SEASONAL AND INTER-ANNUAL VARIABILITY IN THE DISTRIBUTION OF *ELECTRONA CARLSBERGI* IN THE SOUTHERN POLAR FRONT AREA (THE AREA TO THE NORTH OF SOUTH GEORGIA IS USED AS AN EXAMPLE)

A.N. Kozlov, K.V. Shust and A.V. Zemsky*

Abstract

From 1987 to 1989 VNIRO (USSR) conducted six trawl and acoustic surveys in the area to the north of South Georgia Is between 49° to 54°S and 25° to 40°W. The area is within the Polar Frontal Zone where mesopelagic fish from the family Myctophidae are found most frequently and regularly. Seasonal and interannual variability in distribution, density and biomass of the most abundant species of myctophids, *Electrona carlsbergi*, are analyzed and summarized in this paper. The species is also known to form large concentrations throughout the year. Results of surveys showed that the distribution and behaviour of *E. carlsbergi* are strongly related to environmental conditions in the area as well as to the availability and distribution of zooplankton. *E. carlsbergi* was found over the entire study area. The largest concentrations of the species, however, were found mainly along edges of the frontal zone where such fundamental environmental characteristics of water masses as currency dynamics, temperature and density, attain the highest level of variation. The most large-scale and dense concentrations of *E. carlsbergi* were observed in summer (December to February) when fish were distributed in the upper 50-100 m layer. The smallest and less dense concentrations were observed in the winter (June) at 200 m and deeper. The spring and autumn months were noted as transitional for parameters of vertical distribution and density of fish concentrations. Calculations of biomass of *E. carlsbergi* in the area indicated that its variability during the year is related to parameters of spatial and vertical distribution of fish. Interannual variability of *E. carlsbergi* biomass in the area was also observed.

Résumé

De 1987 à 1989, VNIRO (URSS) a mené six chalutages et campagnes acoustiques dans la région au nord de l'île de la Géorgie du Sud, entre 49 et 54°S et 25 et 40°W. Cette région est située à l'intérieur de la zone frontale polaire dans laquelle les poissons mésopélagiques de la famille des Myctophidae se rencontrent le plus fréquemment et le plus régulièrement. Cette communication présente une analyse et une récapitulation de la variabilité saisonnière et interannuelle dans la répartition, la densité et la biomasse d'*Electrona carlsbergi*, l'espèce la plus abondante des Myctophidae. Cette espèce est également connue pour former de grande concentrations tout au long de l'année. Les résultats des campagnes ont montré que la distribution et le comportement d'*E. carlsbergi* sont étroitement liés aux conditions de l'environnement de la région ainsi qu'à la disponibilité et répartition du zooplancton. *E. carlsbergi* a été trouvé dans la totalité de la zone

* VNIRO, 17a Verkhnaya Krasnoselskaya Street, Moscow, USSR 107140

étudiée. Toutefois, ses plus grandes concentrations ont été principalement rencontrées le long des bords de la zone frontale, là où les caractéristiques fondamentales d'environnement des masses d'eau, telles que la dynamique, température et densité des courants, atteignent les niveaux de variation les plus élevés. L'extension et la densité les plus élevées des concentrations d'*E. carlsbergi* ont été observées en été (décembre à février), lorsque les poissons sont répartis dans la couche supérieure de 50 à 100 m. Les plus faibles ont été observées en hiver (juin) à 200 m ou plus. Il a été constaté que les mois de printemps et d'automne étaient transitoires pour les paramètres de distribution verticale et de densité des concentrations de poissons. Les calculs de biomasse d'*E. carlsbergi* dans cette zone indiquent que sa variabilité au cours de l'année est fonction des paramètres de distribution spatiale et verticale des poissons. La variabilité de la biomasse d'*E. carlsbergi* dans cette zone a également été étudiée.

Резюме

За период с 1987 по 1989 гг. ВНИРО (СССР) было выполнено шесть траловых и акустических съемок в районе к северу от Южной Георгии между 49-54° ю.ш. и 25-40° з.д. Этот участок находится в пределах полярной фронтальной зоны, где наиболее часто и регулярно встречаются мезопелагические виды рыб семейства Myctophidae. В настоящем документе суммируются и анализируются данные по сезонной и межгодовой изменчивости распределения, плотности и биомассы наиболее многочисленного вида семейства миктофид - *Electrona carlsbergi*. Также известно, что на протяжении года этот вид образует крупные скопления. Результаты съемок показывают, что распределение и поведение *E. carlsbergi* в значительной мере связаны с состоянием окружающей среды района, а также с доступностью и распределением зоопланктона. *E. carlsbergi*, была обнаружена на акватории всего изучаемого района. Тем не менее, наиболее крупные скопления были обнаружены у кромки фронтальной зоны, где такие основные характеристики водных масс, как динамика, температура и плотность характеризуются наиболее высокой степенью изменчивости. Наиболее значительные по величине и плотности скопления *E. carlsbergi* наблюдались в течение лета (декабрь - февраль), когда рыба находилась в верхнем слое воды (50-100 м). Самые мелкие скопления, характеризующиеся низкой плотностью, наблюдались зимой (июнь) на глубинах в 200 м и более. Параметры вертикального распределения и плотности скоплений рыбы находились на переходной стадии в течение весенних и осенних месяцев. Вычисления биомассы запаса *E. carlsbergi* в данном районе показали, что ее внутригодовая изменчивость связана с параметрами пространственного и вертикального распределения. Также наблюдалась межгодовая изменчивость биомассы *E. carlsbergi* в данном районе.

Resumen

Entre 1987 y 1989, VNIRO (URSS) realizó seis prospecciones de arrastre y acústicas en el área al norte de las islas de Georgia del Sur, entre los 49° y 54°S y los 25° y 40°W. El área está situada dentro de la Zona del Frente Polar, que es donde se encuentran más frecuentemente los peces mesopelágicos de la familia Mictophidae. En este documento se analiza y resume la variabilidad estacional e interanual de la distribución, densidad y biomasa de la especie más abundante de mictófidos, *Electrona carlsbergi*, la cual tiende a formar grandes concentraciones durante el año. De acuerdo a los resultados de las prospecciones, la distribución y el comportamiento de *E. carlsbergi* están íntimamente relacionados con las condiciones ambientales y con la disponibilidad y distribución del zooplancton en el área. *E. carlsbergi* se encontró en toda el área de estudio, empero, las mayores concentraciones se encontraron principalmente a lo largo de los límites de la Zona del Frente Polar, en donde aquellas características ambientales fundamentales de las masas de agua tales como la dinámica de corrientes, temperatura y densidad, alcanzan las máximas variaciones. El mayor volumen y densidad de las concentraciones de *E. carlsbergi* se observaron en verano (diciembre a febrero), cuando los peces se distribuyen en el estrato superior, entre los 50 a 100 m. Los volúmenes y densidades más bajos fueron observados en invierno (junio) a partir de los 200 m de profundidad. Los meses de primavera y otoño fueron considerados de transición para los parámetros de distribución batimétrica y densidad de las concentraciones de peces. Los cálculos de biomasa de *E. carlsbergi* en el área indican que la variabilidad de esta especie durante el año es una función de la distribución batimétrica y espacial de los peces. Se estudió también la variación interanual de la biomasa de *E. carlsbergi* en el área.

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1. INTRODUCTION

Lantern fish, or myctophids (Myctophidae), are widely distributed throughout the Southern Ocean. Due to the number of different species, wide distribution and the high abundance of some species, they represent the bulk of ichthyofauna in the mesopelagic zones of the high seas. About 14 or 15 myctophid species are the most frequently encountered in the Southern Ocean, the majority of which are characterised by circumpolar distribution. The most abundant myctophid species are found in the area of the Southern Polar Front or the Polar Frontal Zone (PFZ) which surrounds the entire Antarctic region from 50° to 60°S and encroaches further to the north or south in some areas. Very few species, however, form large and dense concentrations and their distribution tends to be localised and subject to high levels of variability.

2. RESULTS AND DISCUSSION

Electrona carlsbergi is the most studied of the more abundant myctophids which have high biomass and form regular concentrations. Over many years, the basic biological features, distribution patterns, areas, timing and conditions for the formation of concentrations have been studied in various parts of the Southern Ocean. The largest and most dense aggregations of *E. carlsbergi* occur in the PFZ to the north of South Georgia between 49° and 54°S and 40° and 25°W. *E. carlsbergi* forms regular concentrations in virtually all seasons over this extensive

area of more than 160 thousand square miles. However fish concentrations in this area are extremely unevenly distributed and there are significant fluctuations in the timing of formation and dissipation of concentrations, and in their size, depth of distribution and density. This area proved useful for incidental and directed research into spatial and temporal changes in the environment and *E. carlsbergi* distribution. Soviet scientists conducted a series of studies in this area on board RV *Vozrozhdenie*. They worked for almost two years from October 1987 to June 1989, over which time six detailed oceanographic and acoustic-trawl surveys were carried out. Results of these integrated surveys demonstrated that different environmental conditions in different areas of the PFZ at various times of the year (rate of warming of the surface layer, rate of stratification of water layers, aspects of water dynamics and zooplankton distribution) determine the spatial heterogeneity of *E. carlsbergi* distribution. *E. carlsbergi* was found over the entire study area in the PFZ, although this myctophid species formed concentrations on the edges of the frontal zone in areas where fundamental dynamic and physical phenomena (currents, temperature, density) attain the highest levels of variation. These high-variability areas where the frontal waters converge with Antarctic water masses have the most potential in terms of concentration formation for this species.

It was also discovered that these concentrations adhere very closely to areas of quasi-stationary meandering currents, in other words, the periphery of gyre formations at the junctions of various water masses. It appears that these high-variability areas of the frontal zone play a significant role in the build-up of plankton, duration of fish feeding periods and, consequently, their stable and long-lasting concentrations.

Along the southern border of the PFZ between 40° and 36°W, 30° and 25°W and 49° and 53°S (Figures 1 to 5) *E. carlsbergi* formed fairly regular and large-scale concentrations. At the same time, the location of *E. carlsbergi* schools over the study area of the PFZ varies from season to season and from year to year. During the uncharacteristically cold spring/summer season of 1987 (October-December), *E. carlsbergi* schools were distributed mainly to the north of 50°S, while in the autumn/winter season (April to December, 1987) they occurred to the south of 50°S (Figures 1 to 4). In summer 1988 (December) the areas of large concentrations were to the south of 50°S (Figure 5). The nature of diffusion and interaction of warm and cold waters generally determined, the geographical position of *E. carlsbergi* concentrations which followed the line of the southern edge of the front. This pattern is broken at 40°W where the concentrations extend to 49°S, and at 26° to 23°W where they extend to the south of 53° to 54°S.

Seasonal patterns of vertical distribution and behaviour variations of *E. carlsbergi* were identified. During the spring season (September/October), low-density concentrations were not long, stretching from 0.5 to 10 miles. These concentrations were distributed mainly at depths between 150 and 350 m and had a considerable vertical extent of 50 to 300 m. As the surface temperature rose from 1.5° to 4.9°C, echo recordings showed an increase in the density and length of concentrations near the thermal front. At this time, *E. carlsbergi* concentrations were most frequently recorded in the eastern sector of the area (30° to 25°W) where sub-Antarctic waters merge with the cold Antarctic waters. Analysis of the vertical extent of *E. carlsbergi* at different times of the day demonstrated that in spring concentrations are found at similar depths (100 to 450 m) both during the day and at night. It should be noted that during the night fish were more scattered; the vertical extent of concentrations registered on echo recordings was up to 200-300 m. The shape of the echo recordings indicated the presence of separate shoals or groups of shoals with a smaller vertical extent of between 20 and 200 m. Daily vertical migration at this time was weak, which on the whole led to a decrease in vertical distribution during the formation of shoals. Typical echo-charts of *E. carlsbergi* concentrations in spring are given in Figures 6 to 8.

Compared with the spring season, summer (December to January) witnessed considerable changes in *E. carlsbergi* distribution and behaviour. During this period, fish were located closer to the surface (from 10 to 100 m) at night, while during the day concentrations descended to depths of 160 to 200 m. The length of concentrations increased dramatically and varied from five to 30 miles and longer. In summer, concentrations were ribbon-shaped and

very dense, with a vertical extent from 10-50 to 100-120 m. The majority of *E. carlsbergi* concentrations adhered to the peripheries of meandering currents where the temperature varied from 1.9° to 5.0°C. Typical echocharts of *E. carlsbergi* concentrations in summer are shown in Figures 9 to 12.

Changes in the vertical distribution of *E. carlsbergi* are probably due to the redistribution of zooplankton which occurred in summer. After winter, plankton rises towards the surface and new generations begin to develop, most of the plankton is found in the upper 50 to 100 m layer. Fish feeding occurred on the edge of this layer. Results of research carried out at daily stations revealed that if there is a good food supply, *E. carlsbergi* concentrations are able to keep to the same depths in the course of 24 hours without having to migrate vertically each day.

In autumn (March to April), *E. carlsbergi* concentrations begin to move to deeper waters, are almost constantly spread over depths between 200 and 400 m (more often 220 to 350 m) and do not rise to the upper 100 m layer. In the course of a day, the depth of *E. carlsbergi* distribution does not alter significantly, regardless of the extent or density of concentrations. Moreover, in the morning *E. carlsbergi* forms shoals and later in the day develops more dense concentrations with a considerable vertical extent (up to 200 m). Typical echocharts of *E. carlsbergi* concentrations in autumn are given in Figures 13 to 15.

Compared with autumn, depth of *E. carlsbergi* distribution in winter (June) was practically unchanged. Scattered low-density concentrations were spread over depths of 200 to 400 m and had a vertical distribution of up to 200 m. Daily migrations were not extensive. Density increased during the day and decreased at night. Echocharts of typical *E. carlsbergi* concentrations in winter are given in Figures 16 to 18.

It is apparent that vertical distribution of *E. carlsbergi* concentrations and its behaviour are subject to seasonal variations which are, to a large extent, linked to the seasonal distribution of its primary food, zooplankton. In autumn, it has been noted that these fish tend to migrate to and remain at depths of 200 to 300 m for a long period before the beginning of summer. This is due to the fact that winter plankton also drops to these levels. The overall pattern of *E. carlsbergi* vertical distribution generally remains the same each season and each year.

Data from trawl-acoustic surveys, carried out in different seasons and years, showed that at any given moment from 0.5 to 2.9 million tonnes of *E. carlsbergi* are present in the studied area of the PFZ. Biomass and density calculations made from echo surveys are given in Table 1.

Investigations showed considerable seasonal and interannual fluctuations in the quantitative distribution of *E. carlsbergi* which may lead to significant changes in the instantaneous biomass. The largest and most dense concentrations of *E. carlsbergi* in this area form in summer when the biomass is capable of reaching 3 million tonnes. *E. carlsbergi* biomass can also be substantial in the other seasons (500 to 1 100 x 10^3 tonnes).

Acoustic assessments of *E. carlsbergi* density and biomass were carried out in different seasons not only for the entire study area, but also over smaller individual sites of temporary concentrations having an area of 500 to 700 miles^2 (Table 2).

3. CONCLUSIONS

Following the investigations, fairly distinct patterns emerged in respect of the distribution and behaviour of the most abundant myctophid species, *E. carlsbergi*, in the PFZ to the north of South Georgia. These patterns suggest that the situations outlined above are typical for a particular period, taking into account seasonal and interannual variability of environmental factors. Moreover, when assessing a given situation it is essential to take into consideration

both the general patterns of distribution (adherence of the greater part of *E. carlsbergi* concentrations to higher latitudes in areas of pronounced meandering currents and on the edge of gyre formations) and the characteristics of distribution and behaviour (vertical migration, accumulation, feeding characteristics) for a particular season.

In regard to layers where feeding takes place, *E. carlsbergi* tends to be concentrated in the epipelagic zone in summer and the mesopelagic zone in spring and autumn. Furthermore, it is most likely that feeding conditions during the foraging period determine the pattern of vertical migration: *E. carlsbergi* displays a distinctive daily rhythm in its distribution and behaviour. Depending on the time of the day, concentration density also changes. Aspects of this rhythm depend on the season, time of the day, area and zooplankton concentration.

Table 1: Biomass and density calculations made from echo surveys.

Month and Year	Area of Concentration Distribution ($x10^3$ square mile)	Biomass ($x10^3$ tonnes)	Concentration Density ($x10^3$ tonnes per square mile)
October to November, 1987	54.1	743	4 - 145* 13.8**
December, 1987	73.1	2 944	6 - 284 40.2
March to April, 1988	85.7	911	4 - 87 10.6
June, 1988	95.1	526	4 - 19 5.5
October to November, 1988	95.6	810	3 - 61 8.5
April to May, 1989	29.6	1 107	6 - 257 37.4

* density range
** mean value

Table 2: *E. carlsbergi* biomass and concentration density over localised sites of the PFZ in December 1988.

Month and Year	Area of Concentration Distribution ($x10^3$ square mile)	Biomass ($x10^3$ tonnes)	Concentration Density ($x10^3$ tonnes per square mile)
2 to 5 December, 1988	532	13 811	6 - 77* 26.0**
9 to 12 December, 1988	687	17 885	7 - 102 26.0
18 to 20 December, 1988	676	11 278	9 - 80 16.7

* density range
** mean value

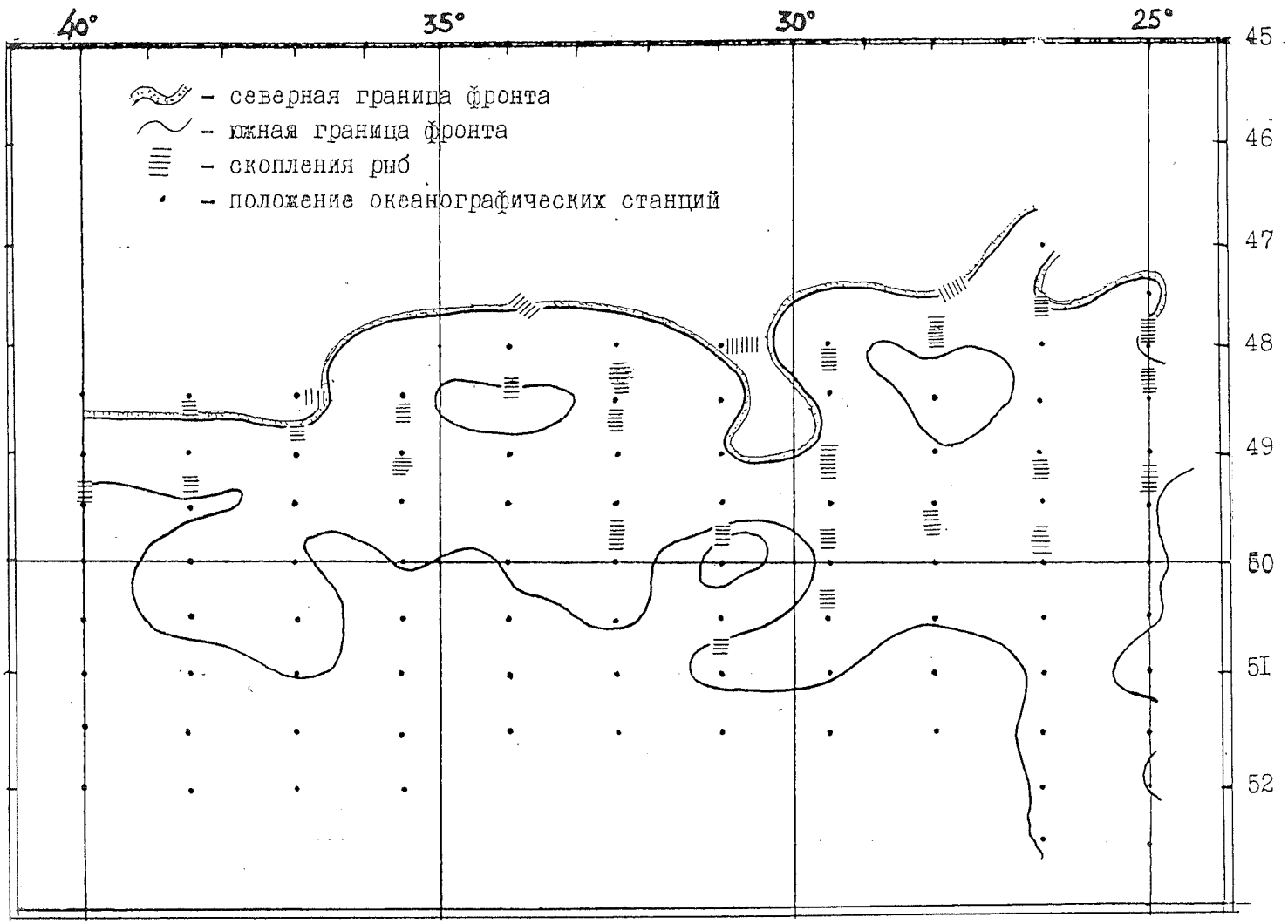


Figure 1: Distribution of large concentrations of *E. carlsbergi* over the Polar Frontal Zone to the north of South Georgia (October to November 1987).

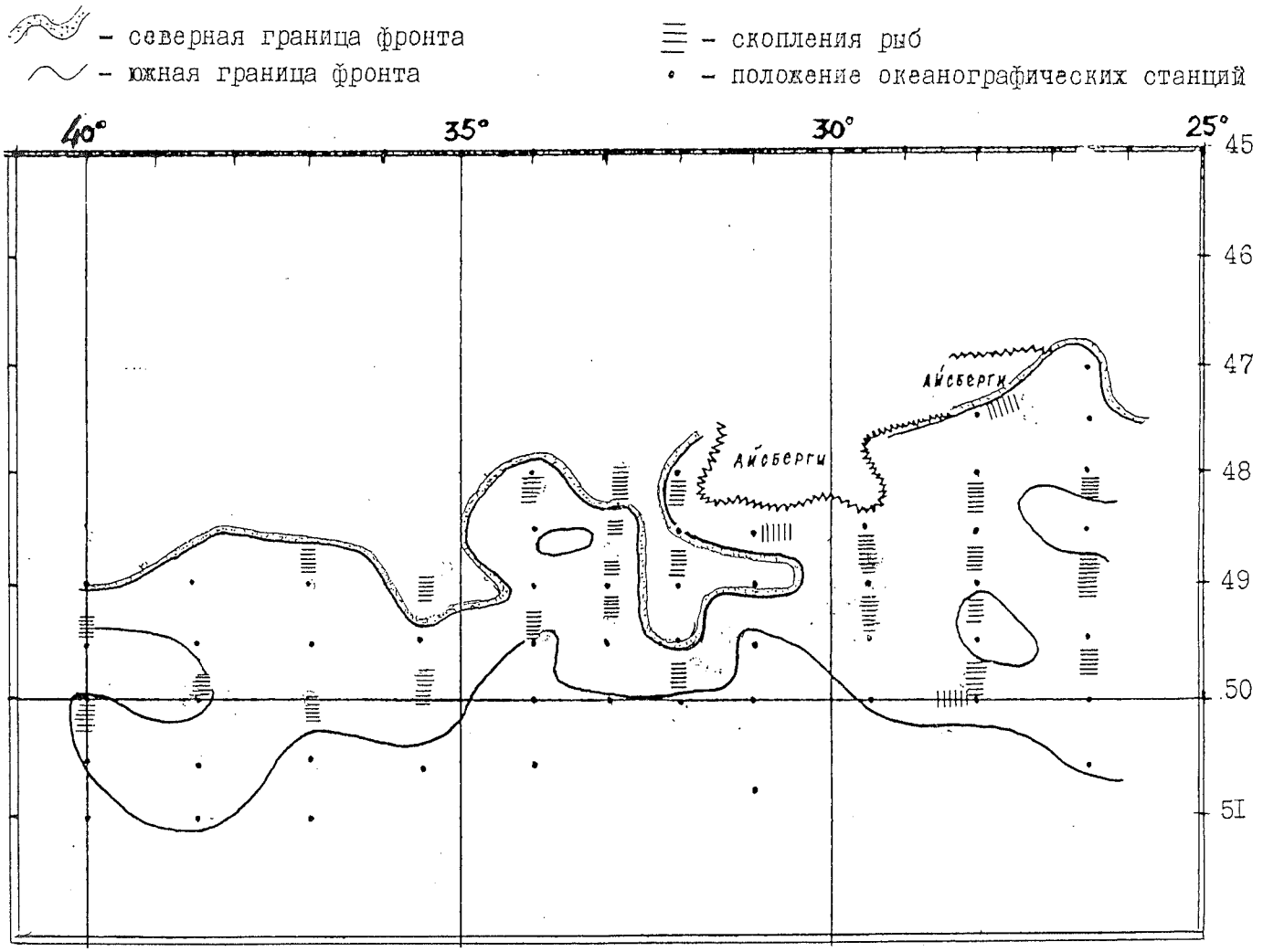


Figure 2: Distribution of large concentrations of *E. carlsbergi* over the Polar Frontal Zone to the north of South Georgia (December to January 1987/88).

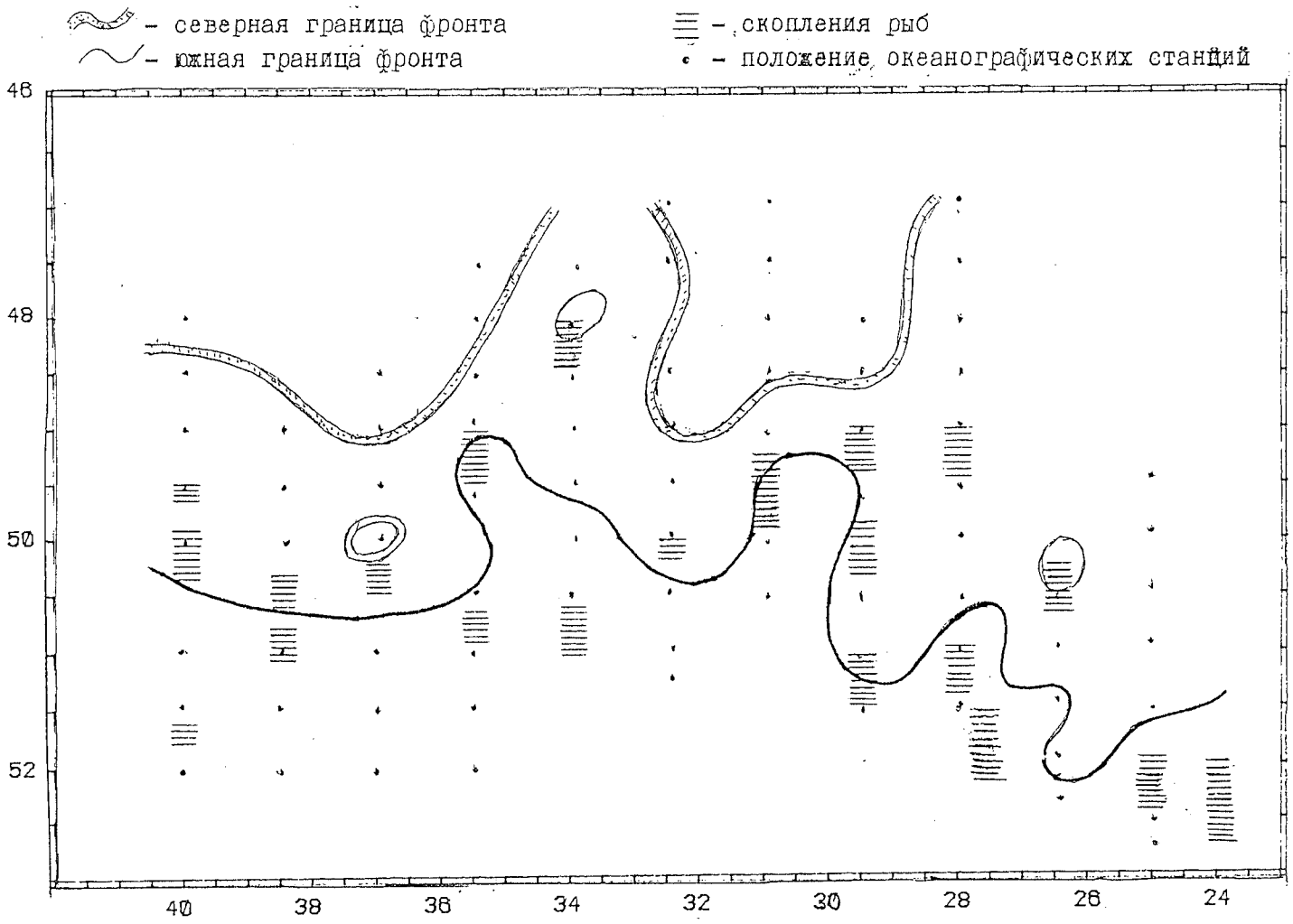


Figure 3: Distribution of large concentrations of *E. carlsbergi* over the Polar Frontal Zone to the north of South Georgia (March to April 1988).

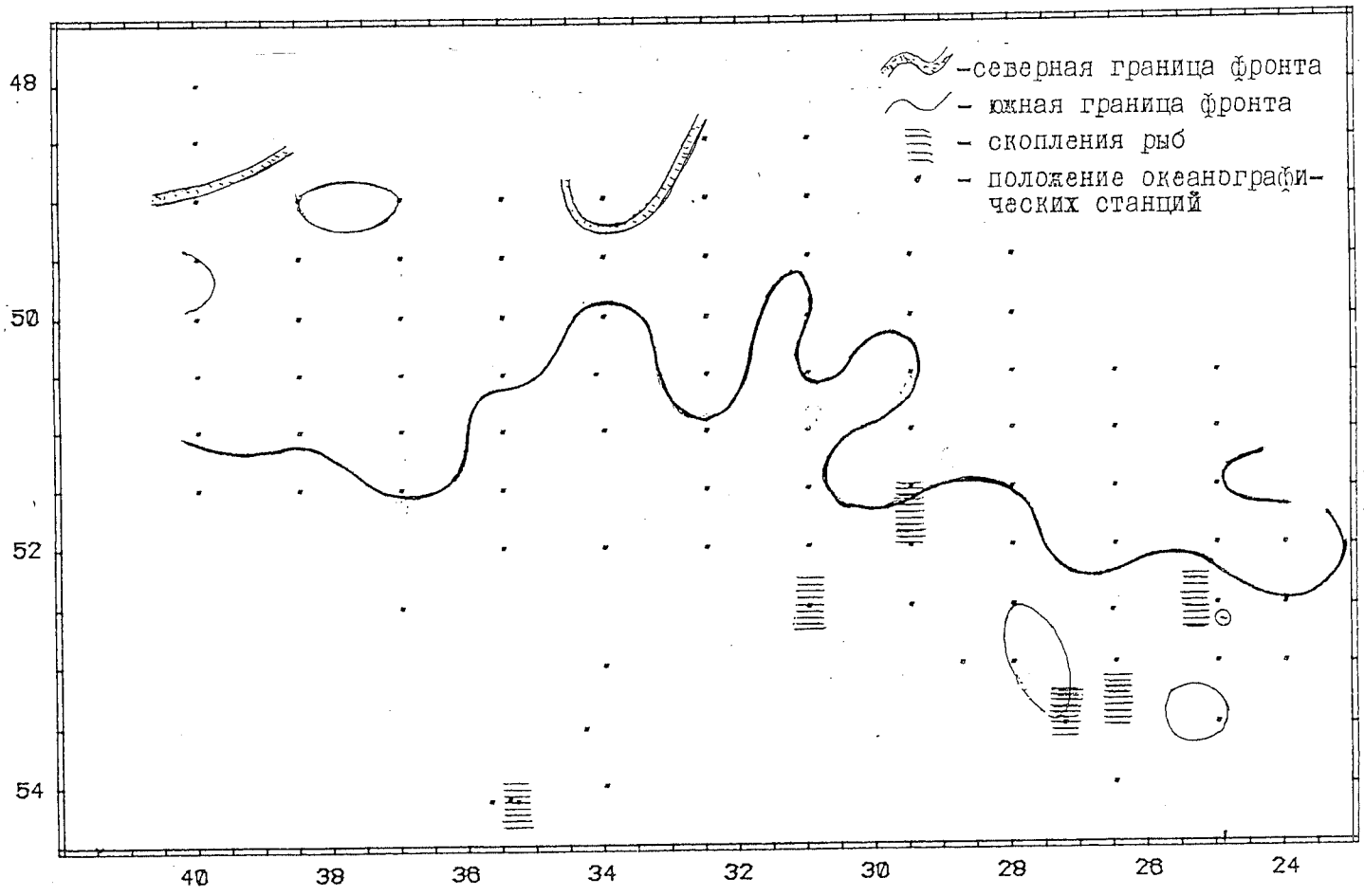


Figure 4: Distribution of large concentrations of *E. carlsbergi* over the Polar Frontal Zone to the north of South Georgia (June 1988).

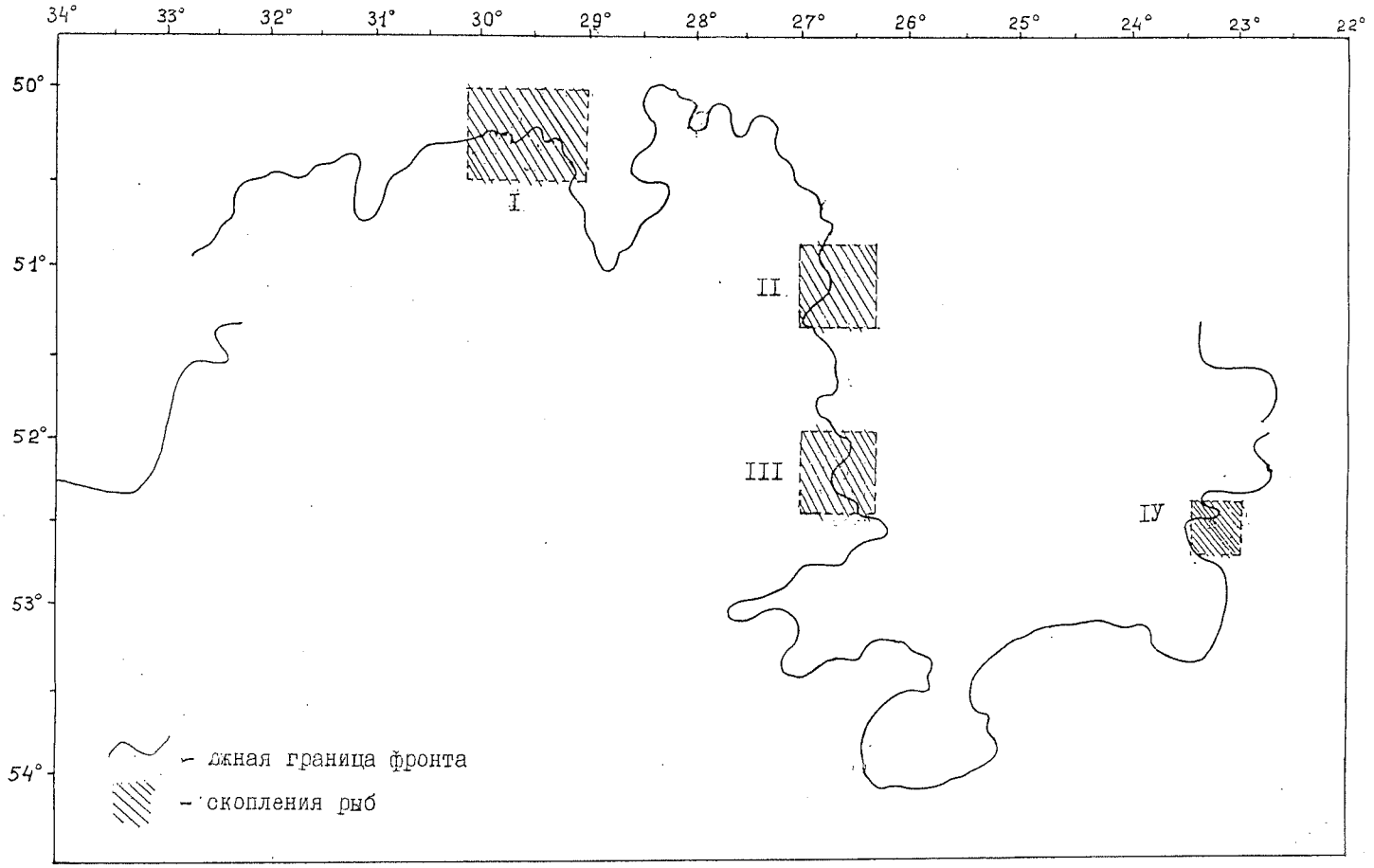


Figure 5: Distribution of large concentrations of *E. carlsbergi* over separate areas of the Polar Frontal Zone to the north of South Georgia (December 1988).

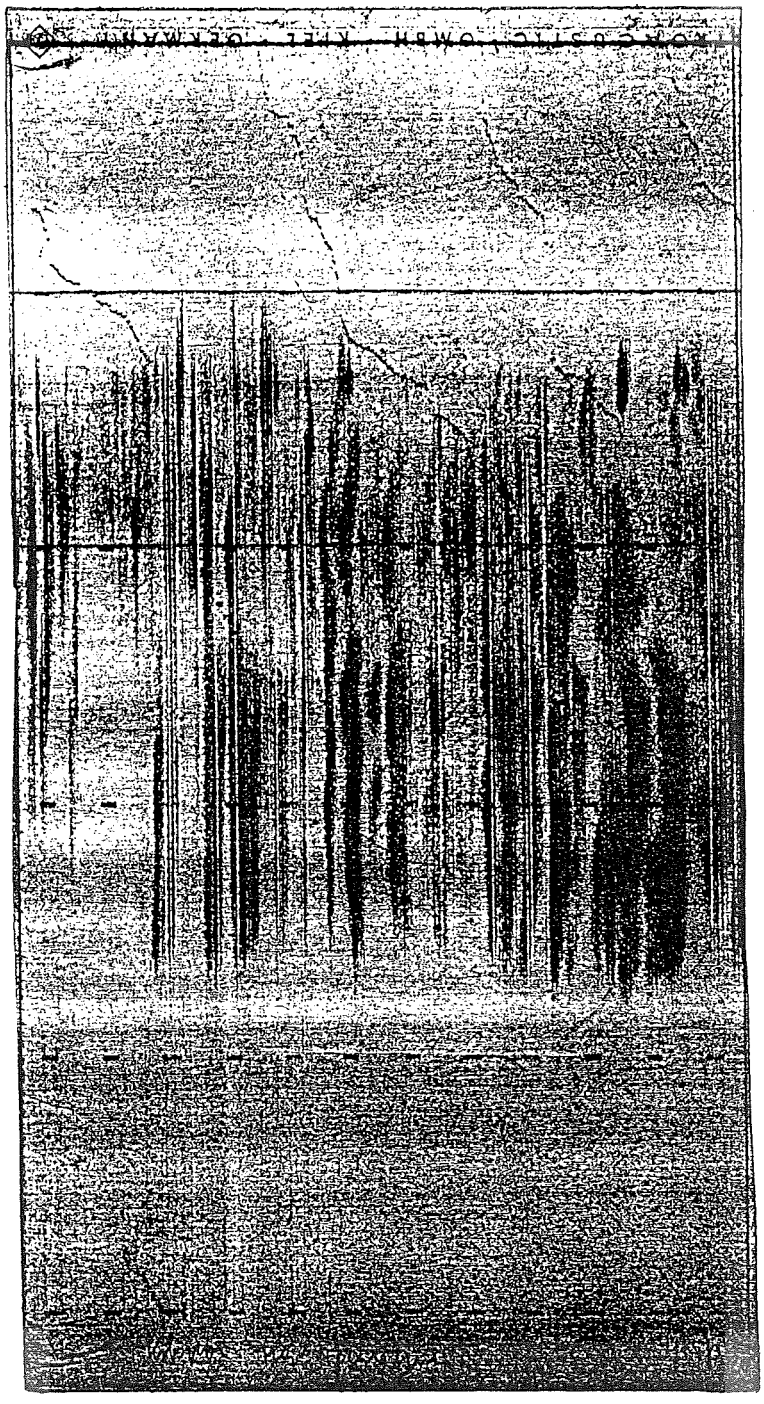


Figure 6: Echocharts of *E. carlsbergi* concentrations in the evening (21:00 to 22:00) at depths of 100 to 380 m in the Polar Frontal Zone (September 1988).

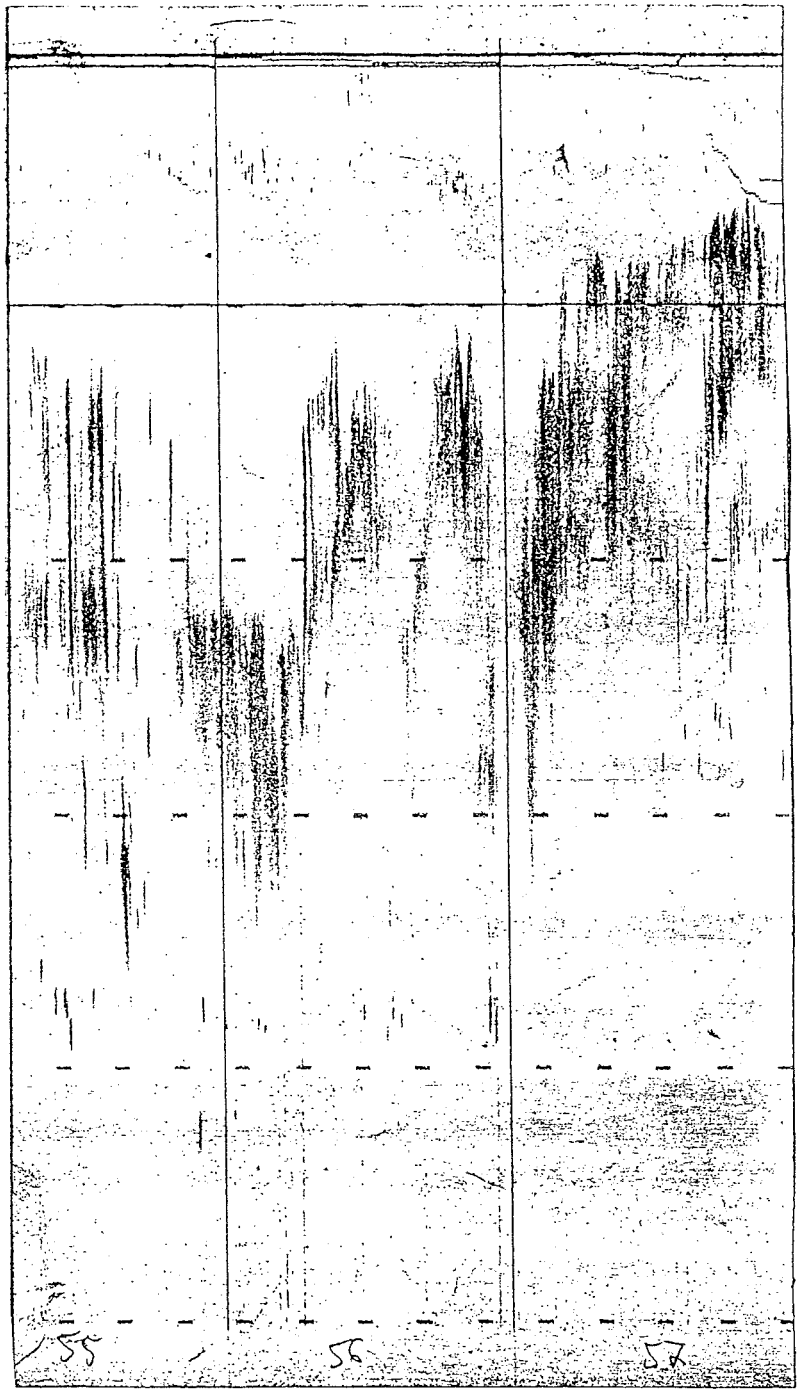


Figure 7: Echocharts of *E. carlsbergi* concentrations in the morning (6:00 to 7:00) at depths of 70 to 350 m in the Polar Frontal Zone (September 1988).

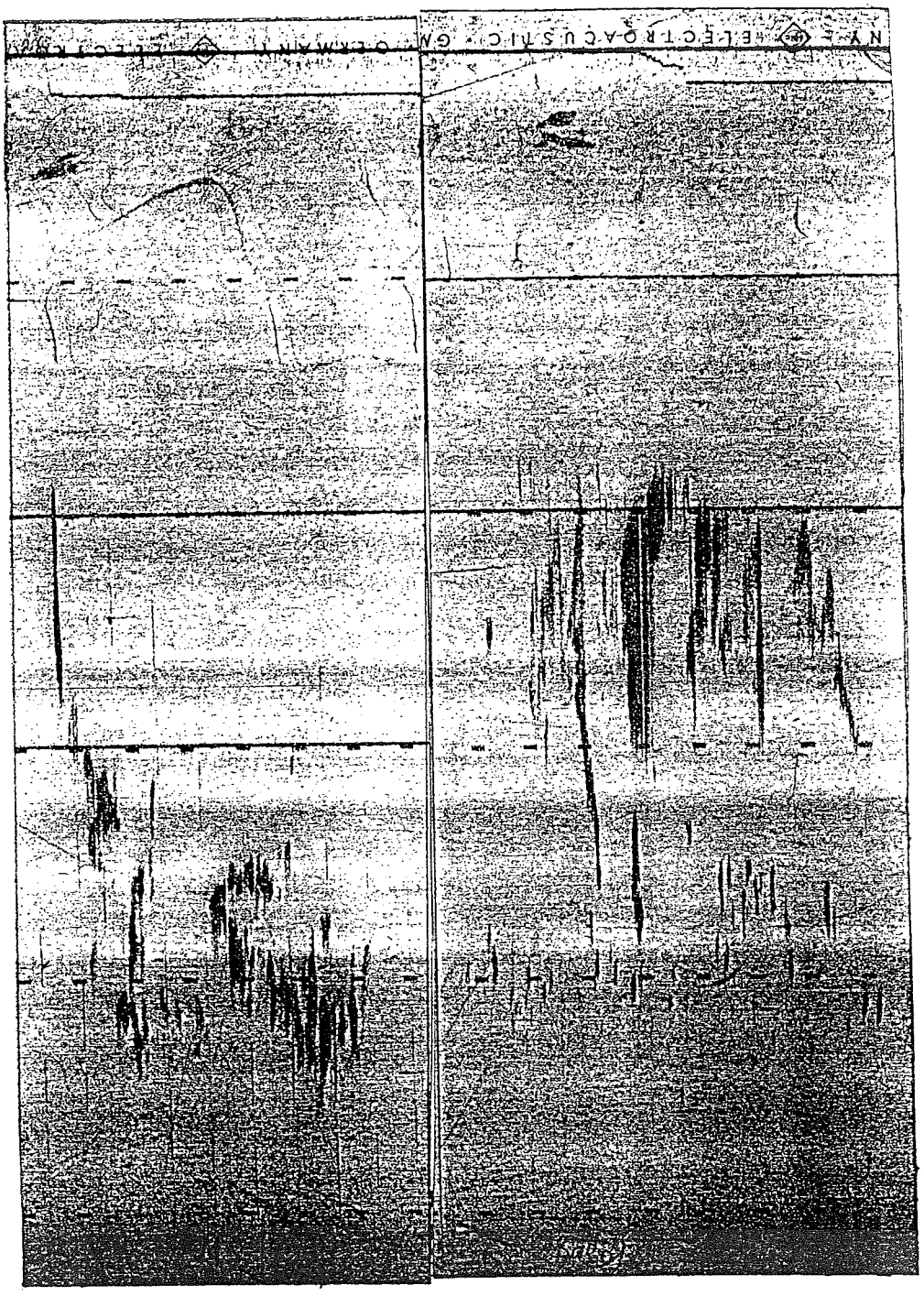


Figure 8: Echocharts of *E. carlsbergi* concentrations during the day (12:00 to 14:00) at depths of 190 to 450 m in the Polar Frontal Zone (September to October 1988).

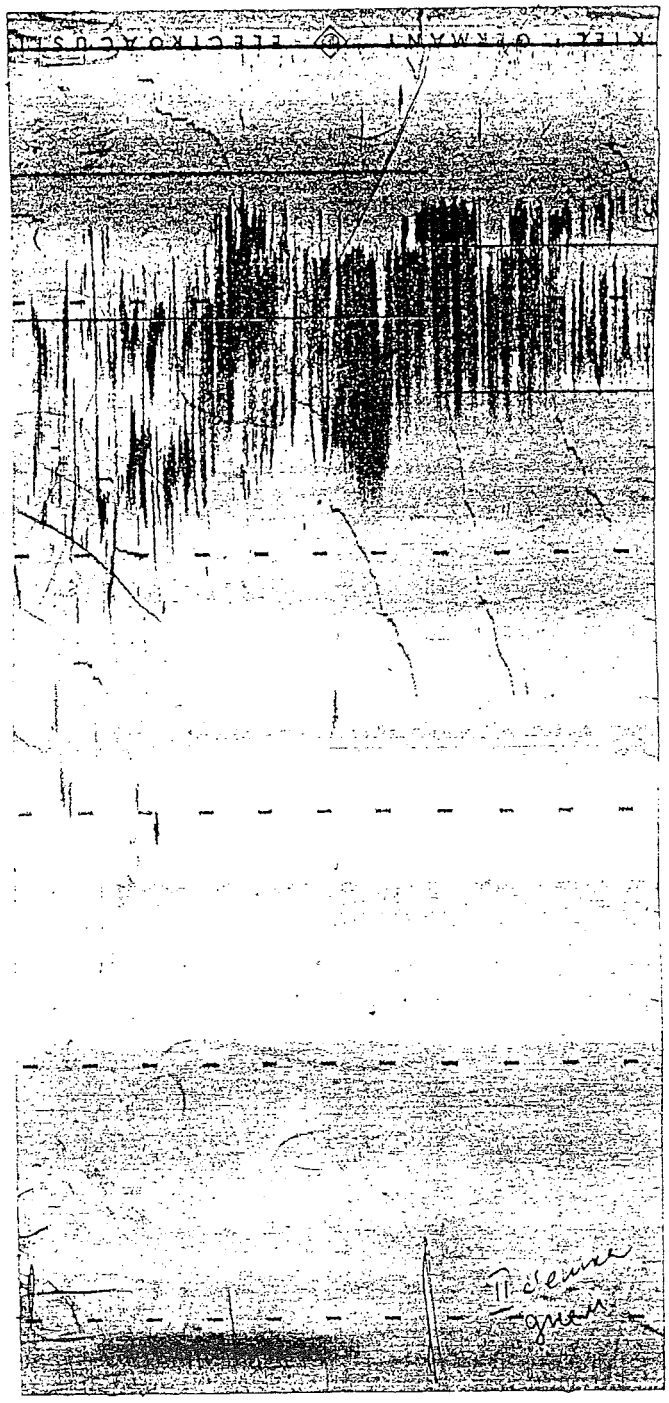


Figure 9: Echocharts of *E. carlsbergi* concentrations during the day (14:00 to 15:00) at depths of 60 to 200 m in the second fine-scale survey area (December 1988).

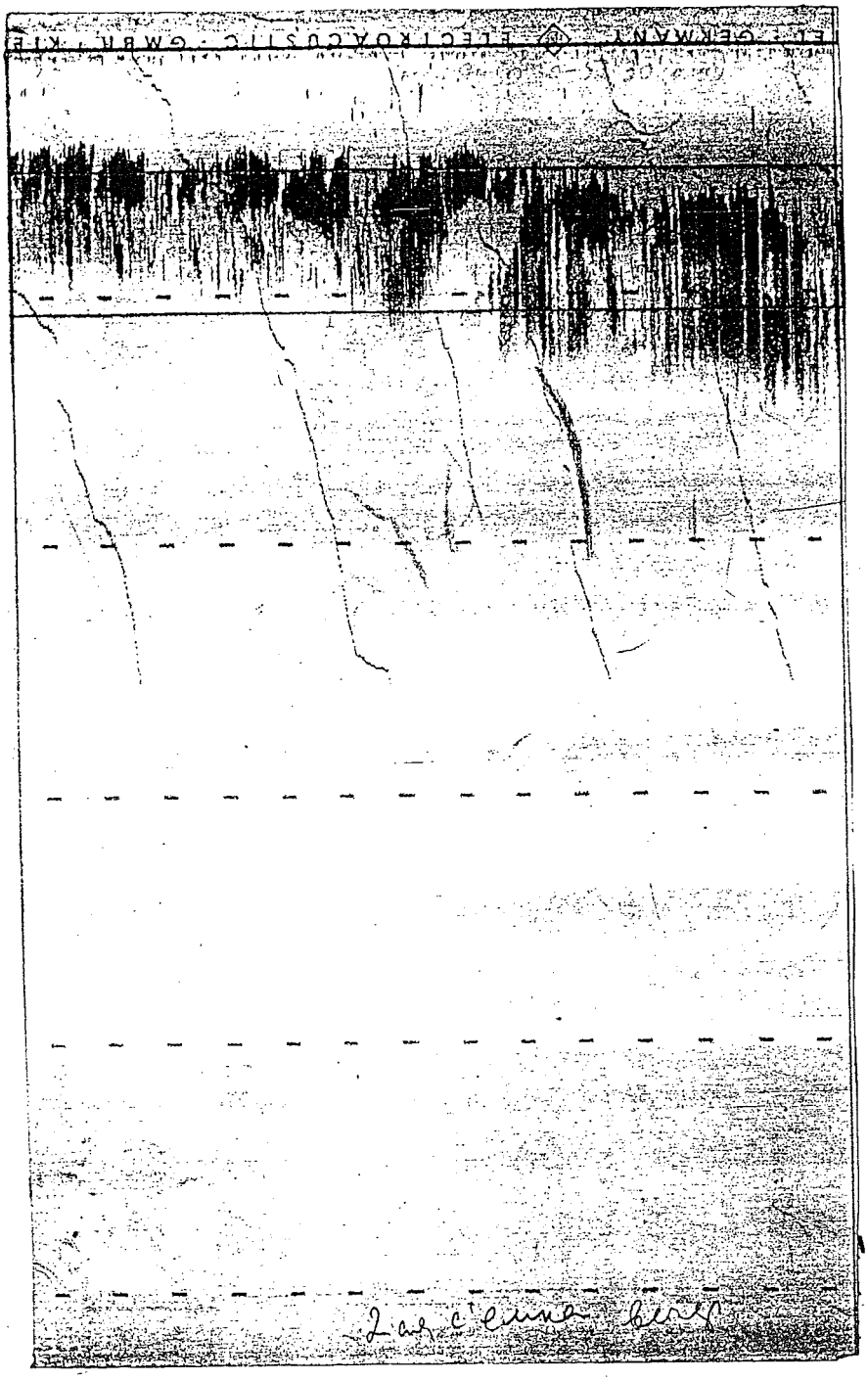


Figure 10: Echocharts of *E. carlsbergi* concentrations in the evening (19:00 to 20:00) at depths of 40 to 130 m in the second fine-scale survey area (December 1988).

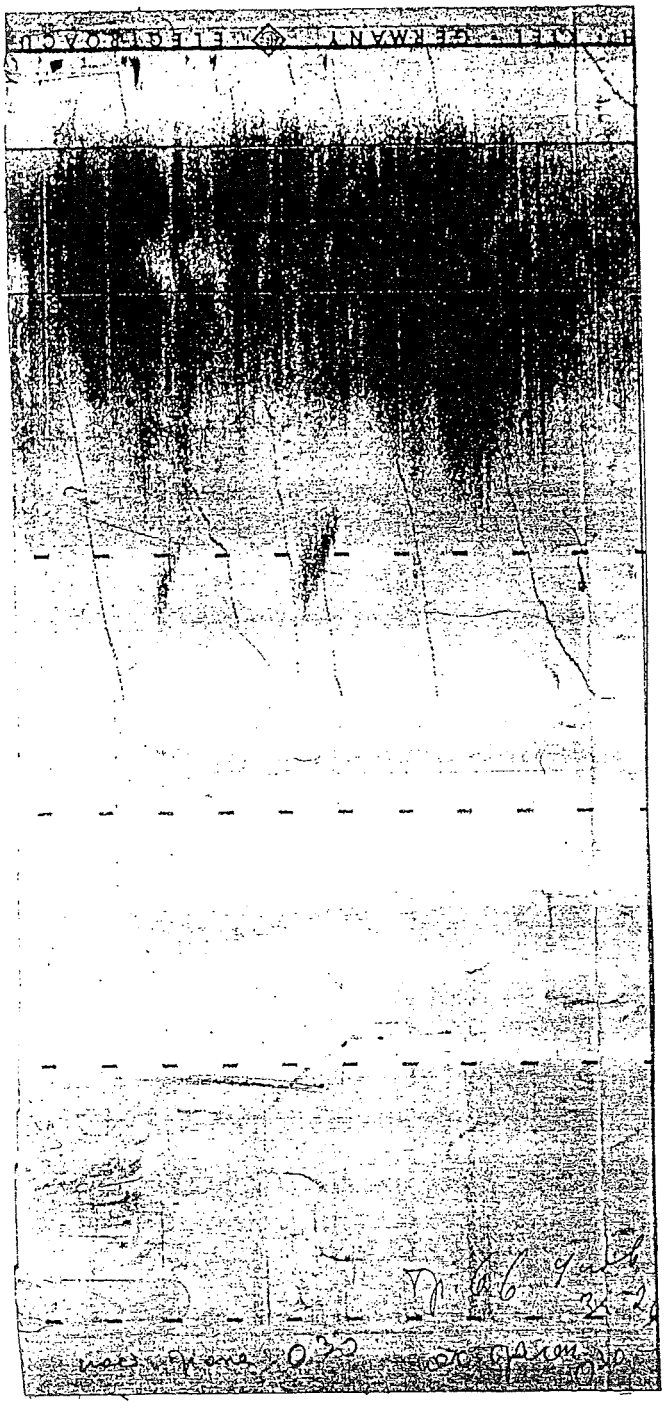


Figure 11: Echocharts of *E. carlsbergi* concentrations at night (00:30 to 01:30) at depths of 40 to 180 m in the third fine-scale survey area (December 1988).

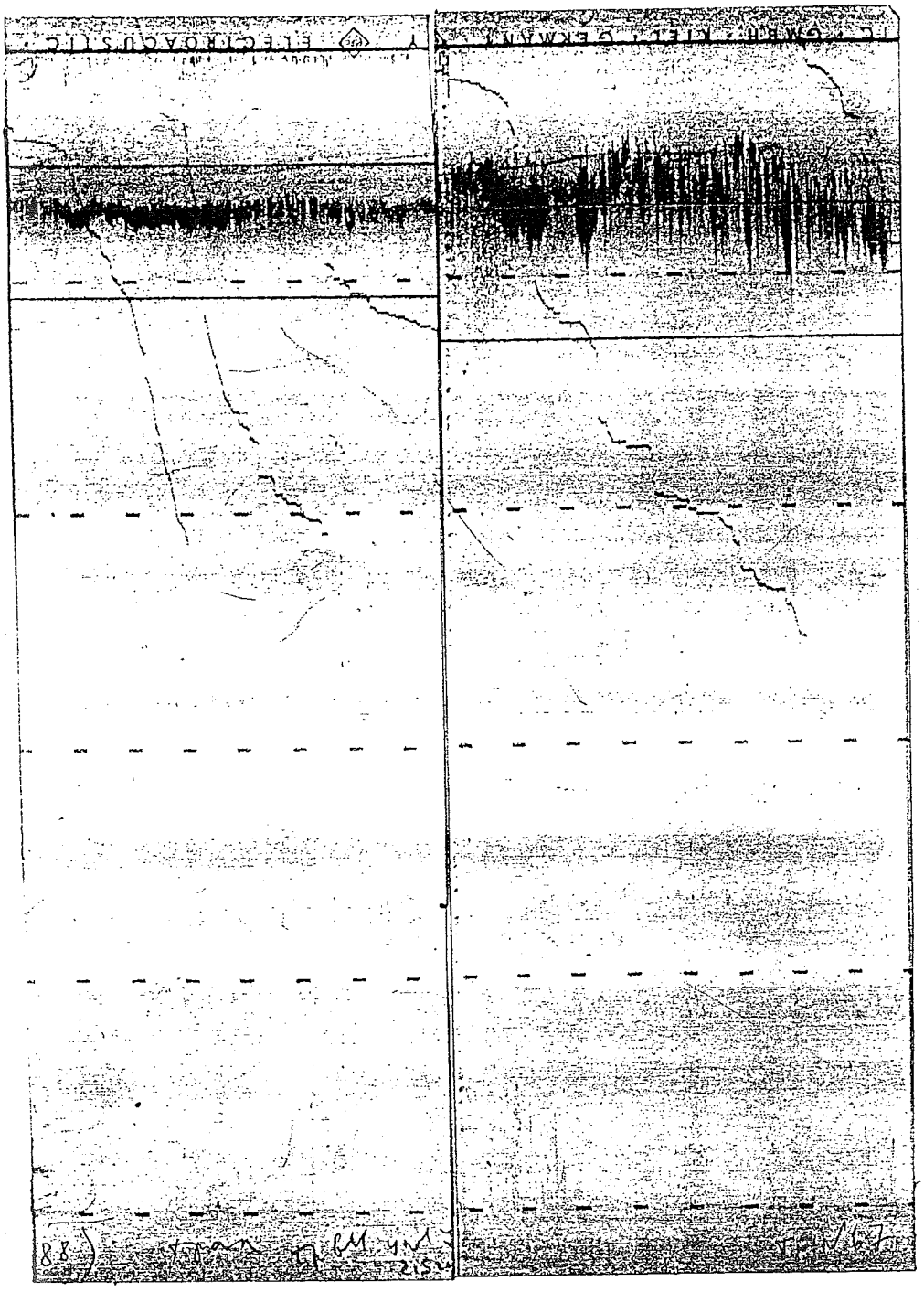


Figure 12: Echocharts of *E. carlsbergi* concentrations during the day [17:00 to 18:00 (a)] at depths of 70 to 80 m in the area of the third fine-scale survey and in the morning [05:00 to 06:00 (b)] at depths of 50 to 100 m.

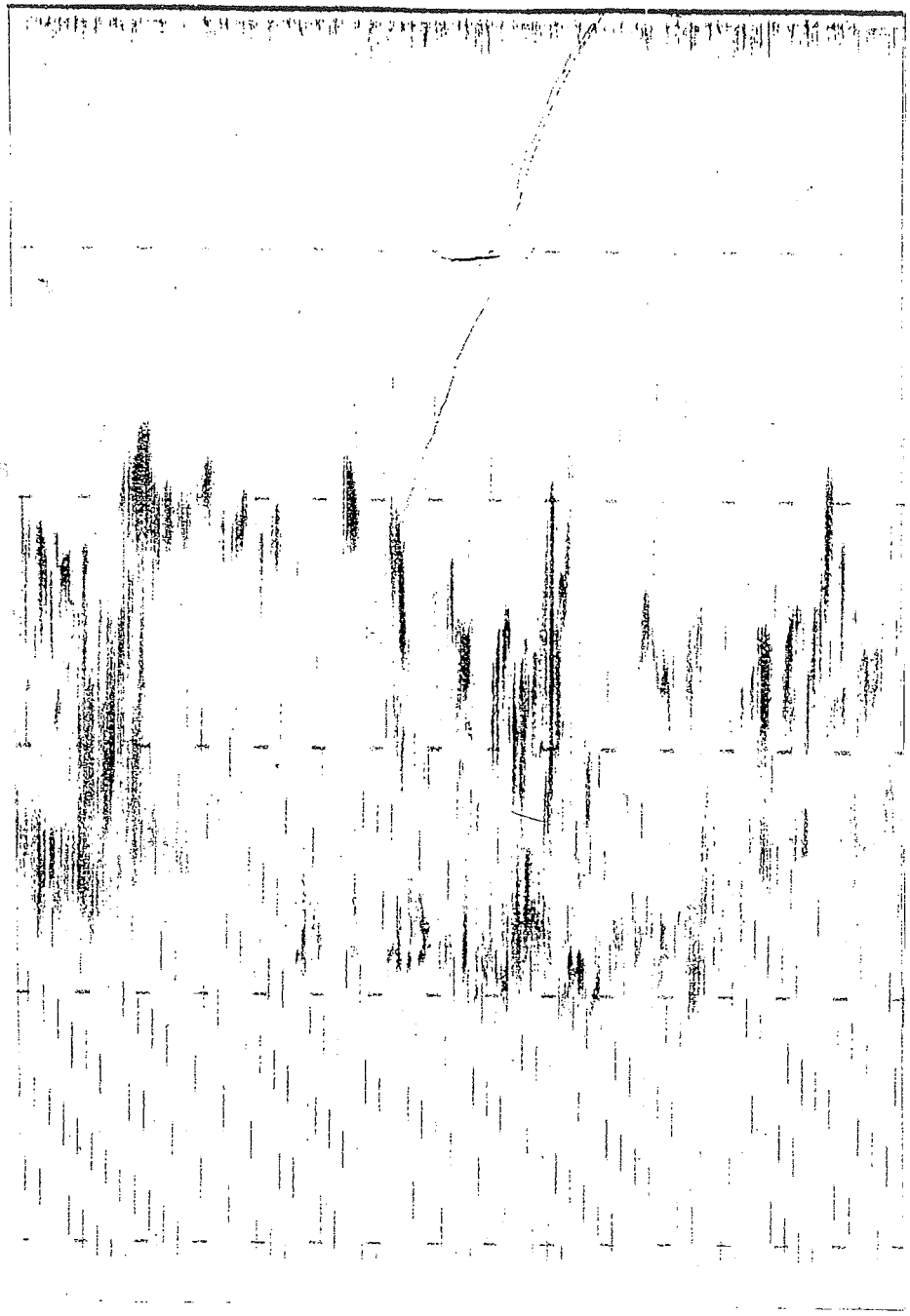


Figure 13: Echochart of haul No. 58.

Mean surface density $\bar{P}_s$ =51.9 t/mile^2

Mean density by volume $\bar{P}_v$ =0.04 specimens/m^3 or 0.32 g/m^3

Change in density by volume:
at 17:00 - P_v=0.03 specimens/m³ or 0.16 g/m³.

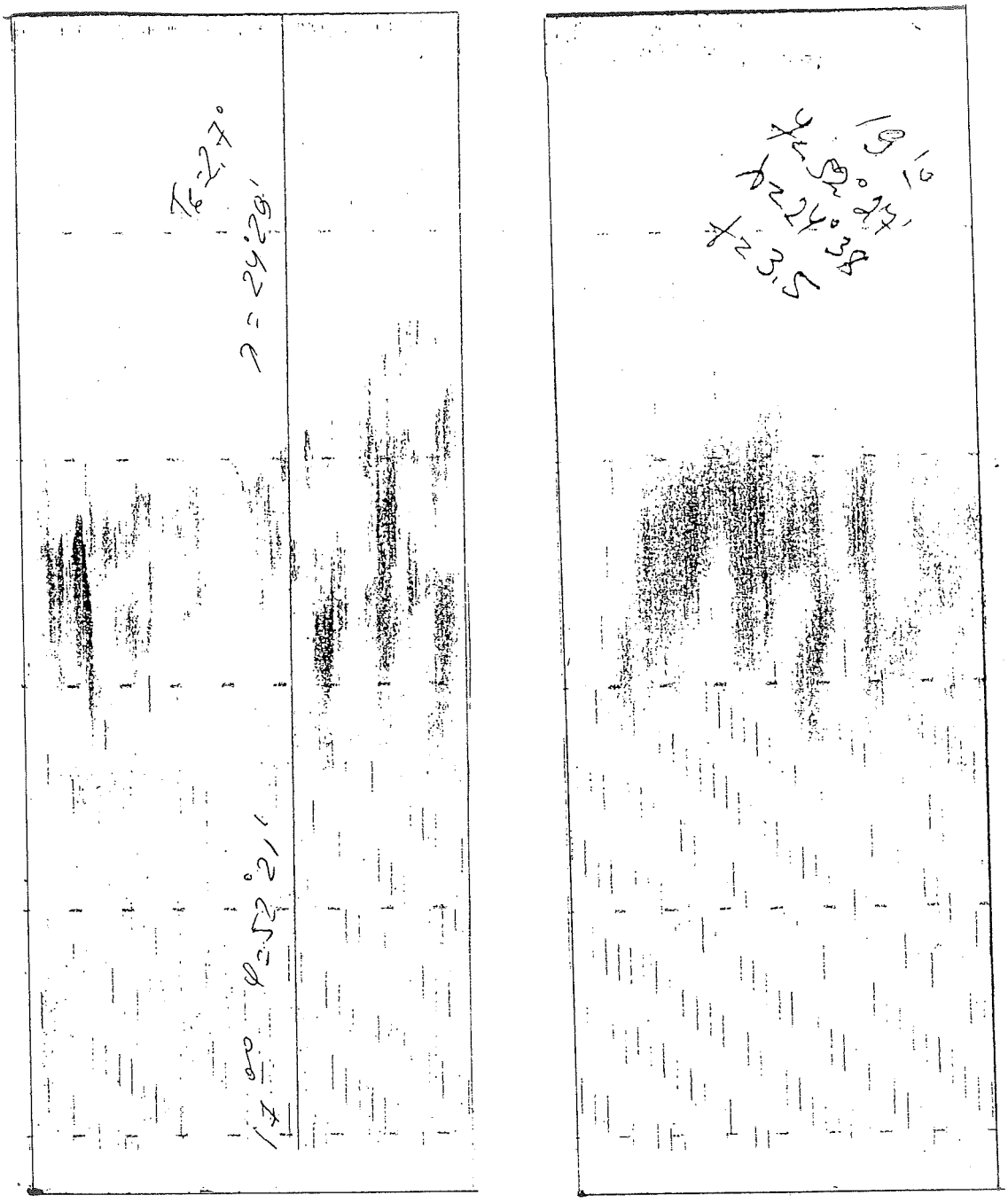


Figure 14: Typical echochart of *E. carlsbergi* concentrations in the second half of the day and during the evening.
Change in surface density:
at 17:00 - P_s=25.8 tonne/mile²; at 19:00 - P_s=24.4 tonne/mile².

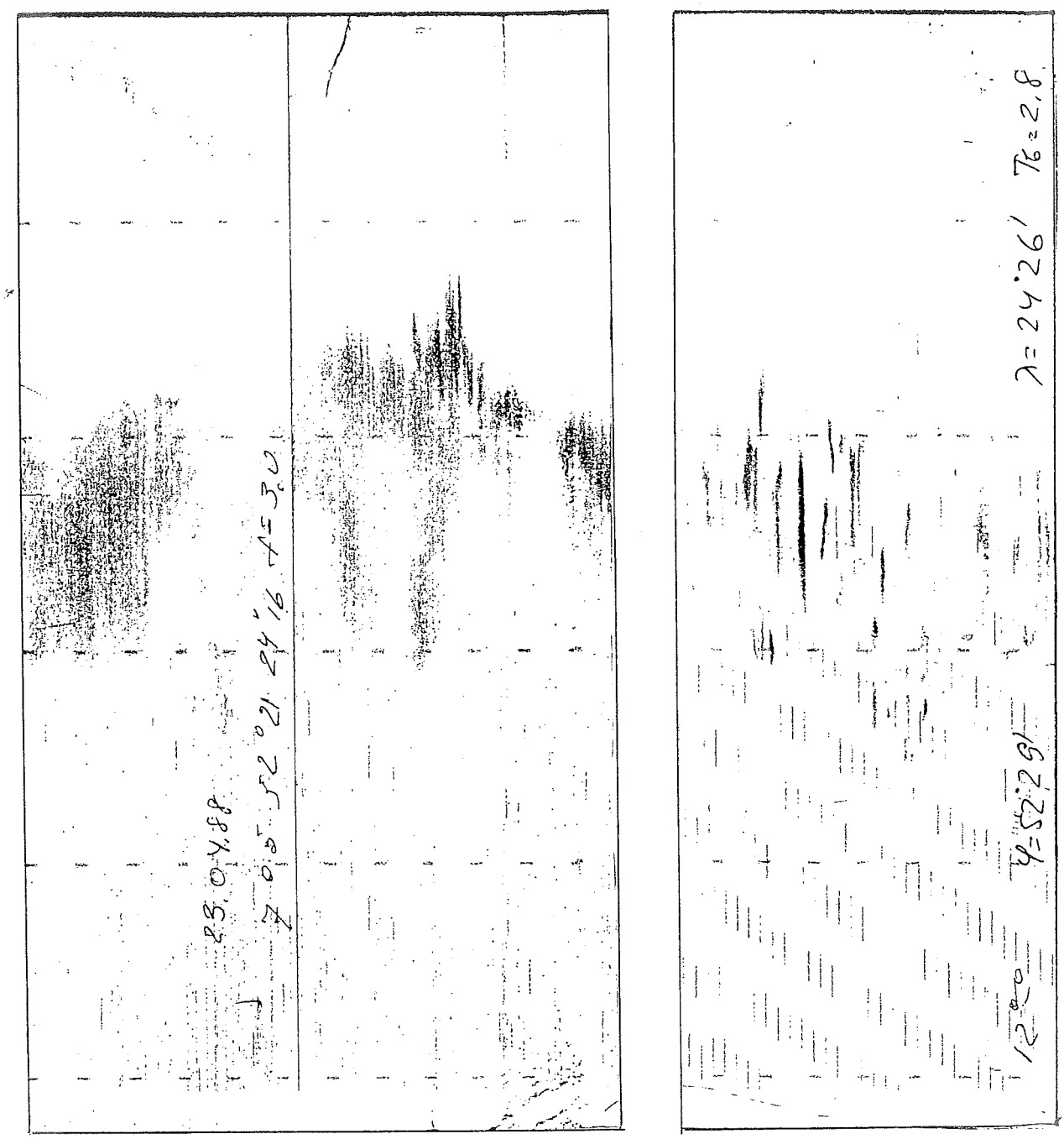


Figure 15: Typical echochart of *E. carlsbergi* concentrations in the morning and daylight hours.
Change in surface density:
at 7:00 - P_s=26.1 tonne/mile^2; at 12:00 - P_s=24.8 tonne/mile^2.
Change in density by volume:
at 7:00 - P_v=0.01 specimens/m^3; at 12:00 - P_v=0.02 specimens/m^3 or 0.16 g/m^3.

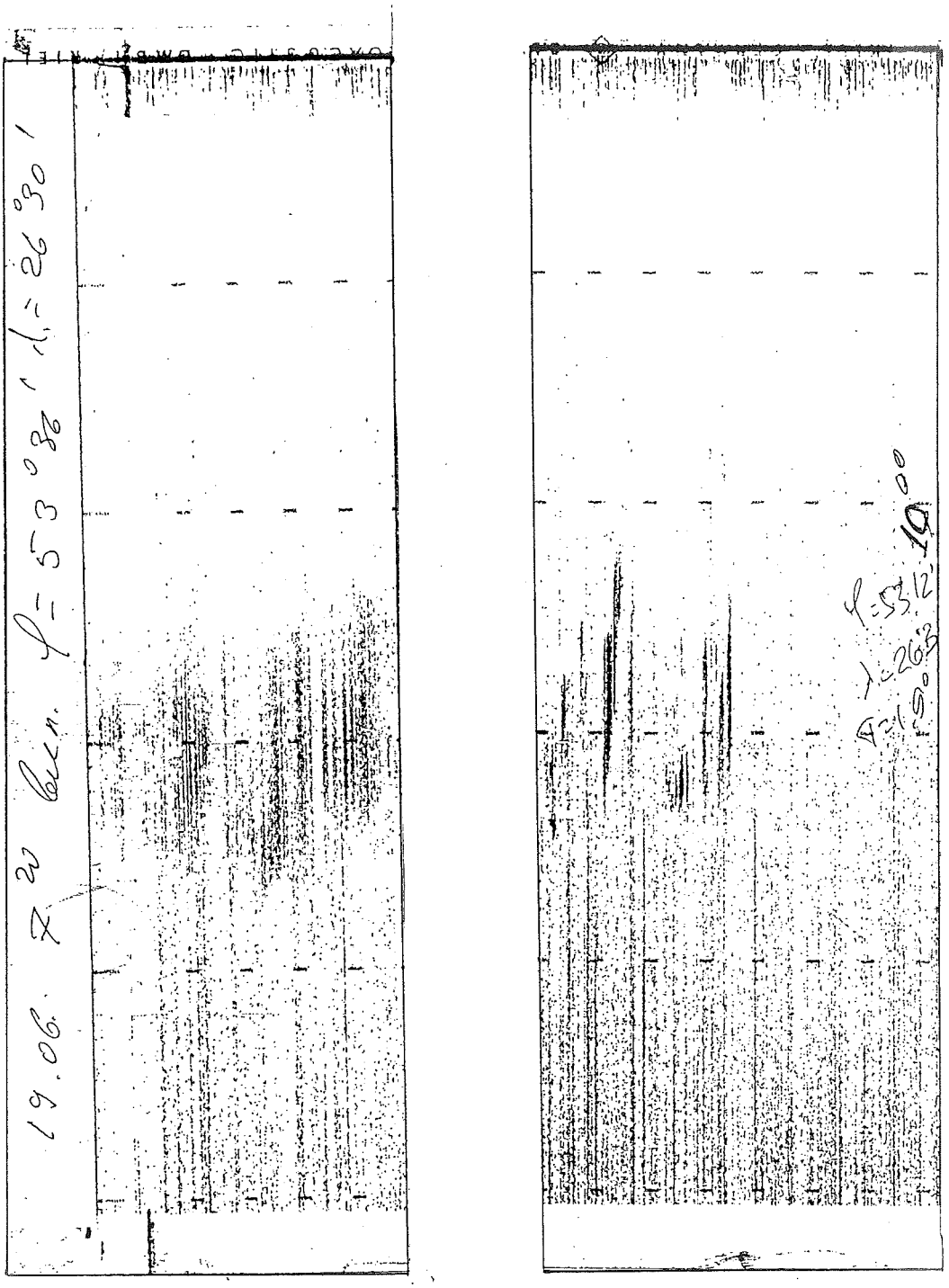


Figure 16: Echochart of *E. carlsbergi* concentrations in the morning and daylight hours.

At 8:00	surface density	$\bar{P}_s$=17.7 tonne/mile^2
	density by volume	$\bar{P}_v$=0.007 specimens/m^3 or 0.056 g/m^3.
At 10:00	surface density	$\bar{P}_s$=18.0 tonne/mile^2
	density by volume	$\bar{P}_v$=0.01 specimens/m^3 or 0.08 g/m^3.

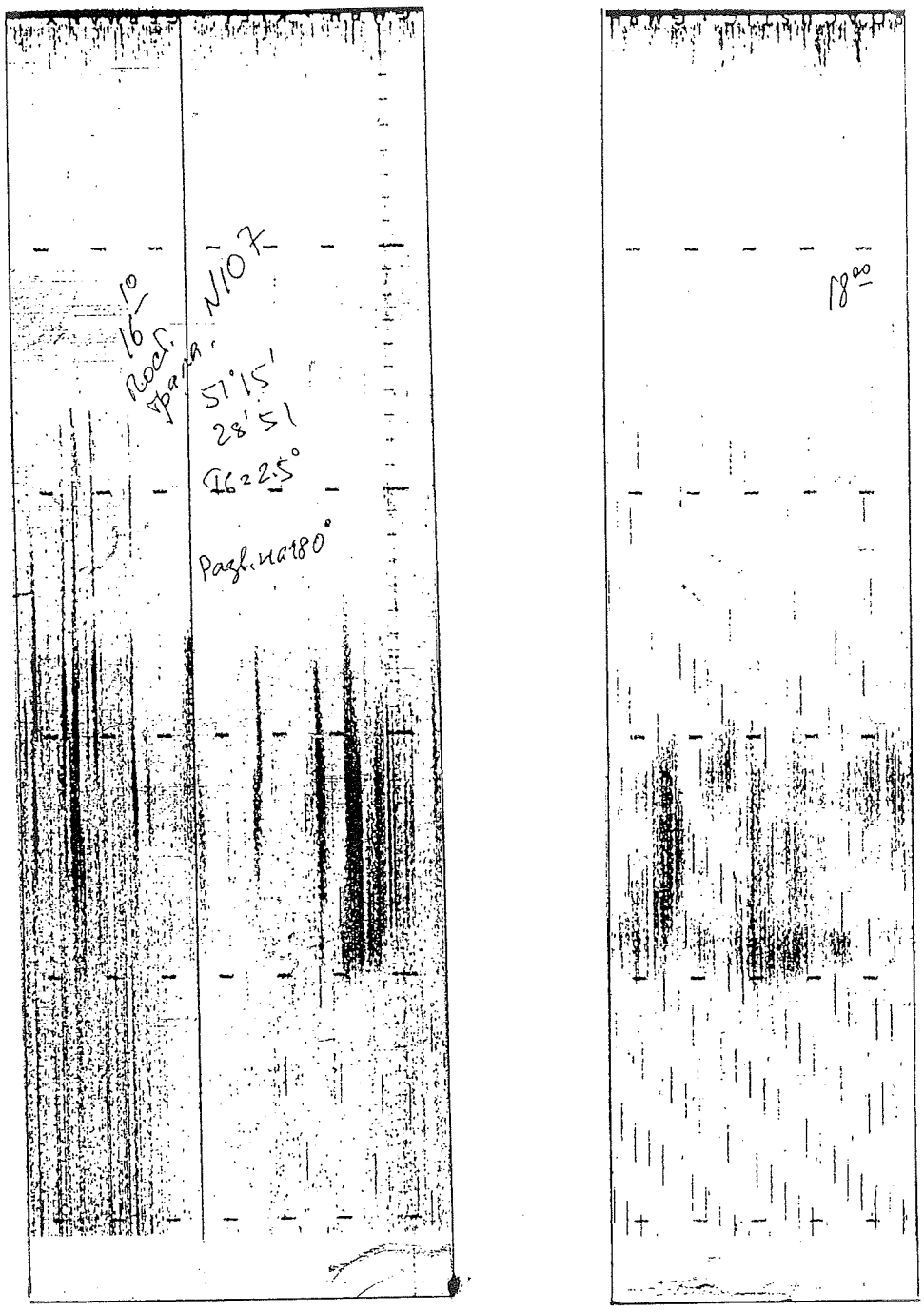
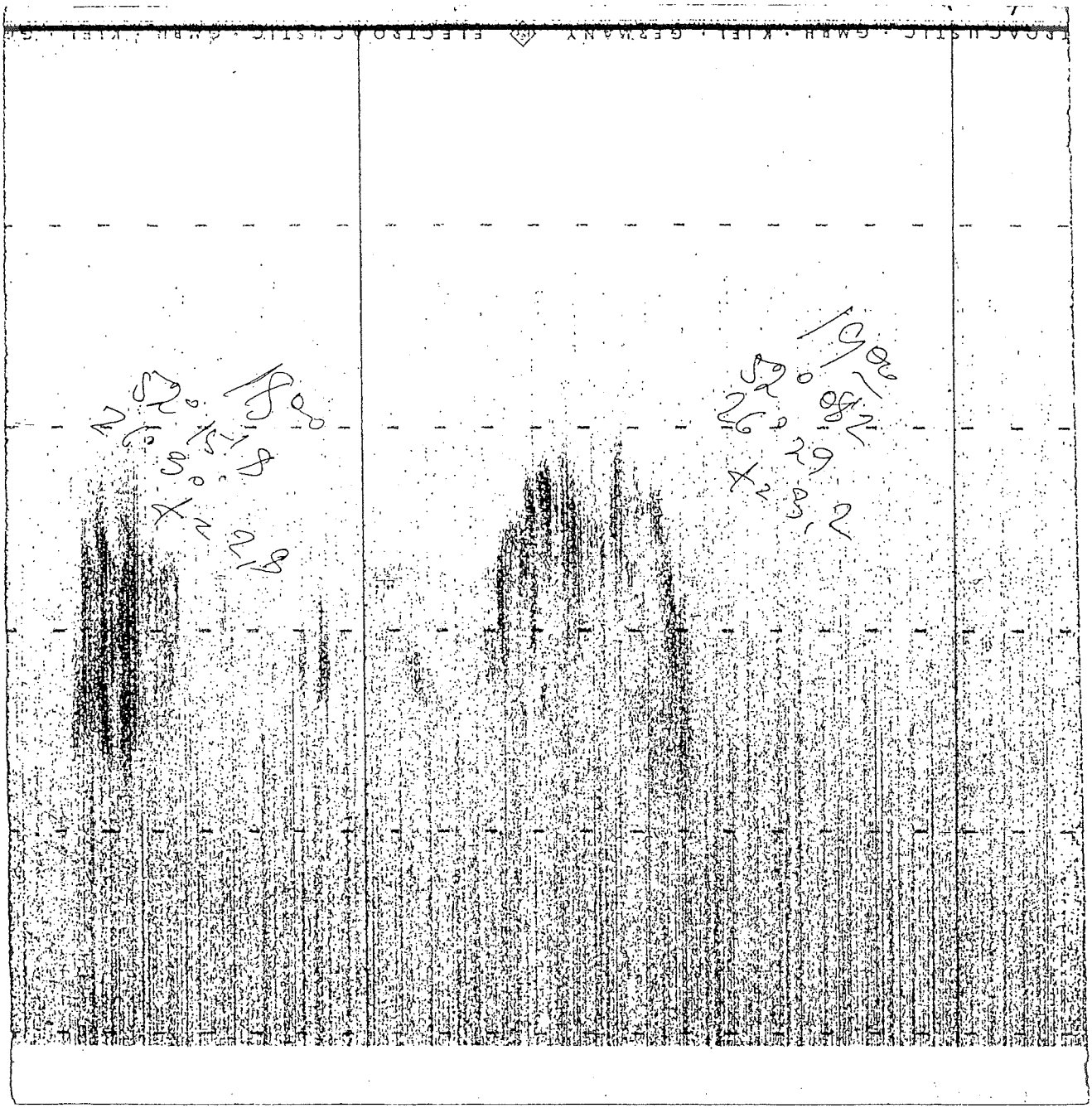


Figure 17: Echochart of haul No. 107.

At 16:10	surface density	$\bar{P}_s$=36.2 tonne/mile^2
	density by volume	$\bar{P}_v$=0.01 specimens/m^3 or 0.08 g/m^3.
At 18:00	surface density	$\bar{P}_s$=30.3 t/mile^2
	density by volume	$\bar{P}_v$=0.007 specimens/m^3 or 0.056 g/m^3.



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Densité moyenne en surface $\bar{P}_s$=51.9 t/mille^2

Densité moyenne par volume $\bar{P}_v$=0.04 spécimens/m^3 ou 0.32 g/m^3

Figure 14: Enregistrement acoustique typique des concentrations d'*E. carlsbergi* pendant l'après-midi et la soirée.
Changement de densité de surface:
à 17h00 - P_S = 25.8 tonnes/mille^2; à 19h00 - P_S=24.4 tonnes/mille^2.
Changement de densité par volume:
à 17h00 - P_V=0.03 spécimens/m^3 ou 0.16 g/m^3.

Figure 15: Enregistrement acoustique typique des concentrations d'*E. carlsbergi* pendant la matinée et de jour.
Changement de densité de surface:
à 7h00 - P_S =26.1 tonnes/mille^2; à 12h00 - P_S=24.8 tonnes/mille^2.
Changement de densité par volume:
à 7h00 - P_V=0.01 spécimens/m^3 ou à 12h00 - P_V= 0.02 spécimens/m^3 ou 0.16 g/m^3.

Figure 16: Enregistrement acoustique typique des concentrations d'*E. carlsbergi* pendant la matinée et de jour.

A 8h00	densité de surface	$\bar{P}_S$ =17.7 tonnes/mille^2;
	densité par volume	$\bar{P}_V$=00007 spécimen/m^3 ou 0.056 g/m^3.
A 18h00	densité de surface	$\bar{P}_S$ =18.0 tonnes/mille^2
	densité par volume	$\bar{P}_V$=0.01 spécimen/m^3 ou 0.08 g/m^3.

Figure 17: Enregistrement acoustique du trait № 107.

A 16h10	densité de surface	$\bar{P}_S$ =36.2 tonnes/mille^2;
	densité par volume	$\bar{P}_V$=0.01 spécimen/m^3 ou 0.08 g/m^3.
A 10h00	densité de surface	$\bar{P}_S$ =30.3 tonnes/mille^2
	densité par volume	$\bar{P}_V$=0.007 spécimen/m^3 ou 0.056 g/m^3.

Figure 18: Enregistrement acoustique nocturne typique d'*E. carlsbergi*. Aucune évaluation de densité ni aucun chalutage n'a été effectué dans ce cas.

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удельной плотности:
в 7.00 - P_V=0,01 шт/м^3 в 12.00 - P_V=0,02 шт/м^3 или 0,16 г/м^3.

Рисунок 16: Запись *E. carlsbergi* в утренние и дневные часы.
в 8.00: поверхностная плотность -$\bar{P}_S$=17,7 т/миля^2
удельная плотность - $\bar{P}_V$=0,007 шт/м^3 или 0,056 г/м^3.
в 10.00: - $\bar{P}_S$=18,0 т/миля^2, $\bar{P}_V$=0,01 шт/м^3 или 0,8 г/м^3.

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в 16.10: поверхностная плотность - $\bar{P}_S$=36,2 т/миля^2
удельная плотность - $\bar{P}_V$=0,01 шт/м^3 или 0,08 г/м^3.
в 18.00: - $\bar{P}_S$=30,3 т/миля^2, $\bar{P}_V$=0,007 шт/м^3 или 0,56 г/м^3.

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Figura 13: Ecograma del lance No. 58

Densidad media de la superficie $\bar{P}_S$ =51.9 t/milla^2

Densidad media por volumen $\bar{P}_V$ =0.04 especímenes/m^3 ó 0.32 g/m^3

Figura 14: Ecograma típico de las concentraciones de *E. carlsbergi* durante la tarde y noche.
Cambio en la densidad superficial:
a las 17:00 hrs - P_S=25.8 t/milla^2; a las 19:00 hrs - P_S =24.4 t/milla^2.
Cambio de la densidad por volumen:
a las 17:00 hrs - P_V =0.03 especímenes/m^3 ó 0.16 g/m^3.

Figura 15: Ecograma característico de concentraciones de *E. carlsbergi* en las mañanas y en horas de luz.

Figura 16: Ecogramas de concentraciones de *E. carlsbergi* en las mañana y en horas de luz.
A las 8:00 hrs:

densidad superficial $\bar{P}_S$ =17.7 t/milla^2

densidad por volumen $\bar{P}_V$ =0.007 especímenes/m^3 ó 0.056 g/m^3.

A las 10:00 hrs:

densidad superficial $\bar{P}_S$ =18.0 t/milla^2

densidad por volumen $\bar{P}_V$ =0.01 especímenes/m^3 ó 0.08 g/m^3.

Figura 17: Ecograma del lance No. 107.
A las 16:10 hrs:

densidad superficial $\bar{P}_S$ =36.2 t/milla^2

densidad por volumen $\bar{P}_V$ =0.01 especímenes/m^3 ó 0.08 g/m^3.

A las 18:00:

densidad superficial $\bar{P}_S$ =30.3 t/milla^2

densidad por volumen $\bar{P}_V$ =0.007 especímenes/m^3 ó 0.056 g/m^3.

Figura 18: Ecograma nocturno característico de *E. carlsbergi*. En este caso no se efectuó arrastre ni se calculó la densidad.