CCAMLR Science, Vol. 5 (1998): 125–164

COMPOSITION AND CHARACTERISTICS OF ICHTHYOFAUNA IN PELAGIC WATERS OF SOUTH GEORGIA (SUBAREA 48.3)

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Abstract

This paper presents the results of randomly stratified pelagic trawl census surveys conducted in Subarea 48.3. From 1984 to 1990 daily sampling stations aimed at studying the vertical migrations of some of the most abundant species were carried out during the six pelagic surveys. Horizontal distribution and length composition of fish, as well as the comparative distribution of krill and juvenile *Champsocephalus gunnari* were studied. The pelagic component of the ichthyocenosis in the subarea consisted of pelagic fishes (mainly Myctophidae), distributed at a depth range of 250 to 300 m, as well as demersal fishes in the pelagic stage of their life cycle. Catches contained both young and adult specimens of 42 species from 16 families. Numerically, catches were dominated by *C. gunnari, Lepidonotothen larseni, Chaenocephalus aceratus* and *Gymnoscopelus nicholsi*. Nototheniidae (12 species), Myctophidae (9 species) and Bathydraconidae (5 species) were the most common families. Adults and juveniles of some demersal species inhabited different areas, i.e. juveniles were distributed mainly in the south, whereas adults were found in the northern shelf area. Diurnal vertical distribution of young and adult fish was also different. Large fishes were most often taken near the bottom, while small ones were caught in the water column. The main food item (up to 60–80%) of both juvenile and adult fish taken by the sampling trawl in the water column was found to be krill. Aggregations of juvenile *C. gunnari* were observed only outside dense concentrations of Antarctic krill.

Résumé

L'auteur présente les résultats de campagnes d'évaluation par chalutages pélagiques, stratifiées au hasard et menées dans la sous-zone 48.3. De 1984–1990, des échantillonnages quotidiens ont été effectués pendant les six campagnes d'évaluation pélagiques pour étudier les migrations verticales de quelques-unes des espéces les plus abondantes. L'étude porte sur la distribution horizontale et la composition en longueurs des poissons, ainsi que sur une comparaison de la distribution du krill et des juvéniles de *Champsocephalus gunnari*. La composante pélagique de l'ichtyocoenose de la sous-zone consiste en poissons pélagiques (Myctophidae en particulier) répartis entre 250 et 300 m de profondeur, et en poissons démersaux au stade pélagique de leur cycle biologique. Les captures ont compris des juvéniles et des adultes de 42 espéces appartenant – 16 familles. Si l'on considére le nombre de spécimens, *C. gunnari, Lepidonotothen larseni, Chaenocephalus aceratus* et *Gymnoscopelus nicholsi* dominaient dans les captures. Les Nototheniidae (12 espéces), Myctophidae (9 espéces) et Bathydraconidae (5 espéces) étaient les familles les plus communes. Chez certaines espéces démersales, les adultes et les juvéniles avaient des habitats différents, les juvéniles par exemple, fréquentaient davantage le sud du plateau, les adultes le nord. La répartition verticale diurne des juvéniles différait également de celle des adultes. Les poissons les plus grands étaient le plus souvent capturés prés du fond, alors que les plus petits se trouvaient dans la colonne d'eau. L'aliment principal (60–80%) tant des poissons juvéniles qu'adultes capturés par le chalut d'échantillonnage dans la colonne d'eau était le krill. Ce n'est qu'en dehors des concentrations denses de krill antarctique que l'on pouvait observer des regroupements de *C. gunnari* juvéniles.

Резюме

Приводятся результаты, полученные при проведении пелагических учетных траловых съемок на основе стратификации по случайным точкам в

Подрайоне 48.3. За период с 1984 по 1990 г. выполнено 6 полноценных пелагических съемок, которые сопровождались суточными станциями для изучения вертикальных миграций наиболее массовых видов. Исследовались горизонтальное распределение и размерные характеристики рыб, а также взаимное распределение криля и молоди *Champsocephalus gunnari*. Пелагическая часть ихтиоцена подрайона была представлена рыбами пелагического комплекса, преимущественно миктофидами, обитающими над глубинами свыше 250-300 м и рыбами придонного комплекса в пелагический период жизни. В уловах были отмечены как молодь, так и взрослые представители 42 видов рыб из 16 семейств. Основу уловов по численности составляли *C. gunnari, Lepidonotothen larseni, Chaenocephalus aceratus* и *Gymnoscopelus nicholsi*, по видовому разнообразию - семейства Nototheniidae (12 видов), Myctophidae (9 видов) и Bathydraconidae (5 видов). У некоторых придонных видов взрослая рыба и молодь занимали различные участки: молодь, как правило, встречалась на юге, взрослая - на севере шельфа. Суточное вертикальное распределение молоди и взрослой рыбы отличалось: крупная рыба чаще всего облавливалась у дна, мелкая - в толще воды. Всю рыбу, выловленную мальковым тралом, объединяло то, что во время нахождения в толще воды основной ее пищей (до 60-80%) был криль. Скопления молоди *C. gunnari* наблюдались только за пределами плотных концентраций антарктического криля.

Resumen

Este trabajo presenta los resultados de prospecciones de arrastre pelágicas estratificadas aleatoriamente en la Subárea 48.3. Durante las seis prospecciones pelágicas efectuadas desde 1984 hasta 1990 se efectuaron estaciones diarias de muestreo a fin de estudiar las migraciones verticales de algunas de las especies más abundantes. Se estudió la distribución horizontal y la composición por tallas de los peces y se hizo una comparación entre la distribución de kril y de los juveniles de *Champsocephalus gunnari*. Los componentes pelágicos de la ictiocenosis en la subárea fueron peces pelágicos (en su mayoría Myctophidae), distribuidos en un estrato de profundidad entre 250 y 300 m, y peces demersales en el estadio pelágico de su desarrollo. Las capturas incluyeron ejemplares juveniles y adultos de 42 especies de 16 familias. En cuanto a números en las capturas, predominaron *C. gunnari, Lepidonotothen larseni, Chaenocephalus aceratus* y *Gymnoscopelus nicholsi*. Las familias más comunes fueron Nototheniidae (12 especies), Myctophidae (9 especies) y Bathydraconidae (5 especies). Los ejemplares adultos y juveniles de ciertas especies demersales habitan áreas diferentes, por ejemplo, los juveniles se encontraron distribuidos principalmente al sur, mientras que los adultos se encontraban en el norte de la plataforma. La distribución vertical diurna de peces adultos y juveniles también fue distinta. Los peces más grandes se capturaron con más frecuencia cerca del fondo, mientras que los más pequeños fueron capturados en la columna de agua. El kril fue el alimento más importante (hasta un 60–80%) de la dieta de los peces juveniles y adultos capturados en la red de arrastre en la columna de agua. Sólo se observaron concentraciones de *C. gunnari* alrededor de las concentraciones densas de kril antártico.

Keywords: pelagic, ichthyofauna, South Georgia, CCAMLR

INTRODUCTION

From 1984 to 1990 scientists from the Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO) carried out six pelagic surveys in the South Georgia area. Although similar work had been carried out by Polish scientists in 1980/81 (Gon and Heemstra, 1990) and during the British Antarctic Expedition in 1985 (White and North, 1985), our research was systematic in nature. This paper summarises some of the results obtained during the AtlantNIRO surveys:

- composition of the pelagic component of the ichthyofauna in shelf waters of South Georgia;
- horizontal and vertical distribution of the most abundant species in the water column; and
- length composition of the most abundant species.

Table 1: The number of hauls carried out during surveys of juvenile fish in the shelf areas of South Georgia and Shag Rocks over several years.

Vessel	*Gizhiga*	*Gizhiga*	*Gizhiga*	*Evrika*	*Pioner Latvii*	*Anchar*
Cruise number	25	28	30	24	26	22
Year	1984	1986	1987	1988	1989	1990
Date	28.5–8.6	30.5–29.6	7.7–8.8	30.3–7.4	8.7–24.7	29.5–7.6
Number of hauls:						
South Georgia	120	105	90	83	106	97
Shag Rocks	21	9	17		18	

This paper, together with summaries of results of bottom surveys, will facilitate the development of optimal methods of conducting trawl surveys (including pelagic surveys) using strata which take into account the distribution of abundant fish species.

MATERIAL AND METHODS

Surveys were conducted using a research 13.6-metre four-panel midwater trawl (vertical opening – 6 m, horizontal opening – 8 m) with a mesh size ranging from 16 to 40 mm. The upper and side net sections were of differing dimensions. The headline of the trawl was made from braided rope and measured 12.5 mm in diameter. A fine-mesh panel with a mesh size of 8–12 mm was placed in the codend of the trawl.

Surveys of pelagic fish in the South Georgia area were conducted using the method developed by Grosslein (1969) for surveying bottom fish in the northwestern Atlantic and subsequently modified by Boronin et al. (1986) for application to the South Georgia subarea. This methodology involves the following steps:

(i) divide the shelf into layers according to geographical and hydrographical divisions which are directly related to the distribution of fish (Boronin et al., 1986);

(ii) select stations within each layer by random points; and

(iii) survey the entire area in the shortest possible time.

Pelagic surveys were carried out in the period from April to August in shelf waters from the fishing zone (70–100 m) to the 500-metre isobath both during the day and at night. The number of hauls conducted varied between 83 and 141 (Table 1). At each location tows were conducted over three depths (without hauling the trawl on board): near the surface, in the middle and the 15-metre near-bottom layer. Trawls were made at each depth at a speed of 3 to 3.5 knots and lasted for 10 minutes.

In order to determine the pattern of daily vertical migrations of juveniles in areas with the highest concentration of fish, several (4–8) series of tows were carried out by the vessels BMRT *Gizhiga* (1986, 1987), RV *Evrika* (1987, 1988), BMRT *Pioner Latvii* (1989) and BMRT *Anchar* (1990) over one to two days. Each series consisted of five to seven tows of 10 to 20 minutes duration at the depth layers 0–15, 50, 75, 125 and 150 m, as well as in the near-bottom layer. The trawl was hauled on board after towing in each of these depth layers.

Two to three series of these tows were made during the day, two to three at night and one at dawn and one at dusk (a total of 36 tows per 24-hour period). During census hauls and at 24-hour stations the following information was recorded: coordinates, time of day, depth at a particular location, depth layer of trawling, trawling speed at start and finish to determine average speed, species composition, number and total length (mm) of individuals of each species caught.

The trawl bag was thoroughly shaken before untying the codend in order to reduce error when determining the size of the catch.

RESULTS

Species Composition of Catches

The data collected were used to determine the species composition of fish (Table 2). For abundant species the samples collected refer to

Table 2: Species taken by a juvenile fish sampling trawl.

Family, Species	South Georgia	Shag Rocks
Rajidae		
Raja spp.	+	
Microstomatidae		
Nansenia antarctica	+	
Bathylagidae		
Bathylagus antarcticus	+	
Paralepididae		
Notolepis coatsi	+	
Anotopteridae		
Anotopterus pharao	+	
Myctophidae		
Krefftichthys andersoni	+	
Protomyctophum bolini	+	
P. choriodon	+	
P. normani	+	
Electrona carlsbergi	+	+
E. antarctica	+	
Gymnoscopelus nicholsi	+	+
G. bolini	+	
G. braueri	+	
Muraenolepididae		
Muraenolepis microps	+	
Liparididae		
Paraliparis spp.	+	
Zoarcidae		
Lycodapus antarcticus	+	
Melanostigma gelatinosum	+	
Nototheniidae		
Dissostichus eleginoides	+	+
Gobionotothen gibberifrons	+	
Lepidonotothen larseni	+	+
L. nudifrons	+	
L. kempi	+	
L. squamifrons	+	+
Notothenia rossii	+	
N. coriiceps	+	
Patagonotothen guntheri		+
Paranotothenia magellanica	+	
Trematomus hansoni	+	
T. eulepidotus	+	
Artedidraconidae		
Pogonophryne spp.	+	
Harpagiferidae		
Harpagifer georgianus	+	
Bathydraconidae		
Bathydraco antarcticus	+	
Parachaenichthys georgianus	+	
P. charcoti	+	
Psilodraco breviceps	+	
Racovitzia glacialis	+	
Channichthyidae		
Chaenocephalus aceratus	+	
Champsocephalus gunnari	+	+
Pseudochaenichthys georgianus	+	
Gempylidae		
Paradiplospinus gracilis	+	
Achiropsettidae		
Mancopsetta maculata antarctica	+	

areas where fish aggregations were formed, for less abundant fish they refer to location of individual hauls. The most diverse families were: demersal – Nototheniidae and Bathydraconidae (12 and 5 species respectively), and pelagic – Myctophidae (9 species). The following species, previously not observed in this area, were found in shelf waters: *Trematomus eulepidotus*, *Pogonophryne* spp., *Parachaenichthys charcoti* and *Racovitzia glacialis*.

Demersal Species

Champsocephalus gunnari

In addition to small fish of age group 1, which comprised 30–50% of catches, significant amounts of larger specimens of *C. gunnari* were also caught quite regularly. These were taken both in hours of daylight and darkness within the entire water column, mainly in the 50-metre near-bottom layer.

Horizontal Distribution

Areas with high concentrations of juveniles were observed during all pelagic surveys on the South Georgia shelf. The densest aggregations (hundreds to thousands of individuals) were observed in the southern, southeastern and southwestern shelf areas. In the northern area handfuls of individuals, sometimes dozens and, on rare occasions, hundreds of fish were taken in catches. Only in those years (1987 and 1990) when the year-class being studied was highly abundant did some catches from the northern shelf area approach hundreds or thousands of fish (Figure 1).

Although juveniles occurred over all depth ranges studied, the density of aggregations varied at different depths. Catches of over 100 specimens per haul were observed at depths between 100 and 200 m and less frequently at depths of 200 to 300 m. Below the 300-metre isobath only very small numbers were caught.

During pelagic surveys in the Shag Rocks and Black Rock areas aggregations of small *C. gunnari* (120 to 140 mm) were only observed in 1989. It is therefore interesting to note that several tens of thousands of juvenile *C. gunnari* of 50 to 80 mm in length were taken in two hauls made in the hours of darkness by a midwater trawl at depths of 30 to 50 m (bottom depth in the area – 130 to 143 m) to the south and southeast of Black Rock (RV *Plunge*, 23 November to 8 December 1996). In the daytime juveniles were found entangled in the trawl netting in hauls taken at depths of 40 to 45 m (bottom depth in the area – 140 to 142 m) to the southwest of this area.

Vertical Distribution

Catches of juvenile fish at daily stations varied depending on sampling depth (from the bottom to the surface), while the overall catch distribution pattern varied over entire 24-hour periods. Catches taken in the upper layer of 0 to 50 m were minimal or zero both during the day and at night. The largest catches were generally taken in the daytime in the 80 to 120-metre layer, and at night – in the 50-metre near-bottom layer. Moreover at night the density of concentrations increased with depth. An exception to this was a 24-hour trawl station carried out by RV *Evrika* in early April 1987, when night-time catches were higher and during daylight hours most juvenile fish remained at depths of 5 to 25 m. Figure 2 shows averaged catches by depth for day and night (as a percentage of total number) for each trawl station. Therefore, vertical migration of juvenile *C. gunnari* occurred as follows: during the hours of darkness juvenile fish were either at the bottom or near-bottom layer, while migration into the upper layers began prior to dawn. It was noted that not all juveniles migrated into the water column; some remained at the bottom or near the bottom. Towards evening juveniles again descended to the near-bottom layer. Such behaviour is apparently related to feeding migration. Thus, the average index of stomach fullness was very low in the morning, increased during the day and approached its maximum level by the end of the day before decreasing again in the second half of the night (Table 3).

Table 3: Mean index of stomach fullness for juvenile *C. gunnari* at different times of the day based on data from 24-hour trawl stations (1989) on the South Georgia shelf.

Time	06:15	08:10	10:15	14:05	18:10	22:15	02:30
Mean index of stomach fullness	0.2	0.2	1.2	1.9	2.0	1.8	0.7

Table 4: The dominant lengths of fish age group 1 at various times (mm).

Species	*Evrika* 30.03–07.04.88	*Gizhiga* Cruise 25 28.05–08.06.84	*Anchar* 29.05–07.06.90	*Gizhiga* Cruise 28 30.05–29.06.86	*Pioner Latvii* 08.07–24.07.89	*Gizhiga* Cruise 30 07.07–08.08.87
P. choriodon				50		
E. carlsbergi			50			
G. nicholsi	60	60	50			60
M. microps				60	60	
G. gibberifrons		50	40	40		
L. larseni	40	50	50	50	60	60
Par. georgianus		110		110	130	
P. breviceps		60			60–70	70
C. aceratus	80	120	110	120	140	120
C. gunnari	60	90	80	100	100	100
Ps. georgianus	80	130	120	90	150	160

Table 5: Length composition of species of Channichthyidae fish in catches (mm).

Species	Survey Period					
	April	May		June		July
	S. Georgia	S. Georgia	Shag Rocks	S. Georgia	Shag Rocks	S. Georgia
C. gunnari	41–94 140–370	62–132 170–390	140-270	65–115 116–410	122–300	78–116 117–356
C. aceratus	42–94 180–350	75–128 180–350		95–134 180–510		84–133 182–473
Ps. georgianus	56–95 190–470	82–130 142–450		82–130 142–490		115–136 143–520

NB: Numerator – the length of juveniles in age-group 1
Denominator – length of fish older than 1 year
Extreme values are given for *C. gunnari* at Shag Rocks

A comparative analysis of daytime and night-time catches shows that the size of the latter was less variable. At night fish were dispersed, while during the day they were aggregated. Catches of juveniles in daytime hauls were usually three to eight times higher than at night. At some trawl stations there were significant variations in catch size, which is probably related to the horizontal transport of juveniles by moving water masses or local currents.

Length Composition

Depending on when the survey was conducted, pelagic hauls mainly contained small fish, 60 to 100 mm in length (Tables 4 and 5) which we assigned to age group 1 (about 50%). Fish length groups of 140–200 and 200–280 mm each accounted for 5 to 10% of catches; maximum length was 410 mm (Figure 3).

The mean length of juvenile *C. gunnari* varied in different areas. In June 1984 the mean length was 98 mm to the west of the island, 91 mm to the south, 105 mm to the east and 110 mm to the north. Juveniles caught in the western and southern areas probably hatch later than in the eastern and northern shelf areas.

Chaenocephalus aceratus

Horizontal Distribution

This species was caught mainly in the southern and eastern areas where it was the predominant Channichthyidae species in deep waters. This species was also predominant at all depths in the northeastern area. Catches generally contained no more than several dozen individuals (Figure 4). In 1986 *C. aceratus* was also fished in the northern shelf area. Over 90% of all catches were taken at depths from 150 to 300 m.

Vertical Distribution

At 24-hour stations juvenile *C. aceratus* were caught below the 50-metre layer in daytime catches and below 75 m at night. Older age

groups were caught over 24-hour periods almost exclusively in the 40-metre near-bottom layer, while at night they were sometimes observed near the surface.

Length Composition

The main length groups of *C. aceratus* in pelagic trawl catches were: 80 to 140 mm (40–45%) and 170 to 250 mm (about 10%), maximum length – 510 mm (Figure 5, Tables 4 and 5).

Length composition of juvenile *C. aceratus* in catches varied from area to area. The largest fish (mean length – 126 mm) were caught in the northeastern area, slightly smaller fish (124 mm) were taken in the southeastern area, while the smallest fish (116 mm) were found in the southwestern shelf area.

Pseudochaenichthys georgianus

Horizontal Distribution

This species was encountered over the entire shelf. Concentrations of this species were found in different areas over the years. The largest catches contained hundreds of specimens (Figure 6). Aggregations of *Ps. georgianus* were observed at depths of between 200 and 300 m, over seabed depressions and valleys. It is worth noting that in the daytime the number of zero catches of *Ps. georgianus* was greater than at night. The largest catches (more than 100 individuals) were taken in the northern shelf area. This species was observed in the southern area only in 1987 and 1990.

Vertical Distribution

Only handfuls of juvenile *Ps. georgianus* were recorded in catches at 24-hour stations. During daylight hours virtually no juvenile fish were caught in pelagic waters, while at night they were observed in catches taken below the 40-metre depth layer. Large individuals were caught diurnally in the 60 to 85-metre near-bottom layer, while at night they were sometimes taken near the surface.

Length Composition

Fish of 70 to 170 mm in length were predominant in pelagic trawl hauls (20 to 35%). Fish measuring 210 to 310 mm accounted for 5 to 10% of catches; maximum length was 520 mm (Figure 7, Tables 4 and 5). Length composition of juveniles varied only marginally by area, however the dominant length in the northwest and southwest was slightly smaller than in the northeastern and southeastern shelf areas.

Lepidonotothen larseni

Horizontal Distribution

This was the most abundant species. At times catches of this species numerically exceeded all other species, even *C. gunnari*. The number of individuals in catches ranged from 0 to 6 500 per haul. Juveniles were caught in all areas of the South Georgia and Shag Rocks shelves, both during the day and at night. Catches of over 1 000 specimens were recorded mostly in the northern and southeast shelf areas at depths of 100 to 200 m (Figure 8). Mean catch per haul decreased as depth increased. The highest proportion of zero catches was observed (up to 83%) in the depth range of 300 to 500 m.

Vertical Distribution

Data from 24-hour stations showed that *L. larseni* undertakes vertical migrations. During the day juveniles were mainly found at depths between 50–60 m and 120–140 m, while at night they occurred at 80–120 m. Catches were usually higher at night than during the day. In some years, however, larger specimens of *L. larseni* (more than 70 mm in length) were caught at night within the entire water column, while during the day catches were insignificant.

Length Composition

Fish of 30 to 250 mm in length were taken in pelagic hauls. Most fish were in the range of 50–70 mm (up to 60%), while the abundance of fish measuring 140 to 200 mm varied over the years from 1 to 20% (Figure 9, Table 4).

Muraenolepis microps

This species was caught in insignificant amounts, from just a few to several dozen individuals, however in some years catches of more than 100 specimens per haul were recorded. The largest catch of this species was 780 specimens. Catches in the order of several

dozen specimens were usually taken at night and around twilight at depths between 110 and 350 m. *M. microps* was mainly observed in the southern, western and northwestern shelf areas, but was not caught at all in the Shag Rocks area (Figure 10).

The length of fish in catches ranged from 35 to 440 mm. The pelagic trawl took fish measuring 35 to 80 mm (comprising 5 to 60% of catches), as well as larger fish of 170 to 210 mm (5 to 85%) and 240 to 280 mm (about 5%) (Figure 11, Table 4).

Gobionotothen gibberifrons

This species was caught in insignificant amounts. The largest catches contained dozens, and less commonly hundreds of individuals per haul. This species was mainly recorded in catches from the southern fishing grounds; in only a few years was it observed in the northern areas of the South Georgia shelf (at depths between 150 and 200 m). No specimens of *G. gibberifrons* were taken in pelagic hauls over the Shag Rocks shelf (Figure 12). It should be noted that this species was only recorded in pelagic hauls made at night or, less frequently, around twilight.

Specimens of *G. gibberifrons* 30 to 110 mm in length were caught in pelagic waters (Figure 13, Table 4).

Psilodraco breviceps

This species was recorded in four surveys (1984, 1987, 1988 and 1989). The largest catches (1987 and 1989) contained more than 100 specimens per haul (Figure 14). During the survey period fish were distributed on the southern part of the shelf where the largest catches were taken. In the northern shelf area two catches of this species were recorded only in 1984.

The length of fish caught ranged from 30 to 200 mm (Figure 15, Table 4). At 24-hour stations small *P. breviceps* (66 mm) were caught over the entire water column, while at night they were taken only in the 10-metre near-bottom layer. Large fish (120 to 190 mm) were observed over the entire water column only at night (Figure 10).

Parachaenichthys georgianus

This species was caught mainly in the north, west and east of the South Georgia shelf. In 1986, however, catches of this species were taken in the southern part of the shelf (Figure 16). Catches contained from a few to several hundred specimens, and only in 1984 were over 100 specimens per haul taken in the eastern area. In pelagic hauls specimens measured from 69 to 215 mm (Figure 17, Table 4).

Typically Pelagic Species

Pelagic fish species caught during the surveys were mainly from the family Myctophidae, which are associated with notal, Antarctic-notal and Antarctic habitat areas. The three most abundant species of this family in catches were: *E. carlsbergi*, *P. choriodon* and *G. nicholsi.*

Horizontal Distribution

E. carlsbergi is an important commercial species which is found in large numbers in the Antarctic Convergence area. During pelagic surveys it was caught primarily to the south and west of South Georgia. It was also found over the Shag Rocks shelf. At night this species was distributed at depths from 140 to 280 m. This species was only recorded in deeper waters in 1988 (March and April). Catches of *E. carlsbergi* ranged from a few to 60 or 70 specimens (Figure 18).

P. choriodon: There is a paucity of data on the distribution of this species. Our information, however, enables us to define more precisely the boundaries of its range and to include the South Georgia subarea as part of this habitat. During the survey period *P. choriodon* was caught both during the day and at night. The largest catches contained more than 100 specimens per haul. Catches of more than 10 specimens were recorded in all areas except the southern part of the shelf, where one catch of this size was taken in 1989 and one in 1990. In 1987 over 100 specimens were recorded in one catch over the Shag Rocks shelf (Figure 20). The shallowest depth at which *P. choriodon* was caught was 120 m. Most catches were taken at depths from 230 to 280 m.

G. nicholsi is widely distributed in sub-Antarctic and Antarctic waters of the Southern Ocean. Significant catches were taken on the South Georgia and South Shetlands shelves, as well as on the continental slope of the Argentine Basin. During the survey period this species was recorded in all areas, and the largest catches were from the southern and eastern sectors. *G. nicholsi* often dominated catches by

number. Catches of this species were larger at night than during the day. In daylight hours the largest haul was 113 specimens, while at night the maximum catch was 279 individuals. This pattern was observed throughout all six surveys. In the South Georgia shelf area fish were mainly distributed between 250 and 350 m (Figure 22).

Length Composition

The length range of *P. choriodon* and *E. carlsbergi* in catches was from 40 to 110 mm. For the latter species, age group 1 was represented by only two specimens (40 mm). Fish measuring over 50 mm constituted the bulk of individuals caught and can be classified as belonging to age groups 2 and 3 (Figures 19 and 21, Table 4). The length range of *G. nicholsi* was 40 to 190 mm. Juveniles of age group 1 (40 to 80 mm) were recorded during four surveys and over the years accounted for between 6 and 27% of the total number of this species (Figure 23, Table 4).

DISCUSSION

Species Composition of Catches

Attempts to analyse the ichthyocenosis dynamics in the South Georgia shelf area were previously made using commercial catch statistics and bottom survey data from research vessels. A summary of information on the eleven most abundant fish species is given in Frolkina (1993).

However, further studies demonstrated that in order to gain a more comprehensive understanding of the way the entire ecosystem functions, it is essential to undertake more research into the ecological features of both abundant and less-abundant fish species at all stages of their life cycles, both in the bottom and pelagic zones.

It is known that virtually all species of Nototheniidae, being demersal fish, are to a certain extent associated with the pelagic zone throughout their entire life cycle. Many fish species from other families are also found in the pelagic waters of the South Georgia area. Thus, during the surveys catches contained both typically pelagic and demersal species.

According to recent data (Gon and Heemstra, 1990), 64 fish species are found within the 500-metre isobath around South Georgia. Our pelagic surveys have uncovered 42 species of fish (Tables 6 and 7), some of which are observed in this area for the first time. The following species have not been mentioned in previous studies as occurring in this area: *T. eulepidotus*, *Pogonophryne* spp., *P. charcoti* and *R. glacialis* (Table 2). *T. eulepidotus* in the Atlantic sector of the Southern Ocean had previously only been recorded around the South Shetland and South Orkney Islands and on the Antarctic shelf (Gon and Heemstra, 1990). It has not been established to what species the samples of genus Pogonophryne belong. According to available data (Gon and Heemstra, 1990), there are about 13 species from this genus on island shelves to the south of South Georgia. Finally, the range of *P. charcoti* in the southern Atlantic includes the South Shetland and South Orkney shelves, as does the range of *R. glacialis*, with the addition of the South Sandwich Island shelf (Gon and Heemstra, 1990). It would appear that at certain times (most likely during the stages of early development) small numbers of these species are brought by currents to the South Georgia shelf and therefore probably represent a secondary, insignificant element of the ichthyofauna in this subarea. Moreover, we cannot exclude the possibility of an error being made in determining the species of certain individuals, for example those assigned to *T. eulepidotus*.

The species composition in pelagic waters of the Shag Rocks and Black Rock shelves was much less diverse, comprising only four species of demersal and two of pelagic fish (Table 2).

The occurrence, abundance and distribution of the most numerous species of fish differed fairly significantly in different years (Table 6). This is due to seasonal and interannual variations in habitat conditions.

Distribution

Survey data showed an uneven pelagic distribution of juvenile fish in the shelf waters of South Georgia. A similar pattern was observed for krill. Obviously, the formation and disintegration of juvenile fish and krill aggregations are caused by similar factors. It is well known that the spatial distribution and size of krill swarms in the shelf area are influenced by hydrodynamics, i.e. by the current system and eddies formed in a particular season. High krill concentrations occur in convergence zones of currents and eddies. In the areas where the

Table 6: Composition of ichthyofauna in the South Georgia area according to published data and the results of AtlantNIRO pelagic surveys.

Source	Total		Demersal		Pelagic	
	Families	Species	Families	Species	Families	Species
Gon and Heemstra, 1990	22	64	9	27	15	37
Our data	16	42	8	24	9	18

Table 7: Occurrence of the most abundant fish species in catches made by a juvenile fish sampling trawl.

Species	*Gizhiga* 1984		*Gizhiga* 1986		*Gizhiga* 1987		*Evrika* 1988		*Pioner Latvii* 1989		*Anchar* 1990	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
P. choriodon	864	3.9	2 092	4.5	286	0.3	-	-	5 034	3.3	449	0.9
E. carlsbergi	243	1.1	104	0.2	315	0.3	276	0.6	231	0.1	+	+
G. nicholsi	1 240	5.6	1 207	2.6	+	+	94	0.2	+	+	+	+
M. microps	187	0.8	780	1.7	262	0.2	75	0.2	377	0.3	+	+
G. gibberifrons	145	0.7	343	0.7	+	+	+	+	+	+	494	1.0
L. larseni	11 494	52.3	22 847	49.5	3 442	3.1	851	1.7	114 096	75.8	8 582	16.9
Par. georgianus	107	0.5	264	0.6	+	+	+	+	194	0.1	+	+
P. breviceps	723	3.3	-	-	367	0.3	65	0.1	1 167	0.8	-	-
C. aceratus	1 151	5.2	1 208	2.6	539	0.5	521	1.1	333	0.2	4 680	9.2
C. gunnari	3 710	16.9	12 629	27.3	24 515	22.0	12 214	24.6	12 746	8.5	35 550	69.8
Ps. georgianus	706	3.2	1 025	2.2	687	0.6	209	0.4	1 506	1.0	572	1.1

current field is a simple linear structure, krill has a dispersed distribution. This explains the apparent heterogeneity of krill distribution. The similar distribution pattern for C. *gunnari* may be explained by the fact that juvenile fish spend most of the day in pelagic waters and are incapable of undertaking active migrations.

Comparison of juvenile and adult fish distribution reveals spatial separation. This appears to be a defence mechanism on the part of juveniles, since, as our observations show, adult fish feed on juveniles. Juvenile *C. gunnari*, especially in the southern shelf area, comprised about 20% of the stomach content of adults. The fact that diurnal vertical migrations of juveniles and adults are out of sync may also be related to this defence mechanism.

Comparison of data on the distribution of Channichthyidae species demonstrated that in the southeastern shelf area there were fewer juvenile *C. gunnari* and more *Ps. georgianus* as depth increased, while at greater depths *C. aceratus* was the dominant species, as it was at all depths in the northeast.

Length Composition

In the analysis of length composition of all species under investigation a fairly significant group of the smallest individuals emerged, which we nominally assigned to age group 1; subsequent length groups were assigned to age groups 2, 3 etc.

Since surveys were carried out in different months (April to June), the length of age group 1 fish varied considerably (Tables 4 and 5).

Other length groups constituted an insignificant proportion of the catch, making it difficult to assign them to any particular age group without first carrying out age determination procedures.

By-catch of Juvenile *C. gunnari* during Krill Fishing

Comparison of juvenile fish distribution based on survey data for the years 1986 to 1990 and krill distribution based on commercial catch data for the same period shows that fish do not form dense concentrations within krill aggregations, but rather on the periphery of such aggregations (Figure 1). In areas of krill aggregations juvenile catches were very small or zero.

We carried out an analysis of the by-catch of juvenile *C. gunnari* in the krill fishery (Frolkina et al., 1992). In the krill fishery some trawls which were probably hauled beyond the bounds of dense krill aggregations had significant catches of juveniles. The highest proportion of juveniles in krill catches was observed in the southeastern shelf area between Clark Rocks and the eastern end of South Georgia at depths up to 200 m where dense concentrations of juveniles are found (North, 1987). However, even in this area juvenile *C. gunnari* appears in by-catches only in the years of strong year classes and fishing mortality represents only a minuscule fraction of natural mortality of fish during the first year of life (Frolkina et al., 1992).

CONCLUSION

- The following species, not mentioned in previous studies as occurring in this area, were observed for the first time: *T. eulepidotus*, *Pogonophryne* spp., *P. charcoti* and *R. glacialis*. The largest numbers of fish species taken in pelagic hauls belonged to the families Nototheniidae, Myctophidae, Bathydraconidae, while the most abundant were families Nototheniidae (*L. larseni*) and Channichthyidae (*C. gunnari*).

- The largest catches of *L. larseni* and *C. gunnari* contained tens of thousands of specimens per haul, several thousand *G. nicholsi* and *P. choriodon*, several hundred *C. aceratus*, *Ps. georgianus*, *E. carlsbergi*, *M. microps*, *G. gibberifrons*, *P. breviceps* and *Par. georgianus*. Only very small quantities of other species were recorded in catches.

- Significant catches of *C. aceratus*, *L. larseni*, *M. microps*, *G. gibberifrons* and *G. nicholsi* were taken at night, while large catches of *C. gunnari*, *Ps. georgianus* and *P. choriodon* were taken both during the day and at night.

- Juvenile fish have areas of distribution which are discrete for each species. Juveniles and adults of the same species have different distributions at spatial and depth scales. Juvenile demersal fish tended to form aggregations in the southern part of the shelf area, while adult fish formed aggregations in the northern sector.

- The fact that juvenile *C. gunnari* and *L. larseni* undertake diurnal vertical migrations was established, and the impact of such migrations on the size of the catch of juveniles of both species has been demonstrated.

- Krill is the main food item for juveniles and adult fish inhabiting pelagic waters. This is likely to result in intense competition between fish species during periods of low krill abundance and to have an impact on the recruitment of the most numerous fish species.

ACKNOWLEDGEMENTS

We would like to express our deep gratitude and appreciation to Dr K.-H. Kock for his advice and comments relating to various sections of this paper.

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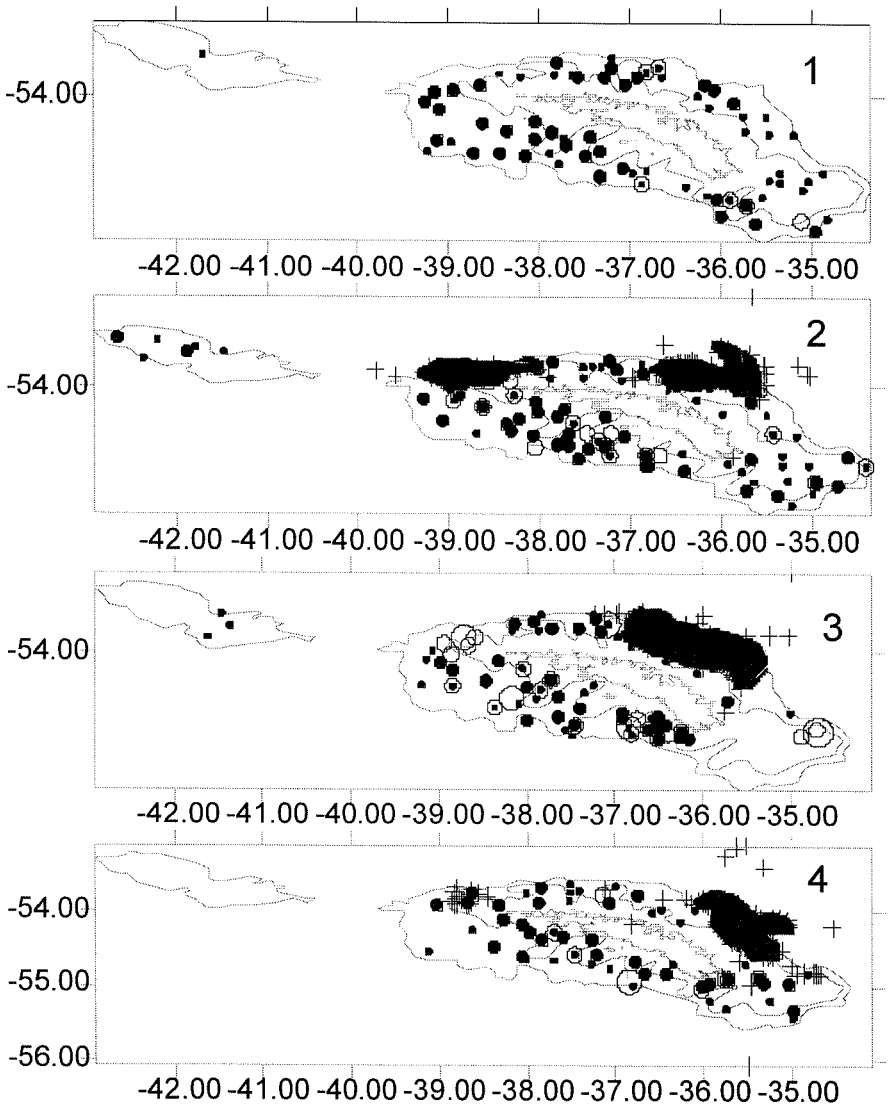

Figure 1: Distribution of juvenile *C. gunnari* in hauls made by a research midwater trawl in Subarea 48.3 and krill fishing grounds:

1 – 1984, BMRT *Gizhiga*, cruise 25 (no krill data)
2 – 1986, BMRT *Gizhiga*, cruise 28
3 – 1987, BMRT *Gizhiga*, cruise 30
4 – 1988, RV *Evrika*, cruise 24
5 – 1989, BMRT *Pioner Latvii*, cruise 26
6 – 1990, BMRT *Anchar*, cruise 22

Key:

•	<10
●	10–100
○	100–1 000
○	1 000–10 000
○	>10 000
+	Krill fishing locations
	Area surveyed by the fishing fleet

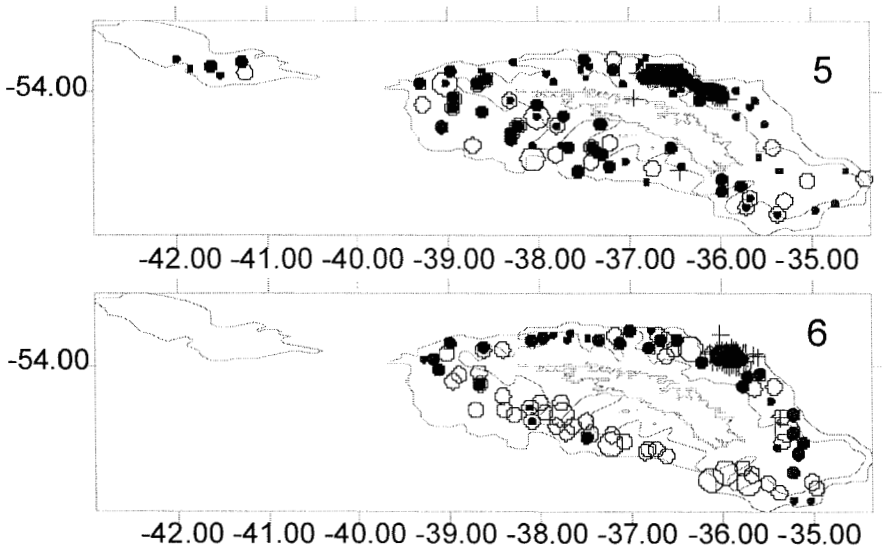

Figure 1 (continued)

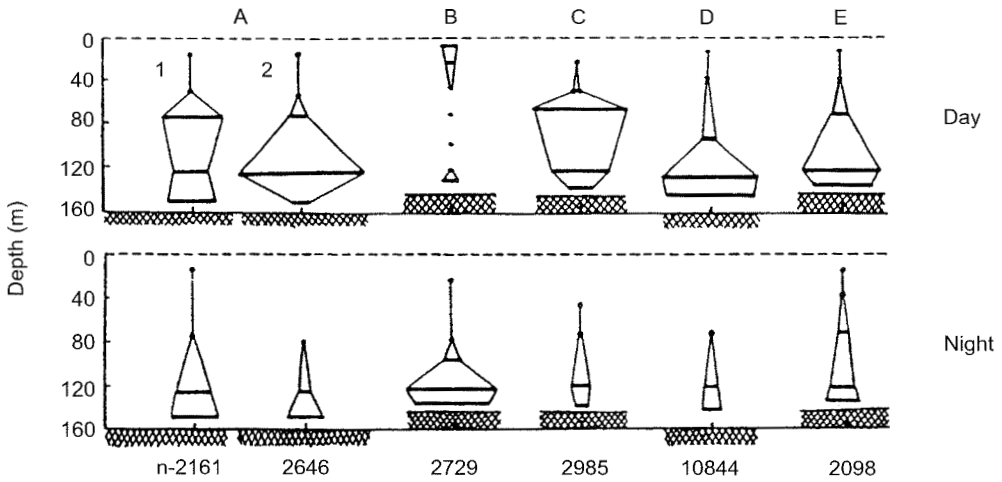

Figure 2: Abundance of juvenile *C. gunnari* at various depths during the day and at night:

A – BMRT *Gizhiga* (No. 1: 6–7 June 1986; No. 2: 24–26 June 1986)
B – RV *Evrika* (2–4 April 1987)
C – RV *Evrika* (8–9 April 1988)
D – BMRT *Pioner Latvii* (21–22 July 1989)
E – BMRT *Anchar* (6–7 June 1990)

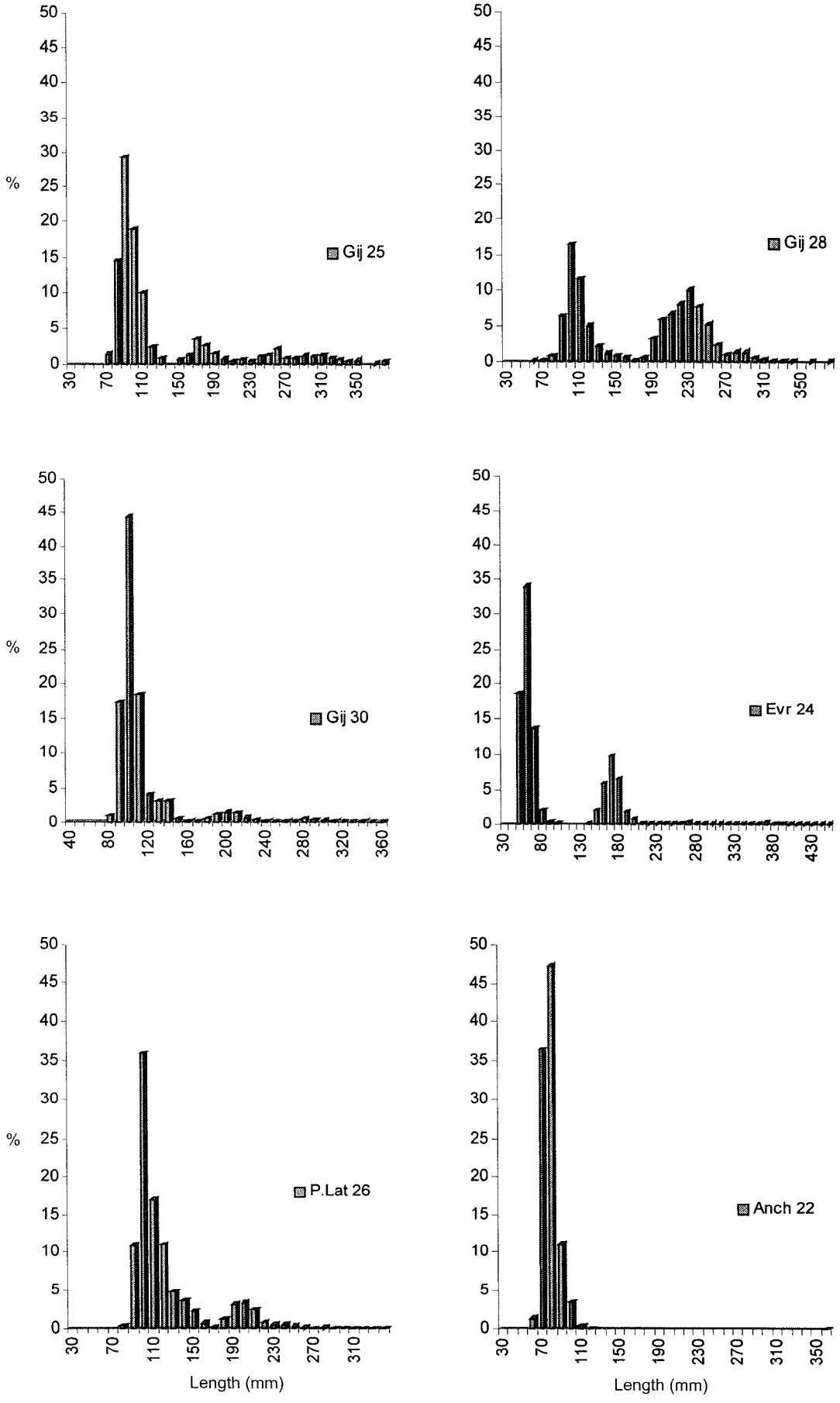

Figure 3: Length composition of *C. gunnari*.

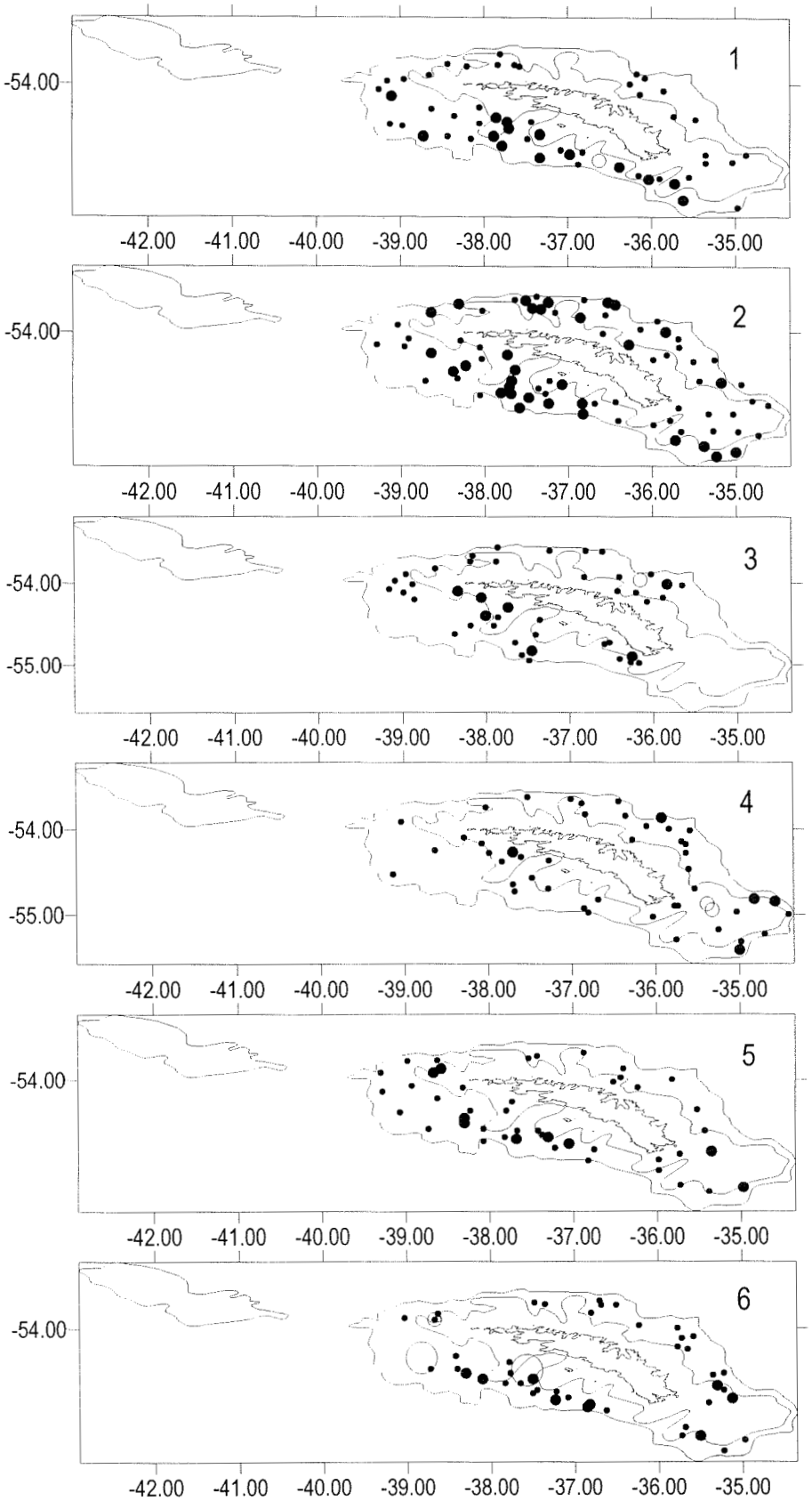

Figure 4: Distribution of juvenile *C. aceratus*. See Figure 1 for key.
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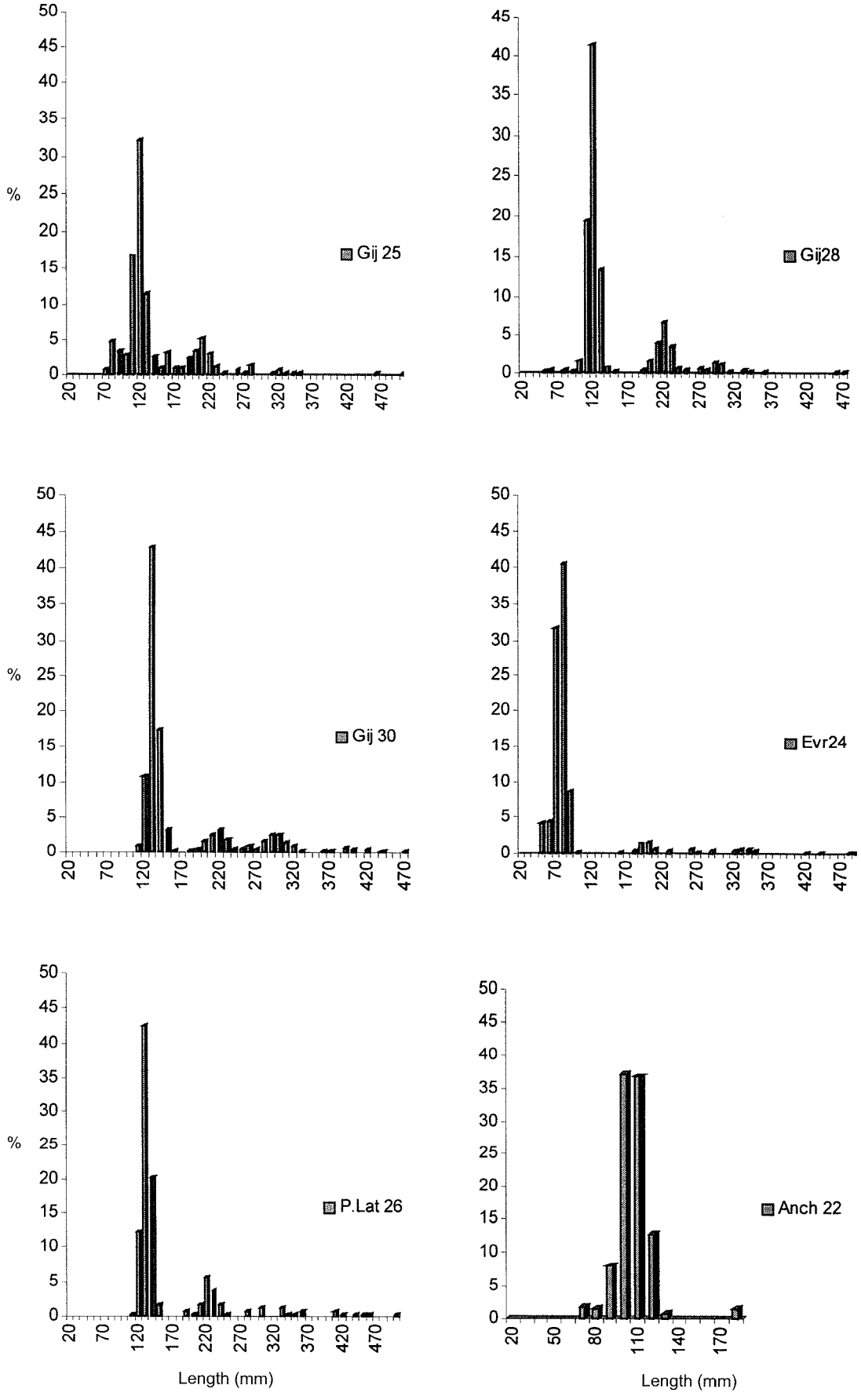


Figure 5: Length composition of *C. aceratus*.

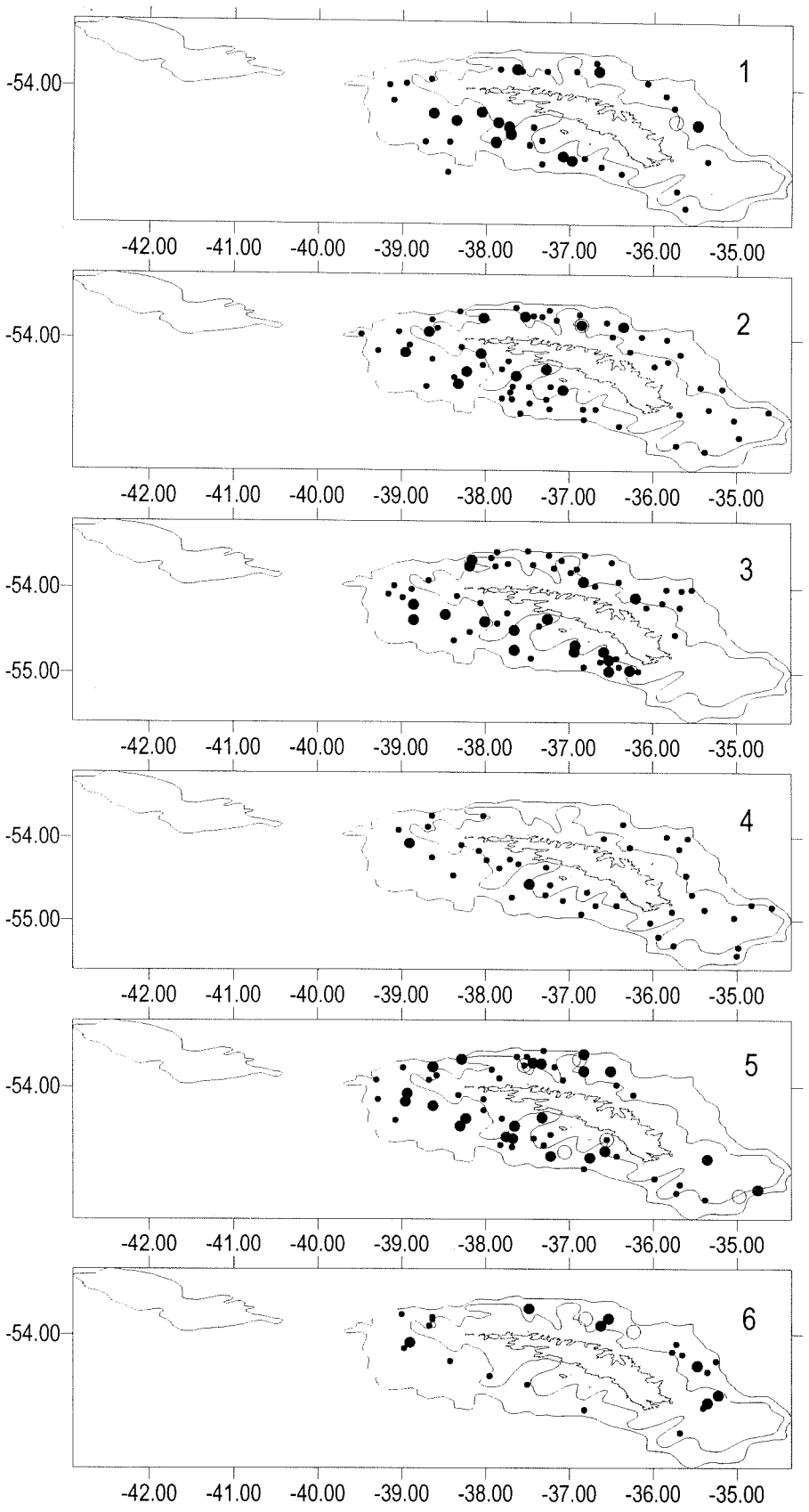


Figure 6: Distribution of juvenile *Ps. georgianus*. See Figure 1 for key. 1 – 1984, 2 – 1986, 3 – 1987, 4 – 1988, 5 – 1989, 6 – 1990

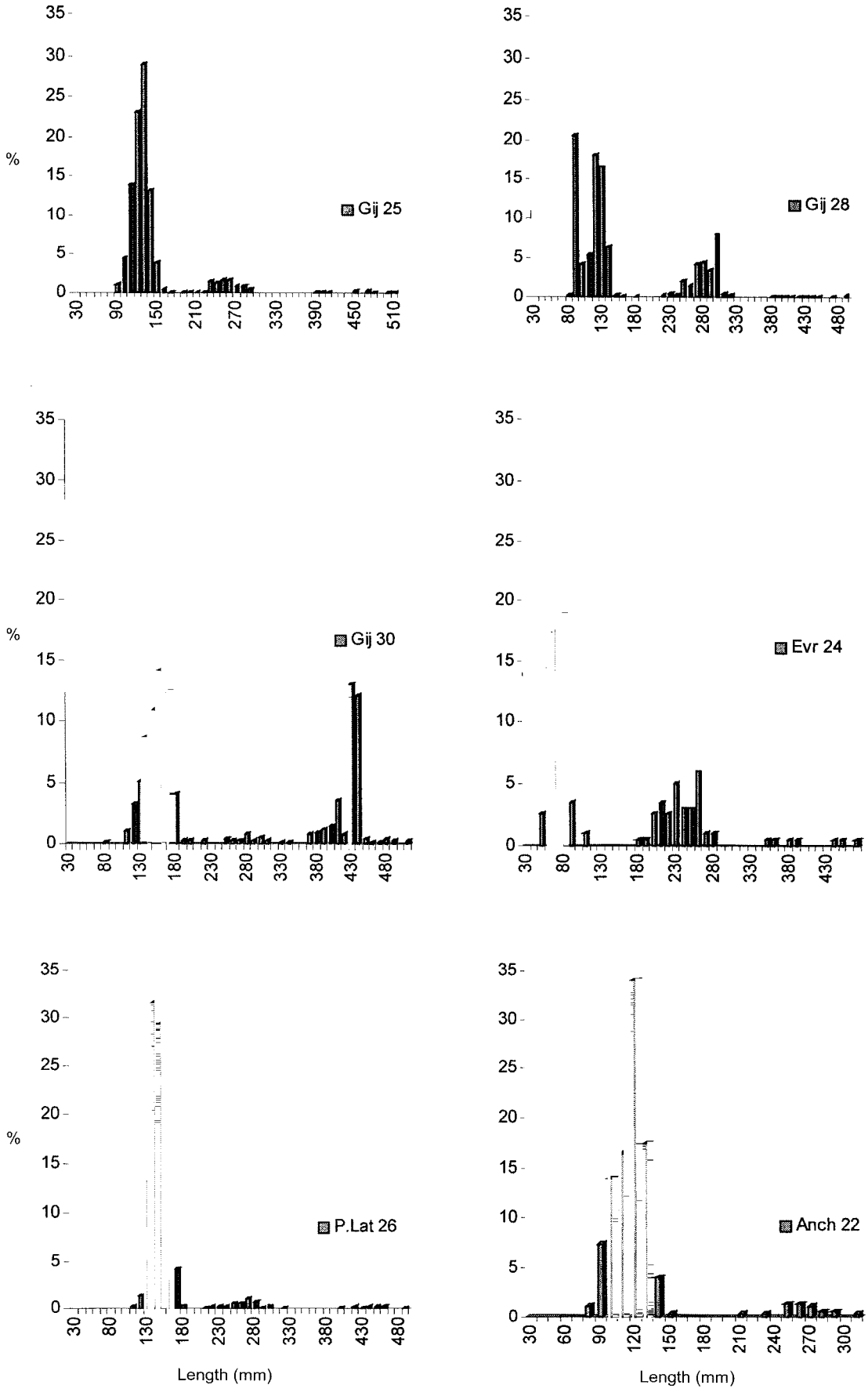


Figure 7: Length composition of *Ps. georgianus.*

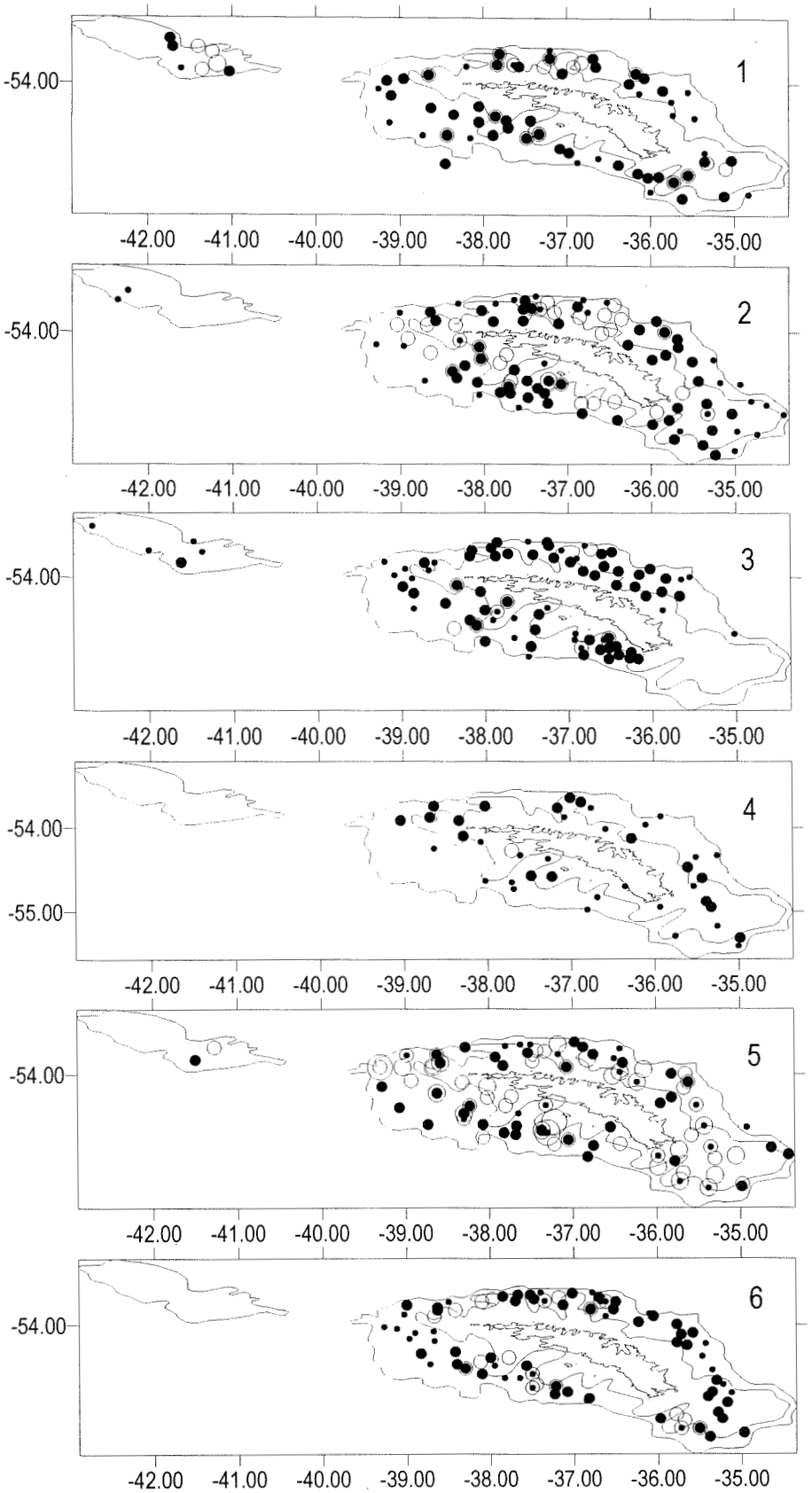


Figure 8: Distribution of juvenile *L. larseni*. See Figure 1 for key.
1 – 1984, 2 – 1986, 3 – 1987, 4 – 1988, 5 – 1989, 6 – 1990

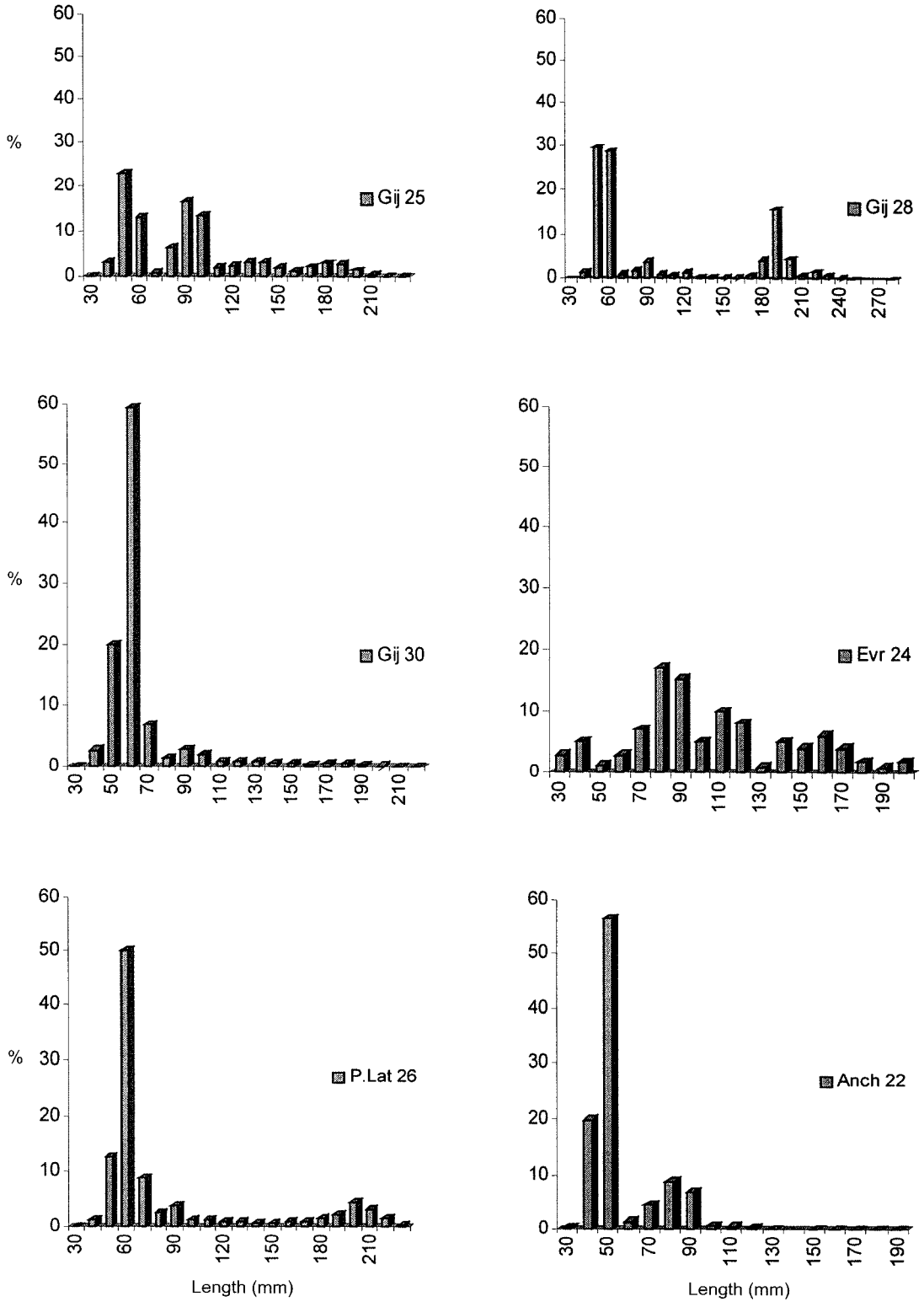


Figure 9: Length composition of *L. larseni.*

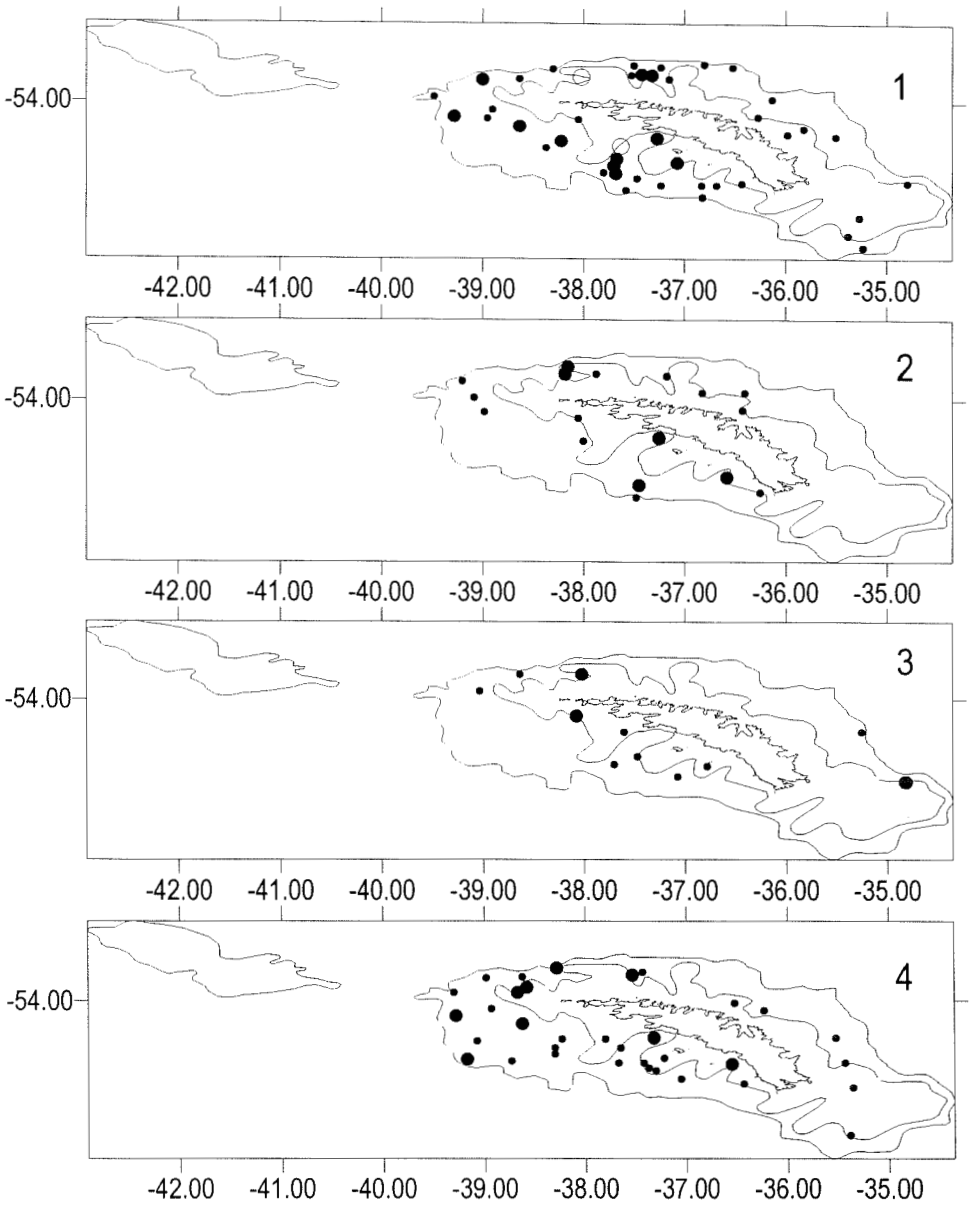


Figure 10: Distribution of juvenile *M. microps*. See Figure 1 for key. 1 – 1986, 2 – 1987, 3 – 1988, 4 – 1989

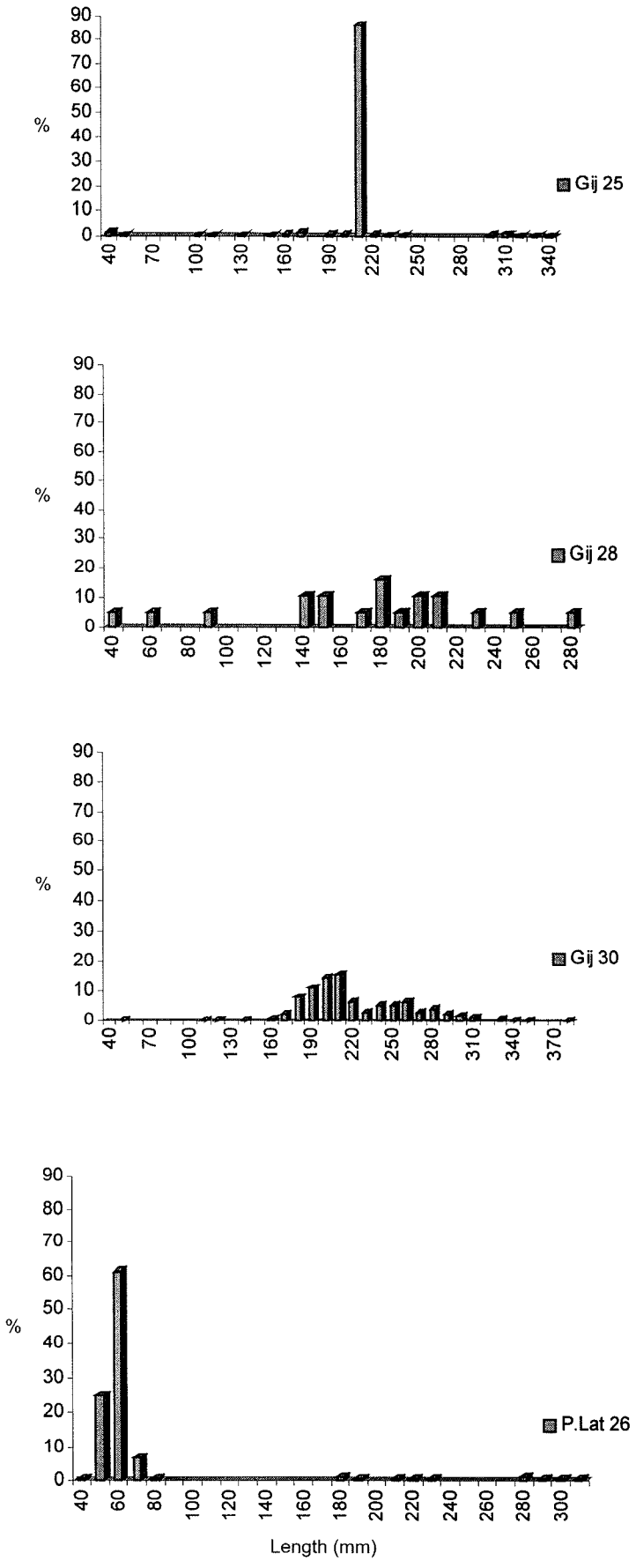
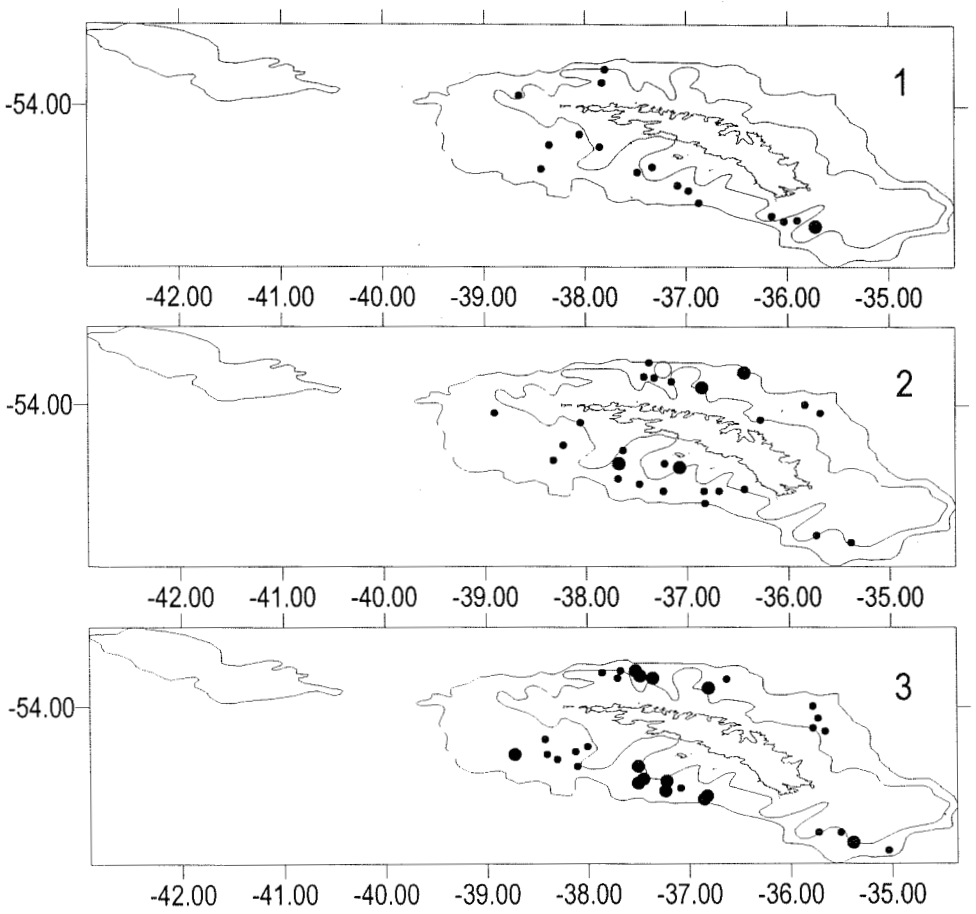


Figure 11: Length composition of *M. microps*.



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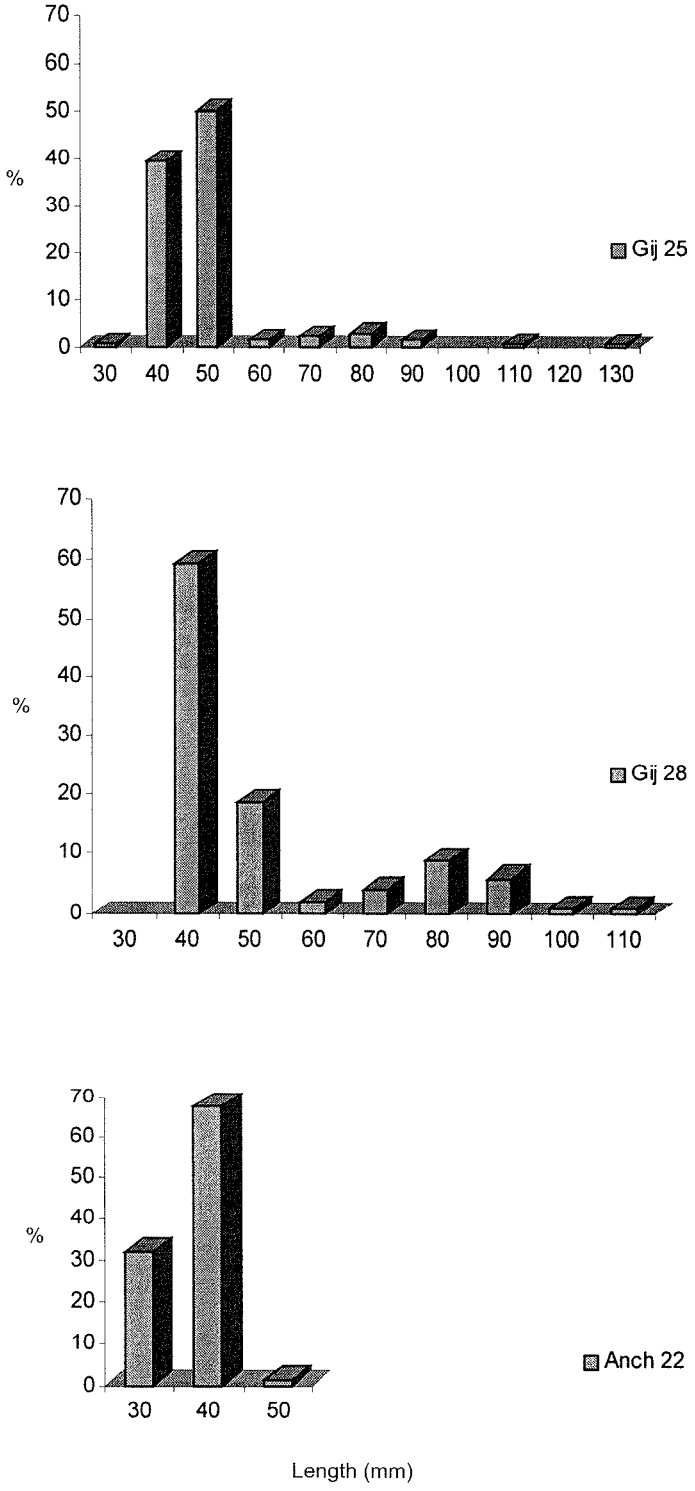

Figure 13: Length composition of *G. gibberifrons*.

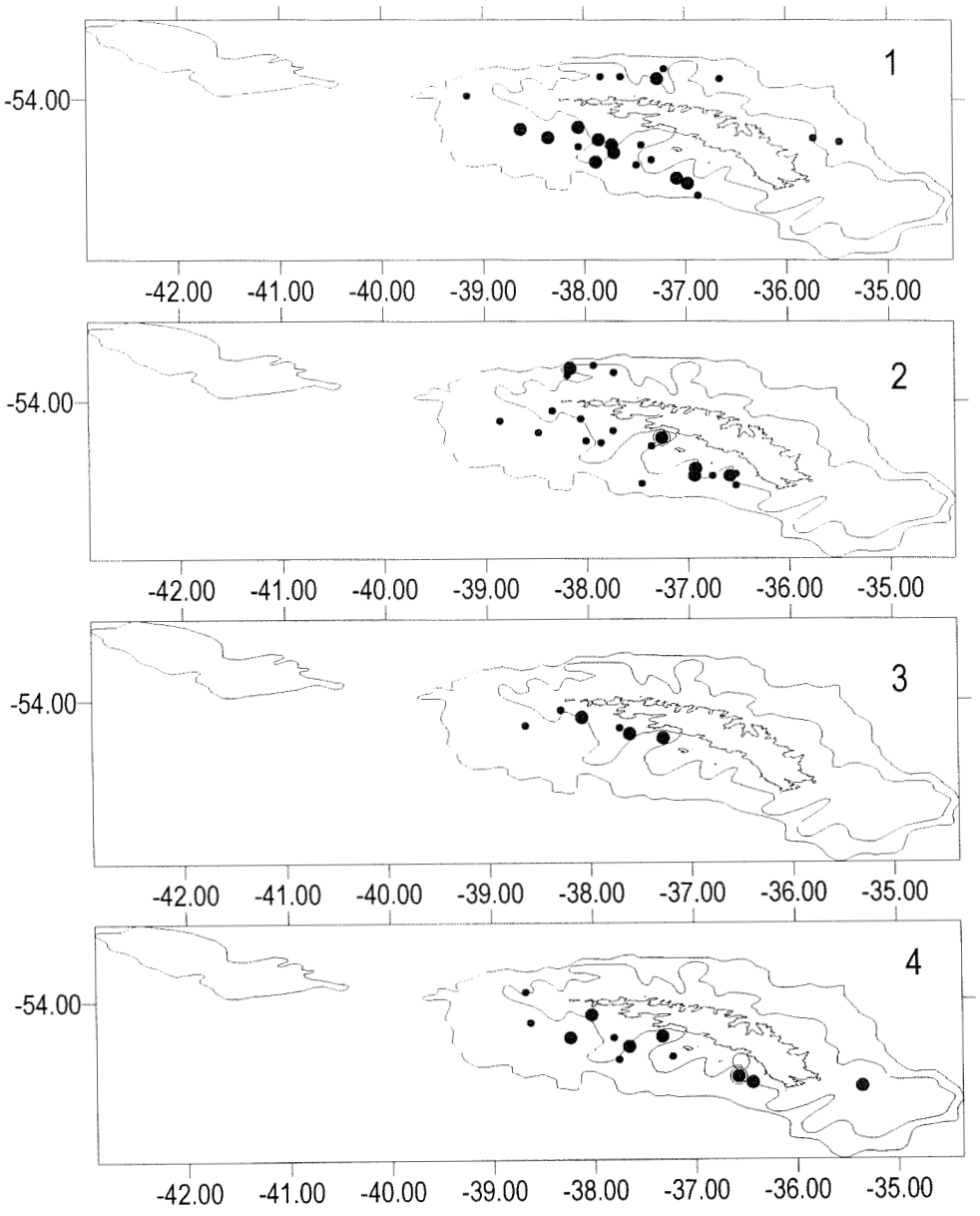

Figure 14: Distribution of juvenile *P. breviceps*. See Figure 1 for key. 1 – 1984, 2 – 1987, 3 – 1988, 4 – 1989

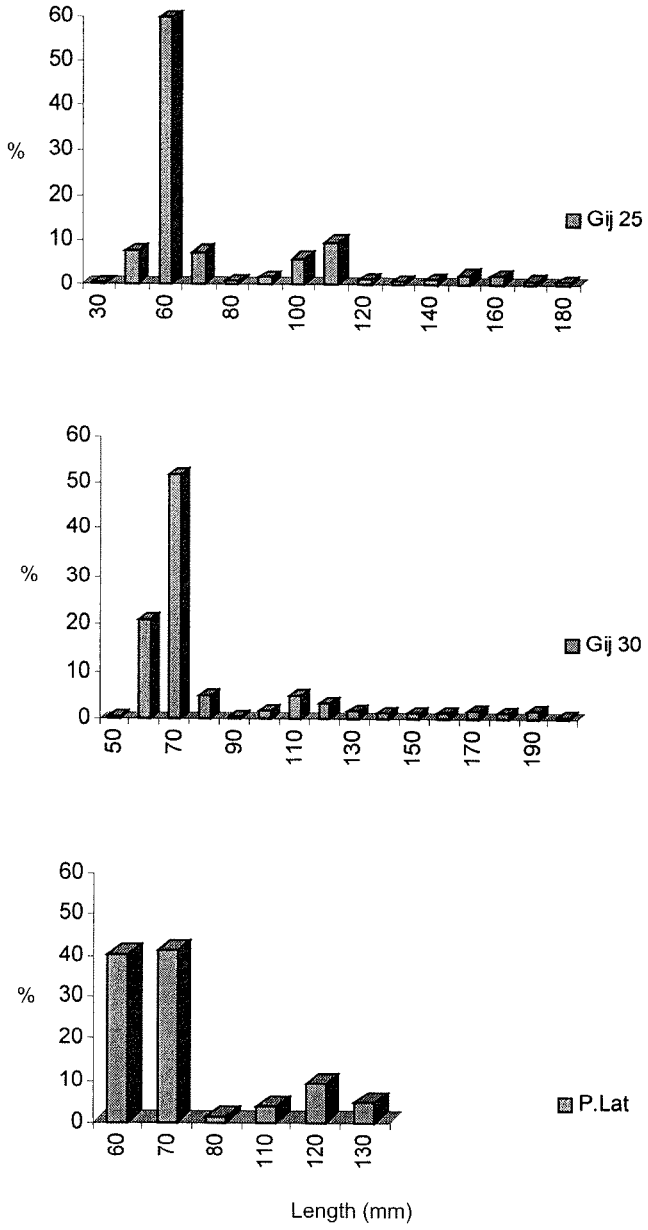

Figure 15: Length composition of *P. breviceps.*

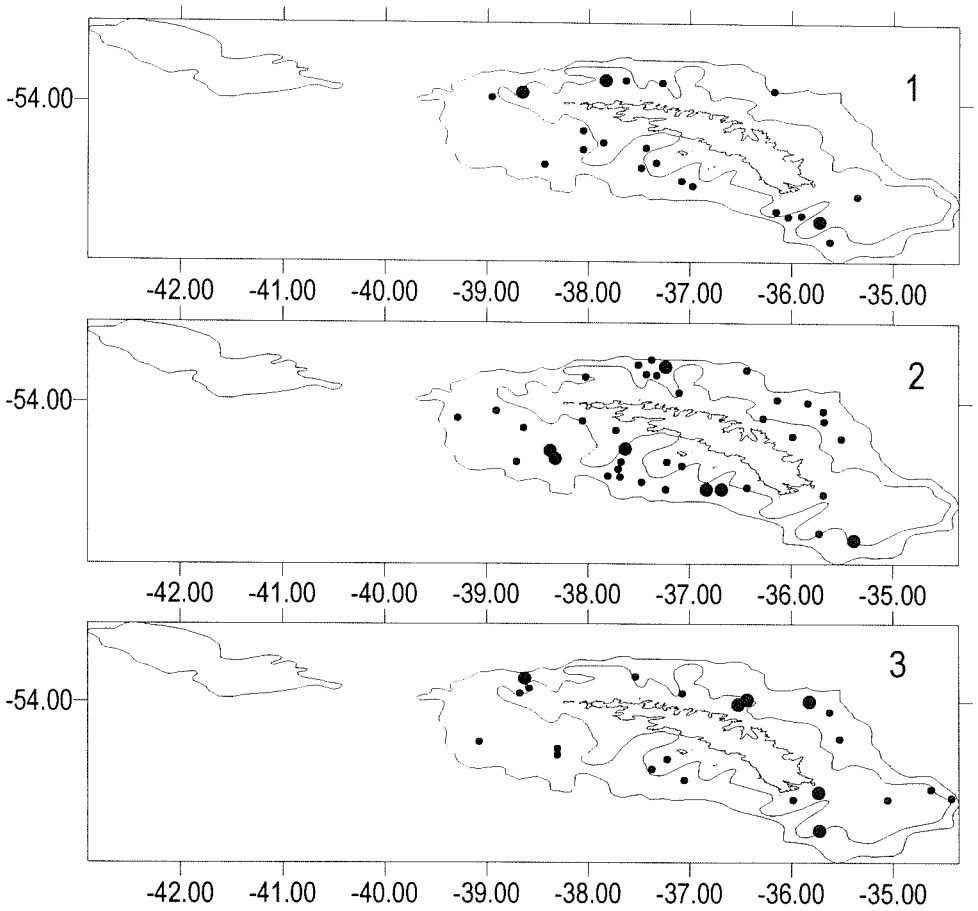

Figure 16: Distribution of juvenile *Par. georgianus*. See Figure 1 for key. 1 – 1984, 2 – 1986, 3 – 1989

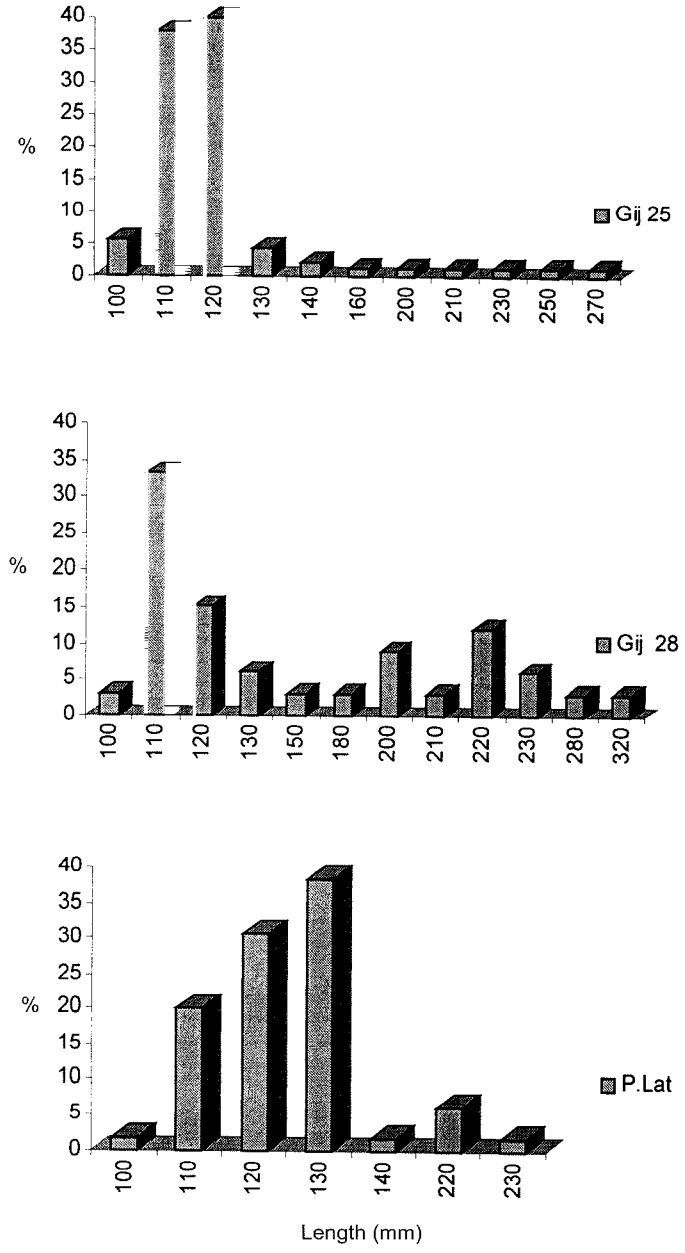

Figure 17: Length composition of *Par. georgianus.*

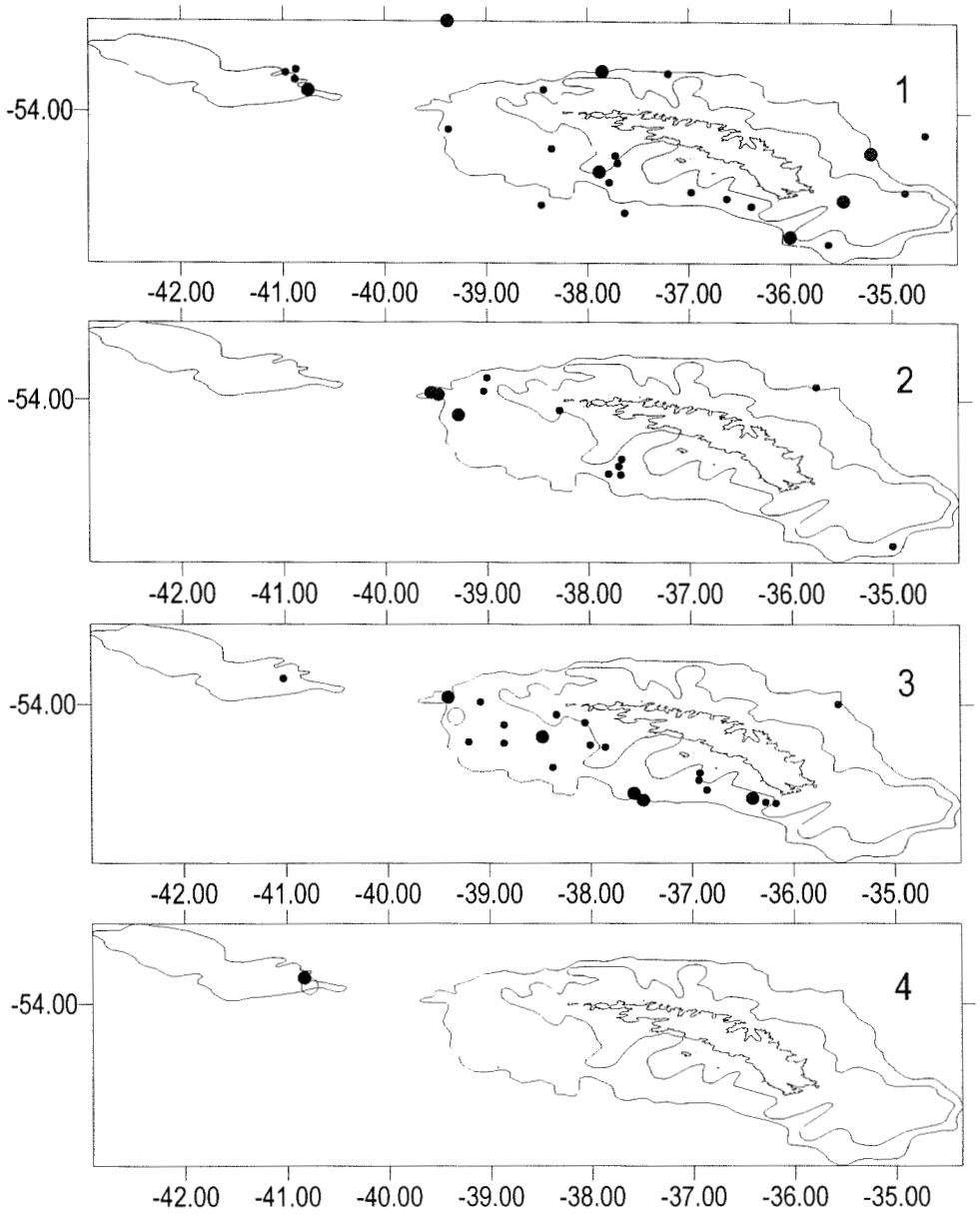

Figure 18: Distribution of juvenile *E. carlsbergi*. See Figure 1 for key.
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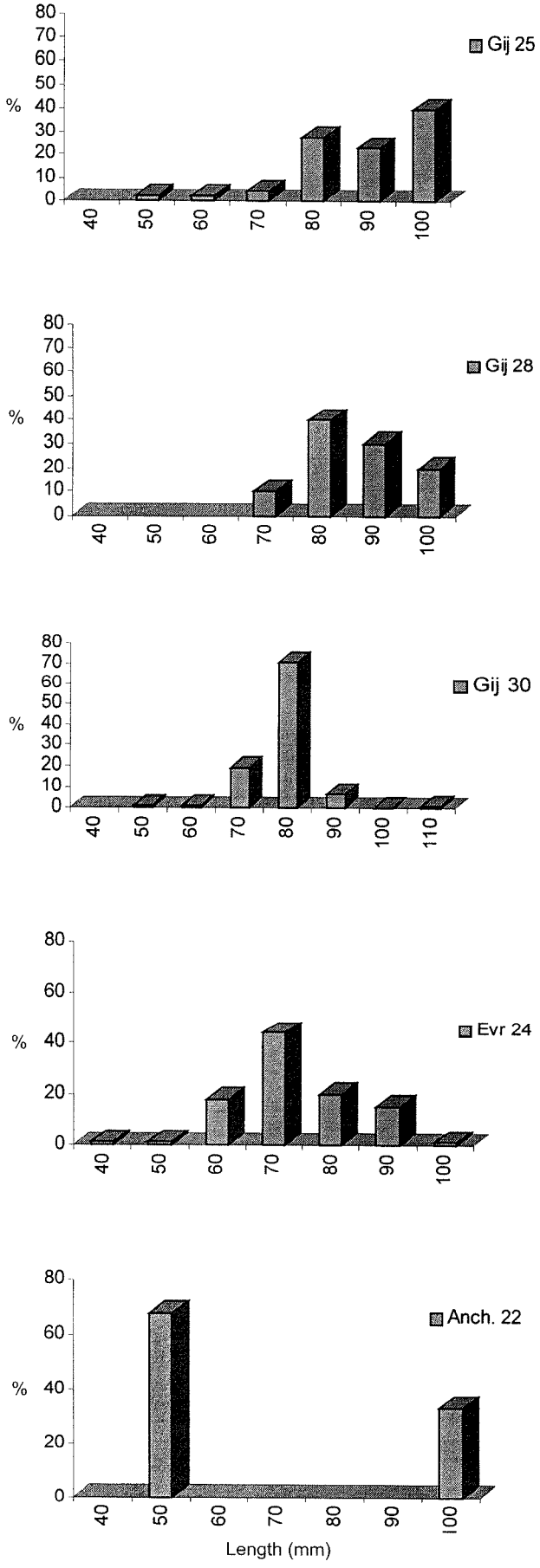

Figure 19: Length composition of *E. carlsbergi.*

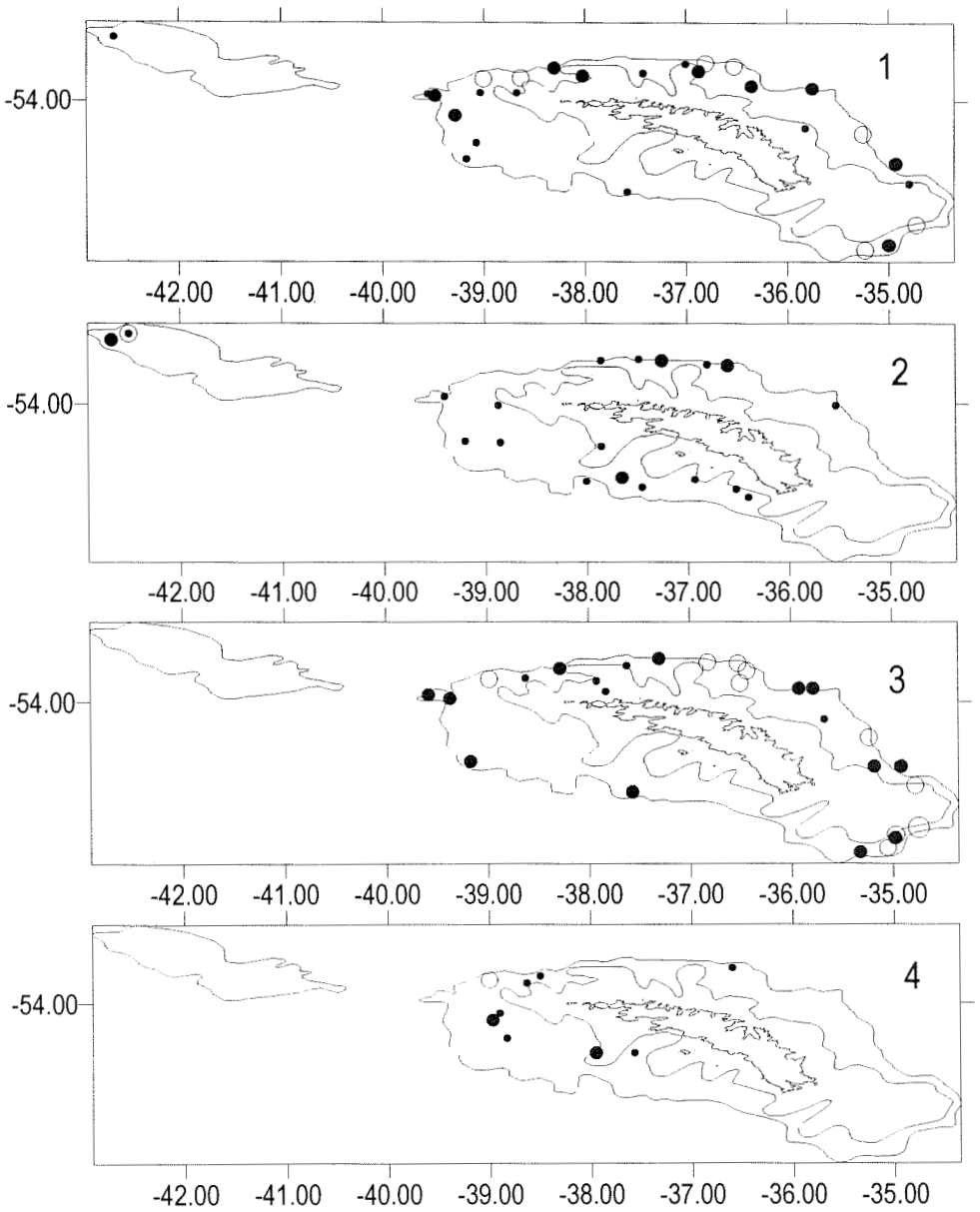

Figure 20: Distribution of juvenile *P. choriodon*. See Figure 1 for key.
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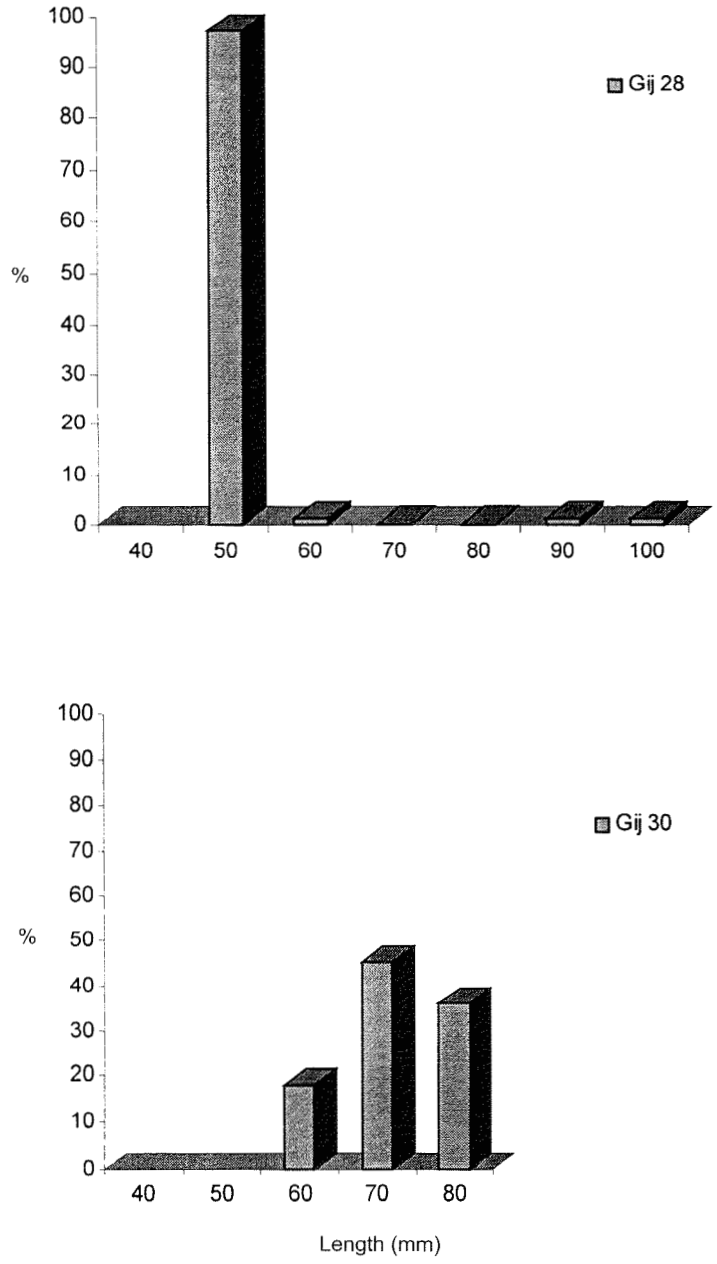

Figure 21: Length composition of *P. choriodon*.

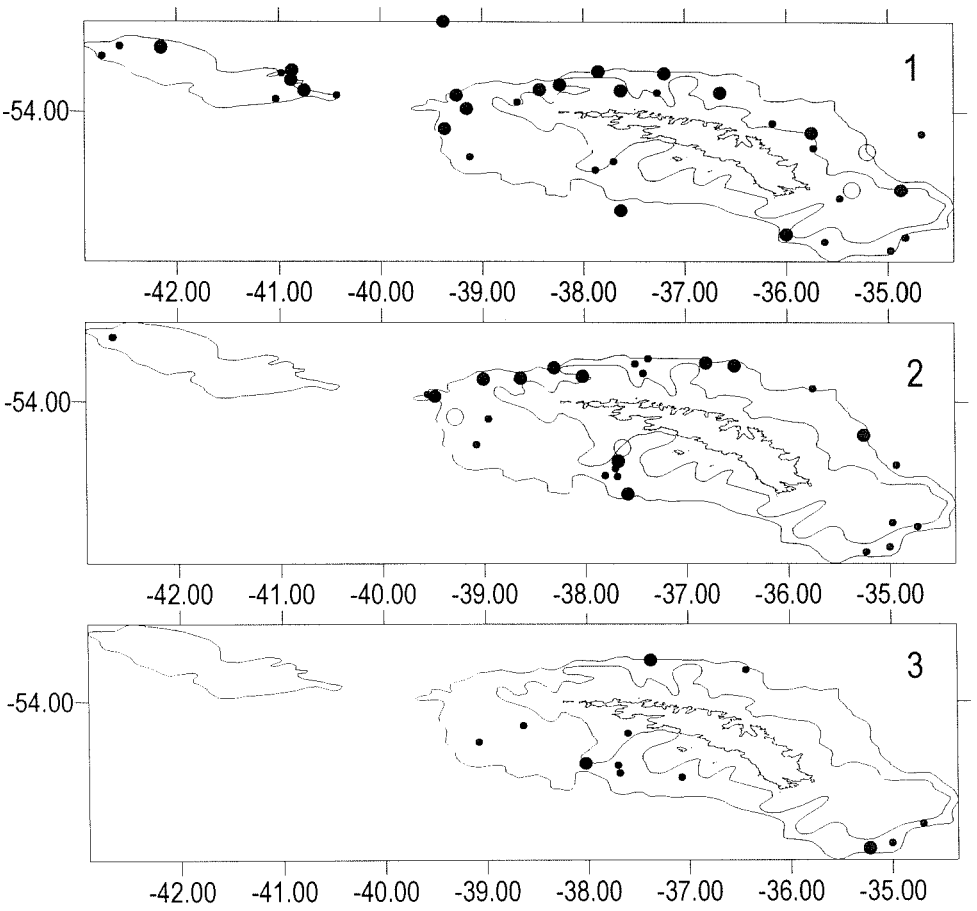

Figure 22: Distribution of juvenile *G. nicholsi*. See Figure 1 for key. 1 – 1984, 2 – 1986, 3 – 1988

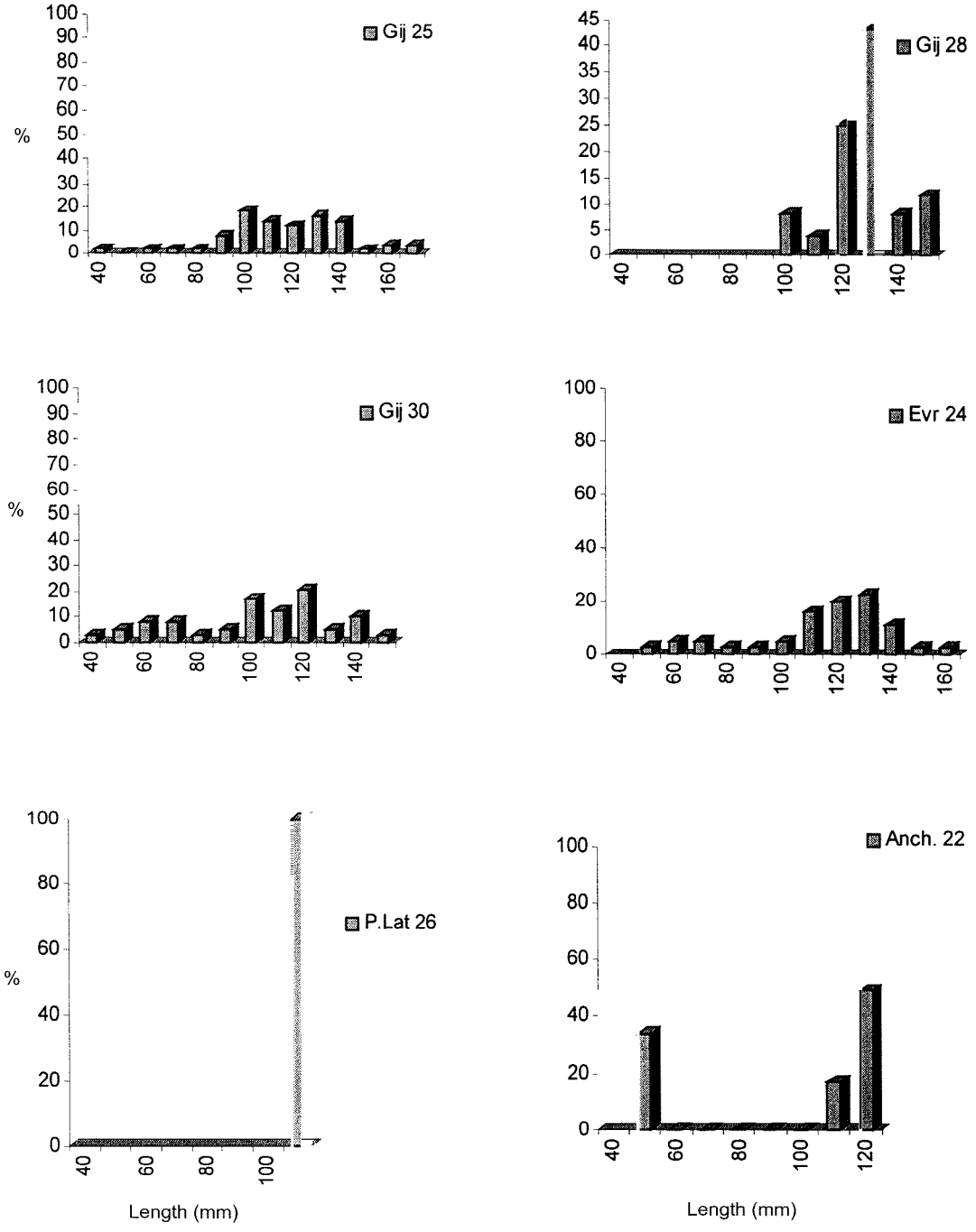

Figure 23: Length composition of *G. nicholsi.*

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1 – 1984, BMRT *Gizhiga*, campagne 25 (aucune donnée de krill)
2 – 1986, BMRT *Gizhiga*, campagne 28
3 – 1987, BMRT *Gizhiga*, campagne 30
4 – 1988, RV *Evrika*, campagne 24
5 – 1989, BMRT *Pioner Latvii*, campagne 26
6 – 1990, BMRT *Anchar*, campagne 22

Clé :

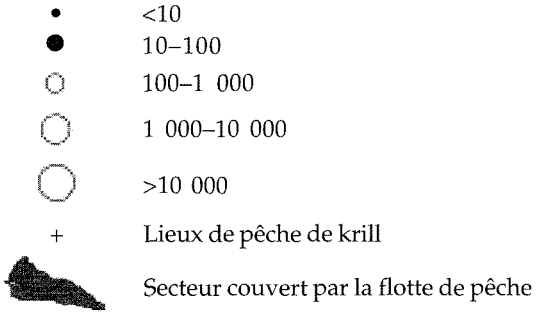

Figure 2: Abondance des juvéniles de *C. gunnari* à diverses profondeurs, de jour et de nuit :

A – BMRT *Gizhiga* (No. 1: 6–7 juin 1986; No. 2: 24–26 juin 1986)
B – RV *Evrika* (2–4 avril 1987)
C – RV *Evrika* (8–9 avril 1988)
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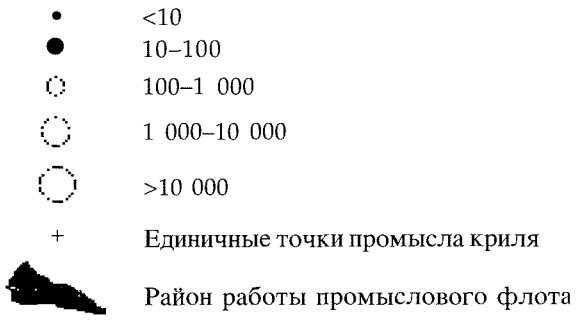
1 - 1984 г., БМРТ *Гижига*, рейс 25 (данные по промыслу криля отсутствуют)
2 - 1986 г., БМРТ *Гижига*, рейс 28
3 - 1987 г., БМРТ *Гижига*, рейс 30
4 - 1988 г., НИС *Эврика*, рейс 24
5 - 1989 г., БМРТ *Пионер Латвии*, рейс 26
6 - 1990 г., БМРТ *Анчар*, рейс 22

Условные обозначения:



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C - НИС *Эврика* (8-9 апреля 1988 г.)
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3 – 1987, BMRT *Gizhiga*, marea 30
4 – 1988, RV *Evrika*, marea 24
5 – 1989, BMRT *Pioner Latvii*, marea 26
6 – 1990, BMRT *Anchar*, marea 22

Clave:
• <10
● 10–100
○ 100–1 000
◌ 1 000–10 000
◌ >10 000
\+ Aladeros de pesca de kril
Area estudiada por la flota pesquera

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B – RV *Evrika* (2–4 Abril 1987)
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