MESOPELAGIC FISH OF THE SOUTHERN OCEAN - SUMMARY RESULTS OF RECENT SOVIET STUDIES

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Abstract

Since 1963, Soviet research on Antarctic mesopelagic fish has been carried out as a part of the general multi-disciplinary program of research on Antarctic biological resources. Studies concentrate primarily on the following four most abundant species: *Electrona carlsbergi*, *Electrona antarctica*, *Krefftichthys (Protomyctophum) anderssoni* and *Gymnoscopelus nicholsi*. The data obtained so far are sufficient to allow a description of the general ecology and distribution of these species. Some data are available on their feeding, reproduction and age/length composition. The paper summarizes recently published results of these studies. A general description of mesopelagic myctophids is followed by more detailed information on individual species. Some details of the biological characteristics of these species are summarized in tables with details on area, season and source of data. Some data, e.g. length composition of samples, are also illustrated in figures. The importance of studies on the role of myctophids in the Antarctic ecosystem is highlighted.

Résumé

Depuis 1963, une recherche soviétique est effectuée sur les poissons mésopélagiques de l'Antarctique, dans le cadre d'un programme pluridisciplinaire de recherche sur les ressources biologiques de l'Antarctique. Les études portent tout particulièrement sur les quatre espèces les plus abondantes, à savoir: *Electrona carlsbergi*, *Electrona antarctica*, *Krefftichthys (Protomyctophum) anderssoni* et *Gymnoscopelus nicholsi*. Les données déjà obtenues sont suffisantes pour permettre la description de l'écologie et de la distribution générales de ces espèces. Quelques données sont disponibles sur leur alimentation, leur reproduction et leur composition en âge/longueur. Le présent document résume les résultats de ces études publiés récemment. La description générale des Myctophidae mésopélagiques est suivie d'informations plus détaillées sur chaque espèce. Quelques caractéristiques de ces espèces sont récapitulées dans les tableaux, y compris des détails sur la région, la saison et l'origine des données. Quelques données, telles que la composition en longueurs des échantillons, sont également illustrées dans les figures. L'importance des études sur le rôle des Myctophidae dans l'écosystème antarctique est soulignée.

Резюме

С 1963 г. советские исследования мезопелагических рыб антарктических вод проводились в рамках общей комплексной программы изучения биологических

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ресурсов Южного океана. В основном исследования сосредоточены на следующих четырех наиболее многочисленных видах: *Electrona carlsbergi, Electrona antarctica, Krefftichthys (Protomyctophum) anderssoni* и *Gymnoscopelus nicholsi*. Данные, полученные к настоящему времени, позволяют описать общую экологию этих видов и их распределение. Имеются некоторые данные по их кормлению, воспроизводству и размерно-возрастному составу. В настоящей работе суммируются недавно опубликованные результаты этих исследований. Общее описание мезопелагических видов миктофид сопровождается более подробной информацией по отдельным видам. В таблицах суммируются некоторые данные по биологическим характеристикам этих видов, при этом указан район получения, сезон и источник этих данных. Некоторые данные, напр. - размерный состав проб, также проиллюстрированы рисунками. Подчеркивается важность изучения роли миктофид в экосистеме Антарктики.

Resumen

Desde el año 1963, la Unión Soviética ha estado realizando estudios sobre los peces mesopelágicos de las aguas antárticas, como parte del programa global multidisciplinario de investigación de los recursos biológicos del océano Austral. La investigación está centrada principalmente en las cuatro especies más importantes: *Electrona carlsbergi, Electrona antarctica, Krefftichthys (Protomyctophum) anderssoni* y *Gymnoscopelus nicholsi*. La información recogida hasta ahora es suficiente para describir de modo general, la distribución y ecología de estas especies. Existe cierta información sobre su comportamiento alimentario, reproducción y composición edad/talla. En este documento se incluye un resumen de los resultados publicados recientemente, una descripción general de los mictófidos mesopelágicos, así como un detalle sobre cada especie. Algunas características biológicas se presentan en forma resumida en tablas, junto con información detallada sobre el área, temporada y fuente de datos. Algunos datos, como por ejemplo la composición por tallas de las muestras, se presentan en figuras. Se hace especial hincapié en la importancia de los estudios de mictófidos en el ecosistema antártico.

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1. INTRODUCTION

True epipelagic fish species are nearly absent in Antarctic waters. Pelagic fish fauna of this area consists primarily of meso- and bathy-pelagic species of the families *Myctophidae*, *Paralepididae* and *Bathylagidae* inhabiting waters from 500 to 1 500 m in depth. Of these three families, species of the family *Myctophidae* are the most widely distributed and abundant, with more than 20 species found in the area. Most of them have a circumpolar distribution (Andriashev, 1964 as cited in Lubimova *et al.*, 1983b; Lubimova *et al.*,1983a).

Soviet research on mesopelagic fish in the Antarctic waters is carried out as a part of the general research program on the biological resources of the Southern Ocean. Since the first research cruise in 1963, fishery-oriented investigations have primarily been conducted by the VNIRO research institute (USSR Ministry of Fisheries) and its branches in Murmansk (PINRO), Kaliningrad (AtlantNIRO), Kerch (YugNIRO) and Vladivostok (TINRO). Research institutes of the USSR Academy of Science (Institute of Oceanology, Moscow) and of the State Committee on Meteorology (Institute of Arctic and Antarctic, Leningrad) also contribute to some aspects of this research.

This paper is summarizes major results of Soviet research on mesopelagic fish in Antarctic waters published in the last 5 to 7 years. The paper deals specifically with the following four most abundant species of *Myctophidae: Electrona carlsbergi, Electrona antarctica, Krefftichthys (Protomyctophum) anderssoni* and *Gymnoscopelus nicholsi.* A complete list of publications is attached.

2. GENERAL DISTRIBUTION AND BIOLOGY OF MYCTOPHIDAE

The data on myctophids of the Southern Ocean collected by the Soviet scientists during many years of research are adequate enough to describe the general ecology, reproduction, distribution and feeding of these mesopelagic species, as well as to identify the most abundant species and environmental conditions under which they are used to form dense concentrations.

In the sub-Antarctic area there are about 20 species of myctophids and about 13 to 14 in the Antarctic area. The most abundant species are *E. carlsbergi, E. antarctica, K. (Protomyctophum) anderssoni,* and *G. nicholsi.* These species predominate over other myctophids both in the sub-Antarctic and Antarctic, and in some places around the Southern Ocean form dense concentrations.

It has been discovered that abundant distribution of these species is limited by the waters associated with the Antarctic Circumpolar Current (ACC) which is the reproductive area for most species of myctophids, and where their eggs and larvae are found (Efremenko, 1987). Eggs and larvae of all myctophids studied are present in the waters of the Antarctic Convergence, and eggs and larvae of *E. carlsbergi* and *K. anderssoni* are observed even further north of the Antarctic Convergence, in the sub-Antarctic. The southernmost recorded distribution of eggs and larvae for *E. antarctica* was in the waters of the Secondary Frontal Zone in the Scotia Sea which are dependent on the ACC.

The circumpolar distribution of myctophids is closely dependent upon the specific oceanographical structure of Antarctic waters, i e. the zonal distribution of major water masses having uniform chemical and physiological properties. A constant flux of food (mainly copepods) is maintained in the area of their habitat (0 to 600 m depth) owing to the process of down-welling which is predominant in this area.

While myctophids inhabit mainly waters of the ACC the most abundant species are distributed as far south as the southern boundary waters of the ACC and the drift ice zone (Lubimova *et al.*, 1983b). Catches of myctophids in these waters were first recorded in the Pacific and Atlantic ocean sectors of the Southern Ocean, namely in the Scotia Sea, Drake Passage, to the north of the Lazarev and Bellingshausen seas, in the north of the Sodruzhestva, Riiser-Larseni and Ross Seas, and over the abyssal waters of the continental slope (Lubimova *et al.*, 1983a). However, such penetration to the south of abundant myctophids is always related to the distribution and activity level of the ACC, particularly of its southern boundary waters. Myctophids do not occur in the shelf waters of the Antarctic continent because their distribution is limited by the distribution of the Antarctic Deep Warm Waters which do not spread over the continental shelf. The presence of myctophids on the shelf of South Shetlands is related to a high level of meandering of the ACC in this area.

Antarctic myctophids occur in waters down to a depth of 1 500 m. Their vertical migrations can extent to epipelagic waters but these migrations are limited to waters of the same temperature gradient (Parin, 1968 as cited in Lubimova *et al.*, 1983b). In general, however, myctophids are distributed in the 200 to 600 m layer and sometimes deeper. Their vertical distribution is always related to the distribution of the Antarctic Deep Warm Waters (below 200 m) (Lubimova *et al.*, 1983a).

In spring/summer adult myctophids are found in the upper layer, but in winter-autumn they migrate to the lower levels of their vertical distribution range. They also undergo diurnal vertical migrations, spending the daylight hours in the upper 50 to 100 m layer and descending to the deep waters at night. These types of vertical migration of adult myctophids are closely related to the diurnal rhythm of their feeding activity.

In general, myctophids of the Antarctic open waters (Lubimova *et al.*, 1983b) feed all year round and have a long reproduction season, as evidenced by the distribution of eggs and larvae. Spawning of many myctophids is apparently serial as in the case of *E. antarctica*. Sampling of gonads in summer/autumn has suggested that spawning takes place in autumn/winter (Efremenko, 1987; Lisovenko, 1987).

Eggs and pre-larvae of myctophids are found predominantly in the mesopelagic Antarctic and sub-Antarctic waters. During autumn/winter, the larvae of myctophids are found in the Deep Warm Waters located south of the Antarctic Convergence. In spring/summer they move into the upper 0 to 200 m layer (Efremenko, 1987a and 1987b).

The precise location of spawning areas of particular species of myctophids has not yet discovered. The uniformity of the water structure around Antarctica provides favourable conditions for mesopelagic fish. The best feeding areas for myctophids are between the SPF and the Antarctic Divergence. *K. anderssoni* and *E. antarctica* share the same feeding and spawning areas. It appears that the spawning areas of *E. carlsbergi* and *G. nicholsi* are outside of the Antarctic Region (Zemsky, 1987). Recent studies of the development of oocytes in *E. carlsbergi* give weight to the hypothesis that spawning grounds of this species are in the notal zone, to the north of the Antarctic Convergence (Mazhirina, 1991). It has been suggested that in the South Atlantic *E. carlsbergi* breeds in the Sub-Tropical and Sub-Tropical Frontal zones (Zemsky and Zozulia, 1991).

The diet of myctophids is not particularly specialized, but varies according to area and season. The food composition of myctophids and, in particular the size of food organisms, also depends upon the size of the particular the species, and varies according to the stage of development of individual fish. A diet of myctophids in the open waters in winter-summer consists primarily of certain species of copepods. They are the staple food for *E. antarctica*, *E. carlsbergi* and *K. anderssoni* as copepods are widely distributed in these waters and are abundant in the surface 500 m layer. In some areas euphausiids are also found in the diet of myctophids. However, the feeding areas of myctophids do not coincide with the distribution of *E. superba,* as they generally cover waters to the south of 60°S (Lubimova *et al.*, 1983).

Myctophids of the 5 to 11 cm length group feed exclusively on small planktonic organisms. Larger myctophids as *E. antarctica* and *G. nicholsi* have also macroplanktonic organisms in their diet, including *E. superba*. In the areas where myctophids occur together with krill (South Orkney, South Shetland and South Georgia Islands) their diet is not limited to krill but also includes other food items. It is likely to be related to the distribution of krill mainly in the upper 50 m layer and hence less available to myctophids which do not reach the surface layer during their vertical migrations.

Some species of fish and squid feed on myctophids. Therefore myctophids are a part of the following food chain (Lubimova, Shust and Popkov, 1987; Podrazhanskaya and Pinskaya, 1987):

Phytoplankton→copepods→myctophids→predatory fish and squids-whales.

A preliminary assessment of natural mortality of all myctophids combined, taking into account their reproductive potential and a short life span, gave a value of up to 50%. There are some inaccuracies in such calculations because the reproductive areas of the four most abundant species do not coincide and a detailed assessment should thus be attempted for each species separately. As mentioned above, spawning and feeding of *K. anderssoni* and *E. antarctica* take place in the same area, while spawning areas of *E. carlsbergi* and *G. nicholsi* are apparently located outside of the Antarctic area (i.e., only a part of adult fish biomass of these species, is located in Antarctic waters) (Zemsky, 1987).

The data collected so far on the general biology and ecology of the most abundant species of myctophids have lead to the conclusion that at all stages of their life history they are confined to the ACC waters although each species has its own characteristic features of distribution, feeding and reproduction. *E. carlsbergi* and *K. anderssoni* are found mainly in the northern boundary waters of the ACC. The area of habitat of this species covers waters from the Southern Frontal Zone to the north to the boundary waters between ACC and High-Latitude Modified Waters to the south. Among other species the distribution of *G. nicholsi* extends furthest to the south (Scotia Sea).

The facts that myctophids are widely distributed in the ACC waters which have an adequate supply of food both for young and adult fish throughout the year, together with specific features of the reproduction of myctophids, are major factors contributing to their high abundance and creating conditions for their potential commercial utilization. The biomass of myctophids in the Antarctic Convergence area, in the Atlantic Ocean sector alone was recently assessed at about 1.7×10^6 tonnes (Filin *et al.*, 1991). Recent biomass assessments of all mesopelagic myctophids to the south of 40°S are around 337×10^6 tonnes (survey data) and $212\text{-}396 \times 10^6$ tonnes (results of calculation by modelling) (Tseitlin,1982 as cited by Lubimova *et al.*, 1983). The biomass of myctophids is about 1/3 to 1/2 of the total biomass of the Antarctic mesopelagic fish, i.e. around 70-130 and $100\text{-}200 \times 10^6$ tonnes, respectively (Lubimova, 1985a; Lubimova *et al.*, 1983a).

3. SUMMARIES OF MAJOR BIOLOGICAL CHARACTERISTICS OF ABUNDANT SPECIES OF MYCTOPHIDS

Some details of the biological characteristics of these species are summarized in the attached tables by known areas, seasons and sources of data. Some data (e.g., length composition of samples) are also illustrated in figures.

3.1 *Electrona antarctica* (Table 1)

Distribution: Inhabits primarily the Antarctic Deep Warm Waters. Distributed mainly within the Antarctic Circumpolar Current (ACC). Dominant in the area of the Polar Frontal Zone (PFZ). In the Atlantic Ocean sector of the Southern Ocean, found everywhere (except in high-latitute waters of coastal seas) from Drake Passage to Bouvet Is.

Reproduction: Spawning is serial and extended. Spawning intensity is greatest in autumn/winter. In summer, the gonads of adult specimens are at maturity Stages III and IV (Lisovenko, 1980). Larvae of *E. antarctica* are found all over the Scotia Sea (Efremenko, 1978).

Feeding: The frequency distribution of food items varies from area to area (see Table 1). The staple food of *E. antarctica* is planktonic crustaceans. Small juvenile fish feed

primarily on copepods, euphausiid larvae and hyperiids. The proportion of *E. superba* and other euphausiids is increasing in the diet of larger adult fish. Data on the feeding of *E. antarctica* indicate low selectivity of food items. *E. antarctica* is an opportunistic feeder and feeds on almost any abundant food organisms.

Migrations: Seasonal vertical migrations are observed (surface layers in the summer and deeper waters in the winter). Diurnal vertical migrations are not markedly pronounced, primarily because food availability (copepods) is sufficient at any depth of the apparent range of vertical movement of *E. antarctica.*

Population parameters: Length compositions from samples taken in various areas does not vary greatly and mainly are within a range of 5.5 to 10 cm (modal length 8.5 to 9.6 cm). Size compositions of samples taken in different areas are shown in Figure 1. Maximum reported length was 12.5. Maximum age is 4 to 5 years. Age of maturity is 2 to 3 years (Shust and Kochkin, 1985). Length at maturity L_{50}=8.6 cm, L_{95}=9-10 cm (Lisovenko and Efremenko, 1982). Females were more frequent in samples (sex ratio reported by different authors is about 1:1.05 to 1.4). The sex ratio was found to be different in different size groups (Lisovenko and Efremenko, 1983).

Biomass and stock assessments: No assessments of the biomass of this species have been reported. Only assessments of a total biomass of all myctophids are available.

3.2 *Electrona carlsbergi* (Table 2)

At present this is the most studied species of the Antarctic myctophids.

Distribution: Distribution of this species covers waters to the south of the Antarctic Convergence to the Antarctic coast and also between the Antarctic and sub-Antarctic Convergences. Concentrations of this species are frequently observed in the waters close to the sub-Antarctic. The species is most abundant in the waters of the Frontal Zone which have high abundance of copepod plankton (up to 150-160 mg/m^3). Its vertical distribution is mainly affected by the position of pycnocline and the degree of illumination at various depth, and is also related to the seasonal cycle of plankton development.

Reproduction: Spawning apparently takes place at the end of winter (June/July) or at the beginning of spring (August/September). From November to May gonads of *E. carlsbergi* were found at development stage II (Konstantinova, 1988, Bouvet Is and Discovery Bank). Recent studies of the development of oocytes in *E. carlsbergi* give weight to the hypothesis that spawning grounds of this species are in the notal zone, to the north of the Antarctic Convergence (Mazhirina, 1991). Recent surveys indicate that *E. carlsbergi* breeds in the waters of the Sub-Tropical and Sub-Tropical Polar Zones (Zemsky and Zozulia, 1991). Individual fecundity is about 12 000 to 25 000 eggs (Mazhirina and Poletayev, 1990)

Feeding: Major food items: copepods (87 to 88% frequency of occurrence in stomachs), also hyperiids and euphausiids. Intensive feeding takes place during the night (23.00 to 24.00) and during the day (14.00 to 15.00) (Konstantinova, 1988, Scotia Sea). Daily food intake is about 4% of body weight (Gerasimova, 1991).

The high proportion of copepods in the diet is related to their high abundance in the areas of distribution of *E. carlsbergi*. Feeding concentrations of *E. carlsbergi* in the Atlantic Ocean sector are observed in the waters of the Antarctic Convergence and further to the north up to the Sub-Tropical Convergence (Lubimova *et al.*, 1983a). Main feeding grounds are thought to be in the Polar Frontal Zone (Zemsky and Zozulia, 1991).

Migrations: Analyses of feeding rates throughout the day revealed two peaks: an extended morning and shorter evening periods. These peaks correspond to diurnal vertical migration. In the down fish migrate up to the surface layer of 80 to 140 m depth; in the night they are found dispersed in the 5 to 100 m layer from the surface. During daylight hours fish descend to the 200 to 250 m depth layer (Zaselskiy *et al.*, 1985; Gerasimchuk, 1989).

Population parameters: Length of individuals in samples is 67 to 96 cm (Atlantic sector). Size compositions of samples taken in different areas are shown in Figure 3. Maximum age is not greater than 5 years. A slight sexual dimorphism was observed in some cases (Zaselskiy *et al.*, 1985, Gerasimchuk, 1989). Mature males and females have different structure of dorsal, caudal and anal fins as well as different body colour. Females at age 2 were found to be larger and heavier. Differences were 2 to 3 mm and 0.7 to 1.0 g ($P=0.01$). Maximum reported length was 10.5. Maximum age is 4 to 5 years. Age of maturity is 2 to 3 years (Shust and Kochkin, 1985). Sex ratio is about 1:1 with a slightly higher occurrence of females.

The mean annual growth rate was estimated to be 1.5 to 1.8 cm (Konstantinova, 1987, Atlantic sector). Growth rates during the first two years of life were found to be 30 to 36 mm per year (Zaselskiy *et al.*,1985). Growth pattern is considered to be close to isometric and described by the following Bertalanffy equations (Konstantinova, 1987, Atlantic sector):

$$L_t = 12.48\ [i-e^{-0.25}\ (t+0.68)].$$

The mean natural mortality of 0.86 was calculated from one year's data on 2- to 4-year-old fish which comprised the bulk of catches (Konstantinova, 1987, Atlantic sector)

Biomass and stocks: Concentrations of *E. carlsbergi* were observed in the Shag Rocks area from June to September (1984 to 87). Density of concentrations was two to three specimens per cubic meter (Zaselski, 1988). Surveys from 1987 to 1989 in the Atlantic sector of the Southern Ocean in the waters of the Antarctic Convergence resulted in a total biomass estimate of about 1.7×10^6 tonnes. About 90% of control catches was found to consist of *E. carlsbergi* (Filin *et al.*, 1991). Density of concentrations of the species was 70 to 100 g per square metre. Later observations in the South Georgia area gave biomass estimates of the species of 5.5-40.4 tonnes per square mile (survey area from 29.6 to 95.6 x 10^3 square miles) (Kozlov *et al.*, 1991).

Statistical analyses of the available data showed that fish from the Scotia Sea and the Antarctic Convergence areas (between 20° and 30°W) had statistically different length (SL). Apparently two different populations of *E. carlsbergi* exist in these areas: one in the waters of the anticyclonic gyre around South Georgia and Shag Rocks and another in the mixed waters of the Antarctic Convergence east of 30°W (Zaselskiy *et al.*, 1985).

Experts from the Northern Branch of the Fish Survey Board (USSR Ministry of Fisheries) attempted to forecast on a short-term basis the location of *E. carlsbergi* concentrations in the waters of the Polar Frontal Zone, taking into account position and dynamics of the atmospheric and oceanic frontal zones. Data on some selected biological parameters of *E. carlsbergi* were also used. Reliability of these forecasts was about 90 to 95% (Zemsky, 1987).

3.3 *Krefftichthys (Protomyctophum) anderssoni* (Table 3)

Distribution: Distribution is similar to *E. carlsbergi.* Found in waters to the south and to the north of the Antarctic Convergence. Concentrations of this species were observed in 1979 over the Discovery Bank in the Scotia Sea (Lubimova *et al*, 1983a).

Reproduction: Spawning and feeding areas of *K. anderssoni* is similar to those of *E. antarctica.*

Feeding: Available data are summarized in Table 3.

Migrations: Data not available.

Population parameters: Size compositions of samples taken in different areas are shown in Figure 4.

Biomass and stock assessments: Assessments of biomass of this species are not reported. Only assessments of a total biomass of all myctophids are available.

3.4 *Gymnoscopelus nicholsi* (Table 4)

Distribution: Distribution in the Atlantic Ocean sector covers waters to the south of the Antarctic Convergence up to the zone of mixing of waters of the High-Latitude Modification with waters of the Secondary Frontal Zone.

Reproduction: Spawning of this species apparently takes place within the same period as that of *E. antarctica*, i.e. at the end of autumn or in the winter (April to June).

Feeding: The diet of *G. nicholsi* consists of larger food organisms than the diet of other myctophids. Main food items are the Antarctic euphausiids, mainly *E. superba.* Intensive feeding takes place in the morning (2.00 to 4.00) and in the evening (18.00 to 19.00) (Konstantinova, 1988, Scotia Sea).

Migrations: Diurnal vertical migration is recorded for this species in spring/summer in all areas studied. In the South Shetlands area, at night *G. nicholsi* is caught by a krill midwater trawl in the 50 to 90 m layer from the surface, whereas during daylight hours it is caught only by bottom trawl at depths of 350 to 700 m. In the shelf waters of South Georgia, *G. nicholsi* was observed near the bottom at depths of 145 to 280 m.

Population parameters: This species is larger than other myctophids. Some specimens are up to 20 cm with a mean length of 16 to 18 cm. Length compositions differ considerably from area to area. Size compositions from samples taken in different areas are shown in Figure 5. Maximum age is less than 5 years. Annual growth rate is 2.7 to 3.4 cm. Growth pattern is considered to be close to isometric and described by the following Bertalanffy equations (Konstantinova, 1987):

$$L_t = 20.35[i\text{-}e^{0.28\,(t+0.14)}].$$

Mean natural mortality of 1.14 was calculated from one year's data on 2- to 4-year old fish which comprised the bulk of catches (Konstantinova, 1987, Atlantic sector).

Biomass and stock assessments: Assessments of biomass of this species are not reported. Only assessments of a total biomass of all myctophids are available.

CONCLUSION

Soviet studies of mesopelagic myctophids in the Southern Ocean are carried out as a part of the general multi-disciplinary program on Antarctic biological resources. Studies concentrate primarily on the following four most abundant species: *E carlsbergi, E. antarctica, K. (Protomyctophum) anderssoni* and *G. nicholsi.* The data obtained so far are adequate to

describe the general ecology and distribution of these species. Some data are available on their feeding, reproduction and age/length composition. It has been suggested that *K. anderssoni* and *E. antarctica* have separate reproductive and feeding areas which are located within the Antarctic region. It has recently become apparent that the reproductive area of two other species, *E. carlsbergi* and *G. nicholsi*, is outside the Antarctic region, in the notal waters to the north of the Antarctic Convergence. Biomass estimates of myctophids are available for some areas in the Atlantic sector of the Southern Ocean, in particular in the South Georgia area. Some estimates of the total biomass of myctophids in the Southern Ocean are also made.

Of these four species, *E. carlsbergi,* is the most studied. This species is known to form dense localized concentrations in the Antarctic waters which can be commercially exploited. In addition to more detailed information on distribution, reproduction and feeding of the species, research effort has concentrated on studies of temporal and spatial variability of fish concentrations under different environmental conditions. It has been claimed that in some cases the available data allow for a reliable forecast of the location of fish concentrations.

However, the suggestion that, at least in the Atlantic sector of the Southern Ocean, spawning and feeding areas of *E. carlsbergi* are located in the notal zone, i.e. outside of the Antarctic region, is by no means most important. The theory claims that some part of the main population of *E. carlsbergi* located apparently in the Argentine Basin, is carried away by the Antarctic Circumpolar Current. Only fish older than one year can survive in the cold Antarctic waters, but the surviving fish never spawn because of the unfavourable environmental conditions (Gorchinsky, 1991). One of the consequences of this theory that so-called expatriated fish are considered lost as breeders and could be exploited without harming the main population in the notal zone. A catch limit on *E. carlsbergi* would be based only on ecological considerations, mainly on parameters of the importance of this species in the Antarctic food web.

This theory, if accepted, may lead to a new fishery in the Antarctic waters. However, mesopelagic myctophids represent only an intermediate level between the primary producers and high-level predators. Any exploitation at intermediate levels will inevitably have an adverse effect on high-level predators. It is known that mesopelagic fish are frequently found in the diet of some species of fish, birds and seals. Unfortunately, available information is scarce. More studies are urgently required on the importance of mesopelagic fish in the Antarctic ecosystem. Any research in the Antarctica and, in particular, research on such a geographically widespread resource as mesopelagic fish, will benefit from international cooperation. The CCAMLR Scientific Committee may wish to play an important role in coordinating future international research on the Antarctic mesopelagic fish.

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Table 1: Biological parameters of *E. antarctica.*

Area	Date	Sampling Technique	Mean Length (cm)	Mean Weight (g)	Sex Ratio	State of Gonad Devel.	Rate of Stomac Fullness	Frequency Distribution of Food by Items (%)	Sample Size	Reference
-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
South Georgia	Dec-Feb 1975,76 and 79	Midwater trawl 30-60 m	7.8-7.9	7.3-8.2	-	III,III/IV	1.9-2.1	Copepods-95%; Euphausiids-72%; Hyperiids-54%	155	Lubimova *et al.*, 1983
South Orkneys	Dec 1974	Midwater trawl	8.8	8.5	-	III	1.4	Euphausiids-90%; Hyperiids-54%	50	Lubimova *et al.*, 1983
South Shetlands	Jan-Feb 1976,78	Midwater trawl	8.7-9.6	8.3-10.2	-	III,III/IV	1.8-2.0	Copepods-30%; Euphausiids-85%; Hyperiids-26%	217	Lubimova *et al.*, 1983
Peter I Is. (Bellingshausen Sea)	Jan 1976	Midwater trawl	9.7	10.5	-	III	3.2	Euphausiids-100%	100	Lubimova *et al.*, 1983
East of South Sandwich Is	Dec 1974	Midwater trawl	8.5	7.4	-	II-III	1.9	Euphausiids (except krill)-55%; Krill-47%; Hyperiids-31%	76	Lubimova *et al.*, 1983
Lazarev Sea	Jan-March 1978,81,84	Midwater trawl 30-70 m	3.5-10.6	–	–	–	1.8	Pteropods-14.7% Ostracods-45.0% Hyperiids-10.8% Copepods-89.1% Euphausiids-36.4%	129	Kozlov and, Tarverdieva 1989
As above	As above	Midwater trawl 380-600 m	3.5-10.6	–	–	–	2.1	Pteropods-20.7% Polychaets-3.4% Ostracods-1.7% Hyperiids-12.9% Copepods-24.1% Euphausiids-81.0%	116	Kozlov and Tarverdieva 1989

Table 1 (continued)

-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
Kosmonavtov Sea	Jan-March 1978,81,84	Midwater trawl 30-70 m	4.0-9.5	–	–	–	1.2	Pteropods-2.0% Hyperiids-14.8% Copepods-84.0%	55	Kozlov and Tarverdieva 1989
As above	As above	350-540 m	4.0-9.5	–	–	–	1.6	Hyperiids-17.5% Copepods-21.0% Euphausiids-52.5%	237	Kozlov and Tarverdieva 1989
Sodruzhestva Sea	Jan-March 1978,81,84	Midwater trawl 50-80 m	4.0-9.5	–	–	–	2.5	Ostracods-2.0% Hyperiids-15.0% Copepods-95.0% Euphausiids-5.0%	100	Kozlov and Tarverdieva 1989

Table 2: Biological parameters of *E. carlsbergi*.

Area	Date	Sampling Technique	Length, Mean or Modal/ (Range) (cm)	Weight (g)	Sex Ratio	Stage of Gonad Devel.	Rate of Stomach Fullness	Frequency Distribution of Food by Items (%)	Sample Size	Reference
-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
South Georgia	Oct-Feb 1979-80	–	8.3-8.8	7.3-7.5	1.27:1	II	2.32-3.12	Copepods-100%; Euphausiids-32%; Hyperiids-67%	346	Lubimova *et al.*, 1983
South Georgia, Scotia Sea and ACC waters 20-40°W	Dec 1982-Jan 1983	–	7.0-7.9 (6.8-9.6)	Max-12.1-14.6 Mean-7.5-8.8	1:1.1	–	–	Copepods-87-88%; Hyperiids-7%; Euphausiids-4%	–	Zaselhskiy, 1985; Zaselhskiy *et al.*,1985
Shag Rocks, South Georgia	June-Sept 1984-87		7.0-7.8 (6.4-9.3)	5.5-6.5	–	–	–	–	–	Zaselhskiy, 1988
Discovery Bank, Bouvet Is	–	–	(3.5-10.3)	–	–	–	–	–		Konstantinova, 1988
	spring/summer 1987-88	–	7.0-7.4	6.3-8.2	–	II	1.9-2.3	Mainly copepods	–	Kozlov and Zemskiy, 1988
North of South Georgia, Polar Frontal Zone	Oct-Jan 1987/88	-	7.0-7.4	6.3-8.2	–	II	1.9-2.3	Mainly copepods	–	
North of South Georgia	June 1989	Midwater trawl	7.9-8.36 (7.0-10.0)	–	–	II	–	–	–	Zozulia and Semskiy, 1989
Atlantic sector	Summer 1987/88, summer/autumn 1989	–	7.6-8.0 (age 2) 82-90 (age 3)	–	–	II	–	–	–	Mazhirina and Poletayev, 1990

Table 2 (continued)

-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
Atlantic Sector, transects at 17° and 10° W between 37°30' and 55°30' S	20 Mar-10 Apr 1989	Midwater rope-trawl, 3600 sq. m opening	8.4 7.0-10.5 exact M and range dependent on catch latitude	7.3-11.2 depending on latitude	from 1:0.85 to 1:1.2 depending on latitude	II-V depending on latitude	0.96-1.47 depending on latitude	–	2072	Zemsky and Zozulia, 1991
Bellingshausen Sea	Jan-March 1978,81,84	Midwater trawl, 50-80 m	(7.8-9.5)	–	–	–	2.8	Pteropods-52%; Copepods-26%; Gammaroids-4.0%; Hyperiids-88%; Euphausiids-12%	50	Kozlov and Tarverdieva 1989
D'Urville Sea	Jan-March 1978,81,84	Midwater trawl, 150-200 and 4000-4400 m	(7.3-10.3)	–	–	–	1.8	Pteropods-12.2%; Ostracods-14.4%; Copepods-87.8%; Hyperiids-10.0%; Euphausiids-47.8%; Salps-14.4%	100	Kozlov and Tarverdieva 1989
Kosmonavtov Sea	Jan-March 1978,81,84	Midwater trawl, 30-70 and 240-540 m	(7.9-10.0)	–	–	–	2.1	Copepods-89.6%; Hyperiids-10.6%; Euphausiids-42.0%; Chaetognaths-16.6%	105	Kozlov and Tarverdieva, 1989

Table 3: Biological parameters of *P. anderssoni*.

Area	Date	Sampling Technique	Length, Mean or Modal/ (Range) (cm)	Weight (g)	Sex Ratio	Stage of Gonad Devel.	Rate of Stomach Fullness	Frequency Distribution of food by items (%)	Sample Size	Reference
-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
Scotia Sea, Discovery Bank	1979	Krill trawl	4.5-7.0	-	-	-	-	-	-	Lubimova *et al.* 1983
Kosmonavtov Sea	Jan-Feb 1984	Midwater trawl 30-70 m	3.0-6.9	-	-	-	2.4	Copepods-96.0% Euphausiids-19.5% Hyperiids-5.1	457	Kozlov and Tarverdieva 1989

Table 4: Biological parameters of *G. nicholsi*.

Area	Date	Sampling Technique	Length, Mean or Modal/ (Range) (cm)	Weight (g)	Sex Ratio	Stage of Gonads Devel.	Rate of Stomach Fullness	Frequency Distribution of Food by Items (%)	Sample Size	Reference
-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
South Georgia	Dec 1974 Jan 1975	Bottom trawl 145-280 m	13.4-14.5	21.2-25.6	80/20	II	1.73-2.35	Mysids-85%; Hyperiids-42%; Krill-21%	115	Lubimova *et al.*, 1983
South Georgia	Feb 1979	Midwater trawl 50 m	16.7	23.5	75/25	II	2.11	Euphausiids (krill)-90%; Hyperiids-34%.	87	Lubimova *et al.*, 1983
South Orkneys	Jan 1980	Bottom trawl 315-500 m	16,7	30.2	66/34	III	1.82	Euphausiids (krill)-100%	50	Lubimova *et al.*, 1983
South Shetlands	Feb 1976 Jan 1980	Bottom trawl 360-590 m	16.8-18.4	29.3-36.2	58/42	III	1.75-2.22	Copepods-100%; Krill-92%; T.macrura (furcilia)-88%; Hyperiids-35%	150	Lubimova *et al.*, 1983
South Shetlands	Jan 1978	Midwater trawl 90 m	18.2	35.8	54/46	III	2.14	Euphausiids (krill)-96%; Hyperiids-27%	50	Lubimova *et al.* 1983
Kosmonavtov Sea	Feb 1984	Midwater trawl 340-540 m	10.0-15.8	-	-	-	1.9	Copepods-33% Euphausiids-65.9% (E.superba-60.2%) Others-7.1%	140	Kozlov and Tarverdieva 1989

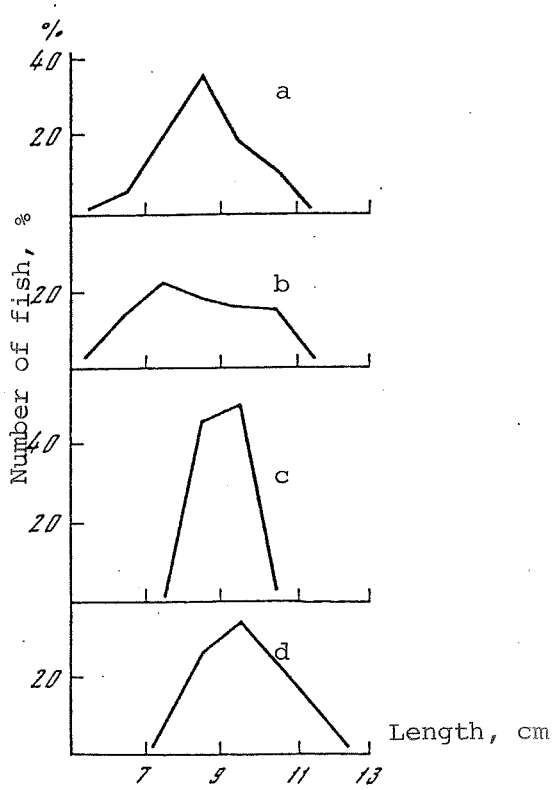

Figure 1: Size composition of *E. antarctica* catches (from Lubimova *et al.*, 1983, research surveys).
a - South Georgia, $SL_{(mode)}$=8.6 cm, n=182
b - east of South Sandwich Is, 53°05'S, 16°15'W, $SL_{(mode)}$=8.1 cm, n=1.67
c - South Shetlands, $SL_{(mode)}$=9.6 cm, n=206
d - Peter I Is, $SL_{(mode)}$=9.7 cm, n=170

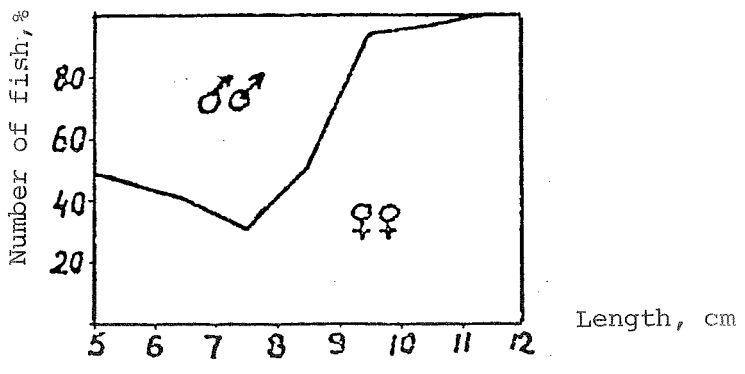

Figure 2: Sex ratio in different size groups of *E. antarctica* catches (from Lisovenko and Efremenko, 1983, research surveys).

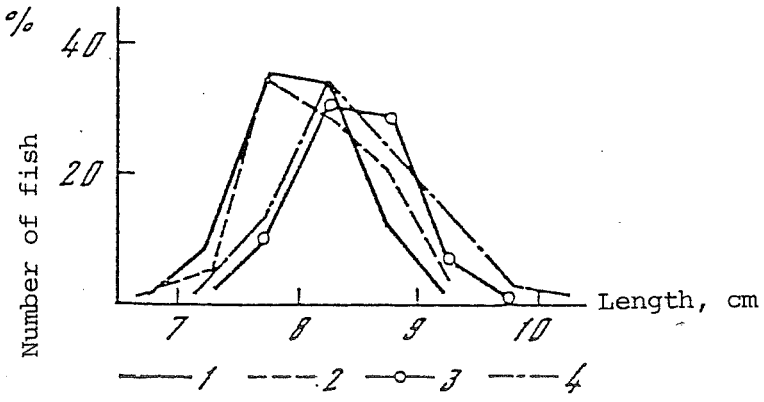

Figure 3: Size composition of *E. carlsbergi* catches (from Lubimova *et al.*, 1983, research surveys to the north of South Georgia, 1979).
1 - January, $SL_{(mode)}$=8.3 cm, n=1 670
2 - February, $SL_{(mode)}$=8.6 cm, n=1 480
3 - November, $SL_{(mode)}$=8.8 cm, n=1 380
4 - December, $SL_{(mode)}$=8.6 cm, n=516

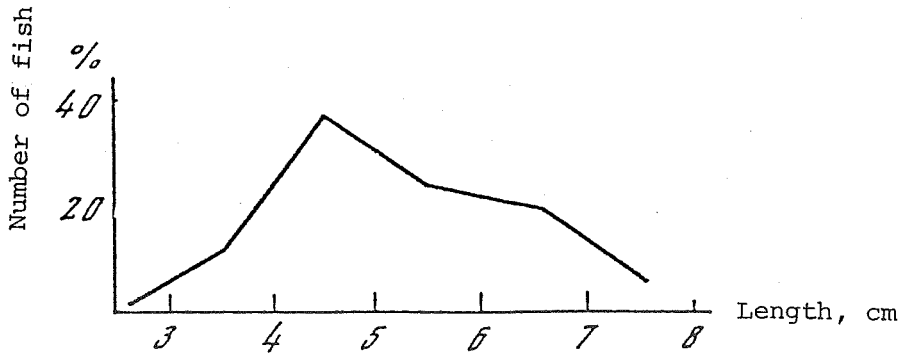

Figure 4: Size composition of *K. anderssoni* catches (from Lubimova *et al.*, 1983, research surveys). East of South Sandwich Is, 54°30'S, 18°35'W, $SL_{(mode)}$=5.3 cm, n=289.

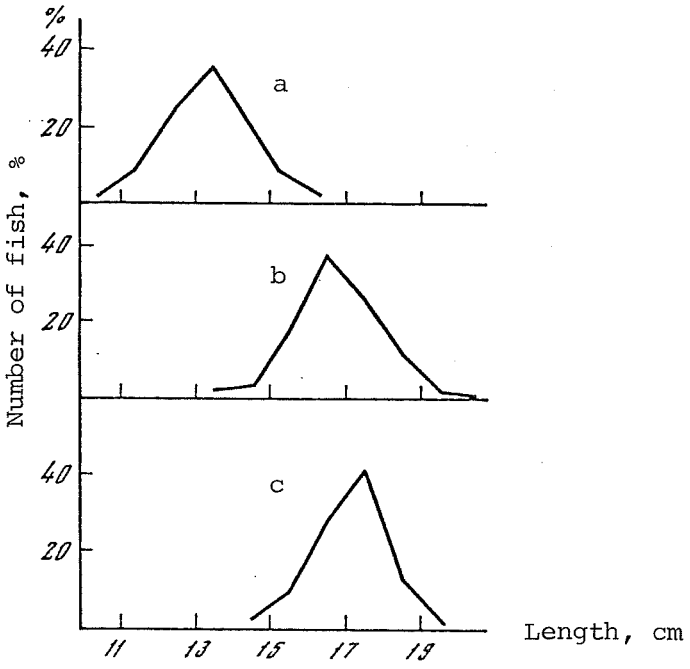

Figure 5: Size composition of *G. nicholsi* catches (from Lubimova *et al.*, 1983 research surveys).

a - South Georgia, $SL_{(mode)}$=13.4 cm, n=466
b - South Orkneys, $SL_{(mode)}$=16.7 cm, n=322
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c - Южные Шетландские о-ва, $SL_{(mode)}$ = 9,6 см, n = 206
d - остров Петра I, $SL_{(mode)}$ = 9,7 см, n = 170

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Рисунок 3: Размерный состав уловов *E. carlsbergi* (Любимова и др., 1983, научно-исследовательские съемки к северу от Южной Георгии, 1979 г.).
1 - январь, $SL_{(mode)}$ = 8,3 см, n = 1 670
2 - февраль, $SL_{(mode)}$ = 8,6 см, n = 1 480
3 - ноябрь, $SL_{(mode)}$ = 8,8 см, n = 1 380
4 - декабрь, $SL_{(mode)}$ = 8,6 см, n = 516

Рисунок 4: Размерный состав уловов *K. anderssoni* (Любимова и др., 1983 г., научно-исследовательские съемки). Восточная часть района Южных Сандвичевых островов, 54°30' ю.ш., 18°35' з.д., $SL_{(mode)}$=5,3 см, n = 289.

Рисунок 5: Размерный состав уловов *G. nicholsi* (Любимова и др., 1983 г., научно-исследовательские съемки).
a - Южная Георгия, $SL_{(mode)}$ = 13,4 см, n = 366
a - Южные Оркнейские о-ва, $SL_{(mode)}$ = 16,7 см, n = 322
a - Южные Шетландские о-ва, $SL_{(mode)}$ = 18,2 см, n = 1 472

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d - Isla Pedro I, $SL_{(moda)}$ = 9.7 cm; n = 170

Figura 2: Proporción de sexos por intervalo de talla de *E. antarctica* (de Lisovenko y Efremenko, 1983, prospecciones de investigación)

Figura 3: Composición por tallas de las capturas de *E. carlsbergi* (de Lubimova *et al.*, 1983, prospecciones de investigación al norte de Georgia del Sur, 1979).
a - Enero $SL_{(moda)}$ = 8.3 cm, n = 1 670;
b - Febrero, $SL_{(moda)}$ = 8.6 cm, n = 1 480;
c - Noviembre, $SL_{(moda)}$ = 8.8 cm, n = 1 380;
d - Diciembre, $SL_{(moda)}$ = 8.6 cm; n = 516

Figura 4: Composición por tallas de las capturas de *K. anderssoni* (de Lubimova *et al.*, 1983, prospecciones de investigación). Al este de las islas Sandwich del Sur, 54°30'S, 18°35'W, $SL_{(moda)}$ = 5.3 cm; n = 289

Figura 5: Composición por tallas de las capturas de *G. nicholsi* (de Lubimova *et al.*, 1983, prospecciones de investigación).
a - Georgia del Sur $SL_{(moda)}$ = 13.4 cm, n = 466;
b - Orcadas del Sur, $SL_{(moda)}$ = 16.7 cm, n = 322;
c - Shetlands del Sur, $SL_{(moda)}$ = 18.2 cm, n = 1 472