BIOMASS OF MYCTOPHIDS IN THE ATLANTIC SECTOR OF THE SOUTHERN OCEAN AS ESTIMATED BY ACOUSTIC SURVEYS

A.A. Filin, K.V. Gorchinsky and V.M. Kiseleva*

Abstract

Acoustic surveys carried out in the summer and autumn of 1987-1989 estimated the biomass of myctophids in the Atlantic sector of the Southern Ocean between 48° and 56° and from 8° to 48°W to be approximately 1.7×10^6 tonnes. Over the greater part of the surveyed area the fish were sparsely distributed. Dense concentrations consisting predominantly of one myctophid species, *Electrona carlsbergi*, were found only in some limited areas. The bulk of the surveyed biomass of myctophids was found to be within the Antarctic Convergence area.

Résumé

Les campagnes acoustiques effectuées pendant les étés et automnes de 1987-1989 ont estimé la biomasse de Myctophidae du secteur Atlantique de l'océan Austral dans la région située entre 48 et 56°S et de 8 à 48°W, à environ $1,7 \times 10^6$ tonnes. Sur la plus grande partie de la région prospectée, les poissons étaient épars. Leurs concentrations denses, composées principalement d'une espèce de Myctophidae, *Electrona carlsbergi*, n'étaient présentes que sur des aires restreintes. Le plus gros de la biomasse a été déclaré provenir de la région de la Convergence Antarctique.

Резюме

Оценка биомассы миктофид в атлантическом секторе Южного океана (48° - 56° ю.ш. и 8° - 48° з.д.) была получена в ходе выполнения акустических съемок в течение летних и осенних периодов 1987-1989 гг. Она составляла приблизительно 1,7 миллионов тонн. На большей части охваченной съемками площади наблюдалось незначительное количество рыбы. Плотные концентрации, в основном состоявшие из одного вида миктофид - *Electrona carlsbergi*, встречались лишь в некоторых ограниченных районах. Основная часть биомассы приходилась на район антарктической конвергенции.

Resumen

Las prospecciones acústicas llevadas a cabo durante el período de verano y otoño de 1987-1989, han estimado la biomasa de mictófidos en el sector atlántico del océano Austral - en la zona comprendida entre los 48° y 56°S y entre los 8° y 48°W - en 1.7×10^6 toneladas. En la

* Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street, Murmansk, 183763, USSR

mayor parte del área estudiada los peces se encontraban dispersos y en las pocas áreas en donde se encontraban en densas concentraciones, la especie predominante de mictófidos fue *Electrona carlsbergi*. La mayor biomasa de mictófidos ha sido registrada en la zona de la Convergencia Atlántica.

1. INTRODUCTION

Lanternfish, or the Myctophidae species, are typical residents of mesopelagic waters in the Southern Ocean. They occur in large numbers and their distribution is circumpolar. In certain areas they occur in dense concentrations which are accessible to commercial fishing. *Electrona carlsbergi* is the most abundant species among myctophids. A total biomass of Antarctic myctophids is presently estimated to be 70-200x10^6 tonnes (Lubimova *et al.*, 1987).

A comprehensive study of the biology and ecology of mesopelagic fish and their place in the Antarctic ecosystem becomes particularly important in view of the good prospect of commercial fishing for these resources in the Southern Ocean. For this reason, special consideration should be given to evaluating the abundance of mesopelagic fish by instrumental techniques. It is impossible to provide reliable scientific recommendations on how to manage fisheries rationally without having information on stock size and dynamics in different areas.

This paper presents estimates of the biomass of myctophids and delineates their distribution in the Atlantic sector of the Southern Ocean.

2. MATERIALS AND METHODS

Acoustic surveys for myctophids in the Atlantic sector of the Southern Ocean were conducted by the RV *Artemida* from 1987 to 1989. These surveys covered the region from 48° to 56°S and between 8° and 48°W during the southern summer and autumn. Five local acoustic surveys were conducted in the region, where concentrations of myctophids were observed.

Values of mean density of fish along the cruise track were integrated for selected intervals of the distance covered (integration intervals - **D**). Echo-integration equipment included an EK-S echosounder (SIMRAD, Norway) and a digital five-channel integrator SIORS. Their operating parameters are listed in Table 1.

An oscilloscope was used to monitor input signals and an "Iskra-226" computer was used for data processing. Ship coordinates were obtained by a satellite navigational system FSN-70 (FURUNO, Japan). Echo intensities from five depth channels (by integration intervals D=5 miles) were continuously recorded and echo recordings simultaneously identified. Control tows for determining size-species composition of fish were carried out in order to verify results of acoustic equipment. A commercial midwater trawl with a small-meshed insertion (12 mm mesh) in a trawl bag was used.

Mesh density of fish along a cruise track was estimated by means of the formulae:

$$P_N = \frac{M_0}{\sigma(L)} \quad (1)$$

or

$$P_W = \frac{M_0}{10^3 \sigma kg(L)} \quad (2)$$

then

$$\sigma_{(L)} = 4\pi \cdot 10^{0.1 \cdot TS(L)} \quad (3)$$

$$\sigma kg^{(L)} = \frac{\sigma(L)}{W} \quad (4)$$

where $\mathbf{P_N}$ = mean density (fish per square mile),
$\mathbf{M_0}$ = mean echo intensity over the transect (number of echo readings covered) (M^2/square miles),
$\sigma_{(L)}$ = "in situ" mean acoustic back-scattering cross-section for single fish of length **L** (m^2),
$\mathbf{TS_{(L)}}$ = "in situ" mean target strength for fish of length **L** (**dB**),
$\sigma\mathbf{kg^{(L)}}$ = mean acoustic back-scattering cross-section per 1 kg of fish weight (m^2/kg),
W = mean weight of one fish (kg),
$\boldsymbol{P_W}$ = mean density of biomass distribution (tonnes per square mile).

$\mathbf{M_0}$ was estimated from:

$$M_0 = \frac{M}{n} \cdot 100 \cdot K_{TVG}(\Delta R) \cdot K_{ATT} \cdot C_I \quad (5)$$

where **M** and **N** = integrator readings and number of pulses per integration interval **D**,
$\mathbf{K_{TVG}}$ = TVG correction coefficient, its value depending on both the mean coefficient of sound absorption within the range surveyed and integration depth Δ **R**,
$\mathbf{K_{ATT}}$ = a coefficient that allows for "gaps" in the performance of the echosounder during surveying under unfavourable weather conditions,
$\mathbf{C_I}$ = constant of integration instruments (m^2/square miles per 100 pulses).

$\mathbf{C_I}$ was calculated from results of calibrations to standard target $\mathbf{TS_{st}}$ = -33.6 dB, completed at the beginning and at the end of each survey and 6.9 m^2/square miles in the second.

For estimation of the density of myctophids (size range within **L**=5-10 cm) expression (2) was employed, where $\sigma_{kg}(\mathbf{L})$ was assumed to be equal to σ_{kg} = 0.0105 (± 0.0025) m^2/kg. This value was obtained by using a relationship derived experimentally "in situ" between myctophid size and target strength at 38 kHz:

$$TS = 25.2 \lg L - 75.0 \quad (6)$$

and the length/weight relationship for these fish (Mamylov, 1988).

Mean acoustic back-scattering cross-section per kilogram of fish weight was taken to be 0.0105 m^2/kg because this value was verified during our earlier surveys of myctophids in the North Atlantic and gave a fairly stable estimate of their biomass as compared with results of control trawlings (coefficient of trawl catchability was taken to be 0.05-0.10).

3. RESULTS

Concentrations of myctophids in the area surveyed were found in the Antarctic Convergence waters and near The Shag Rocks and Black Rock. More dense concentrations were observed in the southernmost part of the Polar Frontal Zone, and particularly in areas of notable disturbances in the water thermohaline structure.

The echosounder recordings showed concentrations of myctophids as long bands or spots (isolated schools) with a height of up to 30 m (Figures 1 and 2). They were chiefly distributed between 50 and 350 m depth.

In the area surveyed, E. carlsbergi predominated almost everywhere. In the majority of cases, as shown by control tows, it accounted for more than 90% of the total catch. Besides fish, salps were also numerous. Among other species, medusas, euphausids and squids were observed.

The size structure of E. carlsbergi was fairly uniform. Specimens of 70 to 80 mm predominated.

An echometric survey for myctophids, carried out from 18 to 31 December 1987 covered the area from 48° to 54°S and between 40° and 48°W (Figure 3) (about 60 000 square miles). It estimated the biomass of fish to be 1 200 x 10^3 tonnes. Figure 4 shows the distribution of myctophids in the survey area.

In control tow catches north of 53°S *E. carlsbergi* accounted for 91 to 97% of the total biomass. The rest consisted of salps and medusas.

South of 53°S the proportion of *E. carlsbergi* was less (60 to 75%). Of other myctophids, most abundant was *Gymnoscopelus nicholsi. Electrona antarctica, Gymnoscopelus braueri* and *G. fraseri* were also encountered.

The survey was then continued from 12 to 17 January 1988 and covered the area near the Shag Rocks and Black Rock. Figure 3 shows the survey route and indicates positions of hydrological stations and control tows. The biomass of myctophids over the survey area (7 200 square miles) was estimated as being 160x10^3 tonnes. The fish were distributed chiefly over rocky slopes. Maximum density was about 350 tonne/square mile (Figure 5). Fish were more dispersed at night than in the daytime.

Over 90% (by weight) of control catches consisted of myctophids, with *E. carlsbergi* accounting for about 85%. Besides this species, *G. nicholsi, Krefftichthys anderssoni, Paradiplospinus antarcticus*, salps and medusas were also found.

In the first ten days of February 1988 an echometric survey for myctophids was conducted in the Polar Frontal Zone from 48° to 51°S and between 36° and 41°W (Figure 3). A preliminary survey in the area enabled us to to obtain an overall picture of myctophid distribution and to elaborate the most optimal survey design. The biomass of myctophids over the survey area (16 000 square miles) was estimated at 300x10^3 tonnes. The most dense concentrations of myctophids in the form of elongated strips were found in the waters of the Frontal Zone (Figure 6).

In control tow catches *E. carlsbergi* accounted for about 90% of the biomass. Of other myctophid species, most plentiful were Gymnoscopelus - *G. nicholsi, G. piabilis, Protomyctophum choriodon* and *K. anderssoni.*

In 1989 acoustic surveys for myctophids were conducted over the area from 47° and 56°S and between 8° and 44°W in the period 30 January to 10 April. The bulk of the biomass was found to be spread along the Antarctic Frontal Zone east of South Georgia. The whole area was surveyed in two stages.

Firstly, the area from 51°30' to 56°00'S and between 20°30' and 26°30'W was surveyed from 20 February to 2 March. Secondly, the area with coordinates 51°30' to 55°00'S and 8°00' to 18°30' (Figure 7) was surveyed from 20 March to 2 April. These sectors had areas of 52 600 square miles and 63 270 square miles respectively. The first survey estimated the biomass of myctophids as being 855×10^3 tonnes, the second one 829×10^3 tonnes. Control catches comprised up to 98-100% of *E. carlsbergi*. Distribution of myctophids over the area surveyed is shown in Figures 8 and 9.

4. CONCLUSIONS

Results of the surveys indicated that in the Atlantic sector of the Southern Ocean there are considerable quantities of myctophids. As estimated by acoustic surveys, the total biomass of myctophids was about 1.7×10^6 tonnes both in 1987/88 and in 1989. Bearing in mind that only the principal areas of myctophid distribution have been surveyed, their total biomass in the western part of the Atlantic sector of the Southern Ocean may be around 2×10^6 tonnes.

The fish were sparsely distributed over the greater part of the area surveyed. In 1987/88 their mean density was approximately 20 tonnes per square mile, and 15 tonnes per square mile in 1989 or 5.8 g/m^2 and 4.4 g/m^2 respectively.

Dense concentrations of myctophids were observed in some limited areas. They consisted mostly of one species - *E. carlsbergi*. The mean biomass in these concentrations was as high as 70 to 100 g/m^2. Concentrations of commercial value were found mainly in the Antarctic Convergence in the form of elongated strips.

In 1989 myctophids were found spread more to westward than in 1988. In 1989 no concentrations were found in the Frontal Zone between 30° and 40°W, whereas in 1988 dense concentrations of *E. carlsbergi* were found in the area.

The concentrations of myctophids encountered did not appear to be difficult to survey acoustically, because they were composed virtually of one species of fish of the same size. Only insignificant numbers of salps, medusas and euphausiids were found in the areas where large quantities of myctophids were present.

The design and implementation of surveys in 1987 to 1989 was seriously impeded by selection of a very large area and by the lack of sufficient information on the distribution of myctophids and their passive migrations. These parameters are highly variable and dependent on oceanographic conditions.

In future, regular annual assessments of the abundance of myctophids in the Atlantic sector of the Southern Ocean will require elaboration of standard methodology for conducting acoustic surveys. Studies of population status and dynamics is a vital element of a comprehensive study of Antarctic myctophids - an important component of the Southern Ocean ecosystem.

REFERENCES

LUBIMOVA, T.G., K.V. SHUST and V.V. POPOV. 1987. Distinctive features of the ecology of mesopelagic fishes (family Myctophidae) from the Southern Ocean. (In Russian).

Osobennosty ekologii mezopelagicheskikh ryb semeistva Myctophidae Yuzhnogo okeana. In: *Biological Resources of the Arctic and Antarctic*. Moscow: Nauka Press. pp. 320-337.

MAMYLOV, V.S. 1988. Results of "in situ" target strength measurements at 38 kHz for major commercial species in the North Atlantic. (In Russian Resultaty otsenki sily tseli "in situ" na chastote 38 kHz dlya osnovnykh promyslovykh ob'ektov Severnoi Atlantiki. In: *Instrumental Methods of Evaluation of the Stock Size of Commercially-Important Species*. Murmansk. pp. 3-18.

Table 1: Operating parameters of the echosounder and integrator.

Echosounder EK-S		Integrator SIORS	
Frequency	38 kHz	Gain	5 dB
Pulse length	0.6 ms	Discriminator	24 dB
Bandwidth	3 kHz	(integration threshold)	(50 mV_p)
Power (gross)	2.0 ÷ 2.5 kW	Integration range	10 to 500 m
TVG	(20 1gR-0)dB		
	136 ÷ 138		
Antenna	8 x 8°		

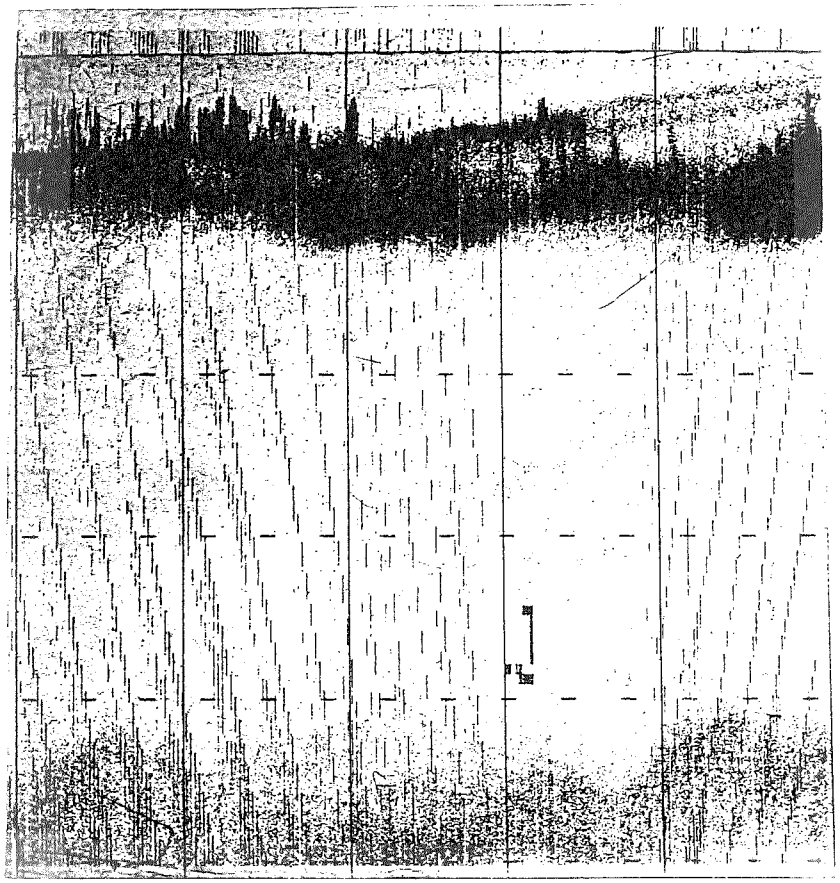

Figure 1: Typical echo recording of myctophids as a band (49°09'S, 38°17'W), 9 February 1988.

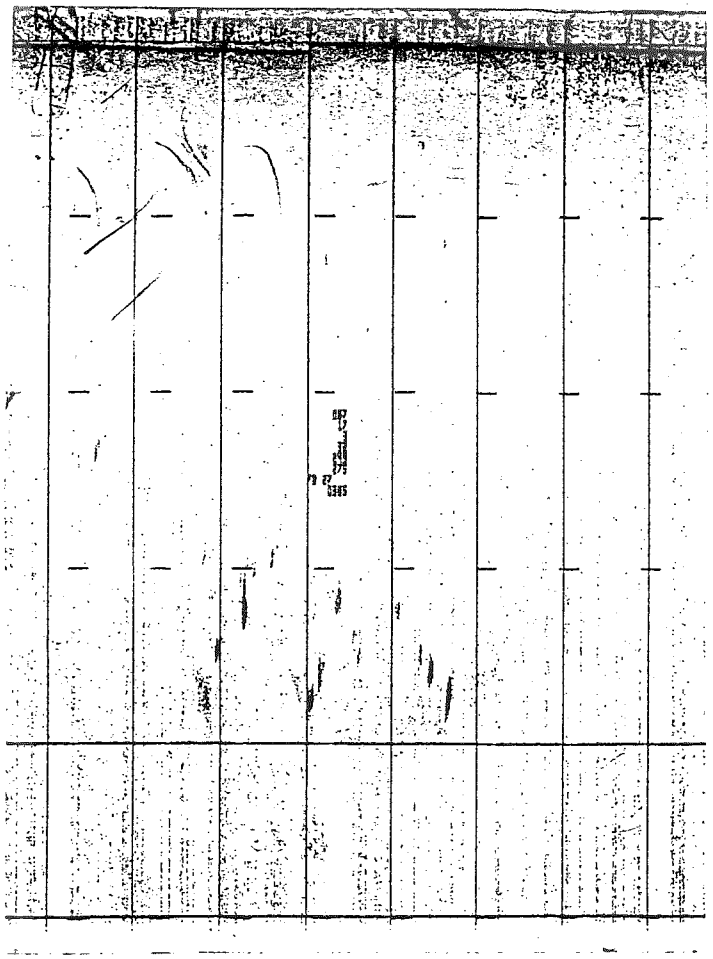

Figure 2: Typical echo recordings of myctophids as discrete schools (49°00'S, 41°30'W), 22 December 1987.

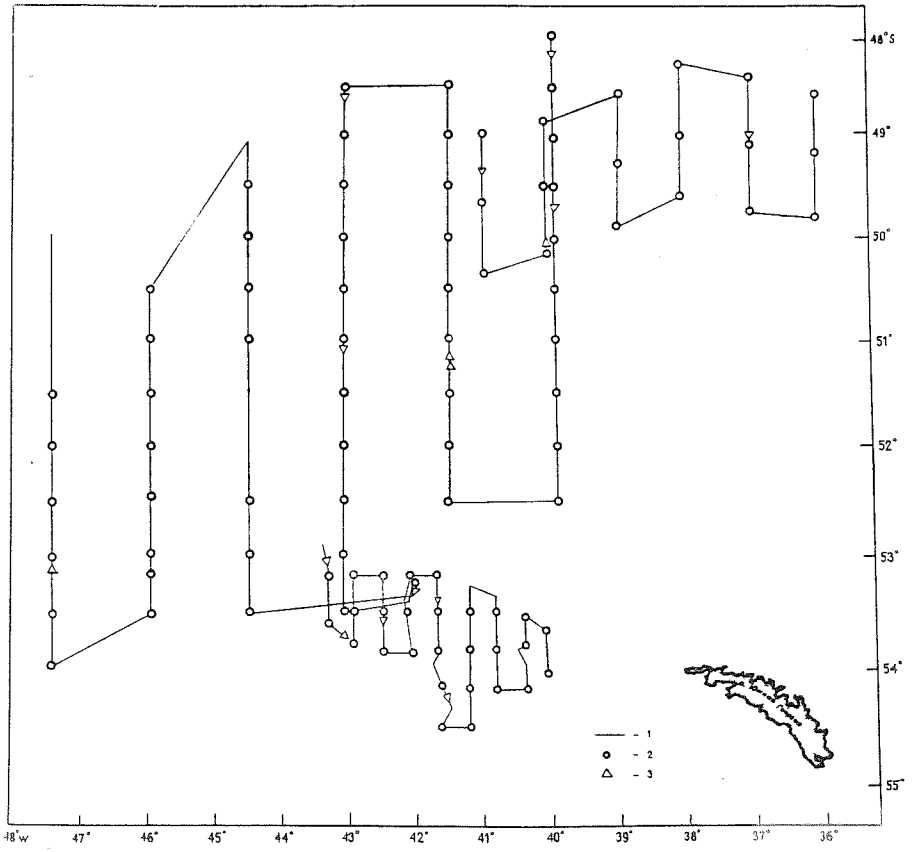

Figure 3: Chart showing the track of acoustic surveys for myctophids in 1987/88.
1 - echometric tracks
2 - hydrological stations
3 - control tows

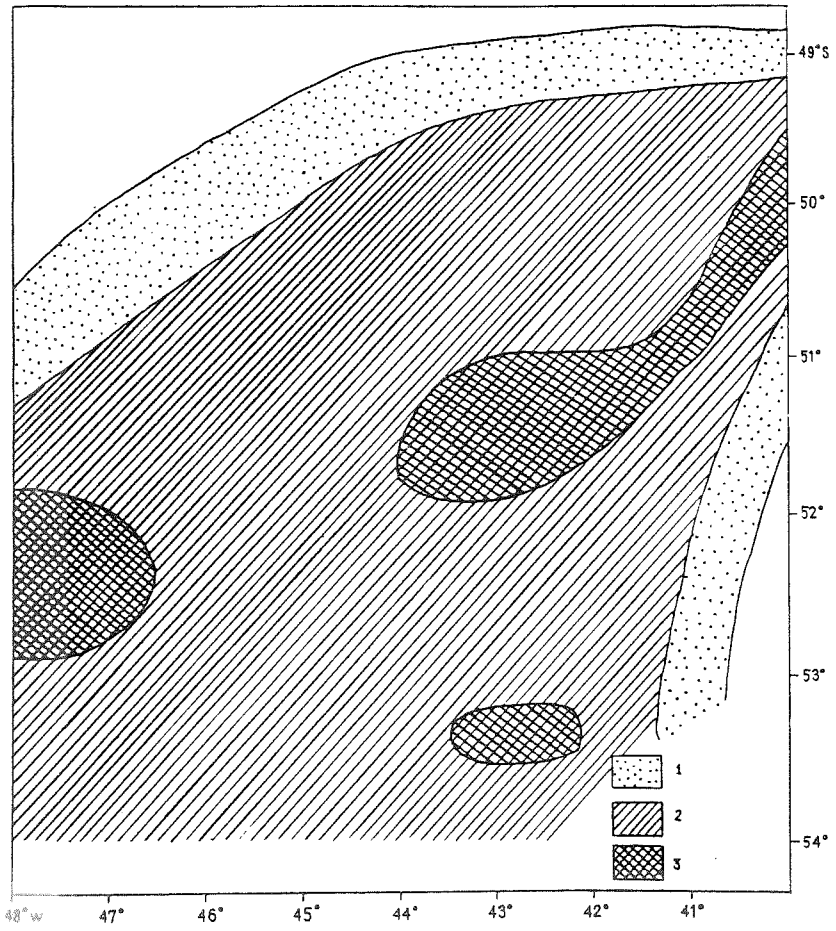

Figure 4: Density of myctophids as estimated by the echometric survey from 18 to 31 December 1987.
1 - 1 to 3 tonnes per square mile
2 - 10 to 50 tonnes per square mile
3 - over 50 tonnes per square mile

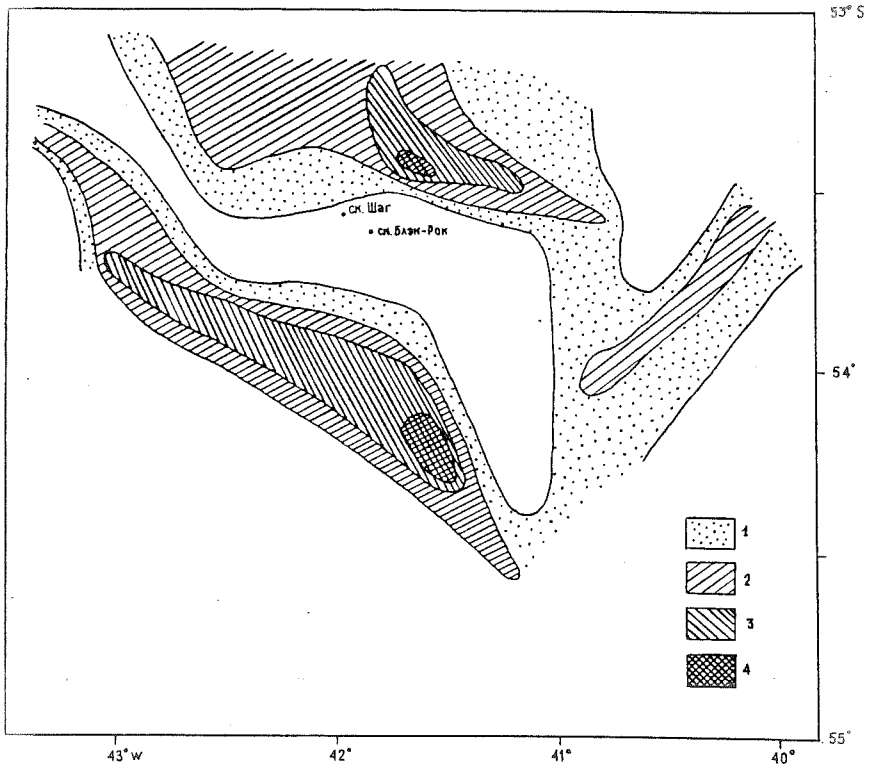

Figure 5: Density of myctophids estimated by the echometric survey near the Shag Rocks and Black Rock from 12 to 17 January 1988.
1 - 2 to 10 tonnes per square mile
2 - 11 to 40 tonnes per square mile
3 - 41 to 150 tonnes per square mile
4 - over 150 tonnes per square mile

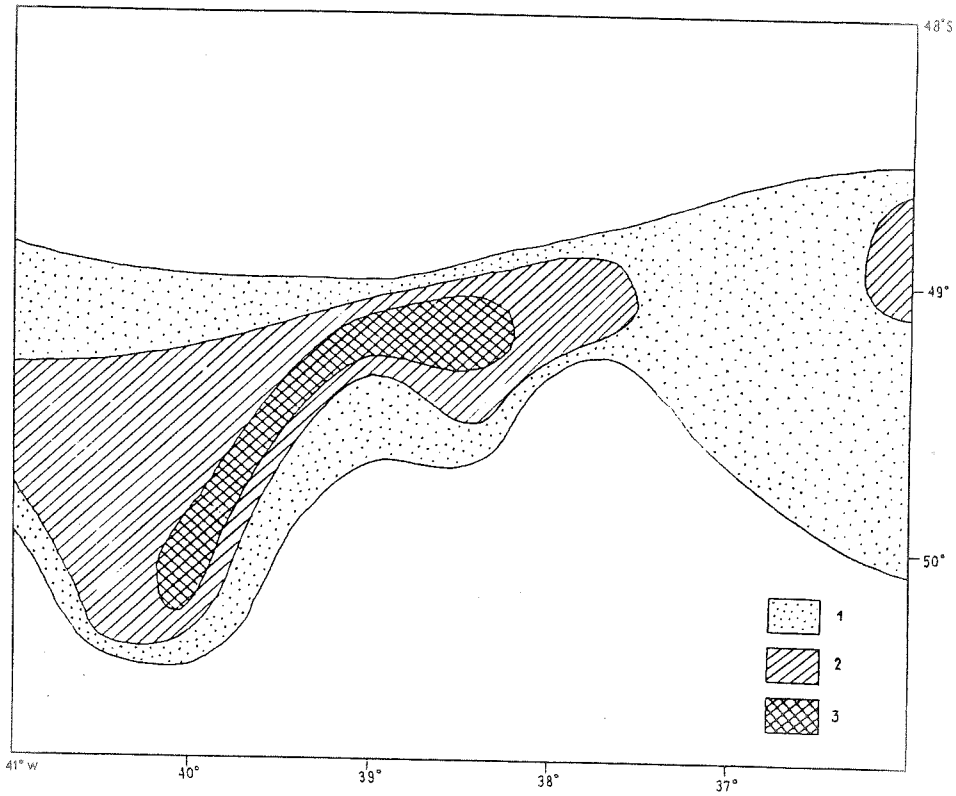

Figure 6: Density of myctophids as estimated by the echometric survey from 2 to 10 February 1988.
1 - 5 to 20 tonnes per square mile
2 - 21 to 100 tonnes per square mile
3 - over 100 tonnes per square mile

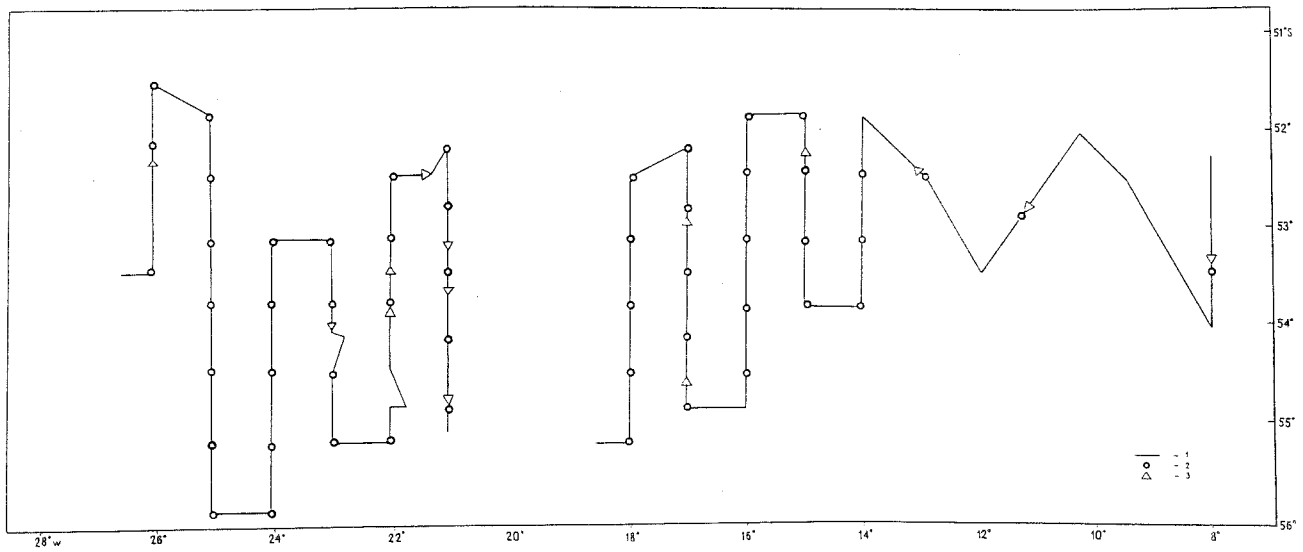

Figure 7: Chart showing the track of acoustic surveys in 1989.
1 - echometric tracks
2 - hydrological stations
3 - control tows

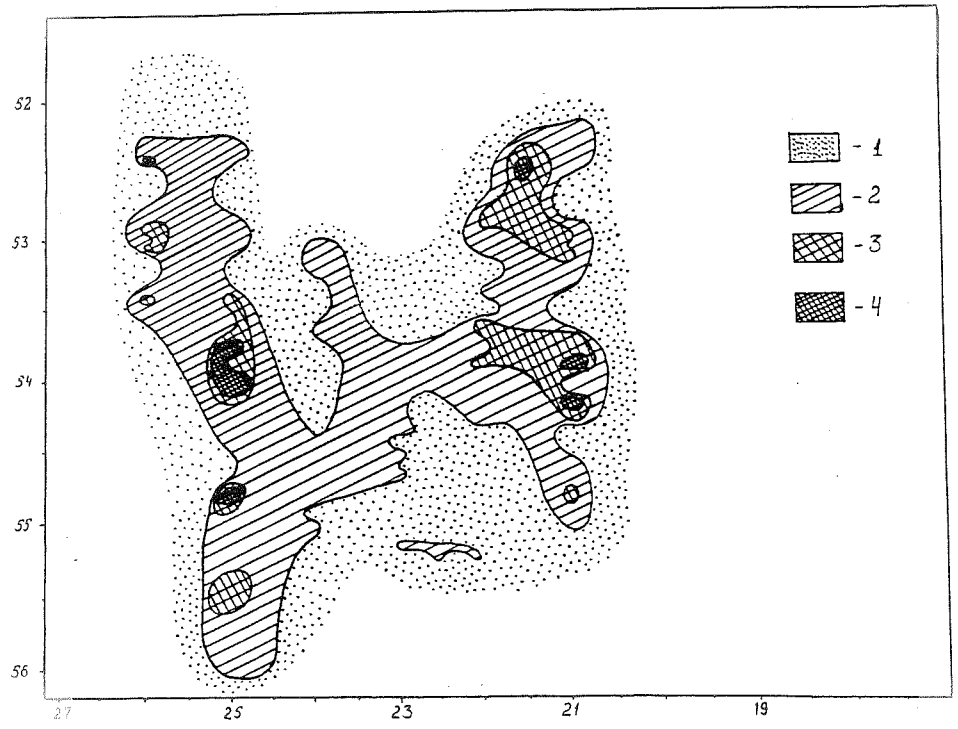

Figure 8: Density of myctophids as estimated by the echometric survey from 20 February to 2 March 1989.
1 - 1 to 10 tonnes per square mile
2 - 11 to 40 tonnes per square mile
3 - 41 to 90 tonnes per square mile
4 - 91 to 140 tonnes per square mile

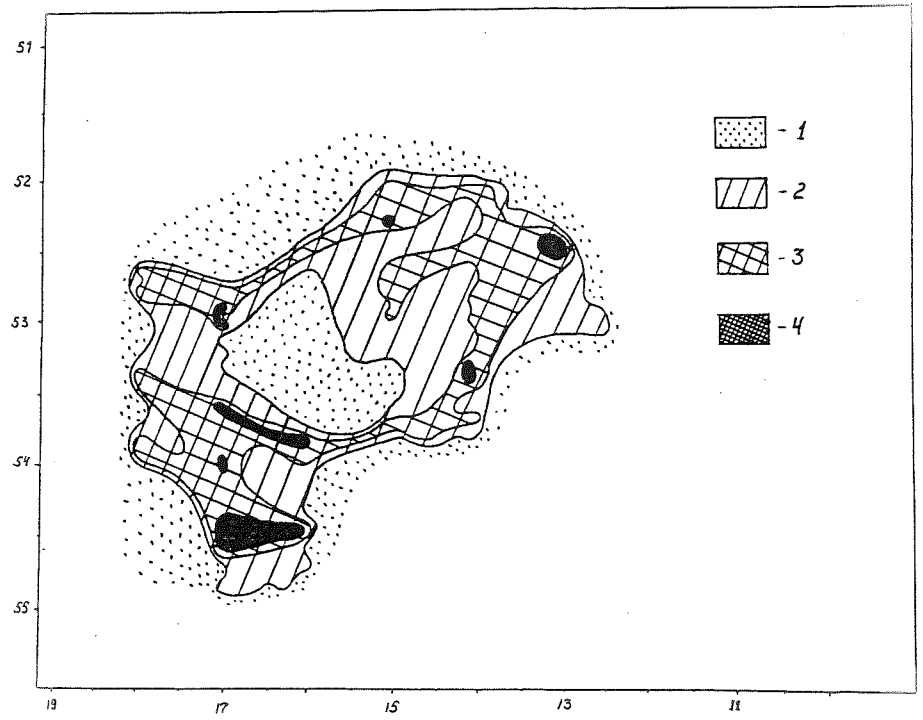

Figure 9: Density of myctophids as estimated by the echometric survey from 20 March to 2 April 1989.
1 - 1 to 10 tonnes per square mile
2 - 11 to 20 tonnes per square mile
3 - 21 to 40 tonnes per square mile
4 - 41 to 60 tonnes per square mile

Liste des tableaux

Liste des figures

Список таблиц

Список рисунков

Lista de las tablas

Lista de las figuras

Figura 3: Mapa de itinerarios de prospecciones acústicas de mictófidos efectuadas en 1987-1988.
1 - trayectorias ecométricas, 2 - estaciones hidrológicas, 3 - arrastres de control.

Figura 4: Densidad de mictófidos estimada de la prospección ecométrica efectuada del 18 al 31 de diciembre de 1987.
1 - 1 a 3 toneladas por milla^2, 2 - 10 a 50 toneladas por milla^2, 3 - más de 50 toneladas por milla^2.

Figura 5: Densidad de mictófidos estimada de la prospección ecométrica realizada cerca de las Rocas Cormorán y Roca Negra, del 12 al 17 de enero de 1988.
1 - 2 a 10 toneladas por milla^2, 2 - 11 a 40 toneladas por milla^2, 3 - 41 a 150 toneladas por milla^2, 4 - más de 150 toneladas por milla^2.

Figura 6: Densidad de mictófidos estimada de la prospección ecométrica efectuada del 2 al 10 de febrero de 1988.
1 - 5 a 20 toneladas por milla^2, 2 - 21 a 100 toneladas por milla^2, 3 - más de 100 toneladas por milla^2.

Figura 7: Mapa de itinerarios de prospecciones acústicas de 1989.
1 - trayectorias ecométricas, 2 - estaciones hidrológicas, 3 - arrastres de control

Figura 8: Densidad de mictófidos estimada de la prospección ecométrica efectuada del 20 de febrero al 2 de marzo de 1989.
1 - 1 a 10 toneladas por milla^2, 2 - 11 a 40 toneladas por milla^2, 3 - 41 a 90 toneladas por milla^2, 4 - 91 a 140 toneladas por milla^2.

Figura 9: Densidad de mictófidos estimada por la prospección ecométrica desde el 20 de marzo al 2 de abril de 1989.
1 - 1-10 toneladas por milla^2, 2 - 11-20 toneladas por milla^2, 3 - 21-40 toneladas por milla^2, 4 - 41-60 toneladas por milla^2.