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# AGE–LENGTH COMPOSITION OF MACKEREL ICEFISH (*CHAMPSOCEPHALUS GUNNARI*, PERCIFORMES, NOTOTHENIOIDEI, CHANNICHTHYIDAE) FROM DIFFERENT PARTS OF THE SOUTH GEORGIA SHELF

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Abstract

Biostatistical data obtained by Soviet research and commercial vessels from 1970 to 1991 have been used to determine the age–length composition of mackerel icefish (*Champsocephalus gunnari*) from different parts of the South Georgia area. An analysis of the spatial distribution of *C. gunnari* size and age groups over the eastern, northern, western and southern parts of the shelf, and near Shag Rocks, revealed a similar age–length composition for young fish inhabiting areas to the west of the island and near Shag Rocks. Differences were observed between those two groups and the eastern group. The larger number of mature fish in the west is related to the migration of maturing individuals from the eastern and western parts of the area. It is implied that part of the western group migrates towards Shag Rocks at the age of 2–3 years. It has been found that, by number, recruits represent the largest part of the population, whether a fishery is operating or not. As a result of this, as well as the species' ability to live not only in off-bottom, but also in pelagic waters, an earlier age of sexual maturity compared to other nototheniids, and favourable oceanographic conditions, the *C. gunnari* stock could potentially recover quickly from declines in stock size and may become abundant in the area, as has been demonstrated on several occasions in the 1970s and 1980s.

Résumé

Les données biologiques des statistiques des navires soviétiques de recherche et de commerce de 1970 à 1991 ont servi à déterminer la composition âge–longueur du poisson des glaces (*Champsocephalus gunnari*) de divers secteurs adjacents à la Géorgie du Sud. Une analyse de la répartition spatiale des groupes de tailles et d'âges de *C. gunnari* sur les secteurs est, nord, ouest et sud du plateau, ainsi qu'à proximité des îlots Shag révèle la similarité de la composition âges–longueurs des juvéniles de poissons fréquentant l'ouest de l'île et les alentours des îlots Shag, mais des différences entre ces deux groupes et le groupe de l'est. La proportion importante de poissons matures à l'ouest est liée à la migration des individus matures des régions est et ouest. Il semble qu'une partie du groupe de l'ouest migre vers les îlots Shag à l'âge de 2–3 ans. De plus, en nombre, les recrues représentent la plus grande partie de la population, qu'une pêcherie soit en activité ou non. En conséquence, et si l'on considère par ailleurs la capacité de l'espèce de vivre non seulement en eaux proches du fond, mais aussi en eaux pélagiques, sa maturité sexuelle à un âge moins élevé que d'autres notothéniidés, et les conditions océanographiques favorables, le stock de *C. gunnari* pourrait récupérer rapidement des décimations du stock et devenir abondant dans la région comme cela a été démontré à plusieurs reprises dans les années 70 et 80.

Резюме

Для изучения размерно-возрастного состава щуковидной белокровки (*Champsocephalus gunnari*) на различных участках района Южной Георгии использованы биостатистические материалы поисковых и промысловых рейсов советских судов за период 1970–1991 гг. Анализ пространственного распределения размерно-возрастных групп *C. gunnari* на востоке, севере, западе, юге шельфа острова и у скал Шаг выявил сходство размерно-возрастной структуры в первые годы жизни между рыбой, обитающей к западу от острова и у скал Шаг, и отличие этих двух группировок от восточной. Большее количество половозрелой рыбы на западе связано с миграцией сюда созревших особей с восточного и западного участков. Предполагается, что часть западной группировки рыбы мигрирует к скалам Шаг

на втором–третьем году жизни. Обнаружено, что, численно, наибольшую часть популяции составляет пополнение, независимо от наличия или отсутствия промысла. Благодаря этому, а также способности вида обитать не только в придонных, но и в пелагических водах, более раннему половому созреванию по сравнению с другими нототениевыми и благоприятным океанологическим условиям запас *C. gunnari* может быстро восстанавливаться и достигать высокой численности в этом районе, что неоднократно случалось в 1970-е и 1980-е годы.

Resumen

Se utilizaron los datos de bioestadística obtenidos de las investigaciones soviéticas y de los barcos de pesca comercial de ese país desde 1970 hasta 1991 para determinar la composición de talla-edad del draco rayado (*Champsocephalus gunnari*) de varias regiones de Georgia del Sur. El análisis de la distribución espacial por talla y edad de las poblaciones de *C. gunnari* de las regiones este, norte, oeste y sur de la plataforma y cerca de las rocas Cormorán, demostró una similitud entre la composición de talla-edad de los peces juveniles que habitan en las regiones al oeste de la isla y cerca de las rocas Cormorán, y una diferencia entre estas dos poblaciones y la del este. La mayor abundancia de peces maduros adultos en la población del oeste se relaciona con la migración de peces juveniles del este y oeste de la zona. Se supone que parte de la población del oeste migra hacia las rocas Cormorán a los 2 ó 3 años. Se observó que los reclutas representan la mayor proporción en número de la población, independientemente de la explotación. Debido a esto, a la capacidad de la especie para habitar tanto cerca del lecho marino como en aguas pelágicas, a la temprana madurez sexual de la especie en relación a otros nototénidos, y a las condiciones oceanográficas favorables, el stock de *C. gunnari* tiene un gran potencial de recuperación de las disminuciones del tamaño de la población, e incluso de alcanzar una gran abundancia en la zona. Esto ya ha sido demostrado en varias ocasiones durante las décadas del 70 y 80.

Keywords: *C. gunnari*, length–age composition, juveniles, immature and mature fish, CCAMLR

## INTRODUCTION

Mackerel icefish (*C. gunnari*) has been, and continues to be, one of the most important commercial species in waters around South Georgia. A number of papers on the ecology of *C. gunnari* have been published (e.g. Permitin, 1982, 1987; Efremenko, 1982; Lubimova, 1980, 1987; Shust, 1987, 1998). The most detailed information on *C. gunnari* has been provided by Kock (1979, 1981) and Sosinski (1981). These articles, however, lack information on the species' life history, e.g. the spatial distribution of various size–age classes of *C. gunnari* on the shelf. In particular, this relates to the size composition of *C. gunnari* off Shag Rocks. Materials collected by AtlantNIRO from 1970 to 1991 allowed us to study the spatial distribution of different size–age classes in considerable detail.

We have analysed and summarised all the data available to us in order to determine the distributional and biological characteristics of *C. gunnari*. We hope the results of our work will help explain a number of features of this species' biology.

CCAMLR scientists are currently giving a great deal of attention to various aspects of the ecology of *C. gunnari*. Studies carried out by scientists from different countries will enable the development of a long-term strategy for managing *C. gunnari* stocks in the South Georgia area which take into account the ecological characteristics of this species.

## MATERIAL AND METHODS

The materials used in this study were collected during research cruises conducted from 1970 to 1991. Supplementary data on *C. gunnari* were taken from commercial fishing vessels of the USSR Northern and Southern Fleets.

In addition, we analysed the results of six pelagic and seven bottom trawl surveys carried out by AtlantNIRO around South Georgia from 1984 to 1991. These surveys covered the area outside the island's territorial waters, i.e. mainly beyond the 100 m isobath.

Pelagic trawl survey methods are described in Frolkina et al. (1998).

For bottom trawl surveys, a HEK-4 bottom trawl was used, which had been considerably modified to prevent snagging on hard bottoms.

The trawl mouth was 18–25 m wide and 7–8 m high. The trawl had a small-mesh liner with 10 mm meshes in the codend.

Bottom trawl surveys were carried out using the same design as pelagic surveys, i.e. stratified random sampling. Depth strata selected were 100–200 m, 201–300 m and 301–500 m. Trawl stations were selected by a random number generator with one trawl station for each 80–100 miles$^2$, with no less than three stations per stratum. Hauls were only made during daylight hours to prevent bias caused by diurnal vertical migrations. The trawl was towed at 3–3.5 knots for 30 minutes. Catchability was assumed to be 100%.

Approximately 200 000 fish were measured. More than 90 000 fish were examined to obtain condition indices (stage of maturity, intestinal fat content, stomach fullness). Length was measured to the nearest centimetre. Maturity stages used by CCAMLR and in Russia are interpreted somewhat differently. The Russian scale is as follows: I – juvenile, II – immature period of protoplasmatic growth and the initial phases of trophoplasmatic growth (maturity coefficient less than 1), III – maturing (maturity coefficient between 1 and 6% of total body weight), IV – prespawning (between 10 and 17%), V – spawning (between 15 and 20%) and VI – spent (end of spawning).

The shelf area was divided into five regions, each containing approximately the same proportion of the population: east – 53°S to 56°S and 34°W to 36°W; west – 53°S to 56°S and 38°W to 40°W; north – 52°S to 54°S and 36°W to 38°W; south – 54°30'S to 56°S and 36°W to 38°W; and Shag Rocks – 52°S to 54°S and 40°W to 43°W. This division enabled the exclusion of zones where fish from various spawning areas (north and south) become mixed.

In addition, for those years for which data on age–length composition were available, the size composition of catches was defined for comparative analyses for each of the following three regions: east and west of South Georgia and Shag Rocks.

Fish age was determined according to Frolkina (1989). Fish were divided into the following four size classes: juveniles (≤15 cm), immature fish (15–25 cm), mature fish (25–39 cm) and large mature fish (≥40 cm plus) (Frolkina, 1999). All age estimates were adjusted according to the Southern Hemisphere split-year, which starts on 1 July. On this date fish age was increased by one year.

## RESULTS

### History of Commercial Fishing for *C. gunnari*

*C. gunnari* was first caught commercially in the shallow waters of Shag Rocks by Soviet vessels in November–December 1970. The total catch was approximately 10 000 tonnes for that period (SC-CAMLR, 1993), giving a catch per unit effort of 55.6 tonnes/vessel/day. In 1971/72 this species, together with *Pseudochaenichthys georgianus*, was occasionally taken in the northern and northeastern regions of the South Georgia shelf, yielding catches at the rate of approximately 40 tonnes/vessel/day in various months. *C. gunnari* comprised 5–10% of those catches. In November–December 1974, December 1975 and January–August 1977, vessels again targeted commercial concentrations of this species off Shag Rocks. Catches were taken at the rate of 50 to 100 tonnes. In subsequent years, the *C. gunnari* fishery shifted to the South Georgia shelf. Dense concentrations off Shag Rocks were not observed for many years thereafter, although abundance of *Patagonotothen guntheri* in this area was high. Large catches of *C. gunnari* were again taken here only from 1983, as was *P. guntheri*, comprising 20–60% of catches (Bunato, 1991).

Large-scale fishing for *C. gunnari* off South Georgia began in 1976/77, when 93 000 tonnes were taken (SC-CAMLR, 1993). During that season, commercial quantities of *C. gunnari* were taken only in the northeast of the area. Other species – *Notothenia rossii marmorata, Gobionotothen gibberifrons* and *Lepidonotothen squamifrons* – formed commercial concentrations in the northwest. In later years, *C. gunnari* was observed distributed over the entire shelf, becoming the main target species and forming the densest concentrations in the north of the shelf (from east to west). Significant catches taken in some fishing seasons (approximately 100 000 tonnes per year) (SC-CAMLR, 1993) did not lead to depletion of the species. Fishing effort usually decreased for a short period (1–2 years) after which it again intensified, yielding large catches. Interest in this species was maintained until 1991 when a total fishing ban was introduced. During this entire period, fishing for *C. gunnari* over the South Georgia shelf was mainly carried out by Soviet vessels (Bunato, 1991).

### Size Composition

Fish were sampled over the entire shelf area and at all designated depth strata (see above). The size range of *C. gunnari* was larger in research

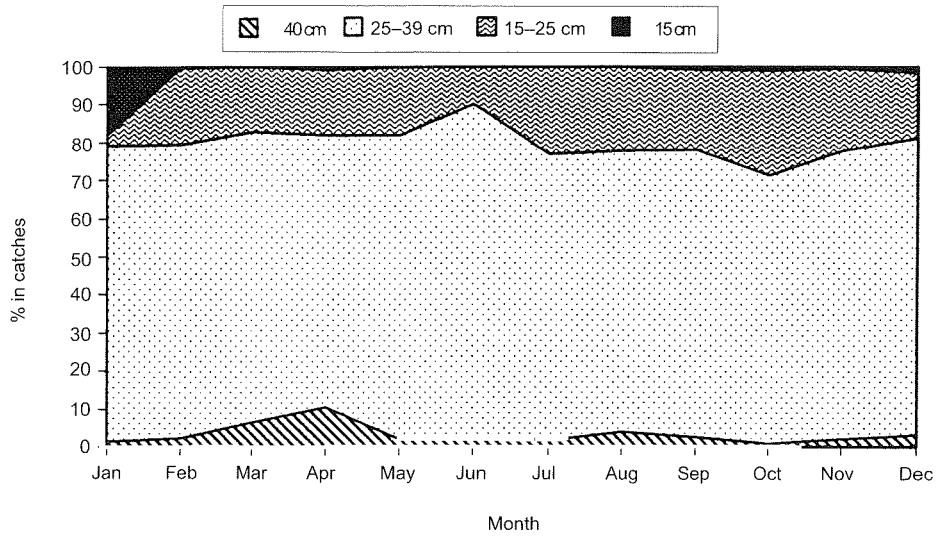


Figure 1: Correlation by month between different age groups of *Champsocephalus gunnari* caught by USSR commercial and research vessels.

hauls than in commercial catches. The smallest individuals (3–4 cm) were found in surveys targeting small juveniles when a midwater trawl with a fine-meshed liner was used. The largest specimens recorded (69 cm) were caught during bottom trawl surveys.

The size of fish in commercial catches ranged from 10–59 cm. The smallest and largest fish recorded from the Shag Rocks region were 6 cm and 47 cm respectively. Usually, fish taken off South Georgia were 20–53 cm long, while fish taken off Shag Rocks measured 19–43 cm.

In general, the size composition of *C. gunnari* varied over the course of the year. On average, immature fish comprised approximately 20% of the catches. The proportion of immature fish increased from July to November, reaching a maxi-mum in October. At that time a new generation of fish reaching 20–25 cm in length (age class 2+) entered the stock targeted by the commercial fishery (Frolkina, 1999) (Figure 1).

Mature fish of 25–39 cm comprised 70–90% of catches throughout the year. Large fish of 40 cm or more were usually found in catches in insignificant numbers (only 1–4%). In March–April, i.e. in the months leading up to spawning, the proportion of large fish increased to 6–10% (Figure 1).

The proportion of young fish in commercial catches was also insignificant (about 1%). Therefore we analysed samples of young fish only from pelagic surveys. The mean length of juveniles by month fluctuated significantly from year to year. The average length of fish observed in May–June 1984, 1986 and 1990, varied between 108 mm in 1984 and 76–80 mm in 1990. During pelagic surveys the largest of juvenile fish, as a rule, were taken to the south and to the east of South Georgia. The smallest fish were taken in the west region of South Georgia (Table 1).

Results of bottom trawl surveys revealed distinct differences in the size composition of fish larger than 15 cm taken in different regions (Table 2). Major differences were evident between the east and west regions of South Georgia and the Shag Rocks region. According to average long-term data, individuals of 15–25 cm comprised 43% of catches in the east and 16% in the west regions of South Georgia, and 27% in the Shag Rocks region. Fish of 26–39 cm comprised 50%, 80% and 71% of catches in these regions respectively. Fish greater than 40 cm made up 5.5%, 3% and 1.6% of catches respectively. Thus, smaller fish of 15–25 cm were most common in the east region of South Georgia, while larger individuals (26–39 cm) were most common in the west region of South Georgia and the Shag Rocks region.

When comparing species composition for various regions, it was only possible to use the results for 1983–1988, when catches were taken simultaneously in all three abovementioned regions. This is because, in the early stages of the *C. gunnari* fishery (1970s), only the eastern part of the shelf was fished, followed by fishing in the northern and western parts of the shelf. It was only from 1983 that dense concentrations were found over the entire subarea, including the shallow-water area around Shag Rocks.

Table 1: Size composition of *Champsocephalus gunnari* less than 15 cm in length in different regions around South Georgia, based on the results of pelagic trawl surveys. (See text for definition of regions.)

| Vessel, Date | Parameters | East | North | South | West |
|---|---|---|---|---|---|
| *Evrika* | Average length (m) | 62 | 58 | 61 | 55 |
| 30/03–07/04 | Length frequency (mm) | 30–90 | 40–70 | 30–90 | 30–70 |
| 1988 | Individual numbers | 563 | 240 | 410 | 94 |
| *Gizhiga* | Average length (m) | 91 | 100 | 96 | 95 |
| 25/05–08/06 | Length frequency (mm) | 70–130 | 80–130 | 70–130 | 70–130 |
| 1984 | Individual numbers | 370 | 85 | 458 | 587 |
| *Anchar* | Average length (m) | 80 | 81 | 78 | 76 |
| 29/05–07/06 | Length frequency (mm) | 60–120 | 60–100 | 60–110 | 60–100 |
| 1990 | Individual numbers | 2 267 | 1 400 | 2 113 | 2 001 |
| *Gizhiga* | Average length (m) | 108 | 108 | 108 | 99 |
| 30/05–29/06 | Length frequency (mm) | 60–130 | 80–130 | 60–140 | 70–120 |
| 1986 | Individual numbers | 110 | 53 | 567 | 334 |
| *P. Latvii* | Average length (m) | 113 | 100 | 116 | 101 |
| 08/07–24/07 | Length frequency (mm) | 90–150 | 80–140 | 80–150 | 70–150 |
| 1989 | Individual numbers | 585 | 259 | 451 | 696 |
| *Gizhiga* | Average length (m) | 103 | 101 | 108 | 100 |
| 07/07–08/08 | Length frequency (mm) | 80–130 | 80–130 | 70–150 | 80–140 |
| 1987 | Individual numbers | 506 | 895 | 2 459 | 1 678 |

Table 2: Frequency of occurrence of *Champsocephalus gunnari* more than 15 cm in length from the east, west, north and south regions of South Georgia and the Shag Rocks region.

| Vessel, Date | Parameters | East | North | South | West | Shag Rocks |
|---|---|---|---|---|---|---|
| | | autumn | | | | |
| *Anchar* | L = 15–25 cm (%) | 66.75 | 6.70 | 31.87 | 9.16 | |
| 07–30/04/1990 | L = 26–39 cm (%) | 24.42 | 85.77 | 64.63 | 86.62 | |
| | L = 40 cm plus (%) | 8.84 | 7.53 | 3.49 | 4.22 | |
| | Average length (cm) | 26.1 | 34.9 | 28.9 | 32.5 | No data |
| | Number of specimens | 1 245 | 3 520 | 2 262 | 4 192 | |
| *Atlantida* | L = 15–25 cm (%) | 45.10 | 16.71 | 23.48 | 13.10 | 2.23 |
| 01/04–27/05/1991 | L = 26–39 cm (%) | 51.82 | 64.03 | 72.56 | 82.83 | 95.88 |
| | L = 40 cm plus (%) | 2.99 | 15.03 | 3.96 | 4.08 | 1.87 |
| | Average length (cm) | 26.8 | 31.8 | 29.6 | 31.5 | 32.3 |
| | Number of specimens | 3 140 | 3 260 | 1 465 | 7 140 | 4 331 |
| *Gizhiga* | L = 15–25 cm (%) | 51.55 | 44.24 | 8.0 | 16.12 | |
| 24/04–23/05/1984 | L = 26–39 cm (%) | 46.80 | 52.05 | 88.12 | 81.03 | |
| | L = 40 cm plus (%) | 1.66 | 2.19 | 3.96 | 2.79 | |
| | Average length (cm) | 26.7 | 27.1 | 32.5 | 31.7 | No data |
| | Number of specimens | 906 | 1 510 | 303 | 1 861 | |
| | | winter | | | | |
| *Gizhiga* | L = 15–25 cm (%) | 15.59 | 1.71 | 3.73 | 0.85 | |
| 10–31/08/1987 | L = 26–39 cm (%) | 76.31 | 76.15 | 79.05 | 97.34 | |
| | L = 40 cm plus (%) | 8.10 | 22.13 | 17.22 | 1.81 | |
| | Average length (cm) | 33.6 | 36.8 | 37.1 | 31.4 | No data |
| | Number of specimens | 667 | 348 | 482 | 827 | |
| | | spring | | | | |
| *Gizhiga* | L = 15–25 cm (%) | 39.97 | 13.41 | 41.31 | 22.14 | 38.16 |
| 16/09–21/10/1986 | L = 26–39 cm (%) | 58.01 | 82.87 | 42.27 | 76.88 | 60.56 |
| | L = 40 cm plus (%) | 1.57 | 0.18 | 4.13 | 0.74 | 1.28 |
| | Average length (cm) | 26.8 | 28.8 | 26.9 | 29.9 | 28.8 |
| | Number of specimens | 4 837 | 6 837 | 2 181 | 4 079 | 3 527 |
| | | summer | | | | |
| *P. Latvii* | L = 15–25 cm (%) | 41.31 | 49.75 | 50.4 | 33.63 | 40.60 |
| 10/12/1988–03/01/1989 | L = 26–39 cm (%) | 43.38 | 44.69 | 45.4 | 58.81 | 58.92 |
| | L = 40 cm plus (%) | 8.72 | 4.92 | 2.56 | 2.63 | 0.49 |
| | Average length (cm) | 27.6 | 27.8 | 27.0 | 29.1 | 26.5 |
| | Number of specimens | 1 513 | 1 403 | 1 055 | 4 457 | 10 493 |

Table 3: Average length (cm) by age of *Champsocephalus gunnari*, caught in different regions of the South Georgia area by USSR research and commercial vessels, by year and quarter.

| | Year | Location | Age | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| I | 1988 | Shag Rocks | 16.2 | 21.4 | 28.7 | 32.6 | 35.3 | 38.3 | | | | | |
| | | East South Georgia | 14.9 | 17.6 | 27.9 | 32.6 | 36.6 | 39.4 | 41.8 | 45.0 | 46.0 | 48.0 | |
| | | West South Georgia | 14.2 | | 30.1 | 32.5 | 35.2 | 39.4 | 42.2 | - | 48.0 | - | - |
| II | 1983 | Shag Rocks | - | 23.7 | 30.8 | 34.23 | 37.0 | 38.5 | - | | | | |
| | | East South Georgia | - | 22.5 | 30.7 | 34.5 | 38.7 | 40.7 | - | 46.5 | 48.67 | 51.0 | |
| | | West South Georgia | - | 27.3 | 30.4 | 35.7 | 39.3 | 41.5 | 44.1 | 47.3 | 49.5 | 50.9 | - |
| | 1984 | Shag Rocks | - | 23.4 | 30.4 | 34.4 | - | - | - | | | | |
| | | East South Georgia | 18.7 | 24.8 | 29.2 | 36.0 | 40.5 | | - | - | - | - | |
| | | West South Georgia | 18.0 | 25.0 | 31.5 | 35.1 | 38.5 | 41.2 | 43.8 | 46.0 | 48.8 | - | - |
| | 1986 | Shag Rocks | - | 22.8 | - | 35.3 | 38.5 | 40.8 | - | | | | |
| | | East South Georgia | | 22.8 | 30.4 | 33.8 | - | 41.0 | - | - | - | - | |
| | | West South Georgia | | 23.0 | 29.0 | - | - | - | - | - | - | - | - |
| | 1987 | Shag Rocks | - | 27.2 | 30.1 | - | 37.4 | 40.8 | 41.5 | | | | |
| | | East South Georgia | - | 26.5 | 30.3 | 35.5 | 38.3 | 39.7 | 40.8 | 45.3 | - | - | |
| | | West South Georgia | - | 27.1 | 30.0 | 34.9 | 39.0 | 40.7 | 42.4 | 45.0 | - | - | - |
| Average for II quarter | | Shag Rocks | | 24.3 | 30.4 | 34.6 | 37.6 | 40.0 | 41.5 | | | | |
| | | East South Georgia | 18.7 | 24.2 | 30.2 | 35 | 39.2 | 40.5 | 40.8 | 45.9 | 48.7 | 51 | |
| | | West South Georgia | 18.0 | 25.7 | 30.2 | 35.2 | 38.9 | 41.1 | 43.4 | 46.1 | 49.2 | 50.9 | |
| III | 1983 | Shag Rocks | - | | 28.3 | 31.3 | 34.9 | 37.8 | - | | | | |
| | | East South Georgia | - | - | 23.4 | 28.9 | 35.6 | 38.5 | | - | - | - | |
| | | West South Georgia | | | 27.6 | 32.1 | 35.2 | 37.4 | 42 | | | | |
| | 1987 | Shag Rocks | - | - | 27.0 | 30.6 | 34.7 | 38.7 | - | | | | |
| | | East South Georgia | - | 19.2 | 26.4 | 31.6 | 36.0 | 38.3 | 43.9 | - | - | - | |
| | | West South Georgia | - | 19.5 | 28.1 | 30.8 | 35.4 | 39.2 | 43.5 | 46.4 | 47.4 | 49.8 | 51.6 |
| Average for III quarter | | Shag Rocks | | | 27.7 | 31.0 | 34.8 | 38.3 | | | | | |
| | | East South Georgia | | 19.2 | 24.9 | 30.3 | 35.8 | 38.4 | 43.9 | | | | |
| | | West South Georgia | | 19.5 | 27.9 | 31.5 | 35.3 | 38.3 | 42.8 | 46.4 | 47.4 | 49.8 | 51.6 |
| IV | 1986 | Shag Rocks | 6.6 | 20.3 | 26.1 | - | 36.3 | 38.1 | 41.0 | | | | |
| | | East South Georgia | 13.8 | 21.4 | 26.2 | 29.7 | 36.8 | 40.5 | 44.5 | 47.1 | 50.0 | 52.2 | |
| | | West South Georgia | 13.6 | 21.7 | 26.4 | 31.6 | 36.2 | 40.4 | 43.6 | 45.8 | 48.5 | - | - |
| | | Shag Rocks | | 19.3 | 27.6 | 31.7 | 34.9 | - | - | | | | |
| | | East South Georgia | - | 21.4 | 27.2 | 31.7 | 36.8 | 40.2 | 45.6 | 47.3 | 49.5 | 53.0 | |
| | | West South Georgia | - | 22.0 | 28.3 | 31.6 | 35.5 | 40.7 | 44.2 | 48.0 | 48.5 | - | - |
| Average for IV quarter | | Shag Rocks | 6.6 | 19.8 | 26.9 | 31.7 | 35.6 | 38.1 | 41 | | | | |
| | | East South Georgia | 13.8 | 21.4 | 26.7 | 30.7 | 36.8 | 40.4 | 45.1 | 47.2 | 49.8 | 52.6 | |
| | | West South Georgia | | 21.6 | 27.4 | 31.6 | 35.9 | 40.6 | 43.9 | 46.9 | 48.5 | | |

Differences in length composition to the north and south of South Georgia were attributed to fish being mixed in different proportions from the east and west regions. When commercial fishing started in South Georgia waters, *C. gunnari* was generally concentrated in any one of three regions considered (i.e. east and west regions of South Georgia and the Shag Rocks region). Therefore, data obtained simultaneously from all three regions were available only from 1983 to 1988.

In the east region of South Georgia the mean length of *C. gunnari* was generally the smallest, due to the presence of large numbers of immature fish (Table 3), while in the west region of South Georgia it was greater, due to lesser numbers of immature fish. At Shag Rocks, the mean length differed from that of fish in both shelf regions of the island. Similar results were obtained from bottom census trawl surveys of *C. gunnari* (Table 2). Mean length was smallest in the east region of the South Georgia shelf due to the predominance of fish measuring 15–25 cm. Large fish were distributed over the entire north region of the shelf (northeast to northwest), and this influenced the mean length of fish in the east and west, and, in some years, in the south of the South Georgia shelf.

The differences in size composition of *C. gunnari* distributed near South Georgia and at Shag Rocks were quite significant and constant.

The length of *C. gunnari* in catches from shallow waters off Shag Rocks was consistently much smaller than around South Georgia. In general, fish of more than 40 cm were not common in the Shag Rocks region. Juveniles of less than 12 cm were not found during annual pelagic surveys from 1984 to 1990. In commercial catches, juveniles of 5–8 cm were observed only in 1986. Fish from the 1+ age group (11–15 cm) at Shag Rocks were only observed in five out of 20 abundant year classes at South Georgia (1975, 1981, 1985, 1986 and 1988).

Table 4: Age composition (%) by year and quarter of *Champsocephalus gunnari* caught in different regions of the South Georgia area by USSR research and commercial vessels.

| Quarter | Year | Region | Age | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| I | 1988 | Shag Rocks | 41.6 | 8.4 | 23.8 | 22.6 | 3.7 | 0.3 | | | | | |
| | | East South Georgia | 1.4 | 1.9 | 50.1 | 22.9 | 19.0 | 3.7 | 0.8 | 0.02 | 0.02 | 0.03 | |
| | | West South Georgia | 6.2 | | 32.3 | 47.4 | 12.9 | 0.8 | 0.4 | - | 0.01 | - | |
| | 1983 | Shag Rocks | - | 27.6 | 61.1 | 11 | 0.2 | 0.1 | | | | | |
| | | East South Georgia | - | 90.2 | 6.7 | 2.3 | 0.2 | 0.2 | - | 0.1 | 0.2 | 0.1 | |
| | | West South Georgia | - | 8.1 | 56.2 | 14.9 | 9.7 | 7.1 | 3.1 | 0.8 | 0.1 | 0.1 | - |
| II | 1984 | Shag Rocks | - | 66.3 | 29.9 | 3.8 | - | - | | | | | |
| | | East South Georgia | 18.1 | 54.7 | 10.6 | 12.5 | 3.2 | 0.6 | - | - | - | - | |
| | | West South Georgia | 6.9 | 16.0 | 40.0 | 32.0 | 2.8 | 1.6 | 0.3 | 0.2 | 0.2 | - | - |
| | 1986 | Shag Rocks | - | 73.2 | - | 23.1 | 3.2 | 0.5 | | | | | |
| | | East South Georgia | | 95.1 | 3.5 | 0.6 | | 0.2 | - | - | - | - | |
| | | West South Georgia | | 78.9 | 21.1 | | - | - | - | - | - | - | - |
| | 1987 | Shag Rocks | - | 16.7 | 81.8 | - | 1.3 | 0.2 | 0.06 | | | | |
| | | East South Georgia | - | 17.5 | 40.9 | 36.6 | 2.9 | 0.8 | 0.8 | 0.4 | - | - | |
| | | West South Georgia | - | 16.8 | 74.8 | 7.0 | 1.0 | 0.3 | 0.1 | 0.01 | - | - | - |
| III | 1983 | Shag Rocks | - | - | 19.8 | 68.8 | 9.6 | 1.8 | | | | | |
| | | East South Georgia | - | | 98.6 | 0.9 | 0.3 | 0.2 | - | - | - | - | |
| | | West South Georgia | - | - | 6.6 | 59.3 | 28.8 | 4.7 | 0.6 | - | - | - | - |
| | 1987 | Shag Rocks | - | - | 44.1 | 54.3 | 1.4 | 0.2 | | | | | |
| | | East South Georgia | - | 0.05 | 11.2 | 18.9 | 37.1 | 29 | 1.7 | - | - | - | |
| | | West South Georgia | - | 0.11 | 28.5 | 47 | 10.5 | 8.2 | 1.5 | 1.8 | 1.3 | 0.7 | 0.6 |
| IV | 1986 | Shag Rocks | 1.1 | 5 | 85.5 | - | 7.7 | 0.7 | 0.01 | | | | |
| | | East South Georgia | 0.3 | 5.4 | 77.9 | 13.1 | 2.4 | 0.6 | 0.2 | 0.1 | 0.01 | 0.02 | |
| | | West South Georgia | 0.15 | 2.8 | 32.1 | 36.2 | 26 | 2.4 | 0.2 | 0.1 | 0.03 | - | - |
| | 1987 | Shag Rocks | - | 0.8 | 22.2 | 66.5 | 10.5 | - | | | | | |
| | | East South Georgia | - | 0.1 | 20.3 | 35.8 | 36.7 | 6.5 | 0.2 | 0.1 | 0.2 | 0.04 | |
| | | West South Georgia | - | 0.2 | 16.4 | 66.7 | 14.7 | 1.8 | 0.2 | 0.04 | 0.03 | - | - |

A regular cycle of fluctuation in size composition and average length of *C. gunnari* was observed at South Georgia (Figure 2), but not at Shag Rocks. This can be attributed to a strong year class which remained abundant over the years (Frolkina, 1993). At Shag Rocks the same size class and age group were predominant in most years except 1970, 1974, 1981 and 1988. This may be an artefact of sampling, however, because in 1974 only survey data, and not commercial catch data, were available. The length composition of fish varied during 1981 and 1988, but the average length of fish in these years was the same as in all other years.

## Age Composition

Fish taken in the commercial fishery off South Georgia were between 1 and 7 years old, with occasional individuals up to 11 years. At Shag Rocks fish were aged up to 5–6 years, with small numbers of individuals up to 7 years old (Figures 3 and 4). As a rule, 3-year-old, and sometimes 4-year-old fish dominated in both areas.

It should be noted that on the South Georgia shelf the presence of one or two dominant age groups was characteristic for *C. gunnari*, not only during years of systematic intensive fishing (1980–1987), but also in preceding years (1971–1976). On the South Georgia shelf, both in the absence of fishing and in years of intensive fishing, fish were recruited to the commercial stock at age 3 (Figure 3), i.e. at the age of first spawning (Frolkina, 1999). Compared to the period 1971 to 1976, the number of fish over 5 years old almost halved from 1980 to 1987.

The age structure of *C. gunnari* off Shag Rocks was found to be different from those on the South Georgia shelf. For Shag Rocks it is characterised by the absence of fish more than 6–7 years old, compared to 10–11 years on the South Georgia shelf, and by the absence of fish less than 12 cm. Entire year classes were sometimes observed to be completely absent for several years (e.g. 1982 year class) (Figure 4).

A comparison of the age structure of *C. gunnari* in different regions shows that it was similar in the west region of South Georgia and the Shag Rocks region, whereas it was different in the east region of South Georgia (Table 4). There were also differences between regions in average length at age (Table 3).

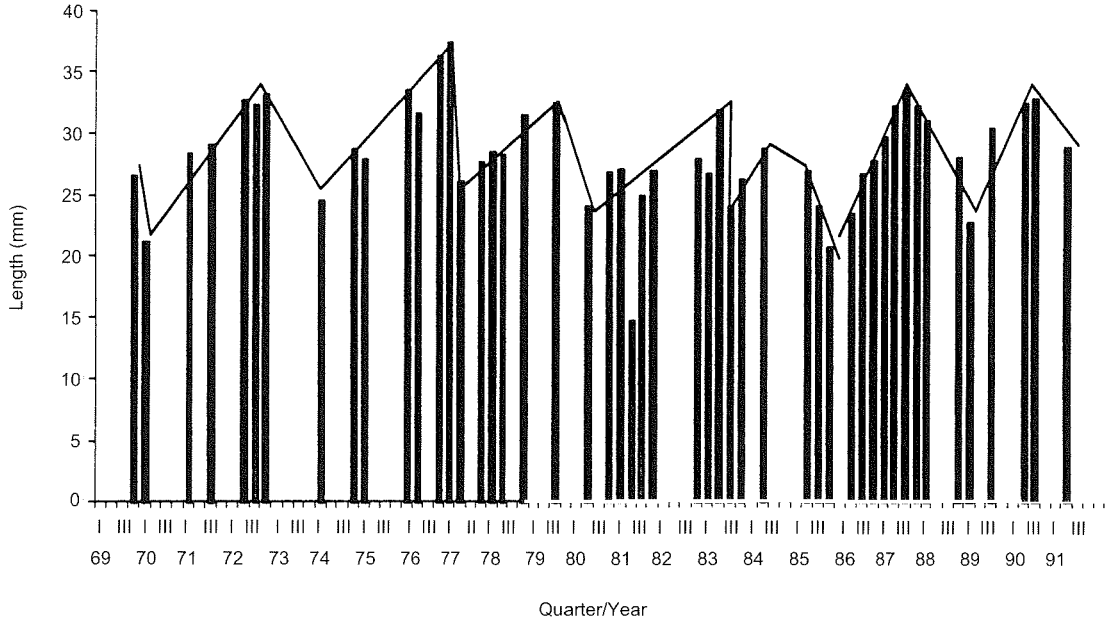


Figure 2: Average length by year and quarter of *Champsocephalus gunnari* from the South Georgia shelf.

A notable feature of *C. gunnari* size–age structure was also observed in near-bottom depth strata: one or two age groups were always prevalent in catches, with age group 3 always being one of them.

## DISCUSSION

The comprehensive data presented here show fluctuations in the length and age composition of the *C. gunnari* population in South Georgia waters (Subarea 48.3) as a whole, as well as in separate regions within that area.

Observed growth was not constant between years and regions, as is evident from differences found in juvenile and immature fish. The highest growth rate was observed in juveniles inhabiting the east and south regions of the South Georgia shelf, while smaller fish were found on the west region. Fluctuations in annual mean fish length in this area could be related principally to the strength of year classes. Thus, fish of the most abundant 1989 year class (1990 survey) were the smallest, juveniles from the 1983 year class (1984 survey) were somewhat larger, while the largest fish were from the weak 1985 year class (1986 survey results) (Table 1).

Immature fish were found throughout the year to the east, southeast and southwest of the South Georgia shelf. As they grow, these fish gradually migrate over the shelf from the south and southwest towards the northeast, and from the southwest towards the west (Frolkina, 1999). The predominance of immature fish in the eastern and northeastern parts of the shelf affected the size composition of catches: the smallest average fish length in catches was found in these parts. The predominance of fish 15–25 cm long in the east and northeast of the shelf could be attributed to more successful spawning in these waters.

In catches from the northwest and west parts of the shelf approximately 80% of fish were 25–39 cm long with, on average, less than 20% of fish measuring 15–25 cm. Therefore it is apparent that the northwest and west parts of the shelf represent a favourable habitat for large fish.

Analysis of the size–age structure of fish around Shag Rocks suggests that this region is an area of expanded *C. gunnari* habitat of the total population around South Georgia, as evidenced by the absence of juveniles, the presence of large fish and the similarity between the early-life age–length composition of fish here and those from the western shelf of South Georgia.

The absence of *C. gunnari* less than 11 cm in length was observed in the Shag Rocks region. Although spawning individuals and even larvae of *C. gunnari* were taken in catches in this region in some years, spawning has always appeared to be relatively unsuccessful. Hatched larvae had obviously been carried by the Antarctic Circumpolar Current either to the South Georgia shelf or far offshore. Since *C. gunnari* from South Georgia and Shag Rocks belong to the same population, as indicated by numerous investigations, *C. gunnari*

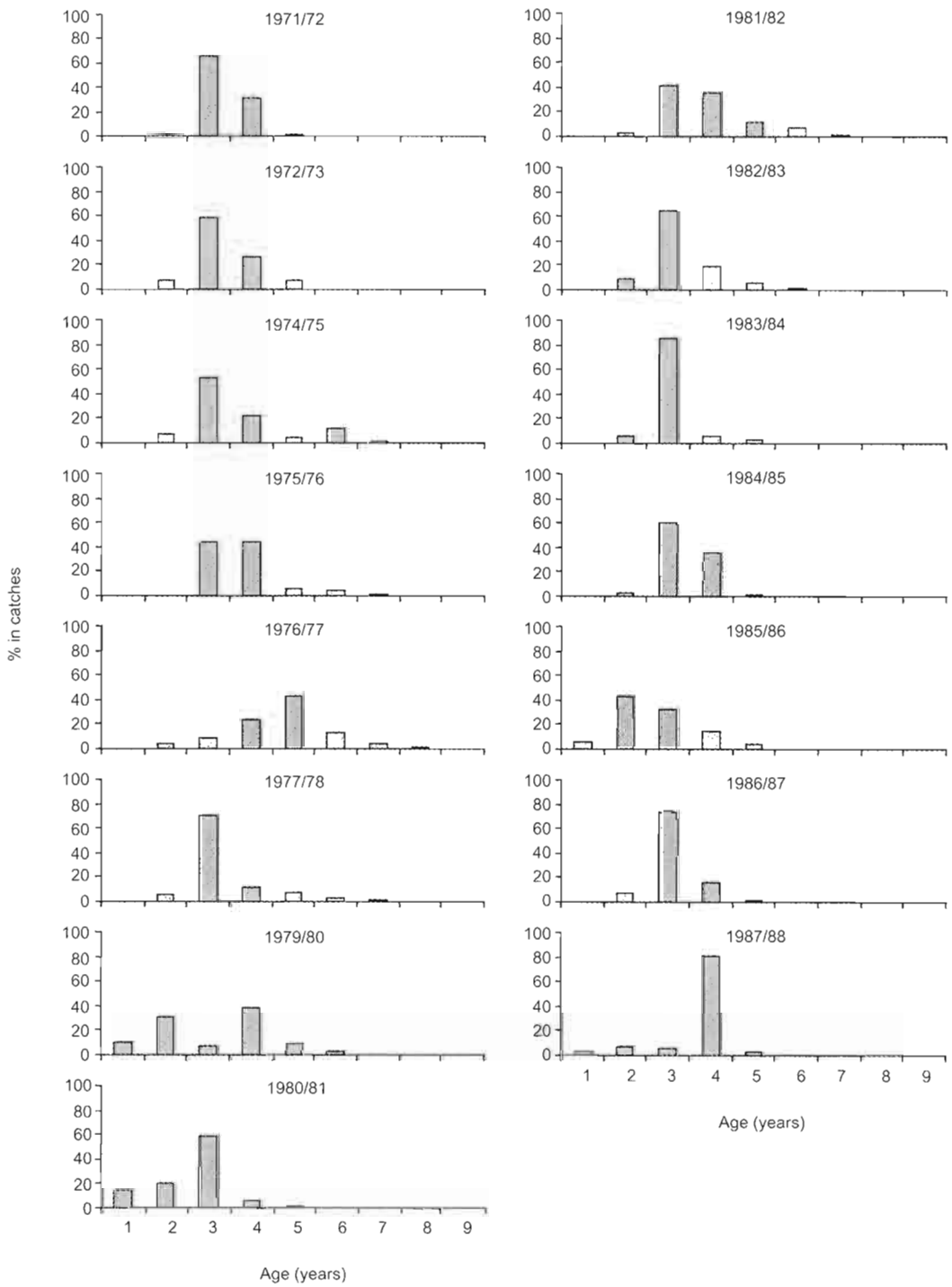


Figure 3: Age composition by year of *Champsocephalus gunnari* caught by USSR research and commercial vessels on the South Georgia shelf.

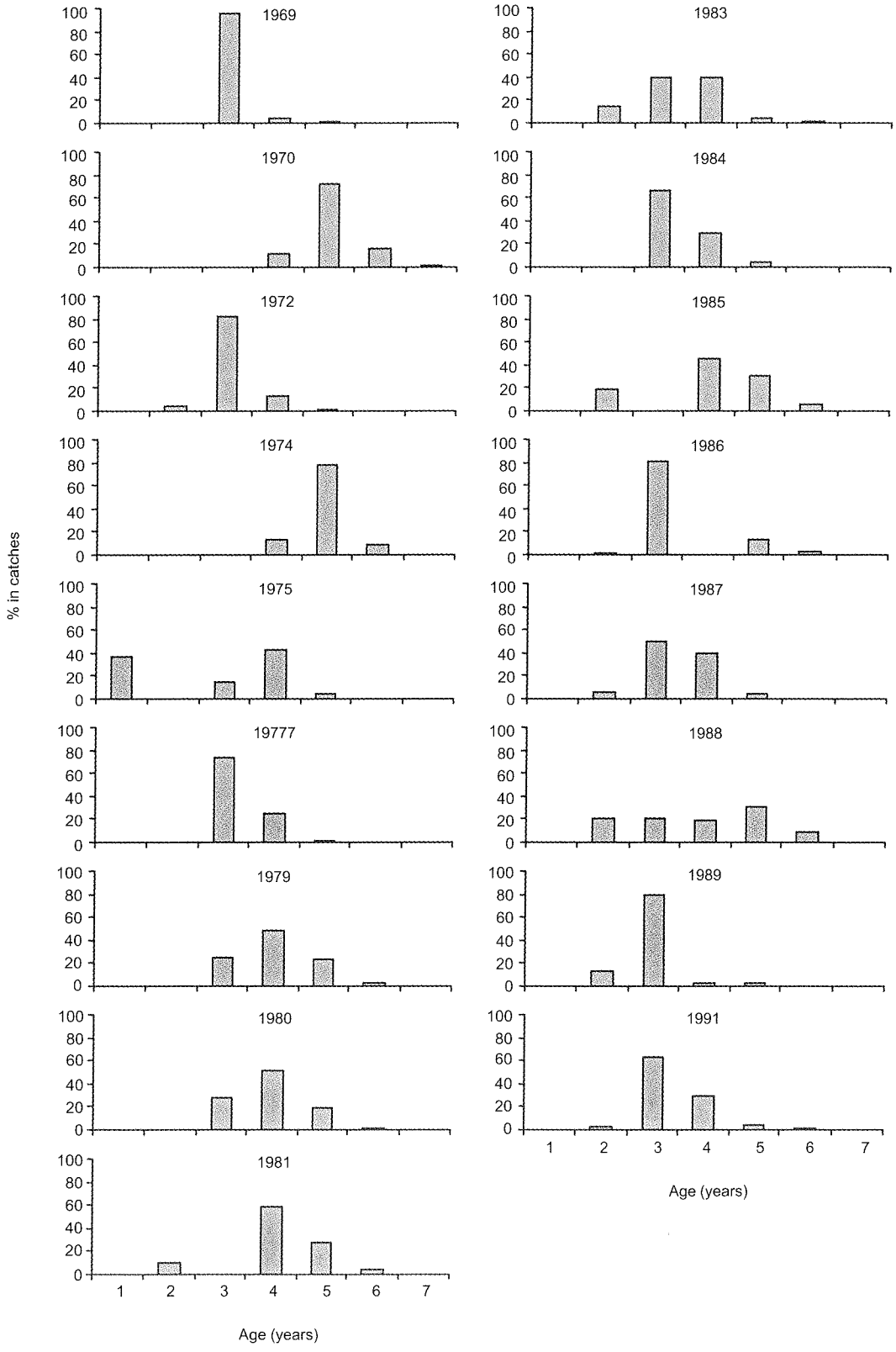


Figure 4: Age composition by year of *Champsocephalus gunnari* caught by USSR research and commercial vessels from the Shag Rocks region.

present in the Shag Rocks region could have migrated from the western part of the South Georgia shelf. The similar size–age structure of 2- to 4-year-old fish from both parts of the *C. gunnari* population corroborates this assumption. Fish from strong year classes sometimes migrate towards Shag Rocks at age 1+ (juveniles, 11–15 cm length) but more frequently at age 2+ (20–25 cm length). It should also be noted that some *C. gunnari* year classes were completely absent in our samples or were at such low abundance that they were not detected. In the case of a weak year class or intensive fishing effort over the shelf, there is no apparent migration of fish towards Shag Rocks. Fish older than 5 years were only caught occasionally.

The dominance of recruits in catches taken on the South Georgia shelf has been noted in all years of observation. This was also noted during surveys of the pre-exploitation population (1965–1969) (Frolkina and Dorovskikh, 1989). The same situation was observed during periods of low-level fishing (1970–1975), as well as high-intensity fishing (1980s). Trawl surveys carried out several years after the ban on fishing was introduced (1997–2000) gave similar results. The exception was the 1976/77 season, when age-group 5 fish dominated catches. This can be explained by the appearance of the highly productive 1971 cohort after the sharp decrease in the *N. rossii* stock. The population later returned to its usual size-age structure.

Analysis of size–age structure data for *C. gunnari* explains how the biomass of this species could dramatically increase in such a short period of time following the reduction in the *N. rossii marmorata* stock and become the most important commercial species. Irrespective of fishing intensity, fish of age-group 3 and, less often, of age-groups 2 or 4, dominated in catches. The total proportion of the two dominating age groups in catches was between 64 and 96%. However, the 1976/77 season was an exception. During the early stages of the *C. gunnari* fishery on the South Georgia shelf the very strong age-group 5 was dominant and fished for the first time. As a result of fishing, the proportion of 5-year-old fish decreased from 11% to 5%. However, as the bulk of the spawning stock has always consisted of first-time spawners (60% on average), this decrease of an older age group did not have an adverse impact on the reproductive capacity of the *C. gunnari* population in the following years of intensive fishing.

Therefore, the *C. gunnari* population from South Georgia can be considered a category II type spawning population (as defined by Monastyrsky (1952)), in which recruits dominate over the rest of the population.

Previously published results showed that 70% of individuals become mature at 30 cm length, i.e. mainly at age 4 (Frolkina, 1999). According to Monastyrsky's method of spawning population analysis, *C. gunnari* age–length structure and abundance are influenced more by biology and environmental factors than the fishery.

In the author's opinion, the pelagic aspects of *C. gunnari* distribution (Andriashev, 1964, 1986), earlier age of maturity compared to that of *N. rossii marmorata*, and favourable oceanographic conditions have allowed *C. gunnari* to rapidly increase in abundance after the decrease in abundance of *N. rossii marmorata* on the South Georgia shelf. These factors contributed to the very rapid restoration of the *C. gunnari* stock after it was significantly depleted by intensive fishing.

## CONCLUSION

The data collected reveal a similarity in the size–age structure of *C. gunnari* during the first years of its life cycle on the western shelf of South Georgia and at Shag Rocks. These two parts of the *C. gunnari* population differ from those on the eastern shelf of South Georgia. *C. gunnari* migrate from the western shelf towards Shag Rocks when they reach 15–25 cm in length. The fishery for *C. gunnari* at Shag Rocks mainly caught 4- to 5-year-old fish. It was also observed that the life span of the species in waters off South Georgia is longer than at Shag Rocks.

Various parts of the *C. gunnari* population have different age–length compositions: on the eastern South Georgia shelf fish of 15–25 cm are dominant, whereas in the western South Georgia shelf individuals of 25–39 cm are dominant.

Irrespective of fishing intensity, the bulk of the population comprises one or two age groups of fish, predominantly at the stage of maturation. This is one of the reasons why the population was able to rapidly increase and become the most important commercial species in the subarea following the sharp decline of *N. rossii marmorata*, and to recover quickly after a pause in fishing.

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