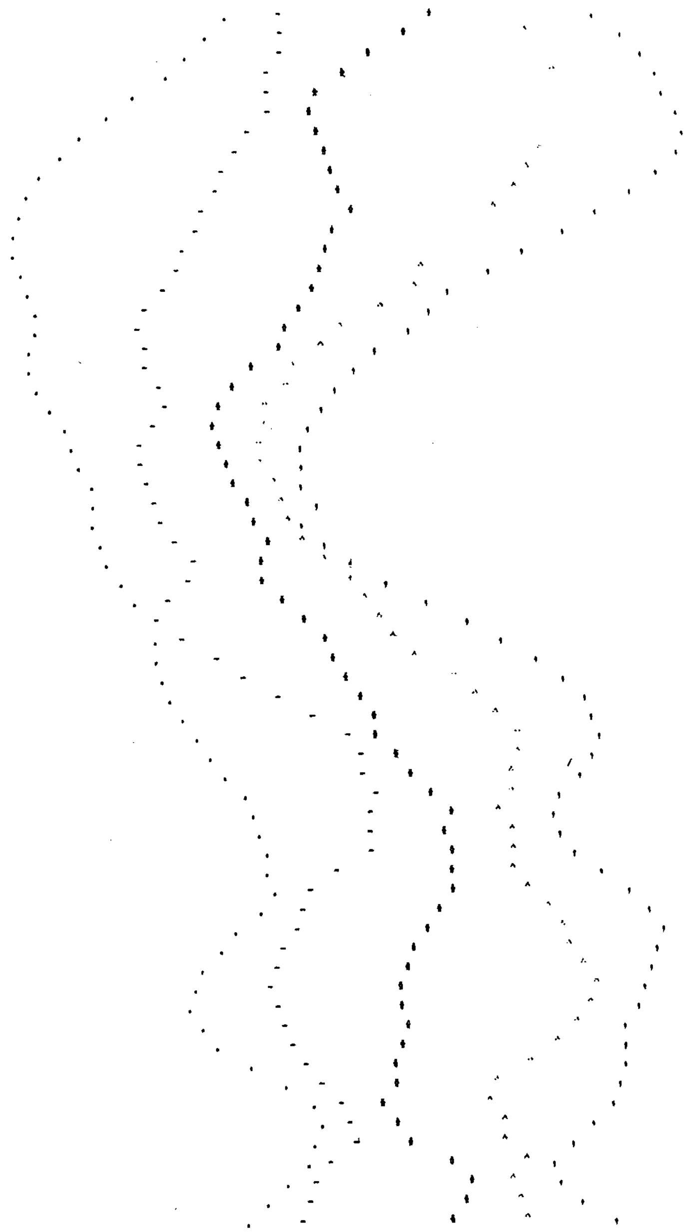

Figure 12 Quantile Contour Plot for the position measures of treatment 2 (present or abundant krill). 1st Decile (.), 1st Quartile (-), Median (*), 3rd Quartile (^) and 9th Decile (,). Log transformed.

Légende du tableau

Tableau 1 — Valeurs propres obtenues à partir de l'analyse de correspondance.

Légendes des figures

Figure 1 — Analyse de correspondance des variantes liées au krill. Projection sur l'axe 1 (horizontal) et 2 (vertical). Les stations où le krill était fort abondant sont représentées par KKKK ou *KKK si les stations sans krill ont les mêmes coordonnées. Les points marqués d'un ! ne sont pas rapportés à l'échelle. Pachyptila spp = Pach; Pygoscelis spp = Pygs; Oceanites oceanicus = OOCE; Pagodroma nivea = PNYV; Fulmarus glacialoides = FGLA; Daption capense = DCAP; Macronectes spp = Macr; Diomedea exulans ± Diomedea epomophora = Derr; Diomedea melanophris = DMEL; Phoebetria palpebrata = PPAL.

Figure 2 — Analyse de correspondance des variantes liées au krill. Projection sur l'axe 2 (horizontal) et 3 (vertical). Pour la légende, voir la Figure 1.

Figure 3 — Analyse de correspondance de toutes les variantes. Projection sur l'axe 1 (horizontal) et 2 (vertical). Pour la légende, voir la Figure 1.

Figure 4 — Analyse de correspondance de toutes les variantes. Projection sur l'axe 2 (horizontal) et 3 (vertical). Pour la légende, voir la Figure 1.

Figure 5 — Tracé de contour des centroïdes de cinq niveaux de krill dans l'espace défini par les 10 variantes dans un ordre décroissant. Données brutes.

Figure 6 — Tracé de contour des centroïdes de cinq niveaux de krill dans l'espace défini par toutes les variantes sauf Pygoscelis spp. dans un ordre décroissant. Données brutes.

Figure 7 — Tracé de contour des centroïdes de cinq niveaux de krill dans l'espace défini par les variantes sensibles (obtenues à partir des données de documentation) dans un ordre décroissant. Données brutes.

Figure 8 — Tracé de contour des centroïdes de trois niveaux de krill dans l'espace défini par toutes les données sensibles dans un ordre décroissant. Données transformées à l'introduction.

Figure 9 — Tracé de contour des centroïdes de trois niveaux de krill dans l'espace défini par toutes les variantes sensibles sauf Pygoscelis spp. dans un ordre décroissant. Données transformées à l'introduction.

Figure 10 Profils des moyennes de trois niveaux de l'abondance du krill. Données transformées à l'introduction. (+ = rare ou absent, * = présent ou abondant, # = très abondant).

Figure 11 Tracé de contour du quantile pour les mesures de position du traitement 1 (krill rare ou absent). ler décile (.), ler quartile (-), médiane (*), 3ème quartile (^) et 9ème décile (,). Transformé à l'introduction.

Figure 12 Tracé de contour du quantile pour les mesures de position du traitement 2 (krill présent ou abondant). ler décile (.), ler quartile (-), médiane (*), 3ème quartile (^) et 9ème décile (,). Transformé à l'introduction.

Encabezamiento de la Tabla

Tabla 1 Autovalores obtenidos del análisis de correspondencia.

Leyendas de las Figuras

Figura 1 Análisis de correspondencia de las variables relacionadas con el krill. Proyección sobre los ejes 1 (horizontal) y 2 (vertical). Las estaciones en las cuales el krill fue sumamente abundante se representan por KKKK, o por *KKK, si las estaciones sin krill tienen las mismas coordenadas. Los puntos marcados con ! están fuera de escala. Especies *Pachyptila* = Pach; especies *Pygoscelis* = Pygs; *Oceanites oceanicus* = OOCE; *Pagodroma nivea* = PNYV; *Fulmarus glacialoides* = FGLA; *Daption capense* = DCAP; especies *Macronectes* = Macr; *Diomedea exulans* ± *Diomedea epomophora* = Derr; *Diomedea melanophris* = DMEL; *Phoebetria palpebrata* = PPAL.

Figura 2 Análisis de correspondencia de las variables relacionadas con el krill. Proyección sobre los ejes 2 (horizontal) y 3 (vertical). Los encabezamientos son iguales a los de la Figura 1.

Figura 3 Análisis de correspondencia de todas las variables. Proyección sobre los ejes 1 (horizontal) y 2 (vertical). Los encabezamientos son iguales a los de la Figura 1.

Figura 4 Análisis de correspondencia de todas las variables. Proyección sobre los ejes 2 (horizontal) y 3 (vertical). Los encabezamientos son iguales a los de la Figura 1.

Figura 5 Trazado de contorno de los centroides de cinco niveles de krill en el espacio definido por las 10 variables en orden decreciente. Datos en bruto.

Figura 6 Trazado de contorno de los centroides de cinco niveles de krill en el espacio definido por todas las variables, excepto las especies *Pygoscelis* en orden decreciente. Datos en bruto.

Figura 7 Trazado de contorno de los centroides de cinco niveles de krill en el espacio definido, por las variables sensibles (en base a datos obtenidos de la documentación) en orden decreciente. Datos en bruto.

Figura 8 Trazado de contorno de los centroides de tres niveles de krill en el espacio definido por todas las variables sensibles en orden decreciente. Datos transformados a logaritmos.

Figura 9 Trazado de contorno de los centroides de tres niveles de krill en el espacio definido por todas las variables sensibles, excepto las especies Pygoscelis en orden decreciente. Datos transformados a logaritmos.

Figura 10 Perfiles de los valores medios de tres niveles de abundancia de krill. Datos transformados a logaritmos. (+ = escaso o ausente, * = presente o abundante, # = muy abundante).

Figura 11 Trazado Cuantil de Contorno para las medidas de la posición del tratamiento 1 (krill escaso o ausente). 1^{er} Décil (.), 1^{er} Cuartil (-), Mediana (*), 3^{er} Cuartil (^) y 9^{o} Décil (,). Transformados a logaritmos.

Figura 12 Trazado Cuantil de Contorno para las medidas de la posición del tratamiento 2 (krill presente o abundante). 1^{er} Décil (.), 1^{er} Cuartil (-), Mediana (*), 3^{er} Cuartil (^) y 9^{o} Décil (,). Transformados a logaritmos.

Заголовок к таблице

Таблица 1 Собственные значения, полученные при анализе совпадений.

Подписи к рисункам

Рисунок 1 Анализ совпадений переменных, относящихся к крилю. Проекции на оси 1(горизонтальную) и 2(вертикальную). Станции, во время выполнения которых количество криля было очень велико, отмечены символом КККК или *ККК - если у станций без криля те же самые координаты. Точки, помеченные "!", выходят за пределы масштаба. Pach - виды Pachyptila, Pygs - виды Pygoscelis; OOCE - Oceanites oceanicus, PNYV - Pagodroma nivea, FGLA - Fulmarus glacialoides, DCAP - Daption capense, Macr - виды Macronectes, Derr - Diomedea exulans + Diomedea epomophora, DMEL - Diomedea melanophris, PPAL - Phoebetria palpebrata.

Рисунок 2	Анализ совпадений переменных, относящихся к крилю. Проекции на оси 2(горизонтальную) и 3(вертикальную). Условные обозначения - как и на Рисунке 1.
Рисунок 3	Анализ совпадений всех переменных. Проекции на оси 1(горизонтальную) и 2(вертикальную). Условные обозначения - как и на Рисунке 1.
Рисунок 4	Анализ совпадений всех переменных. Проекции на оси 2(горизонтальную) и 3(вертикальную). Условные обозначения - как и на Рисунке 1.
Рисунок 5	Контурное построение центроид пяти уровней количества криля в пространстве, определенном 10-ю переменными в порядке убывания. Необработанные данные.
Рисунок 6	Контурное построение центроид пяти уровней количества криля в пространстве, определенном всеми переменными, кроме видов Pygoscelis, в порядке убывания. Необработанные данные.
Рисунок 7	Контурное построение центроид пяти уровней количества криля в пространстве, определенном чувствительными (по опубликованным данным) переменными в порядке убывания. Необработанные данные.
Рисунок 8	Контурное построение центроид трех уровней количества криля в пространстве, определенном всеми чувствительными переменными в порядке убывания. Данные, преобразованные логарифмированием.
Рисунок 9	Контурное построение центроид трех уровней количества криля в пространстве, определенном всеми чувствительными переменными, кроме видов Pygoscelis, в порядке убывания. Данные, преобразованные логарифмированием.
Рисунок 10	Профили средних величин трех уровней количества криля. Данные, преобразованные логарифмированием. (+ - редко встречается или отсутствует, * - имеется или имеется в изобилии, # - очень большое количество).
Рисунок 11	Квантильное построение контуров позиционных измерений ситуации 1 (редко встречающийся или отсутствующий криль). 1-й дециль (.), 1-й квартиль (-), медианное значение (*), 3-й квартиль (^) и 9-й дециль (,). Данные, преобразованные логарифмированием.

Рисунок 12 Квантильное построение контуров позиционных измерений ситуации 2 (имеющийся или имеющийся в изобилии криль). 1-й дециль (.), 1-й квартиль (-), медианное значение (*), 3-й квартиль (^) и 9-й дециль (,). Данные, преобразованные логарифмированием.

SC-CAMLR-VI/BG/18
(WG-CEMP-87/7)

SURVEY OF ANTARCTIC FUR SEALS IN THE SOUTH SHETLAND ISLANDS, ANTARCTICA, DURING THE 1986/87 AUSTRAL SUMMER

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Abstract

A survey of Antarctic fur seals in the South Shetland Islands, Antarctica, during the 1986/87 austral summer indicated that this species is continuing its population recovery and recolonization of rookery sites following 19th Century commercial exploitation. Twelve fur seal pupping sites were identified, some of which had not previously been reported. The largest pupping sites are at Telmo Island and Cape Shirreff, on the north coast of Livingston Island. Total fur seal pup production in the South Shetland Islands in 1986/87 is estimated to be approximately 4000 individuals. Notes on other pinniped species observed during the survey are presented. The optimal sites for combined fur seal and penguin monitoring activites, as part of the CCAMLR Ecosystem Monitoring Program, are recommended as Seal Island, Elephant Island; Stigant Point, King George Island; and Cape Shirreff/Telmo Island, Livingston Island.

Résumé

Une prospection des otaries antarctiques dans les Iles Shetland du Sud, Antarctique, au cours de l'été austral 1986/87 a indiqué que le repeuplement de cette espèce se poursuit et que ses colonies se développent à nouveau après l'exploitation commerciale dont elle a fait l'objet au cours du 19ème siècle. Douze sites de parturition ont été identifiés, dont certains n'avaient pas été signalés auparavant. Les plus grands sites de parturition se trouvent à l'Ile Telmo et au Cap Shirreff, sur la côte nord de l'Ile Livingston. La production totale d'otaries nouveau-nées dans les Iles Shetland du Sud en 1986/87 est estimée à environ 4000 individus. Des notes sur d'autres espèces de pinnipèdes observées au cours de la prospection sont présentées. Les sites optimums suivants sont recommandés pour des activités de contrôle combinées portant sur les otaries et les manchots, dans le cadre du Programme de contrôle de l'écosystème de la CCAMLR: l'Ile des Phoques, Ile Eléphant; Stigant Point, Ile du Roi George; et le Cap Shireff et l'Ile Telmo, Ile Livingston.

Resumen

Una prospección de las focas peleteras antárticas en las Islas Shetland del Sur, Antártida, durante el verano austral de 1986/87 indicó que esta especie está continuando la recuperación de su población y la recolonización de los sitios de anidamiento luego de la explotación comercial del siglo 19. Se identificaron doce sitios de cría de focas peleteras, algunos de los cuales no habían sido informados previamente. Los mayores sitios de cría se encuentran en la isla Telmo y en el Cabo Shirreff, en la costa norte de la isla Livingston. La producción total de cachorros de foca peletera en las Islas Shetland del Sur en 1986/87 se estima en aproximadamente 4000 individuos. Se presentan notas acerca de otras especies de pinípedos observadas durante la prospección. Los sitios óptimos recomendados para las actividades combinadas de control de focas peleteras y pringüinos, como parte del Programa de CCAMLR de Control del Ecosistema, son la isla Seal, la isla Elephant; Stigant Point, la isla King George y el Cabo Shirreff/Isla Telmo, isla Livingston.

Резюме

Съемка южных морских котиков в районе Южных Шетландских островов, Антарктика, в течение австрального лета 1986/87 г. показала, что популяции этого вида продолжают восстанавливаться и вновь занимать старые залежки - после коммерческой эксплуатации вида в XIX веке. Было зарегистрировано двенадцать щенных залежек; о некоторых из них ранее не сообщалось. Крупнейшие щенные залежки находятся на острове Телмо и мысе Ширефф, северный берег острова Ливингстон. Общее количество появившихся на свет щенков морского котика на Южных Шетландских островах в 1986/87 г. оценивается приблизительно в 4000 особей. Также представлены заметки о других видах ластоногих, наблюдавшихся во время проведения съемки. В качестве оптимальных участков для проведения комплексного мониторинга морских котиков и пингвинов в рамках Программы АНТКОМа по мониторингу экосистемы рекомендуются: остров Сил - остров Элефант, мыс Стигант - остров Кинг-Джордж и мыс Ширефф/остров Телмо - остров Ливингстон.

SURVEY OF ANTARCTIC FUR SEALS (ARCTOCEPHALUS GAZELLA) IN THE SOUTH SHETLAND ISLANDS, ANTARCTICA, DURING THE 1986/87 AUSTRAL SUMMER

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INTRODUCTION

Antarctic fur seals, *Arctocephalus gazella*, were commercially harvested and nearly exterminated in the 19th century. In the 1930's small numbers of fur seals (tens of individuals) were once again seen at Bird Island, South Georgia (Bonner, 1968). Since 1956, when censuses were begun in the South Georgia vicinity, the number of pups born at Bird Island and South Georgia increased to a population estimated in the early 1980's at just under 1 million (Payne 1977; Bonner, 1981; Laws 1984). At present, the majority of Antarctic fur seal pups are born at Bird Island, South Georgia, and the Willis Islands, although daughter rookeries have been re-established during the past several decades throughout the Scotia Arc and elsewhere (Bonner 1968; Laws 1984). Surveys have been made during the breeding season at several of these sites but census coverage has been incomplete. Fur seals in the South Shetland Islands have been censused sporadically over the past 80 years, with the first post-exploitation record of successful pup production being reported by O'Gorman (1961) at Cape Shirreff, Livingston Island, in January 1958. However, no attempts to census the entire archipelago have been made since 1965/66 when Aguayo and Torres (1967) surveyed fur seal abundance.

The survey reported here focused on the South Shetland Islands and had three principal objectives : 1) to document the recolonization and current distribution of Antarctic fur seal rookeries, 2) to estimate the current annual pup production in the archipelago, and 3) to identify fur seal rookeries suitable as potential monitoring sites in the land-based network of the CCAMLR Ecosystem Monitoring Program.

METHODS

Surveys were conducted between 23 December 1986 and 12 February 1987 during research cruises aboard the USCGC *Glacier* and the R/V *Prof. Siedlecki*. From 23 December 1986 to 2 January 1987, helicopters from the USCG *Glacier* were used to survey all coastlines of the Elephant Island group, including the Seal Islands, Cornwallis, Clarence, Gibbs, Aspland, and O'Brien Islands (Figure 1). Surveys were flown at approximately 100 meters altitude, with photographs taken of large groups to assist in estimating group size (e.g., southern elephant seals, *Mirounga leonina*). Although the survey focused on Antarctic fur seals, all pinnipeds observed hauled out on land were counted. Species which routinely haul out on ice (e.g., crabeater seals, *Lobodon carcinophagus*, and leopard seals, *Hydrurga leptonyx*) were only sighted on land infrequently whereas southern elephant seals (hauled out on beaches for their annual molting period) were sighted often. Counts of all pinnipeds were tallied by species, with no differentiation made between age and sex classes except for fur seals. At sites where fur seal pups were present, observers counted living and dead pups by censusing colonies on foot.

Surveys from the R/V *Prof. Siedlecki* were conducted between 25 January to 12 February 1987 and were performed by navigating inflatable boats near shore. All ice-free coasts of the South Shetland Islands between Low and Smith Islands and King George Island were examined in this fashion (Figure 1). Where fur seals were observed in abundance, observers landed to search for pups by walking through haulout areas.

RESULTS

A total of 12 Antarctic fur seal pupping sites were identified, some of which were not known prior to this survey (Tables 1 and 2). Numbers of Antarctic fur seal pups at various sites ranged between a single pup each at Fildes Peninsula, Desolation Island, and Smith Island, to 1895 pups (including 235 dead pups) at the Telmo Island north of Livingston Island. Most pupping sites were located on or near King George, Livingston, or Elephant Islands. Only bachelor male fur seals were observed at other sites. No pupping sites were located on the southern coasts of islands along the Bransfield Strait.

Even though the fur seal population is increasing in the South Shetland Islands, not all of the islands known to have had fur seal rookeries prior to exploitation are currently occupied. Our census revealed that although fur seal colonies are being established successfully along the northern coastlines of the South Shetland Islands, recolonization of the southern coasts has not yet begun. Southern coasts are known to have been the sites of large fur seal rookeries which were subjected to heavy commercial exploitation in the 1820/21 and 1821/22 seasons (Stackpole, 1955; Bertrand, 1971). In addition, no fur seals were observed at Cornwallis, Clarence, Gibbs, Aspland or O'Brien Islands. The absence of animals at these islands conforms to previous survey data which indicated few Antarctic fur seals in these areas (Aguayo and Torres, 1967; Hunt 1973; Aguayo 1978).

DISCUSSION

Survey results indicate that both the pup production and the distribution of Antarctic fur seals are continuing to increase in the South Shetland Islands (Table 3). Even for those sites in years when data on the number of pups are not available, the total number of individuals observed appears to be increasing in most areas.

The reason for the differences in growth rates of rookery size between the three islands listed in Table 3 is unknown. Whereas rookeries at Elephant and Livingston Islands have expanded signficantly over the past two decades, the number of pups born at Stigant Point, King George Island, has remained essentially unchanged. To the human observer, there appears to be sufficient space on the Stigant Point beaches for rookery growth. These areas are currently utilized as haulout areas by bachelor males. Determining the extent to which potential difference in habitat and local prey resources between these sites may influence pup survival and rookery expansion requires further study.

Three fur seal pupping sites were identified as potentially good locations for incorporation into the CCAMLR Ecosystem Monitoring Program network : 1) Seal Island, Elephant Island, 2) Stigant Point, King George Island, and 3) Cape Shirreff, Livingston Island. Each of these sites meets the following criteria which are considered important for establishing a field camp for monitoring purposes : 1) at least 100 fur seal pups born annually, 2) at least 10,000 nesting chinstrap penguins, Pygoscelis antarctica, available for similar monitoring studies, and 3) a suitable camp site available for a field team. Cape Shirreff and Seal Island are particularly well suited as monitoring sites because of their abundance of fur seals and geographic position in relation to krill fishing areas. The relative advantages of establishing a monitoring program at these sites will be considered further within national programs and the Working Group for the CCAMLR Ecosystem Monitoring Program.

ACKNOWLEDGEMENTS

The authors are grateful to the officers and crew of the USCG Glacier and the R/V Prof. Siedlecki for excellent logistic support in the field. We also thank M.E. Goebel, R.L. Merrick, S.D. Osmek, W.D. Shuford, and L.B Spear for assistance in the field and laboratory. This work was supported by the National Marine Fisheries Service's Antarctic Marine Living Resources Program and the National Science Foundation's Division of Polar Programs.

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Table 1. Pinniped census in the South Shetland Islands, Antarctica, during the 1986/87 austral summer (E=elephant seal, W=Weddell seal, C=crabeater seal, L=leopard seal).

Location	Fur Seals				E	W	C	L
	Male	Female	Pups Alive	Pups Dead				
King George I.	3,326	147	146	12	2,932	386	2	1
Nelson Island	186	–	–	–	1,070	432	1	1
Robert Island	194	–	–	–	549	141	1	2
Greenwich I.	235	–	–	–	423	40	–	–
Livingston I.	1,912	129	298	–	4,898	264	1	1
Cape Shirreff	1,650	844	673	178	772	134	1	–
Telmo Island	1,607	2,299	1,660	235	3	3	–	–
Snow Island	652	–	–	–	1,494	157	5	–
Smith Island	105	2	1	–	–	8	–	–
Low Island	418	–	–	–	251	34	–	–
Deception Island	520	–	–	–	3	48	1	–
Elephant Island	153	191	235	15	1,315	–	21	4
Seal Island	286	200	241	8	232	4	1	3
Large Leap I.	73	167	254	21	–	–	–	–
Total	11,317	3,979	3,508	469	13,942	1,651	34	12

Table 2. Summary of Antarctic fur seal pup production in the South Shetland Islands, Antarctica, in 1986/87.

Location	Live	Dead	Total
Seal Island (Elephant Is.)	241	8	249
Large Leap Island (Elephant Is.)	254	21	275
Cape Valentine (Elephant Is.)	42	3	45
Cape Lindsey (Elephant Is.)	191	12	203
Stinker Point (Elephant Is.)	2	0	2
Stigant Point (King George Is.)	145	12	157
Fildes Peninsula (King George Is.)	1	0	1
Desolation Island (Livingston Is.)	1	0	1
Cape Shirreff (Livingston Is.)	673	178	851
Telmo Island (Livingston Is.)	1,660	235	1,895
Window Island (Livingston Is.)	297	-	297
Smith Island	1	0	1
Total	3,508	469	3,977

Table 3. Changes in Antarctic fur seal pup production at important rookery sites in the South Shetland Islands, Antarctica. Sites listed are for those areas for which there are past census data comparable with the 1986/87 survey.

Location	Date	Pups[1]	Total[2]	Source
ELEPHANT ISLAND				
Seal Island	7 Jan 66	--	20	Aguayo 1978
	13 Dec 70	16	62	Hunt 1973
	24 Dec 86	249	1250	1986/87 survey
Cape Valentine	16 Feb 66	2	30	Aguayo 1978
	9 Feb 71	3	100	Hunt 1973
	30 Jan 87	45	121	1986/87 survey
Cape Lindsey	16 Feb 66	3	70	Aguayo 1978
	Feb 71	--	30	Hunt 1973
	30 Jan 87	203	468	1986/87 survey
KING GEORGE ISLAND				
Stigant Point	16 Jan 70	123	213	Llano 1971
	Feb 73	80	250	Aguayo 1978
	Jan 82	168	293	Oliva et al. 1986
	1982/83	123	367	Oliva et al. 1986
	31 Jan 87	157	507	1986/87 survey
LIVINGSTON ISLAND				
Cape Shirreff	14 Jan 58	1	27	O'Gorman 1961
	2 Feb 59	2	11	O'Gorman 1961
	1 Jan 66	12	50	Aguayo 1978
	Feb 71	71	201	Aguayo 1978
	25 Jan 73	300	1741	Aguayo 1978
	Jan 82	60	532	Cattan et al. 1982
	1982/83	--	564	Oliva et al. 1986
	1983/84	248	969	Oliva et al. 1986
	1984/85	384	1590	Oliva et al. 1986
	2 Feb 87	851	3345	1986/87 survey
Window Island	21 Jan 66	50	150	Aguayo 1978
	25 Jan 73	70	320	Aguayo 1978
	3 Feb 87	297	646	1986/87 survey

1) Includes both living and dead pups.

2) Total Antarctic fur seals, including pups.

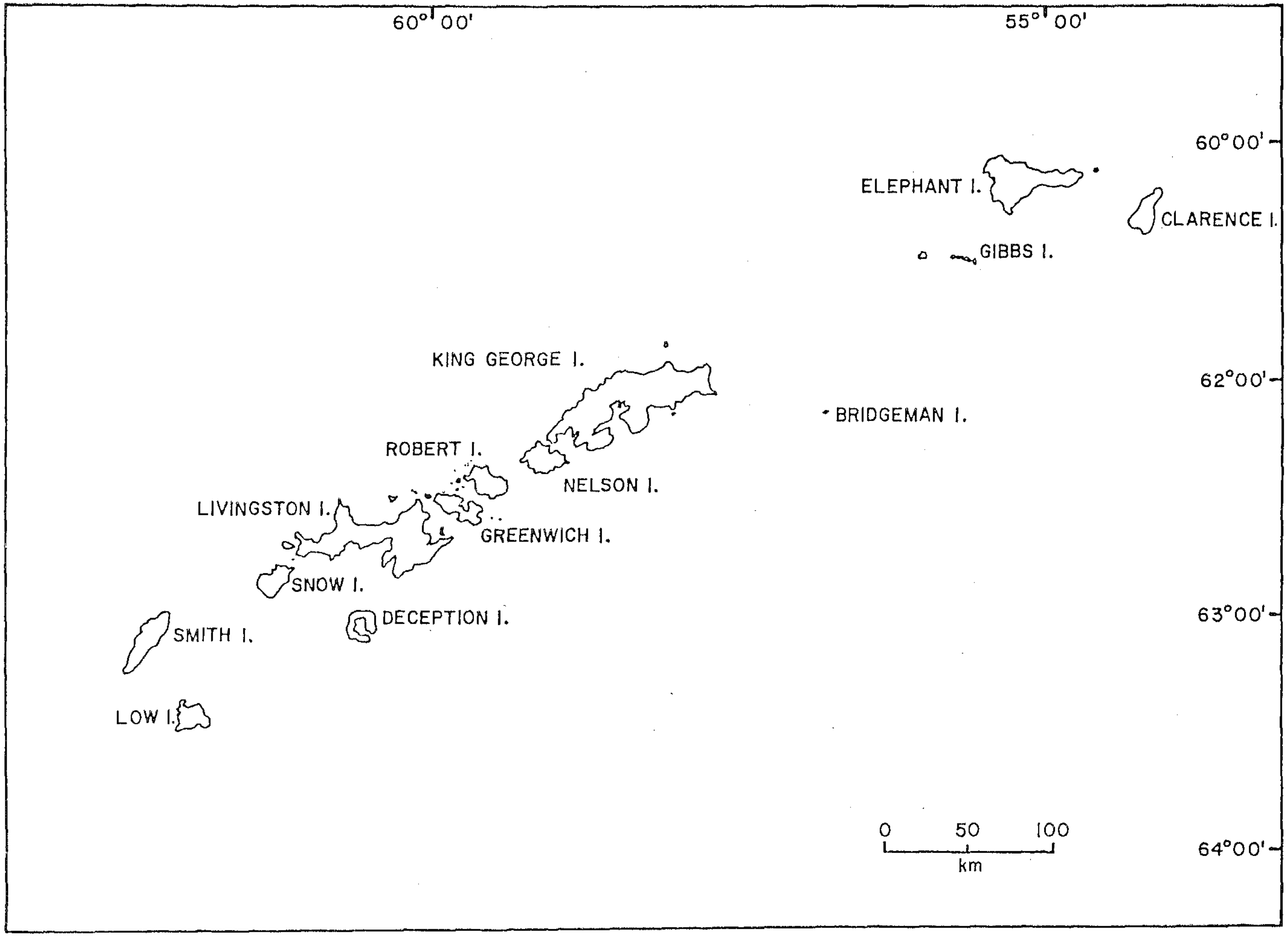

Figure 1. South Shetland Islands, Antarctica study area.

Légendes des tableaux

Tableau 1 Recensement des pinnipèdes dans les Iles Shetland du Sud, Antarctique, au cours de l'été austral 1986/87 (E = éléphant de mer, W = phoque de Weddell, C = phoque crabier, L = léopard de mer).

Tableau 2 Récapitulation de la production des petits des otaries antarctiques dans les Iles Shetland du Sud, Antarctique, en 1986/87.

Tableau 3 Changements dans la production des petits des otaries antarctiques à d'importants sites de colonies dans les Iles Shetland du Sud, Antarctique. Les sites indiqués correspondent aux régions pour lesquelles il existe des données de recensements antérieurs comparables à la prospection de 1986/87.

Légende de la figure

Figure 1 Iles Shetland du Sud, Antarctique, zone d'étude.

Encabezamientos de las Tablas

Tabla 1 Censo de los pinípedos en las Islas Shetland del Sur, Antártida, durante el verano austral de 1986/87 (E = elefante marino, W = foca de Weddel, C = foca cangrejera, L = foca leopardo).

Tabla 2 Resumen de la producción de cachorros de foca peletera en las Islas Shetland del Sur, Antártida, en 1986/87.

Tabla 3 Cambios en la producción de cachorros de foca peletera en importantes sitios de reproducción en las Islas Shetland del Sur, Antártida. Los sitios que se indican corresponden a aquellas áreas para las cuales existen datos de censos anteriores comparables con los de la prospección de 1986/87.

Leyenda de la Figura

Figura 1 Islas Shetland del Sur, Antártida, área de estudio.

Заголовки к таблицам

Таблица 1 Учет численности ластоногих Южных Шетландских островов, Антарктика, в течение австрального лета 1986/87 г. (E - морской слон, W - тюлень Уэдделла, C - тюлень-крабоед, L - морской леопард).

Таблица 2 Сводка по рождаемости у южного морского котика Южных Шетландских островов, Антарктика, в 1986/87 г.

Таблица 3 Изменения в рождаемости у южного морского котика на основных лежбищах Южных Шетландских островов, Антарктика. Перечислены лежбища в тех районах, по которым имеются полученные при проведении в прошлом учета численности данные, которые можно сравнить с результатами съемки 1986/87 г.

Подпись к рисунку

Рисунок 1 Южные Шетландские острова, Антарктика, - район изучения.

SC-CAMLR-VI/BG/14 Rev.1
(WG-CEMP-87/14)

LONG-TERM TRENDS IN THE FORAGING PATTERNS OF FEMALE ANTARCTIC FUR SEALS AT SOUTH GEORGIA*

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Abstract

The number of feeding trips to sea made by female Antarctic fur seals during lactation may reflect the relative availability of local prey resources. Experimental work utilizing tetracycline-marked teeth confirmed that the feeding trip/suckling cycles of females are reflected as starving/suckling layers in the teeth of their pups. A collection of unmarked Antarctic fur seal teeth from Bird Island, South Georgia, was analyzed to estimate : 1) birth year of individuals, and 2) the number of feeding trips made by an individual's mother during lactation.

This analysis showed that between 1962 and 1981 the mean number of feeding trips made by female fur seals varied markedly. From 1962 to 1979 there were several significant increasing and decreasing trends in the mean number of feeding trips, with 1979 being the year with the fewest trips made during the entire 20 year period.

* In press _in_ : Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

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Résumé

Le nombre de voyages alimentaires en mer effectués par les otaries femelles de l'Antarctique au cours de la lactation peut indiquer la disponibilité relative des ressources en proies locales. Des travaux expérimentaux basés sur l'utilisation de dents marquées à la tétracycline ont confirmé qu'aux cycles voyage alimentaire/allaitement des femelles correspondent des couches sous-alimentation/allaitement dans les dents de leurs petits. Un ensemble de dents non-marquées d'otaries antarctiques provenant de l'Ile Bird, Géorgie du Sud, a été analysé afin d'estimer : 1) l'année de naissance des individus et 2) le nombre de voyages alimentaires effectués par la mère d'un individu au cours de la lactation.

Cette analyse a montré que le nombre moyen de voyages alimentaires effectués par les otaries femelles variait nettement entre 1962 et 1981. De 1962 à 1979 sont apparues plusieurs tendances marquées indiquant une augmentation ou une baisse du nombre moyen de voyages alimentaires, 1979 étant l'année durant laquelle les voyages ont été les moins nombreux sur la période de 20 ans.

* Sous presse dans : Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

Resumen

El número de viajes al mar para alimentación hechos por las focas peleteras antárticas hembra durante la lactación puede reflejar la disponibilidad relativa de los recursos de especies presa locales. Un trabajo experimental utilizando dientes marcados con tetraciclina confirmó que los ciclos de viaje para alimentación/amamantamiento de las hembras se reflejan como capas de privación de alimento/amamantamiento en los dientes de sus cachorros. Se analizó una colección de dientes no marcados de foca peletera antártica de la Isla Bird, Georgia del Sur, para estimar : 1) el año de nacimiento de los individuos, y 2) el número de viajes para alimentación hechos por la madre de un individuo durante la lactación.

Este análisis mostró que entre 1962 y 1981 el número medio de viajes de alimentación hechos por las focas peleteras hembra varió marcadamente. Desde 1962 hasta 1979 hubo varias tendencias crecientes y decrecientes significativas en el número medio de viajes para alimentación, siendo 1979 el año con la menor cantidad de viajes hechos durante todo el período de 20 años.

* En prensa en : Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

Резюме

Количество совершаемых самкой южного морского котика выходов в море в поисках пищи в период лактации может отражать относительную доступность местных запасов потребляемых видов. Экспериментальные работы с использованием мечения зубов тетрациклином подтвердили, что циклы поиск пищи/вскармливание у самок соответствуют в зубах щенков чередованию слоев голодания/сосания. Коллекция немеченных зубов южного морского котика с острова Берд и Южной Георгии подверглась анализу с целью определения: 1) года рождения конкретных особей и

2) количества выходов в поисках пищи, совершенных матерью какой-либо особи в период лактации.

Результаты анализа показали, что в промежутке между 1962 и 1981 годом среднее количество выходов в поисках пищи, совершенных различными самками морского котика, сильно варьировалось. С 1962 по 1979 год наблюдались несколько раз тенденции к существенному увеличению и уменьшению среднего количества выходов в поисках пищи, при этом 1979 год оказался годом, когда было сделано наименьшее количество выходов за весь 20-летний период.

* В периодике в: Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

SC-CAMLR-VI/BG/15
(WG-CEMP-87/13)

REPRODUCTIVE PERFORMANCE OF SEABIRDS AND SEALS AT SOUTH GEORGIA AND SIGNY ISLAND, SOUTH ORKNEY ISLANDS, 1976-1987 : IMPLICATIONS FOR SOUTHERN OCEAN MONITORING STUDIES*

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Abstract

Aspects of the reproductive performance over the last decade of Black-browed, Grey-headed and Wandering Albatrosses, Gentoo and Macaroni Penguins and Antarctic Fur Seals, at Bird Island, South Georgia and for Adélie and Chinstrap Penguins at Signy Island, South Orkney Islands, are summarised and reviewed. Breeding success of the Wandering Albatross, which breeds in winter and eats fish and squid, has remained constant, while population size has declined gradually but significantly. The other species at South Georgia, which breed in summer and feed extensively on krill, have shown major fluctuations in some or all of : breeding population size, breeding success, foraging trip duration and offspring growth rate. 1977-78 and 1983-84 were summers of particularly poor reproductive performance by almost all species; circumstantial evidence relating this to reduced availability of krill is discussed. The fluctuations in reproductive performance of the krill-eating, summer-breeding penguins at Signy Island are not synchronised with those at South Georgia; they correlate best (especially for Chinstraps, which suffered badly in 1980-81 and 1982-83) with the date of ice break-out in late spring. Numerous parameters of albatross, penguin and fur seal biology are reviewed in terms of their sensitivity and suitability for detecting changes in the marine environment.

* In press _in_ : Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

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Résumé

Sont résumés et examinés des aspects de la performance de reproduction au cours de la dernière décennie du grand albatros, de l'albatros à sourcils noirs et de l'albatros à tête grise, du manchot papou et du gorfou doré, et de l'otarie antarctique à l'Ile Bird, Géorgie du Sud, ainsi que des manchots Adélie et à jugulaire à l'Ile Signy, Orcades du Sud. La réussite de reproduction du grand albatros, qui se reproduit en hiver et se nourrit de poissons et de calmars, est demeurée constante alors que la taille de la population a connu une baisse graduelle et fort sensible. Chez les autres espèces de la Géorgie du Sud, qui se reproduisent en été et se nourrissent en grande partie de krill, sont apparues des fluctuations importantes dans certains ou dans tous les domaines suivants : taille de la population reproductrice, réussite de la reproduction, durée des sorties d'approvisionnement et taux de croissance des juvéniles. La performance de reproduction de presque toutes les espèces a été particulièrement faible au cours des étés 1977-78 et 1983-84; ce document présente les preuves indirectes d'une relation entre cette faible performance et la disponibilité réduite de krill. Il n'existe pas de concordance entre, d'une part, les fluctuations dans la performance de reproduction des manchots se nourrissant de krill et se reproduisant l'été à l'Ile Signy et, d'autre part, celles qui surviennent en Géorgie du Sud; la meilleure corrélation (surtout pour les manchots à jugulaire qui ont été très affectés en 1980-81 et 1982-83) correspond à la date de libération des glaces à la fin du printemps. De nombreux paramètres de la biologie des albatros, des manchots et des otaries sont examinés sur le plan de leur sensibilité et de leur pertinence quant à la détection des changements dans le milieu marin.

* Sous presse dans : Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

Resumen

Se resume y revisan aspectos del rendimiento reproductivo durante la última década, de los albatros de ceja negra, de cabeza gris y Diomedea exulans (wandering albatros), de los pingüinos Gentoo y Macaroni y de las focas peleteras antárticas en la Isla Bird, Georgia del Sur, y para los pingüinos Adélie y Chinstrap en la Isla Signy, Islas Orcadas del Sur. El éxito reproductivo de Diomedea exulans (wandering albatros), el cual se reproduce en invierno y se alimenta de peces y calamar, ha permanecido constante, mientras que el tamaño de la población ha declinado gradual pero significativamente. Las otras especies en Georgia del Sur, que se reproducen en verano y se alimentan extensamente de krill, han evidenciado fluctuaciones importantes en algunos o todos de los siguientes : tamaño de la población reproductiva, éxito reproductivo, duración de los viajes de forrajeo y tasa de crecimiento de las crías. Los veranos de 1977-78 y 1983-84 fueron de rendimiento reproductivo particularmente pobre para casi todas las especies; se discute la evidencia circunstancial que relaciona esto a una reducción en la disponibilidad del krill. Las fluctuaciones en el rendimiento reproductivo de los pingüinos de la Isla Signy, los cuales se alimentan de krill y se reproducen en verano, no están sincronizadas con aquellas de Georgia del Sur; se correlacionan mejor (especialmente para los Chinstrap, los cuales sufrieron considerablemente en 1980-81 y 1982-83) con la fecha de ruptura del hielo en la última parte de la primavera. Se revisan numerosos parámetros de la biología de los albatros, pingüinos y focas peleteras en términos de su sensibilidad y capacidad para la detección de cambios en el medio ambiente marino.

* En prensa en : Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

Резюме

Сведены вместе и рассматриваются аспекты процесса воспроизводства за последнее десятилетие у чернобрового, сероголового и странствующего альбатросов, папуасского и золотоволосого пингвинов и южного морского котика в районе острова Берд, Южной Георгии и у пингвинов Адели и чинстрап в районе острова Сигни, Южные Оркнейские острова. Репродуктивный успех у странствующего альбатроса, который выводит птенцов зимой и питается рыбой и кальмарами, оставался постоянным, в то время как размер популяции медленно, но существенно сокращался. У других видов, обитающих у Южной Георгии, которые выводят птенцов летом и питаются в основном крилем, наблюдались сильные флуктуации в некоторых или во всех нижеперечисленных аспектах: размер размножающейся популяции, репродуктивный успех, длительность периодов поиска пищи и скорость роста потомства. Лето 1977-78 г.г. и лето 1983-84 г.г. были особенно неудачными в плане воспроизводства почти для всех видов; обсуждаются косвенные сведения, позволяющие связать это с понизившейся доступностью криля. Флуктуации в воспроизводстве пингвинов острова Сигни, которые питаются крилем и выводят птенцов летом, не совпадают по времени с таковыми на Южной Георгии; лучше всего они соответствуют (особенно для пингвинов чинстрап, для которых года 1980-81 и 1982-83 оказались чрезвычайно неудачными) времени вскрытия ледяного покрова в конце весны. Многочисленные биологические параметры альбатросов, пингвинов и морских котиков рассматриваются в отношении их чувствительности и применимости к выявлению изменений в морской окружающей среде.

* В периодике в: Sahrhage, D. (ed). Antarctic Ocean and Resources Variability. Springer. Berlin, Heidelberg, New York, Tokyo.

SC-CAMLR-VI/BG/19
(WG-CEMP-87/6)

SURVEYS OF BREEDING PENGUINS AND OTHER SEABIRDS IN THE SOUTH SHETLAND ISLANDS, ANTARCTICA, JANUARY-FEBRUARY 1987*

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Abstract

Surveys conducted as part of the Antarctic Marine Living Resources Program in 1987 provided data on the number, size, and location of penguin and Antarctic blue-eyed shag colonies and the breeding status of other seabirds in the South Shetland Islands, Antarctica. We encountered several species at many more sites than previously reported, thus increasing the known breeding localities of sheathbills and skuas by threefold, chinstrap penguins by twofold, and Cape petrels and shags by 50%. Our minimum estimate of 1 620 000 breeding Chinstrap penguins, the most abundant penguin in the study area, is about 2.5 times greater than the previous estimate. Although there appears to have been about 40% overall increase in the chinstrap population in the last 20-30 years, about three-fourths of the difference between our counts and previous ones is due to more complete coverage of available nesting habitat in 1987. For the same reason, at least in part, other species of breeding seabirds were also found to be more abundant than previously reported.

* published in NOAA Technical Memorandum NMFS Antarctic Marine Living Resources Program (AMLR)

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Résumé

Des prospections effectuées en 1987 dans le cadre du Programme des ressources marines vivantes de l'Antarctique ont fourni des données sur le nombre, la taille et la position des colonies de manchots et de Phalacrocorax atriceps antarctiques, ainsi que sur la situation concernant la reproduction des autres oiseaux de mer dans les Iles Shetland du Sud en Antarctique. Nous avons rencontré plusieurs espèces à beaucoup plus de sites qu'il avait été auparavant signalé, si bien que les lieux de reproduction connus des chionis et des skuas ont triplé, ceux des manchots à jugulaire ont doublé et ceux des pétrels à cape et des cormorans huppés ont augmenté de 50%. Notre estimation minimum de 1 620 000 manchots à jugulaire reproducteurs (l'espèce de manchot se trouvant en plus grand nombre dans la zone d'étude) est environ 2 fois et demie plus élevée que l'estimation précédente. Bien qu'il semble que la population des manchots à jugulaire ait augmenté globalement d'à peu près 40% au cours des dernières 20-30 années, environ les trois-quarts de la différence entre nos dénombrements et les précédents s'expliquent par une couverture plus complète en 1987 des habitats dont disposent les colonies reproductrices. En partie pour la même raison, l'on a également pu constater que d'autres espèces d'oiseaux de mer reproducteurs étaient plus abondantes que précédemment déclaré.

* publié dans NOAA Technical Memorandum NMFS Antarctic Marine Living Resources Program (AMLR)

Resumen

Las prospecciones realizadas como parte del Programa de los Recursos Vivos Marinos Antárticos en 1987 proporcionaron datos acerca del número, la talla y la ubicación de las colonias de pingüinos y cormoranes de ojos azules de la Antártida y del estado de reproducción de otras aves marinas en las Islas Shetland del Sur, Antártida. Encontramos varias especies en muchos más sitios de los que se habían dado a conocer previamente, triplicando de esa manera los lugares de reproducción conocidos de los pico de vaina y de los skúas, duplicando los de los pingüinos chinstrap y aumentando en un 50% los de los petreles de capa y los cormoranes. Nuestra estimación mínima de 1 620 000 pingüinos chinstrap reproductores, el pingüino de mayor abundancia en el área de estudio, es aproximadamente 2,5 veces mayor que la estimación previa. A pesar de que la población de los chinstrap parece haber aumentado globalmente alrededor del 40% en los últimos 20-30 años, aproximadamente tres cuartas partes de la diferencia entre nuestros recuentos y los previos se debe a una exploración más completa del hábitat de anidamiento disponible en 1987. Por la misma razón, al menos en parte, otras especies de aves marinas reproductoras fueron encontradas en mayor abundancia de lo informado previamente.

* publicado en NOAA Technical Memorandum NMFS Antarctic Marine Living Resources Program (AMLR)

Резюме

В результате съемок, проведенных в 1987 г. как часть Программы по морским живым ресурсам Антарктики, были получены данные по численности, размеру и местонахождению колоний пингвинов и антарктических голубоглазых бакланов и информация о репродуктивном состоянии других морских птиц на Южных

Шетландских островах, Антарктика. Несколько видов наблюдалось на гораздо большем, чем это было известно ранее, количестве участков; таким образом, в три раза увеличивается количество известных гнездовий лопатоклювых и поморников, в два раза - пингвинов чинстрап, и на 50% - капских голубков и бакланов. По нашим оценкам, размножающихся пингвинов чинстрап, самого многочисленного вида пингвинов в районе исследований, было как минимум 1620000, что в 2,5 раза больше, чем по предыдущим оценкам. Хотя, как кажется, за последние 20-30 лет общее количество пингвинов чинстрап увеличилось на 40%, примерно три четвертых разницы между нашими и предыдущими подсчетами следует отнести на счет того, что в 1987 г. более тщательно изучалась территория, пригодная для гнездовий. По той же причине, - по крайней мере частично, - было найдено, что количество размножающихся морских птиц других видов также больше, чем было известно ранее.

* опубликовано в NOAA Technical Memorandum NMFS Antarctic Marine Living Resources Program (AMLR)

SC-CAMLR-VI/BG/36

OBSERVATIONS ON HAUL-OUT PATTERNS AND TRENDS IN THE BREEDING POPULATIONS OF SOUTHERN ELEPHANT SEAL AT PENINSULA VALDES (PATAGONIA) AND STRANGER POINT (25 DE MAYO - KING GEORGE I.)

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Abstract

Southern elephant seal, Mirounga leonina, populations at Península Valdés (Patagonia) and 25 de Mayo-King George I. were studied during the breeding season from 1979 to 1987. Two main objectives were taken into consideration : haul-out pattern and the female population trend. In both places, the intrinsic population growth rate is positive. In 1982, at Stranger Point, a sharp decrease of the female component of the population was observed (r=-56.54%). The recovery of the population at Stranger Point, and the global increase at Península Valdés, indicate the good condition of these populations.

Résumé

Les populations d'éléphants de mer du Sud, Mirounga leonina, à Península Valdés (Patagonie) et 25 de Mayo-Ile du Roi George ont été étudiées au cours de la saison de reproduction de 1979 à 1987. Deux objectifs principaux ont été considérés : les caractéristiques de la venue à terre et les tendances de la population femelle. A ces deux endroits, le taux intrinsèque de croissance démographique est positif. En 1982, à Stranger Point, une forte diminution de la composante femelle de la population a été observée (r=-56,54%). Le repeuplement à Stranger Point et l'augmentation globale à Península Valdés indiquent la bonne condition de ces populations.

Resumen

Se estudiaron poblaciones de elefante marino austral, Mirounga leonina en la Península de Valdés (Patagonia) y en 25 de Mayo - Isla King George, durante la estación reproductora desde 1979 hasta 1987. Se tomaron en consideración dos objetivos principales : el patrón de emergida y la tendencia de la población de hembras. En ambos lugares, la tasa intrinseca de crecimiento de la población es positiva. Se observó en 1982, en Stranger Point, un brusco descenso del componente de hembras de la población (r=-56.54%). La recuperación de la población en Stranger Point, y el aumento global en la Península de Valdés, indican el buen estado de estas poblaciones.

Резюме

С 1979 по 1987 г. во время периода размножения проводились исследования популяций южного морского слона, *Mirounga leonina*, на полуострове Вальдес (Патагония) и на о-ве Кинг-Джордж. Внимание уделялось двум основным целям: изучению закономерностей в прибытии на лежбища и направления изменений в популяциях самок. Темп экспоненциального роста размера популяции - положительный в обоих местах. В 1982 г. на мысе Стрэнджер в популяции наблюдалось резкое уменьшение количества самок (r = -56,54%). Восстановление размеров популяции на мысе Стрэнджер и общее увеличение запасов на полуострове Вальдес указывают на то, что эти популяции - в хорошем состоянии.

OBSERVATIONS ON HAUL-OUT PATTERNS AND TRENDS IN THE BREEDING POPULATIONS OF SOUTHERN ELEPHANT SEAL AT PENINSULA VALDES (PATAGONIA) AND STRANGER POINT (25 DE MAYO - KING GEORGE I.)

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INTRODUCTION

Southern elephant seals, Mirounga leonina, breed on both sides of the Antarctic Convergence. Most of the breeding places are located on islands, except for the herd found on the coast of Península Valdés (Patagonia). The distribution of elephant seal breeding populations is circumpolar and they were recognized as three stocks : South Georgia, Kerguelen and Macquarie (Laws, 1960).

Population decrease was reported by several authors in different stocks : at Kerguelen (Skinner and van Aarde, 1983, Bester, 1982, Condy, 1979); at Macquarie (Burton et al., 1986). At South Georgia censuses were carried out in 1985-1986; the total population estimated was essentially the same as the abundance estimated from the 1951 survey (Croxall, 1986). It is possible that there could be more than one reason for this decrease. One reason could be the competition with fishing fleets since the onset of this decade and their possible influence on the reproductive success, and in the population trends (van Aarde, 1980).

In this paper we present information on the last seven years in two breeding places belonging to the Georgia stock. Two main objectives have been taken into consideration : haul-out pattern, and the female population trend. The first was considered to decide which method would be used in the population estimation of females from these two breeding places.

The second one was included because after the breeding season, females from Península Valdés go to the south (Scolaro 1976) and perhaps they could reach Antarctic waters where they would recover the weight lost during lactation (Vergani, 1986). Changes in food availability could be reflected in trends of the female component of these populations.

A first step in analysing this hypothesis was to compare an Antarctic population trend against a Patagonian one.

METHODS

Censuses were carried out in two different places. One of them was located at 25 de Mayo I. (King George) (1980-1986 except for 1981), where a study area of 5 km between Stranger and Elefante Point was fixed (62°14′ S - 58°30′ W). The other place was located at Península Valdés (Patagonia) (1981-1984). Censuses were carried out on 8 km of coastline; one isolated beach was determined to be representative of the original area and it was used every year to collect the information.

The maximum number of females at Stranger Point was calculated by females plus weaned and dead pups (McCann, 1985) and at Península Valdés a mathematical model as described by Lewis (in press) was used.

Estimates of intrinsic population growth rates were based on the exponential function : $N_t = N_o e^{rt}$ as suggested by Caughley (1977) like that of Skinner and van Aarde (1983).

RESULTS

Differences in time of females haul out were observed between Península Valdés and Stranger Point. Through the whole period of observations, the difference ranged between a minimum of 13 days and a maximum of 29. This variation reflects the different starting point of female arrival.

In Stranger Point the rank was 8/9 to 23/9 and at Península Valdés was 26/8 to 1/9. Similar differences were also found in the date of the peak of females ashore corresponding to 27/10, rank ± 3 to Stranger Point and to 30/9, rank ± 5 to Península Valdés.

Besides, the duration of the breeding season in Stranger Point was 10 days shorter (average) than Península Valdés. In both places it was independently observed, from year to year, the duration and the synchronization of the breeding season of cow haul out.

Differences between both populations may be observed in Figure 1.

In both places, the intrinsic population growth rate is positive (Figure 2). In 1982 in Stranger Point a sharp decrease of the female component of the population was observed ($\bar{r}$ = -56.54%). This fact could be related to some kind of disturbance of the austral ocean (e.g. "El Niño").

DISCUSSION

This paper shows that comparing both places the haul out pattern is different so their breeding seasons are not synchronic ones. If we wish to estimate the maximum number of females ashore on the basis of a single census, at Stranger Point this should be carried out after the 30/10 (27/10 plus the 3-days rank), and at Península Valdés after the 5/10 (30/9 plus 5-days rank). Here the weaning pups immigration from other areas would produce an overestimation of the female maximum number. That is why it was decided to use the model developed and used by Lewis (in press) in previous years to calculate Península Valdés population trends.

Migration between subantarctic and antarctic places after the breeding season have been confirmed with male of elephant seal from Kerguelen to Vestfold Hills (Burton, 1985).

In Patagonia, the number of females involved in the breeding season is greater than the number that goes there for moulting, while at Stranger Point exactly the opposite happens (Vergani, 1985). This fact would allow to speculate on a migration between subantarctic and antarctic places, but population trends do not show a sharp parallelism between them. At Península Valdés it did not happen the sharp decrease of the female component of the population that was observed at Stranger Point in 1982. Here, the most probable hypothesis is an "El Niño" (1982-1983) influence on the ecosystem. (This point will be dealt with in a future paper).

The recovering of the population at Stranger Point and the global increase at Península Valdés indicate the good conditions of these populations. The global increase at Península Valdés was obtained by comparing the total number of females of 1975 and 1982. The first was of 4 400 individuals, data obtained through transforming the number of pups censed by Scolaro (1976) in female number through the application of birth rate. The second was obtained through an aerial census carried out by Lewis (submitted to Marine Mammal Sciences) at the peak point of the breeding season, which rendered 6 400 individuals. The value of $\bar{r}$ between these two years is 0.05, similar to the one estimated for this population by McCann (1985) between 1971-1975.

Through the study of the diet and using directional and time depth recorders it could be proved the hypothesis of Patagonian females reaching Antarctic waters. On the other hand, the comparative study of population trends within the same stock will help achieve a better understanding of the factors affecting them.

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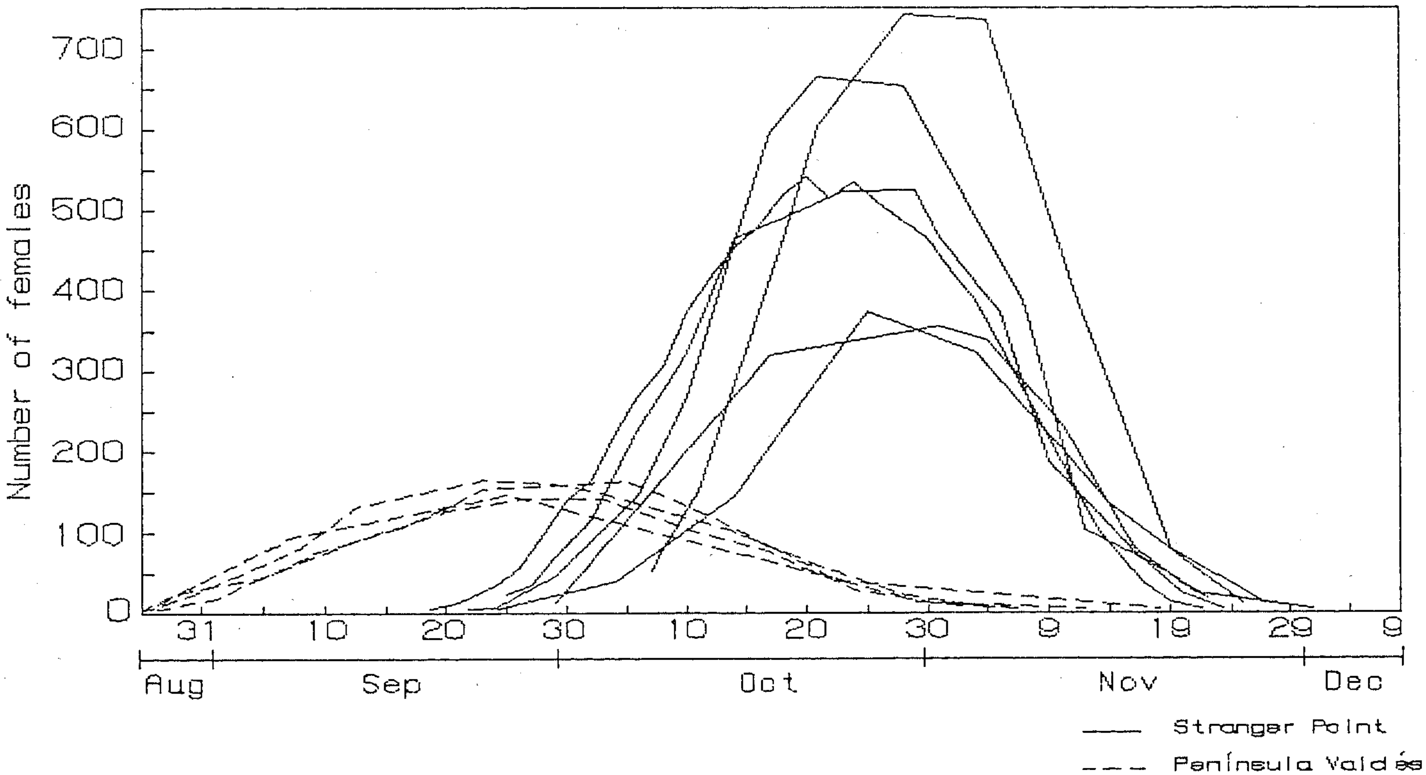

Figure 1 Fluctuations in the number of females during several breeding seasons at Stranger Point and Península Valdés.

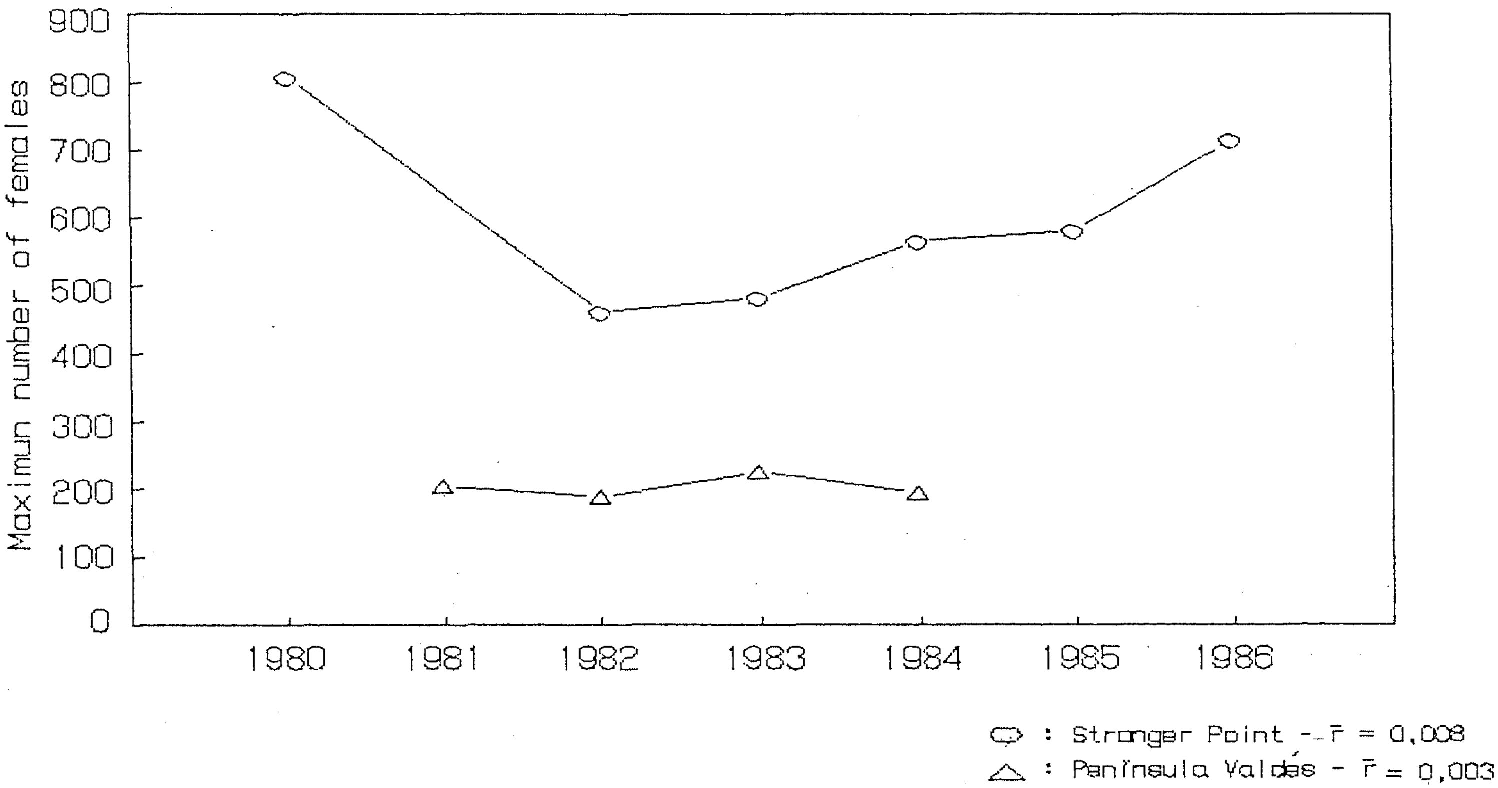

Figure 2 Trends in female component of southern elephant seal population.

Légendes des figures

Figure 1 — Fluctuations du nombre des femelles au cours de plusieurs saisons de reproduction à Stranger Point et Peninsula Valdés.

Figure 2 — Tendances relatives à la composante femelle de la population d'éléphants de mer du Sud.

Leyendas de las Figuras

Figura 1 — Fluctuaciones en el número de hembras durante varias temporadas de reproducción en Stranger Point y la Península de Valdés.

Figura 2 — Tendencias en el componente de hembras en la población de elefantes marinos australes.

Подписи к рисункам

Рисунок 1 — Изменения численности самок в течение нескольких периодов размножения на мысе Стрэнджер и полуострове Вальдес.

Рисунок 2 — Направления изменений в численности самок популяции южного морского слона.

SC-CAMLR-VI/BG/28

SOUTHERN ELEPHANT SEALS AND CCAMLR

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Abstract

This paper describes research findings of primarily South African (including some French and Australian results) studies on the southern elephant seal (Mirounga leonina) in the Kerguelen Province of the Southern Ocean. Sub-populations of this species have declined at Kerguelen, Marion, Prince Edward and Heard Islands. Population studies during the animals' terrestrial phase have failed to explain this observed decline which has also been recently confirmed for the Macquarie Island stock. The availability of food, competition with rapidly growing fur seal populations and competition with fishing fleets have all been suggested as possible causes of the elephant seal's decline in the region. Such explanations assume that a communal feeding ground, not yet identified, exists and that this exerts some common influence on the species' population dynamics. As such, study of both the elephant seal's spatial and temporal distribution during its pelagic phase is extremely important. Recent South African research in this field has been initiated and it is hoped that this will help to elucidate the reasons for the observed decline of M. leonina in the southern Indian Ocean.

Résumé

Ce document décrit les conclusions de recherches entreprises essentiellement par l'Afrique du Sud (et incorporant des résultats obtenus par la France et l'Australie) sur l'éléphant de mer du Sud (Mirounga leonina) dans la province de Kerguelen (océan Austral). Les sous-populations de cette espèce ont diminué dans les îles Kerguelen, Marion, Prince Edouard et Heard. Des études démographiques menées au cours de la phase terrestre des animaux n'ont pu expliquer cette baisse qui a également touché le stock de l'Ile Macquarie comme il vient d'être confirmé. La disponibilité de nourriture, la concurrence avec les populations d'otaries en rapide croissance et la concurrence avec les flottes de pêche ont été suggérées comme causes possibles du déclin de l'éléphant de mer dans la région. De telles explications supposent l'existence d'un secteur d'alimentation commun (qui n'a pas encore été identifié) ayant la même influence sur la dynamique démographique de l'espèce. L'étude de la répartition spatiale et temporelle de l'éléphant de mer au cours de sa phase pélagique est donc extrêmement importante. De récentes recherches sud-africaines dans ce domaine ont été engagées et il est permis d'espérer qu'elles aideront à expliquer les raisons de ce déclin de M. leonina dans l'océan Indien sud.

Resumen

Este documento describe los resultados de los estudios en su mayor parte sudafricanos (incluyendo algunos resultados franceses y australianos), sobre el elefante marino austral (Mirounga leonina) en la provincia de Kerguelén del Océano Austral. Las subpoblaciones de esta especie han declinado en las islas Kerguelén, Marion, Prince Edward y Heard. Los estudios de población durante la fase terrestre de los animales no han podido explicar esta declinación observada, la cual también ha sido confirmada recientemente para la reserva de la isla Macquarie. Tanto la disponibilidad de alimentos como la competencia con las rápidamente crecientes poblaciones de focas peleteras y la competencia con las flotas pesqueras, han sido sugeridas como causas posibles de la declimación del elefante marino en la región. Tales explicaciones suponen que existe un terreno de alimentación comunitario, aún no identificado, y que esto ejerce cierta influencia común sobre la dinámica de la población de las especies. Como tal, el estudio de las distribuciones tanto espacial como temporal del elefante marino durante su fase pelágica es extremadamente importante. Se ha iniciado recientemente una investigación sudafricana en este campo y se espera que esto ayudará a dilucidar las razones de la declinación observada de M. leonina en el Océano Indico austral.

Резюме

В этой работе описаны результаты исследований - в основном Южной Африки (включая некоторые результаты, полученные французскими и австралийскими учеными) - по южному морскому слону (Mirounga leonina) в области Кергелена, Южный океан. Подпопуляции этого вида сократились в районе островов Кергелен, Марион, Принц Эдуард и Хэрд. Исследования популяций во время наземной фазы жизни этих животных не смогли объяснить наблюдавшегося истощения запасов, подтвержденного недавно и для запаса острова Макуори. Доступность пищи, конкуренция с быстро растущими популяциями морских котиков и конкуренция с промысловыми флотилиями - все это было предложено в качестве возможных причин сокращения численности морских слонов в этом регионе. Такие объяснения подразумевают наличие общей пищевой базы (пока не обнаруженной), которая, в свою очередь, оказывает общее влияние на

динамику популяции этих видов. В таком случае чрезвычайно важными являются исследования пространственного и временного распространения морских слонов во время пелагической фазы их жизни. Недавно было начато проведение Южной Африкой исследований в этой области, и имеется надежда на то, что это поможет выявить причины наблюдавшегося сокращения численности M. leonina в южной части Индийского океана.

SOUTHERN ELEPHANT SEALS AND CCAMLR

The southern elephant seal *Mirounga leonina* breeds on islands on both sides of the Antarctic Convergence and comprises three stocks - these being referred to as the South Georgia, Macquarie and Kerguelen stocks. The last includes not only elephant seals of the Kerguelen archipelago, but also those found at Heard, Marion and Prince Edward Islands, Iles Crozet and Amsterdam and St. Paul Islands.

Two pelagic (feeding) and two terrestrial (fasting) phases can be distinguished in the annual cycle of at least the adult breeding elephant seals.

TERRESTRIAL PHASE

The number of breeding elephant seals has been declining at least since 1970 at the Prince Edward Islands (Marion Island), Heard Island, Iles Crozet (Ile de la Possession) and Iles Kerguelen (Peninsula Courbet). These decreases are all of the same order varying from 2.5% (Heard; 1949 - 1985) to 4.6% a^{-1} (Marion; 1973 - 1986) for adult cows. The reason for this decline is obscure and it is possible that factors implicated in these trends may vary with subpopulations.

At Iles Kerguelen, on the other hand, the population decline since 1970 may be part of a long-term fluctuation in the breeding population size related to density as the degree of long-term fluctuation in cow numbers increased with density.

Based upon censuses of parts of the coastlines, both the Kerguelen and Marion elephant seal breeding populations have shown a change in the adult sex ratio in favour of cows, which suggests a selective removal of bulls during their pelagic phase. On the other hand, whole island censuses (Marion) suggested that both cows and bulls declined at the same rates.

Factors responsible have not been identified. Populations of subantarctic fur seals Arctocephalus tropicalis and/or Antarctic fur seals Arctocephalus gazella, sharing the island habitats with the elephant seals during the austral summer, do not compete with them on land as they are spatially and temporally separated during their breeding season.

PELAGIC PHASE

Killer whales Orcinus orca are abundant around Marion Island and Ile de la Possession and show a regular annual visitation cycle closely related to the seasonality in occurrence of elephant seals. They may have contributed to the decline of elephant seals. This appears not to be the case at Iles Kerguelen where killer whales were seldom seen and the magnitude of the decline of elephant seals suggests that other factors, for example the availability of food, are involved.

The diet and foraging behaviour of elephant seals, both geographically and with respect to the position in the water column, are poorly known. It has generally been accepted that elephant seals consume approximately 75% squid and 25% fish, feeding mainly on fish in inshore waters and on cephalopods elsewhere. The large, rapidly expanding A. tropicalis population at Marion Island which feeds on fish, cephalopods and euphausiids may be competing with the declining elephant seal population, especially with the newly independent underyearling elephant seals in the local oceanic zone. Underyearling elephant seals appear to spend most of their summer reasonably close to the island after attaining nutritional independence and are probably in competition with the fur seals, many of which make short feeding trips throughout the summer. At Iles Kerguelen and Heard Island, however, the fur seals A. gazella population is unlikely to compete; it is small and may well utilise a different food resource; for example at South Georgia it feeds largely on krill. On the other hand, whereas no commercial exploitation of fish takes place around the Prince Edward islands and Iles Crozet, commercial catches of fish on the Kerguelen shelf area may have contributed to the downward trend in elephant seal numbers since 1970 through a reduction in food availability.

The initial standing stock of fish for the Kerguelen Shelf area (50 000 km^2) was estimated to be in excess of 230 000 t and with a maximum sustainable yield (MSY) of 80 000 t per annum compared with recently suggested standing stock of only 130 000 t and a MSY of about 20 000 t. Both estimates are far below the 394 000 t of fish the Kerguelen subpopulation of elephant seals would consume annually using a population estimate of 157 000 and published biomass and food consumption estimates of fish stocks need revision, and it seems premature to attribute the declines in elephant seal numbers at Iles Kerguelen to overfishing in the vicinity.

Although elephant seals move widely about the oceans, as evidenced by their visits to the continents abutting on the Southern Ocean, and penetrate both tropical and Antarctic waters, a tendency for small immatures of both sexes to disperse widely from their natal island(s) within the Kerguelen Province in the vicinity of the Antarctic Convergence seems to exist. Sub-adult and adult bulls of 5 a and older, and therefore at or after the growth spurt associated with puberty in the male show a southward displacement into colder water as demonstrated by their presence in the Vestfold Hills, 2 000 km distant from Iles Kerguelen which is the most northerly known source of southern elephant seals.

A non-directional dispersal of elephant seals throughout the circumpolar feeding zone during winter, and concentration on the breeding and moulting sites in summer were assumed in the past but the recorded annual return of some individuals to the Vestfold Hills and movement (an assumed return) of others from there to Iles Kerguelen however, suggest a two-way directional migration for at least part of the population.

In looking for some common factors responsible for the observed declines in the elephant seal subpopulations in the Kerguelen Province, we can suggest two possibilities: first, that the factor(s) responsible for the decline is acting simultaneously, and possibly independently, at or near each of the breeding islands when the subpopulations are gathered during spring and summer; and second, that the factor is operating at some other location, such as a common feeding ground, where the subpopulations may mingle in winter. Also, it can be hypothesized that large sized elephant seals, i.e. older sub-adult and adult bulls, in this extremely sexually dimorphic species range over and feed in marine areas segregated from adult cows and younger (smaller) age classes of both sexes and may therefore be affected differently by environmental conditions. This postulate is important in view of the proposed selective removal of bulls during their aquatic phase, the overall decline in breeding population sizes and self-regulating population model advocating security of the fully adult population as being the key to persistence.

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WG-CEMP-87/15

ARCHIVAL AND SATELLITE-LINKED DATA RECORDERS

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Abstract

This paper provides an overview of currently-available data recorders for use in research on marine animals. These recorders are deployed on freely swimming animals and gather data on aspects of an animal's diving behaviour. The records can be recovered in one of two ways : the data recorder must either be recovered intact, or the data recorder must be capable of disseminating its data via a radio link, such as the ARGOS satellite system. Recorders can be further subdivided into raw-data and processed-data recorders. Raw-data recorders keep a complete record of the diving parameters of interest and thus produce extensive records, whereas processed-data recorders only report summary statistics which may be quite brief. Due to the limited data-handling capacity of the ARGOS satellite system, most satellite-linked recorders will necessarily report processed data.

Résumé

Ce document présente une vue d'ensemble des enregistreurs de données actuellement disponibles et pouvant être utilisés dans les travaux de recherche sur les animaux marins. Ces enregistreurs sont utilisés sur les animaux nectoniques et permettent de recueillir des données sur certains aspects concernant la conduite de plongée d'un animal. Les enregistrements peuvent être récupérés de deux façons : l'enregistreur des données doit être récupéré intact, ou bien il doit être capable de disséminer ses données par une liaison radio, telle que le système de satellite ARGOS. Les enregistreurs peuvent être également divisés en enregistreurs de données brutes et en enregistreurs de données traitées. Les enregistreurs de données brutes conservent les relevés complets des paramètres de plongée présentant un intérêt et produisent ainsi des relevés abondants, alors que les enregistreurs de données traitées ne fournissent que des statistiques récapitulatives qui peuvent être assez brèves. Vu la capacité de traitement limitée du système de satellite ARGOS, la plupart des enregistreurs reliés à un satellite ne pourront procurer que des données traitées.

Resumen

Este documento provee una reseña general de los registradores de datos disponibles actualmente para uso en la investigación sobre animales marinos. Estos registradores son desplegados en animales que nadan libremente y recopilan datos sobre los aspectos del comportamiento de zambullida de un animal. Los registros pueden ser recuperados mediante una de las siguientes dos maneras : el registrador de datos debe ser recuperado intacto, o bien el registrador de datos debe ser capaz de diseminar sus datos a través de una conexión radial, tal como el sistema de satélites ARGOS. Los registradores pueden ser subdivididos además en registradores de datos en bruto y en registradores de datos procesados. Los registradores de datos en bruto mantienen un registro completo de los parámetros de zambullida de interés y producen por lo tanto registros extensos, mientras que los registradores de datos procesados sólo informan estadísticas resumidas, que pueden ser relativamente breves. Debido a la limitada capacidad de manejo de datos del sistema de satélites ARGOS, la mayor parte de los registradores enlazados por satélite necesariamente informan datos procesados.

Резюме

В этой работе дается обзор имеющихся в настоящее время регистраторов данных, которые можно использовать в исследовательских работах по морским животным. Эти регистраторы прикрепляются к свободно плавающим животным и собирают данные по различным аспектам их поведения ныряния. Зарегистрированные данные могут быть получены одним из следующих двух способов: регистратор данных должен быть получен обратно неповрежденным или регистратор данных должен быть способен передавать имеющуюся у него информацию по радио, например, через систему спутниковой связи ARGOS. Далее, регистраторы данных могут подразделяться на регистраторы необработанной и регистраторы обработанной информации. Регистраторы необработанной информации хранят полную запись представляющих интерес параметров поведения ныряния и следовательно выдают большое количество данных, тогда как регистраторы обработанной информации передают только статистическую сводку, которая может быть довольно краткой. В связи с тем, что возможности системы спутниковой связи ARGOS в плане передачи информации ограничены, большинство подключенных к системе спутниковой связи регистраторов по необходимости будет передавать обработанную информацию.

ARCHIVAL AND SATELLITE-LINKED DATA RECORDERS

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This paper is intended to be an introduction into techniques of remote data acquisition of diving behaviour of marine animals. The discussion is divided into two sections : Archival Recorders, which are attached to the animal of interest and subsequently recovered together with the stored data, and Satellite-linked Recorders, wherein the instrument is attached to an animal and data recovery and/or geolocation are provided by the ARGOS Satellite system. Use of either type of recorder allows diving behaviour to be investigated 24 hours a day for periods of days to months with little or no intervention on the part of the investigator. Examples of uses of data recorders might include gathering information on foraging strategies such as feeding depth, dive durations, and diving surface time ratios, both between individuals and between years.

SECTION I. ARCHIVAL DATA RECORDERS

An archival recorder is an instrument which gathers data (.e.g. depth, temperature) about an animal of interest and stores these data until the animal is re-captured and the instrument is recovered. The data are then extracted from the recorder which may be re-useable. The earliest archival data recorders were of mechanical design and fall into two distinct categories : Raw-data recorders, and Processed-data recorders. More recently the electronic equivalents of these two types of recorders have become available.

A raw-data recorder is one in which the original data are recorded verbatim and thus the precise behaviour of the animal under investigation can be re-created. Processed-data recorders perform some manner of data reduction and report summary statistics of the animal's behaviour.

The archival recorders that have been deployed thus far generally measure the depth of diving animals, although they are not necessarily limited in this respect; units have been used which also measure swimming speed, sea-water temperature, and physiological parameters of the diving animal.

Mechanical Raw-data Recorders

This type of recorder is typified by the film time-depth recorder produced by Meer Instruments (1,2). This instrument records dive profiles onto photographic film : increasing pressure due to diving causes an arm containing a small light source to track across the width of the film while an electric motor advances the film at a steady rate. The film must subsequently be developed and the dive profiles digitized before any analysis can be performed. The instrument provides continuous data recording for approximately 11 days with a time of resolution of 30 seconds. The design's main advantage is good data integrity - nothing can destroy the gathered data unless the pressure housing is ruptured. The disadvantages are that the unit is large (250mm by 50mm dia.) and heavy (700g), and data recovery and analysis are labour intensive.

Mechanical Processed-data Recorders

These recorders have been pioneered by Wilson and Bain (3,4) and provide time-at-depth or time-at-speed records. The principle of both units is the same : a radioactive bead is made to move over a piece of photographic film as a result of the depth or speed stimulus. The longer the animal spends at a given depth (or speed), the greater the exposure of the film at the corresponding location. Thus the relative exposure of the film at different depth (or speed) locations provides a measure of the relative time spent at those depths (or speeds). These instruments are very inexpensive to produce and are small and light in weight, but they require careful analysis to extract the data which are generally approximate.

Electronic Raw-data Recorders

These instruments were pioneered by Hill (5) for physiological studies on Weddell seals in the Antarctic. They consist of miniaturized computers which sample data at pre-set intervals and store the data into memory (RAM) for subsequent recovery. The only currently commercially available unit is the Wildlife Computers Microprocessor Time-depth Recorder MK-III. This unit can store up to 256,000 depth readings, which is equivalent to one depth reading every 10 seconds for one month. Because the unit employs a computer to control the data sampling, certain decisions can be made by the computer about the data or the sampling environment to conserve memory. For example data sampling may be inhibited when the animal is hauled out onto a beach or ice-floe. The instruments can also be equipped with a temperature sensor to monitor environmental temperature. The advantages of these units over mechanical time-depth recorders are smaller size (150mm by 24mm dia.), lower weight (120g), more versatile data sampling, and longer record length. Data recovery and analysis are also simpler : data are transferred directly to a personal computer, and immediately ready for graphing or statistical analysis. The disadvantage of these units is that if the batteries fail, all collected data are lost. Further information is available in Appendix 1.

Two other similar instruments are being developed in Dr G. Kooyman's laboratory, and may become available to researchers at some future date. The first was developed by E. Ponganis and is slightly smaller than the Wildlife Computers instrument, but contains less memory (24K RAM vs. 256K RAM). The second is a very small instrument under development for studies on Murres by J. Croal. This unit will measure approximately 60mm by 40mm by 19mm and weigh only 25g. However, memory size will be limited to 8K RAM. Requests for further information on either of these units should be directed to Dr G.L. Kooyman, Physiological Rsearch Laboratory, Scripps Institute of Oceanography, La Jolla, CA 92037, USA.

Electronic Processed-data Recorders

These recorders offer the smallest potential size for electronic recorders because little memory is required to store data. Diving data are summarized into counts of either number-of-dives-to or time-spent-at several pre-defined depth categories. One unit is currently available (the Maret Maximum Depth Recorder (2)), and the other is expected to be available in the summer of 1989 (Northwest Marine Technology (MNT) Archival Tag). The two units reflect very different design philosophies. Maret's unit is re-usable with easily replaced batteries but provides only eight pieces of data - the number of dives to eight different depth ranges. The NMT instrument will be a one-use-only instrument and employ 32K RAM to provide multi-dimensional histograms (e.g., simultaneous categorization of dives by length and maximum depth) as well as brief records of raw data. Perhaps the most interesting feature of the NMT instrument is the onboard detection of sunrise and sunset times. These times can be used to determine the approximate location of an animal in the tropics. It is not known if such a system can be employed in the Antarctic where sunrise and sunset are difficult to determine. Both of these instruments are small and light in weight (particularly the NMT unit), but require either a dedicated read-out unit (Maret) or return to the manufacturer for read-out and location analysis (NMT). Further information on these units is provided in Appendix 1.

SECTION II. SATELLITE-LINKED RECORDERS

One of the major limitations of the archival recorders discussed in the previous section is that they must be recovered. Satellite-linked recorders overcome this problem by transmitting data through the ARGOS Stellite system (the only currrently available satellite for Antarctic work). This technique is not without its problems for marine animals, however, and the instruments which can use the ARGOS system on seals and whales are still under development. The second, and perhaps the most important advantage of satellite-linked recorders is the potential for geolocation of the animal. The details of the ARGOS system and the transmission requirements for geolocation are discussed elsewhere, and this paper will discuss how those inherent limitations will affect the use of the ARGOS system for tracking and recovering data from marine animals. A recent workshop studied these problems in relation to large cetaceans, and is included as Appendix 2.

The transmission requirements of the ARGOS system require that 1 watt transmissions be used. This defines the size of the batteries required to provide such power in the Antarctic cold, and the minimum battery configuration has been determined to be three Lithium "C" cells. The smallest transmitter commercially available measures approximately 50mm by 80mm by 13mm (Telonica, Mesa, Arizona USA), so this makes the smallest complete instrument measure approximately 100mm by 100mm by 35mm after allowing for a pressure housing. Obviously this is too large for small penguins, but could be carried by all Antarctic seals and possibly by some whales (see Appendix 2 for discussion of attachment mechanisms for whales).

Obtaining Geolocation Data

The ARGOS system requires a minimum of three complete transmissions in one satellite pass before a geolocation can be determined. This presents no problem for a seal hauled out on a beach or ice-floe, but makes geolocation of any animal in the water difficult for the following reasons :

1. Three transmissions must reach the satellite. A message will not be received unless the antenna is clear of the water. Careful positioning of instruments is thus vital.
2. Partial messages are ignored by the satellite. This problem can be reduced by only sending the minimum data (four bytes). This makes the transmission as short as possible and reduces the chance of interruption by diving, breaking waves, etc.

3. Transmissions must span a period of 5-10 minutes. The minimum inter-transmission interval is 40 seconds. However three successive transmissions at this interval will rarely provide ARGOS with sufficient data to perform a geolocation; ARGOS requires transmissions throughout a pass of the satellite to geolocate reliably. The animal under investigation should thus spend at least five minutes at the surface or take short dives so that transmissions can be performed on successive surfacings. This could present a problem for certain animals whose diving behaviour is incompatible with these limitations (e.g., elephant seals).

Obtaining Diving Data

The message length of the ARGOS system (four to 32 bytes per transmission) makes transmission of raw data impractical; processed data are obviously required. If the processing can reduce the data to four bytes, then diving data can be recovered with no additional problems over those discussed for geolocation only. If, however, more data are needed, then the transmission can be expanded to 32 bytes. The penalty for this is that the transmission time is longer (1 second vs. 0.3 second) and thus the chance of interrupted transmissions is increased. This may make such transmissions from an animal in the water so unreliable that no data are recovered. At this time I would recommend that only minimum-duration (four byte) transmissions be attempted from pelagic animals.

Diving data can be recovered from seals by using an archival recorder coupled to a satellite transmitter. The archival recorder gathers and processes dive data from the seal when it is in the water and these data are "parcelled" out, 32 bytes at a time, when the seal hauls out onto ice or a beach. There are several ways that data can be compacted so that usable information can be gleaned from 32-byte transmissions. These include partitioning data into bits or nibbles (four-bit units) where possible, and equipping each animal with several identification codes so that more than one message can be transmitted per satellite pass. Such data organisation requires rather sophisticated computer manipulation in addition to the primary data reduction mentioned before under Processed-data Recorders.

The ideal instrument would be able to perform the function of transmitting archived data when the animal is hauled out in addition to providing geolocations when the animal is pelagic. If large amounts of data need to be transmitted, the "C" cells specified earlier may become inadequate and the package must grow to hold larger batteries. Such a unit could no longer be carried by a fur seal without affecting its behaviour and possibly its survival.

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Table 1. Comparison of raw- to processed-data recorders

Raw	Processed
Retains original data	Stores summarized data
Few assumptions about diving behaviour prior to deployment	Requires prior knowledge of diving behaviour to gain maximum information
Generally larger	Generally smaller
Anomalies or malfunctions may be easily identified	Anomalies or malfunctions impossible to recognise
Potentially massive amount of data requiring subsequent graphing and analysis	Small amount of data requiring little further analysis

Table 2. Simple processed-data diving recorders (all can be "home-made")

	Penguin depth	Penguin speed	Time-budget recorder
Dimensions (mm)	70x45x10	45x12 dia	35x25x18
Weight (g)	30	5	7.5
Medium	film & radio-active beads	film & radio-active beads	digital watch
Cost	< US$ 10	< US$ 5	< US$ 20
Data recovery	develop film	develop film	direct obs
Reference	(3)	(4)	(6)

Table 3. Complex archival diving recorders

Supplier	Meer	Wildlife Comp. I	Wildlife Comp.III	Kooyman Ponganis	Kooyman Croal	Maret	NMT
Size (mm)	220x50	140x65x30	150x25	150x25	60x40x19	125x29	100x17
Weight (g)	700	340	120	200	25	112	23
Medium	photo film	48K RAM	64-256K RAM	24K RAM	8K RAM	8 counters	32K RAM
Cost (US$)	2000	700*	1000-1300	*	*	2000	2500*
Data recovery	develop film & digitize	personal computer	personal computer	personal computer	personal computer	dedicated read-out unit	return to mfr

* not currently commercially available

Légendes des tableaux

Tableau 1	Comparaison des enregistreurs de données brutes et de données traitées.
Tableau 2	Enregistreurs de plongée simples pour données traitées (on peut fabriquer soi-même tous ces appareils).
Tableau 3	Enregistreurs de plongée complexes pour archivage.

Encabezamientos de las Tablas

Tabla 1	Comparaciones de los registradores de datos en bruto con los de datos procesados.
Tabla 2	Registradores de inmersiones de datos procesados sencillos (todos pueden ser de fabricación casera).
Tabla 3	Registradores de inmersiones de archivo complejos.

Заголовки к таблицам

Таблица 1	Сравнение регистраторов необработанных и обработанных данных.
Таблица 2	Простые регистраторы обработанных данных о поведении ныряния (все регистраторы можно сделать самим).
Таблица 3	Сложные архивные регистраторы данных о поведении ныряния.

Wildlife Computers

APPENDIX 1

Roger D. Hill, D. Phil.
Suzanne E. Hill, Ph. D

E. 150th Street • Woodinville, WA 98072-7641 (206) 881-304

Microprocessor-controlled Time-Depth Recorder MK-III

General Description

The Wildlife Computers time-depth recorder is a miniature computer designed to gather data on depth, temperature and up to one further user-defined variable. Data are sampled at user-specified time intervals and stored into memory. These stored data are transferred to a personal computer via an inexpensive serial interface when the instrument is recovered. The instrument is mounted in an anodized aluminum pressure housing, and includes a conductivity switch so that data sampling can be inhibited when the animal hauls-out onto a beach or ice floe.

Technical Specifications

» Sampling rates from 1 per second to 1 per 255 minutes; specified by user at time of deployment.

» Crystal controlled clock to ensure accurate time-base.

» Conductivity switch to determine haul-out periods.

» Up to 8 different sampling protocols may be defined which are invoked under specified conditions of depth and/or conductivity (in/out of water).

» 3 standard depth ranges:
0 - 250 m, resolution 1 m
0 - 500 m, resolution 2 m
0 - 1500 m, resolution 6 m

» Unit may be cycled on and off to extend sampling period. Cycle periods, from minutes to days, are specified at time of deployment.

» Memory size from 64 KBytes to 256 KBytes.

» Wide operating temperature: -20°C to +35°C.

» Simple serial interface to personal computer at rates from 300 to 38,400 baud.

» Full documentation of data format to enable user to write analysis software.

» Sufficient power to take 1 million readings and store up to 256 KBytes for > 1 year.

» Units optionally provided with 2 depth ranges to provide wide depth range with higher resolution at shallow depths.

» Optional temperature channel: -5°C to +20°C, resolution 0.1°C.

» Standard housing of anodized aluminum; optional titanium housing available (approx. 200 g).

» Size: 150 mm by 25 mm diameter.

» Weight: 120 g (standard housing).

» Prices from US$ 1000 for 1 channel, 64 KByte instrument.

» Specialized variations can be produced; contact us.

MARET CONSULTING SERVICES

APPENDIX 2

Creative Approaches to Biomedical Engineering, Environmental Research, Chronobiology, Holistic Health and Sports Medicine

H. Maret, M.D.
dent

MAXIMUM DEPTH RECORDER

General Description

The maximum depth recorder is a miniature, digital, eight compartment recorder that stores either the number of times that a preset series of pressure thresholds have been exceeded or the total duration of time spent at or below preset depth thresholds. Every time that the output of a precision pressure transducer exceeds the pressure threshold of any of eight preset and equally spaced compartments, a new count is incremented in these compartments thus creating a histogram plot. The instrument may also be used in the Time-At-Depth mode so that the total time spent at each particular depth is recorded in ten second increments.

The instrument is deployed as a long term data recorder and is useful in gathering physiological and ecological information on the diving behaviour of marine mammals and birds. It may also be used as a safety monitor in human dives where it is of interest to monitor the total time at depth for any particular diver. The instrument must be recovered from the animal or man, but data readout can be effectively accomplished within a few minutes by connecting two ribbon cables to an external data processor. The instrument has been successfully used in the field on seals and penguins in the Antarctic.

Features and Specifications

* 22 Integrated Circuits, 1 Miniature Crystal. All integrated circuits are surfaced mounted construction for increased reliability, capability of future repair, small size and low weight.

* Timing is crystal controlled for stable time-base frequency generation.

* Anodized, aircraft quality, aluminum pressure vessel and bulkhead.

* Wide operating temperature: -20° to $+35^{\circ}$ Centigrade.

* 3 multi-layered circuit boards in a stacked construction for maximum component density.

* Battery box made from polycarbonate with gold plated contacts for increased reliability.

* System connection to processor via two ribbon cables terminated with 14 pin gold-plated dual-in-line connectors. Replacement interconnection cables are inexpensive standard electronics stocked items.

* Dual Operation: Modes of "Time-at-Depth" or "Events-at-Depth" available. One mode preset at the factory but mode may be changed at a later date.

9865 Mozelle Lane • La Mesa, California 92041 • (619) 698-9504

* Low power CMOS design for a minimal power consumption during data acquisition. Unit goes into power conservation mode when data acquisition time exceeds a preset Time-Out period. This prevents total battery exaustion and possible loss of data from memory.

* Time-out period is preselectable and hardwired at the factory in three day increments from 3 to 93 days.Time-out period may be changed at later date.

* Light weight: 3.5 ounces (4.0 ounces with 6 lithium batteries)

* Small Size: 4.95 inches long, 1.15 inches in diameter.

* Batteries: 6 Lithium coin type batteries, Panasonic No. BR-2325. Total battery pack capacity 9 volts at 300 milliamperes-hours. Lithium batteries have extremely high energy density, long shelf life and excellent low temperature operational characteristics.

* Recommended transducer is Entran EPN series. These high sensitivity pressure transducers can be ordered in full range at 5, 15, 25, 50, 100, 250, 500, 1000, 2500, 3500 or 5000 psi. They can normally withstand two times their rated pressure without damage.

* Instrument operates in pulsed mode with a 16 msec transducer on-time. Pulse repetition rate is 10 seconds in Time-At-Depth mode and also in Event mode when not in dive, one second sampling rate when in Dive mode.

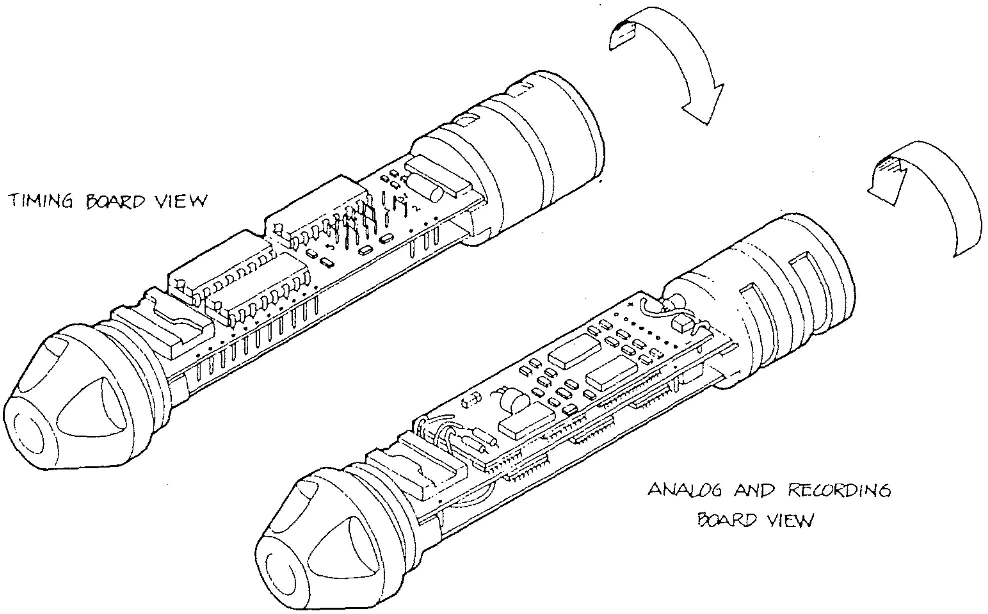
* Calibration to pressure station via a special screw-in connector with built in O-Ring, Swagelock No. B-200-1-OR.

PRICE

Quantities:		Deliveries:
1 - 2	$2,000.00	10 Weeks upon
3 - 5	1,900.00	Receipt of order
6 - 10	1,800.00	

DIGITAL READOUT PROCESSOR

Order Model MDR-Processor Mk.II. This unit is also required to calibrate the instrument. Specifications upon request. Cost is $2500.00



MAXIMUM DEPTH RECORDER

Recorder deployed on Gentoo penguin in the Antarctic.

APPENDIX 3

Product Preview

Archival Tag for Marine Animals

The Archival Tag is intended to gather, process, and record environmental data from which animal behavior can be deduced. In favorable cases the results can include a track of geographic position. The unit is presently under development, and the specifications given below are targets. Potential users who have additional requirements are encouraged to contact NMT, Inc.

Data Taken:

Pressure	0 - 500 Meters depth
Temperature	-5 to 35 Celsius
Light (460NM)	5 Decades including full sun
Auxiliary Sensors	A.C. conductance

Light intensity is measured at an optical diffuser on a stalk extending from one end of the unit. Temperature is measured at the end of the stalk and also internally to the unit. Auxiliary resistive sensors may be connected, and will be excited with A.C.

Onboard Processing:

Algorithms are provided for determining time of sunrise and sunset, and for characterizing the temperature structure of the upper ocean. User-defined programs may be included to expand the pre-defined capabilities.

Data recording:

N-dimensional histogram, time series, and telescoping time series options are provided. User programs may define others.

Memory Size:

32K Bytes user space.

Lifetime:

Multi-year.

Physical Details:

Diameter 17mm, length 100mm, neutrally buoyant. Case is hermetically sealed, corrosion resistant, and biologically compatible for implantation.

For further information, contact Northwest Marine Technology, Inc., Shaw Island, Washington, 98286, USA. Telephone (206) 468-3375

WG-CEMP-87/16

TELEMETRY MONITORING OF ECOLOGICAL RESOURCES

V.B. Kuechle
(USA)

Abstract

Current status of telemetry and location monitoring are discussed. Limitations on weight, communication range and service life are indicated. A general description of attachment methods and their limitations is given. Three automatic tracking system options are described. Several data recording methods are available including paper recorders and data recording using microprocessors with semiconductor memory. Satellite monitoring using the Argos/Tiros system and satellite transmission of data are also covered.

Résumé

L'état actuel de la télémétrie et du contrôle des positions fait l'objet d'une discussion. Les limitations concernant le poids, la portée de la communication et la longévité sont indiquées. Une description générale des méthodes de fixation et de leurs limites est donnée. Trois options de systèmes de tracking automatiques sont décrites. Plusieurs méthodes d'enregistrement de données sont disponibles, notamment des enregistreurs sur bande et des enregistrements de données utilisant des microprocesseurs avec une mémoire à semi-conducteurs. Le contrôle par satellite utilisant le système Argos/Tiros et la transmission des données par satellite sont également discutés.

Resumen

Se trata el estado actual de la telemetría y el control de la ubicación. Se indican las limitaciones en cuanto a peso, distancia de comunicación y tiempo de vida útil. Se da una descripción general de los métodos de fijación y sus limitaciones. Se describen tres opciones para un sistema de localización automática. Se dispone de varios métodos de registro de datos, incluyendo los registradores de papel y el registro de datos usando microprocesadores con memoria de semiconductores. Se cubre también el control por satélite usando el sistema Argos/Tiros y la transmisión de datos por satélite.

Резюме

Обсуждается современное состояние телеметрического и локационного мониторинга. Указываются ограничения веса, дальности связи и срока службы аппаратуры. Дается общее описание способов ввода в эксплуатацию такой аппаратуры и их ограничений. Дается описание трех различных систем автоматического слежения. Имеется несколько методов регистрации данных, включая пишущие регистраторы и регистрацию данных с использованием микропроцессоров с памятью на полупроводниках. Охвачены также мониторинг со спутников с использованием системы Argos/Tiros и передача данных по системе спутниковой связи.

TELEMETERY MONITORING OF ECOLOGICAL RESOURCES

V.B. Kuechle
University of Minnesota[1]

Since the introduction of the commercial transistor in the late 1950s, the application of electronics to the monitoring of biological parameters in wildlife has steadily progressed. Although some early remote sensing was done using subminiature electronic tubes, the first widespread application was location monitoring of animals in the mid 1960s. Monitoring activity has steadily increased since that time with an increase in numbers and types of parameters monitored. Today measurements can also be made using satellites to directly monitor or relay data. Progress is also being made in storing telemetered data for later retrieval and analysis. This paper discusses those recent advances with emphasis on possibilities for application to remote sensing of marine resources.

Radio Location Tags

The most prevalent use of radio tracking is the application where a radio marker beacon is attached to an animal and the animal then relocated using a directional antenna and receiver[2]. Data are usually recorded manually on paper by the observer. These data are then usually entered into a computer for data analysis. Some users enter their data directly into battery powered portable computers for later off-loading to a larger computer for data analysis. This technique eliminates the step of transferring data from paper to a computer. Error checks may also be included in the portable computer program to allow the observer to immediately recheck a data point in the field if a possible error is indicated.

Transmitters used in these applications are available in a wide range of sizes and power levels. There is a general correlation between transmission range, transmission life and weight. This correlation is determined by the energy source, with the most common energy source being a lithium primary cell. These cells have a high energy to weight ratio, excellent shelf life and perform quite well at low temperatures. They are the power source of choice in most applications. They are, however, not available in sizes below about four grams. Large sizes can also present transportation problems because of the classification of their lithium metal anode as a hazardous material.

Solar powered transmitters are also used[3]. Transmitters may depend on solar power only or may have a nickel cadmium rechargeable battery as power backup for periods when the sun is not in view. Unfortunately present designs have not given consistent performance from the solar powered nickel cadmium combination[4]. Mercury or silver-oxide cells are used in most of the small transmitters. Other than degradation of output at low temperatures, their performance is adequate for the application.

To save power, transmitters are usually turned on and off at a set rate. A typical rate is to turn the transmitter on for about 0.015 seconds once each second. This results in a duty cycle of 1.5 percent. Average battery drain is in the range of 0.15 to 0.6 milliamperes, with peak drains of about 10 milliamperes. Transmission life ranges from 45 days for a 2.5 gram transmitter to more than 1500 days for a 600 gram transmitter.

Reception range for these transmitters is quite variable. Small sizes range from 0.5 Km to 2 Km transmission range. For an observer in an aircraft, ranges are about two to five times greater. Transmitters on larger animals range from 5 to 10 Km on the ground and 10 to 100 Km from an aircraft. Transmission range is highly dependent on the transmitter's elevation above ground and on the length of the transmitter antenna. Longer antenna lengths provide higher efficiency and thus greater range. Since transmission for these low-power devices is line-of-sight, elevation of both the transmitter and receiver antenna above ground is also important. Thus a bird in the air will have a much greater transmission range than one on the ground.

Additional parameters can be measured using these transmitters by the addition of suitable sensors which modulate the pulse width, pulse rate or other characteristic of the transmitter[5]. The most commonly used sensor is a mercury switch which is a small glass tube with a ball of mercury that opens and closes an electrical circuit depending on the tilt angle of the tube. This can then be used to indicate activity by increasing the pulse rate as a function of switch closure. Mercury switches are also used to indicate mortality. In this case a clock is reset with each switch closure. If the animal is not active the clock will not be reset and the clock sends an output after a pre-set time, typically four hours. This output then changes the pulse rate, most commonly by a factor of two.

Temperature is also readily indicated by changing the pulse rate as a function of temperature. Pressure may be indicated in a similar manner[6]. These parameters can be measured quite easily because they change slowly with time.

Measurement of physiological parameters is somewhat more difficult because a decision must be made as to what constitutes a valid event[7,8]. In measuring heart rate - the most commonly measured physiological parameter besides temperature - a determination must be made as to what level to trigger the transmitter pulse. If the threshold is too high, heart beats will be missed, if too low, muscle artefacts will cause false indications. Trigger levels of 0.2 millivolts to 0.7 millivolts are used. We use a trigger level of 0.6 millivolts and try to place our electrodes for an electrode potential of 1.5 millivolts ideal, with 1.0 millivolts minimum. Telemetering of other physiological parameters under field conditions is less common. Procuring or developing adequate sensors is the major limitation in making long-term measurements under field conditions. Many sensors require periodic recalibration to assure accuracy and thus are not adaptable to long-term unattended use.

Transmitter attachment is a highly variable field with almost as many attachment methods as applications. Neck collars are the primary mode of attachment for terrestrial mammals. This technique elevates the collar well and provides good weight distribution. Other methods must be used in growing animals or in animals whose necks enlarge during the breeding season[9].

Back-mounted transmitters are the most commonly used attachment method in birds[10]. This technique provides the best distribution of weight to lessen the transmitter's effect on flight dynamics[11]. Transmitters are usually retained in position using a harness of flexible material. Adhesives are also used on birds for short-term applications. Usual life of adhesive attachment on birds is about 30 days when they are lost by feather breakage or molt. Clipping the transmitter to the tail feathers is also an option.

Attachment to marine mammals is often more difficult. If a suitable appendage is available a collar type attachment works well[12]. On animals with hair or fur, adhesive attachments have performed satisfactorily[13]. In any case the package should be small to reduce drag. Packages attached with adhesive will be lost during the animals molt and thus have a useful life of a year or less. Successful attachment to whales has remained a problem. Harpoon methods[14] and barnacle or multiple attachment[15] methods seem most promising.

Implanting the entire transmitter is also an option. It has been used successfully on sea otter[16], river otter[17] and ducks[18] as examples. The major disadvantage is the requirement of a surgical procedure and the reduction in transmission range caused by the body. Range for an implanted transmitter is typically 30 percent of the range which would be received from a transmitter attached externally. Antennas for implantable transmitters are either entirely enclosed within the package, usually as a helix at one end, or a whip external to the main transmitter package. The latter gives higher power output; however, the transmitter must be retained in place or the antenna will tend to form into a ball and become ineffective. Transmitters with integral antennas are usually allowed to "float" either subcutaneously or interperitoneally. In sea otters interperitoneal placement is more successful because it does not leave a lump and the surgical would heals faster[19]. Generally the attenuation of the radio signal is a function of the thickness of the body tissue in the signal's path.

Automatic Tracking Systems

Several systems exist to automatically track the location of animals as they move within the area monitored. The first of these was a system developed at the University of Minnesota in the mid-1960s[20]. It used two mechanically rotating antenna arrays. Originally data were recorded on 16 millimeter film although later a computer was used to determine the angular bearings. A similar system was built at the University of Bordeaux, France[21]. These systems have limited application in Antarctic environments because of their limited portability, high power requirements for the mechanical antenna rotation and the level of technical support needed for successful operation.

A more recent system is one presented by Tracktech AB, of Salna, Sweden. It uses a hyperbolic direction-finding technique which does not need rotating towers. Three systems are claimed to have been sold, but no reports are available on their performance. While this system does not require rotating antennas it requires technically complex receivers and transmitters. Cost for a basic Tracktech system is about US$100 000.00.

A third approach is provided by a system measuring the doppler shift of a signal using an array of antennas which are rotated electronically. Transmitters on the animals have no special requirements. This system offers possibility as a remote, portable tracking station because it does not have rotating towers, has relatively low power requirements and should be able to operate without complex technical support. Although several doppler system are under development, I was not able to get either company to consent to releasing information.

Data Recording

A number of methods and systems have been developed to record data from radio and sonic tags without the presence of an observer. These are usually relatively low cost portable systems.

The first system developed used a low cost analog chart paper recorder that recorded the signal level from the receiver[22]. The chart drives were either spring wound or electric motor driven. They can be used to indicate activity or transmitter proximity to a nest or other specific site. While these units perform well, they have limited application because they must be attended frequently to wind the spring driven motors or recharge the battery. Temperature variations have also been a problem. Power for the units is usually provided by an automobile storage battery. Rustrak and Esterline-Angus are two manufacturers of analog recorders for this application. These systems are usually used to monitor from one to four animals. Monitoring more than four transmitters is difficult because there is no easy way to distinguish the animals on the chart.

To meet the need to monitor more animals and eliminate the need to adjust the receiver gain control, systems based on event recorders were developed. Event recorders typically have 10 or 20 pens which are activated by a voltage signal. They give only a yes or no indication and provide no information on signal level. These systems are ideal for recording presence or absence data. To operate effectively with these event recorders the receivers should have a tone decoder or other level insensitive detection method. The recorders have spring wound drive motors which will operate the recorder for about one week. Receivers in this application are most often powered by automobile batteries.

As microprocessors became more familiar and solid state memory devices gained capacity and became less espensive, systems which store data from the receiver and can later off-load to a small computer are becoming available. These systems use the microprocessor to control the receiver, check the data, record time and data. It can also turn the receiver on and off if desired. Since the system has no moving parts it can operate over a wide temperature range.

Using receivers and a monitoring system developed at the University of Minnesota we have tested operation to -50 degress C without deterioration in operating performance. The model we currently use has a basic interpreter in read only memory so that it can easily be reprogrammed in the field. Speed sensitive operations can be written in assembly language and called from the main program as needed. Using the high level language permits the user to easily change the program or design it to fit his need as required. For our particular device communication to an external computer is done via a RS-232 serial interface. Using this standard interface any number of terminals can be used to communicate with the system and off-load data. Using this system and an adequate power source for the receiver, operation for several months without attention is possible.

Using a microprocessor enables the user to record additional data such as temperature, depth, heart rate or any parameter that can be put into digital form. A microprocessor also permits the user to specify limits which can be used to discard out of range data points.

Satellite tracking

Since the first elk was tracked by satellite in the early 1970s biologists and wildlife managers have been interested in applying this technology to biological monitoring. A number of experiments were conducted utilizing the Nimbus system. However, animal tracking using satellites began in earnest with the Argos system.

The Argos system offers opportunities for monitoring a large number of species. However, its operational characteristics and requirements must be understood if it is going to be used successfully. The system is designed to monitor the location of transmitters (often referred to as platforms) using a satellite in sun synchronous orbit. Some data can also be transmitted along with the information necessary for location. The system's primary design purpose is to monitor meterological sensors on balloons and ocean buoys; monitoring biological data was secondary.

Sun synchronous orbit means that the satellite remains in a fixed orbit in space. However, it covers a different path on the earth as the earth rotates relative to the satellite's orbit. The satellite orbits with a period of 102 minutes. This, combined with its polar orbit, means that points near the equator are in view less frequently than are points near the poles. It is designed to have platforms at the equator in view for at least two passes, whereas platforms nearer the poles will be in view with almost every pass.

The Argos system uses a doppler location technique. As the satellite gets closer to the platform the frequency appears to increase. As the satellite passes over the transmitter, the transmitter frequency appears to decrease. The measurement of the transmitter frequency can then be used to establish a doppler curve. Using the doppler information, the position of the transmitting platform can be determined to within two possible positions. On the next satellite orbit two additional possible positions are determined. One of these positions should coincide with a position from the previous pass. The doppler curve can only be determined accurately if a number of transmissions occur as the satellite passes overhead. This means the platform must transmit over this period. Since the platform transmits once each minute it should be available for at least five continuous minutes. This is not a problem for birds or terrestrial mammals. However, for many of the marine mammals it is a significant consideration.

Argos platforms must be certified by Service Argos before they can be placed in service. Approved platforms are available from a number of commercial sources (see Appendix A).

With the doppler measurement system the frequency of the transmitter must remain stable over time or errors in the doppler location will occur. Thus the transmitter oscillator must remain stable over time and with temperature variations. Another important parameter is the three watt power output requirement. In most cases power is supplied by lithium primary cells. Two problems must be considered : the first is the ability to supply the power for the operating life desired; the second is to have sufficient capacity to supply the peak demand during the transmission period. Both of these factors are increased by low temperatures.

These two factors determine the smallest size of transmitter that can be built. While some decrease in size can be made using custom circuits, very little can be done with the major volume component, the primary battery. Some testing has been done using solar cells and nickel-cadmium batteries. However, reliable operation for more than about nine months has not been achieved.

Currently transmitters weighing approximately two kg and lasting about one year are routinely being deployed on caribou[23], Antarctic seals and polar bear. Units have also been placed on a number of other species with varying degrees of success. A significant problem is attaching packages of this size and weight. Transmitters have been carried by several species of birds with mixed success. The users indicated the weight (170 gm) and bulk were too high[24]. Cost for location-only transmitters is in the 2500 to 3500 US$ range.

There is a service charge for data processing by Service Argos. Typical cost for a platform-year is about 3000 US$ (see Appendix B for a rate schedule). It is possible to bypass Service Argos data processing and to use the down-link data to determine location with an on-site data processor. These data processors are also relatively expensive (20,000 to 30,000 US$) and require technical support.

The Argos system also allows the sending of four eight bit data words with each transmission. These can be used to send data such as temperature, pressure, etc. It should be noted, however, that doing so increases the demand on the power supply.

Satellite Transmission of Data

As an alternative to sending data to satellite, using the Argos system data can be relayed using other data-only satellite systems. Since they are data-only systems these systems permit the transmission of larger blocks of data. A data relay system using the GOES satellite is being tested by a National Marine Fisheries Laboratory. The application of this system is to monitor fish as they traverse remote streams and rivers. Radio frequency tags are attached to fish which are then monitored with a radio receiver and data processor. Data from the receiver data processor are sent to the GOES transmitter once per hour for relaying to the GOES satellite. The GOES system allows sending up to 650 characters per transmission. This application uses commercially available GOES platforms. Data are downlinked to a receiving station at Wallops Island, Virginia where they are available to the user. Power for this system is supplied by solar cells recharging Gel-cell batteries.

Acoustic Tags

Acoustic tags are applied most often in high conductivity or deep water where radio frequency tags will not function. These tags emit a mechanical wave in the frequency range 25 to 200 kHz. The sound energy is received by a hydrophone and a narrow band receiver which separates the signal from the noise. After the signal is received it may be processed using the same methods as described for radio frequency tags.

Tracking range for acoustic tags is dependent on power output and frequency. Signal attenuation increases as frequency increases because absorption loss is frequency dependent. These losses are in addition to spreading losses. Thus using lower frequency transmitters will result in a longer range. Using a lower frequency may cause a problem, however, if the tag frequency is within the hearing range of the animal. Tag size is also frequency dependent because it is desirable to operate the acoustic transducer near its resonant frequency. Transducer resonant frequency is size dependent; efficient low frequency transducers require a large size. Thus it is difficult to build a small low frequency device[25].

Passive Acoustic Sensing

It is possible to monitor objects in ocean environments which are too small for transmitter attachment by transmitting an acoustic signal and measuring the level of reflected signal. These systems use relatively high frequencies and are normally ship mounted. Using these systems it is possible to monitor fish, krill and zooplankton. Assessments of stocks using these techniques is in its preliminary stages[26]. Assessment of biomass is not particularly difficult. However, determination of the organism causing the signal return may prove to be more elusive without concurrent sampling.

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SC-CAMLR-VI/BG/23

A RATIONALE FOR CONSERVATION AREAS WITHIN ANTARCTIC WATERS

R.G. Chittleborough
(Australia)

Abstract

The application of potential conservation measures listed in Article IX 2 of the Convention requires "the designation of regions and sub-regions based on the distribution of populations of Antarctic marine living resources" (Article IX 2 (b)). In order to select meaningful boundaries for such areas, first priority has been given to surface circulation of southern waters and the distribution of krill. This has been supplemented by (limited) information on the distribution of major consumers including baleen whales, seals and penguins. A possible relationship between general flowline features of the Antarctic ice cap and ragional dynamics of the Southern Ocean ecosystem is also suggested.

From the evidence available, the following six potential conservation areas are proposed:

70°W - 15°W
15°W - 40°E
40°E - 90°E
90°E - 150°E
150°E - 160°W
160°W - 70°W

Examples are given of options available for management approaches within these major conservation areas.

Résumé

La mise en vigueur des mesures de conservation potentielles énumérées à l'Article IX 2 de la Convention nécessite "la désignation de secteurs et de sous-secteurs selon la répartition des populations de ressources marines vivantes de l'Antarctique" (Article IX 2 (b). Afin de sélectionner des limites significatives pour ces régions, la circulation de surface des eaux australes et la répartition du krill ont été considérées en toute priorité. S'y sont ajoutées des informations (limitées) sur la répartition des principaux prédateurs, dont les baleines mysticètes, les phoques et les manchots. L'existence d'une relation éventuelle est également suggérée entre les caractéristiques générales du flux de la calotte glaciaire antarctique et la dynamique régionale de l'écosystème austral.

Se basant sur les indications obtenues, les six régions de conservation potentielles suivantes sont proposées:

70°O - 15°O
15°O - 40°E
40°E - 90°E
90°E - 150°E
150°E - 160°O
160°O - 70°O

Le document présente des exemples d'options disponibles quant aux différentes approches d'aménagement au sein de ces principales régions de conservation.

Resumen

La aplicación de las medidas de conservación potenciales listadas en el Artículo IX 2 de la Convención requiere "la designación de regiones y sub-regiones basada en la distribución de las poblaciones de los recursos vivos marinos antárticos" (Artículo IX 2 (b)). Para seleccionar límites significativos para tales áreas, se ha dado primera prioridad a la circulación superficial de las aguas australes y a la distribución del krill. Esto ha sido suplementado por información (limitada) sobre la distribución de los consumidores más importantes incluyendo a las ballenas baleen, focas y pingüinos. Se sugiere también una posible correlación entre las características generales de las líneas de flujo de la capa de hielo antártica y la dinámica regional del ecosistema del Océano Austral.

En base a la evidencia disponible, se proponen las siguientes seis áreas de conservación potenciales:

70°O - 15°O
15°O - 40°E
40°E - 90°E
90°E - 150°E
150°E - 160°O
160°O - 70°O

Se presentan ejemplos de las opciones disponibles para los enfoques de administración dentro de estas principales áreas de conservación.

Резюме

Применение возможных мер по сохранению, перечисленных в Статье IX.2 Конвенции, требует "определения районов и подрайонов на основе распределения популяций морских живых ресурсов Антарктики" (Статья IX.2 /b/). Для того, чтобы выбрать имеющие смысл границы для таких районов, первостепенное значение

придается поверхностной циркуляции южных вод и распространению криля. Также сюда входит информация (ограниченная) о распространении главных консументов, включая усатых китов, тюленей и пингвинов. Выдвигается предположение о возможной связи между линией налегания ледникового покрова Антарктики и региональной динамикой экосистемы Южного океана.

На основе имеющихся данных предлагается шесть следующих районов применения мер по сохранению:

70°з.д.- 15°з.д.
15°з.д.- 40°в.д.
40°в.д.- 90°в.д.
90°в.д.-150°в.д.
150°в.д.-160°з.д.
160°з.д.- 70°з.д.

Даются примеры возможных вариантов стратегии управления в пределах этих главных районов применения мер по сохранению.

A RATIONALE FOR CONSERVATION AREAS WITHIN ANTARCTIC WATERS

INTRODUCTION

Although the Antarctic Treaty and the various conventions applying around Antarctica contain provisions to zone activities within specified areas (including fully protected reserve areas), such provisions have not yet been applied systematically in these waters.

While the Antarctic Treaty System provides for the setting aside of Specially Protected Areas (SPAs), none of the eighteen SPAs so far designated have marine waters as main components. Marine ecosystems are included in the classification of Antarctic ecosystems proposed by the SCAR Sub-Committee on Conservation (1976).

Under the Convention for the Conservation of Antarctic Seals (Annex 5), three marine areas have been set aside as seal reserves (around the South Orkney Islands; in the south-west of the Ross Sea; and in the vicinity of Cape Hallet). There is also provision under this Convention for sealing alternately within six arbitrarily defined sealing zones.

Under the Whaling Convention, a sanctuary for baleen whales was applied in earlier years within the sector from 70°W to 160°W. More recently there has been a move within the International Whaling Commission to extend the Indian Ocean Whale Reserve southwards into Antarctic waters.

The Convention for the Conservation of Antarctic Marine Living Resources provides for management by open and closed areas (Article IX 2 (g). So far only one area has been closed to fishing (within 12 nautical miles of South Georgia).

One of several strategy approaches discussed in Australia's submission to the CCAMLR Working Group developing a conservation strategy (WG-CSD-87/6), is the operation of open and closed areas. This would require "the designation of regions and sub-regions based on the distribution of populations of Antarctic marine living resources", as specified in Article IX 2(b) of the Convention.

As was recognised in the Australian submission, a critical step in this is the selection of boundaries for conservation areas in a manner which ensures ecological as well as economic viability. In this it is desirable that each area, whether open or closed, contains a unit stock of at least the target species, or preferably, a largely self-contained ecosystem.

Complete segregation of the communities within the conservation areas is not essential or even desirable; only that exchanges between them by migration be low in relation to productivity (growth and survival) within a unit.

To date, apart from an early effort to identify separate stocks of whales (discussed later), management areas in the Southern Ocean have had little ecological basis. The FAO set out three arbitrary statistical regions in the Southern Ocean (areas 48, 58, and 88) as part of the world-wide Statlant system for recording fisheries operations. These three main areas were subsequently sub-divided, particularly in the Southwest Atlantic and Western Indian Ocean sectors, mainly for the purpose of separating demersal fishing operations on discrete banks and shelves.

With the increasing emphasis now on krill harvesting, it is timely to consider whether the areas and sub-areas defined largely for other purposes might be applied effectively to this fishery, under a management convention designed to conserve the ecosystem as a whole rather than the harvested species alone. As stated by Latogursky (1986), "the problem is gaining in importance because of the necessity of setting krill catch quotas for each fishing country in the near future". While a rather arbitrary separation into a number of major regions might suffice as an initial basis for a workable management regime, under the ecosystem approach required by the convention it would be far preferable if areas could be defined on a sound ecological basis.

AN ECOLOGICAL BASIS FOR DELINEATING CONSERVATION AREAS

Water circulation and distribution of krill:

Latogursky (1986) reviews available information upon which it might be possible to differentiate stocks of krill within the Southern Ocean. On the basis of surface water circulation, he suggested at least six cyclonic systems, although the longitudinal limits of each were not specified. Two or three of these systems are of large scale and were suggested as habitats for independent populations of krill.

When the surface water circulation for this region (Lubimova 1982, Fig. 1) is overlaid by the distribution of krill concentrations (Lubimova 1982, Fig. 28), the resultant shows fair agreement between the location of gyres and major concentrations of krill (Figure 1). On this basis, the following separation is suggested:

Sector 1	70°W -	15°W	Weddell gyre
2	15°W -	55°E	
3	55°E -	100°E	Prydz gyre
4	100°E -	150°E	
5	150°E -	140°W	Ross gyre
6	140°W -	70°W	

No major surface gyres are evident from 100°E to 150°E, or from 140°W to 70°W, though it is possible that quasi-stationary cyclonic eddies of smaller dimension may occur. The krill distribution within these two sectors appears to be correspondingly patchy.

The identification of concentrations of krill within major gyres has led to an examination of samples for evidence of morphological or biochemical differences that might support an hypothesis of genetic separation of stocks. However, as far as has been determined to date (Latogursky 1986; MacDonald, Williams and Adams 1986) there appears to be a continuous exchange of gene pool throughout the Antarctic populations of *Euphausia superba*. Thus, while there may be unit stocks sufficiently discrete for management purposes, there is adequate exchange to maintain a common genetic entity of *E. superba* as a single composite population. As pointed out by Latogursky, one of the important research tasks is to determine the routes and rates of exchange between one sub-population and another. However, as this may take considerable time to achieve, some interim management framework is required.

Distribution of consumers:

Following the ecosystem approach, we should now examine whether the sectors based on water circulation and the distribution of a key food species, are consistent with the distribution of the major consumers. The various consumers differ greatly in mobility as well as in their environmental needs and responses, so can hardly be expected to show identical patterns of distribution and movements.

Whales: During the height of the pelagic whaling era some fifty years ago, six whaling Areas were delineated (Mackintosh 1942) within the following sectors:

Area II	60°W - 0°
Area III	0° - 70°E
Area IV	70°E - 130°W
Area V	130°E - 170°W
Area VI	170°W - 120°W
Area I	120°W - 60°W

These Areas were based on knowledge available at the time, of the distribution of the larger baleen whales during the summer feeding season, and migration paths to breeding grounds in lower latitudes. Humpback whales were the most clearly segregated into unit stocks. However, while unit stocks of humpback whales within the major Areas were sufficiently discrete to maintain consistently different proportions of body pigment patterns and differing age/size composition as a result of non-uniform fishing pressures (Chittleborough 1965), marked humpback whales occasionally moved from one stock to another. Blue whales, and particularly fin whales, however, were far less clearly segregated into unit stocks (Mackintosh 1942), while sei and minke whales were little segregated at all.

For a re-examination of the distribution of the larger baleen whales during the feeding season, the summer sightings from RRS Discovery II from 1933 to 1939 are well representative (Mackintosh 1942), affording an index quite independent of catches by whaling fleets concentrating in selected areas. The distribution of whale sightings shown in Figure 2 indicates feeding concentrations within each of the Sectors from Figure 1, apart from an anomaly within Sector 5. As mentioned by Mackintosh, Discovery II did not cover the main whaling grounds in the Weddell Sea so that the known concentration of large baleen whales in Sector 1 was not well recorded.

Some further indication of the distribution of the larger baleen whales in the Southern Ocean is gained from the maps prepared by Mizroch et al. (1985), based on catches by pelagic whaling fleets. The distribution of blue, fin and humpback whale catches peak well within each of the sectors delineated from Figure 1, though there is little sign of a discrete concentration of these whales within the sector from 100°E to 150°E. Catches of whales within the sector 160°W - 70°W were relatively low, partly because this was a declared Sanctuary Area so that virtually no whaling took place there from 1931/32 to 1954/55 (Horwood 1986). However, when re-opened to whaling, the modest catch rates confirmed earlier suggestions that this sector did not support a large stock of baleen whales. This may reflect a paucity of krill concentrations within that sector.

While some examination has been made of changes in the distribution of larger baleen whales in the Southern Ocean from season to season, and within a season (Mizroch et al 1985), variations in distribution have not been linked directly with variability in the distribution and abundance of krill. Chittleborough (1965) showed that in the Antarctic summer of 1958/59, humpback whales that usually fed between 160°E and 180° spread westward as far as 110°E, and suggested that the wider dispersion of that stock in that season may have been caused by poor development of quasi-stationary cyclones responsible for aggregations of food in the usual feeding grounds.

Seals: The Convention for the Conservation of Antarctic Seals (Annex 4) provides for alternating closures within six sealing zones south of 60°S, having the same meridian boundaries as the Whaling Areas. These Zones are quite arbitrary as so little is known of the distribution and abundance of the pelagic Antarctic seals.

From satellite imagery during the summers of 1970/71 to 1972/73, Gilbert and Erickson (1977) proposed six residual pack ice regions persistent from year to year and presumed to act as foci during the southern summer for seal populations, particularly crabeater seals (Figure 3). Sighting surveys of seals hauled out on pack ice in location A (January-February, 1972) and in location B (January, 1973) enabled densities to be compared with earlier surveys in location F. The observed density of crabeater seals in location A was higher than in location B (1.62 and 1.02/km^2 respectively), but both were well below the previously recorded density in location F (6.56/km^2). No data were available on the densities of seals on pack ice during the summer in locations C, D and E.

Gilbert and Erickson found no correlation between the concentration of chlorophyll in surface waters and the density of crabeater, leopard, Ross or Weddell seals.

On the basis of residual pack ice recorded in the summers of 1970/71 to 1972/73, Gilbert and Erickson proposed zones for seal management divided at 25°W; 22°E; 72°E; 142°; 180°; and 70°W. They suggested that these six zones afford the best available units for shaping management strategies, proposing separate limits for each seal species in each zone.

Satellite imagery supplied by NASA of residual pack ice present during February of 1974 and 1975 confirm the presence of extensive pack ice remaining in locations A, B and F, indicate less extensive and fragmented areas of pack ice in locations C and D, and show little sign of residual pack ice in location E. Hence, while locations A, B and F may afford prospects for discrete populations of these seals (during summer), the case for other separate populations is less substantial. More direct observations are required.

On the other hand, the location of residual pack ice in summer may be less important to pelagic seals than the location, early in spring, of ice floes suitable for pupping and mating, and close to ready supplies of food for the newly weaned pups.

Birds: If the total breeding stock at each rookery of Antarctic seabird was known, together with the foraging range of that species during the breeding season, some inferences might be drawn concerning the distribution of food species at that time. While the locations of most breeding sites of Antarctic seabirds are generally known (e.g. Watson 1975), and counts are being monitored at certain sites, a reliable composite, quantitative picture of the distribution of each species is not readily available.

Figure 4 shows an assessment of the distribution and abundance of breeding stocks of Adelie penguins around Antarctica. This has been derived from Wilson (1983), referring back where necessary to Croxall and Kirkwood (1979) and Horne (1983), and including subsequent additions such as that of Hoshiai et al (1984). It should be noted that as counts were made in different decades they might not all be directly compatible since populations cycle, as evidenced by the steady decline in certain rookeries during the 1970s, followed by a sharp recovery in the early 1980s (Hoshiai et al 1984). Breeding sites favoured by Adelie penguins appear to be linked with localities having little residual pack ice each summer. The density of Adelie penguins recorded in summer on residual pack ice off the Oates and George V coasts (145°E - 170°E) was very low (0.02 per km^2) (Gilbert and Erikson, 1977). Figure 4 shows that the largest breeding stocks of Adelie penguins occur in the eastern margin of the Ross Sea, the coast adjacent to the Prydz Bay gyre, and on the Antarctic Peninsula.

Emperor penguins, breeding on fast ice rather than land, at a different time of the year and having different food preferences to Adelie penguins, might be expected to have different constraints to their distribution. However, Figure 5 indicates the main breeding concentrations to occur also on the eastern margin of the Ross Sea, the coast adjacent to the Prydz Bay gyre, as well as to the south of the Weddell Sea. Aerial surveys (in summer) by Gilbert and Erickson (1977) recorded very low densities on residual pack ice in the Bellingshausen and Amundsen seas (85°W - 135°)W and off the Oates and George V coasts (145°E - 170°E) (0.028 and 0.016 emperor penguins per km^2 respectively).

The rationale for conservation zones based on seabird distribution and abundance may be rather different from one based on the postulated distribution of Antarctic seals. Nevertheless, the areas of greatest concentrations of Adelie and Emperor penguins appear to relate well to the three major gyres of the Antarctic surface water circulation (i.e. the Ross Sea, Prydz Bay region, and Weddell Sea), and the resultant concentrations of food resources.

Relation to land systems:

To date there have been few attempts to relate features of the Antarctic ice cap to regional dynamics of the Southern Ocean and consequent sub-divisions of the marine ecosystem. In an approach to a framework for protected areas within both terrestrial and marine ecosystems, Keage (1986) comments that "an untried land planning concept with potential for polar protected sites is the use of ice catchments and selected ice flowlines, in combination with the adjoining pack ice zone, to delimit conservation units". Keage points out that amongst other effects, the ice cap has a controlling influence on the continental and adjacent surface wind circulation and sea ice movements near-shore.

Figure 6 shows the thirteen major ice catchments and their flowlines on the Antarctic ice cap. Where the ice sheets are extensive and the flowlines convergent, terminating in extensive ice shelves, there are productive marine ecosystems offshore (e.g. Ross Sea, Weddell Sea and Prydz Bay systems). Where there are extensive ice sheet catchments having diverging or parallel ice flow, the adjacent marine systems appear to be rather more diffuse in their productivity. Where the ice sheet catchments are least extensive, adjacent marine systems seem to be least productive, as seen in the Bellingshausen and Amundsen Seas (70°W to 150°W), where baleen whales, crabeater seals and penguins are relatively sparse, as discussed in previous sections.

Another aspect relating to land systems is the growing awareness of the need for Specially Protected Areas declared on land in order to protect breeding sites of birds or seals, to be extended into adjacent water where they feed.

MAJOR CONSERVATION AREAS PROPOSED

From the limited evidence so far available pointing to discrete or semi-discrete systems, as based on surface water circulation and krill distribution (Figure 1), baleen whale distribution (e.g. Figure 2), residual pack ice as a possible indicator of seal distribution (Figure 3), seabird breeding concentrations (Figures 4 and 5), and the major ice catchments of the Antarctic ice cap (Figure 6), the following sectors of Antarctic Surface Water are proposed as having some consistent ecological basis as potential conservation areas:

Sector	1	70°W - 15°W
	2	15°W - 40°E
	3	40°E - 90°E
	4	90°E - 150°E
	5	150°E - 160°W
	6	160°W - 70°W

These potential conservation areas within the CCAMLR region are shown in Figure 7. Future investigations might well verify that Sectors 1, 3 and 5 contain the most productive sub-systems. As further studies are made of both krill and their consumers, it may be found that stocks in certain adjacent sectors are much more closely linked than elsewhere (e.g. sectors 3 and 4), or that finer subdivision might be possible on the basis of local bathymetric effects (e.g. in Sector 6).

While supporting Latogursky's listing of the further studies required to refine the boundaries of such sub-systems, the interactions between them, the transport of krill from one to another, and the assessment of krill stocks in each (as well as their variability), we suggest that the six sectors set out above afford a basis for initiating a conservation strategy for these resources.

There may be a need for later adjustment of boundaries of these conservation areas as their resources, processes and relationships are better understood. Provided, however, that all fishing data are recorded in the form recommended by the Scientific Committee of CCAMLR (see Report of SC-CAMLR-IV, 1985; paragraph 5.9), any re-arrangement of boundaries can be accommodated if needed in the future, since the location of every haul will have been recorded. The need for recording data in this matter was re-iterated during the fifth meeting of the Scientific Committee (see the strong recommendation made in Report of SC-CAMLR-V, 1986, paragraph 5.35).

It is proposed that the conservation areas as presently defined be utilised in selecting open and closed areas as part of the CCAMLR process of shaping and implementing a conservation strategy for Antarctic marine living resources.

MANAGEMENT WITHIN CONSERVATION AREAS

While the tactics of management within the major conservation areas can be developed after the general framework of a conservation strategy has been agreed, some indication of the options available might be outlined here.

The simplest management procedure would be to open three of the major Sectors to krill harvesting (e.g. Sectors 1, 3 and 5 of Figure 7), leaving the intervening Sectors (2, 4 and 6 respectively) closed. That might be preferable to opening each Sector in turn through successive years as proposed under the Sealing Convention.

However, these Sectors are so large and the distribution of certain species within them so circumscribed, that it might be preferable to zone activities within each Sector. Thus within a Sector there might be sub-areas open to specified types of harvesting (perhaps with limited open seasons or catch limits); and sub-areas open to all activities. In such an approach, inshore zones which include nursery areas or the feeding grounds of shore-based breeding colonies, might be given greater protection than offshore (oceanic) zones.

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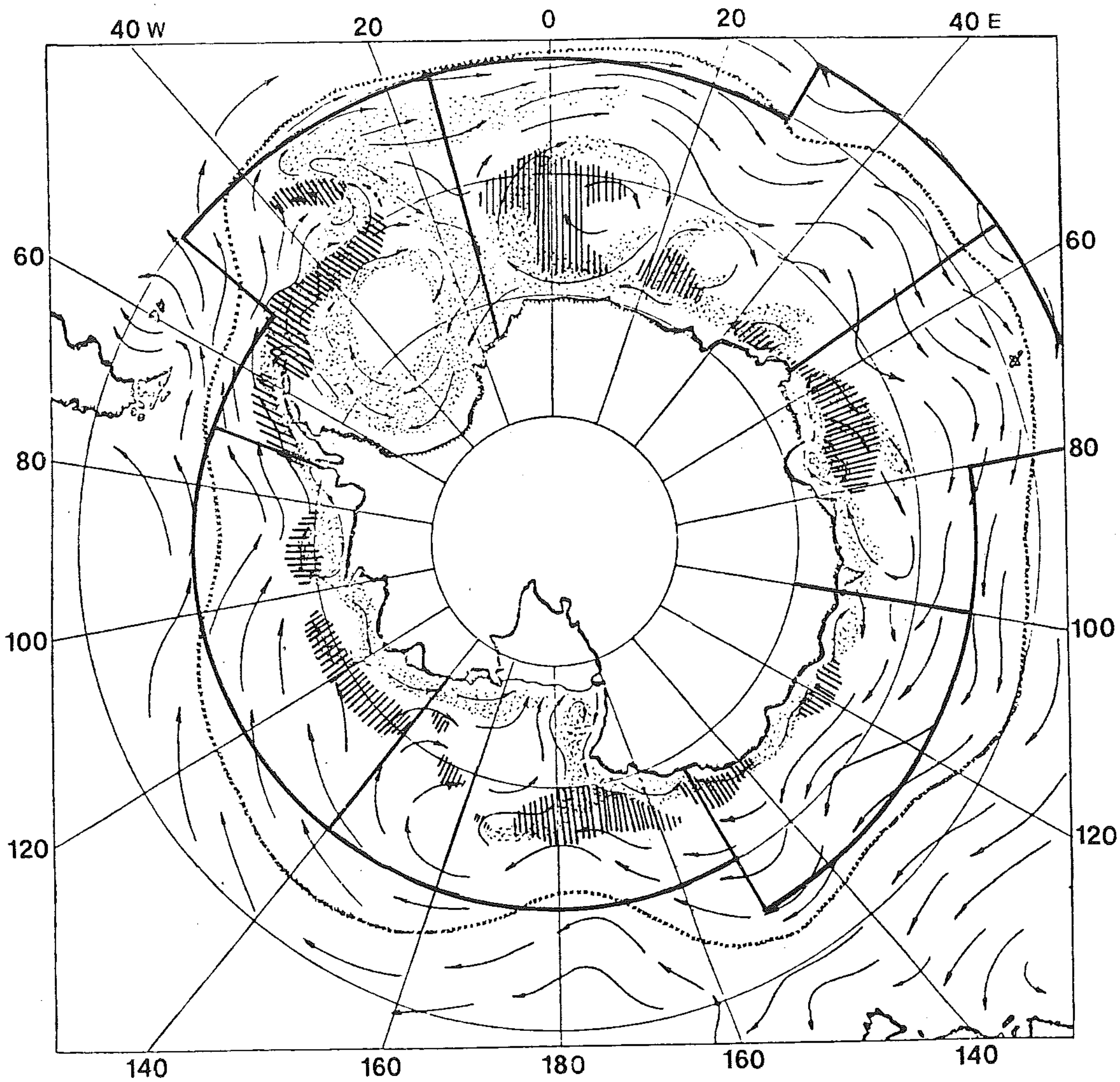

Figure 1 Surface circulation and krill concentrations (hatched areas) within the CCAMLR Convention Area (from Lubimova, 1982).

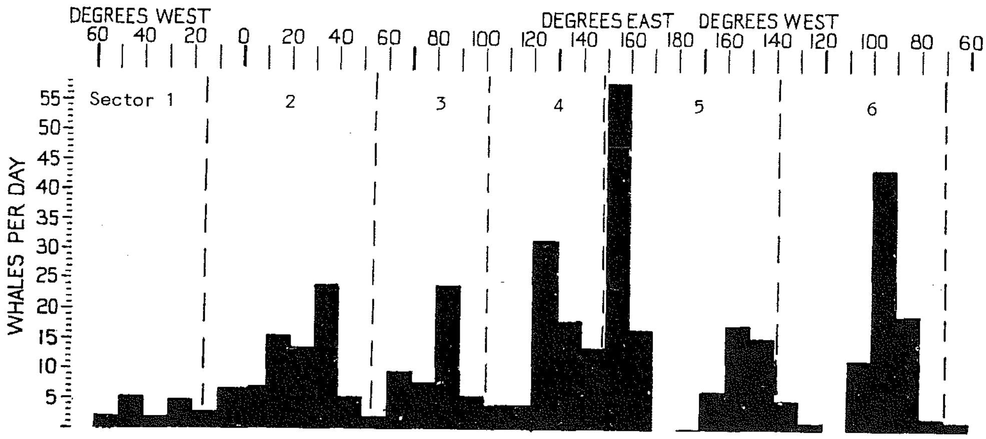

Figure 2 Estimated numbers of whales, presumed to be Blue, Fin or Humpback, seen per day south of 50°S during selected passages of Discovery II, 1933-9. (From Mackintosh, 1942). Proposed krill sectors from Figure 1.

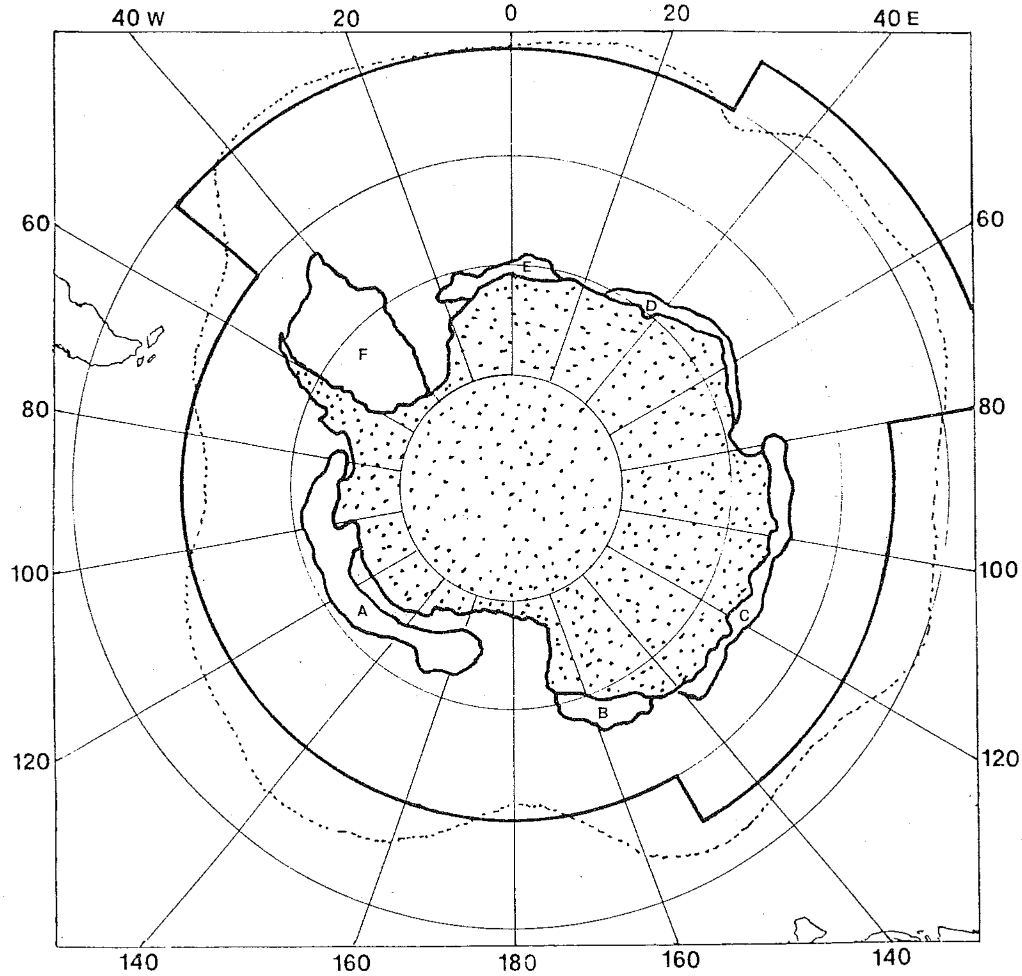

Figure 3 Six residual pack-ice regions presumed to constitute population centers for pelagic Antarctic seals in the austral summer. These regions were as follows : A, Amunsden and Bellingshausen Seas; B, Oates Coast; C, Wilkes Land; D, Queen Maud Land; E, Halley Bay; and F, Weddell Sea. (After Gilbert and Erickson, 1977).

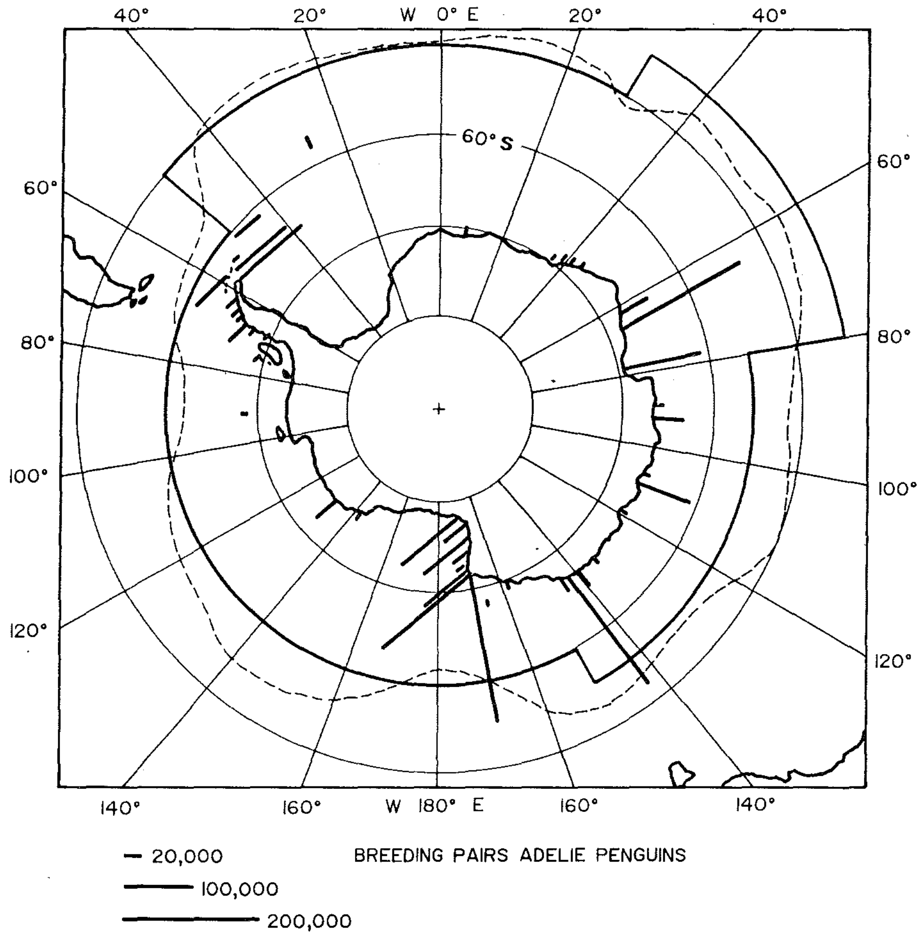

Figure 4 Breeding stocks of Adelie penguin, Pygoscelis adeliae, grouped in 1° latitude x 2° longitude.

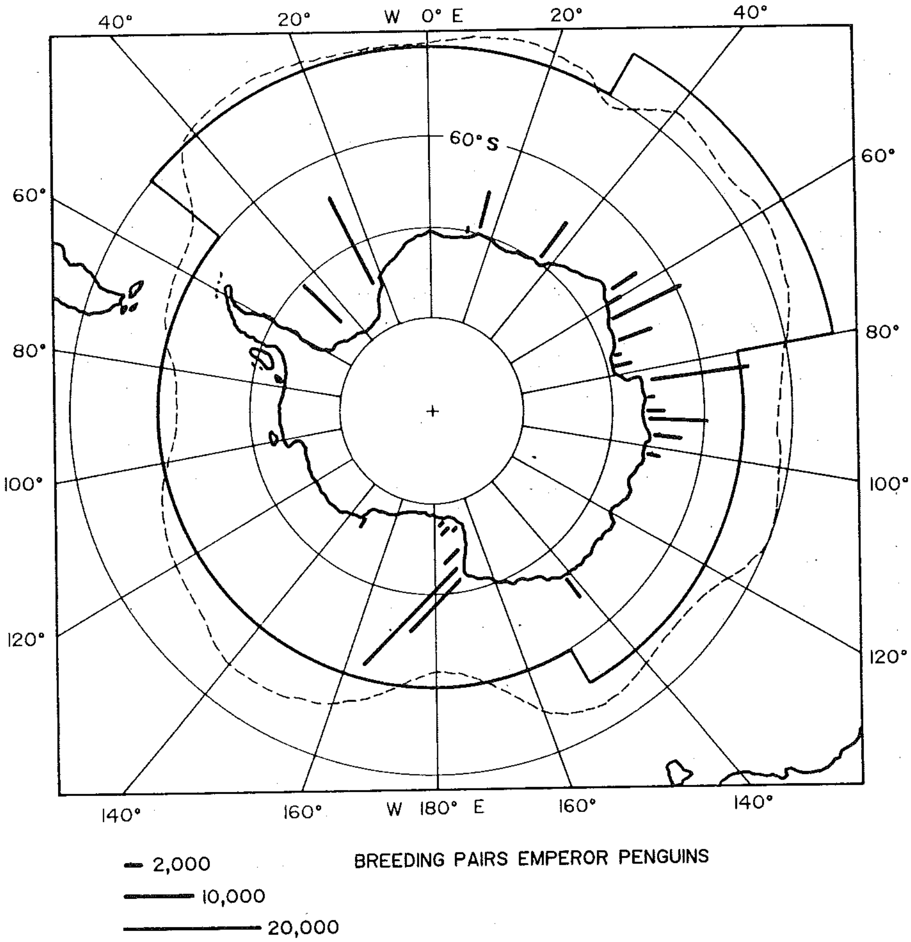

Figure 5 Breeding stocks of Emperor penguin, Aptenodytes forsteri.

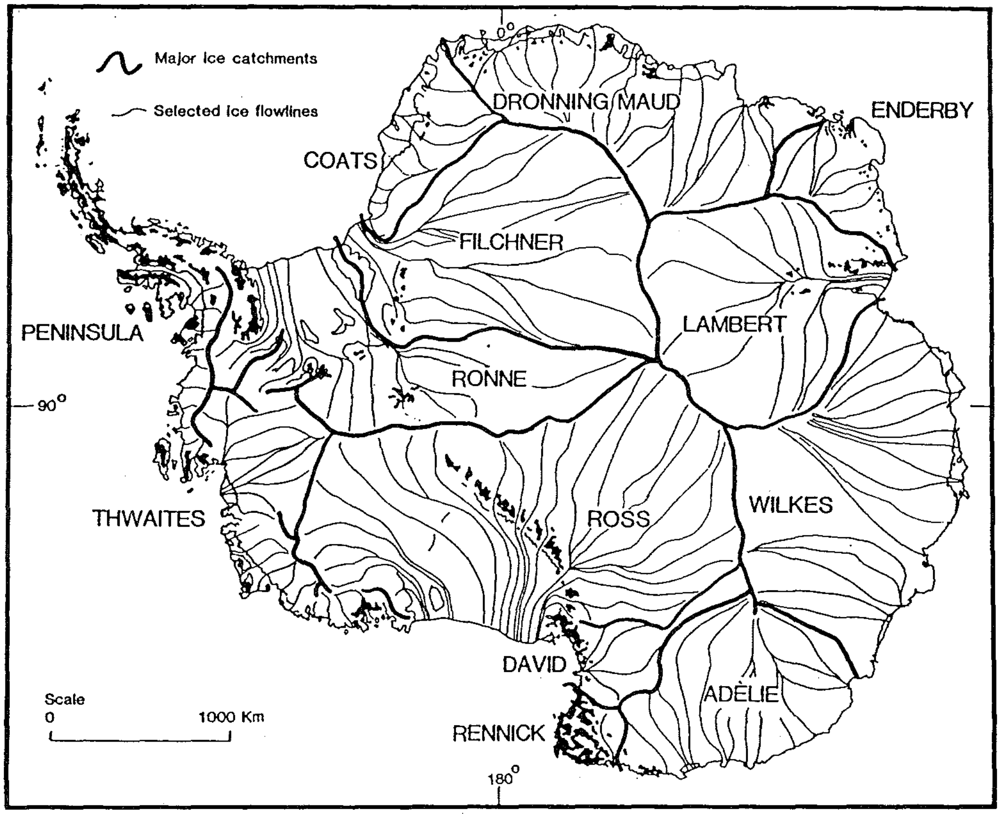

Figure 6 Major ice catchments and flowlines for the Antarctic ice cap, as adapted by Keage (1986) from Drewery (1983).

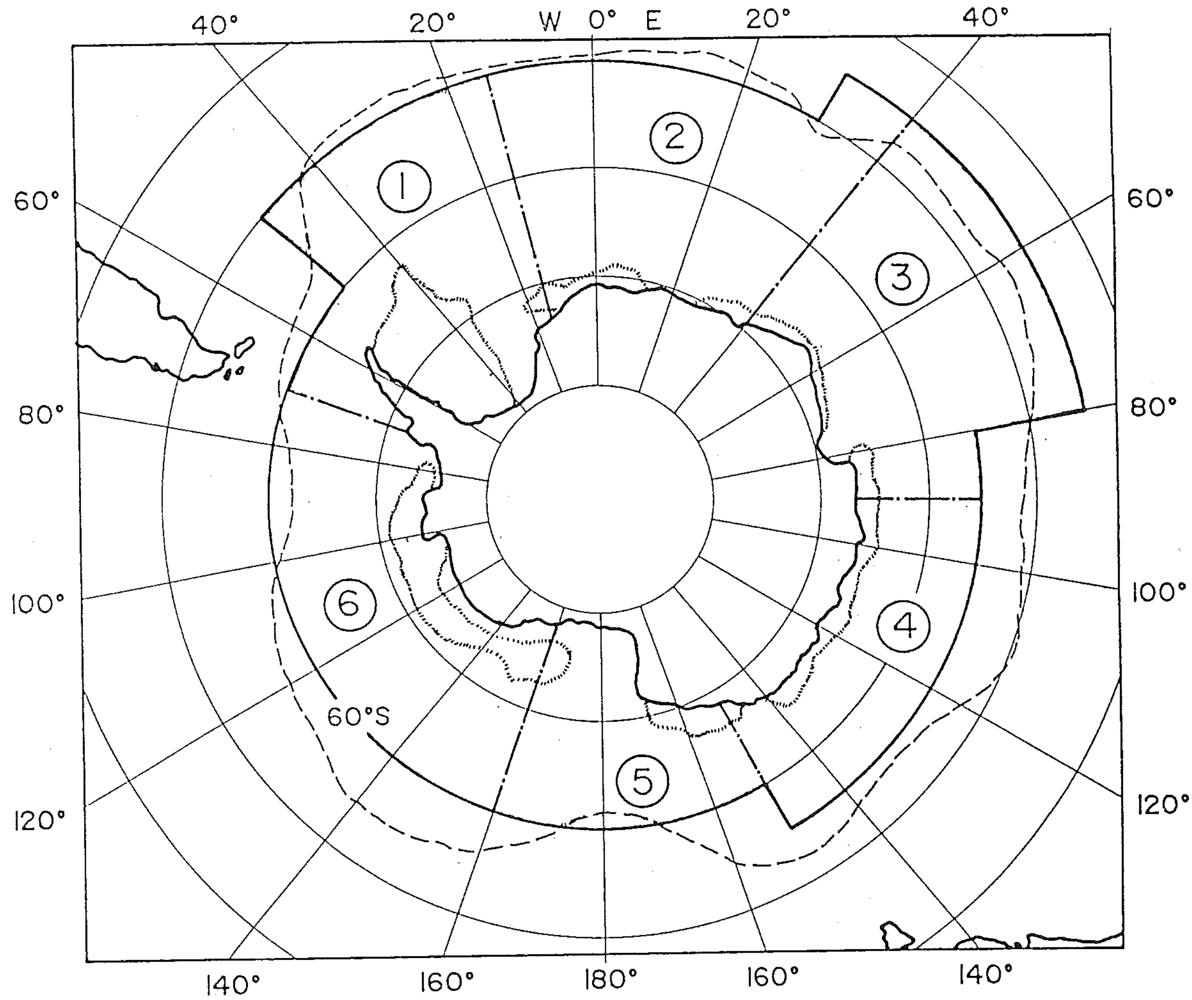

Figure 7 Potential management areas within the CCAMLR region.

Légendes des figures

Figure 1 Circulation de surface et concentrations de krill (zones hachurées) au sein de la zone de la Convention de la CCAMLR (d'après Lubimova, 1982).

Figure 2 Nombres estimatifs de baleines (présumées être des rorquals bleus, des rorquals communs ou des jubartes) aperçues par jour au sud de 50°S au cours de passages sélectionnés de Discovery II, 1933-9. (D'après Mackintosh, 1942). Secteurs de krill proposés d'après la Figure 1.

Figure 3 Six régions de banquise résiduelle présumées constituer des centres de population pour les phoques des couches pélagiques de l'Antarctique au cours de l'été austral. Ces régions sont les suivantes : A, mers d'Amundsen et de Bellingshausen; B, Côtes Oates; C, Terre de Wilkes; D, Terre de la Reine-Maud; E, Baie de Halley; et F, Mer de Weddell. (D'après Gilbert et Erickson, 1977).

Figure 4 Stocks reproducteurs du manchot Adélie, Pygoscelis adeliae, groupés par 1° de latitude X 2° de longitude.

Figure 5 Stocks reproducteurs du manchot empereur, Aptenodytes forsteri.

Figure 6 Principales accumulations et flux pour la calotte glaciaire antarctique, adapté par Keage (1986) d'après Drewery (1983).

Figure 7 Zones d'aménagement potentielles au sein de la région de la CCAMLR.

Leyendas de las Figuras

Figura 1 Circulación superficial y concentraciones de krill (áreas sombreadas) comprendidas en el Area de la Convención de CCAMLR (según datos de Lubimova, 1982).

Figura 2 Cantidades estimadas de ballenas presumiblemente Azules, Aleta o Jorobadas, vistas por día al sur de 50°S durante travesías seleccionadas del Discovery II, 1933-9. (De Mackintosh, 1942). Los sectores de krill propuestos han sido tomados de la Figura 1.

Figura 3 Seis regiones de hielo a la deriva residual que se presume constituyen centros de población de focas antárticas pelágicas en el verano austral. Estas regiones fueron las siguientes : A, Mares de Amundsen y Bellingshausen; B, Costa Oates; C, Tierra de Wilkes; D, Tierra de la Reina Maud; E, Bahía Halley; y F, Mar de Weddell. (Según Gilbert y Erickson, 1977).

Figura 4 Poblaciones reproductoras del pingüino Adelie, Pygoscelis adeliae, agrupadas en 1° latitud x 2° longitud.

Figura 5 Poblaciones reproductoras del pingüino Emperador, Aptenodytes forsteri.

Figura 6 Principales captaciones de hielo y líneas de flujo para el casquete glaciar Antártico, según adaptación de Keage (1986), de la información de Drewery (1983).

Figura 7 Areas de administración potenciales comprendidas en la región de CCAMLR.

Подписи к рисункам

Рисунок 1 Поверхностная циркуляция и скопления криля (заштрихованные участки) в зоне действия Конвенции АНТКОМа (Любимова, 1982 г.).

Рисунок 2 Примерное количество китов, как предполагается, синих, финвалов или горбатых, встречавшихся ежедневно к югу от 50 °ю.ш. во время отдельных рейсов "Дисковери II", 1933-39 гг. (Макинтош, 1942 г.). Предлагаемые на Рисунке 1 крилевые участки.

Рисунок 3 Шесть районов остаточного пакового льда, являющихся, как предполагается, районами концентрации популяций пелагических антарктических тюленей в течение австрального лета. Эти районы следующие: A - моря Амундсена и Беллинсгаузена, B - Берег Отса, C - Земля Уилкса, D - Земля Королевы Мод, E - залив Хэлли, и F - море Уэдделла (по Гилберту и Эриксону, 1977 г.).

Рисунок 4 Размножающиеся запасы пингвинов Адели, Pygoscelis adeliae, сгруппированные по участкам в 1 °широты на 2° долготы.

Рисунок 5 Размножающиеся запасы императорских пингвинов, Aptenodytes forsteri.

Рисунок 6 Основные ледовые ловушки и линии налегания ледникового покрова Антарктики, переработка Кигом (1986 г.) данных Дрюэра (1983 г.).

Рисунок 7 Возможные районы управления в зоне действия Конвенции.