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

A.W. North
(United kingdom)

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 Champsocephalus gunnari.

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 Champsocephalus gunnari.

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

A.W. North
British Antarctic Survey, NERC
High Cross, Madingley Road
Cambridge CB3 OET, United Kingdom

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 Nototheniodei 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

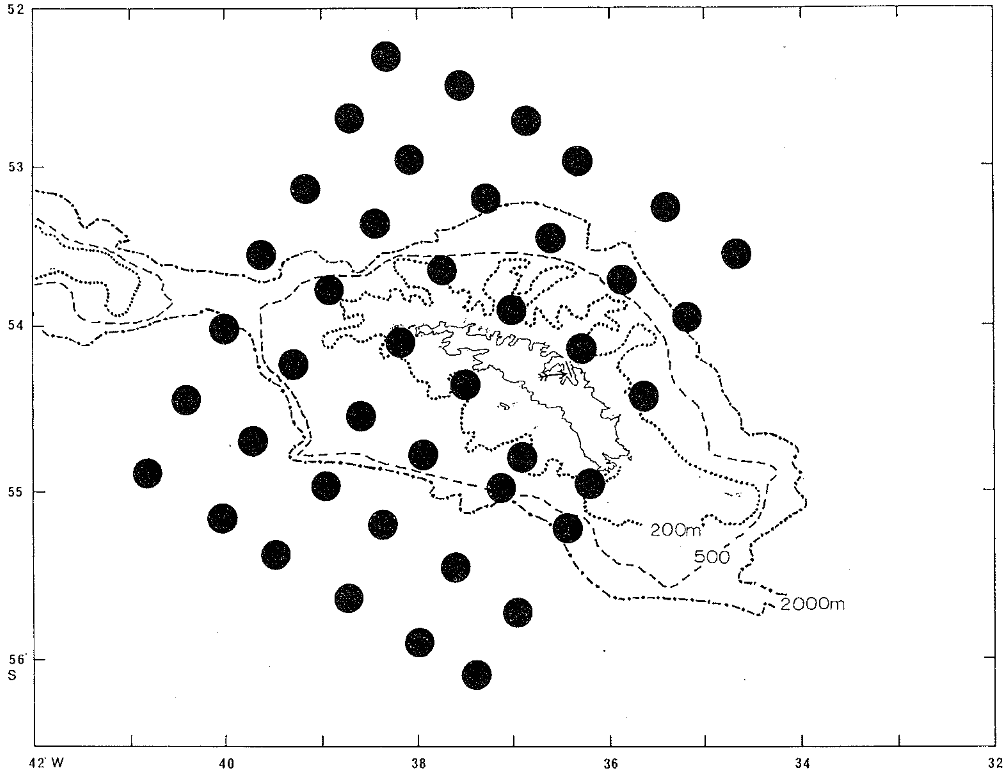
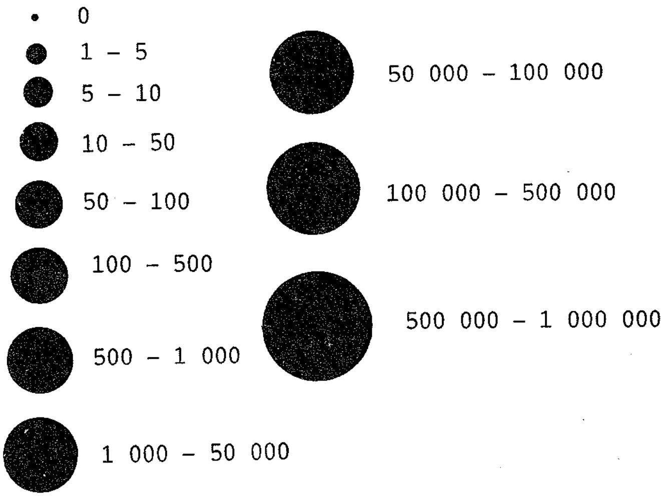


Figure 1 South Georgia zone survey, stations sampled.



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

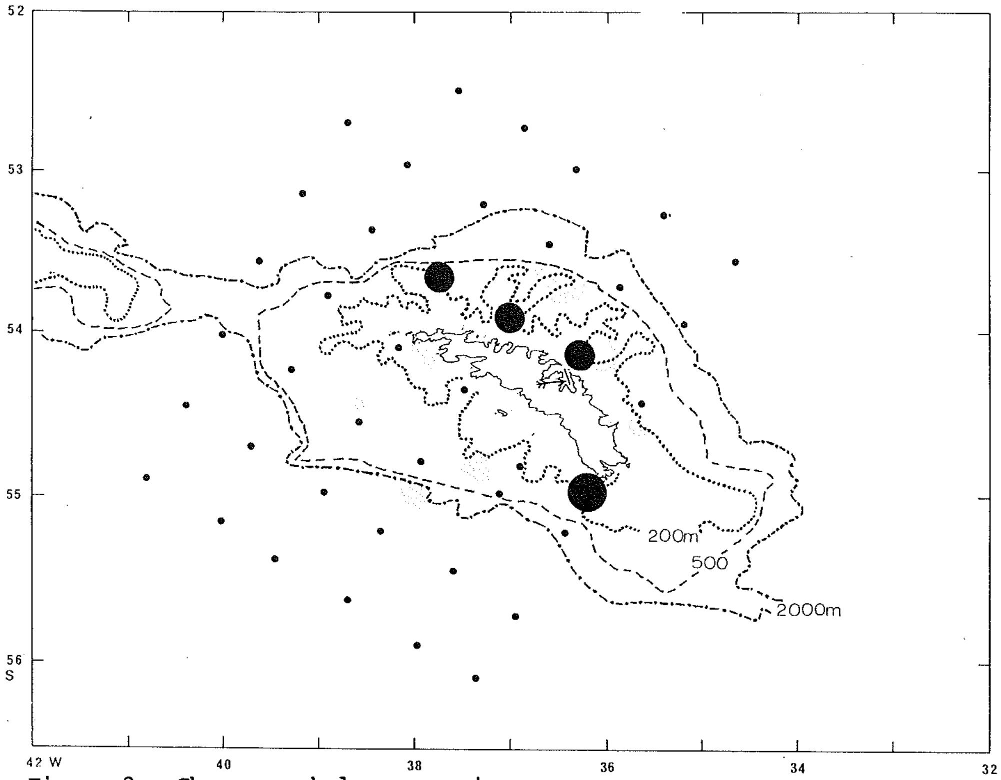


Figure 2 <u>Champsocephalus gunnari</u>.

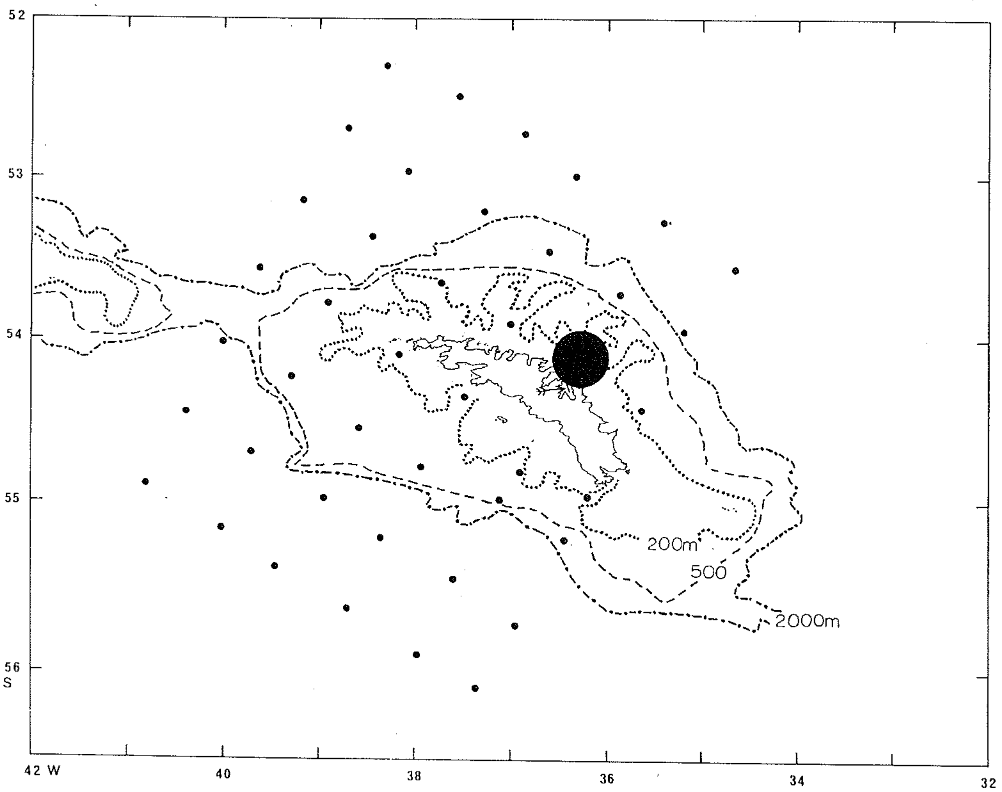


Figure 3 <u>Pagothenia hansoni</u>.

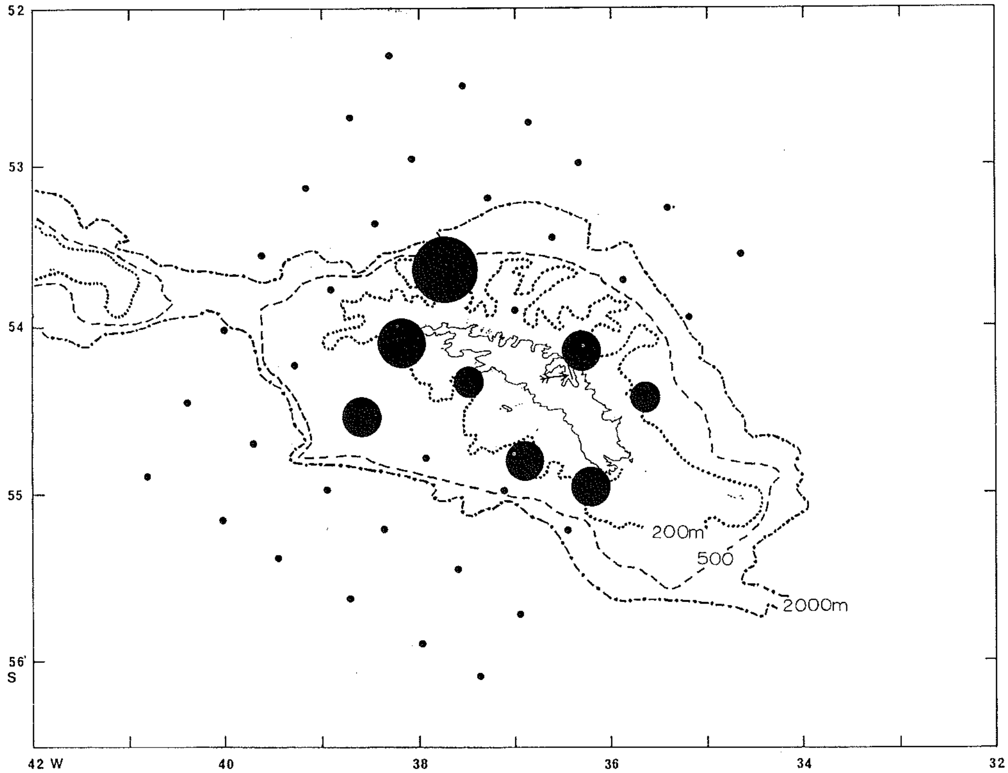


Figure 4 Nototheniops larseni.

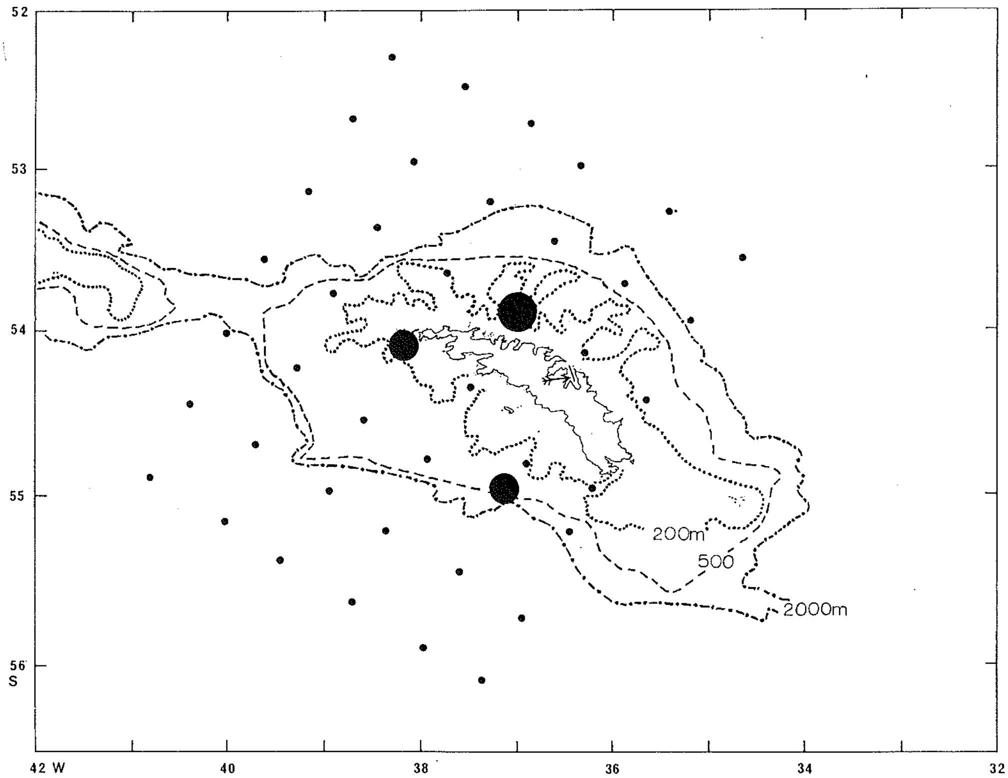


Figure 5 Notothenia kempi.

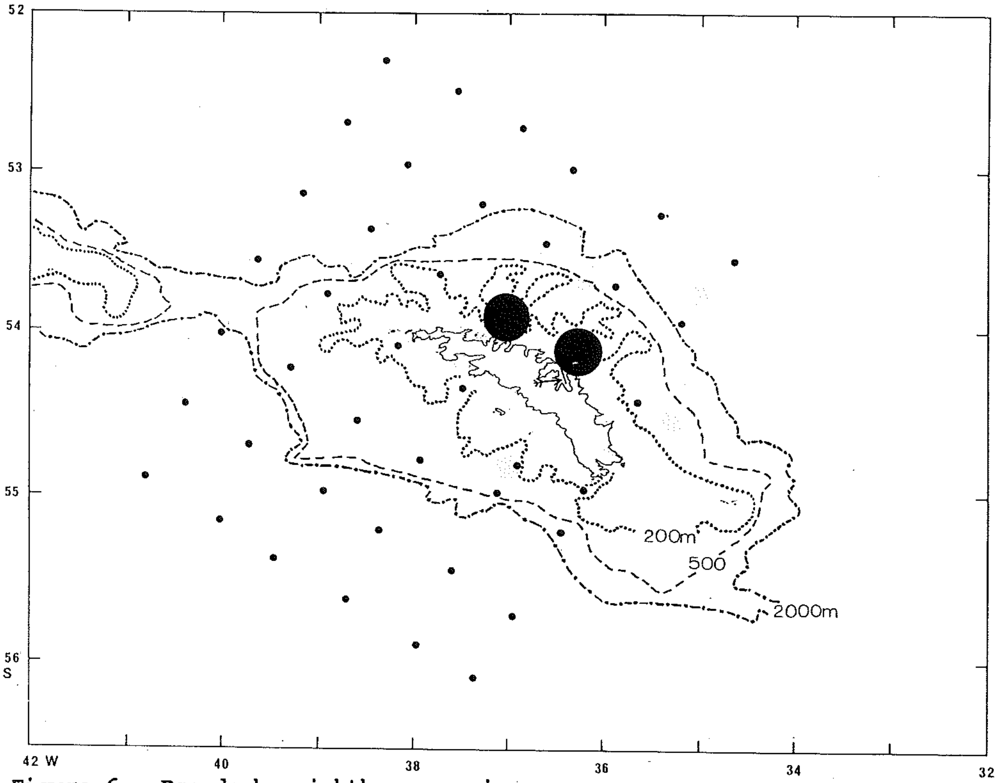


Figure 6 Pseudochaenichthys georgianus.

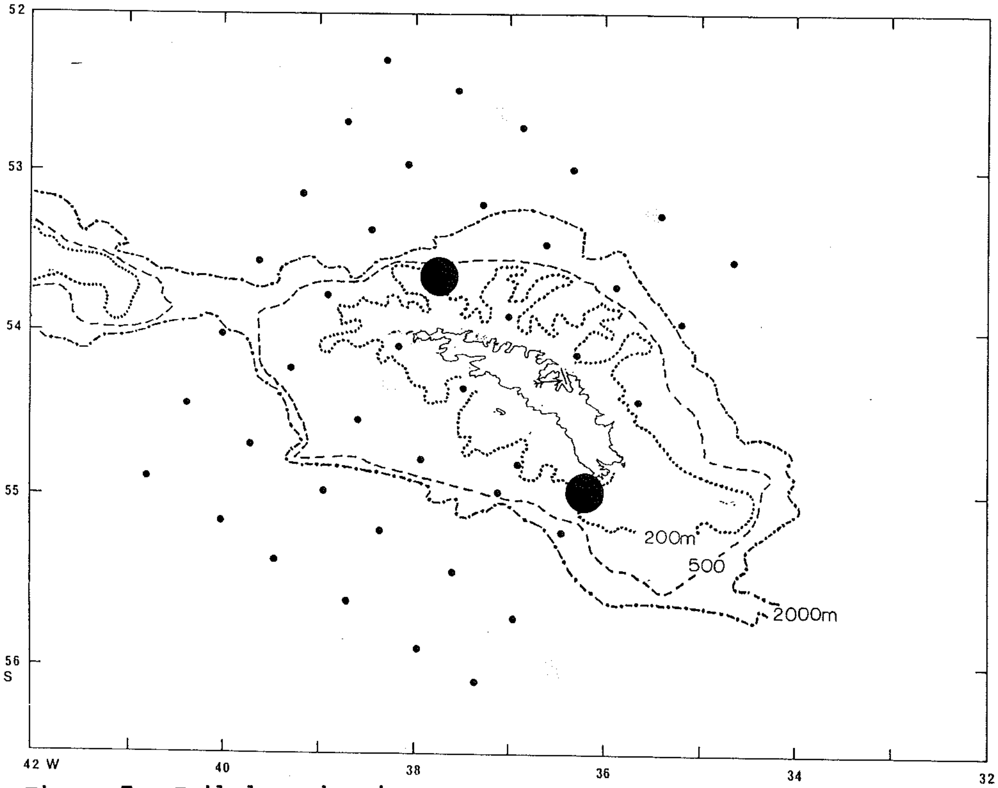


Figure 7 Psilodraco breviceps.

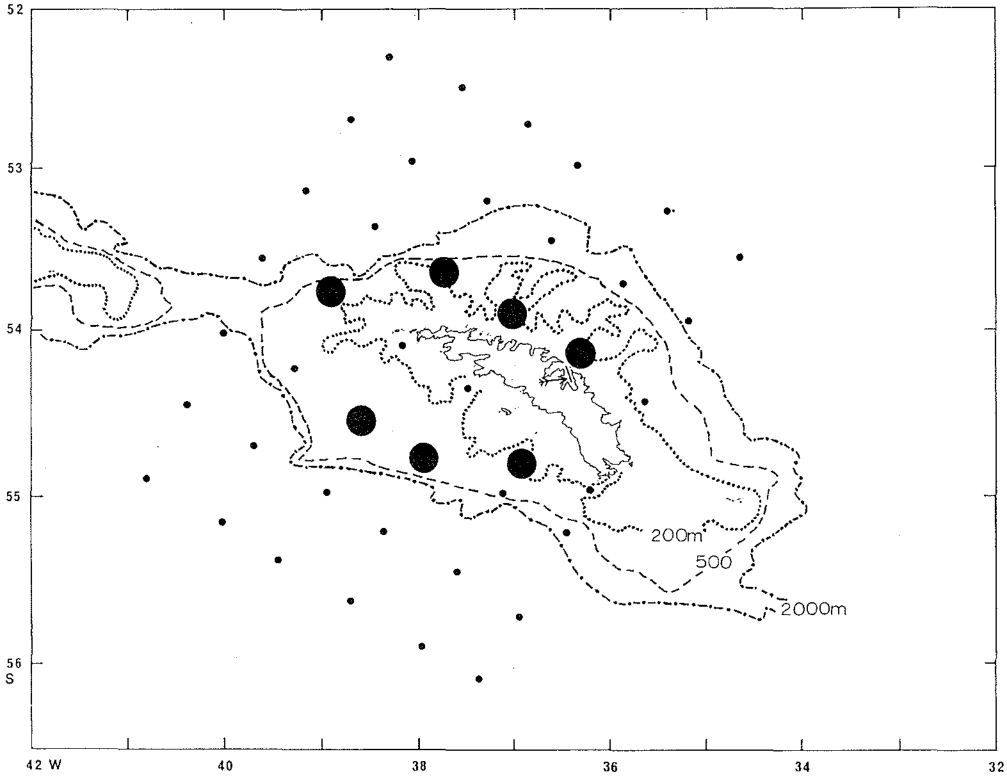


Figure 8 Muraenolepis microps.

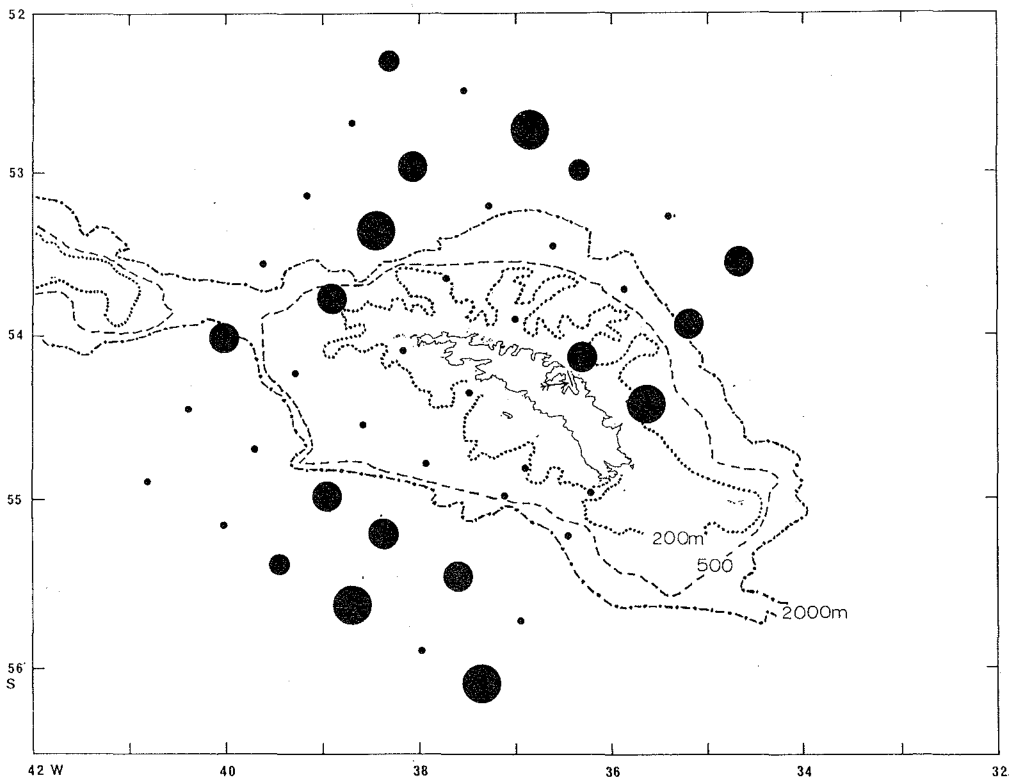


Figure 9 Notolepis coatsi.

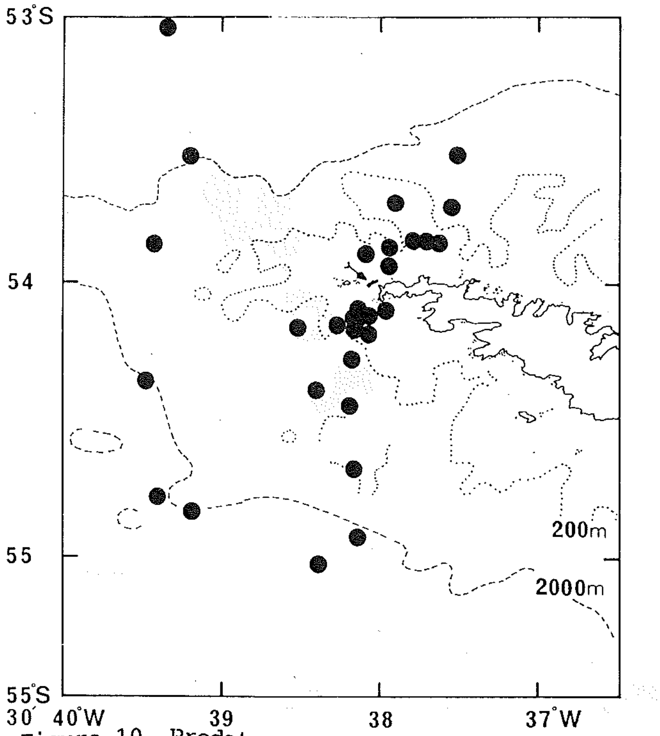


Figure 10 Predator-prey cruise, stations sampled.

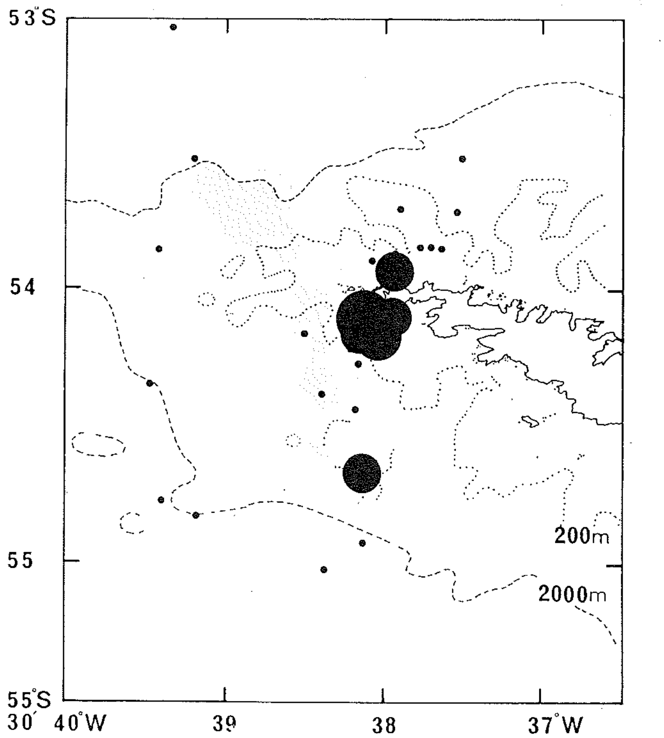


Figure 11 Champsocephalus gunnari.

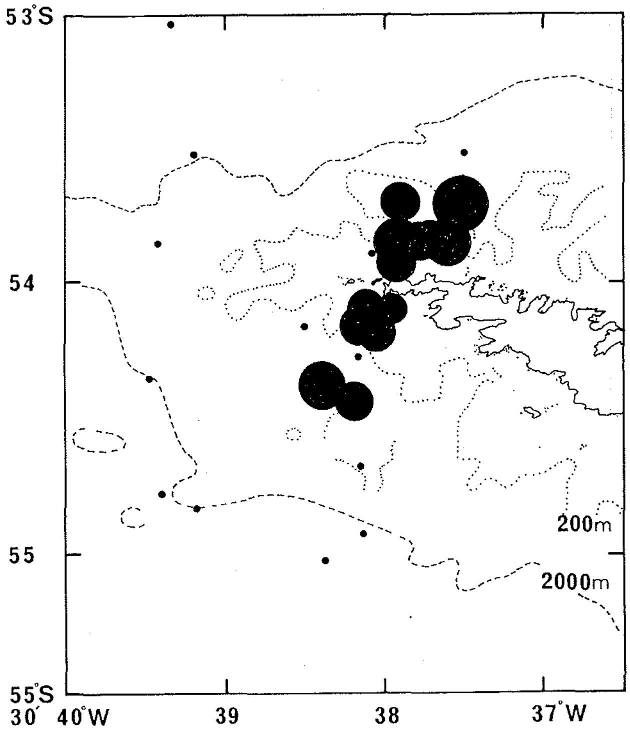


Figure 12 Notothenia gibberifrons.

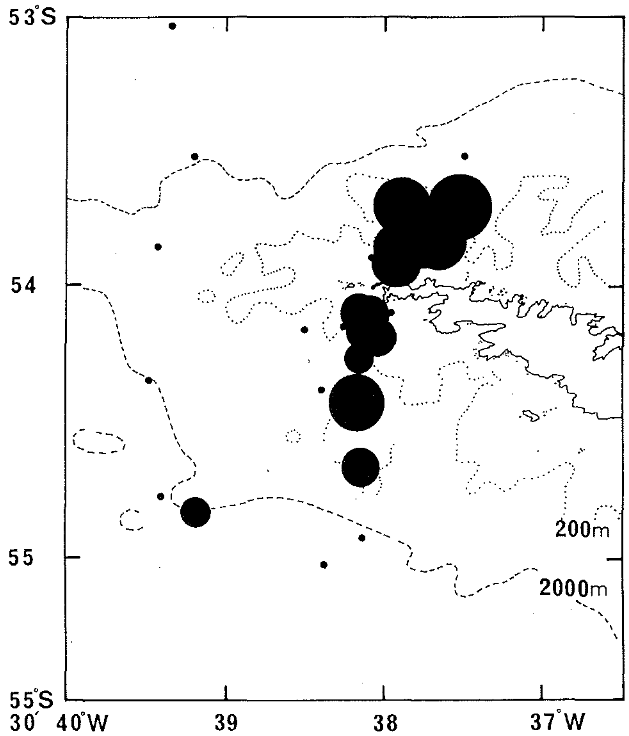


Figure 13 Nototheniops larseni.

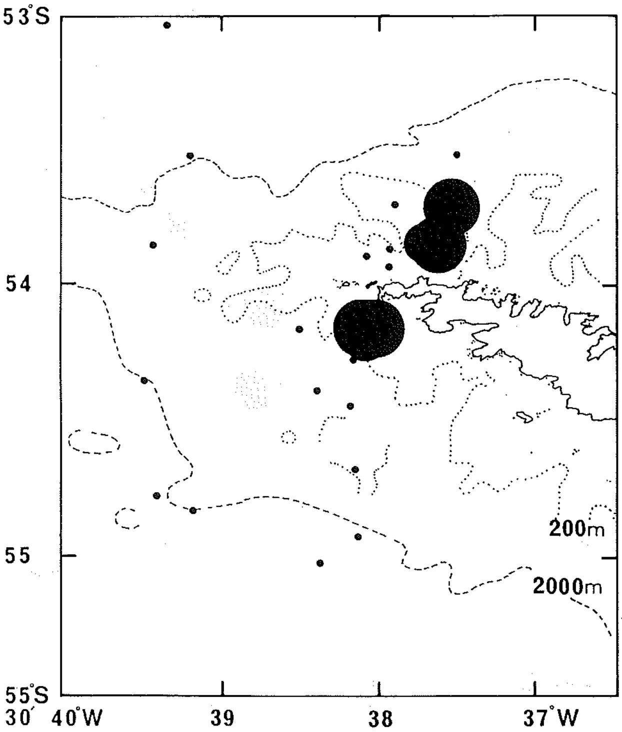


Figure 14 Nototheniops nudifrons.

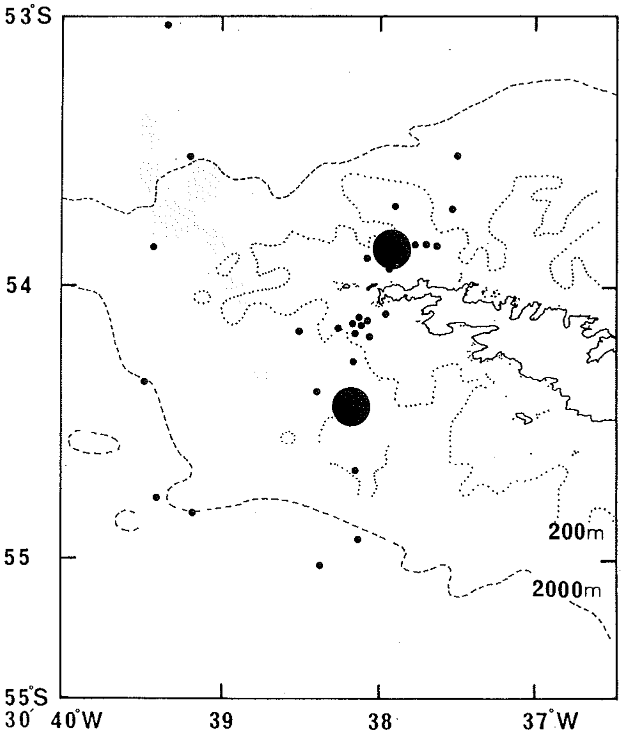


Figure 15 Pseudochaenichthys georgianus.

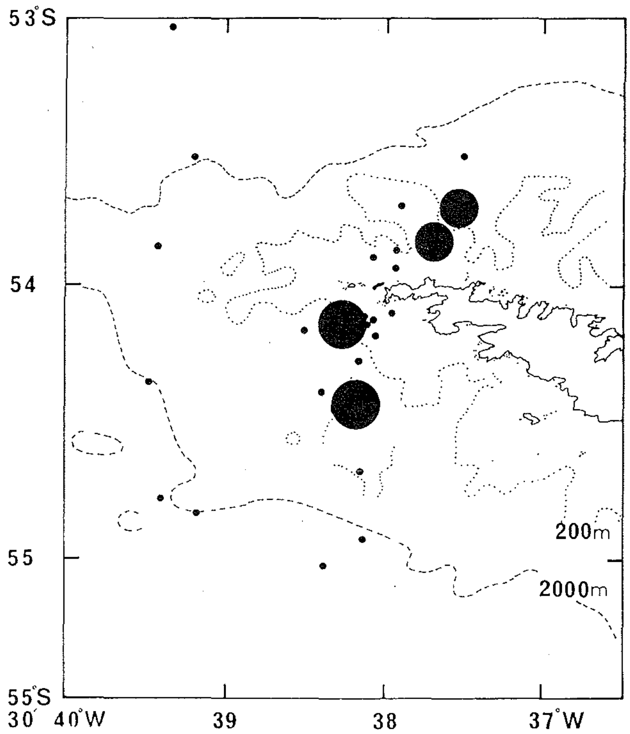


Figure 16 Chaenocephalus aceratus.

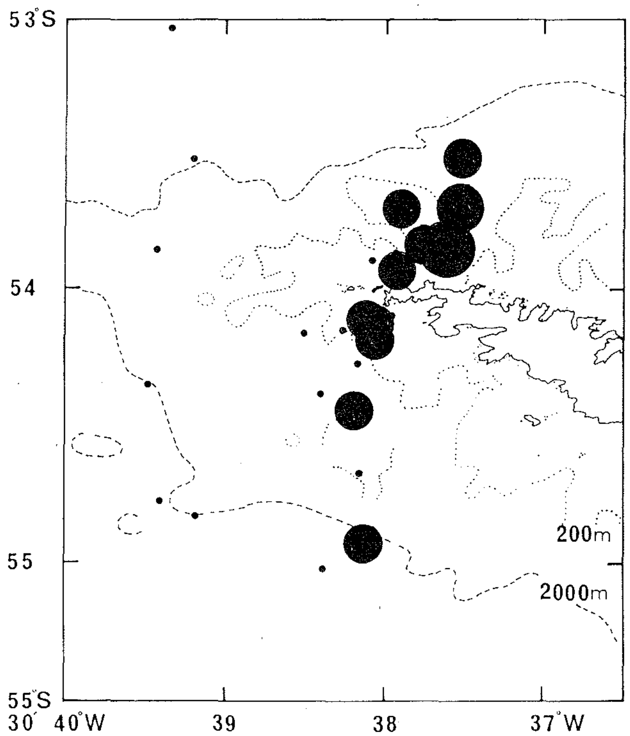


Figure 17 Muraenolepis microps.

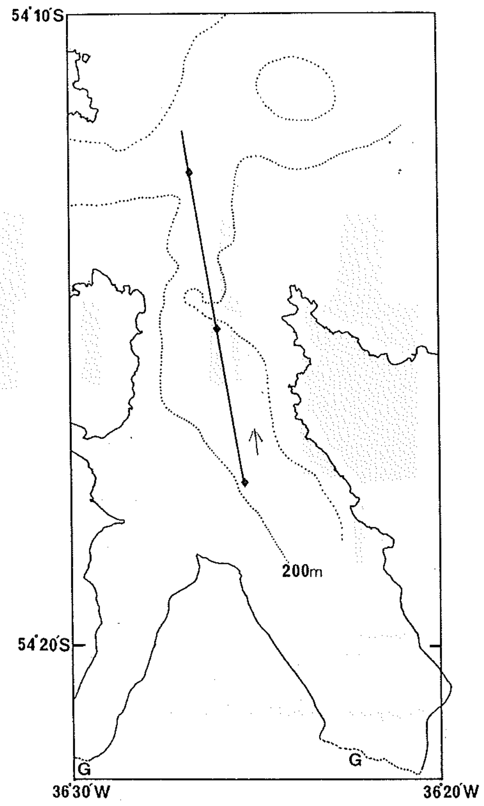


Figure 18 Cumberland East Bay, samples along line of station indicated.

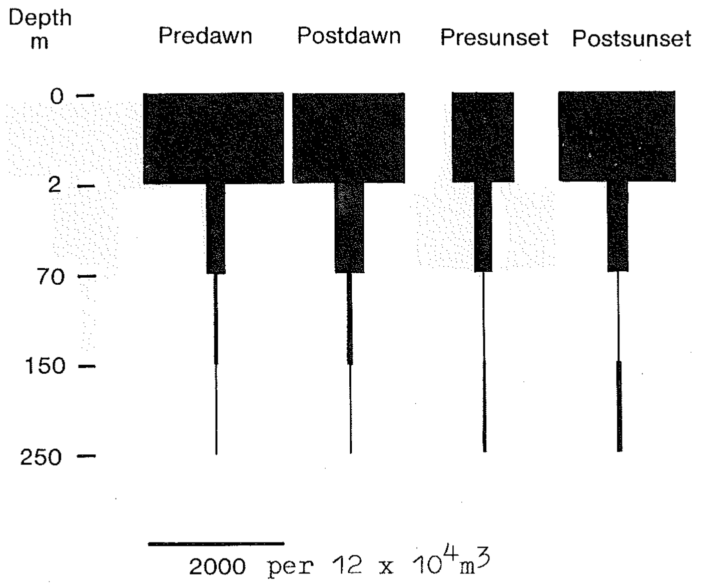


Figure 19 Notothenia sp. eggs.

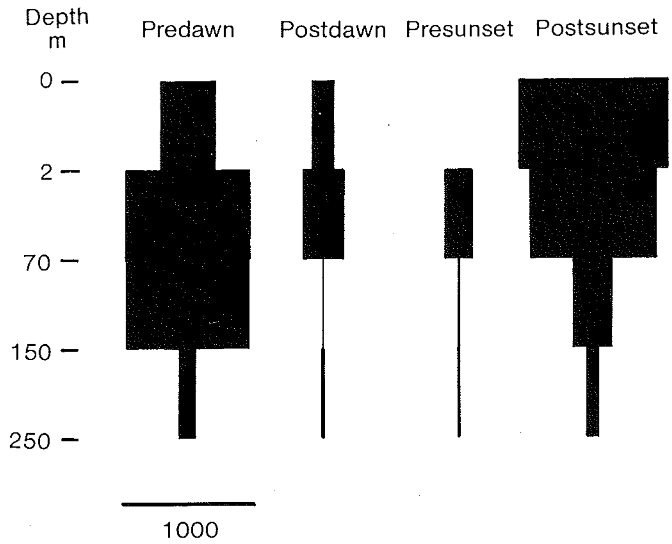


Figure 20 Champsocephalus gunnari.

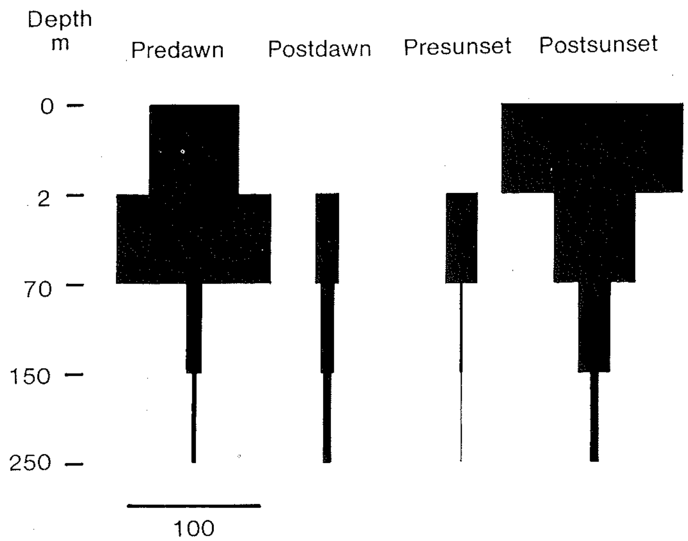


Figure 21 Nototheniops larseni.

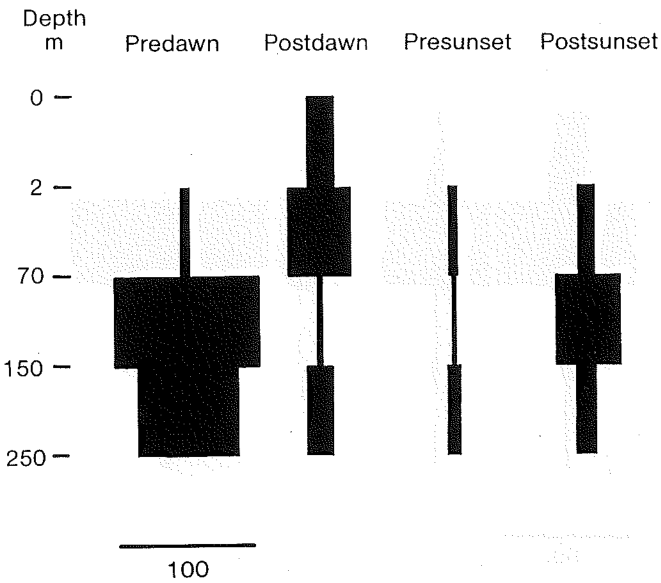


Figure 22 Pseudochaenichthys georgianus.

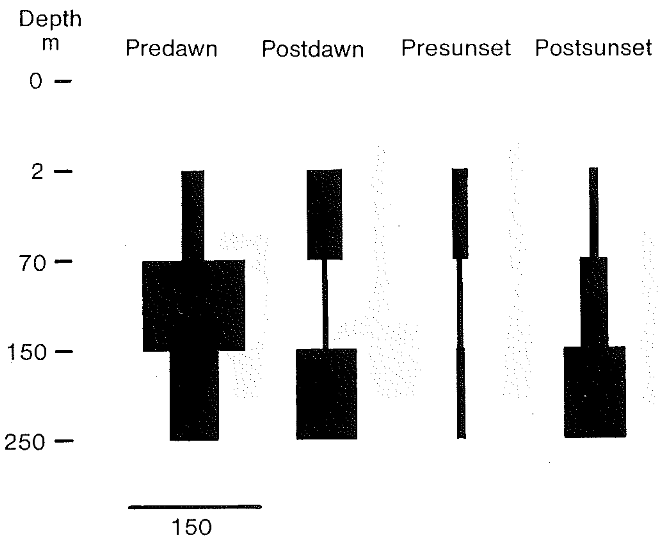


Figure 23 Chaenocephalus aceratus.

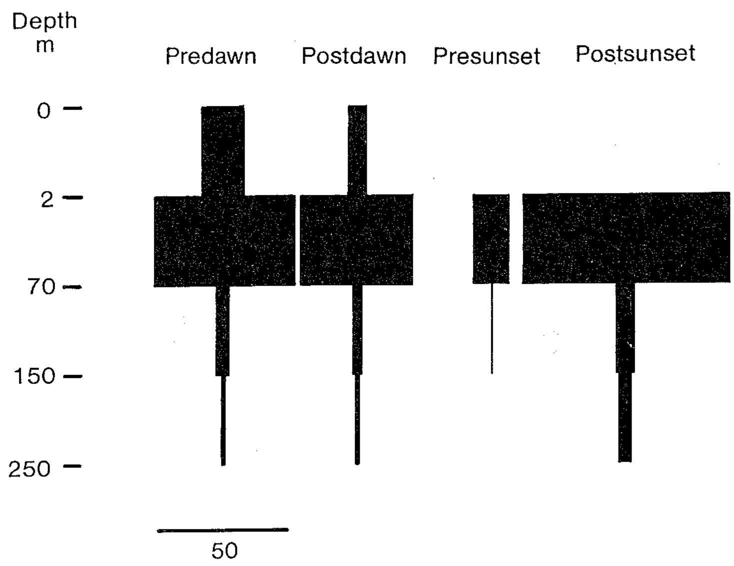


Figure 24 Parachaenichthys georgianus.

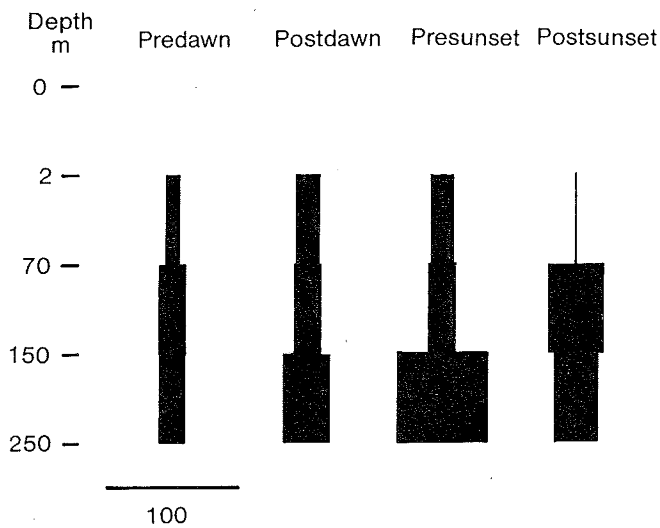
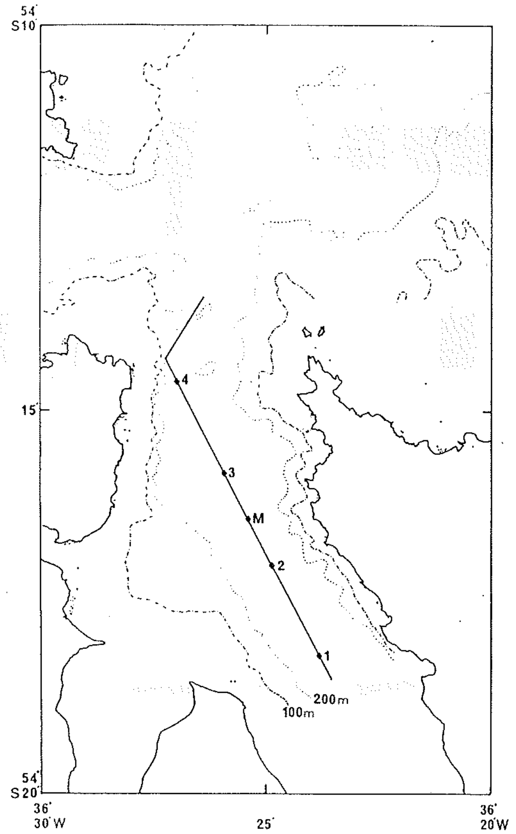
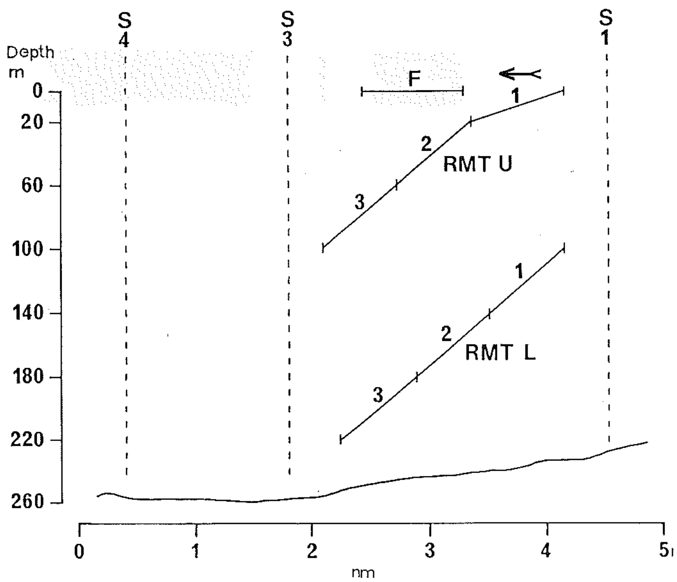


Figure 25 Electrona antarctica.



(a) Location



(b) Vertical section.

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

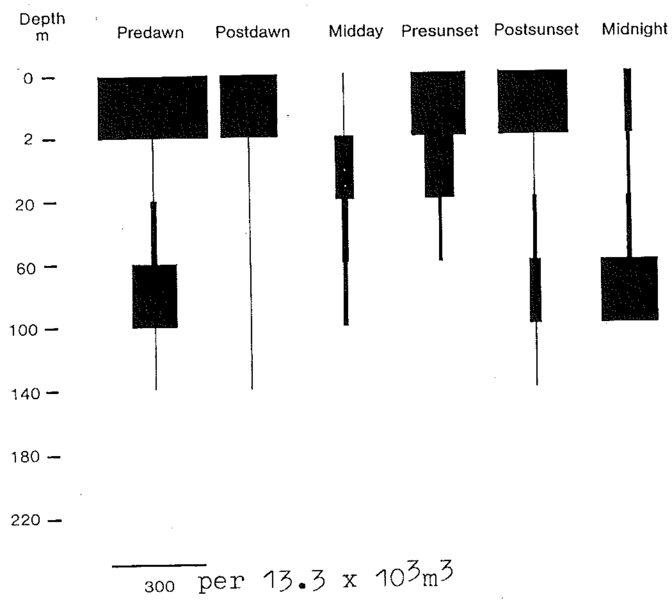


Figure 27 Champsocephalus gunnari.

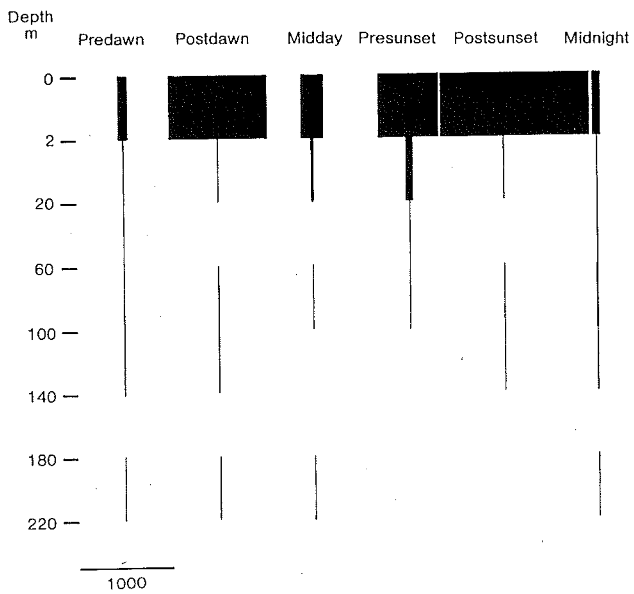


Figure 28 Notothenia gibberifrons.

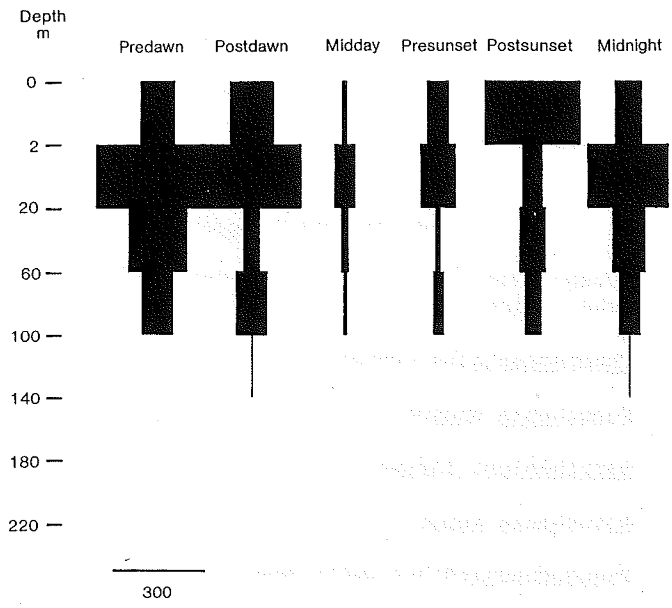


Figure 29 Nototheniops larseni.

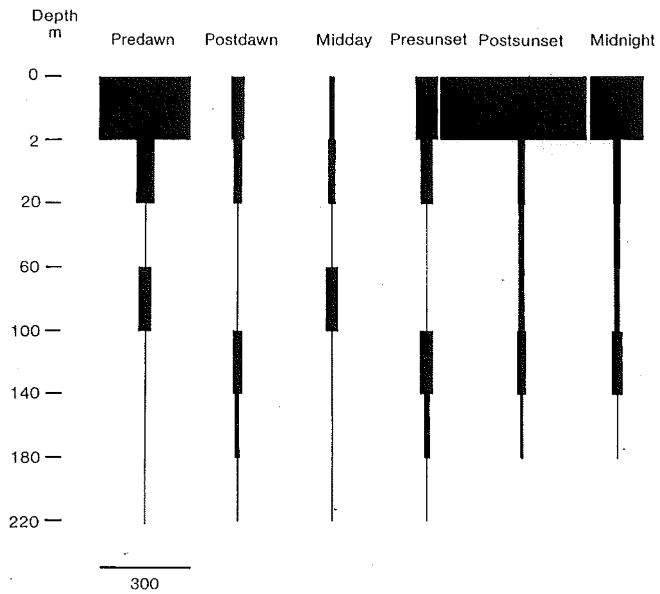


Figure 30 Pagothenia hansoni.

Légende du tableau

Tableau 1 Nombre de reprises.

Légendes des figures

Figure 1	Prospections de la zone de la Géorgie du Sud, stations échantillonnées.
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	Expédition prédateur-proie, stations échantillonnées.
Figure 11	*Champsocephalus gunnari*.
Figure 12	*Notothenia gibberifrons*.
Figure 13	*Nototheniops larseni*.
Figure 14	*Nototheniops rudifrons*.
Figure 15	*Pseudochaenichthys georgianus*.
Figure 16	*Chaenocephalus aceratus*.
Figure 17	*Muraenolepis microps*.
Figure 18	Baie est de Cumberland, échantillons prélevés sur la ligne de la station indiquée.
Figure 19	*Notothenia* 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.
Figure 26	Baie est de Cumberland, station échantillonnée le long de 1-3. (a) Position (b) Section verticale.
Figure 27	Champsocephalus gunnari.
Figure 28	Notothenia gibberifrons.
Figure 29	Nototheniops larseni.
Figure 30	Pagothenia hansoni.

Encabezamiento de la Tabla

Tabla 1	Número de observaciones.

Leyendas de las Figuras

Figura 1	Prospección de la zona de Georgia del Sur, estaciones de donde se tomaron muestras.
Figura 2	Champsocephalus gunnari.
Figura 3	Pagothenia hansoni.
Figura 4	Nototheniops larseni.
Figura 5	Notothenia kempi.
Figura 6	Pseudochaenichthys georgianus.
Figura 7	Psilodraco breviceps.
Figura 8	Muraenolepis microps.
Figura 9	Notolepis coatsi.
Figura 10	Expedición de prospección de depredadores-especies presa, estaciones de donde se tomaron muestras.
Figura 11	Champsocephalus gunnari.
Figura 12	Notothenia gibberifrons.
Figura 13	Nototheniops larseni.
Figura 14	Nototheniops rudifrons.
Figura 15	Pseudochaenichthys georgianus.
Figura 16	Chaenocephalus aceratus.
Figura 17	Muraenolepis microps.

Figura 18 Bahía Cumberland East, se indican las muestras a lo largo de la línea de la estación.

Figura 19 Huevos de especie Notothenia.

Figura 20 Champsocephalus gunnari.

Figura 21 Nototheniops larseni.

Figura 22 Pseudochaenichthys georgianus.

Figura 23 Chaenocephalus aceratus.

Figura 24 Parachaenichthys georgianus.

Figura 25 Electrona antarctica.

Figura 26 Bahía Cumberland East, estación de donde se tomaron muestras a lo largo de 1-3. (a) Ubicación. (b) Sección vertical.

Figura 27 Champsocephalus gunnari.

Figura 28 Notothenia gibberifrons.

Figura 29 Nototheniops larseni.

Figura 30 Pagothenia hansoni.

Заголовок к таблице

Таблица 1 Количество повторов.

Подписи к рисункам

Рисунок 1 Район проведения съемок у Южной Георгии, выполненные станции со взятием проб.

Рисунок 2 Champsocephalus gunnari.

Рисунок 3 Pagothenia hansoni.

Рисунок 4 Nototheniops larseni.

Рисунок 5 Notothenia kempi.

Рисунок 6 Pseudochaenichthys georgianus.

Рисунок 7 Psilodraco breviceps.

Рисунок 8 Muraenolepis microps.

Рисунок 9 Notolepis coatsi.