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ECOLOGICAL TRANSFORMATIONS IN THE SOUTHERN ARAL SEA REGION AS A FACTOR OF POPULATION DYNAMICS (ON THE EXAMPLE OF *RHOMBOMYS OPIMUS* AND *ONDATRA ZIBETHICA*)

Mambetullaeva S.M., Utemuratova G.N., Yeshchanova S.Sh.
Karakalpak Research Institute of Natural Sciences
Nukus city, Republic of Uzbekistan
Email: jaloliddin.1992@mail.ru

Abstract. The article presents the results of a systematic analysis of the impact of large-scale ecological transformations in the Southern Aral Sea region on the population of *Rhombomys opimus* and *Ondatra Zibethica*. The dynamic system of regional hydro-regime and landscape-climatic transformations, which determine the long-term dynamics of the number of rodent populations, is discussed herein. Based on the results of the study, conclusions were drawn about the behavior coherency of the elements of a non-equilibrium self-organizing system, the dynamics of priorities in the system of factors under consideration, the necessities to take into account adaptation processes when quantitatively assessing the correlation of factors and objects of influence.

Key words: Southern Aral Sea region, ecological transformations, system dynamics, population size, coherence, synergetics

INTRODUCTION

A distinctive feature of modern systems ecology is the use of systems analysis and synergetics in the study of non-equilibrium natural complexes. An important place in these scientific areas is given to systemic connections. The nonlinearity of internal connections and interactions with the external environment, inherent in nonequilibrium structures, is also characteristic of the Aral Sea ecosystem, which undergoes large-scale transformations and has complex structural dynamics.

The high rate of crisis transformations and processes creates a unique opportunity for an accelerated study of the rate and nature of adaptation, the degree of tolerance of the biota to environmental changes, which in conditions of stability takes much longer. Moreover, the information content and reliability of the research results under the conditions of the crisis are higher than under the conditions of full-scale experiments, in the setting of which it is difficult, if not impossible, to adequately model ecosystem relations as a whole.

Ecological transformations in the Southern Aral Sea region (a sharp decrease in river runoff, drying up of the Aral Sea, removal of salts from the post-aquatic land, etc.) have both a singular and systemic effect on soil and climatic conditions [15], and as a consequence on biota. The spatiotemporal and structural dynamics of the biota of the Southern Aral Sea region is mainly due to the specificity of local interactions of the populations constituting the ecosystem with inert components of the environment.

The dynamics of the number of animals is one of the most complex problems of modern environmental science. This problem is of great theoretical and applied importance, since the knowledge of many important aspects of the evolutionary process and the development of

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measures for the rational use of natural resources and the preservation of biodiversity depend on its solution [25, 26].

The scientific literature devoted to the analysis of the dynamics of the population of mammals has accumulated a variety of data on populations inhabiting under various geographic, climatic and biocenotic conditions [7, 16, 22]. The overwhelming majority of the available work in this direction was carried out for stable, evolutionary developing ecosystems. At the same time, given the growing global environmental problems (deforestation, global warming, etc.), it is important to study the dynamics of natural complexes associated with crisis transformations.

The aim of this work is a quantitative systemic analysis of the impact of ecological transformations in the Southern Aral Sea region on the number of rodent populations under changing habitat conditions.

MATERIALS AND METHODS

The choice of *Rhombomys opimus* and *Ondatra Zibethica* as the object of study is due to several reasons: 1) rodents are very sensitive to changes in environmental conditions and can serve as bioindicators of ecological change [7, 18]; 2) rodents – a widespread group of mammals – are influential and dominant members of arid ecosystems [18, 21]; 3) *Rhombomys opimus* and *Ondatra Zibethica* are one of the most population-studied representatives of the fauna of the Southern Aral Sea region. [3, 11, 17].

Ondatra is a representative of indicator species that determine the degree of anthropogenic disturbance of the territory, and is a valuable trade potential. The habitat area in the Aral Sea region for the ondatra (Ondatra Zibethica) is deltaic reservoirs. In 1950-1960 s in Amudarya delta there were more than 490 lakes with a total area of 840 km2, in 1980 there were about 30 large lakes with an area of 76.3 km2 [1,19]. At present, the total area of wetlands in Amudarya delta has decreased and is more than 292795.4 hectares now [1, 5]. The reduction in the areas of these reservoirs, which is a direct consequence of the Amudarya runoff, led to a decrease in the population of the ondatra in the period 1961-2000.

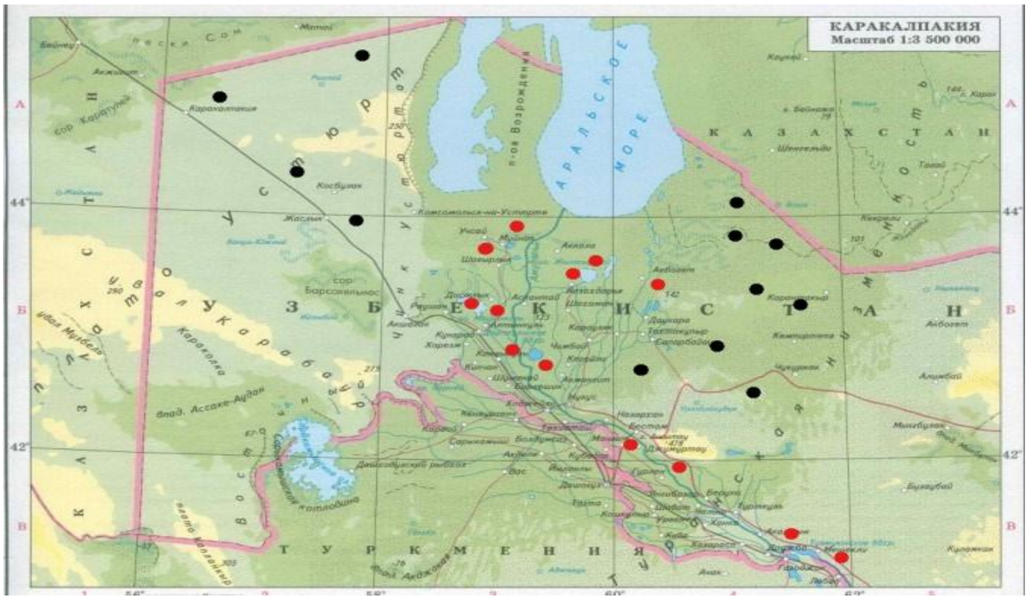

Figure 1. The main habitats and the populations areas of *Rhombomys opimus* (●) and *Ondatra Zibethica* (●) in the Southern Aral Sea region

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The great gerbil (*Rhombomys opimus*) – is a widespread and important component of arid biogeocenosis. In the Southern Aral Sea region, the great gerbil inhabits in the main sandy and clayey massifs of the Northwestern Kyzylkum, Zaunguz Karakum and Ustyurt, intra-oasis sands, causal strips and remnant hills [3, 6, 23]. The territory of the Northwestern Kyzylkum is characterized by the predominance of cellular-ridge sands with a diffuse type of settlements of great gerbils [3, 13, 17].

The general methodology of this study is a systematic approach with elements of synergy. One of the methods of system analysis, as a sequence of actions to establish structural links between the elements of the system under study, is the selection of individual structural elements from the system [14]. Accordingly, in this work, the structural elements isolated from the ecosystem of the Southern Aral Sea region are the cenosis-forming species of small mammals *Rhombomys opimus* and *Ondatra Zibethica* and the relationship-impact of the system of factors, including the dynamics of the Amudarya discharge, climate and post-aquatic land. In this case, only the main parameters are taken into account, and the influence on the result of most of the set of interacting system components is not taken into account, which is justified by the works [7, 21].

Ecological transformations affecting the dynamics of the number of rodents are presented as a dynamic system of factors. The change in Amudarya hydro-regime (Fig. 2) is the primary cause of the transformations of the ecosystem of the Aral Sea and the Aral Sea region as a whole, therefore it can be considered a system-forming connection. The dynamics of the scale and salinity of the post-aquatic land of the Aral Sea, which is directly related to the process of its desiccation, and hence to the hydrological regime of Amudarya, is included in the system under consideration as a potentially favorable factor for great gerbils, contributing to the expansion of the range. And, finally, the third factor of the system – regional climate changes – is associated with the previous two direct and indirect causal relationships, assessed in quantitatively [2, 15].

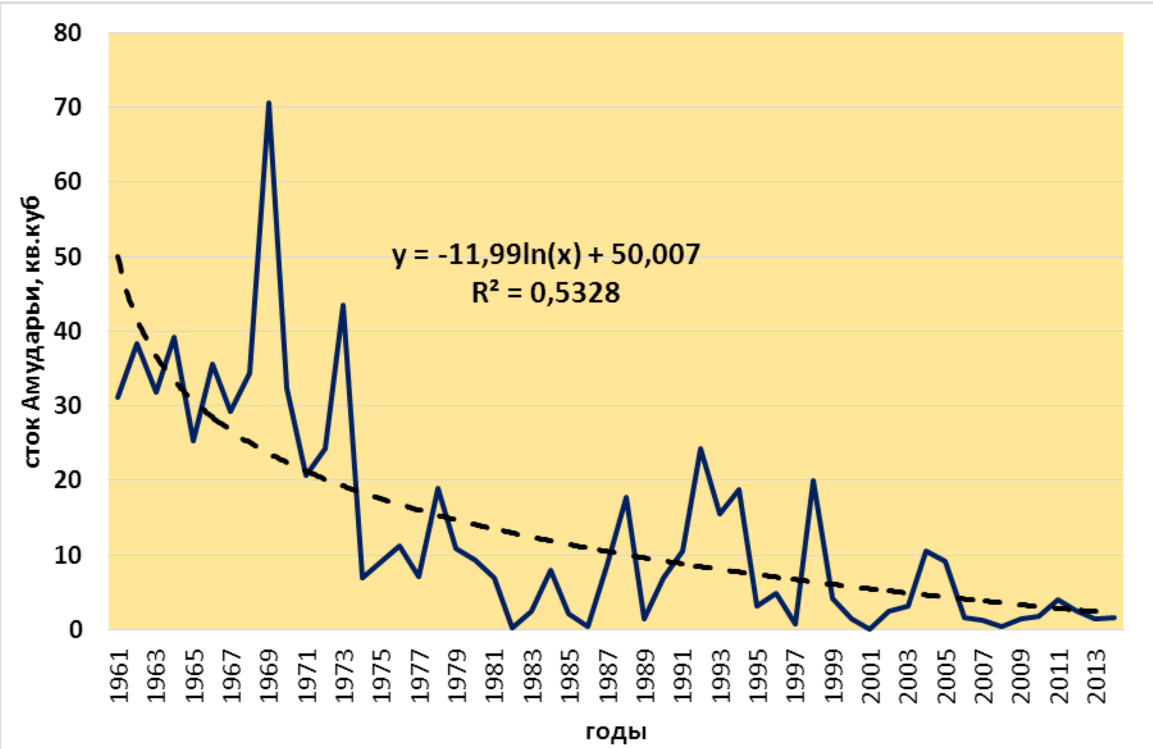

Figure 2. Long-term dynamics of the Amudarya runoff and its trend

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So, the hydrological regime of Amudarya is one of the main factors determining the population size of meso- and hydrophilic species of animals and plants; for other species of biota it is transbiotic, mediated mainly by climatic changes in the region towards an increase in aridity and continentality. From a synergistic point of view, the dynamics of fluctuations of natural processes and an integral property of dissipative dynamic systems – the coherence of the response of the elements of the ecosystem of the Southern Aral Sea region to ecological transformations are also considered in the study [8, 12].

Studies of the dynamics of the population of *Rhombomys opimus* and *Ondatra Zibethica* were carried out by us at the places indicated on the map of the Republic of Karakalpakstan (Fig. 1). Records of the population of gerbils were carried out regularly using the standard trap-line method four times a year (April, June, August, October). Trapping of rodents was carried out according to a single generally accepted method [16]. At each stationary site, 100 night-traps were set. The traps were placed in a line at a distance of 5 meters from each other Trap locations were permanent and accurate. Bread with vegetable oil served as bait. For the purpose of comparative analysis of the data obtained, the studies were carried out in the same stations. When traps are exposed for one night, although fresher material is obtained, it is less reliable in terms of the age composition of the sample from the population than when traps are caught in several days [9].

The distribution and abundance of the ondatra were determined by taking into account the inhabited dwellings of the animal and the traces of its vital activity on selected routes. Residential lodges (holes), separate groups of food huts, tables and latrines located at a distance greater than the radius of the average range of the family were taken into account [6, 9, 11, 13, 17]. The lifestyle and diurnal cycle of rodents were studied using direct observations in different seasons and times of day. When studying the diet of rodents, the contents of the stomachs were analyzed, and the plants were collected from the feeding grounds [3, 13, 21].

The dynamics of the scale and salinity of the drained bottom of the Aral Sea was calculated using an analytical model based on the implementation of the author's imitation macromodel [15]. The data was used in the work on the average annual consumption of the river Amudarya in the range of the Samanbay gauging station [1] (Fig. 3). Data on the average summer air temperature in 1960-2018 were taken from the work [1] and directly from the Karakalpak Republican Hydrometeorological Center. Data processing was carried out by the authors using autocorrelation functions and by the "optimal interpolation" method [12]. For quantitative assessing of the impact of the system of factors on the population size of *Rhombomys opimus* and *Ondatra Zibethica*, the methods of correlation analysis were used.

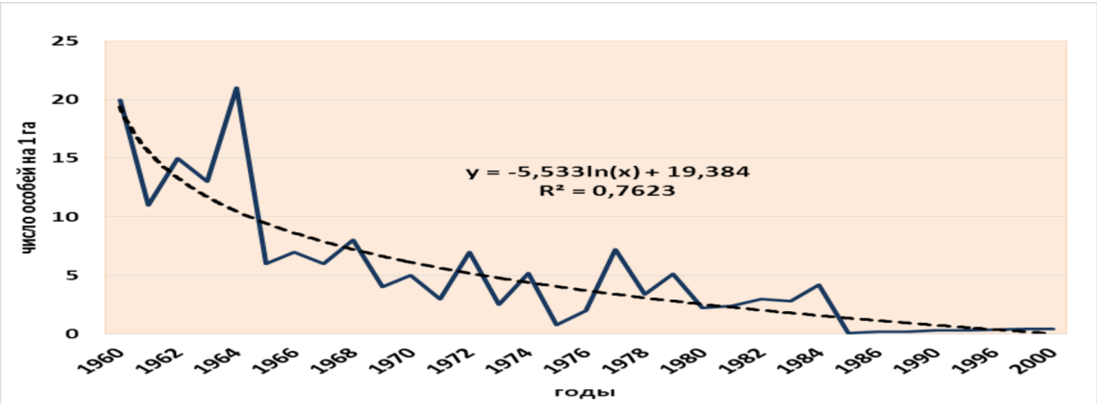

Figure 3. Population dynamics of *Ondatra Zibethica* in the period of degradation and its trend

The construction of graphs, histograms and trends with the determination of the reliability assessment was carried out in Microsoft Excel 7.0. To clarify the proximity of the relationship between the parameters, the Pearson correlation coefficient was calculated using the StatSoft STATISTICA 8.0 program.

RESULTS AND DISCUSSION

The study of the relationship of local population dynamics with such large-scale spatial processes as changes in the Amudarya hydro-regime, climate and post-aquatic land of the Aral Sea, showed significant quantitative and qualitative differences in the response of biota to these factors even within the same order (*Rodentia*) of mammals.

Before proceeding to a discussion of the results, we note one case that complicates the adequate modeling of the dynamics of the population size. This is the oscillatory nature of the functioning and development of natural objects and processes. The superposition of different-scale geophysical, climatic and biological vacillations and fluctuations of anthropogenic origin creates a complex factual picture of the object under study.

If the vacillations in the system have a constant period and amplitude, then they are established independently of the initial conditions and are maintained due to the properties of the system itself, and not due to the effect of a periodic force, the system is called self-oscillatory [12]. According to the given definition, natural fluctuations in the number of rodent populations can be attributed to self-oscillations, therefore, as not corresponding to the subject of this article, they are ignored.

In the dynamics of the ondatra population in the Southern Aral Sea region, we have identified two periods: 1) the years 1961-2001 – the period of decrease in the number to almost zero (the period of degradation, Fig. 3); 2) from 2002 to the present – a period of slow but steady growth in numbers (recovery period, Fig. 4).

As a result of works aimed at maintaining irrigation-waste lakes and the creation of new reservoirs in the delta, fed by river and collector-drainage waters, the total area of the lakes has significantly increased [19, 20]. Thus, the living conditions of the ondatra improved, which led to an increase in its number, starting in 2002.

The exponentiality of the trend indicates an increase from year to year in the growth rate of population and an asymptotic approximation to the normal dynamics of the population size. We have noted that this example of a positive anthropogenic impact is another confirmation of the general law of the prevalence of destruction rates over recovery rates: the average rate of decline in ondatra population during the degradation period is 1.2 animal unit / ha / year, the average growth rate during the recovery period is 0.9 animal unit/ha/year. Despite the coincidence of the logarithmic nature of the dynamics of the Amudarya hydrological regime and the number of the ondatra population, the same tendency to decrease and the correlation of the corresponding time series ($\rho = 0.56$) were not high enough.

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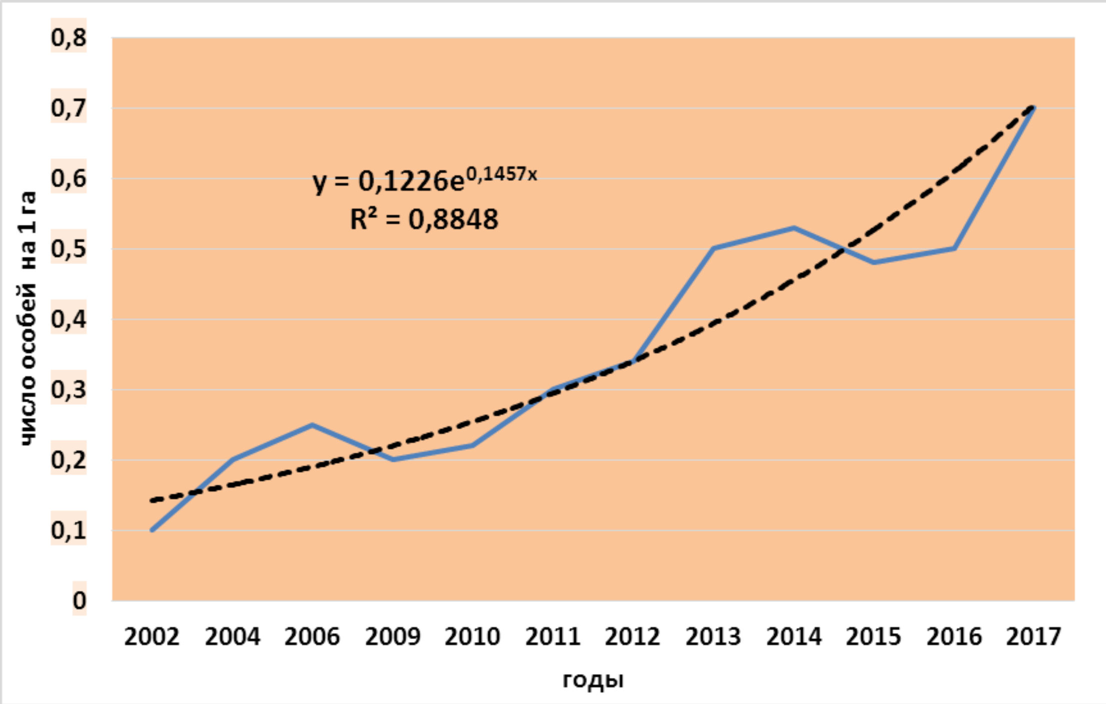

Figure 4. Population growth of *Ondatra Zibethica* in 2002-2017 (recovery period)

The delay in the response of the ondatra numbers is explained by the peculiarities of the hydro-regime of the delta water reservoirs, which are fed mainly by collector-drainage waters and underground runoff. As it is known, the speed of these flows is extremely low; therefore, the change in their consumption is delayed by several years from changes in the river flow. The correlation coefficient calculated taking into account this time lag is 0.74. For the ondatras living along Amudarya river and canals, there is no lag and the correlation coefficient of the ondatra abundance with Amudarya consumption in the Samanbay line is equal to 0.81. Thus, it can be concluded that the main factor for the dynamics of the ondatra population is the Amudarya hydro-regime.

Unlike the ondatra, the great gerbil reacts positively to the transformation of the ecosystem of the Southern Aral Sea region – its abundance has a clear tendency to increase (Fig. 5). The correlation coefficient of the numbers of the great gerbil with the consumption of Amudarya, as expected, is negative and equals -0.23. The same weak, but positive, correlation (ρ = 0.24) with an increase in the potential area – is the post-aquatic land of the Aral Sea. Active colonization of the drained bottom is hindered by its growing salinity. Correlation analysis showed that the main disturbing factor causing large fluctuations in the abundance of the great gerbil is the climatic regime of the biotope. The highest correlation of the dynamics of the numbers of gerbil is with the average summer temperature: ρ = 0.24. The results obtained indicate a significant nonlinearity of the population dynamics of the great gerbil and its more complex dependence on changes in environmental conditions.

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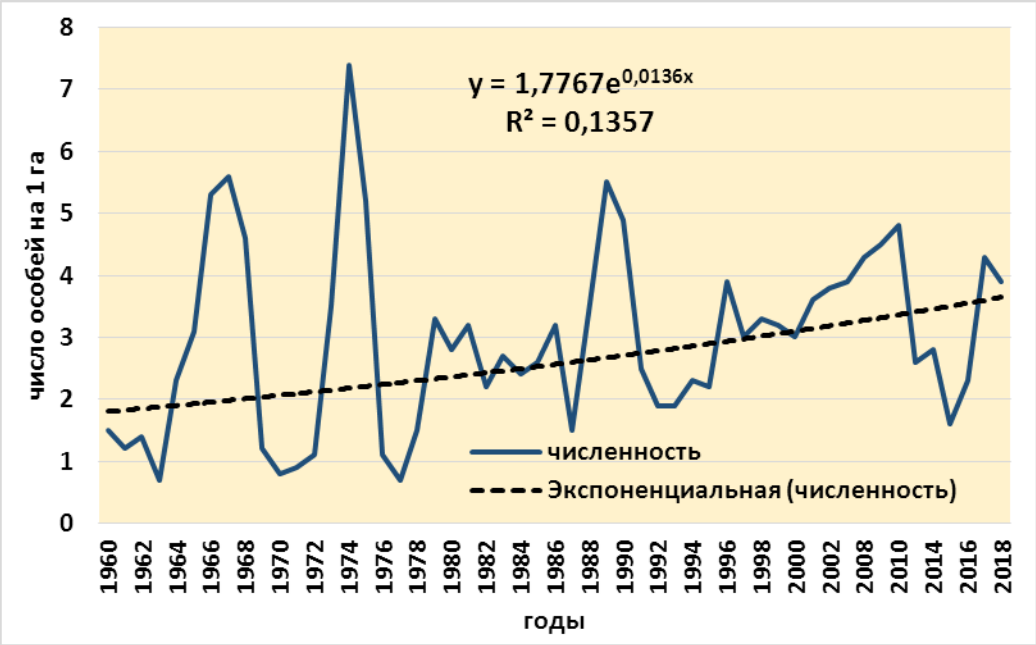

Figure 5. Population dynamics of the great gerbil and its trend

Comparative analysis of the population dynamics of ondatras and gerbils reveals significant qualitative and quantitative differences due to the difference in habitat conditions, ranges of tolerance of these species to external influences and in the intensity of adaptation processes.

At the same time, the ecosystem of the Southern Aral Sea region, like any self-organizing dissipative structure, has the property of coherence, i.e. consistency of behavior of all its elements. In this case, the coherence of the population dynamics of the gerbil and ondatra is manifested in the excitation of fluctuations with large amplitudes by ecological transformations at the initial stages of the ecological crisis and their gradual attenuation under the influence of adaptation processes, which in this aspect can be considered as a negative feedback [10, 24].

Another example of coherence is the clear response of the phytocenosis and the numbers of ondatra to the dry years 2003 and 2006. The vegetation of the lower reaches of Amudarya, for which the hydro regime is the main factor, responds to low water immediately [2, 4], and the ondatra population responds with a decrease in numbers in the next few years (the occurrence of a time lag is explained above).

Coherence in combination with the analogy method determines the presence of a reaction to a strong disturbing signal of the entire structure of a dynamic system. In other words, the results of studies of the dynamics of individual elements of the ecosystem can be comparable and mutually ratifiable.

CONCLUSION

Changes in the hydrological regime of the Amudarya basin is the primary cause of large-scale ecological transformations in the Southern Aral Sea region. Even with its relative stabilization, the destructive processes launched by it (drying up of the Aral Sea, salt removal, desertification, changes in climate and biota) continue to operate with a positive dynamic gradient. Thus, often subordinate processes in the causal chain become the main factors of changes in the elements of the ecosystem of the Aral Sea and the Aral Sea region.

Long-term dynamics of the population of ondatra is characterized by a period of decrease from 1962 to 2002 according to a logarithmic law and a recovery period according to an exponential law, asymptotically approaching natural. The break in the dynamic gradient is due to the anthropogenic factor. The main factor of ondatra dynamics is the Amudarya hydro-regime.

1. The population dynamics of the great gerbil in the period 1961-2016 is positive and depends on complexly interacting landscape and climatic factors. The highest correlation of the dynamics of the gerbil population – is with the average summer air temperature.
2. Long-term dynamics of the population size of *Rhombomys opimus* and *Ondatra Zibethica* in the Southern Aral Sea region is almost completely determined by ecological transformations.
3. The coherence of the behavior of the elements of a non-equilibrium self-organizing system, which manifests itself in generalizations exceeding the scale of inter-element interactions, can serve as a kind of measure for validating the results of studying the dynamics of the behavior of individual elements of the system.
4. Nature conservation measures for the restoration of populations that carried out taking into account the existing factors and tendencies of developing systems on the example of the ondatra population, demonstrate high efficiency and the ability to quickly change the sign of the dynamic gradient, and thereby increase the importance of the anthropogenic factor in improving the ecological situation.

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