BIOCOMPLEXITY PROBLEM RELATED TO THE OKHOTSK SEA FISHERIES

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Abstract. *Okhotsk Sea belongs to seas with high productivity the ecosystem of which functions under rigorous climate. Spatial-temporal fields structure of basic hydrological and ecological characteristics of Okhotsk Sea is heterogeneous. In the paper the chemical, physical and biological processes, occuring into the sea waters, are studied.*

Keywords*: system modeling, intelligent technics, sea ecosystem*

Introduction

Chemical, physical and biological processes, occuring into the sea waters, are studied by many authors to assess its bioproductivity. According to the investigations by Terziev et al. (1993), Shuntov (1986) and Zenkevitch (1963) the following structural discretization of Okhotsk Sea can be realized. Five ecological layers exist. Layer 1 is one of maximal photosynthesis. It is situated above the thermocline and has depth about 20-30 *m*. Really it corresponds to the wind-mixed layer. Layer 2 occupies water space from 30 to 150 *m* in a depth. It has low temperatures and oxygen saturation about 80-90%. Layer 3 is characterized by low oxygen saturation (15-20%). It lies between the depth of 150 to 750 *m*. Layer 4 extends for 750 *m* up to depth of 1500 *m*. This layer has minimal oxygen saturation (10-15%). Last layer 5 is situated deeper 1500 *m*. It is characterized by oxygen saturation of 25-30 %. The Okhotsk Sea aquatory is divided by the zones having specific ecological features (Berdnikow et al., 1989; Suzuki, 1992). Spatial distribution of fish biomass depends on seasonal conditions and to a great extent correlates with layers above entioned. The use of the sea biological resources is function of this distribution. The fishing intensity essentially depends on knowledge of biomass distibution in the zones with specific environmental conditions. Any authors (Berdnikov et al., 1989; Plotnikov, 1996; Vinberg and Anisimov, 1969; Aota et al., 1992; Krapivin et al., 2000) try to solve this task by means of models simulating the ecosystem dynamics. However the modeling results not always turn out to be sufficiently representative and to reflect the classification of sea zones by their productivity scale. Biocomplexity indicator is one of such simple forms to identify these zones. Really it is shown many investigators the Okhotsk Sea zones with high productivity are characterized by complex many- levels trophic graph (Terziev et al., 1993). This effect is not universal to another seas. For instance, Peruvian current ecosystem has high productivity in zones where trophic graph is short (Krapivin, 1996). These situations are distinguished with the migration processes. That is why the biocoplexity of these ecosystem is formed by various ways.

The biocomplexity problem

Consider the following components of Okhotsk Sea ecosystem mentioned in Table 1. Trophical piramid $X = ||x_{ij}||$, where x_{ij} is binary value equaled to «1» or «0» under existence or absence of nutritive correlation between the *i*th and *j*th components, respectively. Define the biocomplexity as function:

$$\xi(\phi,\lambda,z,t) = \sum_{i=1}^{20}\sum_{j=1}^{19} x_{ij} C_{ij} \qquad (1)$$

where φ and λ are geographical latitude and longitude; *t* is current time; *z* is the depth;

$$x_{ij} = \begin{cases} 1, if B_m \geq B_{m,\min}; \\ 0, if B_m \langle B_{m.\min}; \end{cases}$$

$B_{m,min}$ is the minimal biomass of the *m*th component consumed by other trophic levels;

$C_{ij} = k_{ji} B_{i,*} / \Sigma_{j+}$ is the nutritive pressure of the *j*th component upon the *i*th component;

$\Sigma_{i+} = \sum k_{im} B_{m,*}$ is real food storage which is available to the *i*th component; $m \in S_i$

$B_{m,*} = max\{0, B_m - B_{m,min}\}$; $k_{im} = k_{im}(t, T_W, S_W)$ ($i = 1, \dots, 17$) is the index of the satisfaction of nutritive requirements of the *i*th component at the expense of the *m*th component biomass; k_{im} ($i = 18,19$) is the transformation coefficient from *m*th coponent tothe *i*th component; $k_{i\,20}$ is the characteristic of anthropogenic influence on the *i*th component; $S_i = \{i : x_{ij} = 1\ j = 1, \dots, 19\}$ is the food spectrum of the *i*th component' T_W is water temperature; S_W is water salinity.

Design the aquatory of Okhotsk Sea by $\Omega=\{(\varphi,\lambda)\}$. Value of biocomplexity indicator for any area $\omega \in \Omega$ is determined by formula:

$$\xi_\omega(z_1, z_2, t) = (1/\sigma_\omega) \int_{(\varphi,\lambda)\in\omega} \int_{z_1}^{z_2} \xi(\varphi, \lambda, z, t) d\varphi d\lambda dz$$

where $[z_1, z_2]$ is water layer located between the depths of z_1 and z_2.

Maximal value of $\xi = \xi_{max}$ (≈ 20) is reached during spring-summer time when nutritive relations into the Okhotsk Sea ecosystem are extended, the intensity of energetic exchanges is increased, horizontal and vertical migration processes are stimulated. In the winter time value of ξ is changed near ξ_{min} (≈ 8). Spatial distribution of ξ reflects a local variability of food spectrum for the components. Fig.1 and Table 2 show the examples of such distribution. Comparison of this distribution with the distribution of zones with industrial fish accumulations (Terziev et al., 1993) shows that there is correlation between these distributions.

In the common case an indicator ξ reflects the level of complexity of Okhotsk Sea ecosystem. Change of the ξ is realized in consequence of migration processes and the variability of nutritive interactions. Subsystem B_{20} playes in these processes a role of external source of change in the other components. These changes are interpreted in the terms of fishering and impacts causing the variations of components biomass.

Calculations show that basic variability into the $\xi^* = \xi/\xi_{max}$ is caused by migration processes. Under this the quick redistribution of interior structure of matrixes X and $\|C_{ij}\|$ are occured. For instance, according to Terziev et al.(1993) many fishes during spring time migrate to the shelf zone, and during winter time they move to the central aquatories of sea.

Therefore value $\xi^* \to 1$ during spring and $\xi^* \to 0.6$ during winter for the shelf zone, respectively. It means that biocoplexity of Okhotsk sea ecosystem in the shelf decreases by 40% in winter in comparison with spring. For the central aquatories the ξ^* is changed near during year. Such stability of biocomlexity indicator is explained by the balance between nutritive correlations and productivity during spring, summer and winter times.

It can be to establish that variability in the ξ^* reflects the changes of fish congestions which are controlled by environmental conditions. Specifically, during spring time *Clupeapallasi escapes* occupy the area with the $T_W < 5^oC$. Other fishes have the elective depth for their feeding and spawning (Terziev et al. 1993). All these processes influence on variability of the ξ^*.

A more detail investigation of correlations between value ξ^* and structural and behavioral dynamics of Okhotsk Sea ecosystem demands additional studies.

Conclusions

This report introduces main idea how to move from verbal description of biocomplexity to the numerical scale of it. In future study it is necessary to take into consideration of bottom relief (Udintsev, 1957), climate trends (Shinohara and Shikama, 1988), ice fields dynamics (Sekine and Nakagama, 1992), detail components of trophic piramid (Ueno, 1971; Terziev et al., 1993; Nishimura, 1983), bottom sediments (Bezrukov, 1960), and currents structure (Moroshkin, 1964; Kawasaki and Kono, 1993). Also it ia necessary to add to the formula (1) the members describing the anthropogenic impacts on the ecosystem considering in a socio-economic sense.

Table 1.Trophic piramid of Okhotsk Sea ecosystem taking into consideration under the biocomplexity indicator formation. Designations:

Energy and matter consumers	Energy and matter sources																		
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{16}	B_{17}	B_{18}	B_{19}
Phytoplankton, B_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Bacterioplankton, B_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Microzoa, B_3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Herbivores, B_4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carnivores, B_5	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Zoobentic animals, B_6	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Flat-fish, B_7	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
Coffidae, B_8	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
Ammodytes hexapterus, B_9	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	1	0	0	0
Mallotus, B_{10}	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0
Theragra chalcogramma, B_{11}	0	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0
Salmonidae, B_{12}	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	1	0	0	0
Coryphaenoides, B_{13}	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
Reinchardti ushippoglossoi des matsuurae, B_{14}	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
Clupeapallasi pallasi Val, B_{15}	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
Crabs, B_{16}	0	0	0	0	0	1	0	1	1	1	0	1	0	0	0	1	1	0	0
Laemonema longipes, B_{17}	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Biogenic salts, B_{18}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Detritus, B_{19}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
People, B_{20}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

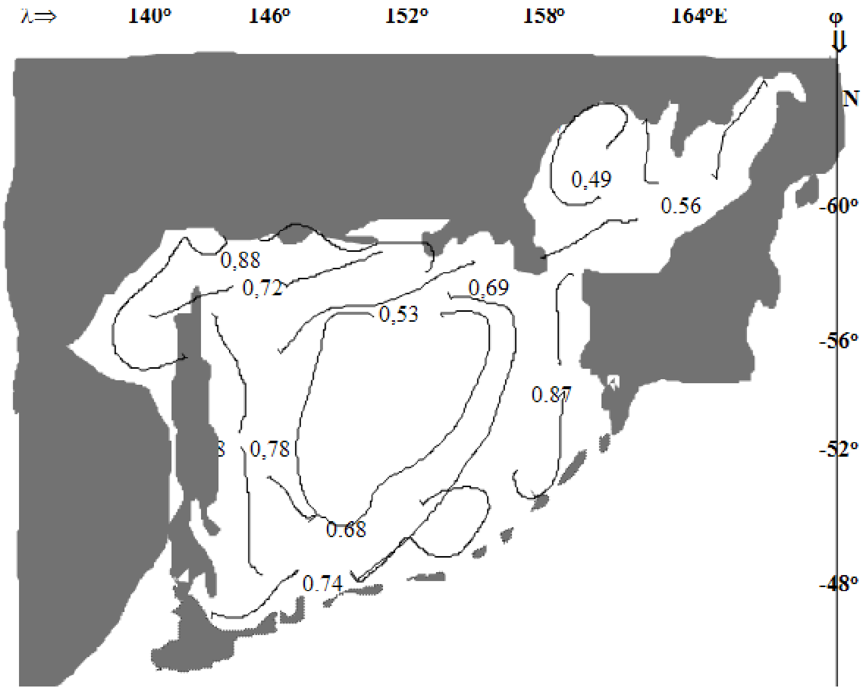

Figure 1. Spatial distribution of biocomplexity indicator $\xi^* = \xi/\xi_{max}$ for the spring-summer time.

Table 2. Estimations of biocomplexity indicator ξ^* for the different layers in spring-summer and winter

Season	Layers				
	1	2	3	4	5
Spring - Summer	0,89	0,93	0,62	0,34	0,21
Winter	0,31	0,49	0,71	0,39	0,21

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