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Ecological Studies of Conditions of Silver Hake Distribution on Nova Scotian Shelf Within the Framework of the USSR-Canada Program

by

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ABSTRACT

Results of ecological surveys of the Scotian Shelf carried out in June-August 1988 and aimed at exploration of environmental conditions influencing silver hake distribution are presented. The surveys were carried out by the Soviet ship "Strelnya" in accordance with the USSR-Canada program of fisheries research. The program involved meteorological, hydrological, hydrochemical, hydrobiological and ichthyological observations. Two surveys of the shelf slope, one survey covering the entire shelf and 8 surveys of small shelf locations during the "patch" study were made during the cruise. Silver hake distribution was compared with the water temperature field geostrophic circulation, dissolved oxygen, phosphate and zooplanktonic food distribution. Hydrological conditions favourable to formation of feeding and prespawning aggregations were distinguished. Among those were the near-bottom temperature of 7-9°C, dynamic heterogeneities along the "shelf-slope" front, the zone of rising water and regions with increased phosphate content. The distribution of zooplanktonic food patches was found not always to be consistent with localization of silver hake aggregations. Possible reasons for this are considered.

INTRODUCTION

The silver hake is the main commercial fish in the licenced Soviet fishery on the Scotian Shelf. A narrow band of the outer shelf edge 100 m deep and deeper and the continental slope between 59° and 65°W are alloted for fishing operations.

The fishery is based on feeding and prespawning silver hake aggregations which are formed in the fishing groung in April-August. With the onset of massive spawning (June-August), the silver hake shoals migrate to the shallow waters and become inaccessible to fishing. Under such conditions, even small-scale spatial changes of the silver hake biotope may exert considerable influence on the distribution of the latter and, consequently, on the fishery success. The USSR-Canada program is aimed at identification of environmental factors responsible for the silver hake distribution, monitoring of most important of these, gaining data for constructing prognostic models and development of recommendations for optimum hake fishery. The research work employed the following hypotheses:

1. the silver hake abundance and the area of its aggregations in the fishing ground depend on its stock size;
2. formation of silver hake aggregations on the slope during the feeding period in April-June depends on optimum temperature conditions arising under the influence of hydrological front "shelf-slope". Near-bottom temperature gradient ranging from 6° to 10°C can be considered as the index of such conditions;
3. stability of aggregations depends on the distribution of food organisms, food composition and quantity in space;
4. quantity and distribution of food on the slope are dependent on the extent of cold and warm water advection onto the slope, fluctuations of hydrological front "shelf-slope" and peculiarities of mezoscale circulation on the slope;
5. dates of the silver hake spawning migration from the slope to shallow waters are governed by two factors at least: rates of gonad maturation and water temperatures on the slope and spawning grounds in the shallow waters.

To verify these hypotheses, the research was supplemented by the study of meteorological, oceanographic and hydrochemical parameters and zooplankton and silver hake sampling during ecological surveys of the shelf area and shelf slope and patch surveys (field observations).

In this paper the results of the first stage of the research carried out by the Soviet ship "Strelnya" in June-August 1988 are considered.

MATERIALS AND METHODS

Ecological surveys were carried out during prespawning and spawning periods. Two surveys of the slope between 59° and 64°W (June and July), one survey of the Scotian shelf (August) and eight surveys of three shelf slope locations were made. Survey schemes are shown in figs. 1A, 4A, 7 and 18.

Meteorological observations were made by traditional techniques using aneroid barometer, psychrometer and anemometer.

Oceanographic measurements and water sampling from standard horizons were made by Nansen bottles and deepwater thermometers.

The salinometer was used to determine the salinity, the phosphate content was determined by means of the photoelectro-calorimeter and the dissolved oxygen content by the Winkler's method.

The data on the phosphate and dissolved oxygen content were added to the complex of observations intended for the water indication in the three - layered structure of the shelf waters and indentification of the upwelling zones.

The plankton was sampled with the bongo plankton-sampler (smaller model) at the ship's speed of 3.5 knots by oblique sampling from the bottom to the surface in the layer of 0-200 m.

The zooplankton sample processing was limited by estimating the macrozooplankton biomass represented by the following species; Euphausiidae, Hyperiidae, Sagitta sp., Metridia lucens, Calanus finmarchicus and Copepoda. Distribution charts were plotted for the total biomass of the above-stated species, for Euphausiidae biomass and Calanus finmarchicus biomass. These charts were then compared with the silver hake distribution.

To sample the adult silver hake, a bottom trawl DT-TV 30/36 was used for research haulings of 30 minute duration. Catch processing involved massive measurements and biological analyses of the silver hake including sampling for feeding studies. The results of the analysis of the silver hake stomach content collected on board "Strelnya" will be presented individually.

Daily catch statistics was used to have an idea of the distribution of the silver hake commercial aggregations.

RESULTS

Oceanographic conditions and silver hake distribution

The analysis of the silver hake distribution relative to oceanographic conditions, which encompass water temperature fields, phosphate and dissolved oxygen content and circulation pattern showed that silver hake aggregations were formed in the shelf slope areas with the near-bottom temperature of 7-9°C along the boundary between the cold intermediate layer and near-bottom warm slope waters in the zone of the temperature and dynamic gradient.

Thus the commercial silver hake aggregations fished by the fleet in the first half of June actually represented a single big patch on the shelf slope between 61° and 63°W (fig. 1B) in the hydrological front zone with the near-bottom temperature of 7.2-9.5°C. The area was noted for the approach of a warm meander or eddy with the temperature of 10-12°C to the slope which resulted in the increase of the temperature gradient in the 100-200 m layer (fig. 1C). The rize of the water on the slope can be easily seen from the horizontal and vertical distribution of phosphates and dissolved oxygen (figs. 2A, B and 3). The areas of increased phosphate content and lower dissolved oxygen indices coincide with the location of the silver hake aggregation.

On the geostrophic circulation chart (fig. 2C), the commercial silver hake patch was located in the dynamic front zone between the above - shelf south-west oriented flow and offshore north-east oriented flow of the slope waters. The presence of a cyclonic eddy there was indicative of the development of upwelling processes on the slope.

Oceanographic conditions of the silver hake distribution during the second ecological survey dated 3-16 July were actually identical to those observed during the June survey though commercial aggregations did not form a single patch by that time and represented a few separate patches scattered above the slope (fig. 4C). The distribution of the research catches (fig.4B) taken both inside and outside the alloted fishing area coincided with the commercial silver hake patch distribution. The temperature, hydrochemical and dynamic characteristics of the waters around these patches were similar to those observed during the first survey (figs. 4C, 5 and 6). The silver hake abundance and density on the slope decreased due to migration to the Sable Island shallow waters in the end of June.

During the ecological survey carried out on 12-29 August, the observation complex involved the same characteristics as during the slope survey (fig. 7). Only research catches yielded some data on the silver hake distribution in August as no supplementary information was available due to cessation of the commercial fishery in mid-July. In fig. 8 showing the distribution of the research silver hake catches, two areas with the largest catch values can be distinguished. The first area is located between 62° and 63°W and shows three stations with relatively high catches taken on the slope, on western extremity of Emerald Bank and in the Emerald Deep. The second area is located between 60° and 61°30W and also shows three stations with high catches taken on the shelf slope, on the Sable Island shoal and northwestward of it. The near-bottom water temperature in these areas fluctuated between 6.7 and 9.1°C. Large catches were timed to the hydrological front "shelf-slope", to the boundary between the intermediate cold layer and warm bottom water and to the areas with warm near-bottom waters 100 m deep and deeper (fig. 9). Relative to phosphate and dissolved oxygen distribution, the largest silver hake catches were associated with the areas of increased phosphate and decreased dissolved oxygen content (figs. 10 and 11). As is evident from fig. 12 showing geostrophic circulation, these catches were timed to the dynamic front on the slope and the periphery and center of mezoscale anticyclonic eddies.

Silver hake and zooplanktonic food distribution

Large zooplankton makes up a considerable proportion in the silver hake diet forming at the same time the food base for some other fish species also eaten by the silver hake. So it can be assumed that there exists a relationship of the distribution of the latter and the zooplanktonic food distribution. As it has already been noted, the distribution of three macrozooplankton components, namely, the summed biomass of six largest and most abundant species, the Calanus finmarchicus biomass and the Euphausiidae biomass were considered to make the comparative analysis.

From the comparison of the zooplankton distribution and the distribution of commercial aggregations and research catches it can be inferred that in many cases the areas of commercial aggregations and large research catches coincided with the areas of the zooplanktonic food concentration of large density. During the June slope survey, the silver hake commercial aggregation was observed mostly "to greeze" on a dense zooplanktonic patch (> 500 mg/m^3) represented mainly by Calanus finmarchicus (fig. 13). However no such coincidence was recorded as to Euphausiidae.

On the July chart of the silver hake commercial aggregation distribution four zones of the fishing area can be identified which coincided with the zones of high zooplankton density (> 1000 mg/m^3) while the largest silver hake aggregation was timed to the zooplankton patch with the biomass exceeding 10000 mg/m^3 and reaching the maximum value of 23700 mg/m^3 in the center (fig. 14). As is evident from the figure, Euphausiidae predominated in the patch, and Calanus finmarchicus made up the bulk of the zooplankton in the rest of the survey area.

The comparison of the zooplanktonic food distribution field and the research catch size in August (figs. 15-17) showed that larger silver hake catches were mainly taken in the areas with larger zooplankton biomass (> 1000 mg/m^3). Such zooplankton concentrations occupied over half of the shelf area (fig. 15). As before, Calanus finmarchicus and Euphausiidae were predominant. Maximum concentrations of these species were observed near the slope south-westward of Sable Island (> 50000 mg/m^3) and in the eastern part of the area under investigation (20000 mg/m^3). It should be noted that only in the first and only case the largest silver hake catch was taken in the area of maximum concentration of Euphausiidae. The peculiarity of distribution of these forms in August was manifested in that their larger concentrations occurred over the outer shelf edge and in the inshore zone. Euphausiidae were not common in the central

part of the shelf. Unlike Euphausiidae, Calanus f. formed large concentrations on the shelf and in the inshore zone occurring in insignificant numbers on the slope in the front area.
The August survey demonstrated that sometimes large silver hake catches were taken at low concentrations of the zooplanktonic food (for example, the slope part at 62°W) and, on the contrary, the silver hake was not available in the catches despite large zooplankton concentrations (eastern extremity of the survey area). In such cases, specific oceanographic conditions were the main factor governing the silver hake distribution. A large silver hake catch in the first case was taken along the hydrological front at the temperature range typical of the silver hake. In the second case, the area of large zooplankton concentration was occupied with cold waters of the intermediate layer usually avoided by the silver hake (fig. 9). The absence of the zooplanktonic food in the silver hake habitat can be explained by the fact that it may be eaten out by the silver hake or the other fish. Besides, as circulation exerts a strong influence on the zooplankton drift and the distribution of the latter is characterized by patchiness of distribution, food patches and silver hake aggregations do not always coincide. Thus the review of the results of the analysis of the silver hake, zooplanktonic food and oceanographic characteristic distribution shows that some of the above-stated hypotheses are corraborated. Indeed, the feeding and prespawning silver hake aggregations are formed in the gradient zone at the temperature of 7-9°C along the boundary between warm slope waters and cold intermediate layer. The existence of the dynamic front along the slope and upwelling processes promote formation of the zooplanktonic food "patches" there and associated silver hake aggregations. The July and August surveys showed that compared to June, the silver hake concentrations on the slope sharply decreased and the silver hake moved to the shelf parts having charcteristic temperature and dynamic conditions. In 1988, the spawning silver hake migration began late in June-early in July and was maily caused by massive transition of the females to the spawning stage.

"Patch" studies

Two approaches can be used to make observations of environmental conditions responsible for formation and dispersion of a commercial aggregation. The observation can be started either in the area devoid of any aggregation and then record its appearance there or find the area with an aggregation and carry out surveys of that area until the aggregation moves away or disperses. We preferred the second option, as prior to the beginning of the works in June we had possessed the information on the distribution of the areas with commercial silver hake aggregations, where the fleet had operated. "Patch" studies were made in three slope parts (fig. 18). The area of each was 25 x 30 miles. Three transects in normal to the slope with the in-between distance of 10-15 miles were made in each area. Four stations 7-10 miles apart were occupied along each transect. The areas with silver hake aggregations were selected based on the information provided by the fishing fleet or on the research trawling data for the previous slope survey.

Carrying out of as many surveys of the selected area as possible is the main condition of the "patch" study. This allows for continuous control of the change and succession of situations in the environment and of the distribution of the object of interest. To meet this condition, quick-operating oceanographic instruments are required, which, unfortunately, are missing on board our ships. The complex of "patch" observations was limited by the water temperature measurements using the thermobathygraph and deep-water thermometers (sometimes disposable XBTs were used), and zooplankton sampling with small bongo model. The duration of one survey was 1.5-2 days.

Three successive surveys of the first area were made from 19 to 24 June. By the moment of the first survey planned for 19-20 June, two silver hake aggregations fished by commercial ships were detected in the survey area on the slope (fig. 19.1). Daily catches amounted to 29-47 tons. Both aggregations were located in the thermal front zone with the near-bottom temperature of 8-9°C. During the first survey, the front passed in parallel to the slope. The larger silver hake aggregation occupied the south-western angle of the survey area, and the smaller one kept to the mid-shelf.

During the second survey on 21-22 June, the temperature front outline changed having curved shorewards (fig. 19.2). At that time the temperature gradient intensified in the western and eastern parts of the survey area and weakened in the center. Simultaneously the size and density of the western aggregation increased, and the second aggregation moved eastwards, where intensification of the temperature gradient was recorded.

During the third survey on 22-24 June (fig. 19.3), the temperature front resumed its position parallel to the slope, which resulted in equalizing the tempearture gradient along the entire slope section. At that time no commercial silver hake aggregations were observed in the survey area. Possible explanations can be that they either moved outside the survey area or were fished by the fleet. Thus, as noted above, it was another manifestation of a qualitative correlation between the distribution of the silver hake aggregations and the temperature front "shelf-slope".

When 3 situations of the zooplankton distribution are compared (figs. 19.4-19.12), the following peculiarities become evident. The analysis of the distribution of the total seston biomass (figs. 19.4-6) during the three surveys shows that the biomass increased during the second survey against the initial situation due to more dense patches in the west and east of the survey area. This might have favoured the increase of the hake patch during that period in the south-western corner and promoted the movement of the second silver hake patch to the east. If then the distribution of Calanus finmarchicus (figs. 19.7-9) and Euphausiidae (figs. 19.10-12) is considered, it will be obvious that the density of the zooplanktonic food in the west increased mainly due to appearance there of the Euphausiidae patch, and the increased density in the east was due to appearance of the Calanus f. patch. Unfortunately, the picture of the zooplankton distribution during the third survey is incomplete because of undersampling during the third survey in the western part of the survey area. Strengthening of the wind prevented completion of the sampling program. What can be noted is that considerable zooplankton density at that time in the eastern part of the area persisted due to Calanus f. To summarize the situation observed in the first survey area, we can state that the period from 19 to 24 June was noted for deformation of the temperature front with intensification of the temperature gradient in the periphery, where one silver hake patch increased in size, and the other moved from the center to the periphery. These processes were accompanied by the rize of the zooplanktonic food density due to appearance of the Euphausiidae patch in the west and Calanus f. patch in the east. Proceeding from the fact that the temperature conditions and high density of the zooplanktonic food during the third survey persisted at least in the eastern part, it can be assumed that the eastern silver hake patch was rather fished by commercial ships than moved outside the survey area.

The second survey area selected for "patch" study also had a commercial silver hake aggregation located on the slope westward of the first survey area (fig. 20). According to catch stations, the silver hake catches fluctuated from 16 to 53 tons per hauling day. From 24 to 28 June, we managed to make only two successive surveys of the area. The comparison of two successive situations disposed considerable differences between them. The temperature gradient on the slope was more intensive during the first survey (fig. 20.1). At the temperature front, namely, at the point where the aggregation was recorded on the slope, a small shelf-oriented meander was formed. During the reiterated survey (fig. 20.2), the temperature gradient at the front appeared to be weakened, the meander destructed, the size of the silver hake aggregation reduced and its density decreased. The comparison of the zooplanktonic food and silver hake distribution (fig.20.3-7) did not reveal any significant correlation between the two. In the first situation, the silver hake aggregation did not coincide with the patch of maximum zooplankton density represented mainly by Calanus f. The closest to the silver hake aggregation was the Euphausiidae patch, but even that patch was located somewhat northwards of the aggregation (fig. 20.7). The second situation is a little bit obscure, for five stations failed to yield the zooplankton data. Strengthening of the wind to wind force 6 prevented from zooplankton sampling at these stations. Nevertheless, the available figures of the zooplankton distribution during the second survey suggest that the food base did not improve during that period (26-28 June), which might have caused diminution of the silver hake aggregation. The strengthening of the wind was evidently responsible for changes of temperature and feeding conditions in the second situation. To summarize the situation observed during the second survey, we can again state the existence of a qualitative relationship of the silver hake distribution and temperature conditions on the slope. To have a more general idea of the reasons that contributed to formation of aggregations on the slope, the analysis of the silver hake feeding must be made, for it is a factor having a direct influence on its distribution during the feeding and prespawning periods.

A series of surveys in the third area, located within approximately the same limits as the previous survey area, was carried out from 27 July to 10 August with a forced week's time interval from 30 July to 5 August. The correlation between the silver hake distribution and temperature conditions was most obvious during this period. The silver hake distribution plotted in figs.21.1-3 was based on half hourly research catch data. The silver hake aggregation in the south-eastern corner of the slope area, where the maximum catch constituted 150 kg, can be seen. During the first survey, the increased temperature gradient in the 100-200 m layer resulted from intrusion of the tongue of cold waters of the intermediate layer to warm slope waters and conditioned formation of the silver hake concentration on the slope. If the boundary of this tongue is timed to position of the 5°C isotherm, it will be seen that it occupied a considerable part of the area having intruded from the north-east, where the water temperature was below 4°C. During the next surveys, the advection of these cold waters weakened, the area limited by the 5°C isotherm reduced and the temperature increased. This resulted in weakening of the temperature gradient on the slope and simultaneous diminution of the aggregation. The research catches were very small and did not exceed 10 kg. Large catches (100 kg and greater) taken in the northern part of the area, in the shallow waters, are worth noting. They come from the silver hake spawning ground, where the bulk of the aggregation migrated to in the end of June. Due to technical reasons, the trawling at this station was not made during the first survey, however, we strongly believe that the spawning aggregation occurred there at that time as well.

The situations with the zooplanktonic food distribution (figs. 21.4-12) were identical to those observed during the second survey, namely, the zooplankton density was the lowest in the slope area occupied by the silver hake aggregation. This peculiarity was typical of all the three surveys and concerned both the seston biomass distribution and the distribution of *Calanus finmarchicus* and *Euphausiidae*. This lack of coincidence may have two explanations: either the silver hake fed on the fish (including small silver hake) or the survey speed lagged behind the speed of change of situations of the zooplankton distribution. To make these speeds meet, firstly it is necessary to resort to more efficient survey methods with the use of hydrographic probes and plankton samplers of MOCNESS and BIONESS type. Secondly, to provide a regular control of the silver hake aggregation dynamics the total amount of works during the survey must be divided between two ships having placed, say, control of the silver hake aggregation on one of them. The analysis of samples for silver hake feeding studies (Vinogradov, verbal communication) shows that the silver hake caught during the third survey fed on *Euphausiidae* though the distribution of the latter refutes this. Thus an assumption on the lack of correspondence between the speed of the survey and the speed of spatial variability of plankton fields seems to be more realistic.

DISCUSSION

When summarizing the results of the 1988 summer experiment on the study of the silver hake distribution conditions, i.e. the environmental factors contributing to formation and dispersion (movement) of its aggregations, it can be inferred that the silver hake strictly keeps to oceanographic conditions typical of its habitat. These conditions are formed on the shelf slope in frontal zone "shelf-slope" at increased temperature gradients with the near-bottom temperature of 7-9°C. The silver hake also forms aggregations on the shelf in places accessible to near-bottom warm waters with the above-stated temperature range (depths over 120 m) where they border upon cold intermediate layer. The analysis of hydrochemical indices shows that most likely locations for aggregation formation are those rich in nutrients and having minimum dissolved oxygen content. Nutrient content is a more convincing index of the two. As is evident from comparison of the silver hake distribution and the dynamic structure of the slope waters, the silver hake aggregations occupy a narrow band between two opposite directed flows: above-shelf south-west oriented and offshore north-east oriented flows. The shelf slope situated between these main flows is a quasi-stationary zone generating mezoscale cyclonic eddies, i.e. the zone of rising waters. This peculiarity becomes still more important during the spring-summer increase of the zooplanktonic food and related formation of feeding silver hake aggregations on the slope. The August survey shows that, the silver hake aggregations on the slope are associated with the boundaries of the warm water advection in the deepwater part of the shelf and with heated waters of the upper layer in the spawning ground westward of Sable Island.

The analysis of locations of fields of the zooplanktonic food and silver hake aggregations very often revealed the lack of correspondence. This correspondence was a more usual case during the surveys of the slope and shelf, but was almost lacking during the "patch" studies. One of the reasons for this may be inefficiency of "patch" studies when only one ship is used under rapidly changing environmental conditions. In this context, it would have been desirable to use quick-operating oceanographic instruments at the next research stage, and to divide the observation series between the Soviet and Canadian ships.

ACKNOWLEDGEMENTS

I am most grateful to N.N.Reshetnikova and T.G.Kórolkova for large and tedious work on processing zooplankton samples collected during the "Strelnya" cruise and estimating the biomass of zooplankton components.

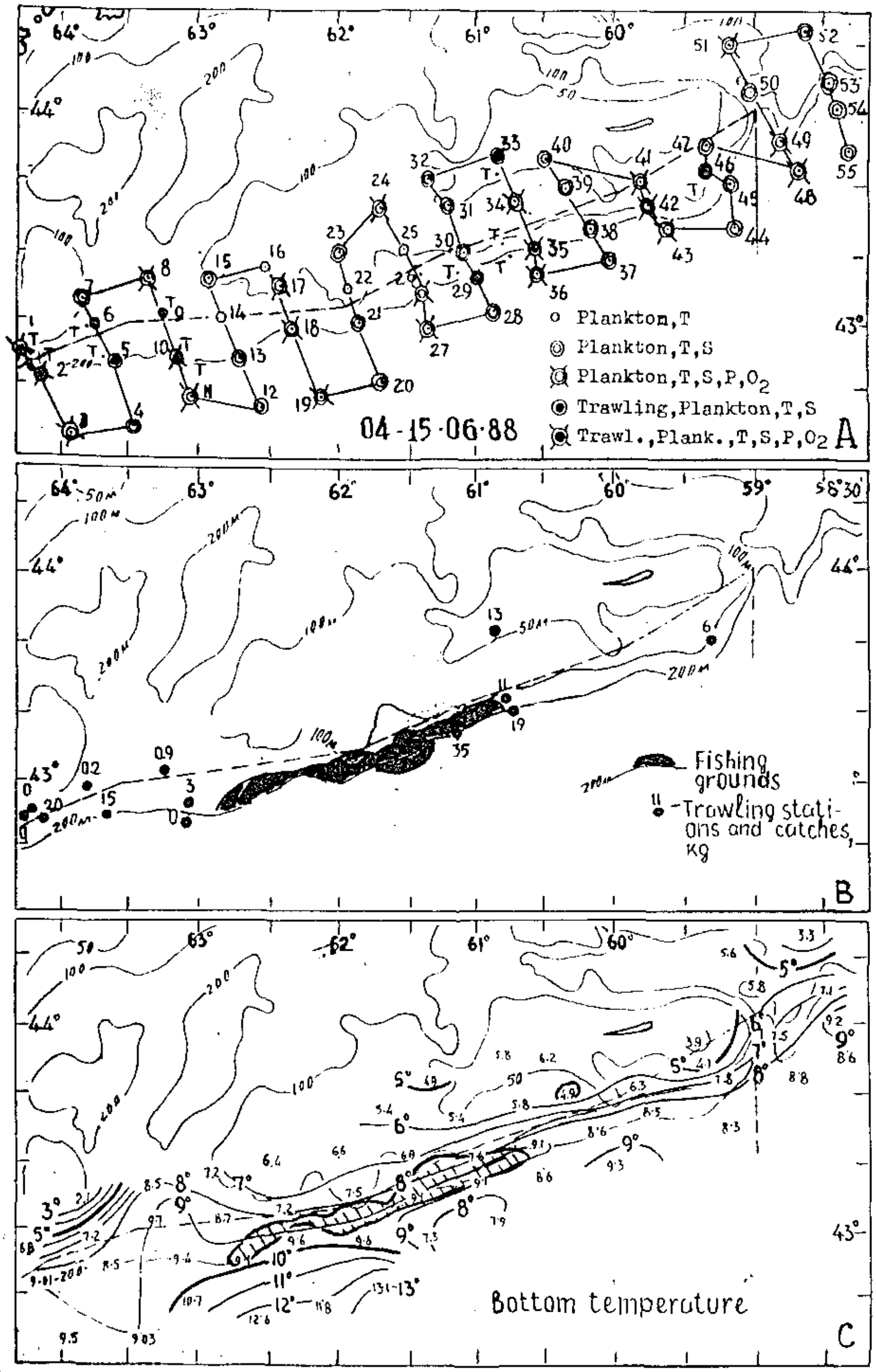

Fig. 1. Scheme of stations (A), distribution of silver hake commercial aggregations (B) and near-bottom water temperature (C) during the slope survey on 4-15 June 1988.

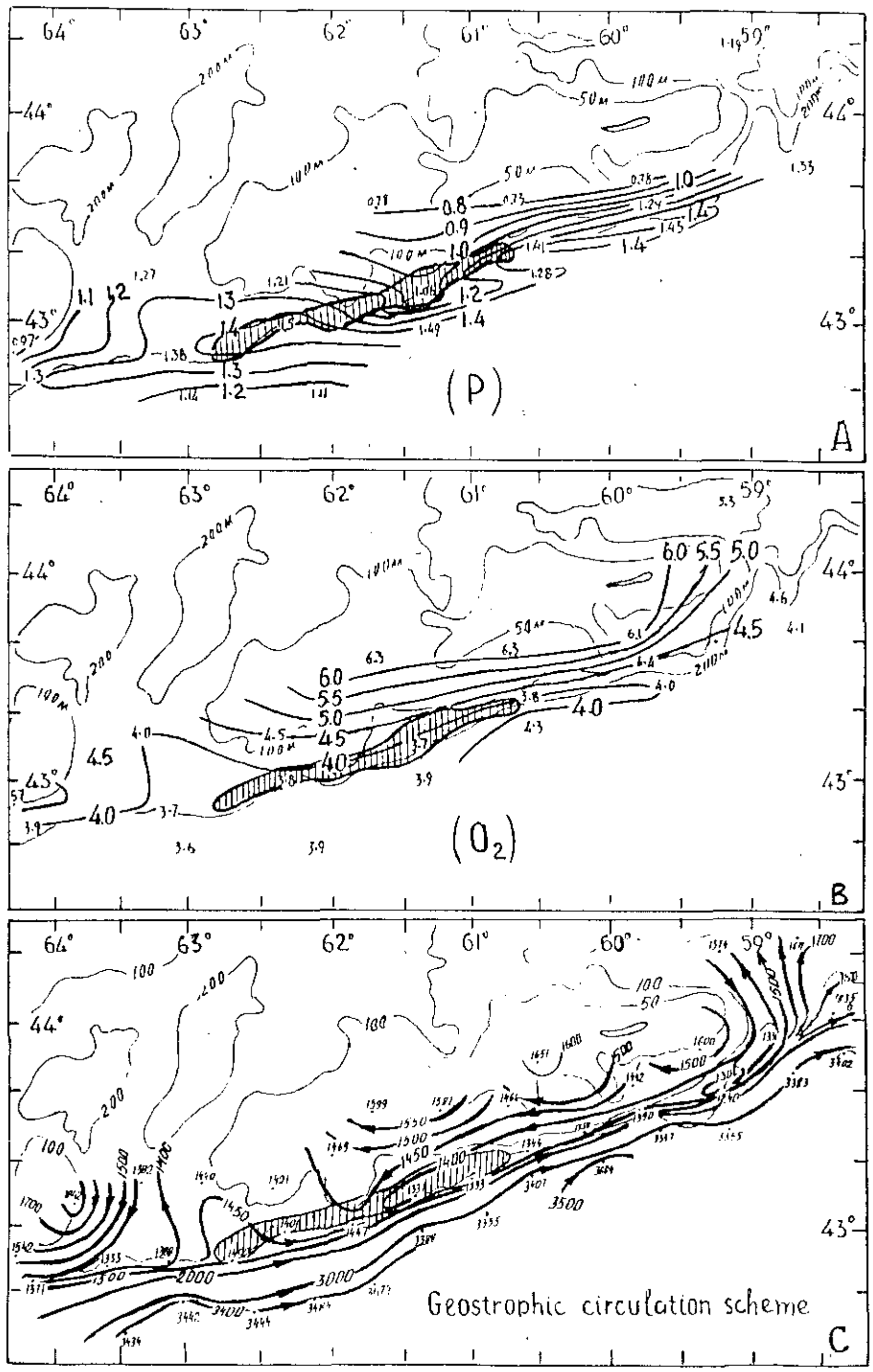

Fig. 2. Distribution of phosphates (A), dissolved oxygen (B) and geostrophic circulation on the slope on 4-15 June 1988.

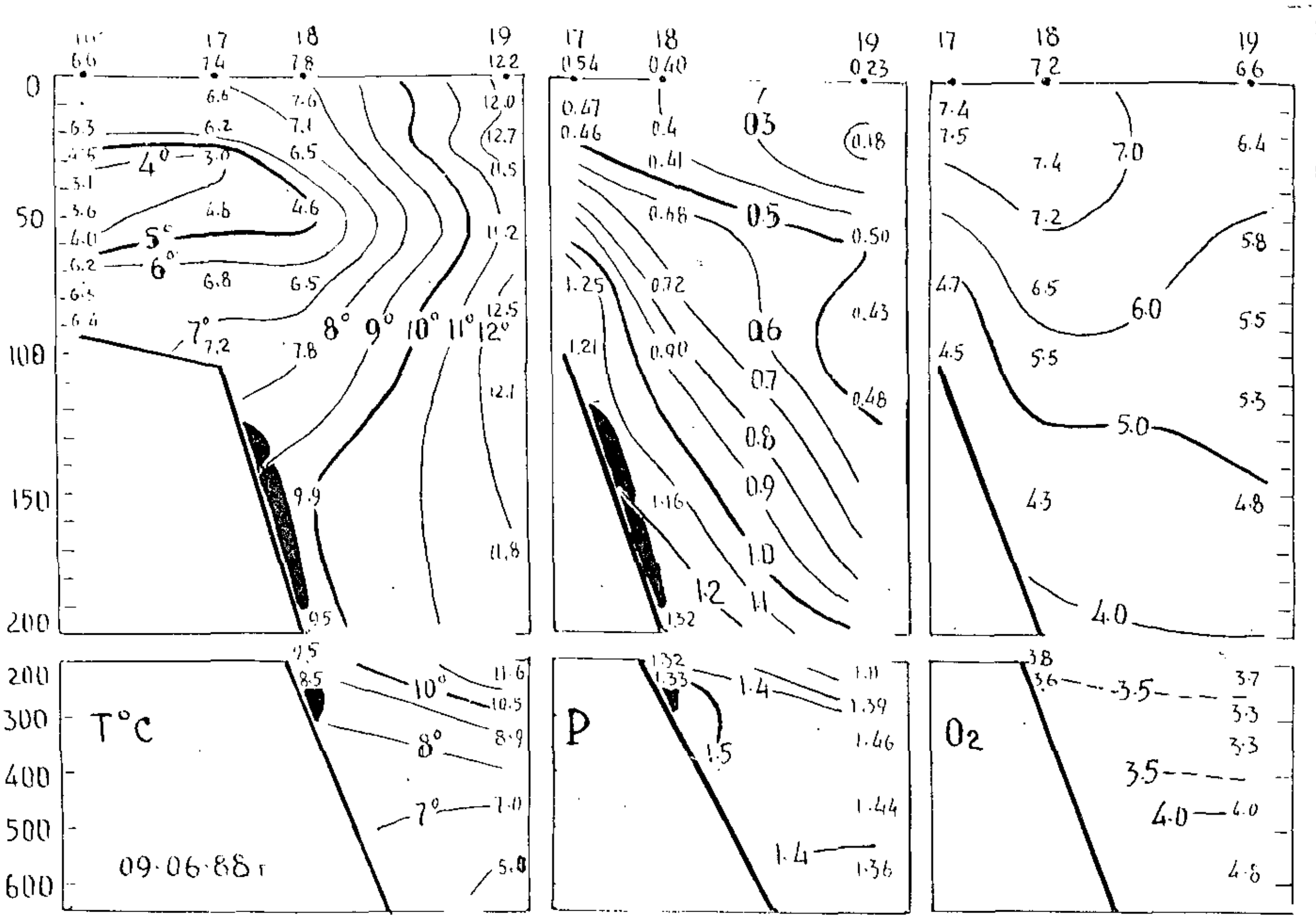

Fig. 3. Vertical distribution of temperature, phosphates and dissolved oxygen in the area of commercial aggregation on 9 June 1988.

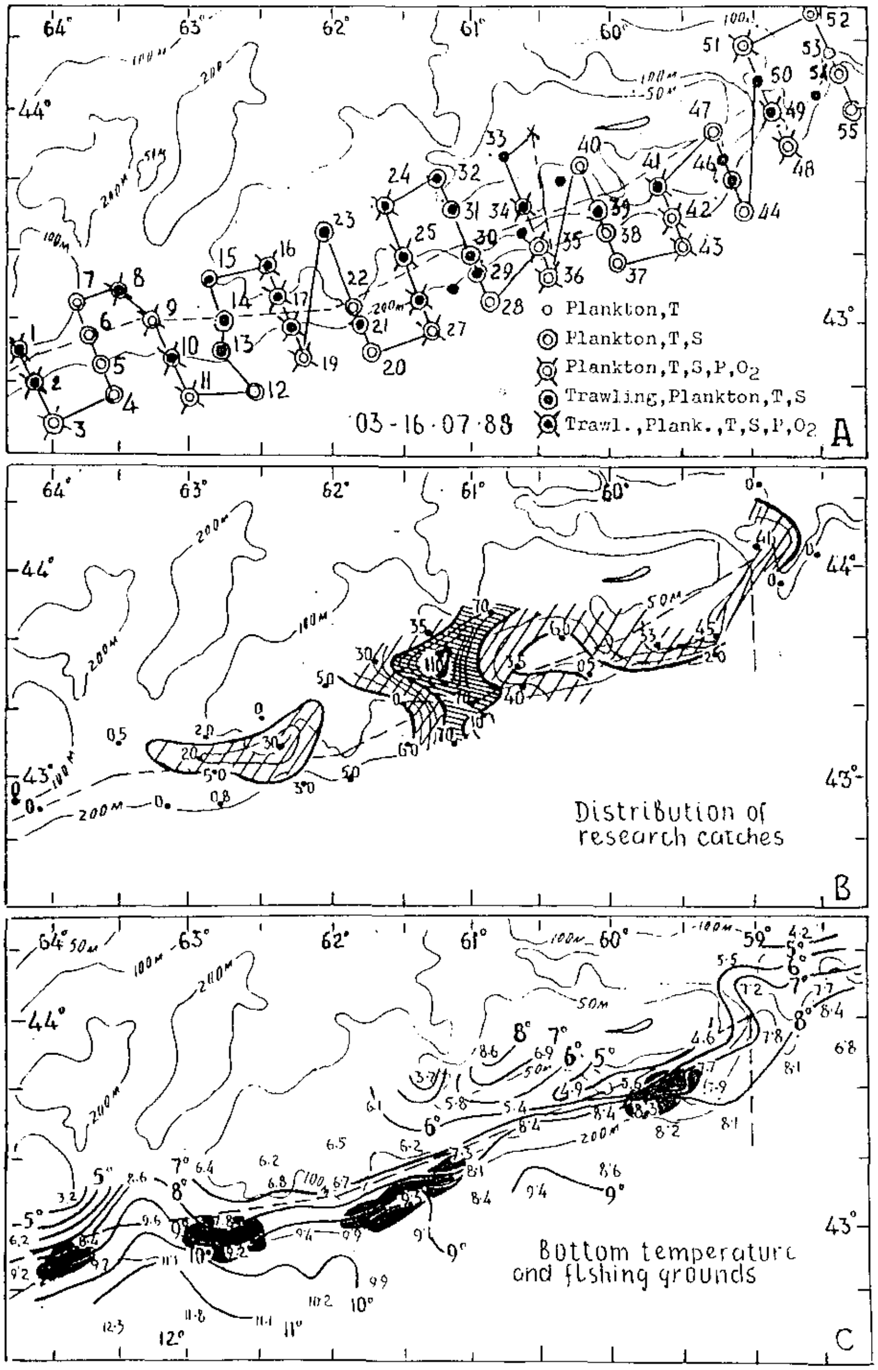

Fig. 4. Scheme of stations (A), distribution of research catches (B) and commercial silver hake aggregations in the near-bottom water temperature field (C) on 3-16 July 1988.

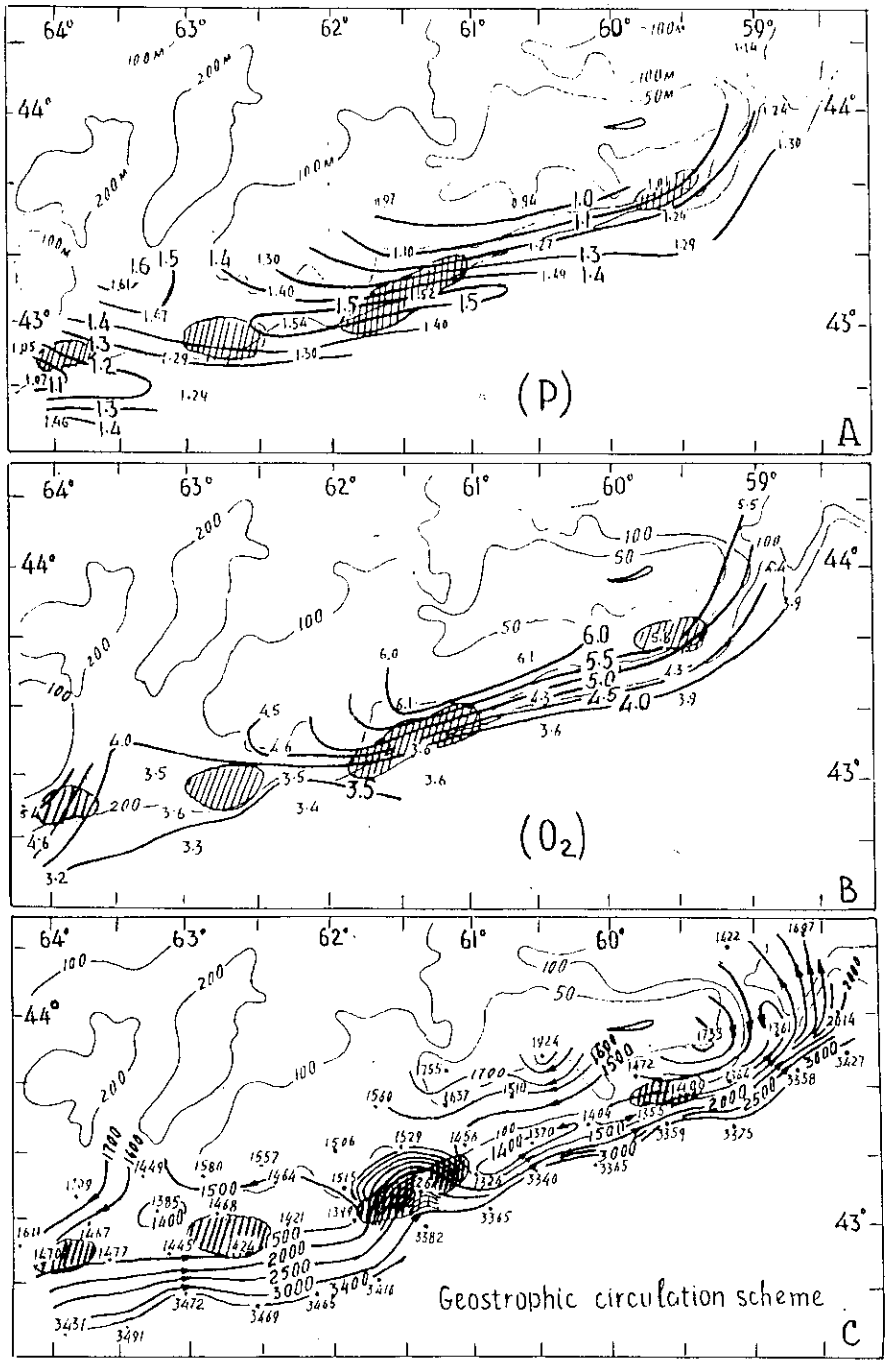

Fig. 5. Distribution of silver hake commercial aggregations in the field of near-bottom distribution of phosphates (A), dissolved oxygen (B) and geostrophic circulation (C) on 3-16 July 1988.

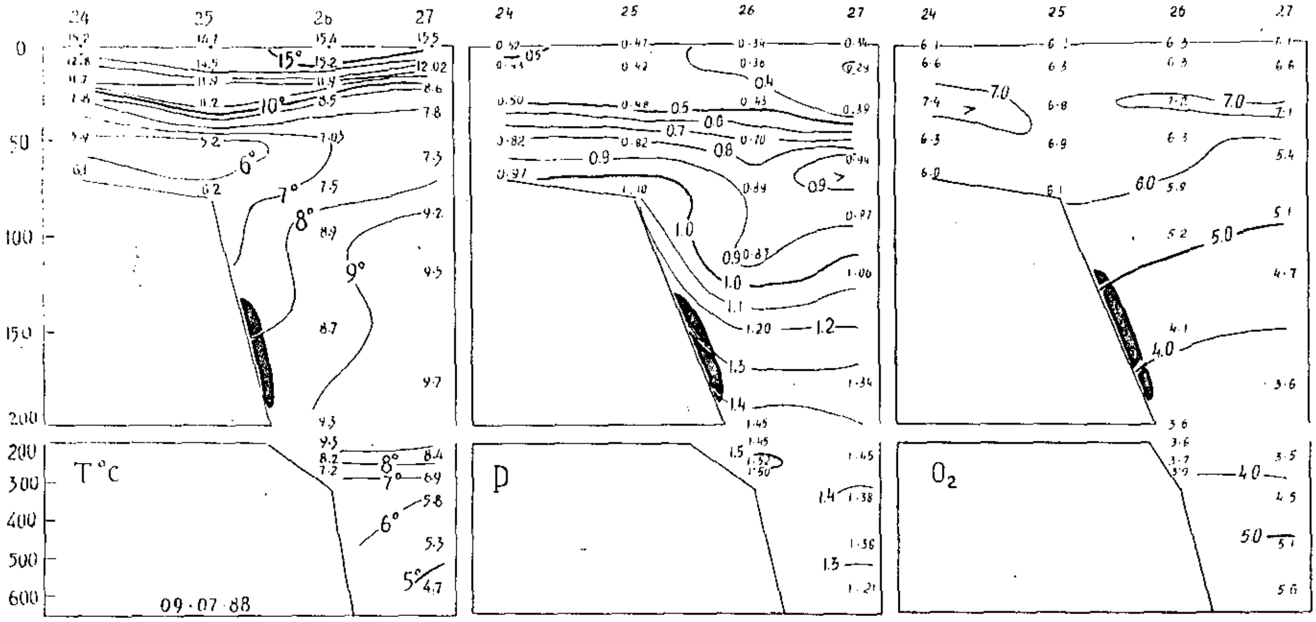

Fig. 6. Vertical distribution of temperature, phosphates and dissolved oxygen in the area of silver hake aggregation on 9 July 1988.

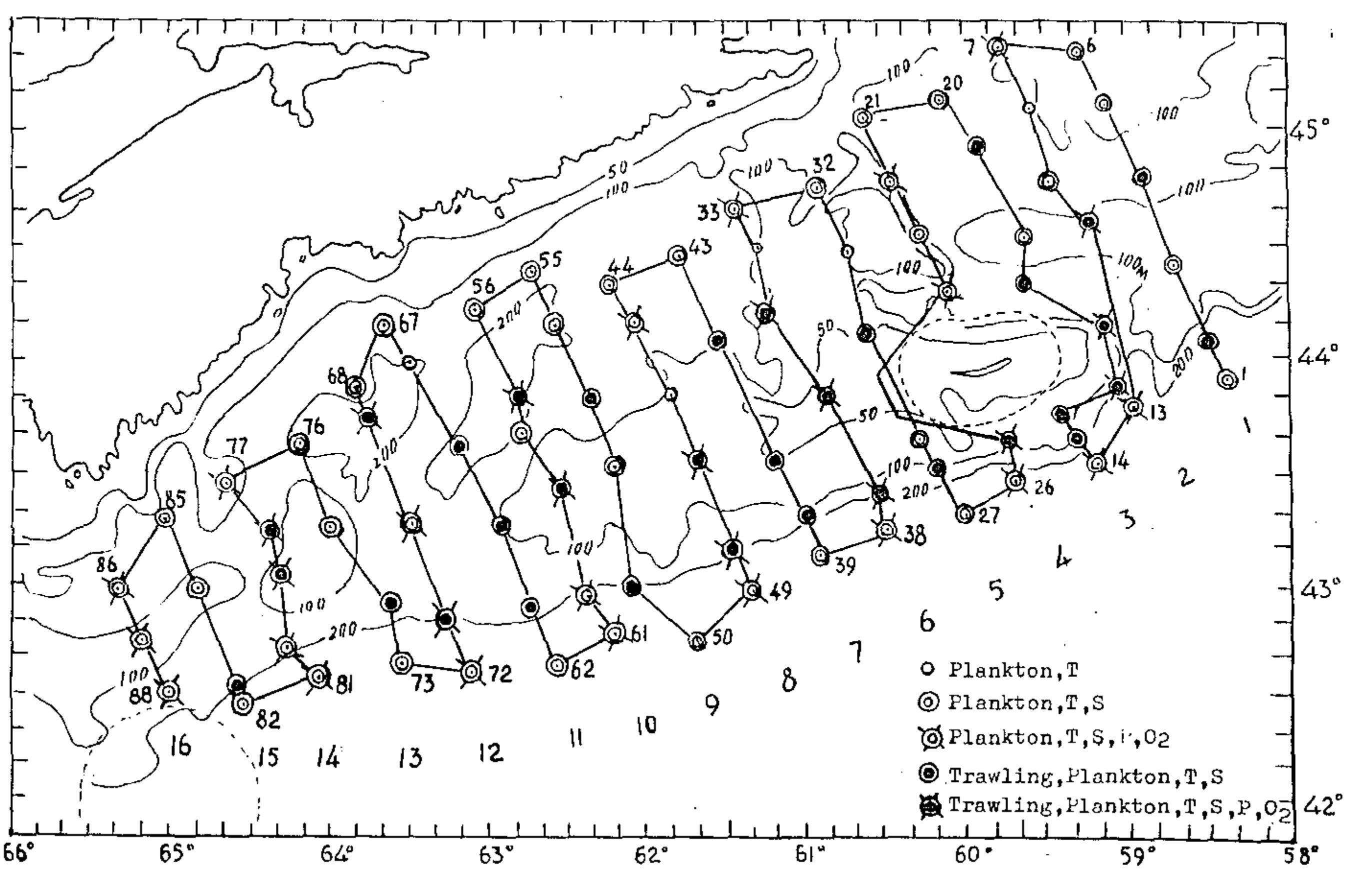

Fig. 7. Scheme of stations during ecological survey of the Scotian Shelf area on 12-29 August 1988.

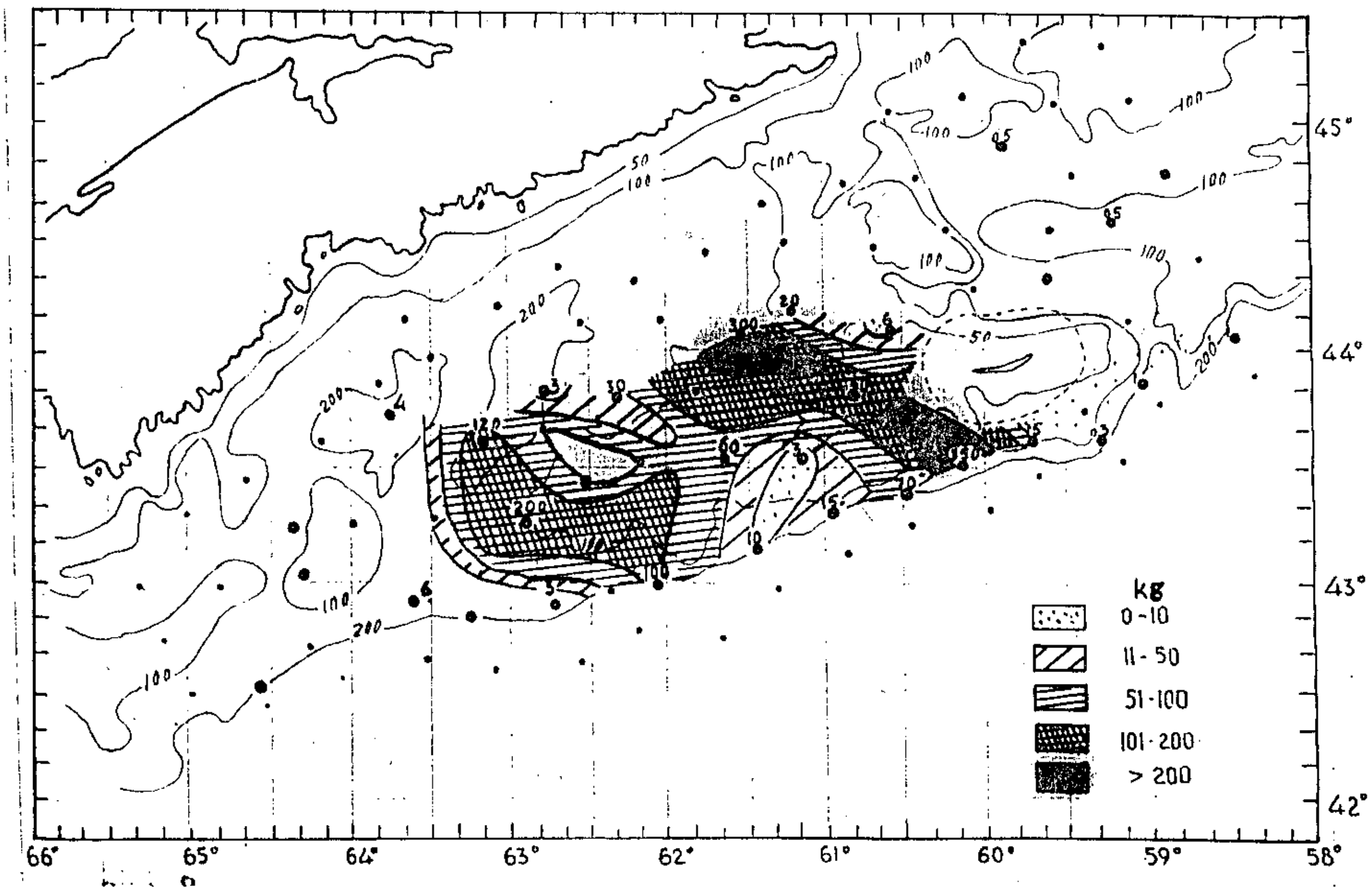

Fig. 8. Distribution of silver hake research catches (kg) on 12-29 August 1988.

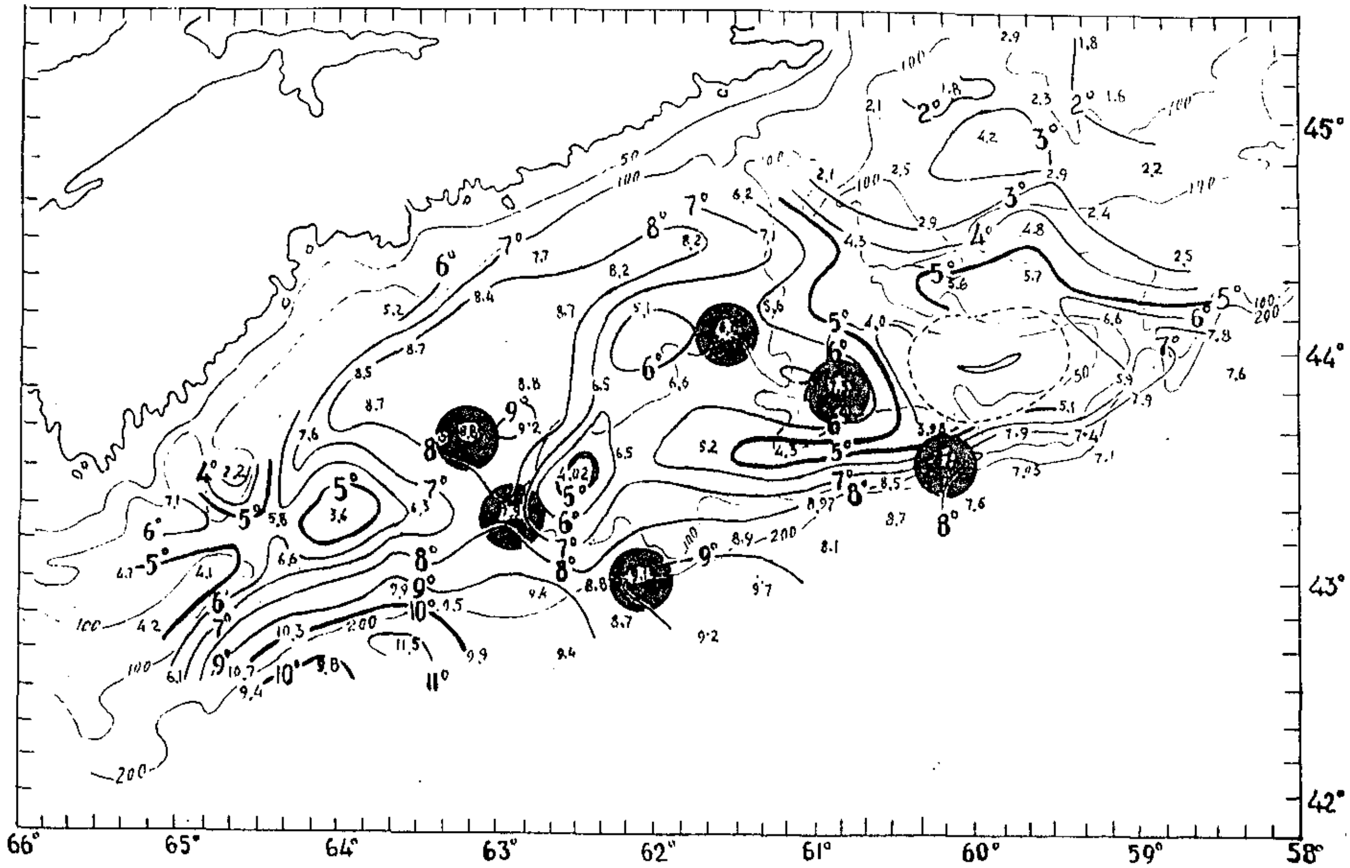

Fig. 9. Distribution of near-bottom water temperature and largest research silver hake catches on 12-29 August 1988.

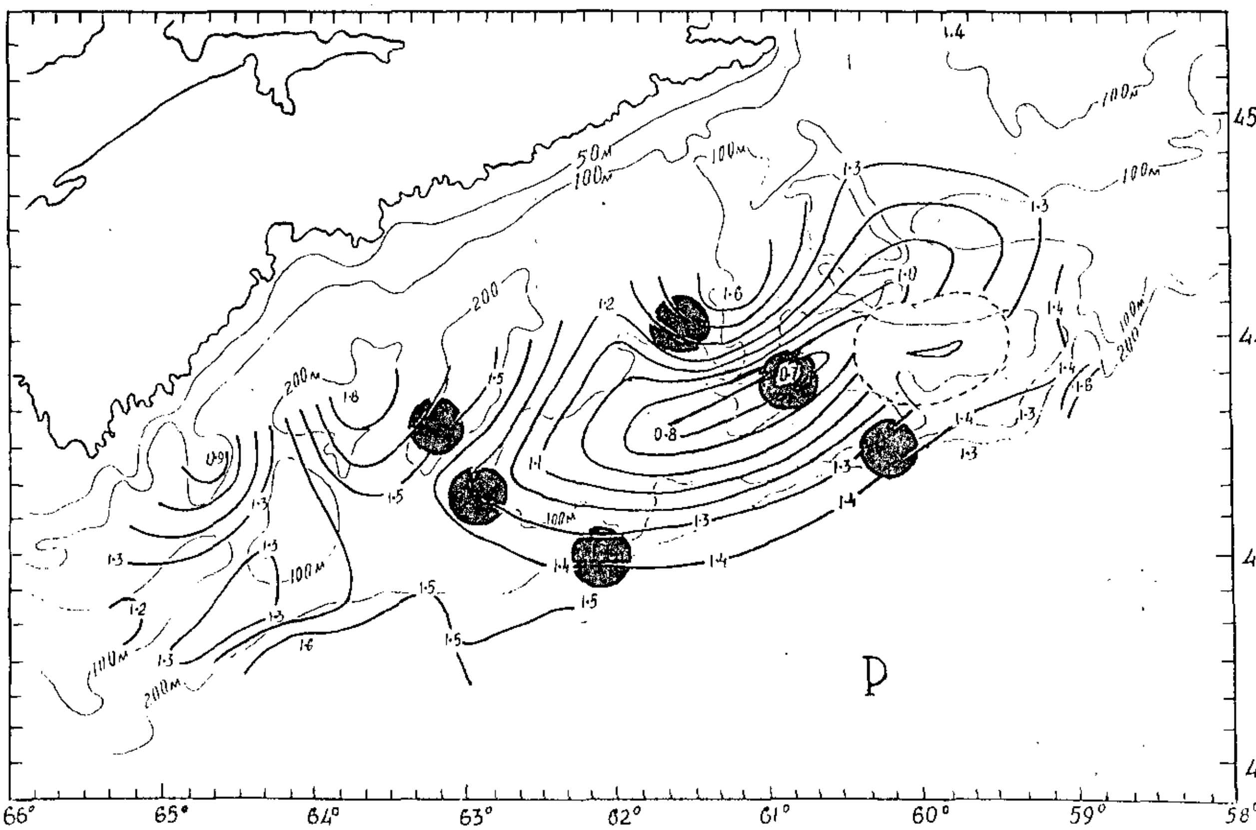

Fig. 10. Distribution of phosphates near the bottom and of largest research silver hake catches on 12-29 August 1988.

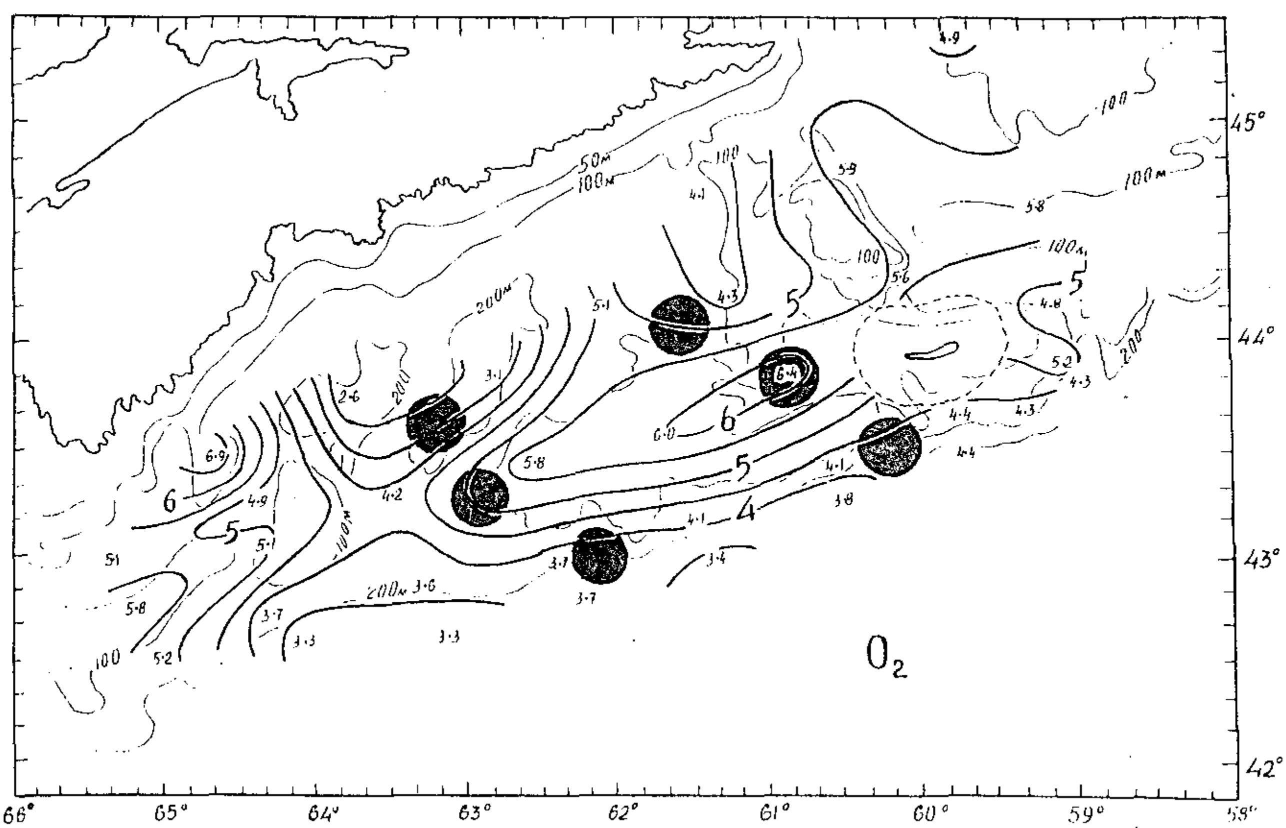

Fig. 11. Dissolved oxygen and largest research silver hake catch distribution on 12-29 August 1988.

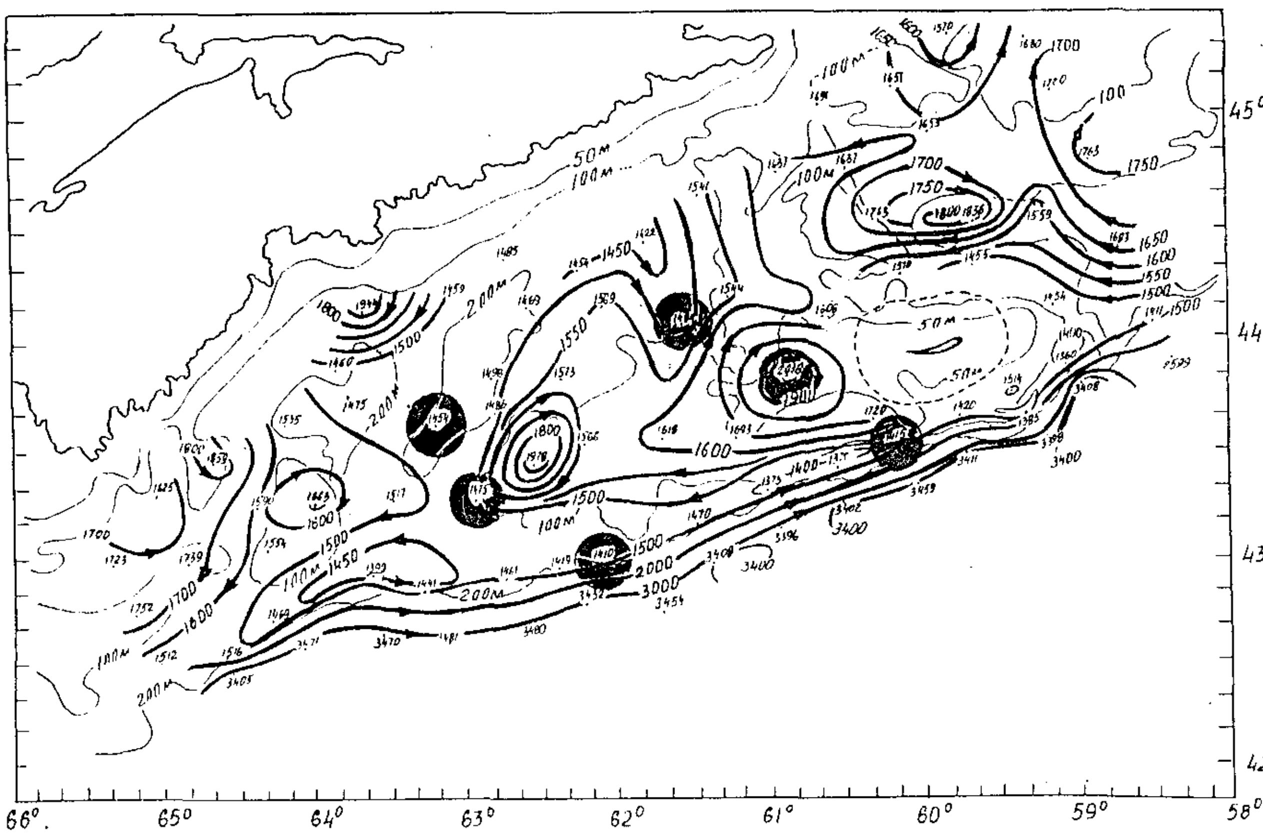

Fig. 12. Geostrophic circulation field and distribution of largest silver hake catches on 12-29 August 1988.

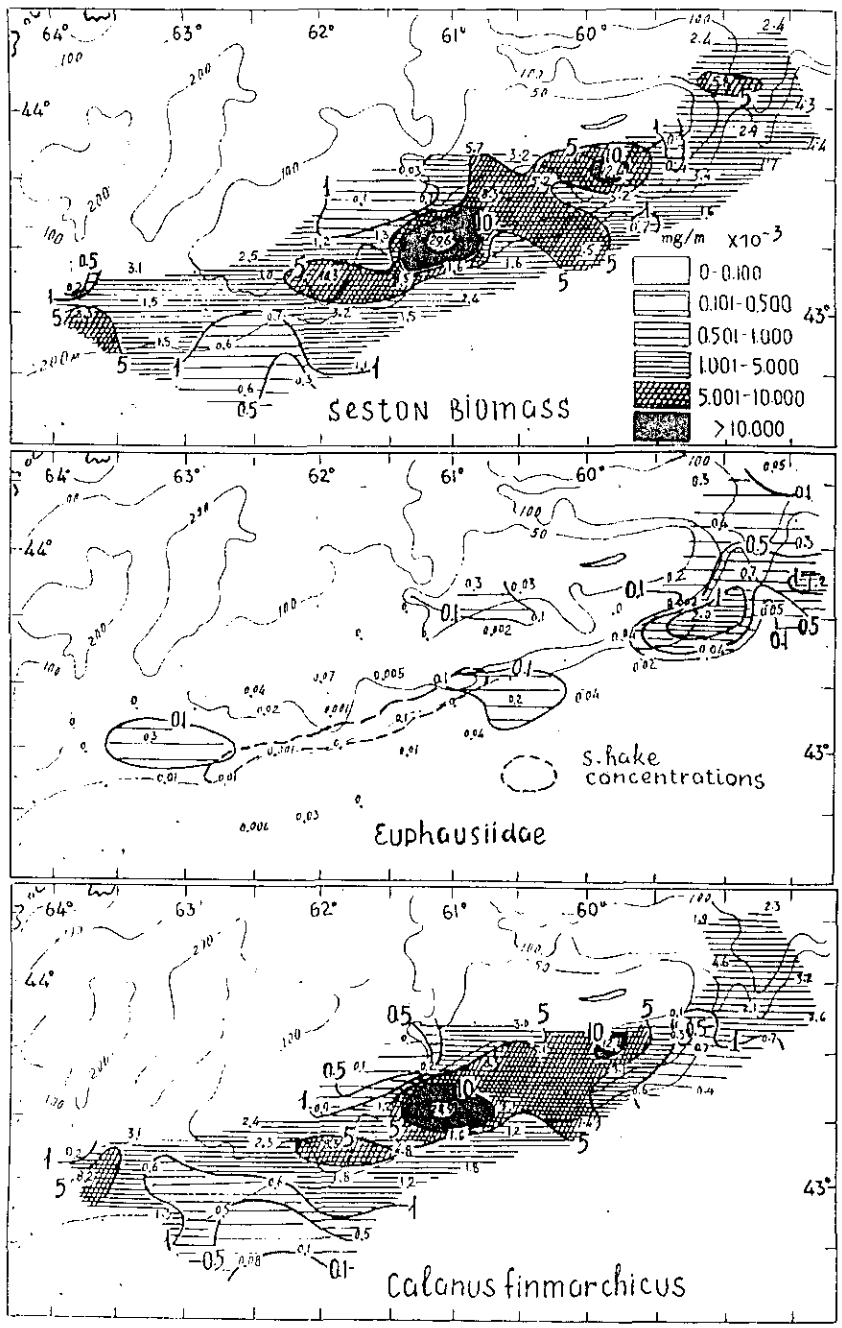

Fig. 13. Zooplanktonic food distribution on the shelf slope on 4-15 June 1988.

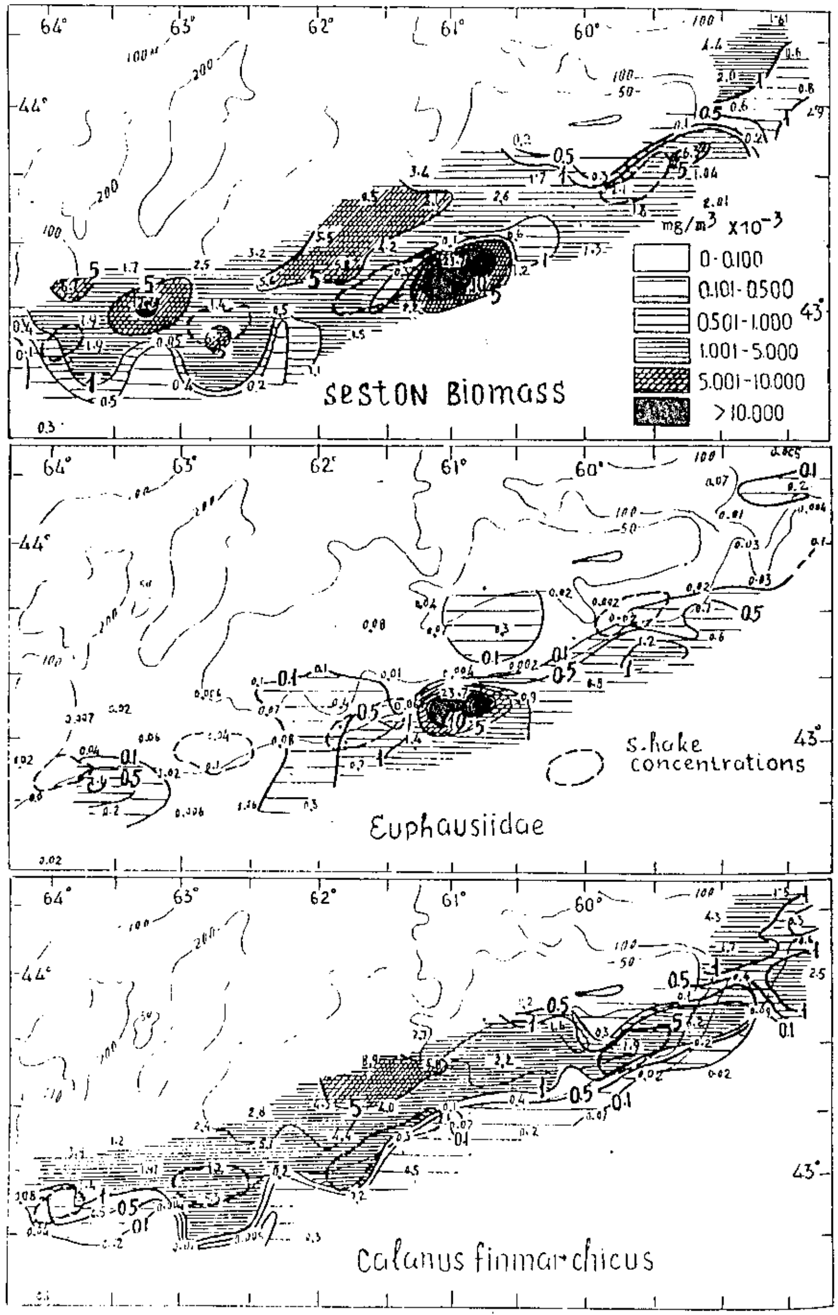

Fig. 14. Zooplanktonic food distribution on the shelf slope on 3-16 June 1988.

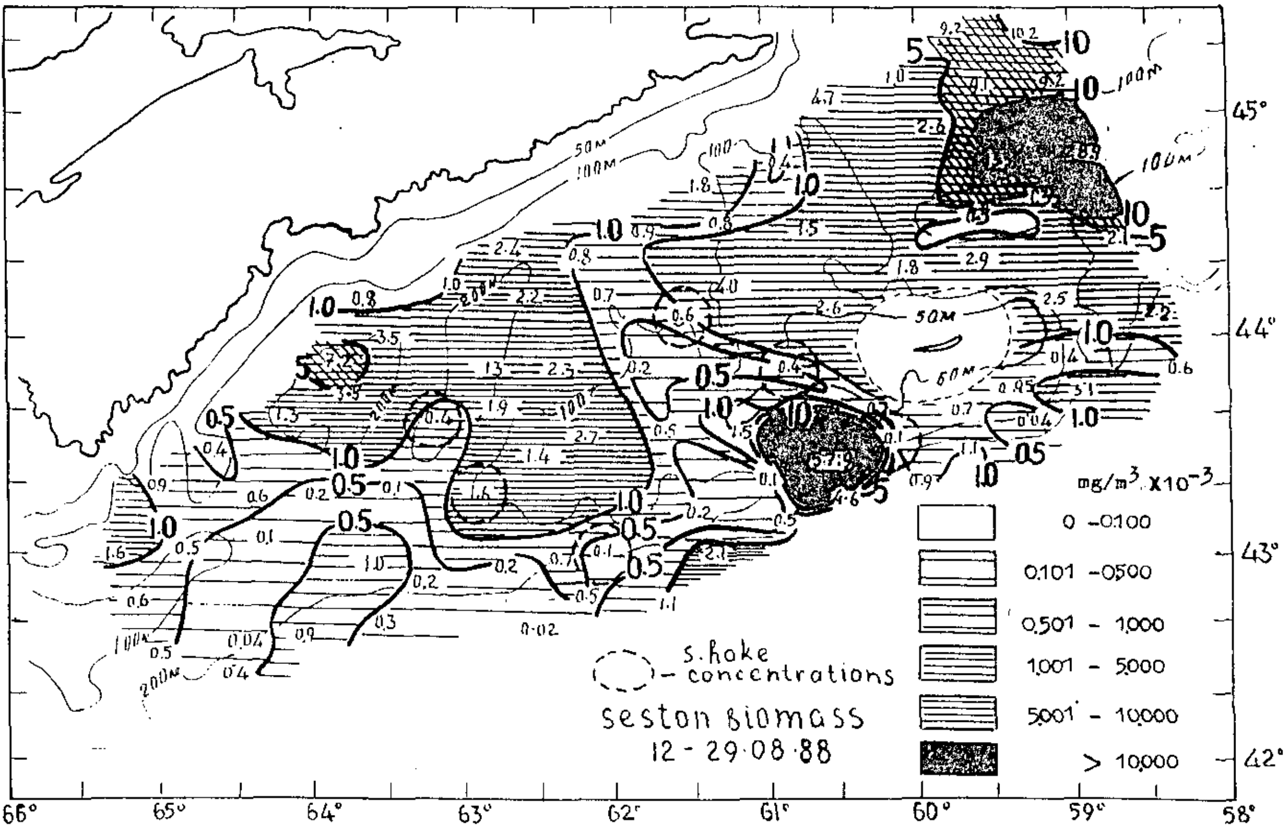

Fig. 15. Distribution of seston biomass on the Scotian Shelf on 12-29 August 1988.

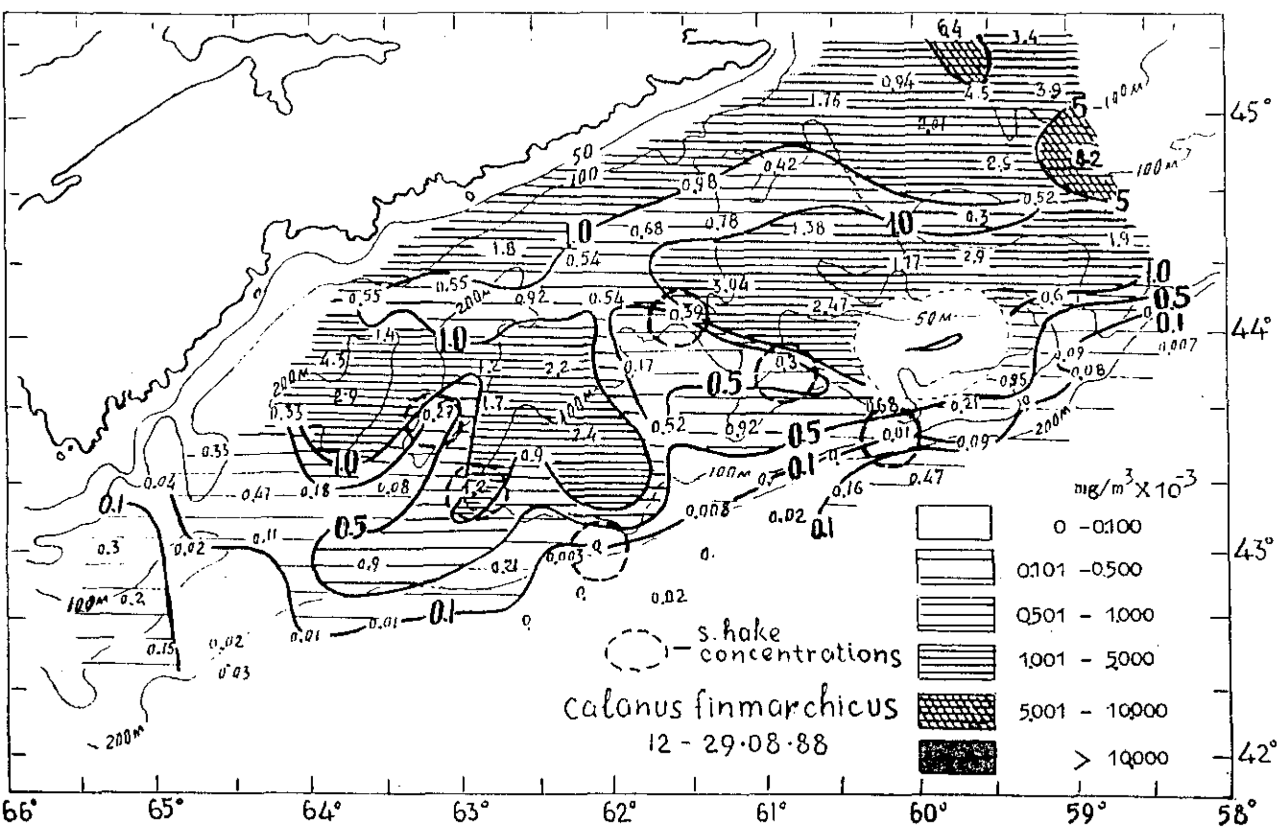

Fig. 16. Distribution of *Calanus finmarchicus* biomass on the Scotian Shelf on 12-29 August 1988.

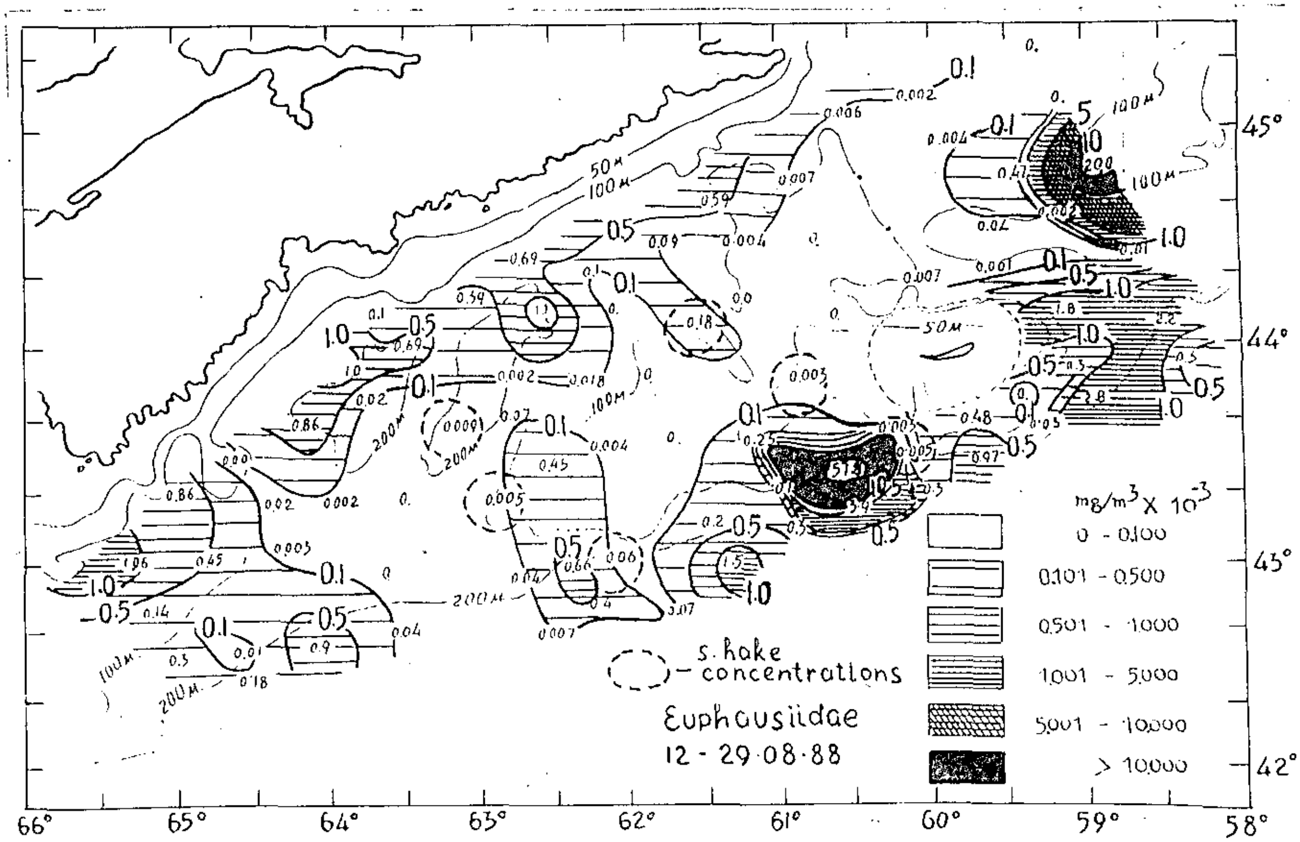

Fig. 17. Distribution of <u>Euphausiidae</u> biomass on the Scotian Shelf on 12-29 August 1988.

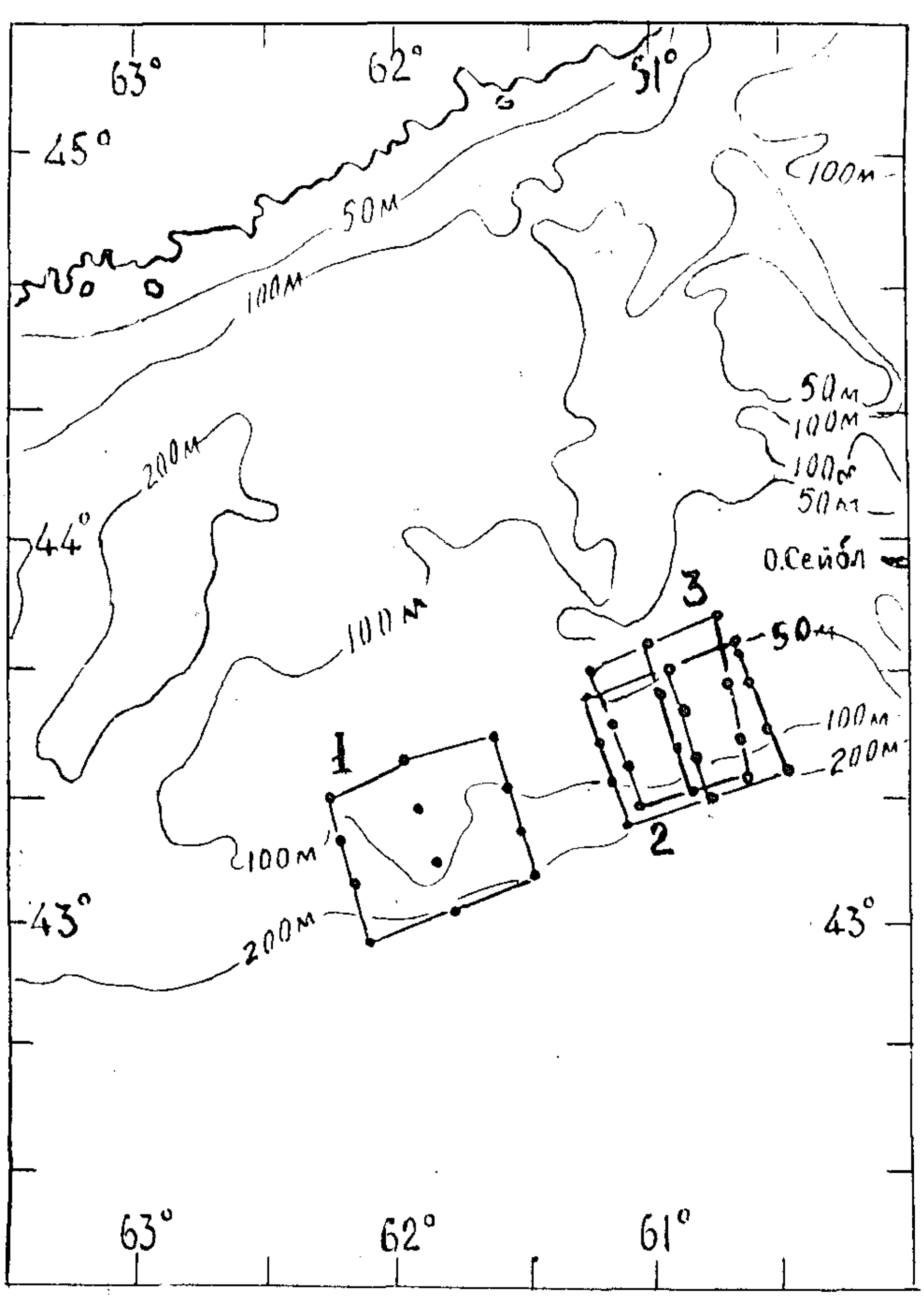

Fig. 18. Location of areas for "patch" studies.

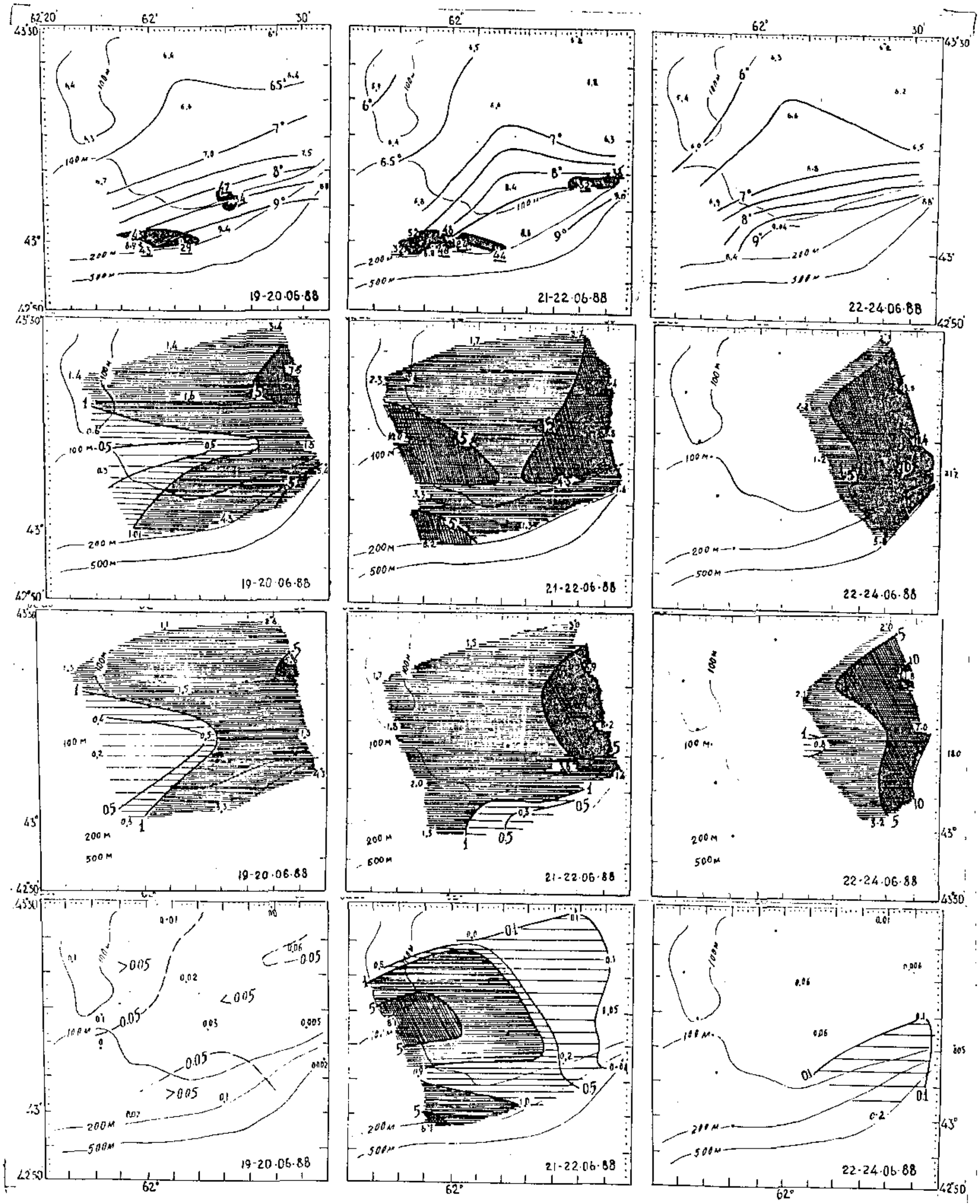

Fig. 19. Distribution of silver hake commercial aggregations, near-bottom water temperature and zooplanktonic food biomass from the results of three surveys of the first area on 19-24 June 1988.
[1-3 - near-bottom temperature and commercial aggregations; 4-6 - seston biomass; 7-9 - *Calanus finmarchicus* biomass; 10-12 - Euphausiidae biomass.]

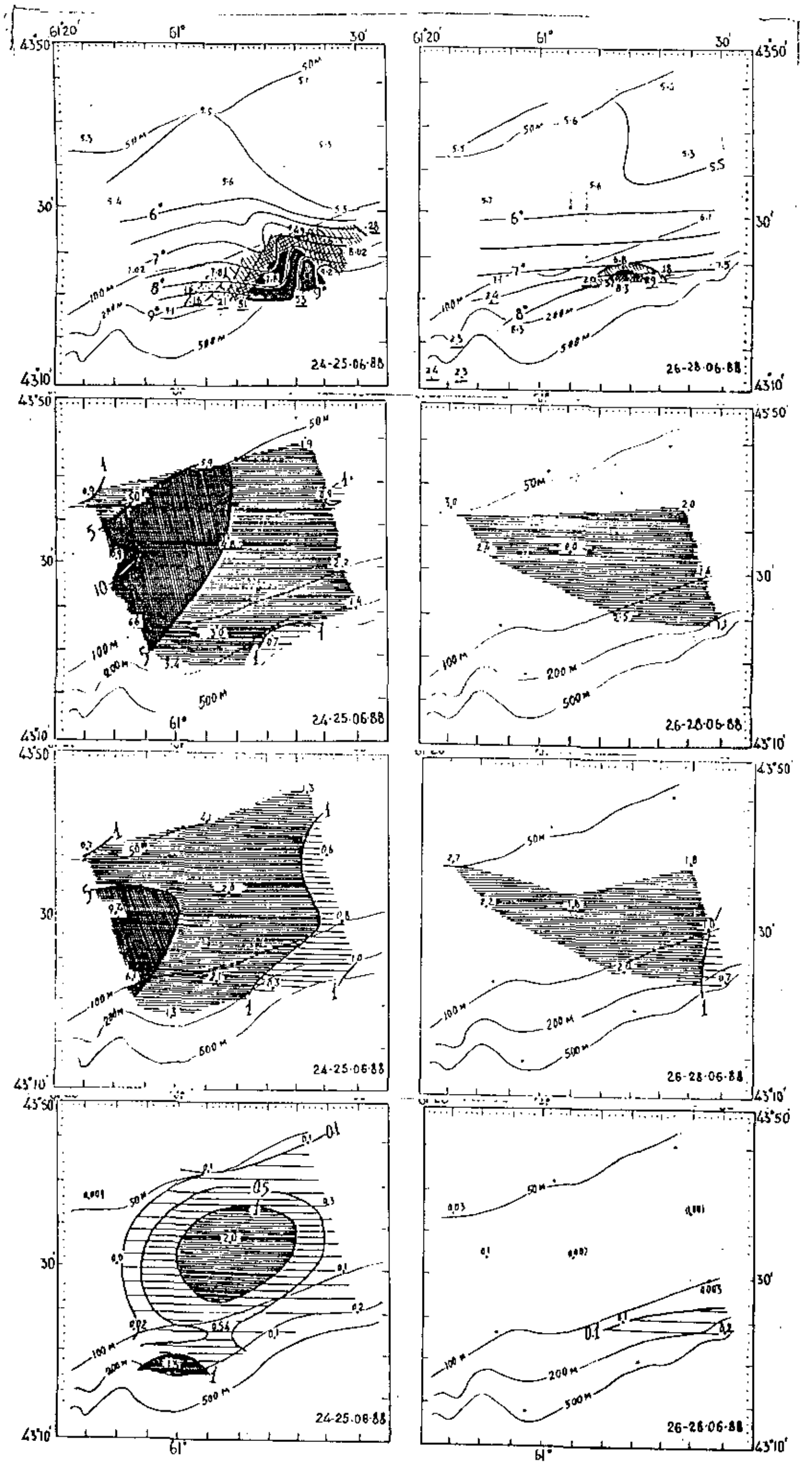

Fig. 20. Distribution of commercial silver hake aggregations, near-bottom water temperature and zooplanktonic food biomass from the results of two surveys of the second area on 24-26 June 1988.
[1-2 - near-bottom temperature and commercial aggregations; 3-4 - seston biomass; 5-6 - *Calanus finmarchicus* biomass; 7-8 - Euphausiidae biomass.]

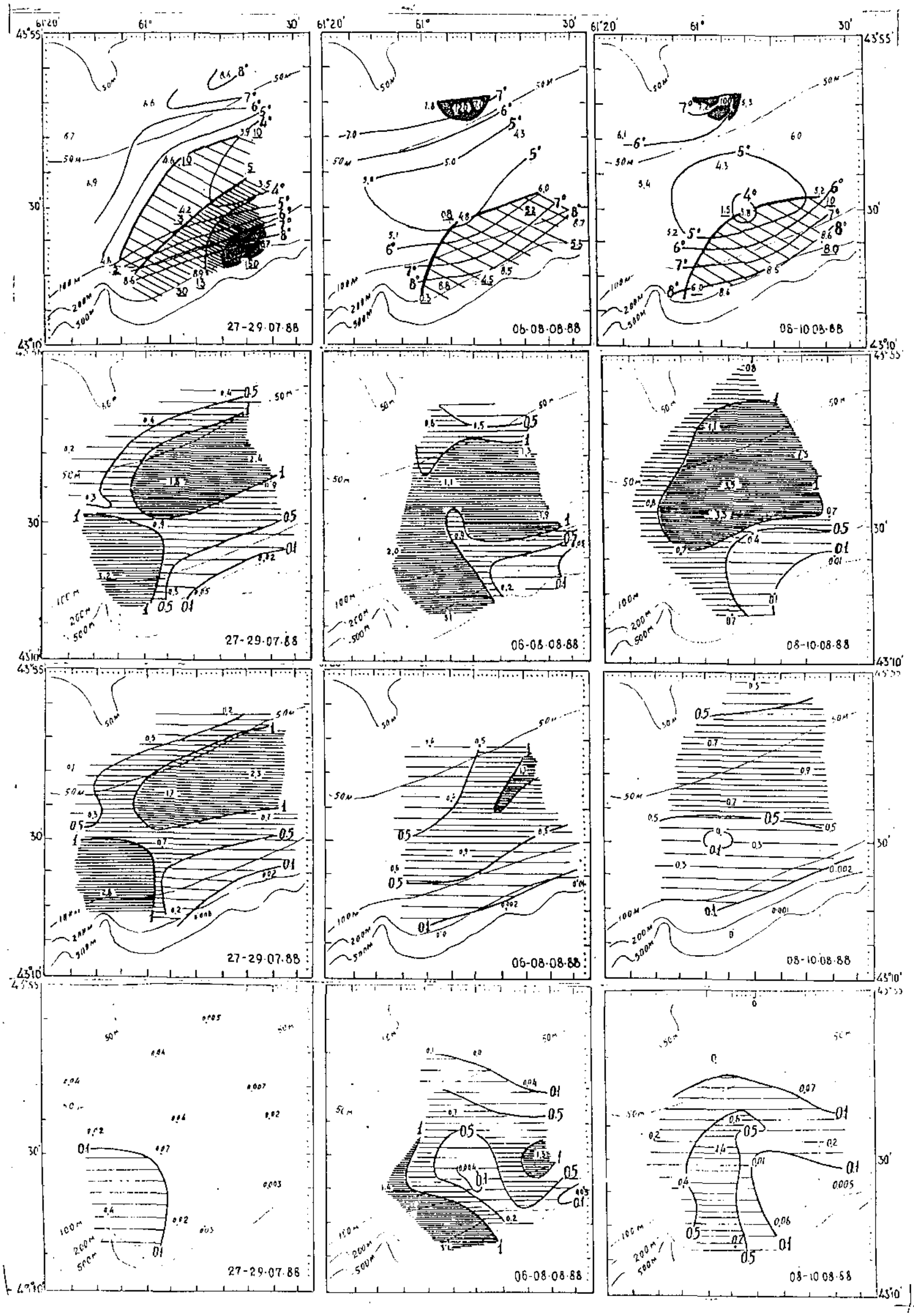

Fig. 21. Distribution of commercial silver hake aggregations, near-bottom water temperature and zooplanktonic food biomass from the results of three surveys of the third area on 27 July-10 August 1988.
[1-3 - near-bottom temperature and research catches; 4-6 - seston biomass; 7-9 - *Calanus finmarchicus* biomass; 10-12 - Euphausiidae biomass.]