Natalia N. Mitina*, Boris M. Malashenkov, Leonora A. Telitchenko
Water Problems Institute of the Russian Academy of Sciences; Gubkin str., 3, Moscow, 119991, Russia; Tel. +7 499 1357190
* **Corresponding author:** e-mail: natalia_mitina@mail.ru

CRITERIA OF THE ECOSYSTEM STABILITY IN THE NORTHERN REGION OF THE CASPIAN SEA

ABSTRACT. The aim of the work is to determine the criteria of the marine shallow-water ecosystem stability using the Northern region of the Caspian Sea as a case study. For each 260 reference points, we received data on 76 parameters, including physical-geographical, hydrochemical, and hydrobiological characteristics that have been analyzed by the method of principle components. The analyzes of these data allowed us to reveal and evaluate principal geoecological factors that influence the distribution of *Acipenseridae* in the Caspian Sea as a top level of the ecosystem's trophic chain. The main geoecological factors and the factor of anthropogenic load of the Caspian Sea ecosystems' stability have been determined.

KEY WORDS: The North Caspian Sea, criteria of the aquatic ecosystem stability, sub-aquatic natural complex, anthropogenic load, landscape forming factors, factor analyses, sturgeon population.

INTRODUCTION

One of the criteria for the stable state of the Caspian Sea ecosystem is the wellbeing of long-lived sturgeon fishes (*Acipenser population*) as species that reside at the upper trophic level of the aquatic ecosystem. Its population is presently subjected to a heavy anthropogenic impact. Of a special significance for their spawning, fattening, and winter stay, are the underwater natural complexes of the northern Caspian Sea aquatic environment, where each of the water areas is important for normal functioning of this population. Therefore, in order to preserve the most productive northern region of the Caspian Sea, it is necessary to carry out zoning of its underwater natural complexes and of their landscape-forming factors and to determine the quantitative significance of each factor. In the natural conditions, it is difficult to separate factors that impact sturgeon fishes one from another and it is even more difficult to estimate quantitatively the role of each of these factors. In this study, an attempt is made to fill in this gap.

The objective of this study is to determine the main factors that characterize the basic features and influence the stable functioning of the Caspian Sea ecosystem, according to the degree of their significance. To achieve this objective, the following tasks were solved:

1) Creation of a data base of a number of basic geoecological characteristics of the underwater landscapes in the northern part of the Caspian Sea collected in filed studies and from literature sources and their subsequent statistical processing;

2) Subsequent mapping of water areas with similar natural conditions and classification and complex zoning of the region under study;

3) Selection of basic parameters that characterize integrally the state of each underwater landscape component using results of pairwise correlation analysis;

4) Definition of basic factors as criteria determining the conditions of stable existence of sturgeon fishes applying the method of main components to the region as a whole and to its large underwater natural complexes represented by physical-geographical areas and sub-areas.

THE STUDY OBJECT AND RESEARCH METHODOLOGY

To study the region, which is bordered from the north, east, and west by the coasts, and from the south – by a boundary running along the straight line from the cape Burun to the cape Segendi, the data on different parameters of the state of sea environment were analyzed. These data were obtained by on-ship observations carried out on standard cross-sections in 1960–2000. Overall, thousands of marine stations were installed over this region, where tens of thousands observations were carried out. The data of the entire historical line of observations in a 0-m horizon and in the near-bottom layer for the warmest (August) and the coldest (February) months were interpolated to the nodes of a regular grid with a step of 25×25 km using GIS-technologies. Thus, for all the observed and calculated oceanographic parameters of the study sea environment, three-dimensional data matrixes were formed, which became the basis for the analysis of the environmental state of the bottom natural complexes (BNC). These parameters included geologic-geomorphological (depth, relief type), lithological (granulometrical composition and type of bottom sediments); hydrodynamical (wave height); climatic (total and absorbed solar radiation, balance of radiation); hydrological (average multi-year winter (February) and summer (August) temperatures of surface and near-bottom water, ice distribution); biological (distribution of five species of sturgeon fishes; total biomass of phytoplankton, zooplankton, and zoobenthos; biomass of dominant species of phytoplankton, zooplankton, and zoobenthos; as well as a number of forage types for zoobenthos sturgeon species (*Abra, Nereis* and others)); hydrochemical (salinity, distribution of Cl, SO_4, HCO_3, Ca, Mg, NO_2, NH_4, PO_4, Si, O_2, Ph in water and bottom sediments, alkalinity); and anthropogenic pollution (concentrations of oil hydrocarbons (HC), phenols, synthetic surface-active substances (SSAS)). The coast landscapes were also taken into account [Landscape Map of the USSR, 1987] (Fig. 1). As a result, data sets for 54 parameters were obtained for each reference point (totally, 260 points). Thus, the analyzed variables represent the integral characteristics of the landscape-forming and geoecological factors, covering the entire complex of components of the coastal zone landscapes.

In order to distinguish and to map water areas with similar natural conditions, the landscape zoning of the sea-bottom natural complexes was carried out. The basic types of the bottom natural complexes were determined, which are typical to the water area under investigation and refer to three sub-areas of the Caspian Sea: (1) the Northern-Caspian shallow-water, (2) the Northern-Caspian deeper-water, and (3) the northern part of the Central Caspian sub-area (Fig. 2). For quantitative substantiation of structural changes in the interconnections between the components of the sub-areas that fulfill different functions in the sea ecosystem, the initial matrix of variables characterizing the entire study region was appropriately subdivided. As a result, four matrixes of variables were compiled: the first – characterizing the entire water region under study and incorporating the data of all observation points, included 54 columns and 211 lines; the second – for the Northern-Caspian shallow-water sub-area, with a size of 54×69; the third – for the Northern-Caspian deeper-water sub-area with a size of 54×77; the fourth – for the Northern part of the Middle Caspian area with a size of 54×65, involving data of the observation points lying in the central part of the sea (area including the Mangyshlak rapids and south of it).

The initial matrix for the entire study region was treated using the method of

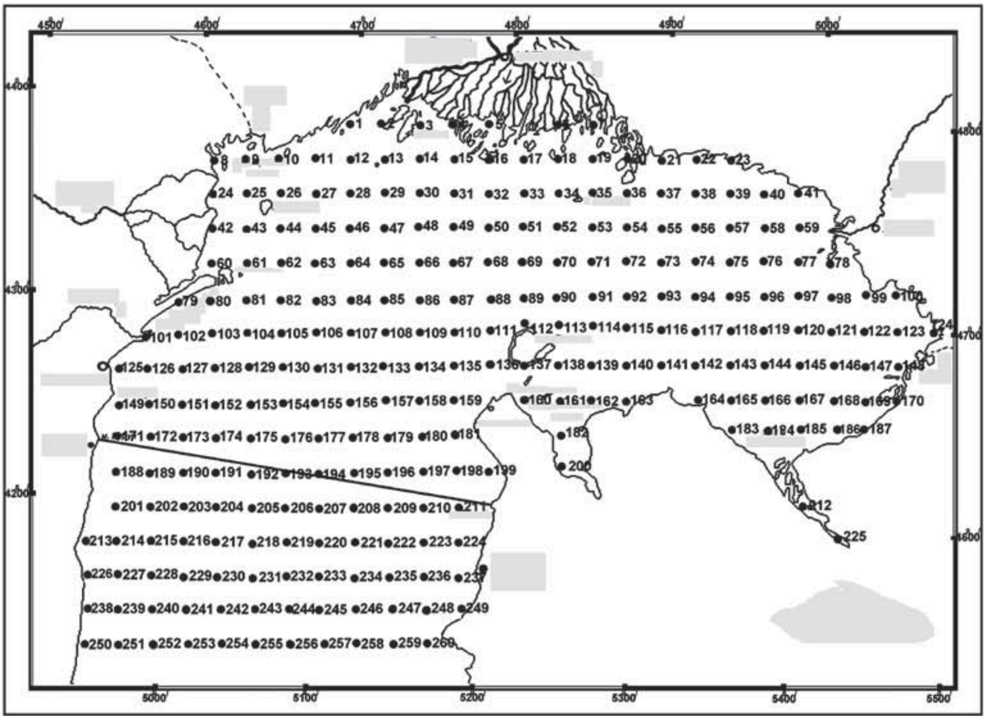


Fig. 1. The map of the observation points' locations

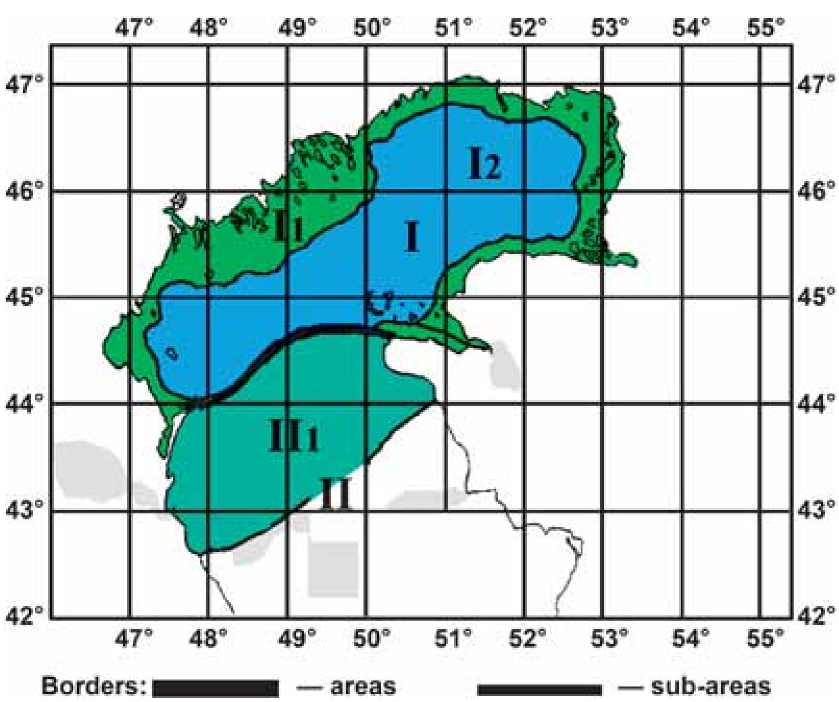


Fig. 2. The map of basic natural complexes

pair correlation analysis. Into consideration there were taken the strong correlating links ($r \geqslant 0.7$) that characterize the interaction between the components of the underwater natural complexes. The matrix diagonal consists of sufficiently high correlation coefficients (r) and more than half of the matrix has coefficients $r > 0.3$; hence, the variables selected for the analysis are sufficiently representative.

The number of different factors influencing an open ecosystem is great; therefore, it is necessary, during the investigations, to identify those indices and factors that determine the ecosystem's stable functioning. For this purpose, it is necessary to select such integral indices that determine qualitatively the integral state of any component in the ecosystem according to some certain function [Pegov, 1992]. Such approach allows obtaining the most general pattern of an integral parameter. In accordance with the above-said, we have selected the integral indices characterizing each of the basic components of the underwater landscape and connected with other indices by strong correlation links. Here, no strong correlation links were revealed between the density of sturgeon distribution over the water area and other indices; the links were established only at the level of mean coefficients ($r \geqslant 0.31–0.5$).

In order to determine the significance of the influence of different parameters on the density of sturgeon distribution, the entire collection of data was processed using the factor analysis with the aid of the method of main components. The method was aimed at defining the regular features governing the phenomenon under study (namely, the density of sturgeon distribution over the water area), i.e., those basic factors that determine the behavior of a large number of various characteristics of this phenomenon [Braverman and Muchnik, 1983]. This helped to distinguish, among the measured variables, a small number of hidden factors characterizing basic features of sturgeon fishes distribution. For solution of this task and using the results of correlation analysis, there was selected a row of parameters for 211 observation points (because, in this case, the entire data row was required) and a row of variables that describe quantitatively the basic features of natural complexes in the study region.

Basic factors for the entire region were defined from the analysis of the initial matrix with a size of 14×211 (i.e., consisting of 211 lines or points of observation, and 14 variables (columns), which quantitatively described 14 features of different BNC components). Then, for substantiation of the influence of abiotic factors on the sturgeon existence, the obtained basic variables characterizing the ecosystem's integral state were processed by the method of main components, where the dependent variable "C" is the catch of sturgeon fishes. The variables measured were as follows:

X1 – average multi-year temperature of the sea surface for February (°C) – characterizes hydrological and thermal regime of the Caspian Sea;

X2 – boundaries of ice distribution (coded in estimated numbers) – this variable characterizes natural climatic, and hydrological conditions of the North Caspian area in winter period;

X3 – NO_2-distribution on the sea surface (mkg NO_2/l) – characterizes hydrochemical conditions;

X4 – O_2-distribution (mg/l) on the sea surface – characterizes hydrochemical conditions;

X5 – average annual distribution of salinity ($^0/_{00}$) in surface waters – characterizes hydrochemical regime in the sea;

X6 – radiation balance per year (MJ/m^2) – determines the difference between incoming and outgoing solar energy and characterizes climatic conditions;

X7 – depth (m) – serves as a characteristics of the sea-bottom relief;

X8 – distance from the Volga-Caspian main channel (in km) – characterizes a degree to which the Volga River runoff influences pollution of the sea area;

X9 – distribution of the total biomass of the zooplankton (g/m^2) in the Caspian Sea – characterizes the sea biological complexes;

X10 – distribution of the total biomass of the phytoplankton (mg/m^3) in the Caspian Sea – characterizes biological complexes of the sea and determines its productivity;

X11 – distribution of biomass of the zoobenthos (g/m^2) – characterizes conditions for forming forage resources of sturgeon fishes;

X12 – average annual distribution of phenols (mg/l) in the water – characterizes a degree of pollution of the water area (as one of basic components of water pollution);

X13 – average annual distribution of oil hydrocarbons (OH) (mg/l) in the water – characterizes a degree of pollution of the water area (as one of basic components of water pollution);

X14 – distribution of five species of sturgeon fishes (*Acipenser gueldenstaedtii Brandt; Acipenser nudiventris Lovetsky; Acipenser persicus Borodin; Acipenser stellatus Pallas; Huso huso Linnaeus*) in the North Caspian Sea area (coded in estimated numbers).

Thus, the defined variables make it possible to cover the entire complex of components composing the sea-BNC.

Tables 1–4 present the matrix of pair linear correlation coefficients of the selected parameters. Table 1 presents the matrix of the pair correlation links between the integral variables for the entire studied region. Table 2 presents the matrix of the pair correlation

Table 1. The matrix of the pair correlation links between the integral variables for the entire studied region

Varia-bles	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	1													
X2	–0.77	1												
X3	–0.2	0.41	1											
X4	0.3	0.02	0.38	1										
X5	0.61	–0.78	–0.58	–0.3	1									
X6	0.35	–0.55	–0.38	–0.4	0.61	1								
X7	0.75	–0.75	–0.46	–0.05	0.79	0.46	1							
X8	–0.01	0.05	–0.16	0.05	–0.03	–0.16	–0.03	1						
X9	0.51	–0.41	0.01	0.3	0.31	0.21	0.43	–0.16	1					
X10	–0.32	0.36	0.31	0.21	–0.47	–0.41	–0.32	–0.12	–0.1	1				
X11	0.31	–0.5	–0.36	–0.24	0.62	0.53	0.37	–0.08	0.07	–0.5	1			
X12	–0.43	0.55	0.01	0.16	–0.55	–0.55	–0.42	0.42	–0.4	0.24	–0.42	1		
X13	0.25	–0.26	0.08	0.04	0.23	0.31	0.12	–0.2	0.3	–0.04	0.17	–0.65	1	
X14	–0.1	0.17	0.18	0.21	–0.13	–0.16	–0.15	–0.13	0.21	0.12	–0.17	–0.03	0.12	1

Table 2. The matrix of the pair correlation links between the integral variables for the Northern-Caspian shallow-water sub-area

Vari-ables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
X1	1													
X2	–0.71	1												
X3	–0.23	0.5	1											
X4	0.15	0.16	0.37	1										
X5	0.37	–0.65	–0.54	–0.41	1									
X6	0.31	–0.69	–0.42	–0.54	0.6	1								
X7	0.45	–0.54	–0.54	–0.22	0.65	0.46	1							
X8	0.02	–0.03	–0.24	0.05	0.1	–0.19	0.03	1						
X9	0.08	0.05	0.12	0.1	–0.18	0.09	–0.001	–0.22	1					
X10	–0.31	0.5	0.43	0.06	–0.37	–0.18	–0.04	–0.44	0.2	1				
X11	0.35	–0.66	–0.3	–0.11	0.67	0.67	0.44	–0.02	–0.1	–0.26	1			
X12	–0.35	0.34	–0.21	0.32	–0.3	–0.55	–0.14	0.46	–0.21	–0.09	–0.36	1		
X13	0.32	–0.3	0.09	–0.37	0.3	0.38	0.07	–0.21	–0.03	–0.05	0.33	–0.83	1	
X14	–0.21	0.3	0.24	–0.11	–0.06	–0.04	–0.12	–0.18	0.42	0.08	–0.3	–0.08	–0.14	1

Table 3. The matrix of the pair correlation links between the integral variables for the Northern-Caspian deeper-water sub-area

Vari-ables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
X1	1													
X2	-0.33	1												
X3	0.18	0.24	1											
X4	0.2	0.35	0.43	1										
X5	0.23	–0.82	–0.4	–0.58	1									
X6	0.05	–0.3	–0.19	–0.51	0.53	1								
X7	0.12	–0.64	–0.22	–0.08	0.55	0.11	1							
X8	-0.1	0.41	–0.42	0.18	–0.4	–0.3	–0.38	1						
X9	0.07	–0.21	0.36	0.2	0.08	–0.02	0.2	–0.5	1					
X10	0.05	0.02	–0.17	0.37	–0.21	–0.39	–0.02	0.3	0.11	1				
X11	0.15	–0.35	–0.26	–0.48	0.6	0.43	0.13	–0.3	–0.1	-0.52	1			
X12	–0.21	0.51	–0.18	0.32	–0.64	–0.45	–0.4	0.79	–0.42	0.25	-0.36	1		
X13	0.22	–0.2	0.3	0.13	0.24	0.22	0.14	–0.35	0.43	0.03	0.03	-0.55	1	
X14	0.02	0.1	0.38	0.44	–0.18	–0.23	0.25	–0.30	0.43	0.16	-0.23	-0.05	0.17	1

Table 4. The matrix of the pair coefficient correlations between the integral variables for the Northern part of the Middle Caspian area

Vari-ables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
X1	1													
X2	–0.82	1												
X3	–0.52	0.58	1											
X4	–0.04	0.21	0.45	1										
X5	0.35	–0.33	–0.5	–0.53	1									
X6	0.52	–0.64	–0.57	–0.57	0.61	1								
X7	0.7	–0.59	–0.55	–0.4	0.73	0.7	1							
X8	0.8	–0.72	–0.49	–0.24	0.31	0.44	0.55	1						
X9	0.7	–0.72	–0.46	–0.07	0.33	0.63	0.62	0.4	1					
X10	–0.76	0.6	0.39	0.01	–0.3	–0.2	–0.44	–0.62	–0.38	1				
X11	–0.07	–0.03	–0.06	–0.06	–0.05	0.16	–0.04	–0.3	0.21	0.21	1			
X12	0.6	–0.55	–0.38	–0.24	0.13	0.32	0.23	0.6	0.42	–0.5	0.006	1		
X13	–0.16	0.24	0.42	0.6	–0.3	–0.35	–0.24	–0.3	–0.11	0.18	0.13	–0.38	1	
X14	–0.23	0.3	0.55	0.45	–0.3	–0.3	–0.25	–0.2	–0.23	0.36	0.03	–0.20	0.46	1

links between the integral variables for the Northern-Caspian shallow-water sub-area. Table 3 presents the matrix of the pair correlation links between the integral variables for the Northern-Caspian deeper-water sub-area. Table 4 presents the matrix of the pair coefficient correlations between the integral variables for the Northern part of the Middle Caspian area

Over half of the matrix has values $r > 0.3$. Hence, the data selected for the analysis are representative. The use of the method of main components for the analysis of the correlation matrix allows distinguishing basic factors that influence the distribution of sturgeon fishes in each selected area and estimating their significance.

Table 5 presents the basic components in the factor analysis. The columns in the Table characterize the obtained general factors for the selected areas. Their contribution to the total dispersion is different and is determined by their own numbers and their contribution (in %) to the total sturgeon dispersion. Also, the total contribution of the defined factors to the total dispersion is shown. From Table 5, we can see that the first three factors defined for each area under consideration determine, for the entire region, 67.9% of sturgeon dispersion. For the Northern-Caspian shallow-water sub-area, it is 66.4%. For the Northern-Caspian deeper-water sub-area, it is 66.6%. For the Northern part of the Middle Caspian area, it is 72.0%. Thus, the major part of the parameters' variability falls on these three factors. Therefore, in further analysis, we used only three general factors, as the rest of the factors provide a small contribution to the total dispersion.

In the first group of columns in Tables 6–9, the loads of 13 parameters on three general factors obtained by the method of main components are included. In the second group, the final factor loads were obtained through three rotations. Table 6 presents the factor matrix for the data analysis of the entire studied region. Table 7 presents the

Table 5. Main components for the factor analysis

		1	2	3	4	5	6	7	8	9	10	11	12	13
Studied region	Eigen values	5.160	2.013	1.651	0.881	0.739	0.589	0.492	0.429	0.371	0.265	0.182	0.131	0.097
	Variation percentage	39.7	15.5	12.7	6.7	5.6	4.5	3.7	3.3	2.8	2.1	1.4	1.0	0.7
	Total percentage	39.7	55.2	67.9	74.6	80.3	84.8	88.6	91.9	94.8	96.8	98.2	99.2	100.0
Northern-Caspian shallow-water sub-area	Eigen values	4.788	2.430	1.411	1.212	0.864	0.687	0.584	0.335	0.269	0.179	0.102	0.093	0.044
	Variation percentage	36.8	18.7	10.9	9.3	6.6	5.3	4.5	2.6	2.1	1.4	0.8	0.7	0.3
	Total percentage	36.8	55.5	66.4	75.7	82.3	87.6	92.1	94.7	96.8	98.2	99.0	99.7	100.0
Northern-Caspian deeper-water sub-area	Eigen values	4.447	2.569	1.649	1.077	0.887	0.563	0.515	0.433	0.338	0.223	0.149	0.089	0.061
	Variation percentage	34.2	19.7	12.7	8.3	6.8	4.3	4.0	3.3	2.6	1.8	1.1	0.7	0.5
	Total percentage	34.2	53.9	66.6	74.9	81.7	86.0	90.0	93.3	95.9	97.7	98.8	99.5	100.0
Northern part of the Middle Caspian area	Eigen values	6.049	1.907	1.410	1.102	0.540	0.479	0.439	0.330	0.251	0.190	0.148	0.111	0.043
	Variation percentage	46.5	14.6	10.8	8.48	4.1	3.6	3.3	2.5	1.9	1.4	1.1	0.8	0.3
	Total percentage	46.5	61.1	72.0	80.5	84.7	88.4	91.7	94.3	96.2	97.7	98.8	99.7	100.0

Table 6. The factor matrix for data analysis of the entire studied region

Variables	Factor 1		Factor 2		Factor 3	
	Before rotation	After rotation	Before rotation	After rotation	Before rotation	After rotation
X1	0.706	0.293	0.280	0.854	0.489	0.036
X2	–0.867	–0.581	–0.078	–0.672	–0.236	–0.158
X3	–0.505	–0.744	0.609	–0.065	–0.157	0.306
X4	–0.206	–0.632	0.625	–0.577	0.559	–0.115
X5	0.911	0.799	–0.172	0.442	0.047	0.166
X6	0.734	0.718	–0.163	0.087	–0.353	0.408
X7	0.809	0.566	0.014	0.657	0.312	0.045
X8	–0.135	0.072	–0.416	0.074	0.556	–0.700
X9	0.460	–0.045	0.571	0.695	0.232	0.312
X10	–0.540	–0.616	0.341	–0.170	–0.077	0.08
X11	0.663	0.704	–0.259	0.088	–0.216	0.227
X12	–0.698	–0.351	–0.409	–0.289	0.465	–0.814
X13	0.382	0.037	0.508	0.209	0.401	0.721

Table 7. The factor matrix for data analysis for the Northern-Caspian shallow-water sub-area

Variables	Factor 1		Factor 2		Factor 3	
	Before rotation	After rotation	Before rotation	After rotation	Before rotation	After rotation
X1	0.605	0.489	0.002	0.293	0.657	–0.055
X2	–0.877	–0.785	–0.133	–0.309	–0.291	0.202
X3	–0.574	–0.768	–0.560	0.297	0.242	0.263
X4	–0.440	–0.377	0.152	–0.310	0.793	0.061
X5	0.841	0.808	0.191	0.221	–0.163	–0.241
X6	0.833	0.749	–0.214	0.444	–0.189	0.105
X7	0.674	0.834	0.181	–0.089	0.018	0.147
X8	–0.013	0.044	0.723	–0.358	0.009	–0.696
X9	–0.066	0.044	–0.372	–0.039	0.326	0.671
X10	–0.416	–0.309	–0.544	–0.045	–0.152	0.745
X11	0.764	0.653	–0.011	0.367	0.103	–0.119
X12	–0.513	–0.170	0.798	–0.909	–0.046	–0.293
X13	0.497	0.093	–0.604	0.917	–0.052	–0.054

Table 8. The factor matrix for data analysis of the Northern-Caspian deeper-water sub-area

Variables	Factor 1		Factor 2		Factor 3	
	Before rotation	After rotation	Before rotation	Before rotation	Before rotation	After rotation
X1	0.248	–0.008	–0.283	0.102	–0.244	0.141
X2	–0.767	0.189	–0.024	–0.206	0.488	–0.840
X3	–0.121	0.108	–0.0773	0.665	0.469	–0.592
X4	–0.550	0.704	–0.610	0.171	–0.200	–0.360
X5	0.896	–0.517	0.242	0.133	–0.248	0.789
X6	0.622	–0.706	0.266	0.113	0.313	0.213
X7	0.570	0.039	–0.073	0.246	–0.528	0.765
X8	–0.690	0.332	0.476	–0.809	–0.244	–0.203
X9	0.278	0.229	–0.708	0.774	–0.058	0.129
X10	–0.387	0.795	–0.210	–0.122	–0.708	0.248
X11	0.632	–0.777	0.389	–0.050	0.268	0.237
X12	–0.839	0.428	0.349	–0.716	–0.127	–0.387
X13	0.395	–0.009	–0.579	0.650	0.020	0.110

Table 9. The factor matrix for data analysis for the Northern part of the Middle Caspian area

Variables	Factor 1		Factor 2		Factor 3	
	Before rotation	After rotation	Before rotation	Before rotation	Before rotation	After rotation
X1	0.863	0.918	0.440	0.322	0.085	0.045
X2	–0.861	–0.821	–0.241	–0.337	–0.139	0.123
X3	–0.742	–0.437	0.227	–0.475	0.014	0.422
X4	–0.459	0.089	0.750	–0.488	0.239	0.774
X5	0.620	0.093	–0.456	0.868	0.013	–0.198
X6	0.773	0.329	–0.392	0.711	0.253	–0.322
X7	0.806	0.421	–0.171	0.828	0.146	–0.057
X8	0.783	0.785	0.306	0.238	–0.288	–0.213
X9	0.732	0.653	0.162	0.428	0.486	0.090
X10	–0.659	–0.790	–0.484	–0.133	0.216	0.002
X11	–0.034	–0.103	–0.239	–0.001	0.749	0.018
X12	0.623	0.732	0.242	–0.148	–0.204	–0.462
X13	–0.441	–0.155	0.423	–0.096	0.519	0.862

factor matrix for the data analysis for the Northern-Caspian shallow-water sub-area. Table 8 presents the factor matrix for the data analysis of the Northern-Caspian deeper-water sub-area. Table 9 shows the factor matrix for the data analysis for the Northern part of the Middle Caspian area. The rotations were made in order to estimate more completely the loads of particular variables on the main components and implemented by means of replacing diagonal elements of the correlation matrix by corresponding estimates of communion. Rotation of the factorial matrix is necessary to determine more precisely and clearly a contribution of each variable to any of the factors. This was the final purpose of the factorial analysis by the method of main components. Indeed, it is seen from the analysis of Tables 6–9 that all the significant variables (1–13) are divided into groups according to their loads on the three distinguished general factors; each group contributes considerably to one or another factor and carries a certain meaning.

ANALYSIS OF THE FACTORIAL MATRIX OBTAINED FOR THE ENTIRE STUDY REGION

Factor 1 has the highest share of the total dispersion in the factorial matrix: it determines 39.7% of the variables (Table 5). The largest loads (Tables 6 and 10) on the factor come from the variables X3, X4, X5, X6, X10, and X11. Taking into account the combination

Table 10. The general table of the landscape-forming and geo-ecological factors of stability in the studied region ecosystem

The entire studied Caspian Sea region		
Factor 1	**Factor 2**	**Factor 3**
X3, X4, X5, X6, X10, X11	X1, X2, X7, X9	X8, X12, X13
Hydroecological factor of the food resources forming	Wintering – post-wintering factor	Factor of anthropogenic load
Northern-Caspian shallow-water sub-area		
Factor 1	**Factor 2**	**Factor 3**
X2, X3, X5, X6, X7, X11	X12, X13	X8, X9, X10
Hydroecological factor of the food resources forming in winter	Factor of anthropogenic load	Feeding conditions for growth of the young generation
Northern-Caspian deeper-water sub-area		
Factor 1	**Factor 2**	**Factor 3**
X4, X6, X10, X11	X3, X8, X9, X12, X13	X2, X5, X7
Hydroecological factor of the food resources forming	Factor of anthropogenic load on zooplancton	Wintering factor
Northern part of the Middle Caspian area		
Factor 1	**Factor 2**	**Factor 3**
X1, X2, X8, X9, X10, X12	X5, X6, X7	X4. X13
Factor of anthropogenic load during wintering – post-wintering period	Hydroecological factor	Factor of hydrocarbon pollution

of the parameters enclosed into the given factor, it can be assumed that it characterizes the influence of forage resources in the sea on the sturgeon fishes distribution. We define it as the **"Geoecological factor of food resources formation".**

The Caspian Sea is located at relatively low latitudes, which provides an intensive inflow of solar radiation; the annual radiation balance is positive [Caspian Sea.... 1986]. For the entire sea area, the radiation balance is positive from March to October and reaches maximum values in June and July. Intensive warming of the North Caspian water promotes development of the phytoplankton, which typical feature is the increase of biomass with a temperature rise [Project "Seas".... 1996]. At the same time, penetration of dissolved organic substances to the sea, among which is nitrogen – the most important for feeding plankters, also influence the development of phytoplankton and, via it, of all other units in the trophic chain. As the Caspian Sea benthos predominantly contains phytophagous animals – eaters of plankton and benthos algae, as well as detritus [Kasymov and Askerov, 2001], the biomass of benthos depends directly on the biomass of phytoplankton.

Mass development of the major fresh-water and autochthonous complexes of the bottom fauna is observed in the coastal desalted areas of the North Caspian Sea at depths of below 6 m [Caspian Sea..., 1989; Kushnarenko, 2003], whereas beyond the 100-m isobath, where food, oxygen, and heat are limited, the amount of benthos is low (fractions of a gram per 1 m^3) [Project "Seas"..., 1996]. These areas with scanty bottom population are not worth as fattening sea places for benthos-eating fishes, though they occupy over 60% of the entire Central and South Caspian Sea area.

Salinity of the North Caspian Sea is not the only important physical-chemical characteristics of its waters, but it, to a great extent, determines its biological productivity. It has been established that the main factors determining the North Caspian salinity formation [Caspian Sea...,1986; Pakhomova and Zatuchnaya, 1966] include river runoff, wind regime, water dynamics (water currents, rises and falls of waves), and water exchange with the central part of the sea. About 80% of freshwaters of the river runoff belong to the North Caspian Sea [Project "Seas"..., 1996]. Conditions for fattening of young and adult fishes in the sea are formed under the influence of biogenic runoff and salinity. Besides, as a rule, the volume and the character of the river runoff determine scales and effectiveness of spawning of fishes in river deltas and channels. Such fishes include the most valuable marketable sturgeon and catadromous fishes.

Distribution of salinity in shallow waters determines the predominance of development of specific communities of plankton and benthos, i.e., of the food base for fishes. The North Caspian Sea salinity regime appeared to be favorable for bottom organisms of the Mediterranean complex [Biological productivity..., 1974]. Some of the organisms (*nereis, abra, cerastoderma,* crab) are the main feeding objects of adult sturgeon and salmon. It has been shown in the studies of the adaptation process of young sturgeon fishes to salt water, that they are able to survive in water with increased salinity after gradual, step-by-step transition to this environment [Biological grounds..., 1979].

Oxygen content in water is determined by intensity of physical processes (gas exchange between sea and atmosphere, transfer by water masses) that occur in it, as well as by its formation, during photosynthesis, and consumption of it, during biochemical processes. Oxygen deficit may cause changes in physiologic-biochemical processes in the organism of fishes, their behavior, and deteriorate migration abilities of weakened species. There were cases [Ecological factors..., 1993] when the deficit of oxygen emerged so quickly that fishes were late to leave the famishing zone and died. It is also known that the deficit of oxygen in winter causes, besides the death of fishes, their mass escape to adjacent areas. Formation of areas with oxygen deficit negatively influences development of zoobenthos and the basic feeding objects of fishes – benthophages [Katunin, et. al., 2005].

Thus, this factor has the greatest importance, as they, to a considerable degree, determine both the conditions for forming food resources for sturgeon fishes and the conditions of their natural habitat.

Factor 2 has the second (by magnitude) significance. According to it, 15.5% of the total dispersion is determined (Table 5). After rotation, the high values (>0.7) of variables X1, X2, X7, and X9 (Tables 6 and 10) were revealed, which allows us to define it as the **"Wintering – post-wintering factor".** The factor includes the values of winter temperature, depth differences (availability of winter-staying holes), ice extent, and the amount of zooplankton, i.e., the most important conditions for surviving of sturgeon fishes in winter period.

The northern part of the sea freezes up every year; a considerable sea area is covered by fixed ice – fast ice that composes there the major part of the ice cover [Caspian Sea..., 1986]. Even during very mild winters, the northern and the north-eastern shores of the Caspian Sea are blocked by fast and drift ice. Formation of the constant ice cover may cause oxygen deficit in winter-stay holes, which leads to oxygen hunger of sturgeon fishes and their mass death.

With water cooling in the northern part of sea in autumn, the sturgeon fishes migrate to the south. In spring, with warming of water and development of forage, they return from wintering places to the more shallow-water northern part for fattening. The Russian sturgeons that stay for wintering in the northern part of the sea are characterized by seasonal distribution along depths., i.e., a decrease of the habitat depth from winter to summer and visa versa. They do not form steady winter accumulations and pass from one hole to another during winter. Beluga, Persian sturgeon, and acanthi, in winter, leave the northern part of the Caspian Sea [Kasymov and Askerov, 2001] and meet mainly in its central and southern parts.

A considerable part of the sea plankton consists of meroplankton or temporary plankton. The major parts of the benthos animals in their larval stage [Odum, 1975] have plankton forms that, before settling down onto the bottom, are enclosed into the plankton during different periods of time. Availability of zooplankton in the given factor allows us to define it as "**post-wintering**", as in spring, the plankton consists mainly of representatives of zoobenthos being in the early ontogenesis stage and, hence, representing feeding products for ichthyofauna in subsequent fattening periods. Seasonal changes of the zooplankton in the northern part of the Caspian Sea depend mainly on two factors – temperature and salinity [Kasymov and Askerov, 2001]. Plankton develops weakly in winter under the ice, but in spring, with warming of water, its biomass begins growing actively.

The **"Wintering – post-wintering factor"** determines seasonal migrations of sturgeon fishes across the sea, as well as the conditions for forming the forage base for the subsequent fattening period.

Factor 3 is the third by its significance. Its contribution to the total dispersion in the factorial matrix is 12.7% (Table 5). Maximum loads of variables (r>0.7) X8, X12, and X13 (Tables 6 and 10) on the given factor indicate that it can be characterized as the **"Factor of anthropogenic loading".** It is not an accident that this factor includes, together with the variables characterizing distribution of oil and phenols across the water area, also the variable that determines the influence of the runoff from the Volga River. Investigations of 1975–1999 [Katunin, et. al., 2000] show that the interannual dynamics of oil hydrocarbons in the Volga River and North Caspian Sea is synchronized. Increase or decrease in oil hydrocarbon concentrations in the Volga water in each particular year is accompanied by a simultaneous change in the content of this compounds in the North Caspian Sea. The same happens with contamination by phenols that are one of the most widely spread contaminants penetrating to surface waters with wastes from the plants of oil-refinery, shale-processing, timber, chemical, coke-chemical, and aniline-dye industries. All the largest channels of the Volga River and its main channel flow into the western sector of the North Caspian Sea [Biological productivity...,1974; Mouth area..., 1998] from where the majority of contaminants penetrates. At the same time, the eastern coast of the North Caspian Sea is located in a more advantageous position, i.e., unlike the western coast, it actually does not have a developed river network and is less populated [Geoecology..., 2001]. An important role in transfer and transformation of contaminants belongs to the along-coastal current directed mainly from north to south; a part of contaminants come by transit with the river flow into the sea due to this process [Makarova and Kurapov, 2002].

Such components of biocenoses as nekton, plankton, and benthos [Ivanov and Sokolsky, 2000] possess a high accumulating ability relative to micro-admistures of the environment and are very sensitive to the action of toxicants in the sea (for example, HC, SSAS, phenols, heavy metals) that can concentrate with transition from one level of the trophic chain to another, usually influencing more heavily those organisms that are located at the chain end than those being at the beginning of the chain, i.e., producers with a short-lived cycle [Nelson-Smith, 1977]. Sturgeons are long-living fishes, therefore, the consequences of oil intoxication under long systematic action of small doses may be manifested in several generations [Ivanov and Sokolsky, 2000].

The investigations (1993–1999) [Geraskin, et. al., 2005] of physiological state of the Russian sturgeon, salmon, and beluga, fished up in the sea showed that oil pollution in increased concentrations is received by sturgeons in the natural conditions as a stress-factor and, in combination with other toxicants, leads to an increase of impacts on fishes. Consequences of chronic poisoning by small doses of toxicants, which do not cause the effect of escaping, are even more dangerous. In areas affected by these toxicants [Ecological factors..., 1993], there is a sharp increase in abnormally altered fishes, pathological changes of liver, a decrease in number of feeding fishes due to disturbance in their coordination of food-procuring behavior, removal to spawn, and a partial loss of orientating ability during migration.

Pollution of water basins causes ever-growing forced migrations of fishes from areas with unfavorable conditions, having a character of escape and affecting directly or indirectly the stability of a habitat of the population (local stock), structure of the population, and the process of reproduction [Ecological factors..., 1993]. At the same time, even in the centers of volley-type disposals of toxic waters, a part of species appears to be able to sensor a threat and to try to escape from the polluted zone, which is quite feasible, as oil pollution [Khoroshko and Emirova, 2002] has generally a mosaic character. Possibly, just the ability to sensor the zone of pollution and leave it in proper time determines a relatively low impact of the "Factor of anthropogenic loading" on the sturgeon fishes distribution.

ANALYSIS OF THE FACTORIAL MATRIX OBTAINED FOR THE NORTHERN-CASPIAN SHALLOW-WATER SUB-AREA (SHALLOW-WATER ZONE)

Factor 1. After rotation, the high final loads on the given factor (Tables 7 and 10) have variables X2, X3, X5, X6, X7, and X11. Taking into account the meaning of the variables that are included in this factor, it can be considered as similar (with slight changes) to the **"Factor of forming food resources"** determined for the entire study region; it can be characterized as the **"Geoecological factor of forming food resources in winter time",** as this factor of the Northern-Caspian shallow-water sub-area is summed with the variables characterizing the conditions for existence of sturgeon population in winter period (variables X2 and X7), which are especially complicated in shallow-water areas because of ice situation, and does not include the variables characterizing the distribution of oxygen and the total phytoplankton biomass, as in the coastal zone there is usually no oxygen deficit and phytoplankton does not serve as food for adult sturgeon fishes. This factor is also the first in defining general factors for the entire study region, but, in this case, its contribution to the total dispersion of the variables decreases to 36.8%.

Factor 2 has the second (by significance) load in the factorial matrix: it determines 18.7% of the total dispersion (Table 5). The highest load ($r > 0.7$) on the factor comes from variables X12 and X13 (Tables 7 and 10), which allows us to define it as the **"Factor of anthropogenic loading"**, actually identical to **Factor 3** for the entire region. The factor includes the variables characterizing pollution of the study area by phenols and oil, but does not include variable X8 that characterizes the degree of influence of the Volga River runoff, because, in this case, only the coastal areas are considered, to where pollutants are penetrating from populated settlements, with wastewaters from fields, etc. At the same time, its contribution to the total dispersion of variables is higher than that of the **"Factor of anthropogenic loading"** for the entire region and increases to 18.7%. As the seawater areas receive the major impacts of anthropogenic pollution which amounts to 90 % and is deposited in the coastal zone, the significance of this factor has increased compared with the entire sea area and has shifted to the second place.

Factor 3 has a 10.9%-contribution to the total dispersion in the factorial matrix (Table V). The high contribution of variables X8, X9, and X10 (Tables 7 and 10) to this factor makes it possible to characterize it as a factor determining conditions for fattening of young sturgeon fishes after they swim down to the sea, i.e. , the **"Factor of feeding conditions for fattening of young fishes**".

Analyzing the variables enclosed into this factor – a distance from the Volga-Caspian main channel, distribution of biomass of zooplankton, and phytoplankton – it can be concluded that the factor indicates the importance of the high-productive shallow-water areas of the North Caspian Sea and, first of all, of the mouth area of the Volga River for fattening of young sturgeon fishes during their swimming down to the sea. The factor's variables clearly show that the hydrogeological conditions of the rivers flowing into the sea and biogenic substances penetrating with the river flows determine conditions for forming the phytoplankton's biomass in the sea shallow-water areas, which, at early stages of sturgeon evolution, are the main objects of feeding and zooplankton.

ANALYSIS OF THE FACTORIAL MATRIX OBTAINED FOR THE NORTHERN-CASPIAN DEEPER-WATER SUB-AREA

Factor 1 has the largest importance of the total dispersion in the factorial matrix and amounts to 34.2% of the variables' dispersion (Table 5). After rotation, the high final loading (Tables 8, 10) on the factor is given by variables X4, X6, X10, and X11. The enclosed variables actually coincide with the same variables of **Factor 1** for the entire region, excluding variables X3 and X5, characterizing the sea hydrochemical regime as, due to circulating features of water currents in the central part of the North Caspian Sea, the hydrochemical parameters determined by the Volga River runoff are sufficiently stable. Despite the fact that the contribution of this factor to the total dispersion for the North Caspian-deeper sub-area is somewhat lower than that of the first factor for the entire study region (39.7%), it can be also defined, by the meaning of the variables enclosed into it, as the **"Geoecological factor of forming food resources"** for the North Caspian- deeper sub-area. Owing to this factor, there is a potential to estimate the role of hydrochemical, natural-climatic, biotic, and food resources in distribution of sturgeon fishes across the northern part of the sea area.

By significance, **Factor 2** occupies the second place. Its contribution to the total dispersion amounts to 19.7% (Table 5). After rotation, there were revealed the high values of variables X3, X8, X9, X12, and X13 (Tables 8 and 10), which enables defining this factor as the **"Factor of anthropogenic loading on zooplankton"**, which actually coincides with **Factor 3** for the entire region. They show the determinant influence of the Volga River runoff upon penetration and distribution of pollutants across the northern part of the Caspian Sea, which, in turn, controls the zooplankton's biomass – the basic food resources for fattening of young sturgeon fishes.

Factor 3 (by significance) has a contribution to the total dispersion in the factorial matrix equal to 12.7% (Table 5). The highest loading comes from variables X2, X5, and X7 (Tables 8 and 10), which allow defining it as the **"Wintering factor"**. It has a number of significant differences from the **"Wintering – post-wintering factor"** for the entire region. The **"Wintering – post-wintering factor"** is the second, by significance, for the entire region (its contribution is 15.5%) and determines both seasonal migrations of sturgeon fishes across the sea area and conditions of forming a forage base for the subsequent fattening period. The **"Wintering factor"**, for the Northern-Caspian deeper-water sub-area, allows one to estimate the importance of the habitat's sea state, depth differences (availability of wintering holes), and ice distribution for the distribution of sturgeon fishes in winter period, but it does not determine conditions of forming the forage base for fishes. Possibly, this is connected with the fact that, in winter period, the major sturgeon fishes migrate to deeper layers of the Central Caspian Sea.

ANALYSIS OF THE FACTORIAL MATRIX OBTAINED FOR THE NORTHERN PART OF THE NORTHERN PART OF THE MIDDLE CASPIAN AREA

Factor 1 is the most important for the Northern part of the Middle Caspian area, as its contribution to the total dispersion amounts to 46.5% (Table 5). A significant load on the factor comes from variables X1, X2, X8, X9, X10, and X12 (Tables 9 and 10), so it can be characterized as the **"Factor of anthropogenic impact in wintering – post-wintering period"**. Unlike the analogous **"Wintering – post-wintering factor"** for the entire study region, it includes not only actually all the variables (except X7), but, additionally, a number of new variables – X8, X10, and X12, pointing to the importance of anthropogenic impacts in winter period on the given sub-area subjected, in this period, to eutrophication. The importance to be protected from anthropogenic impacts in the wintering – post-wintering period for the Central Caspian Sea is doubtless, as, in winter, the sturgeon fishes migrate just to this region and just the Central Caspian is subjected to eutrophication, which intensifies and accelerates due to anthropogenic pollution.

Factor 2 is the second by significance; it determines 14.6% of the total dispersion (Table 5). After rotation, the values of variables X3, X5, X6, and X7 are high (Tables 9 and 10), which enables its determination as the **"Geoecological"**. This factor corresponds partially to **Factor 1** for the entire study water area and indicates a threat of methane at large depths, which creates a hazard for existence of sturgeon population wintering in this region.

The contribution of **Factor 3** to the total dispersion in the factorial matrix amounts to 10.8% (Table 5). Due to the maximum values of variable X4 and X13 (Tables 9 and 10) it can be defined as a factor of anthropogenic loading manifesting itself especially vividly in this area in the form of the **"Hydrocarbon contamination". Unlike Factor 3** for the entire region, the given factor for the central sea part did not include the variables characterizing the influence of the Volga River runoff and distribution of phenol contamination across the water area, but did include variable X4, characterizing oxygen distribution over the sea surface. It is possible that, for the central sea part, the river runoff does not already play such an important role in the distribution of pollutants across the water area and that oil pollution increases due to active development of sea deposits in this part of the sea. Presence of variable X4 in the factor is not occasional; the existence of the oil film on the water surface promotes formation of zones of hypoxia due to a decrease in intensity of aeration processes, which obstructs breathing of fishes and forces adult fishes to leave the polluted areas and can lead to increase in depths [Sapozhnikov and Belov, 2005]. This factor helps estimating the role played by the distribution and geography of hypoxia zones in the distribution of sturgeons over the sea area. Additional input of organic substances during water pollution by oil products deteriorates gas regime in the sea.

CONCLUSIONS

1. The analysis of the obtained data enabled distinguishing three basic factors, including the study parameters and the total dispersion, loading of which amounts to 67.9%. Thus, there are three significant characteristics that, in combination, considerably determine the existence of sturgeon fishes in the northern part of the Caspian Sea. The established factors are closely interconnected with each other, but they are not equal in magnitude: the largest, among them, is the **"Factor of forming food resources"**, which has the basic load in the factorial matrix. The **"Wintering – post-wintering factor"** is the intermediate by significance and it is the linking factor between the first and the third, i.e., the **"Factor of anthropogenic loading"**.

The conditions of wintering of species staying in wintering holes of the North Caspian Sea are important factors for existence of sturgeon fishes. These conditions are determined by distribution of the ice cover, whose area varies year to year and depends on a number of factors, in particular, on temperature and depth of water. In turn, the same factors determine also the conditions of forming the zooplancton's biomass in spring as an initial evolution stage of the majority of species of zoobenthos. The **"Factor of anthropogenic loading"** carries the lowest loading in the factorial matrix as compared with the previous factors. Combination of the variables enclosed into the factor shows that the input and the distribution of pollutants across the water area in the northern part of the sea depend mainly on the Volga River runoff.

2. To a greater extent, the distribution of sturgeon fishes depends on formation of a forage base for the species, i.e., the biomass distribution of the bottom fauna across the northern part of the sea area. This is illustrated by the first factor, namely, by sufficient amounts of biogenic elements and incoming solar energy, which determine intensive development of the phytoplankton as the basic food of the zooplankton. The zooplankton serves, in turn, as the basic food of the zoobenthos that is a component in the ration of many fish species – benthophages; sturgeon fishes of the Caspian Sea are feeding at different stages of ontogenesis both by zooplankton, zoobenthos, and fishes.

3. The leading factor in winter for the Northern-Caspian shallow-water sub-area, especially in its north-eastern and eastern parts with severe icing regime, is the factor of forming of forage resources. The next, by significance, is the factor of anthropogenic loading that, in this case, does not include the variable characterizing the distance from the Volga River mouth, which is the main supplier of polluting substances to the region. Many water zones of the this sub-area lie beyond the influence zone of the Volga River and are subjected to anthropogenic pollution coming with discharges from local rivers, coastal settlements, industrial and agricultural enterprises, runoff from fields, etc. The third significant factor of stability of this ecosystem is the factor of feeding conditions for fattening of young sturgeon fishes for which the Northern-Caspian shallow-water sub-area is a natural habitat.

4. Analysis of the factorial matrix obtained for the Northern-Caspian deeper-water sub-area showed a predominant influence of the **"Geoecological"** factor of forming

food resources. However, due to circulating features of water currents in the central part of the North Caspian sub-area, the hydrochemical parameters, determined by the Volga River runoff, are sufficiently stable and, thus, are not presented in this factor. The second is the **"Factor of anthropogenic loading on zooplankton"**. Actually coinciding with **Factor 3** for the entire study region, it shows a determinant influence of the Volga River runoff on the input and distribution of pollutants across the northern part of the Caspian Sea water area, which, in turn, determine the zooplankton's biomass – the basic food resources for the fattening of young sturgeon fishes. The third (by significance) **"Wintering factor"** has a number of essential differences from the **"Wintering – post-wintering factor"** for the entire study region. It enables estimation of the influence of the sea state in the habitat (availability of wintering holes) and ice distribution on sturgeon distribution in winter period. However, the factor does not determine the conditions of forming the food base of sturgeon fishes. Possibly, this is connected with the fact that, in winter period, the majority of sturgeon fishes migrate to deeper areas of the Central Caspian Sea.

5. In the Northern part of the Middle Caspian area, **Factor 1** can be characterized as the **"Factor of anthropogenic impact in wintering – post-wintering period"**. The importance of being protected against anthropogenic impacts this time of the year for the Northern part of the Middle Caspian area is doubtless, as, in winter, sturgeon fishes migrate just to this area and just the Northern part of the Middle Caspian area that suffer eutrophication at depth which intensifies and accelerates due to anthropogenic pollution. The second significant factor is defined as the **"Geoecological"** and it indicates a threat of generating methane on the bottom, which creates a hazard for existence of sturgeon population wintering in this region. The third is the factor of anthropogenic loading manifesting itself in this area in the form of the **"Hydrocarbon contamination"**, as, in this case, this factor did not include the variables characterizing the influence of the Volga River runoff and distribution of phenol contamination across the water area, but did include a significant contribution of variable X4, characterizing oxygen distribution over the sea surface. Oil pollution in the given area increases due to active development of sea deposits in the shelf zone. The widely spread oil film on the water surface causes the formation of hypoxia zones due to a decrease in intensity of aeration processes, which obstructs breathing of fishes and forces adult fishes to leave the polluted areas and can lead to their depths [Sapozhnikov and Belov, 2005].

6. The landscape zoning of the region carried out in this study made it possible to analyze the geoecological situation in the sea and to reveal the factors of stable existence of different sub-areas both in the northern part of the Caspian Sea and its ecosystems as a whole. As the natural geoecological factor of forming forage resources is the main criterion determining stability of the ecosystem state in the northern part of the Caspian Sea, the processes of dynamics or changes in natural conditions of the region (including climatic fluctuations) lead to the most considerable changes in its ecosystem. Thus, for predicting possible changes in the composition and stability of the water ecosystems in the Caspian Sea, it is necessary to use an integrated approach that considers both the growing anthropogenic impact and possible climatic changes.

Shift of the significance of the factor of anthropogenic loading to the second place for each sub-area from the third place for the entire region indicates that an ecosystem of a larger size and having a more diverse set of natural complexes possesses buffer ability to "compensate" for the areas that disappear under the impact of increasing anthropogenic loading, thus, giving mobile representatives of the ecosystem a chance to exist in other equatorial natural complexes that are, initially, are less suitable for them. From the standpoint of landscape science, this tendency confirms, obviously, a biological phenomenon discovered, in the early 1970s, by Professor L.S. Berdichevsky: during a strong anthropogenic impact the *"fish spawning occurs often in places not typical to the given species.... becoming matched are the dates and places of spawning of different fish species, including commercial and non-commercial species".*

For the Central Caspian Sea, the shift of the factor of anthropogenic loading to the first place means, obviously, that the ecosystem's buffer capacity is exhausted due to the active development of this area by oil-producing companies. ■

REFERENCES

1. Biological grounds of sturgeon breeding in the water bodies of the USSR. (1979). Moscow: Publ. House "Nauka". 222 p. (In Russian)

2. Biological productivity of the Caspian Sea. (1974). Moscow: Publ. House "Nauka". 245 p. (In Russian)

3. Braverman, E.M., Muchnik, I.B. (1983). Structural methods of empirical data processing. Moscow: Publ. House "Nauka". 464 p. (In Russian)

4. Caspian Sea: Hydrology and hydrochemistry. (1986). Moscow: Publ. House "Nauka". 261 p. (In Russian)

5. Caspian Sea: Ichthyofauna and marketable resources. (1989). Moscow: Publ. House "Nauka". 236 p. (In Russian)

6. Ecological factors of spatial distribution and movement of hydrobionts. (1993). St.-Peterburg: "Hydrometeoizdat". 335 p. (In Russian)

7. Geoecology of shelf and coasts of Russia. (2001). Edited by N.A. Aibulatov. Moscow: Publ. House "Noosphera". 428 p. (In Russian)

8. Geraskin, P.P., Metallov, G.F., Aksenov V.P., et.al. (2005). Oil pollution of the Caspian Sea as a factor of impact on the physiological state of sturgeons. Proceedings of the 1st Int. Scien.-Prac. Conference "Problems of preserving the Caspian Sea ecosystem in the conditions of oil and gas deposits development". Astrakhan: Publ. House "KaspNIRH". pp. 54–60. (In Russian)

9. Ivanov, V.P., Sokolsky, A.F. (2000). Scientific fundamentals of protection of biological resources in the Caspian Sea against oil pollution. Astrakhan: Publ. House "KaspNIRH". 181 p. (In Russian)

10. Kasymov, A.G., Askerov, F.S. (2001). Biological diversity: oil and biological resources of the Caspian Sea. Baku: Publ. House "Print Studio". 325 p. (In Russian).

11. Katunin, D.A., Khripunov I.A., Egorov, S.N., et. al. (2005). Multi-year dynamics of forming the zones of hypoxy in the North Caspian Sea. in areas of oil and gas deposits. Proceedings of the 1st Scientific-Practical Conference "Problems of preserving the Caspian Sea ecosystem

in conditions of development of oil and gas deposits". Astrakhan: Publ. House "KaspNIRH". pp. 98–101. (In Russian)

12. Khoroshko, V.I., Emirova, R.I. (2002). Monitoring of toxicant contents in the tissue of hydrobione. Fishing investigations in the Caspian Sea. Astrakhan: Publ. House "KaspNIRH". pp. 71–77. (In Russian)

13. Kushnarenko, A.I. (2003). Ecologic-ethological principles of quantitative account of fishes in the North Caspian region. Astrakhan: Publ. House "KaspNIRH". 180 p. (In Russian).

14. Landscape Map of the USSR. Scale 1: 2500000. (1987) Moscow. (In Russian)

16. Makarova, E.N., Kurapov, A.A., (2002). Influence of the Volga River runoff on the water state in the North Caspian Sea areas set aside for oil extraction. The current problems of the Caspian Sea: Proceedings of Int. Conference devoted to the 105th Anniversary of KaspNIRH. Astrakhan: Publ. House "KaspNIRH". pp. 202–204. (In Russian)

16. Mouth area of the Volga River: hydrologic-morphological processes, regime of contaminants and influence of the Caspian Sea level variations. (1998). Moscow: "GEOS". 280 p. (In Russian).

17. Nelson-Smith, A. (1977). Oil and ecology of the sea. Moscow: "Progress". 302 p. (In Russian)

18. Odum, Yu. (1975). Principles of ecology. Moscow: Publ. House "Mir". pp. 435–436. (In Russian)

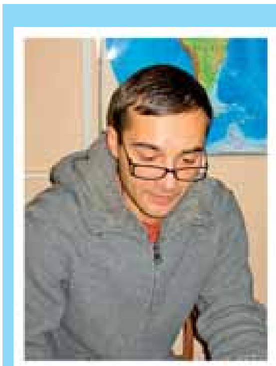
19. Pakhomova, A.S. , Zatuchnaya B.M. (1966). Hydrochemistry of the Caspian Sea. Leningrad: "Hydrometeorological Publ. House". 243 p (In Russian)

20. Pegov, S.A. (1992). Natural resources use: prediction and management. Theory and methods of geographical prediction: potential and ways. Moscow: "Nauka". pp. 111–117. (In Russian)

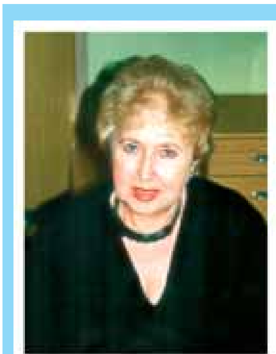
21. Project "Seas". Hydrometeorology and hydrochemistry of seas. (1996). Issue 2. Hydrochemical conditions and oceanological principles of formation of biological productivity. Edited by Terzieva, F.S., Maksimovskaya, M.P., Yablonskaya, E.A. Vol. 6. Caspian Sea. St.-Peterburg: "Hydrometeoizdat". 322 p. (In Russian)

22. Sapozhnikov, V.V., Belov, A.A. (2005). Causes of changes in the Caspian Sea ecosystem and its current state. Proceedings of the 1st Scientific-Practical Conference "Problems of preserving the Caspian Sea ecosystem in conditions of development of oil and gas deposits". Astrakhan: Publ.House "KaspNIRH". pp. 181–187. (In Russian)

Natalia N. Mitina studied at the Lomonosov Moscow State University, Geographical Faculty, and graduated in 1977. She received her PhD in 1994 and Doctor of Sciences Degree in 2005. Since 1996, she is senior scientist of the Institute of Water Problems RAS. The focus of her research is in the area of sub-aquatic marine landscapes and hydro-ecology. Main publications: Geoecological Investigation of sub-aquatic shallow-water landscapes (2005); Estimation of the Volga-Caspian water ecosystems stability under the possible climate change and anthropogenic load (2011, co-author Malashenkov, B.M.); Determination of hydro-ecological factors stability of the Volga-Caspian aquatic ecosystems stability in designing their protection (2010, co-author Malashenkov, B.M.)



Boris M. Malashenkov studied at the Moscow State Regional University, Geographical Faculty, and graduated in 2003. He received his PhD in 2008. Since 2003, he is scientist of the Institute of Water Problems RAS. The focus of his research is in the area of hydro-ecology and marine ecology. Main publications: Natural-resource potential of the Caspian Sea subaquatic landscapes (2010); Evaluation of the local natural-resource potential of bottom complexes in the North of the Caspian Sea (2008); North Caspian Sea bottom natural complexes (2009, co-author Mitina, N.N.)



Leonora A. Telitchenko studied at the Moscow State University, Biological Faculty, and graduated in 1958. She received her PhD in Biology in1961. Since 1981, she is associated professor of the Biological Faculty, Lomonosov Moscow State University. The focus of her research is in the area of hydrobiology and water ecosystems communities. Main publications: Some aspects in natural waters quality management in sustainable development present condition (2011, co-author Mitina, N.N.); Methodological approaches to the water ecosystems sustainability determination (on example of the Northern region of the Caspian Sea) (2010, co-author Mitina, N.N.)