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SYMPOSIUM ON ANOMALOUS OCEANOGRAPHIC CONDITIONS

Ecological Conditions of Silver Hake Concentration on the Scotian Shelf Area

by

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Abstract

Silver hake (Merluccius bilinearis (Mitchill) distribution and density in the Scotian Shelf area was researched in relation to some environmental conditions, including near bottom water temperature, salinity, circulation, wet biomass of net zooplankton, density of small and large zooplankton. Complex observations were carried out by means of successive surveys in the investigation area at 61°W, covering shallow waters and the outer shelf edge. Hydrological observations at the stations were fulfilled with probe of STD type. To present the mesoscale circulation field, the diagnosis model of three-dimension circulation was used, based on the barogradient ratios, taking into consideration only its horizontal part. Water temperature, salinity, density and atmospheric pressure were taken as initial data to the model. Zooplankton sampling was carried out with the egg-net of 80 cm opening diameter, or with the large BONGO plankton sampler, fixed on the upper rope of the trawl. Research hauls were carried out by the bottom trawl "Hake-4M", used by AtlantNIRO as a standard fishing gear in trawl surveys to assess demersal fishes abundance. The towing period was 30 min at each station. The fields of the above characteristics distribution obtained in six surveys of the investigation area , were compared to each other, to catch per effort value and silver hake distribution. The factors were revealed, which had the major impact on the silver hake distribution. The results of researches are useful to conduct inventory trawl surveys and to monitor the conditions affecting the silver hake distribution.

Introduction

The work presented is the final part of the researches carried out during 1988 and 1990 within the frames of Soviet-Canadian agreement on fishery in the Scotian Shelf area, which were aimed at the problem of environmental conditions impact on the silver hake distribution in breeding and prespawning periods. Materials were collected in two cruises of Soviet research vessels - middle-tonnage trawler "Strelnya" (June-August, 1988) and large-tonnage trawler "Evrika" (May-July, 1990), based on the ecological surveys of the Scotian Shelf and multiple surveys of small shelf areas. The entire silver hake distribution pattern in relation to the ecological conditions (near-bottom temperature field, salinity, oxigen, phosphates content, geostrophic circulation and forrage zooplankton) was presented in the NAFO Report (Sigaev, 1990) according to the results of surveys in 1988, and in Report to NAFO (Sigaev, 1994) with the results of surveys and statistically treated data on catches and environmental conditions, according to the shelf slope surveys in 1990. The article presented considers only observations in the investigation area in 1990. This is stipulated by the fact, that observations in the investigation area have been carried out incompletely in 1988. Three attempts were made "to fix" in the prespawning silver hake aggregations, however, due to various reasons including those of technical nature, surveys in each area were unable to be repeated more than 3 times.

Unlike the surveys in 1988, in 1990 only one shelf area was selected, where 6 surveys were carried out, including measurements of water temperature, salinity, phosphates, sampling of forrage zooplankton and exploration catches of hake at each station. As compared to survey in 1988, the oxigen content measurements were excluded from the observations, as that factor is not a limiting one in the silver hake ecology. The other observations in the investigation area were similar in 1990 and 1988. The major purpose of successive surveys in the investigation area was to monitor the variability of environmental conditions and to reveal the factors, affecting the silver hake distribution and density.

Material and Methods

The results of observations at 12 stations, repeated 6 times during 26 June - 12 July, 1990, in the shelf area between 60°30' and 62°30'W are used as the material. At each station, half-hour-hauls were carried out with the trawl, adopted in AtlantNIRO to fulfil inventory trawling surveys of demersal fishes from large vessels and to fish hake. It promotes comparison of exploration and commercial catches. Hydrological observations and water sampling were carried out with the hydrological probe of STD type. Zooplankton was sampled with a large BONGO plankton sampler or taped net of 80 cm in diameter, attached to the upper rope of a trawl and equipped with flowmeters. Unlike the surveys in 1988, when zooplankton was sampled by the step-oblique towing of entire water layer, in 1990 sampling was made directly in the layer of a towing and simultaneously with a towing. Wet biomass of zooplankton in each sample was weighted aboard the vessel, and dominated species, density and species composition of zooplankton were determined in the AtlantNIRO laboratory. The obtained complex data on the environmental conditions and silver hake catches were used to create and analyse the distribution fields of hydrological features, zooplankton and silver hake catches.

To describe water flow fields in more details as compared to the geostrophic circulation, the non-linear quasigeostrophic model for three-dimension circulation assessment (D-2) by Sarkisyan was used (Sarkisyan, 1977, 1986; Stepanov and Sarkisyan, 1977). The latter is based on the known equations of hydrodynamics. General practical application of the model is shown in works by Tjuriakov, Kuznetsova (Leningrad Hydrometeorological Institute, LGMI), Sedykh (AtlantNIRO) etc.(Tjuriakov, Kuznetsova, 1972, 1976, 1978, 1982; Tjuriakov et al., 1978; Sedykh, 1975). The assessment of three-dimension circulation by the model for our investigation area was carried out also in LGMI. The results were presented in the paper by Kuznetsova L.N. et al. (Kuznetsova et al., 1993). Water temperature and salinity fields at stations of the investigation area for standard levels, interpolated from the station points to the knots of the uniform grid of the fields estimated were used as the initial data to determine water flows. The atmosphere pressure fields, observed at stations also were interpolated to the knots of the grid and were used together with the data on a bottom relief. It should be mentioned, that the model allows to estimate the horizontal movement velocity and direction at selected levels, three components of the vertical movement (drift, gradient and barocline) and the total vertical velocity. In our research the horizontal circulation fields are of the most interest, since we study the distribution of the near-bottom species. In that case it would be desirable to obtaine the near-bottom circulation fields of the investigation area. The model utilized provided the calculation of water flow velocity and direction at standard levels for the investigation area grid knots. Due to the shelf bottom slope, the following approach was used to determine the near-bottom water flow field. For each estimated field at the standard level velocity values were selected only from the points, located nearest to the bottom, starting from the filed at 30-m level, followed by 50 m, 75 m, 100 m and 150 m levels. Fields of vectors and horizontal flows modules for each of 6 surveys, created in above way, was considered as near-bottom structures of the horizontal circulation. Further, the attempt was made to reveal the circulation heterogenity in the form of mesoscale gyres by vectors. For that purpose continuous lines were drawn medial to the estimated points towards the vectors within each field.

Results

Silver hake catches distribution. Silver hake catches distribution in the investigation area during 26 June - 12 July is shown in the Figure 1. The survey-to-survey catch distribution shows that hake is actually absent in the depth range from 100 to 50m, ant its major concentration occures on the slope at the depth of 120-150m and below. Besides, the most efficient hauls appeared at the stations of the extreme southern row. Catches at the stations of the northern slope row were, as a rule, one or two orders of magnitude lower, than southern ones. Catch in the slope area varied from 0 to 1770 kg per half an hour, which is stipulated by different environmental conditions. As to the shallow area (the area of major hake spawning), it should be note, that at early stage of works in the investigation are prespawning hake occured there only in insignificant amounts (14-18 kg per half an hour) as compared to the slope area. It shows the lack od spawning in that time. However, by the end of the period (9-12 July) large aggregations of spawning hake were observed in the area, and the catch amounted to 10500 kg per half an hour. It evidenced that the major hake spawning in the shallow area off Sable Island occured in the first ten days of July. To follow hake catch variations in the slope area, the catch values were averaged for each survey. Values obtained are presented in the Table. The values in the Table show that the lowest average catch values on the slope are obtained during the second and fifth surveys, the highest - during the third one, and intermediate values associated to the first, fourth and sixth surveys. Below we try to explaine those variations, assuming the environmental conditions impact on the latter.

Near-bottom temperature and catches. As is seen from Figure 2, the near-bottom temperature field varied from survey to survey, however, during entire period silver hake distributed within its temperature range of 7.5-10.5°C. That factor affects the hake occurence on the slope at the depth not less than 100-120 m, since the layer of 100-50 m is characterized with the cold intermediate water avoided by hake. The near-bottom layer temperature varied within 0.7-5.0°C in the investigation area. All exploratory hake catches within above temperature range were zero. As is noted before (Sigaev, 1990, 1994), temperature gradient at the shelf-slope front is another important environmental factor for silver hake. As to that factor within the investigation area, it may be noted that, during the surveys the above-mentioned index varied temporaly. The lowest temperature gradient near the bottom was observed during the second and fifth surveys (Fig. 2.2 and 2.5). During the second survey the gradient lowered apparently due to the cold water advection decrease over entire investigation area. During the fifth survey the gradient reduced on the contrary due to the warm water advection in the area between 60°50 and 61°15W.

Note, that during two above surveys, the average hake catch at the slope amounted to the lowest values. In other cases the temperature gradient near the bottom remained high. In general during the observation period, the temperature field in the investigation area was characterized by temperature decrease at intermediate depths due to increased advection of cold waters, starting from the third survey. As is seen from Figure 2 the near-bottom temperature minimum decreased as following: 2.7, 2.6, 2.2, 1.8, 1.6 with simultaneous extention of cold water area. The above process provided retention of high gradients at the shelf-slope front. Thus, we may conclude, that water temperature at the depths of hake distribution and temperature gradient shall be considered as the major environmental factors, controlling the silver hake distribution in the Scotian Shelf area. The above information allows also to recommend for inventory trawling surveys of adult hake to avoid trawl stations on the shelf within the layers at depths of 100-50 m, as the catches always will approach zero. Since areas of the above-mentioned depths constitute considerable part of the shelf, the restriction will save time and expenses of inventory surveys.

Near-bottom salinity and catches. The distribution od salinity and hake catches is similar to that of temperature, i.e. all considerable catches of hake are obtained within the maximum salinity gradient zone at the slope (Fig.3). The gradients decrease also was observed during the second and fifth surveys. If the salinity fields are presented according to the three-layer structure of the shelf water masses, it may be stated that the hake aggregations associate with the warm slope water mass, characterized by salinity of 33.50-35.50‰ (Bryantsev, 1964, 1967). As Figure 3 shows, all significant catches of hake are obtained within the above salinity range. Thus, the factor of salinity may became a reliable indication of breeding and prespawning hake aggregations on the shelf.

It should be noted, that in major spawning grounds of hake salinity does not seem to be one of the major factors, since its values in the surface water mass of spawning grounds are considerably lower than on the slope (32.05-32.20‰).In this case temperature conditions remain to be the major factor, or in other words, sufficiently warm water in the spawning grounds provides optimal conditions to hake eggs and larvae development and survival. Besides, water circulation in the shallow area off the Sable Island which is the quasi-stationar anticyclonic eddy (Sigaev, 1978), restricting hake eggs and larvae transport outside the shallow area at the early stage of development, is likely to become an important factor.

Water circulation in the investigation area. Two circulation models were used to present water flow filed in the investigation area. The first model is truly geostrophic one, taking into consideration water density redistribution and Coriolis force. The second model is based on hydrodynamic equations, taking in account a gradient, barotropic and drift components, bottom relief and boundary conditions. The results of the geostrophic circulation estimation are shown in the Figure 4. In the Figure the water flow fields are rather uniform and reveal the general westward transport and the lack of any significant heterogenity within the restricted investigation area. Thus the reliable interpretation of catch distribution in the geostrophic circulation field is impossible. Horizontal part of circulation, estimated with the hydrodynamic model for a near-bottom surface is shown in Figure 5. In the knots of the water flow assessment grid, arrows show the direction and numbers - vecolity in cm/sec. Dotted lines point the gyre contours. Those fields fundamentally differ from the previous ones, as they have heterogenities in the form of mesoscale eddies, comparable to the investigation area. Following the survey-to-survey water flow pattern, some peculiarities may be outlined. The first survey shows the anticyclonic eddy formation in the center of the investigation area near the bottom, which developes and extends over the entire area during the second survey. During the third survey some smaller eddies of the oposite rotation are found. During the fourth survey, the entire area was occupied by one cyclonic eddy, and during the fifth survey two eddies of opposite rotation were observed. Finally, during the last survey, one anticyclonic eddy was formed over the investigation area near the bottom. The estimated near-bottom flow velocities seems comparable to the actual ones of the shelf. A more detailed consideration of variations in the near-bottom flows pattern supposes that the eddies replacement directed from the last westwards in accordance to the geostrophic transport. Simultaneous consideration of water flow fields on Figure 5 and catch distribution reveals the following peculiarities. During the second survey when the average catch was low, stations were located on the slope in the center of the anticyclonic eddy. During the fifth survey, when the average catch was also low, stations were at the southern edge of two opposite directed eddies. Besides low catches during this survey occured in the northward water flow between the above eddies. Catches of the avergae size were obtained at stations, located at the dominating eddies periphery.(Surveys 1, 4, 5), Maximum average catch at the slope associated with the case, when a definite pattern had not been developed yet in the investigation area. The above-mentioned mesoscàle circulation features in the investigation area, certainly, do not directly affect the silver hake aggregations distribution and development. This effect may be expected rather through development and distribution of forage zooplankton patches, discussed below.

Phosphates distribution. The near-bottom distribution of phosphates is similar to those of water temperature, salinity and geostrophic circulation (Fig. 6). Along the slope the gradient developes due to the rapid increase of phosphates content with depth. The common picture is intensified by the upwelling events, related to the intrusion of warm slope water on the shelf. Upwelling of water of increased nutrients content results in devepolment of vegetal plankton, followed by zooplankton in the area as well as in all other ocean areas. Thus, along the shelf slope the bioproductive zone occures continuously, providing the base to forage zooplankton development.

Examples of high nutrients content water upwelling are shown in Figure 7.

Forage zooplankton and catches. The data on wet biomass and on forms dominating in samples were used to compare zooplankton distribution and hake catches. Both biomass values and hake catches were averaged only in samples from the slope. Those data and catches are presented in Table. As the table shows hake catch value does not correspond to the average wet biomass of zooplankton. At this point the comparison of catches and forage zooplankton species dominating in each survey, while the latter are divided into small and large forms, reveals apparent correspondence of them (Fig. 8). Low hake catches at the slope associate with small forms dominating (Calanoida) in surveys 2 and 5; and noderate catch associates with approximately equal number of large and small zooplankton (Euphausiidae and Calanoida) at the slope in surveys 1 and 4. The maximum average catch associates with large forms domination at the slope (Euphausiidae) in survey 3.

Isolines in the Figure 8 shows equal wet biomass of zooplankton in grams per catch. The following symbols are assumed to illustrate the forms, dominating in samples:

Sh	Shrimp	C	Calanoida
E	Euphausiidae	Co	Copepoda
Th	Themisto	Sa	Saggita
Ma	Magatyphanae	Tu	Tunicata
Me	Meganichtyphanes norvegica	O	Ovapisces
G	Gammariidae	Al	Alga
Ct	Ctenophora		

Let us follow survey-to-survey qualitative and quantitative variations in the major forms distribution.

During the first survey, as is seen from Figure 8, the small zooplankton dominated at the eastern slope and formed a patch of biomass over 300 g per a catch in the center. Westwards the large zooplankton of lower biomass values dominated, however, the hake catch in the area was higher than in the eastern part. It evidences the hake selectivity for food items. Note, that at that time the catch at the slope corresponded to the average one during the period of observation in the investigation area.

In the second survey (Fig. 8(2)) the small forms dominated, which dominated in the same patch of biomass over 300 g per catch eastwards. The patch size considerably decreased as compared to the first survey. Note, that the average hake catch at the slope was relatively low in that time.

During the third survey (Fig. 8(3)) significant variations were observed related to apparent domination of large zooplankton in the areas of hake fishing at the slope. Two patches were distinguished. In the eastern patch the large forms dominated. Its biomass exceeded 300 g per catch. The western patch of the biomass over 500 g per a catch consisted mainly of Calanus, and the hake catch was zero in the area. Further southwards along the slope the Eupahusiidae domination was noted (145 g per a catch). Exactly in that area of the slope the hake catch was maximum for entire period of observation in the investigation area (1700 kg), as well as the average value of the hake catch. It seems, that in that case the hake ability to select larger food appeared as well.

During the fourth survey both small and large zooplankton forms dominated in samples from the slope; however the highest hake catches were obtained at stations, where the large forms dominated (Fig. 8(4)). The zooplankton distribution was more uniform than in the previous surveys when the density was slightly higher at the slope (200 g per a catch). As was mentioned above, the hake catch at the slope averaged by stations, was compatible to the intermediate value.

During the fifth survey zooplankton density decreased and amounted mainly below 200 g per a catch (Fig. 8(5)). A small patch of biomass over 200 g per a catch was found at the western boundary of the investigation area. Small and moderate size forms dominated in the catches. Remember, that the average hake catch at the slope was compatible to the lowest value during the survey period.

During the last survey (Fig. 8(6)) two strong patches of zooplankton (with the biomass over 2000 g per a catch in the center) again appeared in the investigation area. In that period moderate size zooplankton (Themisto) dominated at the slope though Euphausiidae and shrimps dominated by weight at separate stations. As a result, the average hake catch at the slope increased.

Following the zooplankton distribution over entire investigation area for all 6 surveys, it is found that in the depth range of 100-50 m near bottom Calanus is the main dominating species, which is known to occure in the cold intermediate layer. In conclusion, it should be noted that the forage zooplankton density variability has the less impact on the hake density distribution, than zooplankter's size. Thus, food selectivity is the second major factor, affecting this species distribution.

Circulation and zooplankton distribution. Apriori it may be supposed that the near-bottom circulation fields, estimated based on the model D-2, and near-bottom forage zooplankton distribution should be compartible. However, the comparison of Figures 5 and 8 shows that the zoplankton distribution features may be explained by the water flow pattern not in all surveys. Let us discuss in order zooplankton patches distribution in surveys and location of mesoscale eddies found. In the first survey a zooplankton patch of Calanus domination occured in the eastern periphery of the anticyclonic eddy where the near-bottom water flow was directed south-south-eastwards, i.e. from the shallow areas to the slope, and turned westward at the slope. It seems to promote Calanus transport from shallower depth to deeper waters, into zone of high gradient, and further westward transport along the shelf-slope front which was indicated by the patch extension from the east to the west. It is likely the case when the hydrological front "shelf-slope" acts as "the liquid wall", restricted plankton uptake outside the shelf. At the western slope the current vectors had opposite direction from the south to the north, along the boundary belt between the anticyclonic eddy and the adjacent cyclonic one. It may promote Eupahusiidae aggregation in the area.

In the second survey the patch of Calanus occured in the eastern periphery of the same, but destroyed, anticyclonic eddy where vectors were also directed from the north to the south. To the west the water flow had the northward direction, however Calanus dominated there also which may be the result of aggregation due to its transport from the eastern patch along the slope.

In the third survey the vectors directions were similar to the previous one: predominance of the transport from the north to the south in the eastern part, and from the south to the north - in the western part. Besides, zooplankton patches were associated with the periphery of the opposite derected eddies.

The fourth survey was characterized by a relatively uniform zooplankton distribution on the slope where the southern periphery of the distroyed cyclonic eddy with predominated eastward vectors was located. The fifth survey revealed, as was noted above, two eddies of different direction with the southern periphery at the slope. Opposite direction of water flow vectors seems unlike to promote apparent zooplankton patches formation. To the east at the southern periphery of the anticyclonic eddy the middle-size zooplankton predominated, and to the west (at the southern periphery of the cyclonic eddy) Calanus was dominating species.

In the sixth survey the eastern patch of zooplankton occured at the eastern periphery of the large cyclonic eddy, where middle-size zooplankton predominated. The western patch, with middle and large forms predominating, was affected by the western periphery of the eddy, where the water flow was directed west-north-westwards. Thus, generally we may conclude that the forage zooplankton patch distribution and composition are compatible to the near-bottom eddies location and flow vectors direction. It may be noted also that eddies occured at the boundary between two water masses directly determine the density distribution of zooplankton species, often uptaken by the hake. In any case, the near-bottom flows revealed, evidence the likely northward transport of Calanus, distributed in the cold intermediate layer and its aggregation in some areas of the hydrological front, as well as its transport in the opposite direction. Similarly, the large zooplankton from the warm slope water may concentrate in the front area, and its patches may shift northwards of the front. The above-mentioned allows to suppose that the most favourable feeding conditions for the silver hake occure in the area of predominating water flow along the slope and the lack of cross flows, i.e. in the front stability conditions. The more detailed pattern of forage zooplankton distribution was obtained based on the results of sample sorting at the laboratory. Figures 9 and 10 show the density distribution of some relatively large (Euphausiidae, Gammariidae, Giperiidae) and small (Calanoida) forms in the investigation area which more precisely reflects the dynamics of the large and small zooplankton patches and the relation of the latter to the average hake catch dynamics at the slope.

The analysis of hake stomach contents from samples, obtained at the investigation area stations and in the slope surveys shows that the bulk of the silver hake (modal length of 28-33 cm) uptakes mainly Euphausiidae, and rarely Gammariidae, Giperiidae, shrimps, anchovy and very rarly - Calanus. Even in those cases when Calanus predominated in zooplankton samples, hake stomach content consisted mainly of Euphausiidae. Thus, it may be concluded that feeding and prespawning hake aggregations are mainly formed in the large zooplankton patches.

Finally, to summarize the ecological conditions of silver hake aggregations in the Scotian Shelf area, we may conclude the following:

1. Surveys in the investigation area confirmed that feeding and prespawning silver hake aggregations develope at the warm side of the hydrological front "shelf-slope" at the temperatures of 7.5-10.5°C. In the cold water of the intermediate layer at the depth of 50-120 m no aggregations of the silver hake develope and the latter occures only by individuals. This conclusion may be utilized in inventory surveys.

2. The front, as the boundary between two water masses, is the necessary environment condition for the hake, providing both optimal physical conditions and forage base, as it is the major instrument of the latter development and redistribution.

3. Euphausiidae which aggregates in patches also at the warm side of the front "shelf-slope" constitutes the feeding base of the modal-s ze hake.

4. The analysis of the near-bottom circulation shows that the lack of cross flows, distructing a "liquid wall" which restricts the major food transport northwards to the temperature conditions, unfavourable to hake, and carring small zooplankton unsiutable for hake feeding from the north to the front, appeares the most favourable condition of development and maintenance of forage zooplankton patches at the front.

1. Briantsev V.A., 1963. Water masses of the Scotian Shelf. Trudy AtlantNIRO, 1963, issue X, pp. 15-18. (In Russian).
2. Briantsev V.A., 1967. Features distribution and wind shift of water masses in the Scotian Shelf area. In book: "Oceanological researches in Atlantic", Kaliningrad, AtlantNIRO, pp. 104-114. (In Russian).
3. Kuznetsova L.N., Tjuryakov B.I., 1978. Thermohaline processes impact on the ocean circulation. In book: "The World Ocean research and exploration". Interdepartment collection, issue 65, LGMI,LPI, Leningrad, pp. 61-69. (In Russian).
4. Kuznetsova L.N., Tjuryakov B.I., 1982. Wind and water baroclinity effect in the ocean vertical circulation development. In book: "The World Ocean research and exploration". Interdepartment collection. LGMI, LPI, Leningrad, issue 77, pp. 56-62. (In Russian).
5. Kuznetsova L.N., Korobov V.A., Gospodarik V.V., Sigaev I.K., 1993. Eddy pattern and its variability in the Scotian Shelf area. These of the report to the 7-th regional conference: Complex study of the Atlantic Ocean. Kaliningrad, p. 35. (In Russian).
6. Sarkisyan A.S., 1977. Digital analysis and prediction of sea currents. Leningrad, Gydrometizdat, 182 p. (In Russian).
7. Sarkisyan A.S., 1986. Methods and results of water circulation in the World Ocean. Leningrad, Gydrometeoizdat, 151 p. (In Russian).
8. Sedykh K.A., 1975. Vertical water circulation in the North-East tropical Atlantic during September 1971 - May 1972. Trudy AtlantNIRO, issue 61, Kaliningrad, pp. 3-13. (In Russian).
9. Sigaev I.K., 1978. (Intra-year variability of geostrophic circulation on the continental shelf off New England and Nova Scotia. ICNAF Selected papers, No. 3, pp. 97-107.
10. Sigaev I.K., 1990. Ecological studies of conditions of silver hake distribution on Nova Scotia shelf within the framework of the USSR-Canada programme. NAFO SCR Doc. 90/14, 31 p.

11. Sigaev I.K., 1994. Distribution of silver hake, water temperature and zooplankton on the Scotian Shelf in May-July 1990, NAFO SCR Doc. 94/4, 11p.

12. Stepanov N.V., Sarkisyan A.S., 1977. Diagnostic assessment of horizontal circulation of the World ocean waters. Journal "Marine hydrophysical research", No. 1, pp. 37-44.

13. Tjuriakov B.I., Kuznetsova L.N., 1972. Wind and thermohaline currents and their variability as related to variations of macrosynoptic processes. Proces-Verbaux. No. 12, pp. 125-129.

14. Tjuriakov B.I., Kuznetsova L.N., 1976. Development of vertical circulation of wind and thermohaline origin in the North Atlantic. In book: "Analysis of hydrometeorological processes and long-term prediction in the North Atlantic". Inter-department collection, LGMI, LPI, issue 60, pp. 57-65, (In Russian).

15. Tjuriakov B.I., Kuznetsova L.N., Sedykh K.A., 1978. (Mesoscale structure of three-dimention circulation in the fishing ground off the North-West Africa.

16. Tjuriakov B.I., Kuznetsova L.N., 1982. Wind and water baroclinity effect in the ocean vertical circulation development. Interdepartment collection. The World Ocean research and exploration, LGMI, LPI. (In Russian).

Table

Distribution of average silver hake catch, wet biomass of zooplankton and plankton species predominated in samples

Survey No.	1	2	3	4	5	6
Date	26-27 VI	27-29 VI	30.VI--01.VII	01-02 VII	04-05 VII	09-12 VII
Average catch kg/0.5 hour	272	109	447	253	101	181
Average zooplankton biomass (g/catch)	170	233	221	136	164	660
Predominated plankton species	E/C	C	E	C/E	C	Th

E - Euphausiidae, C - Calanoida, Th - Themisto

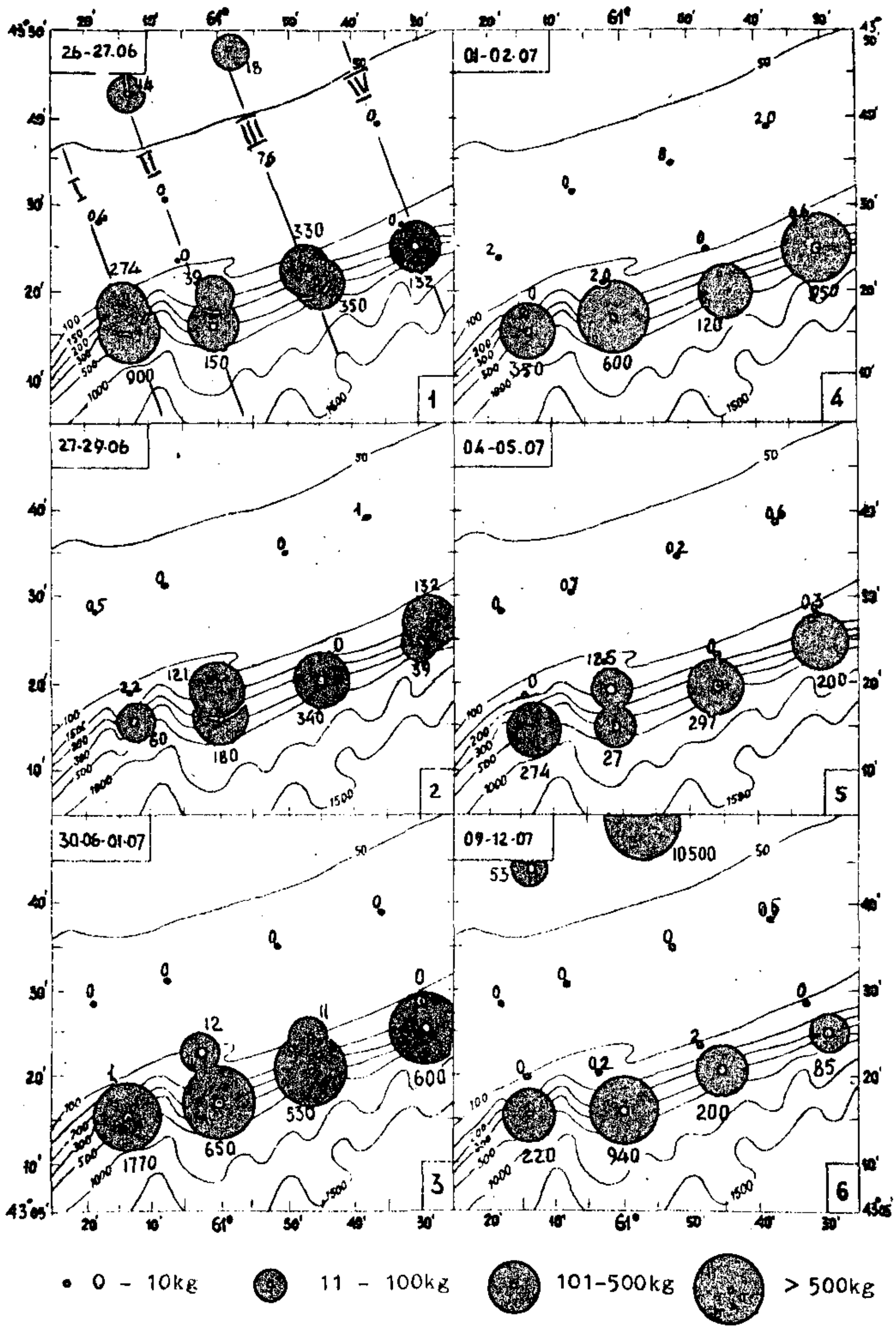

Fig. 1. Exploration catches distribution in the investigation area during 26 June - 12 July, 1990 (kg).

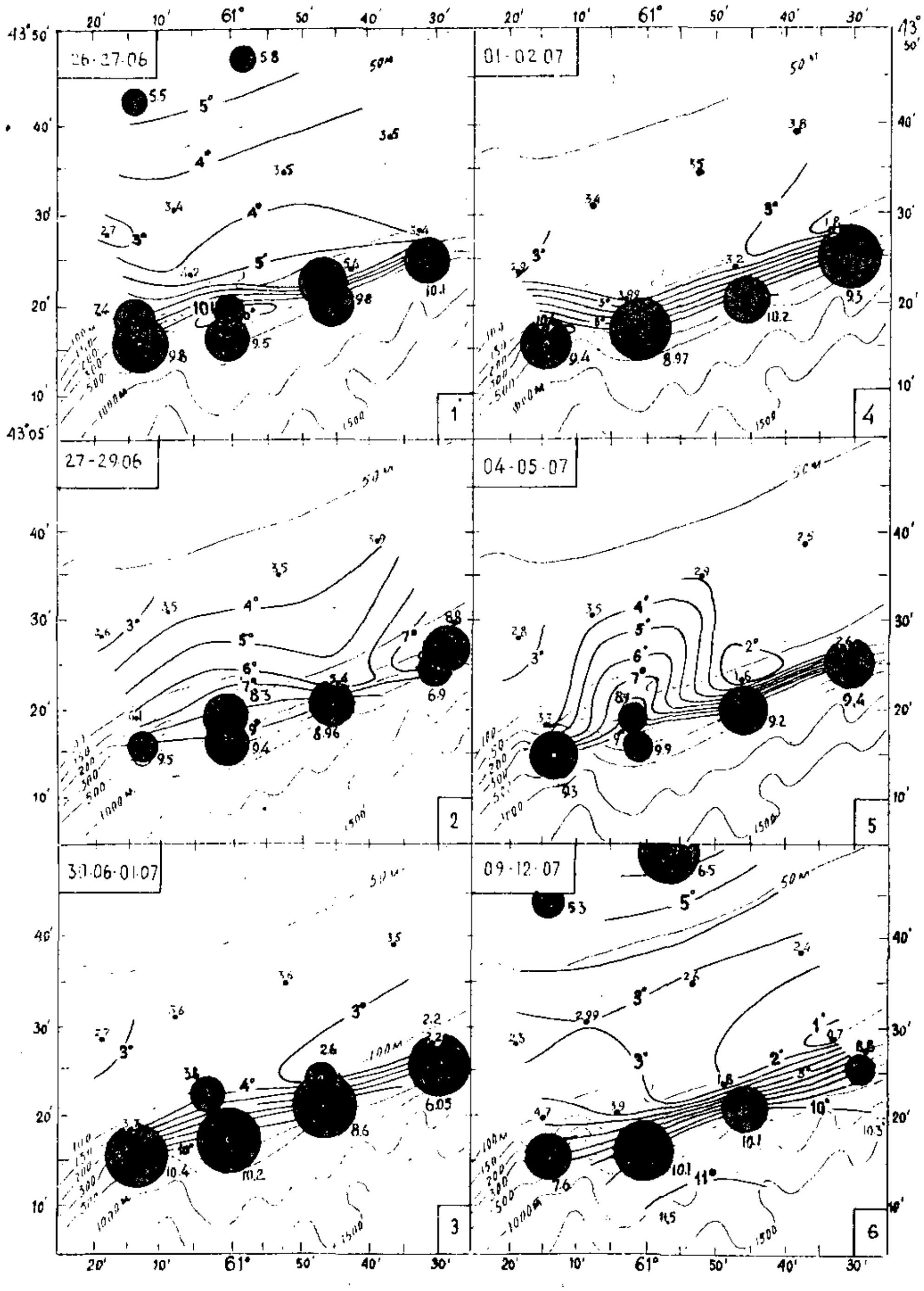

Fig. 2. Distribution of near-bottom temperature (0°C) and silver hake catches in the investigation area during 26 June - 12 July, 1990.

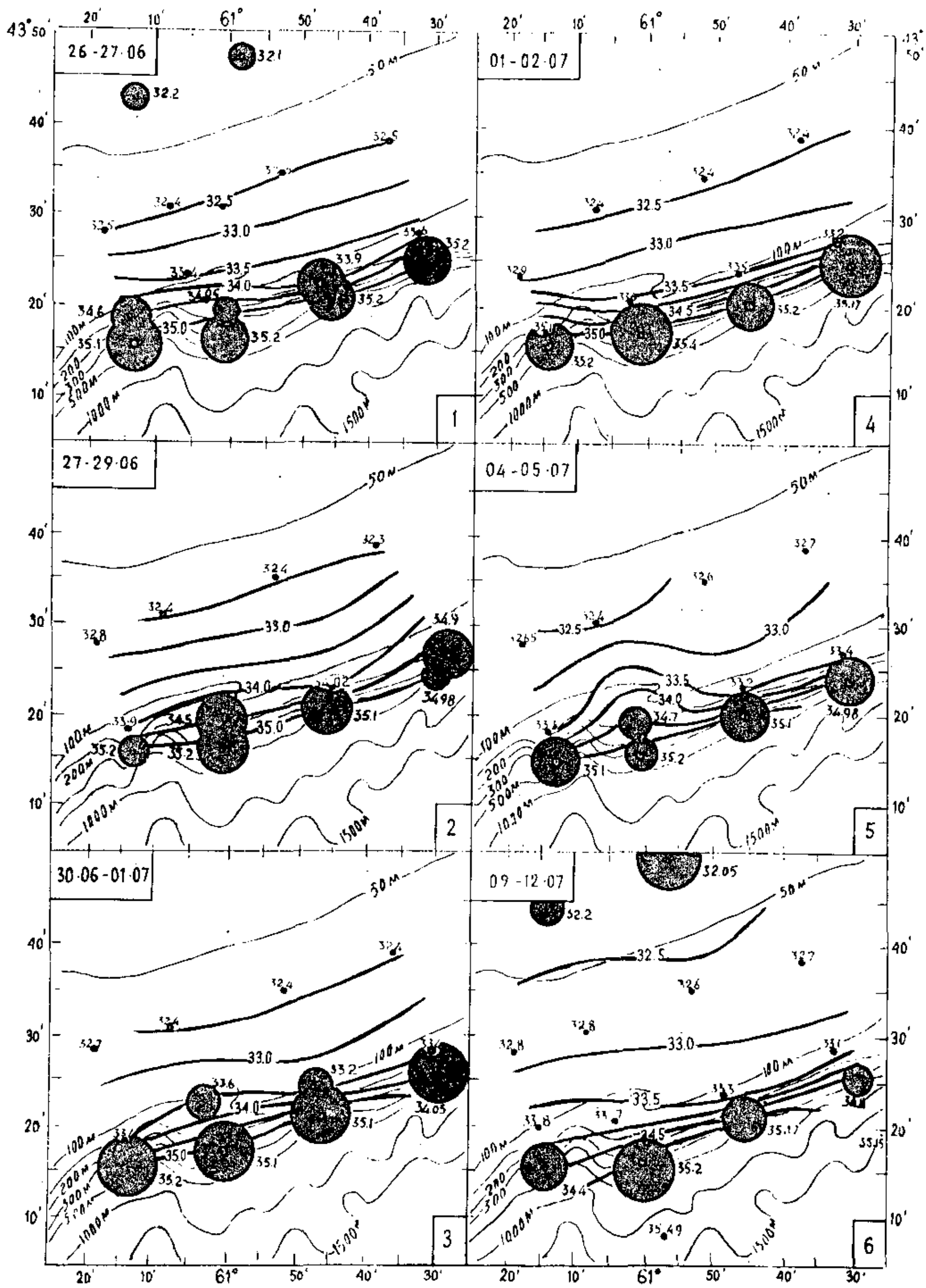

Fig. 3. Distribution of near-bottom salinity and silver hake catches in the investigation area during 26 June - 12 July, 1990.

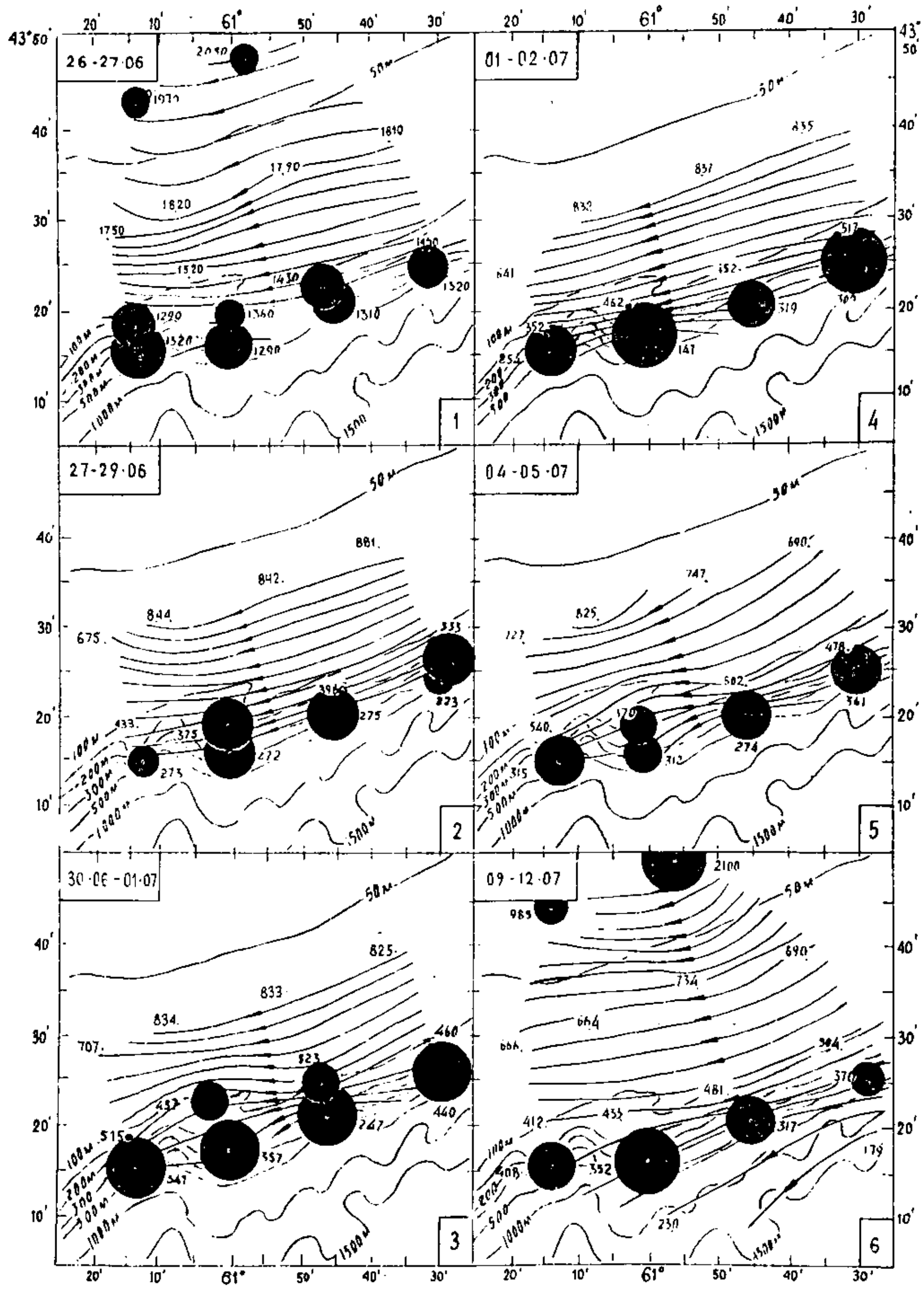

Fig. 4. Fields of geostrophic circulation and silver hake catches in the investigation area during 26 June - 12 July, 1990.

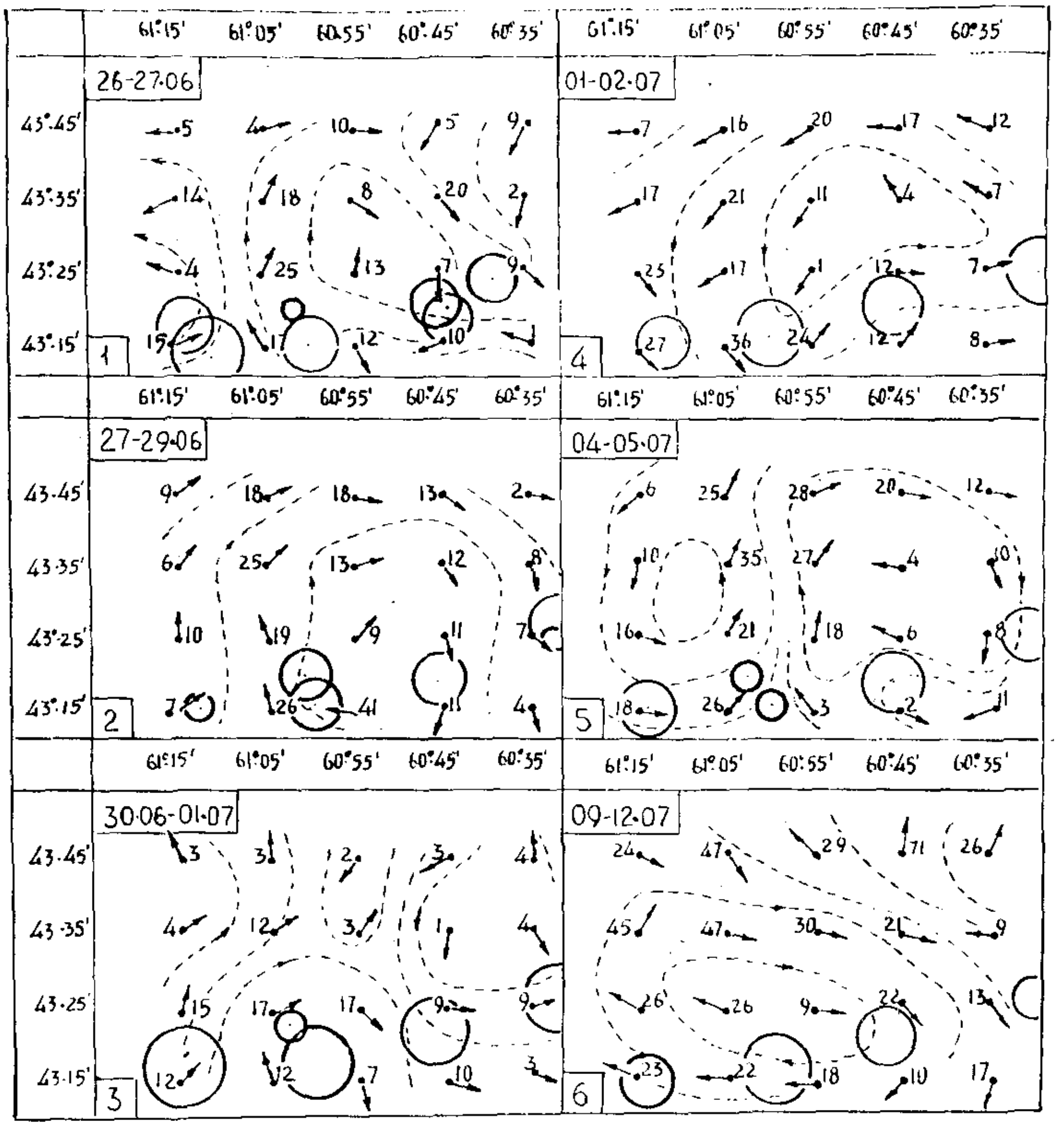

Fig. 5. Fields of near-bottom horizontal circulation, estimated by the Sarkisyan's model D-2, and silver hake catches distribution.

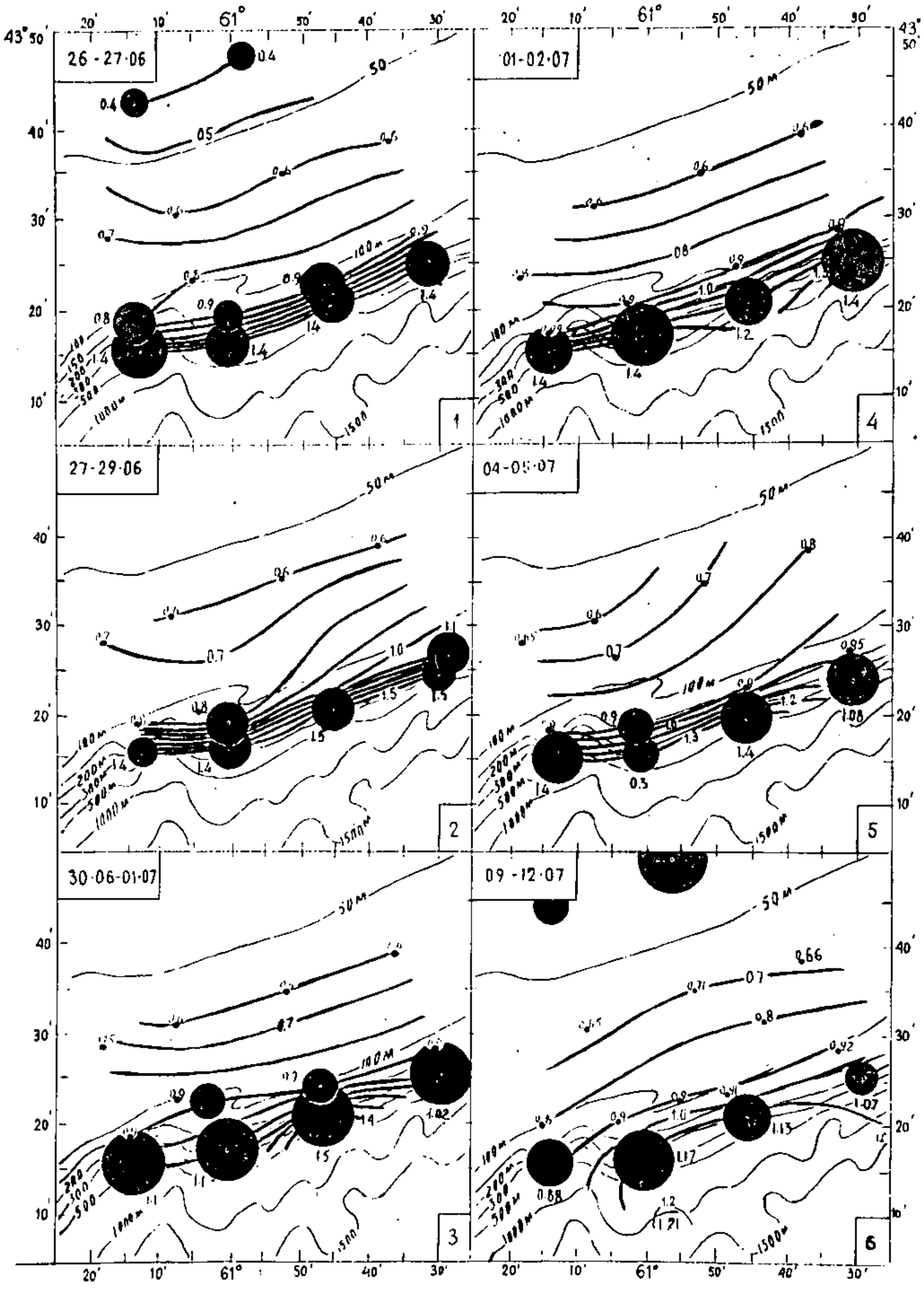

Fig. 6. Phosphates (PO) distribution near-bottom in the investigation area during 26 June - 12 July, 1990.

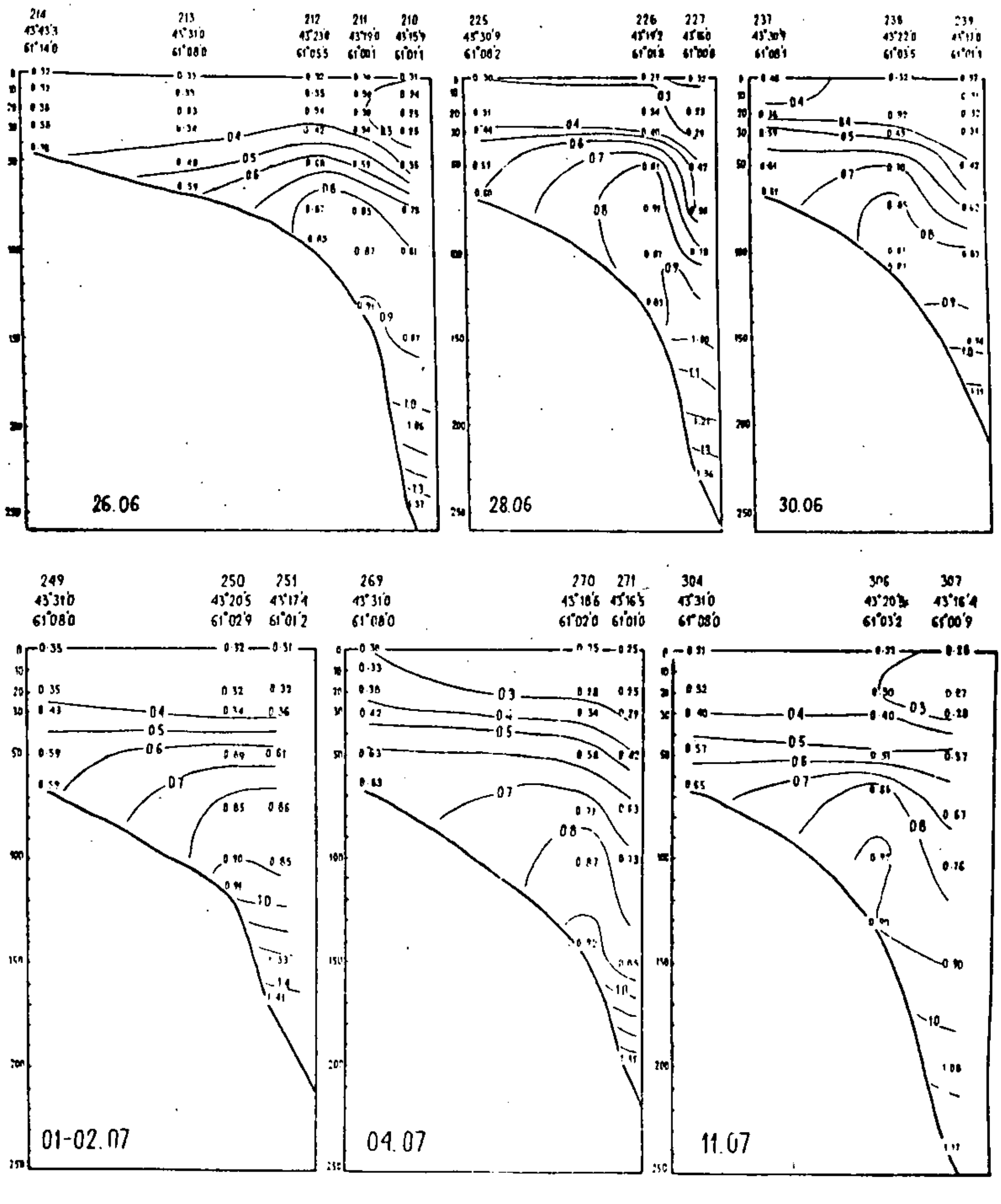

Fig. 7. Phosphates vertical distribution at the section 2 of the investigation area during 26 June - 12 July, 1990.

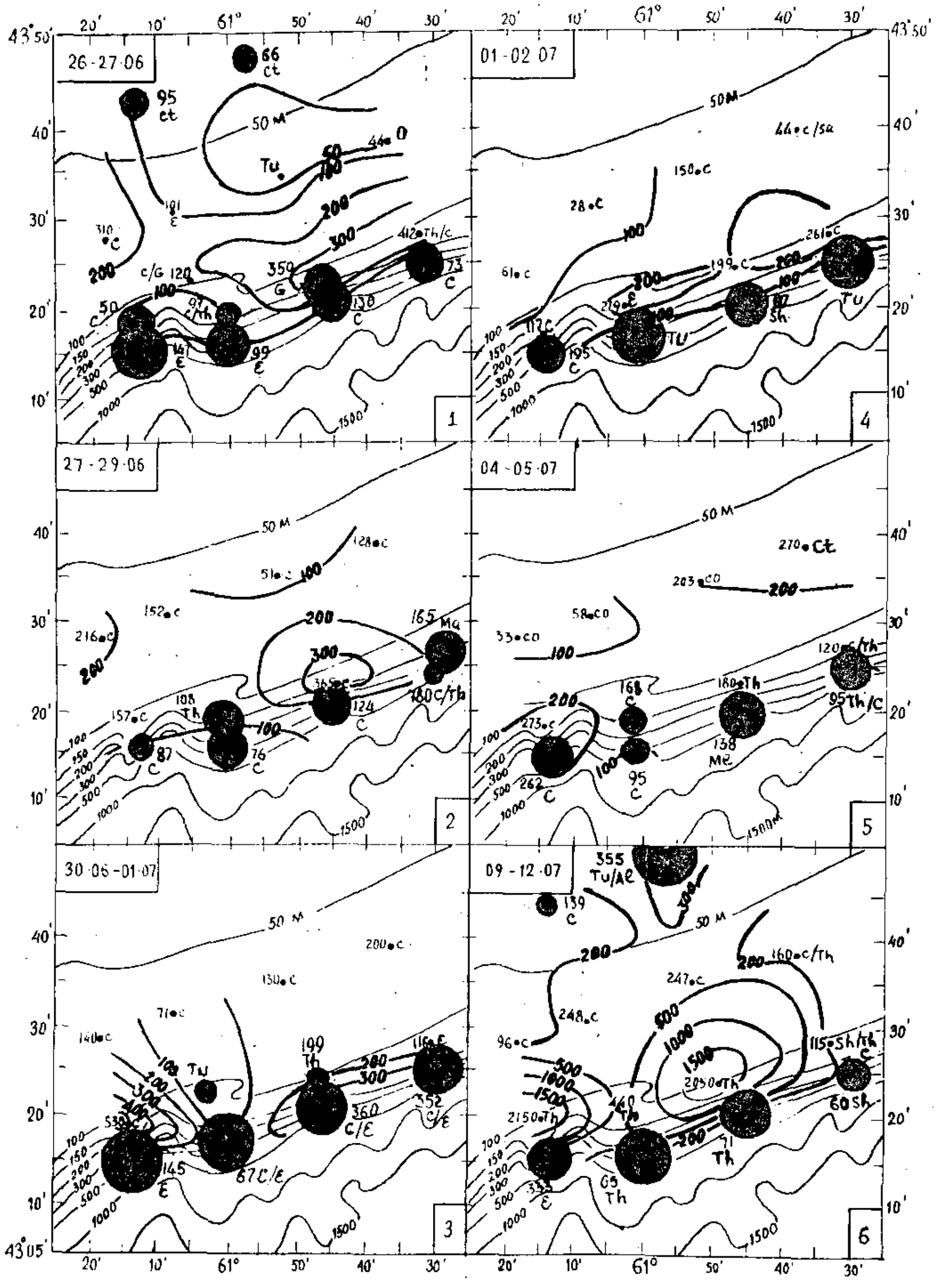

Fig. 8. Distribution of wet biomass (g/catch) of zooplankton, predominated in samples and silver hake catches.

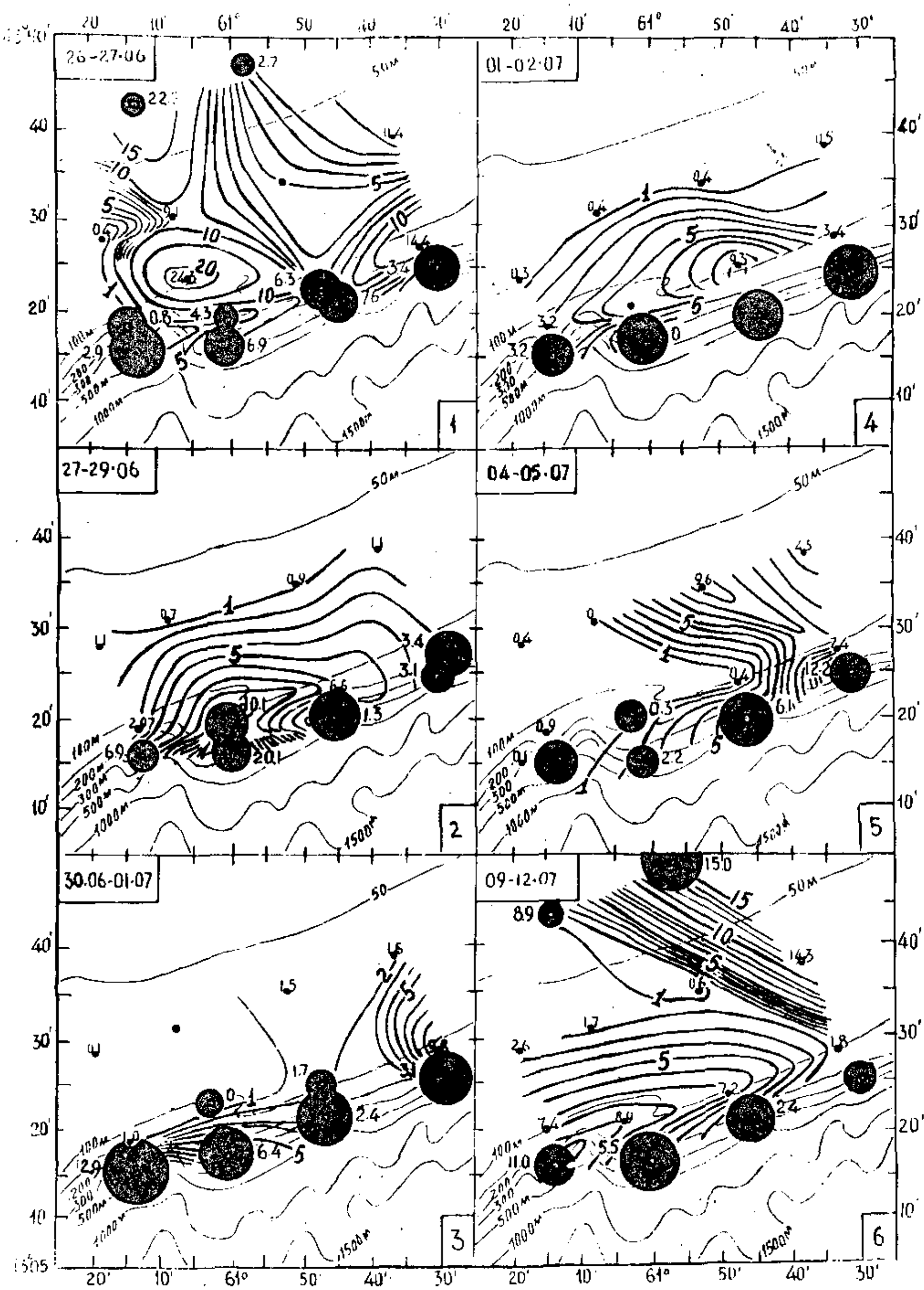

Fig. 9. Distribution of large zooplankton (Euphausiidae, Gammaridae, Gyperiidae, shrimps) in mg/m^3 in the investigation area during 26 June - 12 July, 1990, and silver hake catches.

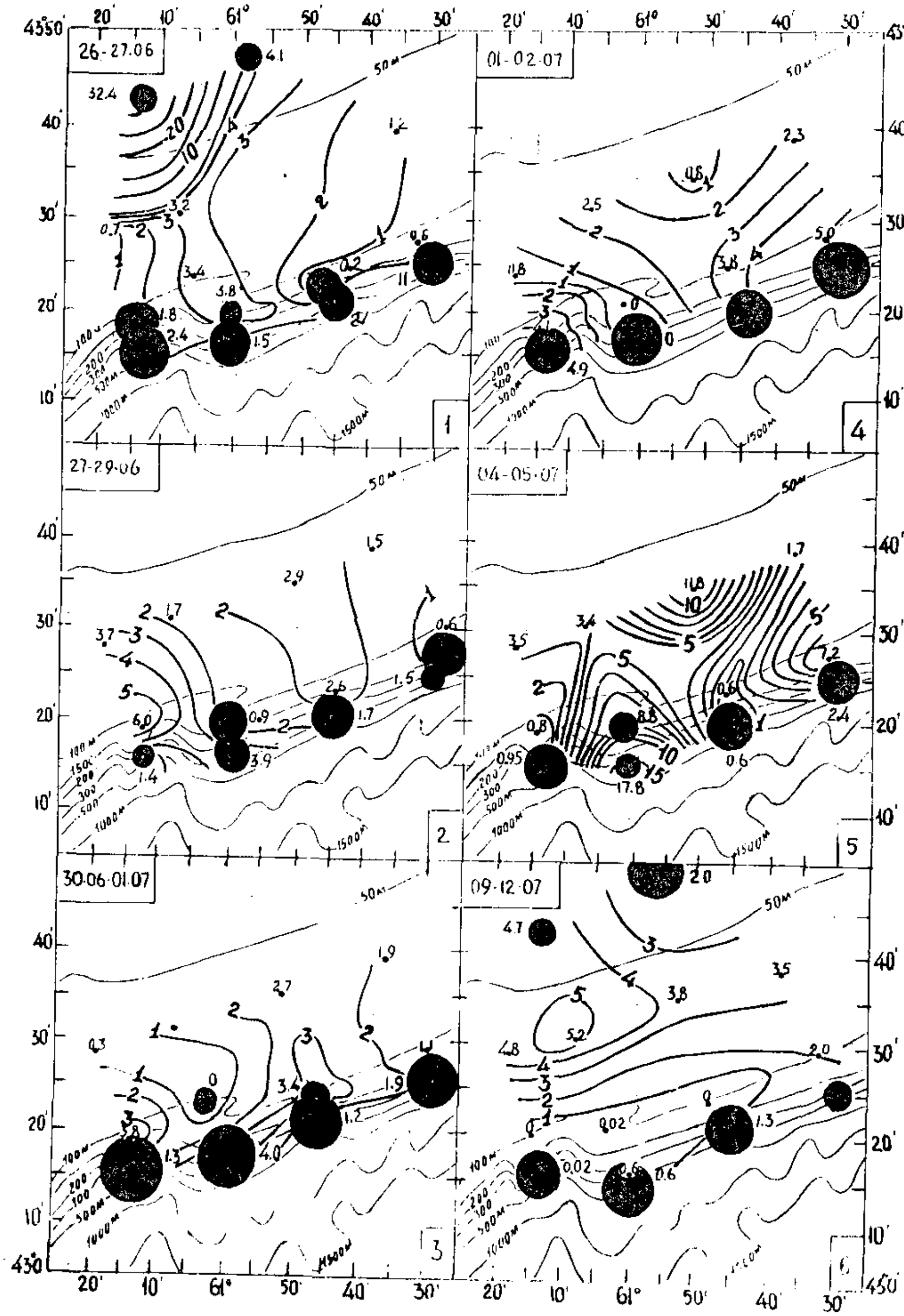

Fig. 10. Distribution of small zooplankton (Calanus) in mg/m^3 during 26 June - 12 July, 1990 and silver hake catches.