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CONSERVATION OF SMALL MAMMAL FAUNA BIODIVERSITY AS A FACTOR OF SUSTAINABLE DEVELOPMENT OF THE SOUTHERN ARAL SEA REGION

Sveta Mambetullaeva*, Gulnarakhan Utemuratova, Ziyuar Allamuratova, Indira Khodjalepesova

Karakalpak Scientific Research Institute of Natural Sciences, 230100, Republic of Karakalpakstan, Nukus, Street Uzbekistan Guzari, 41, Uzbekistan

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Abstract

The long-term joint dynamics in the conditions of the Southern Aral Sea region of the population size of the most typical predator-prey system for this region is studied. It is shown that the specifics of the dynamics of natural processes in the conditions of the crisis of the Aral Sea region require the development of special simulation models taking into account the control parameters and order parameters of the destabilized ecosystem.

Keywords: *Southern Aral Sea region; population dynamics; predator-prey model; approximation; coherence; ecosystems*

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1. Introduction

The problem of preserving the biological diversity of the planet in the modern world is one of the most acute. The international community is making a lot of efforts to preserve and multiply it. The initial and one of the most important stages of environmental protection measures is environmental monitoring. The intensive impact of human activity on the biosphere leads to a decrease in the areas of natural ecosystems, as well as to the disappearance of the species diversity of flora and fauna, which necessitates the search for modern synergetic approaches to solving the problems of preserving landscape and biological diversity.

Currently, the problems of transformation and changes in natural processes that are intensively occurring on our planet, which are commonly referred to as environmentally crisis processes, have been brought to the fore [20]. Long- term and short-term forecasting and the establishment of general patterns of dynamics of the processes of destabilization of ecosystems is of great scientific and practical importance for making responsible decisions to reduce and prevent their consequences at the state level in various regions of the world.

For the Republic of Uzbekistan, one of the first places among the important problems of crisis processes is the drying up of the Aral Sea. The Aral ecological crisis, being a complex of complex natural processes, has a specific type of dynamics, different from natural, evolutionary successions. First of all, this is a significant non-linearity and high speed of processes. As numerous studies by the authors have

* Corresponding author. Tel.: +998 (61) 223-45-10
E-mail address: svetmamb@mail.ru

shown, before the eyes of one generation of people, the drying up of the Aral Sea occurred, the degradation of the grandiose reed beds that occupied more than 600 thousand hectares in the lower reaches of the Amu Darya delta [4], the disappearance of 60 species of wild animals and plants, the proportion of endangered species increased (12 species of mammals, 26 species of birds and 11 species of plants [30]). Accordingly, structural and functional connections are dynamic in various communities of the ecosystem of the Southern Aral Sea region, where, by the way, the consequences of the Aral crisis are maximally manifested [8].

The general hypothesis of unsteady dynamics of bio- and ecosystems is replacing theories about the linear and predictable nature of the dynamics of biological systems in extreme conditions of their functioning [22, 27, 24, 28].

In the course of structural and functional reorganization, "coadaptive biota complexes" are formed, the development of which, according to the principles of synergetics, occurs coherently (coherently) throughout the system in the direction of one or more attractors. Tracking the self-organization of an ecosystem in crisis and, in particular, determining the point of stabilization, i.e. the attractor, is an urgent task.

The population reactions of a species can reflect the dynamics of the ecosystem as a whole, therefore, the population approach, when the biology of a species has been studied sufficiently fully, can be successfully used to study the state of natural ecosystems [17]. The classical model object of research on a wide range of problems of theoretical and applied ecology is a large group of small mammals [1].

Small mammals, being an important component of natural ecosystems, are widely used as model objects in environmental research, including those that address the problems of anthropogenic environmental transformations [11]. In modern population studies, rodents, due to their position in the trophic chains of ecosystems, can be directly used for bioindication of the natural environment.

Many rodent populations have cyclical dynamics. Population cycles are characterized by regularity, although they may have different amplitudes. The cessation of cyclic dynamics or the violation of its regularity can be considered as an example of non-stationary dynamics [1].

A continuous series of monitoring of small mammal populations has revealed the massive acyclicity of rodent population processes in various regions of the CIS countries (Russia, Kazakhstan, Kalmykia, etc.) [29, 23]. One of the alleged causes of cycle disruption is a change in climatic conditions [21] or a deterioration in the food supply [26].

For the Southern Aral Sea region, the main consequence of the destabili- zation of the cyclical dynamics of the rodent population was a sharp overregulation and instability of the hydro regime of the Amu Darya River, which led to vegetation degradation (Table.1), in particular, plants that serve as a feed resource for rodents: species of *Tamarix hispida, T.ramosissima, Halosta chysbelangeriana, Haloxylon aphyllumAtriplex heterosperma, A.fomini, A.tatarica, Salsola dendroides Ammo- dendron Conollyi, Glycyrrhiza glabra, Bassiahis sopifolia, Kochia scoparia, Artemisia halophila, Pragmites australis* etc. [7, 10, 15, 16].

Thus, it is possible to distinguish the "plants-rodents-predator" system as a kind of coadaptive community with trophic connections and coherence of population processes [25]. The study of connections and coherence has a special cognitive value. The cognitive nature of connections lies in the fact that, if it is impossible to directly study an object, we can judge the presence or absence of certain properties by the behavior of objects closely related to it. Coherence in combination with the method of analogies makes it possible to detect the presence of a reaction to a strong disturbing signal of the entire structure of a dynamic system [9].

Table 1. Dynamics of the area of tugai vegetation and the number of plant species in the lower reaches of the Amu Darya (according to Bakhiev et al., 2012; Mamutov, 2006; Matzhanova et al., 2018)

Years	**1960-1969**	**1970-1979**	**1980-1989**	**1990-1999**	**2000-2009**	**2010-2015**
The area of tugai vegetation, thousand hectares	300	70	50	30	25	22

Number of plant species	302	183	106	62	89	73

Thus, the coherence of the behavior of the elements of a nonequilibrium self-organizing system can serve as a kind of test measure for the results of the study of the dynamics of the nature of individual components of the biosystem. Away from the point of bifurcation of the discrete space, the behavior of the elements of the biosystem can also be at the level of interelement interactions, for example, the consistency of population changes in the predator-prey system due to trophic connections.

Based on the above, the study of the long-term systemic dynamics of the "plants-rodents-predators" community using a synergistic approach is of particular scientific interest.

2. Materials and methods

The study was conducted for the territory of the Southern Aral Sea region, shown on the schematic map (Fig. 1). At the same time, a large amount of factual material was used, collected over the period 2018-2023 by specialists of the Karakalpak Scientific Research Institute of Natural Sciences in the field of ecology, zoology, botany. Due to the fragmentary nature of the monitoring data, the spatial and temporal alignment of the series of observations was used by methods of statistical analysis of time series [2].

The methodology of this study is a synthesis of several approaches: synergetic, population-based and simulation. The use of several mutually complementary methods allows you to study several aspects of the object under study at once.

The traditional mathematical model "predator-prey" Lotki-Volterra [6] is used to describe binary interspecific relations in the studied system "plants- rodents-predators"

$$\begin{cases} \frac{dx}{dt} = ax - bxy \\ \frac{dy}{dt} = -cy + dxy \end{cases} \quad (1)$$

with the appropriate initial conditions

$$\begin{cases} x(0) = x_0 \\ y(0) = y_0 \end{cases} \quad (2)$$

where x and y – is the population size of victims and predators, a – is the specific rate of growth of the victim population in the absence of predators, b — is a constant characterizing the rate of consumption by the predator population of individuals of the victim population, c – is the specific rate of mortality of predators, d – is a constant characterizing the rate of increase in the number of predators due to the biomass of consumed victims [3].

Fig. 1. Schematic map of the research area in the region Southern Aral Sea Region

Taking into account the factor of intraspecific competition among predators and prey, respectively (1) the system will take the form:

$$\begin{cases} \frac{dx}{dt} = ax - bxy - r_1 x^2 \\ \frac{dy}{dt} = -cy + dxy - r_2 x^2 \end{cases} \qquad (3)$$

where $r_1, r_2 -$ the coefficient of intraspecific competition between prey and predator [6].

Equations (3) with initial conditions (2) are a Cauchy problem for a system of nonlinear ordinary differential equations, which is solved by the Runge-Kutta method.

To quantify the binary discreteness of the long-term population dynamics of the components of the "plants-rodents-predator" system, an approximation of time series of data (actual and model) was carried out at the first stage [5]. We have introduced the coefficients of coherence of the rate of change in the number of populations (KSP) and rates (KTP), calculated as the correlation coefficients of the first and second derivatives of the equations approximating the dynamics of populations, respectively.

3. Results and discussion

In the model (2)-(3) for the structural relationship "rodents-predator", the following input data are used: initial values $x_0 = 17.2, y_0 = 8.3,$ parameters $a = 0.02,$ $b = 0.0003,$ $c = 0.03,$ $d = 0.00004,$ $\lambda_1 = 0.003,$ $\lambda_2 = 0.0001.$

Analysis of data from field studies of the number of rodents (*Microtus Ilaeus*) and foxes per 1 ha (*Vulpes Vulpes*) (Table.2) shows significant variation for rodents and relative stability for predators. The variety of methods and the lack of a unified spatiotemporal monitoring system naturally reduce the reliability of the model results, as evidenced by significant discrepancies.

Table 2. Discrepancies between the data of field studies and model data on population dynamics of predator (*Vulpes Vulpes*) and rodents (*Microtus Ilaeus*)

Years	***Microtus Ilaeus***		Discrepancies	***Vulpes Vulpes***		**Discrepancies**
	Field study data data	The value of model		Field study data data	The value of model	
1960-1969	17,20	17,20	0,00	8,30	8,30	0,00
1970-1979	13,14	13,14	0,00	6,14	6,14	0,00
1980-1989	2,23	11,03	-8,80	5,38	4,55	0,83
1990-1999	0,68	9,76	-9,08	3,60	3,37	0,23
2000-2009	4,35	8,93	-4,58	2,25	2,50	-0,25
2010-2019	3,95	8,37	-4,42	1,81	1,85	-0,04

The standard deviation between the data of field studies and the value of the model data of rodents is $\rho_{грыз} \approx 5{,}7$, and foxes $\rho_{лис} \approx 0.34$. The relationship between the number of rodents and foxes by year is characterized by a high correlation both according to actual and model data (respectively, $k_{фак} \approx 0{,}78$ и$k_{мод} \approx 0{,}99$).

The graphical representation of the simulation results [Fig. 2] clearly demonstrates the consistency of the long-term dynamics of the number of foxes and rodents. We see that the decrease in the number of both populations occurs almost synchronously, since the dependence of the fox population on the number of rodents leads to the fact that the dynamics of foxes adjusts to the dynamics of rodents. The model clearly simulates a violation of the cyclical nature of natural fluctuations in the population of rodents, which in reality manifests itself in a gradual attenuation of fluctuations.

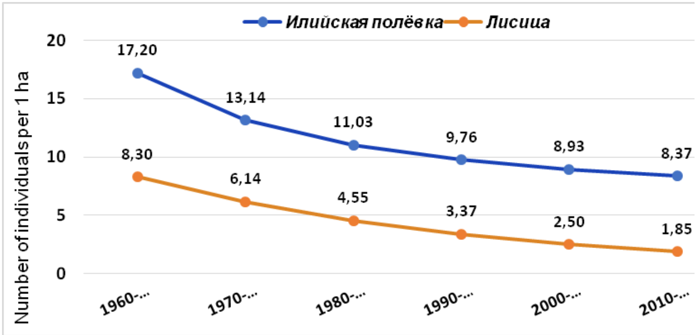

Fig. 2. Dynamics of rodent and fox populations based on simulation results

The relationship that develops between plants and herbivores can also be considered as a predator-prey relationship. For the "plants-rodents" relationship, the following input data are accepted in the model: initial conditions $x_0 = 302, y_0 = 17.2$, parameters $a = 0.0014,\ b = 0.0019,\ c = 0.005,\ d = 0.0001,$ $\lambda_1 = 0.0001,\ \lambda_2 = 0.003$. In contrast to the "rodent-predator" interspecies relationships, the correlation between the number of plants and rodents is high both for model data ($k_{мод} \approx 0{,}98$) and for actual data ($k_{фак} \approx 0{,}94$).

Note that the Lotka-Volterra predator-prey model, focusing on simulating the dependence of the dynamics of the predator on the trajectory of the victim, "underestimates" the number of rodents, so that the number of *Microtus Ilaeus* individuals per 1 ha for the decade 2010-2022 decreases from 8.37 in the case of rodents-predator to 5.79 for communication "Rodent - Plants." According to the results of the study, we observe a violation of the cyclical fluctuations in the number of rodent populations (Fig. 2).

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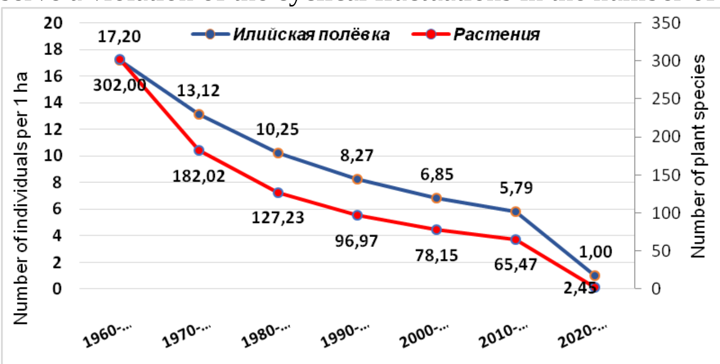

Fig. 2. Dynamics of the number of plant species and *Microtus Ilaeus* according to the simulation results

Significant discrepancies with the model data do not allow Lotka- Volterra's predator-prey model to be considered adequate for describing real interspecific relationships and population numbers in regions of environmental disasters. Since the entire structure of the ecosystem, including trophic relationships, is changing under crisis conditions, the minimum requirement for the applicability of this model to describe long-term population dynamics is the unsteadiness of all coefficients [14]. This requires separate studies to determine these coefficients as functions of time. Long series of relevant factual data are needed to identify patterns of long-term population dynamics. In this study, we had fairly representative information on rodents and plants. For this purpose, the KSP and KTP described above were calculated for the "Plants-Rodents- Predator" system (Table 3):

Table 3. The values of the coefficients of coherence of the rate (KSP) and the rate (KTP) of

population dynamics

Years rate	**1960-1969**	**1970-1979**	**1980-1989**	**1990 -1999**	**2000 -2009**	**2010-2019**	**KSP**
Plants	-20,3150	-8,0650	-6,9650	-0,8150	4,3850	-19,5650	
Microtus Ilaeus	-0,5660	-0,2823	-0,1582	-0,1013	-0,0660	-0,0538	0,5390
Vulpes Vulpes	-1,2354	0,1921	-0,1304	-0,3009	0,0466	-0,2579	0,7355

Years rate	**1960-1969**	**1970-1979**	**1980-1989**	**1990-1999**	**2000-2009**	**2010-2019**	**KTP**
Plants	2,8775	0,2125	0,2775	0,8525	-0,2825	-5,3475	
Microtus Ilaeus	0,0406	0,0185	0,0079	0,0042	0,0028	-0,0012	*0,7045*
Vulpes Vulpes	0,3320	0,0108	-0,0435	0,0155	0,0344	-0,1404	*0,9064*

The restoration of a number of data from field studies in such a situation is possible using the response function to the number of rodents, the method of analogies and the coherence of the dynamics of the number of these two species, especially manifested according to the provisions of synergetics, in a crisis [19]. Thus, taking into account the multidimensional impact of the Aral ecological crisis, which significantly changed the structure of the ecosystem of the Southern Aral Sea region as a whole, modeling of natural processes in this region, including population dynamics, in our opinion, should be systematic, taking into account the specificity of the dynamics of elements of the natural environment in a crisis. The high values of KSP and KTP justify the reliability of the reconstructed series of data on the dynamics of the number of foxes used in the simulation. Obviously, the more accurate the scientific information about the nature of the observed relationships between the two species, the higher the reliability of the reconstructed data series.

4. Conclusions

1. The specifics of the dynamics of natural processes in a crisis (in this case, the Aral crisis) require the development of special simulation models taking into account the control parameters and order parameters of a destabilized ecosystem. The classic predator-prey Lotka-Volterra models, built for a normally, sustainably functioning ecosystem, turn out to be inadequate for crisis conditions.
2. With a shortage of data on the long-term population dynamics of a species, the proposed method of reconstructing the series of observations based on the relationships of this species with another well-studied species is a fairly effective method of structuring input data in mathematical modeling of natural processes.

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