SYNOPTIC ECOSYSTEM MONITORING AS A METHODOLOGICAL BASIS FOR RESOURCE EXPLORATION IN THE NORTH-EAST ATLANTIC

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Studies performed within the framework of the Program of comprehensive resources exploration in open waters of the North-East Atlantic ocean (NEA), 2002-2006, allowed us to articulate and develop methodological basis for synoptic fishery-ecosystem monitoring aimed at studying:

- effect of hydrophysical processes, natural synoptic periods (cycles), on biological phases of the fish stock status;
- peculiarities of hydrometeorological processes and identification of essential phases of their development (studies of the oceanic weather);
- development of peculiarities of hydrophysical, biological, and fishery processes which affects both the evolution of hydrophysical structures, and their intermittent changes leading to formation and shifts of zones with high biological and fish productivity;
- innovative system approach to studying oceanologic and biological importance of the ocean synoptic variability which sometimes exceeds seasonal variability (i.e. development of ecosystem oceanography).

Background

Materials of this paper are based on a new approach to fishery exploration studies, namely the complex synoptic monitoring of the natural-industrial system of 'marine living resources – environment – fishery'.

Data were collected by 20 fishing vessels which participate in implementation of the Program studies. Overall, we have analyzed more than 10,000 trawlings, sampled and measured more than 260,000 fishes, and examined biological characteristics more than 30,000 fishes.

Environmental data were collected using satellite and air surveillance over changes in SST and sea level. For the analysis purposes we also used databases on the atmosphere weather in the Northern Hemisphere.

METHODOLOGICAL BASIS FOR SYNOPTIC MONITORING OF MARINE ECOSYSTEMS AND FISH PRODUCTIVITY

Earlier studies (Girs, 1978) revealed the following fundamental features of the natural synoptic cycles in the atmosphere:

1) Essential synoptic cycles which are observed in the atmosphere are associated with macrocirculation and affect the entire hemisphere or its larger part, i.e. they are global;

2) Essential synoptic cycles are characterized by intrinsic stability;

3) An essential synoptic cycle retains a particular sign of variability in the hydrological features;

4) Essential synoptic cycles demonstrate continuity of their development.

Duration of essential synoptic cycles varies from two to ten days, mostly totaling three or five days. These periods are marked by a particular direction of evolution in synoptic processes. Further, the processes undergo a complete change in one or two days which leads to formation of another circulation type in the atmosphere with different direction and intensity of the cyclonic transport and the anticyclonic distribution. Dzerdzeevskij (1968) suggested that an essential synoptic cycle continuously drives transformation of the potential energy into the kinetic one, the latter redistribution in the atmosphere, and formation of air currents. As a result, various regions see development and growth of the atmospheric features which contrast with the underlying surface, radiative heating and equilibrium and when attaining their threshold dissipate abruptly to give way to another essential circulation mechanism.

Further studies which we consider especially important for development of the fishery and oceanography knowledge showed coupling of the meteorological and hydrophysical cycles and identified seven types of oceanic essential cycles with their individual complexes of hydrophysical conditions, including *inter alia* water circulation and thermocline fields, nature and shifts of the ice cover, as well as variations in the sea level.

It is especially interesting that in half the cases changes in the atmospheric and oceanic essential cycles occurred on the same day, in 43% of all the studied case the lag did not exceed one day, and only in 7% of the cases this lag could comprise two days.

We consider that spectrum analysis would be the best basis for analysis of the synoptic variability aimed at identifying of regularities common at various spatial and temporal scales. Here we would like to present main results of studies made in various part of the ocean, including results of our own studies. We would present main results of the synoptic frequencies splitting in accordance with the spectrum. Table 1 summarizes input data, including facsimile charts of the daily mean SST, daily maps of the upper thermocline characteristics (Fuks, 2002), and our own results.

Table 1

Synoptic characteristics of various regions of the World ocean

	Depth	Characteristics	Energy transport zone (days)	Notes
Gulf Stream	0	SST field	3-5, 7-10, 12-16, 25-30	
Kuroshio	0	SST field	3,5-4,5; 5-7, 8-9, 10-11, 13-18, 21-31	
Gulf Stream	0	Shift of the temperature front	4-6, 7-8, 10-13, 23-25	
Kuroshio	0-100	Depth of the upper thermocline	4-8, 12-15, 25-30	
SWA (South-West Atlantic)	0	Zonal current	2,5; 5; 10	
North Atlantic Norwegian Sea	0	Anomalous sea level	3-5	Our results

Comparison of the spectrum ranges of the energy transport frequencies shows fairly good similarity of common regularities in various oceanic regions. We could suggest that these regions have components of the synoptic variability with period durations of a month, half month, and 4-5 days.

From the practical point of view, it is very important to know relationship between fluctuations at different points of the region. We could use coherence in fluctuations to assess stability of their deviation from the spatial mean. The higher is stability (i.e. the more spatially stable are such temporal parameters of fluctuations as period and frequency), the higher is probability of successful development of the spatial prediction relationships.

We could illustrate the stability characteristics (only in the coherence aspect!) in various ranges. These assessments have many practical applications in fishery and oceanography because they allow us to identify our capacity in building prediction models of fishing conditions at various spatial and temporal scales.

Month-long fluctuations (a 21-31 day period) are the most stable and associated with the current main flow. Sometimes the fluctuation coherence attains 0.7-0.8, i.e. the spectrum of stable fluctuations coincides with that of significant peaks.

Stability of the half-month fluctuations (a 13-18 day period) is considerably lower. On the average, it does not exceed 0.3. And here the areas of elevated coherence does not coincide with those of maximum fluctuations. The area of high stability values lies outside of the main flow of the currents.

Stability of the rest components of variability, on the average, does not exceed 0.3 and attains 0.5-0.6 only at certain points.

Minimum stability characterizes four-day fluctuations (a 3.5-4.5 day duration), i.e. fluctuations cause by meteorological variability in non-periodic variations in natural circulation mechanisms.

This principal conclusion provides for special requirements to studies of the variability mechanisms of this range because our research showed that this very range determined the main variability in fishing conditions at all pelagic fisheries.

Particular research efforts should be devoted to the variation peculiarities of the fluctuation peaks in various regions..

As it was already mentioned, studies of synoptic events in the ocean imply certain difficulties, including long continuous observations performed on spatial and temporal scales which allow us to identify the entire frequency range of synoptic processes. Studies of the low frequency range (1 -10 day periods) are particularly difficult.

Satellite high-resolution observations allow us to measure SST, chlorophyll content, and the sea level on a quasi-real time basis.

This level of research capacity provides database for development of ecosystem oceanography.

Application of remote sensors in oceanic observations and satellite based vessel monitoring systems (which allow for determination of trawling coordinates) help to create database with frequency and regularity required in studies of impact which low-frequency (short-term) variability in hydrophysical and meteorological processes could have on formation of oceanic zones with elevated productivity as well as in assessments of the fish aggregation biomass.

Systematic use of a wide array of various observations (e.g. satellite data on the sea level changes, biological and fishery data collected aboard fishing vessels, air-survey data on chlorophyll, turbidity, SST, etc., as well as datasets obtained in research expeditions) provides for a completely new degree of the monitoring quality and for a possibility to study formation of regularities in synoptic events (with duration of 1 -10 days). Research activities such as annual marine polygon surveys in the NEA and development of eddy-gradient models for assessment of divergence/convergence zones have made it possible to address a number of important issues concerning the formation mechanisms of zones with elevated or potentially elevated biological and fish productivity (Shatohin et al., 2002; Shatohin, 2003, 2004).

Results of our studies made the basis for development of information technologies of synoptic monitoring of variability in the state of potentially productive zones on a quasi-real time basis. These technologies have been implemented by fishing vessels of the Western and Northern basins and are annually applied to provide information services at fisheries of mackerel, seabass, herring, and blue whitening in the North-East Atlantic ocean.

Formation mechanisms of zones with elevated biological and fish productivity in the NEA

Distribution of the planktivorous feeding stocks in the synoptic dynamic formations is interesting both in pure biological aspects, and in fishery aspects, particularly for searching of fish aggregations (Parsons et al., 1982; Bocharov, 1990; Shatohin et al., 2002).

It is known that plankton (despite its significant daily vertical migrations and sometimes horizontal migrations) is transported by currents, and we could assume it as transport of passive substance.

Among issues related to this research problem, studies of conditions of formation of elevated plankton concentrations in eddies and low-frequency waves (these dynamic formations dominate on the synoptic scale) are of particular interest.

Advanced techniques of remote observations of the sea level over large marine areas on the synoptic scale allow us to assess variability in currents, divergence/convergence zones, advection rates, and other oceanographic features.

Various applied problems of the fishery oceanography require an answer to the following question: To what extent structural elements (eddies) which we identify on maps of the sea level anomalies correspond to traditional ideas about water dynamics in the fishing grounds and about the role of water dynamics in the marine living resources distribution and behavior ?

Therefore, we have analyzed maps of the sea level anomalies and temperature distribution on various horizons.

Figure 1 illustrates the vertical section at the tack along 68°20° (acoustic survey aboard R/V Smolensk, July 8 – 17, 2003). It is vivid that the anticyclonic depression zone corresponds to positive values of the sea level anomalies, while the rise corresponds to negative values (the cyclonic zone). Figure 2 shows a similar case for the section along is 67°00.

We have also considered data obtained during deepwater measurements by drifting buoys against the background of variations in the field of sea level anomalies. Figure 3 illustrates eight fragments of fields of the sea level anomalies with a ten-day interval and respective position of the deepwater drifting buoy No. 6900194. Each fragment has a full track of the drifting buoy with a marked position for the moment of the deepwater measurements. Figure 4 shows data of the deepwater measurements of temperature along the drifting (a ten-day interval).

The diagram shows that the quasi-stationary anticyclonic fragment of the track ($\Delta\xi > 0$) corresponds to the zone of depression, while the cyclonic fragment ($\Delta\xi > 0$) corresponds to the zone of rise.

It is noteworthy that the drift followed the trajectory close to circular one coupling with the cyclonic (counter-clockwise) spinning. On all eight fragmental maps of the sea level anomalies this area was occupied by cyclone. On first three maps the buoy shifted into the anticyclone area. The last station was made in the area of the developing cyclone.

The obtained results successfully prove the justice of general perceptions about circulation in the oceanic eddy formations. These formations are easily identified on the maps of the sea level anomalies and clearly tracked in time as quasi-stationary. This is very important because in case of clearly defined non-stationary formations we observe a somewhat different situation.

Thus, satellite observations provide a completely new possibility of tracking individual events in the ocean.

Using numerous statistical data (daily data from fishing vessels operating in the Western and Northern basins since 1982), we made calculations to identify core fishing areas on the synoptic scale of variability.

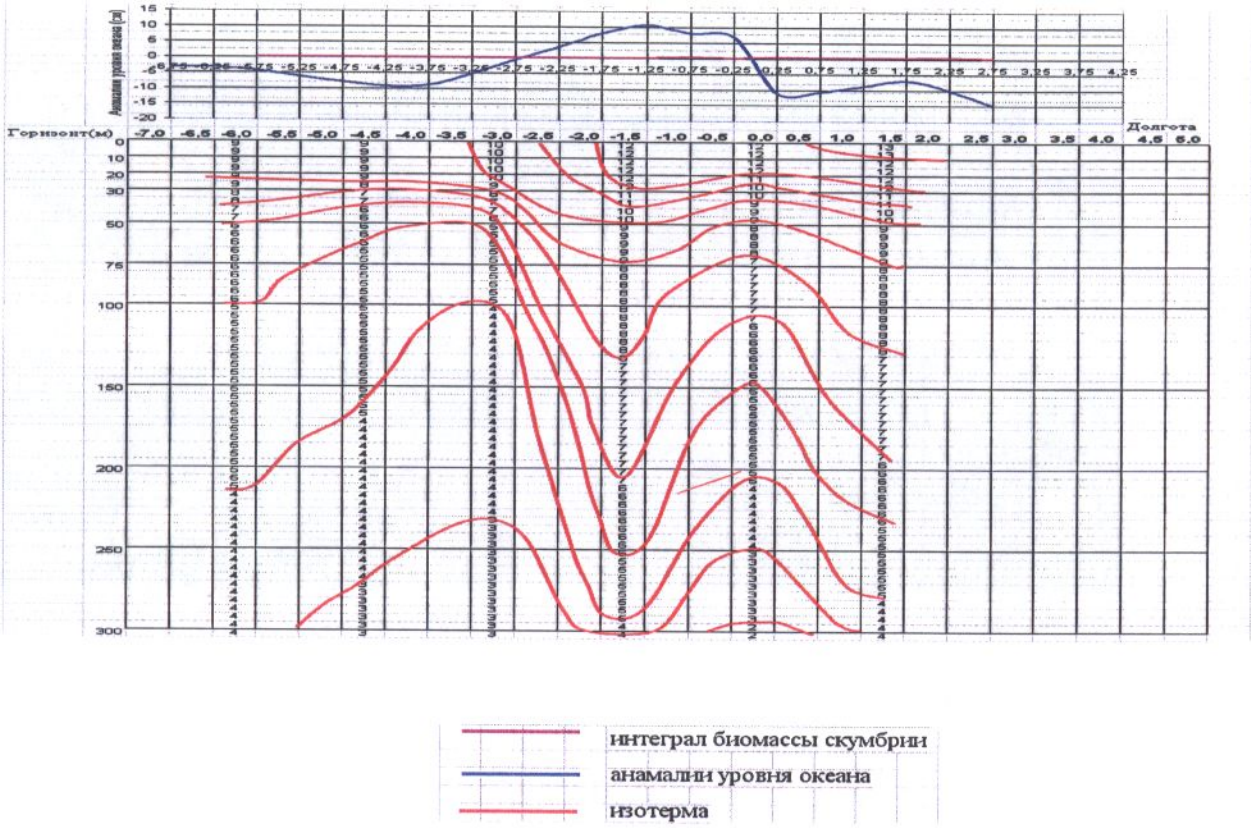


Fig. 1. Sea level anomalies, integral values of the mackerel biomass, and vertical distribution of temperature along 67°00 N (July 8 – 17, 2003).

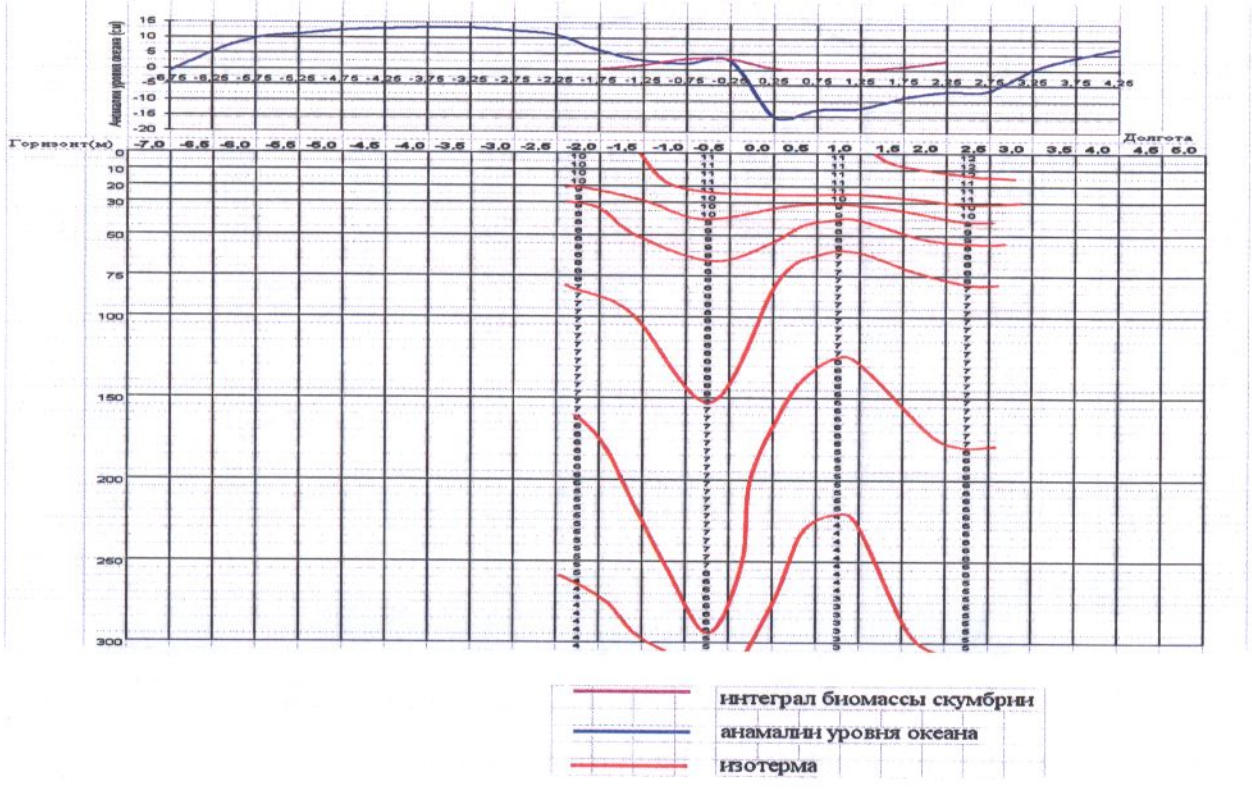


Fig.2. Sea level anomalies, integral values of the mackerel biomass, and vertical distribution of temperature along 68°20 N (July 8 – 17, 2003).

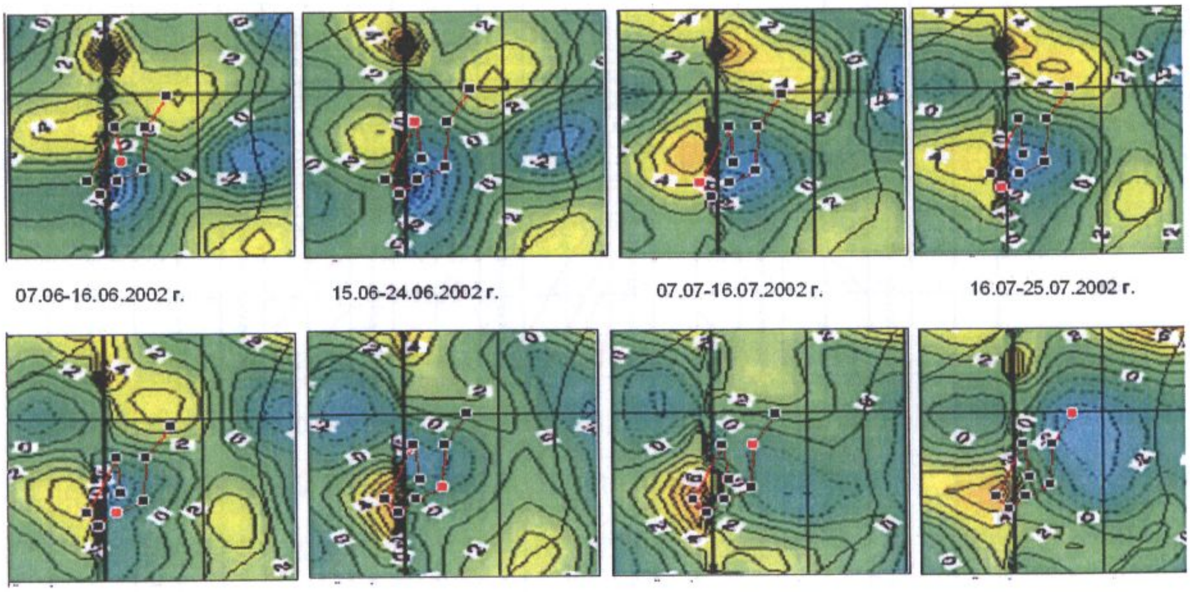


Fig.3. Track of the deepwater drifting buoy No. 6900194 against the background of variations in the field of sea level anomalies, June 11-August 30, 2002

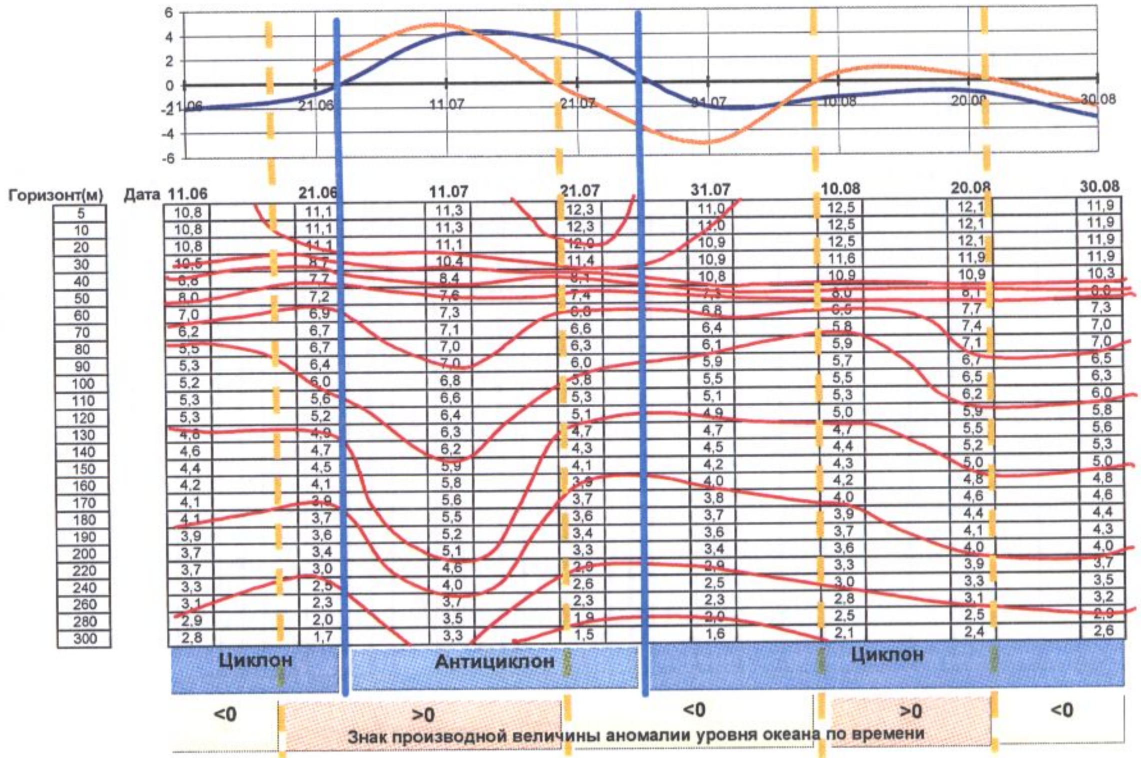


Fig.4. Thermodynamic analysis of the vertical section along the trajectory of the deepwater drifting buoy No. 6900194, June 11-August 30, 2002

Further, we compared the identified core fishing areas with the SST maps and fields of the sea level anomalies and their derivatives for each fishing square. Catch distribution, output, and repeated fishing operations in each fishing square were considered two-dimensional functions of the variables: $y = \frac{\partial(\Delta\xi)}{\partial t}, x = \Delta\xi$.

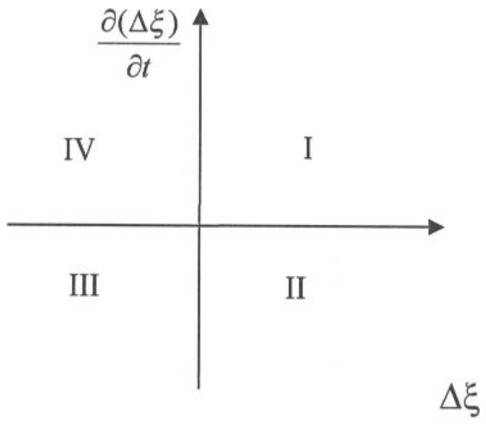
Here y-coordinate represents the rate of changes in the sea level anomalies in time, while x -coordinate represents anomalies $\Delta\xi$. Quarters of the coordinate plane in the field of variables $\frac{\partial(\Delta\xi)}{\partial t}$ and $\Delta\xi$ could be easily interpreted as follows:

Quarter I: $\frac{\partial(\Delta\xi)}{\partial t} > 0$, $\Delta\xi > 0 \Rightarrow$ the growing zone of convergence;

Quarter II: $\frac{\partial(\Delta\xi)}{\partial t} < 0$, $\Delta\xi > 0 \Rightarrow$ the dissipating zone of convergence;

Quarter III: $\frac{\partial(\Delta\xi)}{\partial t} < 0$, $\Delta\xi < 0 \Rightarrow$ the growing zone of divergence;

Quarter IV: $\frac{\partial(\Delta\xi)}{\partial t} > 0$, $\Delta\xi < 0 \Rightarrow$ the dissipating zone of divergence.

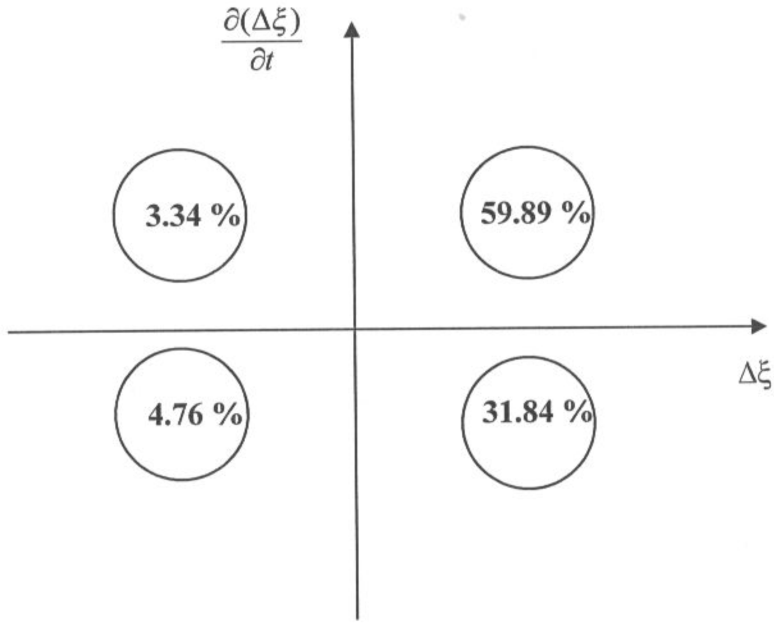


Based on the estimates of the catch distribution C ($\frac{\partial(\Delta\xi)}{\partial t}$, $\Delta\xi$), output O ($\frac{\partial(\Delta\xi)}{\partial t}$, $\Delta\xi$), and number of days at sea N ($\frac{\partial(\Delta\xi)}{\partial t}$, $\Delta\xi$) for the period since 1992 till 2006, we derived respective distributions and calculated their mean integral characteristics for each uniform synoptic natural period (USP) (Table 2).

Arithmetic mean of the catch percentage, 1992 - 2004

$\frac{\partial \xi}{\partial t}\,\frac{см}{5\ \ сут}$

		15.0	0.02	0.32	0.27	0.33		
	0.34	10.0	2.40	4.58	1.85	0.56	0.04	
0.30	2.70	5.0	14.48	24.70	9.45	0.83	0.06	
-10.0	-5.0	0.0	5.0	10.0	15.0	20.0	25.0	$\Delta\xi$ см
0.12	4.04	-5.0	12.53	13.41	2.68	0.39	0.05	
0.14	0.46	-10.0	1.31	1.19	0.19			
		-15.0	0.09					



Earlier studies also showed stable relationship between locations of ridges on the distribution surface $\Delta\xi(\psi,\lambda)$ (where $\Delta\xi$ is the anomaly of the sea level) and location of the migration routes.

Regularities in formation of the migration trajectories were studied on the basis of numerous statistical data. It is shown that migration are principally influenced by tendencies in rearrangement of $\Delta\xi(\psi,\lambda)$ fields which occurred during the change of synoptic periods, mainly due to the structure deformation (dissipation) of the divergence zones. Developing positive deformations of the divergence zones were changing the sign (evolving into convergence zones) provide routes for migrations between the "old" quasi-stationary anticyclonic eddies and "new" cyclonic zones with a step-wise development of consecutive fishery.

Secondly, these studies suggested a good correspondence between relatively stable fishery and anticyclonic eddies and, generally, convergence zones (zones of positive anomalies of $\Delta\xi(\psi,\lambda)$ which could concentrate additional plankton stocks from adjacent divergence zones).

Thirdly, these studies suggested that elevated concentrations of mackerel were associated with "warm" sectors of the anticyclonic formations.

And at last, the presented estimations allowed us to make the fourth applied conclusion about positive dependence of the fishing conditions on "growing" anticyclones and various convergence zones of other nature.

Similar estimations were made for the blue whitening fishery. Unlike the mackerel fishery closely related to the feeding period of this species (which tells on the database coverage), the blue whitening fishery continues almost all year round. Therefore, it allows us to identify relationship between the fishing grounds and the eddy structures for principal periods in the life cycle of this species. Estimations showed that during the blue whitening feeding, wintering, and migration periods this fishery is generally (in 82% of all cases) located within the anticyclonic eddies. The only exception was the spawning period when the fishery pattern was the opposite. In most cases (79%), spawning concentrations occurred in cyclonic eddies which could be related to the biological necessity of larvae to rise to the upper oceanic layers. *Summarizing the presented results and considering earlier studies of the formation mechanisms for zones with elevated biological and fish productivity* (Shatohin, 2002, 2003), *we could describe the main formation mechanism of these zones*. The main source of primary production is zones of cyclones and cyclonic formations of the hollow type and, in a more general non-stationary case, $\frac{\partial\xi}{\partial t}\langle 0.$ zones. Here, it is very important to differentiate roles of the cyclone cores and peripheries. While the core zones generally influence intensity of the nutrient fluxes into layers of active photosynthesis, the peripheries are zones of elevated biological productivity (i.e.

these are zones of the main increase in primary production, the phytoplankton biomass). This difference is related to necessary time lags which depend on general conditions of the photosynthesis process in different water masses and divergence zones. Further, phytoplankton and zooplankton are transported to adjacent convergence zones and anticyclonic eddies to concentrate generally driven by the warm water advection which increases the convergence intensity. This is a formation mechanism for zones with elevated fish productivity. Rich food stocks attract fish aggregations to these areas, thus, providing favorable fishery conditions. As a rule, it happens during the change of natural meteorological synoptic periods; for mackerel, it happens in 95% of all cases, while for herring, it is 92%, and for capelin - 96%). *Structural changes in the field of sea level anomalies also happen during this period.*

Assessing the ecological role of the sea level variability, we could draw the following fundamental conclusion: variability in the oceanic level and its derivatives represent *a cumulative driving force of the main hydrophysical and bioproductive processes in regulation of the ecosystem production, as well as its spatial distribution and uptake (Shatohin, 2004). Regulation of production and its spatial distribution is generally determined by development of "necessary" environmental conditions directly dependent, or indirectly reflecting in variability in the sea level structure. The "regulation" mechanism of the production uptake on the lower trophic levels depends on the production availability and limitation which depend on the geometric and structural patterns of fields of the sea level anomalies.*

The ecosystem main resource potential is concentrated in zones of elevated biological and fish productivity. *Formation of these zones is intermittent both spatially and temporally.* Not a few researches call them anomalous, however, they are essentially regular and could be found anywhere showing high variability. The main challenge of our studies is understanding of mechanisms of such intermittent events: development of zones with elevated fish productivity, irregular distribution of zooplankton concentrations, scales of their spatial and temporal stability, simultaneous and abrupt change in the target fish species behavior over the entire area of its distribution, etc. *Such intermittent changes which emerge as a sharp* *response of the studied natural system (or its models) to gradual changes in the environment are generally defined as catastrophes. In the theory of catastrophes there is an important notion of "bifurcation"* which means "splitting" and is generally used to describe various qualitative changes or development of various discrete objects out of indiscrete ones. *It should be noted that these processes imply very small changes in the system state.* We have discussed the most popular with researchers formation mechanism of zones with elevated fish productivity, i.e. a quadripole (two cyclones and two anticyclones) of the saddle type. Change in synoptic periods causes bifurcation which occurs at a special point of equilibrium. When an anticyclonic bridge (the convergence zone) develops uniting two independent anticyclones fish can migrate along this bridge from the "old" anticyclone to the "new" one; in this case fishery will abruptly move to a new zone of elevated fish productivity. *The bifurcation mechanism could explains previously poorly understood "abrupt" emergence (formation) of a new fishing ground.* Certainly, we should remember that this "abruptness" depends on the general "geometric" situation which determines structure of the divergence and convergence zones in the fields of the sea level anomalies (length and formation of "ridges", their stability, configuration, etc.). Thus, the bifurcation mechanism determines food availability for fish aggregations.

The presented mechanisms of formation for zones with elevated biological and fish productivity made the basis for monitoring of several fishing areas in the NEA.

Redfish in the Irminger Sea

1. Comparative analysis of location of fishing areas associated with feeding and spawning migrations covered the entire period of Russian redfish fishery in the Irminger Sea. Feeding aggregations of the deepwater redfish were located in zones of anticyclones and other anticyclonic formations in 83% of all the studies cases. Spawning aggregations were generally found in areas of cyclonic circulation.

2. In the last five years area of the convergence zones within the redfish feeding grounds increased significantly (5 times), compared to 1993-1999. We would suggest that this change explain decrease in the fishery yield and earlier migration of small-sized fish to waters off Greenland.

Studies of distribution, migrations, and biomass assessments for mackerel in the Norwegian Sea

1. Studying dependence of the feeding grounds' location on the synoptic variability in recent years, we developed classification of the formation mechanisms for the mackerel fishing grounds and migration routes.

2. Our specialist have developed techniques for short-term and long-term forecasting of the mackerel fishing grounds and seasons, as well as operative forecasting techniques to forecast fishing conditions (earliness of forecast: 1.5 month - 3-5 days).

3. Regular assessments of dynamics of the mackerel aggregation biomass were made for various uniform periods of the synoptic variability (on the basis of satellite surveillance over trawling operations (Fig.5-8).

4. Our specialists have developed information technology of at sea adaptive/managed experiments connected with scientific plans to study the impact which dynamics of the anomalous level structures produce on formation of zones with elevated biological and fish productivity. Implementation of this technology follows the pattern set by herring and mackerel fisheries, i.e. extensive use of fishing vessels with researches aboard.

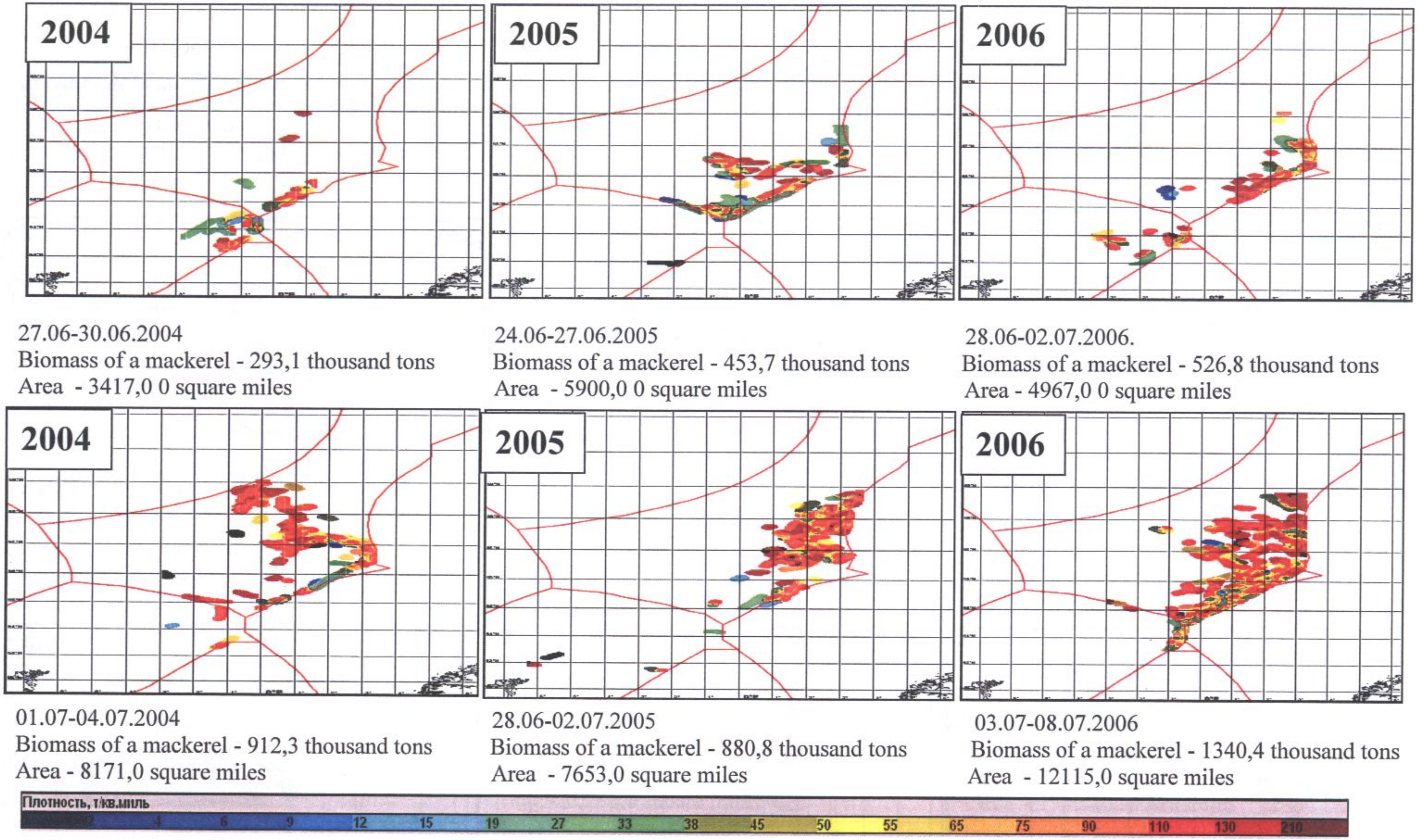
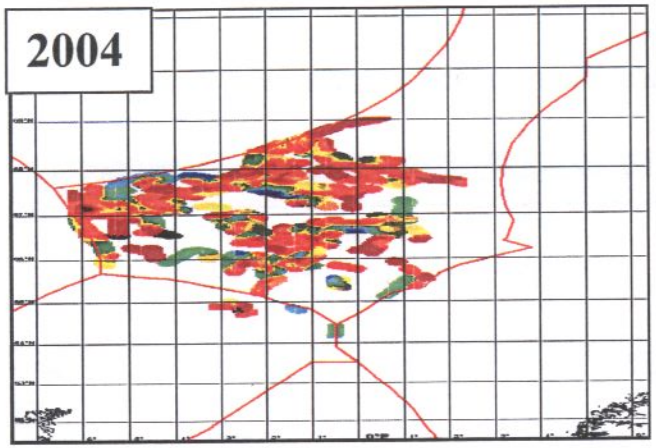
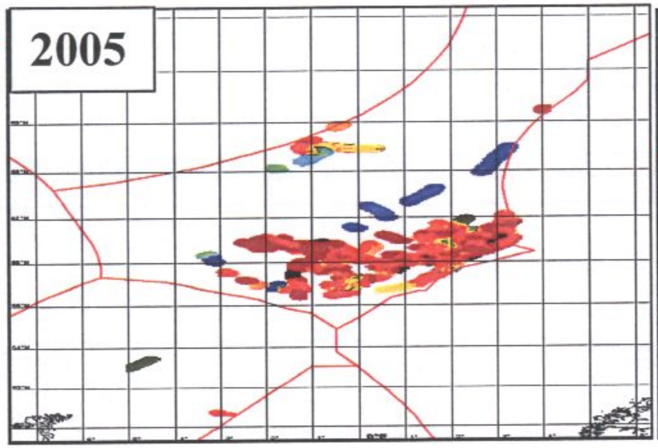


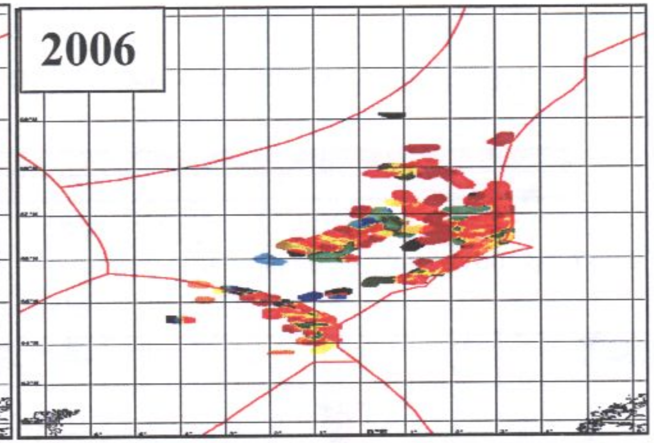
Fig.5. Dynamics of quantitative estimation of biomass feeding mackerels on the natural synoptic periods (NSP), Norwegian sea, 2004-2006



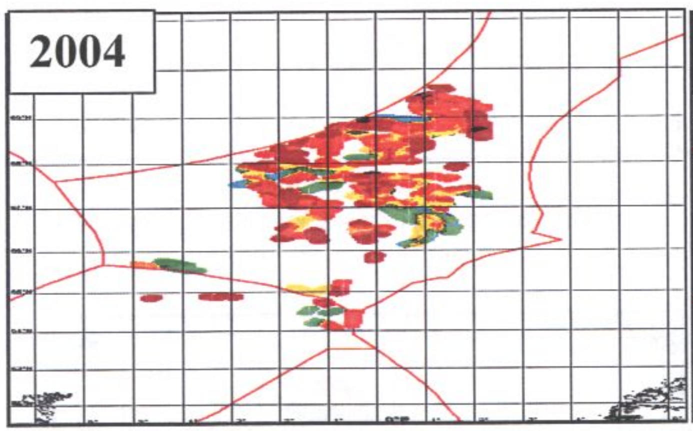
05.07-11.07.2004
Biomass of a mackerel - 1786,7 thousand tons
Area - 17811,0 square mil



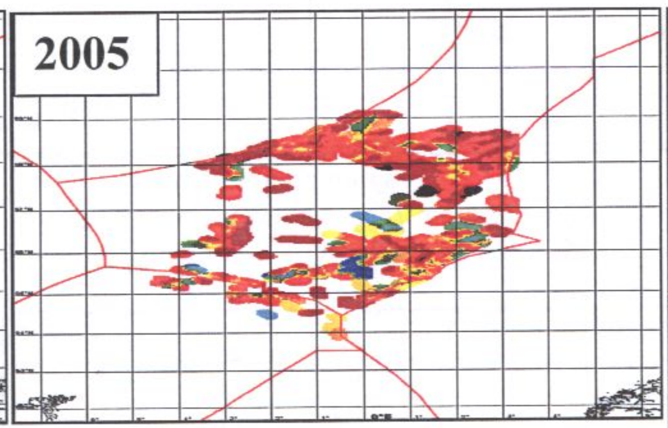
03.07-06.07.2005
Biomass of a mackerel - 1142,8 thousand tons
Area - 9533,0 square miles



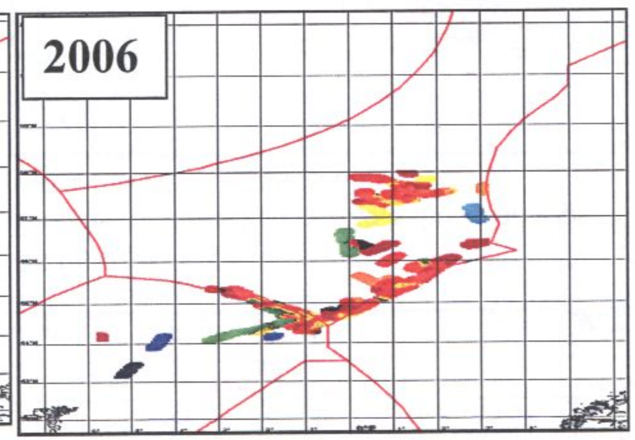
09.07-13.07.2006
Biomass of a mackerel - 1168,0 thousand tons
Area - 10480,0 square miles



12.07-15.07.2004
Biomass of a mackerel - 1535,6 thousand tons
Area - 13443,0 square miles



07.07-13.07.2005
Biomass of a mackerel - 2237,5 thousand tons
Area - 18728,0 square miles



14.07-17.07.2006
Biomass of a mackerel - 759,3 thousand tons
Area - 7214,0 square miles

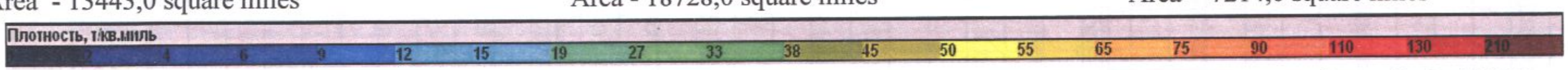
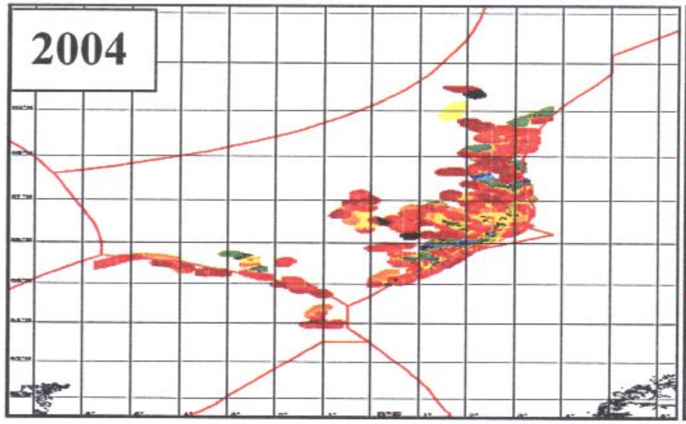
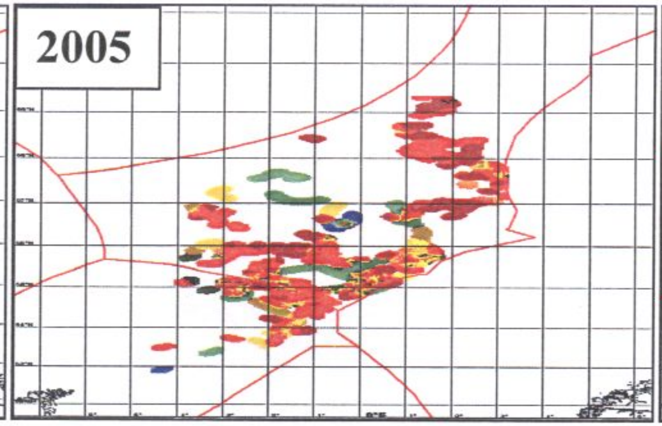


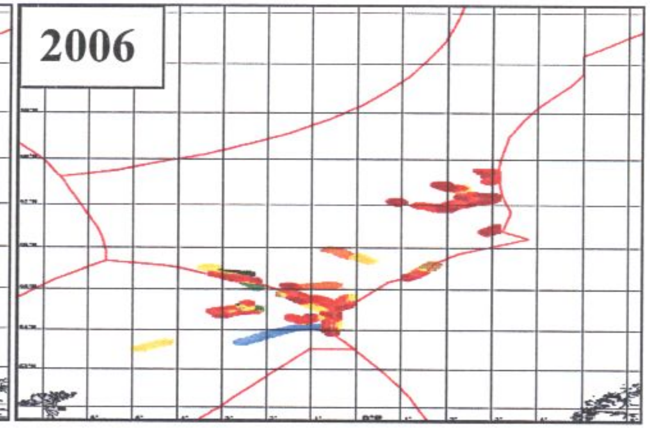
Fig.6. Dynamics of quantitative estimation of biomass feeding mackerels on the natural synoptic periods (NSP), Norwegian sea, 2004-2006



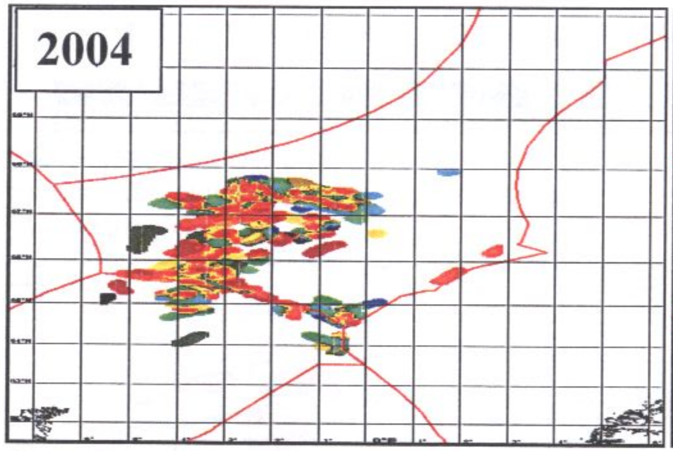
16.07-20.07.2004
Biomass of a mackerel - 1333.6 thousand tons
Area - 11642.0 square miles



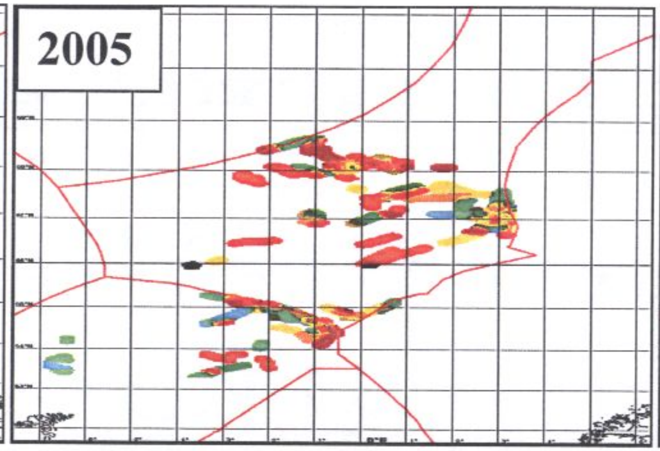
14.07-19.07.2005
Biomass of a mackerel - 1723,5 thousand tons
Area - 15083,0 square miles



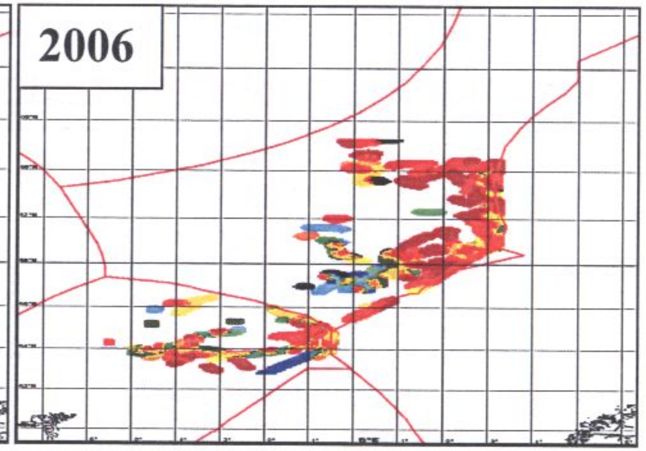
18.07-20.07.2006
Biomass of a mackerel -568,8 thousand tons
Area - 4835,0 square miles



21.07-25.07.2004
Biomass of a mackerel - 1067,5 thousand tons
Area - 12547,0 square miles

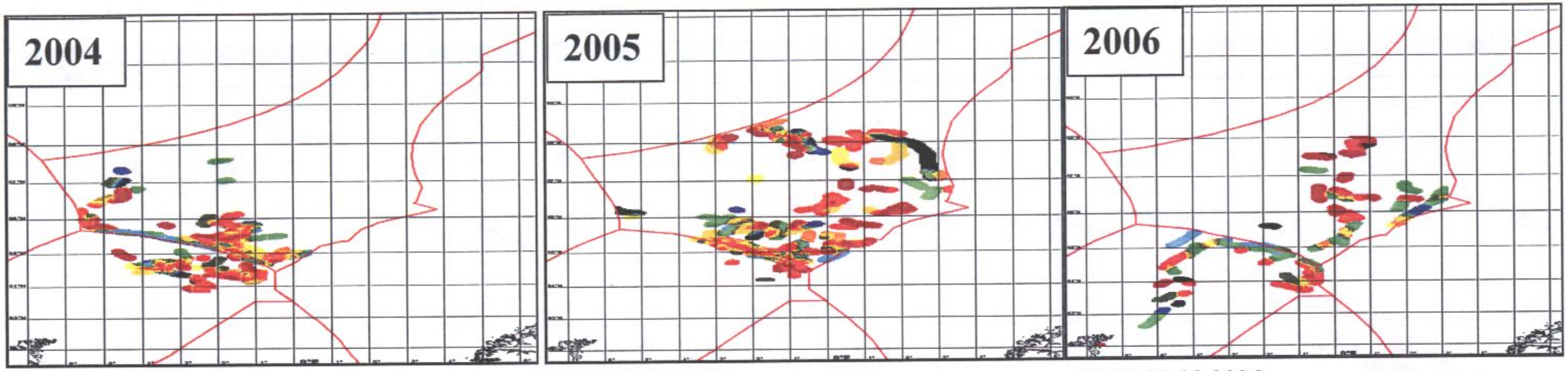


20.07-22.07.2005
Biomass of a mackerel - 928,6 thousand tons
Area - 10296,0 square miles



21.07-29.07.2006
Biomass of a mackerel - 1497,5 thousand tons
Area - 13360,0 square miles

Fig.7. Dynamics of quantitative estimation of biomass feeding mackerels on the natural synoptic periods (NSP), Norwegian sea, 2004-2006



26.07-28.07.2004
Biomass of a mackerel - 719,4 thousand tons
Area - 7616,0 square miles

23.07-28.07.2005
Biomass of a mackerel - 1031,0 thousand tons
Area - 11467,0 square miles

30.07-04.08.2006
Biomass of a mackerel - 759,0 thousand tons
Area - 7767,0 square miles

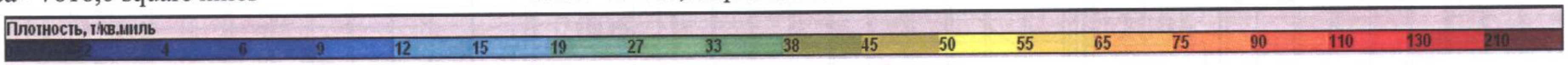


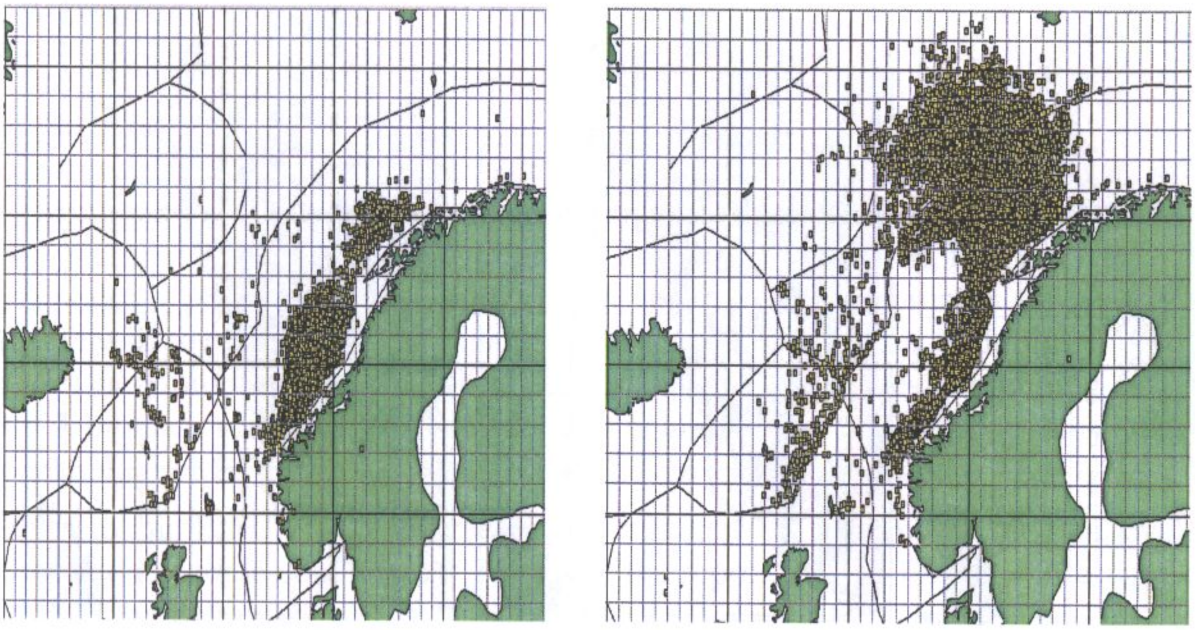
Fig.8. Dynamics of quantitative estimation of biomass feeding mackerels on the natural synoptic periods (NSP), Norwegian sea, 2004-2006

Norwegian spring-spawning herring

All the above mentioned formation mechanisms for zones with elevated fish productivity associated with low frequency range (1-18 days) of variability in the sea level anomalies are also true for the Atlantic herring distribution and migrations of.

Here, we would present only two facts important for planning and organization of further surveys of the herring stock dynamics:

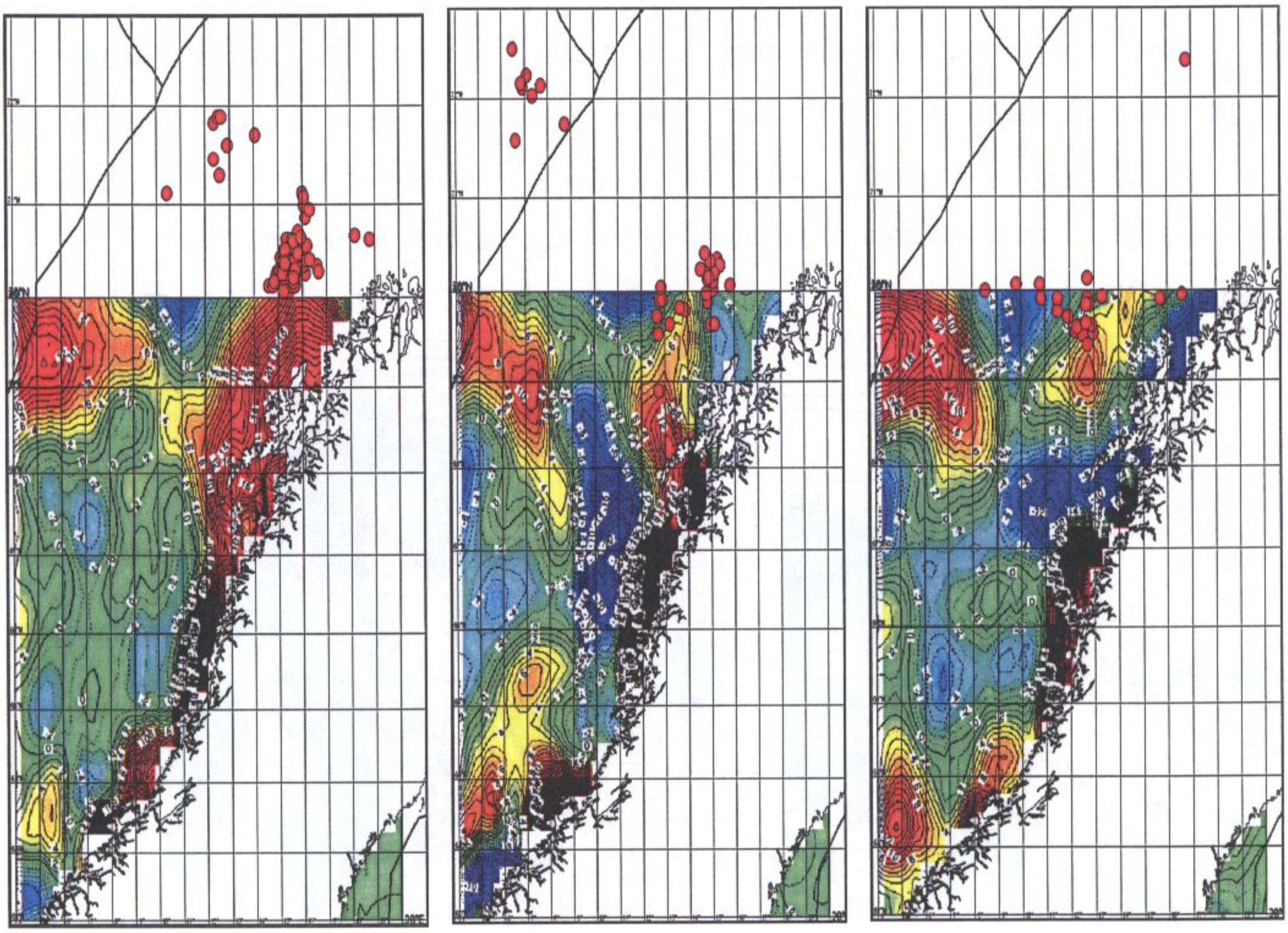
- in the last seven years which were marked by elevated advection of the Atlantic water masses, the area of the herring feeding grounds increased at least 2.5 times (рис. 9);



1985-1996 1997-2006

Fig. 9 . Dynamics of the Atlantic herring feeding grounds, 1985-2006

- examined dependence of the fish stock formation on the bifurcation mechanism of the sea level variations at particular points could be used in predictions of possible wintering areas for different size-at-age groups of the herring stock (Fig. 10).



1 decade 2 decade 3 decade

Fig. 10 Bifurcation mechanism of the wintering grounds formation for different size-at-age groups of Atlantic herring (Norwegian Sea, October, 2006)

REFERENCE

1. Bocharov L.N. Systemnyi analiz v kratkosrochnom rybopromyslovom prognozirovani (System analysis in short-term fishing prediction) // L., Nauka. 208 p. (in Russian)

2. Girs A.A., K.V. Kondratovych, "Methods of long-term weather forecasts" // L. Hydrometeoizdat.1978. p.402.

3. Dzerdzeevskij B.L. Tsirkulyatsionnie mehanizmy v atmosfere Severnogo polushariya v HH stoletii (Circulation mechnasms in the Northern Hemisphere

atmosphere in the 20th century) // In: materialy meteorol. issled. Mezhduved. Geofiz. Komitet pri Prezidiume AN SSSR. M., 1968. 134-141 pp. (in Russian)
4. Parsons T.R., Takahashi M., Hargreiv B. Biologicheskaya okeanografiya (Biological oceanography). M. 1982. (in Russian)
5. Fuks V.R. Vozmozhnosti ispol'zovaniya sputnikovoi al'timetricheskoi informatsii dlya okeanograficheskogo obespecheniya promysla (Use of satellite altimeter information for the fishery oceanographic support) // Protokol 2/31/1 zasedaniya sektsii promyslovoi okeanologii Mezhvedomstvennoi Ihtiologicheskoi Komissii, 25 aprelya 2002 (in Russian)
6. Shatohin B.M., Vanyushin G.P., Gusev A.K., Fuks V.R., Zaharchuk E.A. Vozmozhnosti ispol'zovaniya sputnikovoi al'timetricheksoi informatsii dlya okeanologicheskogo obespecheniya promysla (Use of satellite altimeter information for the fishery oceanologic support) // Tez.dok.XII Mezhd.konf. po promysl. okeanolog. Kaliningrad. 2002. 127-131 pp. (in Russian)
7. Shatohin B.M., Klochkov D.N., Boichuk S.I., Tsiekals M.K. Opyt informatsionnogo obespecheniya resursnyh issledovanij i monitoringa promysla v more Irmingera (Information support of resource exploration and fishery monitoring in the Irminger Sea) // Mater. Vseros. nauchno-tehn. konf. Ch.4. «Nauka i obrazovanie -2003». Murmansk, 2003. 129-130 pp. (in Russian)
8. Shatohin B.M. Issledovanie zakonomernostei i mehanizmov formirovaniya zon povyshennoi biologicheskoi i rybopromyslovoi produktivnosti, kak osnova novyh podhodov v planirovanii uchetnyh s'emok zapasov i poiska promyslovyh skoplenij (Studies of regularities and mechanisms of formation of zones with high biological and fishery productivity as the basis for innovated approaches in planning of the stock biomass surveys and search for fish aggregations) // Voprosy promyslovoi okeanologii. M., VNIRO. Vyp.1. 2004. 147-167 pp. (in Russian)

9. Shatokhin B.M. Result of research of influence of hydrometeorological cycles on formation of trade conditions // Theses of the report. XI All-Russia conference on a trade of oceanography. Kaliningrad, 1999. P.101.

10. Shatokhin B.M. Methodological of a basis and practice of the decision of problems of short-term forecasting of a craft with use satellite altimetry information // Theses of the report. XI All-Russia conference on a trade of oceanography. Kaliningrad, 2002. With. 266-269.
11. Shatokhin B.M. Research of an ecological role altimetry surface of ocean and bifurkation mechanisms of formation of zones on raised fishery trade productions // Theses of the report. "Mathematic modeling and information technologies in research bioresources of the World ocean ". Vladivostok, 2004. P.133-136.