

## SPAWNING LOCATIONS OF MACKEREL ICEFISH AT SOUTH GEORGIA

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## Abstract

Historical information on the distribution of spawning and larval mackerel icefish (*Champscephalus gunnari*) within CCAMLR Subarea 48.3 (South Georgia and Shag Rocks) is assessed. This is considered alongside new data from commercial fisheries and research surveys. It is concluded that there is strong evidence of inshore spawning at South Georgia during April within and close to the bays on the north side of the island. Some spawning almost certainly occurs over much of the island shelf, although this appears to be at a very much lower intensity than inshore. There is some evidence of spawning at Shag Rocks. There are also indications of a possible second spawning season in January, although the evidence is weak. Concentrations of larval icefish within Cumberland Bay are an order of magnitude higher than in adjacent coastal waters and their density declines exponentially offshore. All this evidence indicates that the most important spawning locations are within the bays.

## Résumé

Étude d'informations historiques sur la répartition du poisson des glaces (*Champscephalus gunnari*) à l'époque du frai et à l'état larvaire dans la sous-zone 48.3 de la CCAMLR (Géorgie du Sud et îlots Shag). En parallèle sont examinées de nouvelles données issues des pêcheries commerciales et des campagnes de recherche. Les auteurs arrivent à la conclusion que tout semble indiquer que la ponte a lieu en avril, près des côtes de la Géorgie du Sud, notamment dans les baies, ou en leur proximité, le long de la côte nord de l'île. Les poissons se reproduisent très vraisemblablement sur la plus grande partie du plateau, mais apparemment en moins grande densité que près des côtes. La ponte semble également se produire dans les îlots Shag. Bien que l'on ne puisse encore indubitablement le confirmer, une deuxième période de frai semblerait avoir lieu en janvier. Les concentrations de larves de poisson des glaces dans la baie Cumberland sont dix fois plus élevées que dans les eaux côtières adjacentes et leur densité décroît exponentiellement vers le large. De toute évidence, les sites de reproduction les plus importants se trouvent dans les baies.

## Резюме

В статье оцениваются ретроспективные данные о распределении нерестовой ледяной рыбы (*Champscephalus gunnari*) и ее личинок в пределах Статистического подрайона 48.3 (Южная Георгия и скалы Шаг). Эти данные рассматриваются наряду с новыми данными коммерческого промысла и исследовательских съемок. Эти данные свидетельствуют о нересте в прибрежных водах Южной Георгии в течение апреля, в заливах на северной стороне острова или поблизости от них. Отчасти, нерест почти наверняка происходит на большей части шельфа острова, хотя скорее всего с гораздо меньшей интенсивностью, чем в прибрежных водах. Есть данные, что нерест также происходит у скал Шаг. Возможно, существует и второй нерестовый сезон в январе, хотя данных об этом недостаточно. Концентрация личинок ледяной рыбы в заливе Кумберланд на порядок выше, чем в прилегающих прибрежных водах, а их плотность экспоненциально понижается в направлении от берега. Все это говорит о том, что основные места нереста находятся в заливах.

## Resumen

Se evaluaron los datos históricos sobre la distribución del draco rayado (*Champsocephalus gunnari*) en desove y de sus larvas en la Subárea 48.3 de la CCRVMA (Georgia del Sur y Rocas Cormorán), junto con los nuevos datos de las pesquerías comerciales y de las prospecciones de investigación. Se ha concluido que en Georgia del Sur durante el mes de abril el desove ocurre en las bahías del norte de la isla y alrededores. Se puede decir casi con certeza que el desove ocurre en la mayor parte de la plataforma insular, aunque aparentemente con mucho menor intensidad que en la costa. Existen ciertos indicios de que el desove también ocurre en las Rocas Cormorán, y de que podría haber una segunda temporada de desove en enero, aunque la evidencia de ello es escasa. La concentración de larvas de draco rayado en la bahía de Cumberland es un orden de magnitud mayor que en las aguas costeras adyacentes y su densidad disminuye exponencialmente al alejarse de la costa. La información indica que los lugares de desove más importantes se encuentran en las bahías.

Keywords: mackerel icefish, *C. gunnari*, spawning, South Georgia, CCAMLR

## INTRODUCTION

Over the past 30 years there has been a fishery, large in some seasons, for mackerel icefish (*Champsocephalus gunnari*) in CCAMLR Subarea 48.3 at South Georgia and Shag Rocks. Commercial fishing has taken place over much of the shelf at depths to around 500 m. Conservation measures for this species have included a total allowable catch and a prohibition on fishing during what is assumed to be the spawning season. These provisions were considered by Parkes (2000), and reviewed during the 1999 meeting of the Scientific Committee's Working Group on Fish Stock Assessment (WG-FSA), where it was recommended that the closed season to protect spawning aggregations should be between 1 March and 31 May. Arising from this, WG-FSA recommended that further research was needed to identify more clearly the spawning locations and the distribution of juvenile fish. This paper seeks to address these objectives.

## BACKGROUND INFORMATION

Arising from a sampling program conducted from 28 November 1950 to 24 April 1951 in Husvik Harbour using fish traps and a trout net, Olsen (1955) noted that various species of *Notothenia* were present throughout the period along with a few specimens of the Bathydraconid *Parachaenichthys georgianus* and the channichthyid *Chaenocephalus aceratus*. The first specimen of *C. gunnari* was caught on 16 March, five more on the following day, two on 20 March and 14 on 30 March. On 5 April the catch was just three, and no further specimens were taken on 22 or 24 April.

Using a trawl in Cumberland West Bay on 5 April, Olsen (1955) reported a catch of 4 000 *C. gunnari* in a single haul. With the exception of eight small specimens (67–77 mm), all other fish were in the size range 230–440 mm, mature and almost ripe. Olsen notes that the males gave milt when pressed but that the roe of all females was of a hard and dry consistency; it is not clear whether at that time the female gonads were at an advanced stage 3 or stage 4.

Olsen (1955), citing information in papers by Lönnberg (1905), Norman (1938) and Nybelin (1947), noted that *C. gunnari* had never been recorded from inshore waters in summer and concluded that the spawning stock migrates into the fjords in March.

In a study of several species on the South Georgia shelf, Permitin (1973) noted that *C. gunnari* gonad maturation occurred during February and March. No sampling appears to have been undertaken as part of that study during April, the period when Olsen (1955) noted the greatest number of fish appearing in inshore waters. Permitin (1973) did find small numbers of ripe individuals over much of the shelf but inferred that the bulk of spawning activity took place close inshore or in the fjords.

Added weight was given to these conclusions by Kock (1981), who had obtained samples on the shelf and in some of the fjords where he found dense pre-spawning aggregations in the central parts of Fortuna, Cumberland and Royal Bays during late March and early April 1978. No such concentrations had been present there when the same bays had been sampled in February of the same year. Further evidence that spawning occurs in the inshore waters has come from the distribution

of larvae which are most commonly found in inshore waters (Kock, 1981; Slosarczyk, 1983; North, 1987).

In this paper we compare results from these observations with recent studies to provide a clearer insight into *C. gunnari* spawning seasons and migrations.

## MATERIALS AND METHODS

Data were derived from four sources:

- inshore sampling from the British Antarctic Survey (BAS) Research Station at King Edward Point, South Georgia;
- BAS larval fish surveys;
- bottom trawl sampling over the South Georgia and Shag Rocks Shelf during demersal fish surveys; and
- commercial fisheries operated by Poland and the former USSR.

Inshore sampling was undertaken using trammel nets (27 m long, 1.8 m deep with 7.6 cm inner and 43 cm outer meshes) which were operated from small boats within Cumberland East Bay. The nets were generally set in the late afternoon and hauled early the following morning. Sampling was undertaken from March 1978 to January 1981. Sampling depth ranges were 10–13, 15–16 and 90–200 m, with all depth ranges sampled in all months.

Results from demersal fish surveys have been reported to WG-FSA and typical examples are described in Everson et al. (1991) and Parkes (1993).

Data from the commercial fisheries of the former USSR were collated from logbooks and organised into a database at the Institut für Seefischerei in Hamburg, Germany. Data from the Polish fishery were provided by Sea Fisheries Institute in Gdynia, Poland. The analysis of these data was restricted to fish greater in total length than 29 cm, the size at which 95% of the fish had become sexually mature (Everson et al., 1996). Most *C. gunnari* have been reported from waters less than 400 m deep (e.g. Kock, 1981; Everson et al., 1991; Parkes, 1993), a depth range that encompasses the continental shelf of the region. Maturity stage was assessed according to one of three protocols, a comparison of which is given in Everson et al. (1999). For the analyses reported here, all maturity stage data were

standardised to the CCAMLR five-point scale (Kock and Kellermann, 1991; CCAMLR, 2000). For the analysis of the data from all months, the South Georgia shelf was divided into four sectors separated by latitude 54°S at the western end of South Georgia and longitude 37°W. In addition, Shag Rocks was treated as a separate sector.

Information on larval fish distribution came from several research cruises. During August 1983 a regular grid of 42 stations spaced at 30 n mile (55 km) intervals was sampled over the South Georgia shelf and adjacent deep oceanic waters using a Rectangular Midwater Trawl (RMT8). Of these stations, 26 were in water deeper than 2 000 m, 11 were in the shelf/slope region in water between 200 and 2 000 m deep, and the remaining five were made in water shallower than 200 m deep (North, 1987, 1990). A further series of hauls was undertaken between 26 December 1986 and 4 January 1987 along transects running offshore from the major embayments on the north coast of South Georgia. Sampling was undertaken using an RMT8 at stations up to 20 km from the mouth of each bay (North, 1990; White, 1998). Additional sampling was undertaken within Cumberland East Bay on a transect running along the main axis of the bay (North, 1987; 1990; North and Murray, 1992). Only samples taken during darkness were used in this analysis, since many larvae avoid the net during daylight (North and Murray, 1992). All larval fish in the catches were counted and their numerical density (*A*) estimated as number per 10 000 cubic metres of water filtered.

## RESULTS

### Inshore Sampling of Adult Fish

Catches of *C. gunnari* followed the same pattern in each season with none being caught in the months from September to January. The monthly distribution of catch rates is shown in Figure 1. The mean number of *C. gunnari* per net was very low during February and also from June to August. There was a sudden increase in numbers in March leading to a peak in May. All the fish at this time were observed to be coming into spawning condition. Ripe fish (gonad stage 4) occurred at all depths sampled between 15 m and 200 m.

### Offshore Sampling of Adult Fish

Information from commercial fisheries and the demersal fish surveys has been combined for this

analysis. The data are presented in two forms. In Figure 2, monthly histograms showing the proportions of reproductively active fish, that is those in stages 3 (developing), 4 (ripe) and 5 (spent) as a proportion of the total, from Shag Rocks and the four sectors of the South Georgia Shelf have been plotted.

The results indicate that developing fish were present over much of the shelf region, however ripe fish did not appear in large quantities except in the northeast South Georgia region. Spent fish were also present in the same region, although from the results there does not appear to be a smooth transition from ripe through to spent fish. There is evidence of a similar trend at Shag Rocks although the effect is less strong. There is some evidence that a small proportion comes into spawning condition around October and January, particularly in the regions west of South Georgia, although the effect is not strong. Results of the distribution of stage 5 fish are strongly influenced by the September 1997 survey, indicating that spent fish were widespread over the shelf throughout the region.

Haul-by-haul data are plotted in Figure 3. During January most of the reproductively active fish, that is those with gonads in stages 3, 4 and 5, were present around Shag Rocks and to the north of South Georgia, predominantly off Cumberland Bay. In February and March ripe fish were present off Cumberland Bay and also off Shag Rocks. In April ripe fish were present within Cumberland Bay, immediately offshore and also at Shag Rocks. Spent females were present off Cumberland Bay. During May ripe females were again present in Cumberland Bay and in June spent females were present off Cumberland Bay and at the western end of South Georgia. No data were available from Shag Rocks for May and June.

The presence in January of a few ripe and spent individuals near Shag Rocks and off Cumberland Bay may indicate some early season spawning, equally it may be a result of interannual variation in the gonad cycle discussed by Everson et al. (2000). The data available do not allow further investigation of that topic. The most important period leading up to spawning is clearly during March and April, when most spawning fish are present in the vicinity of Cumberland Bay and around Shag Rocks.

#### Larval Fish

Even though the August 1983 sampling program covered a wide area, *C. gunnari* larvae were only found at four stations, three of which were close

inshore to the north of South Georgia and the fourth close to Drygalski Fjord at the eastern end of the island (Figure 4).

Larval *C. gunnari* were present along the near-shore transects sampled in December–January 1986/87 (Figure 5). The greatest number of larvae was caught at the nearshore end, and the statistical distribution of larval density ( $A$ ) was highly skewed. A logarithmic transformation was applied to partly normalise the data, and a regression line fitted by the method of least squares which gave the following relationship:

$$\ln(A + 1) = 5.32 - 0.218 * D$$

$$N = 55, R^2 = 33.5\%, F_{1,54} = 26.7$$

where  $A$  is larval density in number per 10 000 m<sup>3</sup> of water filtered, and  $D$  is the distance offshore of the sampling site in kilometres. The results are plotted in Figure 6 along with the fitted regression line.

## DISCUSSION

### Distribution of Adult Fish

Information from the groundfish surveys and commercial fisheries throughout the year corroborates the suggestion of a migration to the northeast side of the island put forward by Frolkina (1999). Even though there is a strong case for concluding that the northern side of South Georgia is a region where pre-spawning fish are found, the lack of a clear transition to the spent stage indicates that the main spawning events are not taking place where the commercial fishery was operating. Such a conclusion is in line with the observations of Dr V. Herasymchuk (pers. comm.), who noted that fishing vessels from the former USSR fleet did not operate within 12 miles of the mainland of South Georgia. The evidence from Kock (1981), who found spawning concentrations close inshore and within the bays, is indicative of a spawning movement around to the northeast of the island and migration inshore to within, or at least the vicinity of, the bays. This conclusion is supported by the results of Frolkina (1999).

The results from the inshore trammel net catches match those of Olsen (1955) very closely. These indicate that, in the one season sampled by Olsen and four seasons sampled by BAS, the pattern is the same with sexually mature fish

appearing inshore during March and leaving the inshore area in May. All the fish sampled at these times appeared to be close to spawning.

We conclude from these results that the bulk of spawning is taking place at two localities: Shag Rocks and in the vicinity of Cumberland Bay. Also, while some spawning may be taking place early in the season, the main spawning period appears to occur during April and May.

#### Distribution of Eggs and Larvae

In common with many Antarctic fish, *C. gunnari* produces large eggs greater than 3 mm in diameter (Kock and Kellermann, 1991). Although Antarctic fish eggs have been found in plankton samples, these reports relate to few species and the list does not include *C. gunnari*. In spite of extensive sampling in Cumberland Bay through the months following spawning, no *C. gunnari* eggs were found in any samples in the study reported by North (1987, 1990) or White et al. (1996). We conclude that the eggs are most likely to be demersal and probably remain close to the spawning location and are consequently out of the range of conventional plankton nets.

There is general agreement that the eggs hatch mainly during August and September (see Kock and Kellermann, 1991) so that the distribution of early larvae at that time should reflect that of the eggs. During an extensive net haul survey over the South Georgia shelf and adjacent oceanic waters in August 1983, North (1987) only found *C. gunnari* larvae at four stations, all of which were on the shelf or close inshore along the north coast of South Georgia. Extensive year-round sampling from within Cumberland Bay showed that early larvae of *C. gunnari* were present from July to November (North, 1990). During January the larvae underwent diurnal vertical migration over the upper 100 m of the water column within the bay (North, 1987, 1990; North and Murray, 1992).

Sampling from within Cumberland East Bay during January 1987 gave a density of larvae of around one per cubic metre (North and Murray, 1992), a density an order of magnitude greater than that from sampling outside the bay a month earlier. Information from sampling the stations outside the bay but within 20 km of the coast, as shown in Figures 5 and 6, demonstrates that the larvae are concentrated in the coastal region. Within the distance range of the sampled sites of 3.5 to 19 km offshore, the regression indicates a 30-fold decline in density. This sampling regime only extended

about one third of the way from the coast to the shelf break of South Georgia, suggesting very strongly that the larvae are concentrated close inshore and predominantly within the bays.

The physical oceanography of the South Georgia region is complex. Offshore the circulation is within the Antarctic Circumpolar Current, whereas on the shelf there is a separate water mass, the South Georgia Shelf Water (SGSW) with slower circulation controlled by local topographic and physical oceanographic features (Brandon et al., 2000). Concentrations of krill are found within the SGSW over much of the shelf and, in particular, close to the shelf break (Trathan et al, 1998). If *C. gunnari* larvae were generally dispersed within SGSW, then they would be as widespread as krill. The period of several months between the hatching of *C. gunnari* and the sampling dates is sufficient for any larvae that might have been produced over the shelf to be widely distributed over that region and out to the shelf break either by diffusion or local circulation within the SGSW. The exponential decline offshore after such a period of time indicates that the process by which the larvae are entering the shelf waters away from the coast is slow and points to their origins being within relatively sheltered bays. The presence of icefish larvae within Cumberland Bay from July to February and their absence from waters over most of the shelf indicates that the bays are the main source of most of the larvae. Thus, even though there may be spawning over parts of the shelf away from the bays, this appears never to be in such quantity that large numbers of larvae appear in plankton samples.

#### CONCLUSION

We conclude that, while there is undoubtedly some spawning taking place over the shelf around South Georgia, most adult fish appear to move close inshore to spawn. The most important spawning grounds appear to be located within the bays on the northern side of the island or in the immediate coastal region. Consequently, protection of the majority of spawning concentrations can be achieved by a ban on fishing within and close to the bays during the main spawning season of April and May rather than a total ban over the whole South Georgia shelf.

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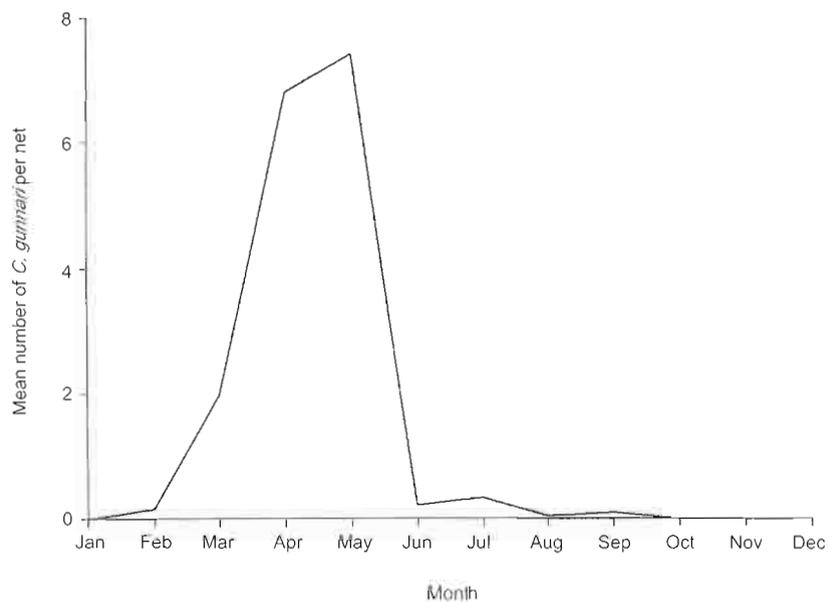


Figure 1: Mean number of *Champsocephalus gunnari* per trammel net fished in Cumberland East Bay, South Georgia, in each month from 1978 to 1980.

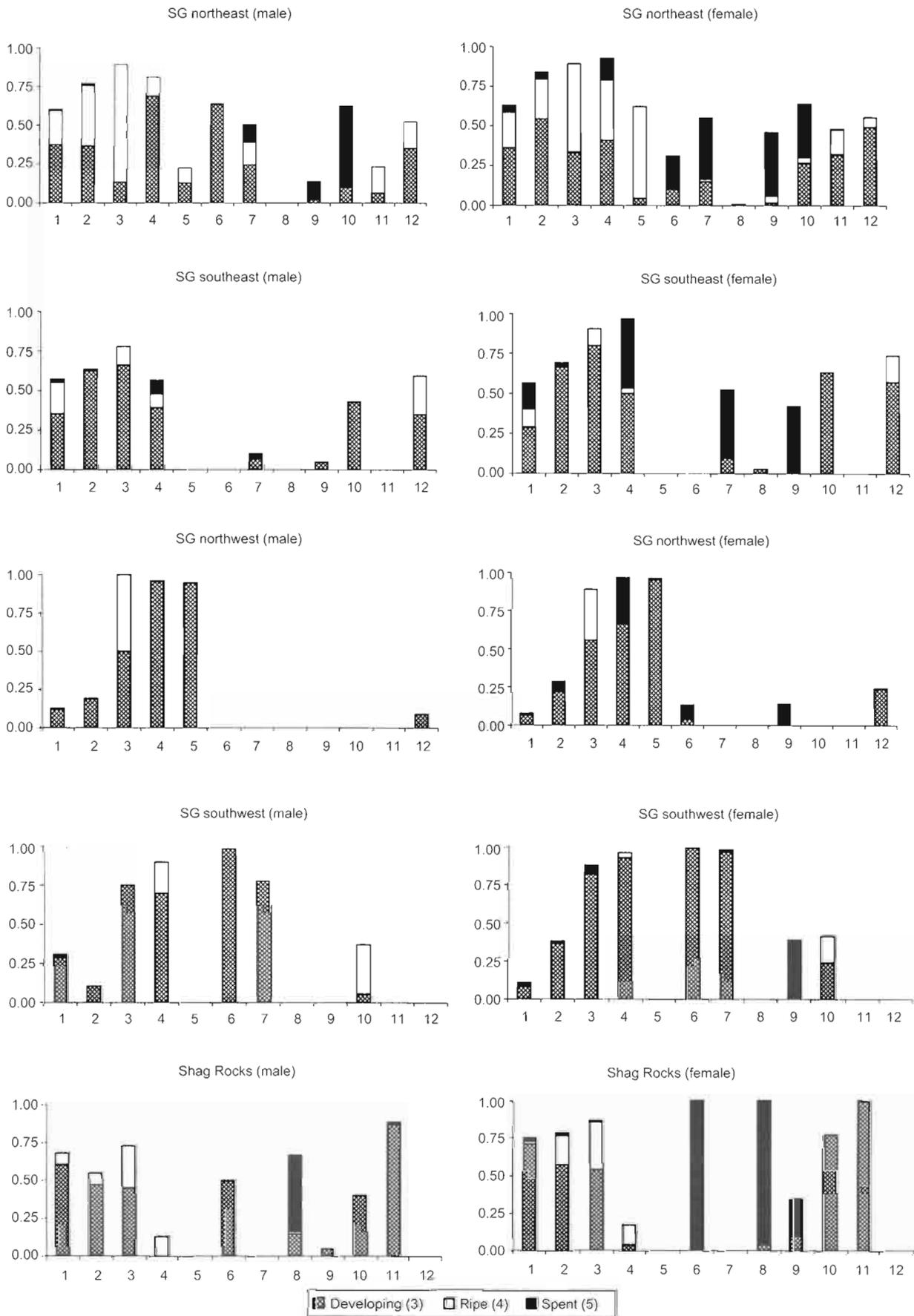


Figure 2: Proportion of gonad stage 3, 4 and 5 *Champsocephalus gunnari* present in each month within five regions of shelf in Subarea 48.3.

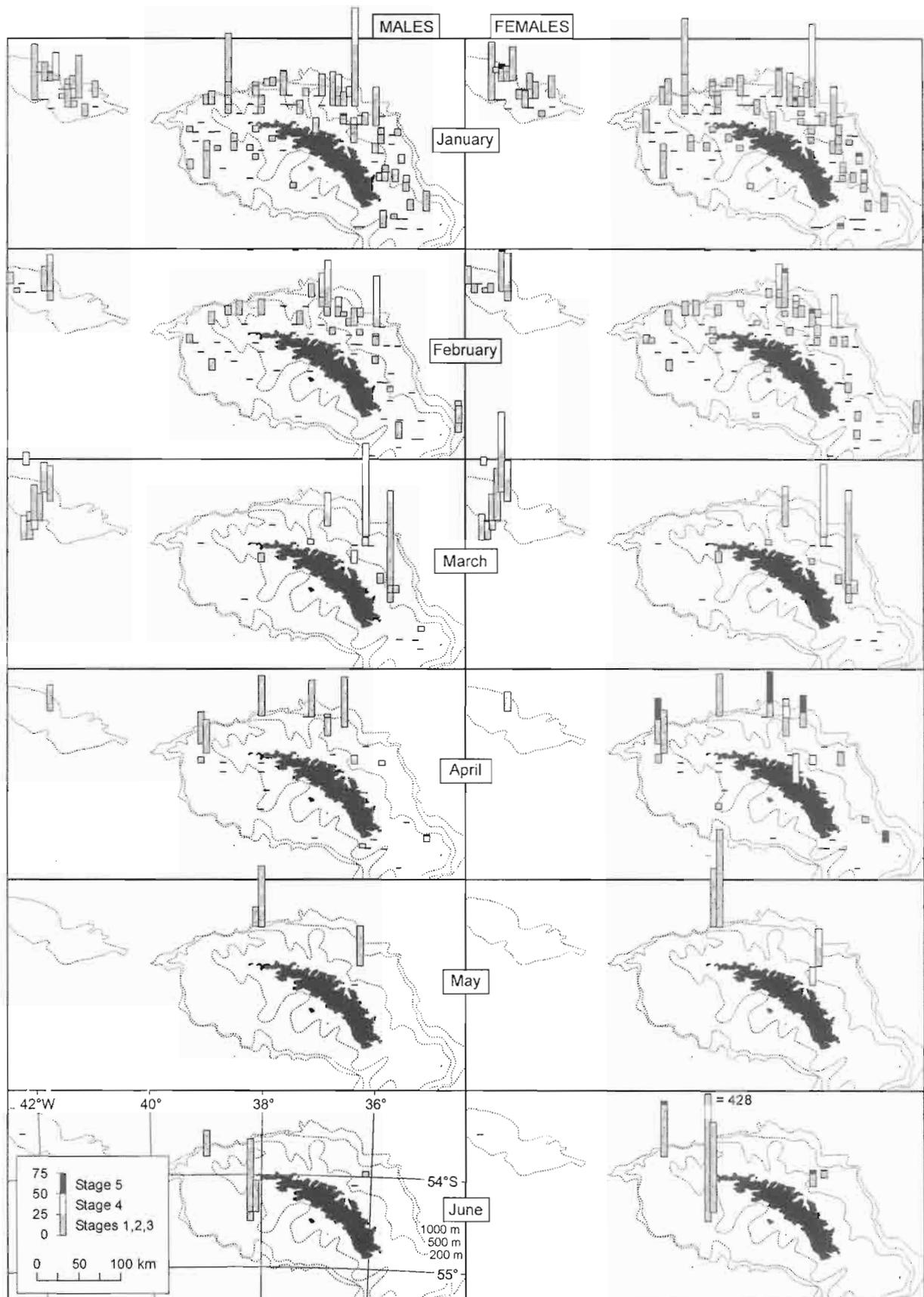


Figure 3: Sampling locations from January to June showing the proportions of maturity stages in the catches of *Champscephalus gunnari* for each month.

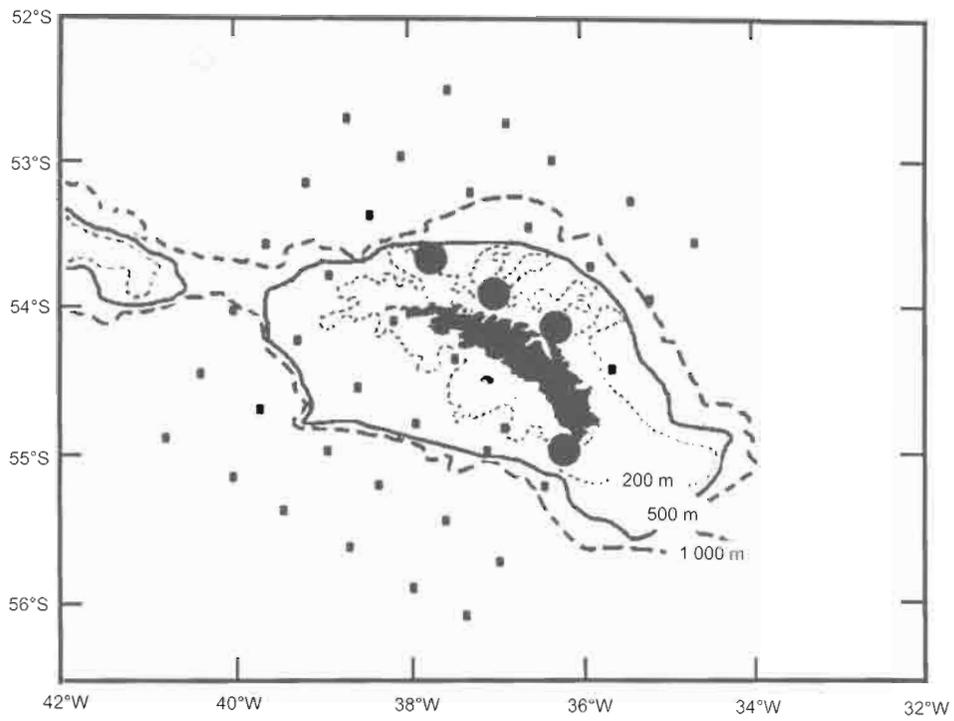


Figure 4: Sampling locations of RMT8 hauls during August 1983 showing the locations at which larval icefish were caught (North, 1987).

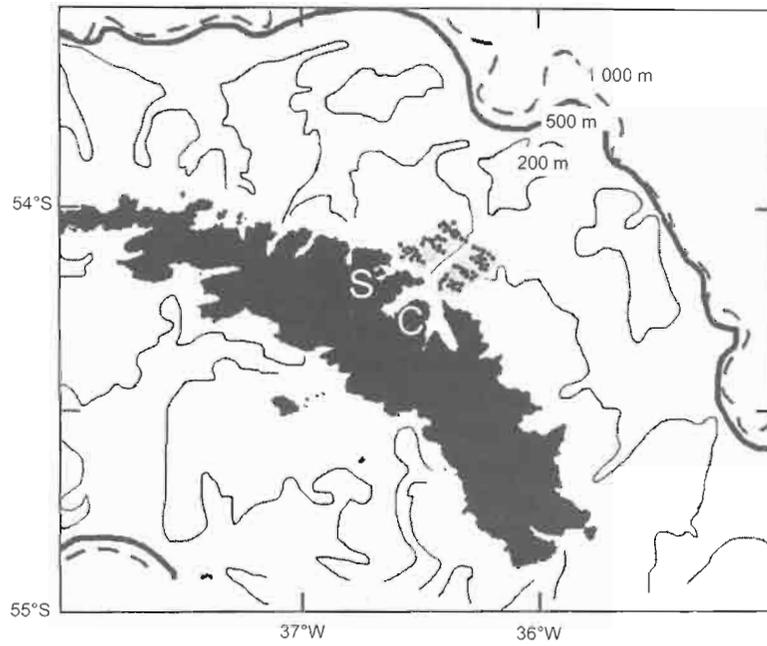


Figure 5: RMT8 sampling stations (shaded area) for larval fish in December 1986 and January 1987 off the entrance to Cumberland and Stromness Bays.

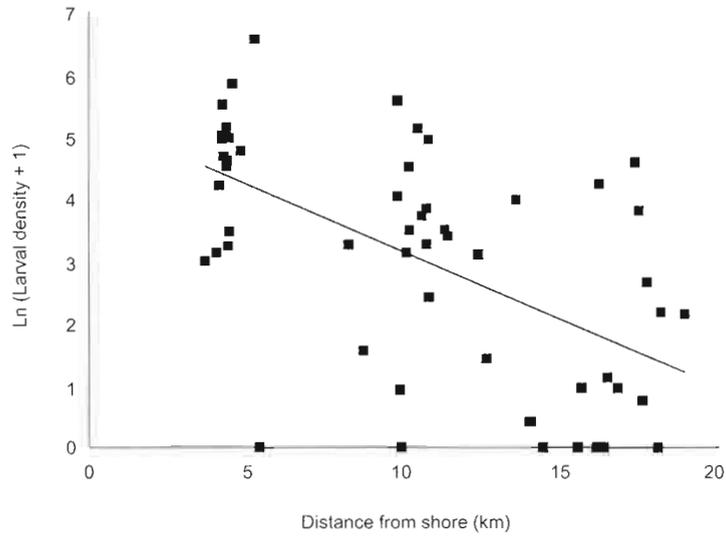


Figure 6: Density of larval *Champsocephalus gunnari*, in RMT hauls sampled at the stations indicated in Figure 5, plotted against distance range from the nearest part of the coastline of South Georgia.

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