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ANALYSIS AND MODELING OF A DYNAMIC INTERACTION BETWEEN THE COMBINED POPULATIONS

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The analysis of the combined populations of «predator–victim». Based on the discrete data of the growth of the population by years determined a rough plan of the regulation of population size. The cases of the location of the two predators in the area.

Keywords: the population size, modelling, discrete analysis

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АНАЛИЗ И МОДЕЛИРОВАНИЕ ДИНАМИКИ ВЗАИМОДЕЙСТВИЯ ОБЪЕДИНЁННОЙ ПОПУЛЯЦИИ

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Проведён анализ объединённой популяции «хищник-жертва». На основе дискретных данных прироста численности популяции по годам определён примерный план регуляции численности популяции. Рассмотрены случаи нахождения двух хищников на ареале.

Ключевые слова: численность популяции, моделирование, дискретный анализ.

Introduction. Environmental crisis currently developing on our planet is global and covers the entire biosphere. Its structure includes, among other things, the natural component, which is expressed in the visible degradation of the environment, the destruction of living organisms because of changes arising in it under the influence of human activity [1-3]. The extinction of biological species is dangerous for the biosphere because it leads to a decrease in biological diversity of natural ecosystems, which ensures their resistance to various external influences [1, 2].

Problem statement. "Predator-prey" interaction is one of the most widespread types of biotic interactions in nature. Predation is when animals (predators) find, grab, kill and eat other animals (preys) while getting food. Predators often catch and kill sick or non-viable individuals of prey, as a rule, not involved in reproduction, so predators can be attributed to the effective "methods" of evolution of living organisms [1-3]. Based on the above, it is obvious that studies on forecasting the number of natural populations, depending on a certain type of impact, are currently relevant.

Theoretical models of combined populations. In the course of evolutionary development, which is based on the interaction between predator and prey, the soundest and most adapted to the influence of environmental factors individuals survive in the population. That is, "predator-prey" is an interaction, in the process of which representatives of predators and representatives of preys evolve [1, 2].

In natural conditions, there is the following time and cause-and-effect chain: prey reproduction - predator reproduction - sharp reduction of prey number - reduction of predator number –prey reproduction, etc. [4, 5]. This cybernetic system with negative feedback leads to a stable equilibrium. Waves of fluctuations of predator and prey follow each other with constant phase difference, and on the average, the number of both predator, and prey remains constant [4].'

The model of coexistence of biological species on the type of "predator-prey" is called Lotka–Volterra model. This model was first used by Alfred Lotka in 1925 to describe the dynamics of interact-

ing biological populations. In 1926-1931, similar and more complex models were developed by Italian mathematician Vito Volterra, who derived the laws of periodic cycle, conservation and violation of averages in the study of the relationship between predator and prey [1, 4, 6].

In case of existence of any interspecies interaction, including the "predator-prey" type, the population is called "combined". Systems of homogeneous differential equations of first order, represented in Fig.1 are used in the description of such interspecies interactions

$$\begin{cases} \dfrac{dN_1}{dt} = \overbrace{a_1 N_1}^{\text{I}} + \overbrace{b_{12} N_1 N_2}^{\text{II}} - \overbrace{c_1 N_1^2}^{\text{III}} \\ \dfrac{dN_2}{dt} = \underbrace{a_2 N_2}_{\text{I}} + \underbrace{b_{21} N_1 N_2}_{\text{II}} - \underbrace{c_2 N_2^2}_{\text{III}} \end{cases}$$

Fig.1. General scheme of differential model components of combined population

In these systems: N_1 and N_2 — number of predator and prey populations; a_1 and a_2 —population growth rate coefficients; b_{12} and b_{21} —population interaction coefficients; c_1 and c_2 —coefficients of population self-limitation (intraspecific competition, anthropogenic impact, natural mortality).

The equations of population dynamics speed are divided into three sections (Fig. 1) [7, 8]:

I — section of own exponential growth: components for describing population dynamics without limiting factors;

II — section of interspecies interaction: the form of interspecies interaction is determined by the sign of coefficients b_{12} and b_{21}, and the degree of interaction is determined by their value;

III — section of limiting factors: natural mortality, intraspecific competition, anthropogenic impact.

In the form of predator-prey interaction, the coefficients in section II have different signs, i.e. the predator is the limiting factor for the prey and the prey is the food resource for the predator.

Anthropogenic impact of human hunting for predators is introduced in section III as a separate component and acts as a limiting factor [2, 9].

Selection of initial conditions and calculation results. Deer was chosen in this work as a prey in the model "predator-prey". In Russia deer is found in the Northern European parts, in the Far East, Northern Urals, in forests and tundra of Western and Eastern Siberia.

The largest reduction in the number of reindeers contributes to the population of their natural enemies — predators. Depending on the habitat of species of living organisms, the impact of predators on reindeer populations is quite different. This may be due to the number of populations of both predators and preys, the presence or absence of other types of food, as well as the number of other environmental conditions of living organisms, including climatic features of the territory [5, 10, 11].

It is the wolf, as a predator, that is the main natural enemy of reindeer in nature. The largest number of individuals of reindeer populations suffers from wolf attacks on the vast territories of tundra and forest-tundra. The populations of wolves move behind the populations of reindeer, so the habitats and the number of wolf populations are directly dependent on the quantitative characteristics and migration of reindeer populations [1, 5].

Lynx is the northernmost species of cat family. The diet of lynx includes both medium and large ungulates, including deer [1, 2].

In this paper, we consider the relationship between the predators represented by wolves and lynx, and the prey - deer, with the following initial data:

— the number of individuals of prey population (deer) - no more than 1828, each year the population increases by 0.387 units;

— the number of individuals of main predators population (wolves) — no more than 15, there are 33 deer per wolf per year, wolf population increases by 0.126 units each year;

— the number of individuals of additional predators population (lynx) is unknown, one lynx per year accounts for 21 deer, each year the population of lynxes increases by 0.218 units;

— death of individuals of prey population (deer) is only due to interspecific interactions with predators populations (wolves and lynx) and for no other reasons;

— death of individuals of predator populations (wolves and lynx) does not occur at all.

To analyze the size of the combined population, the following problems were set in a discrete form:

Problem 1: calculate the number of deer individuals in one and three years and in five and ten years in the absence of interspecies interactions with predators;

Problem 2: calculate the number of individuals in deer population at the same time intervals, if the number of individuals in wolf population is 15 and does not change during the specified time intervals;

Problem 3: calculate the number of individuals in deer population at the same time intervals, if the number of individuals of wolves is 15 and increases each year by a given proportion;

Problem 4: calculate the number of individuals of increasing wolf population in which the number of individuals of deer will remain approximately the same (about 2 thousand) during the initial five years of life of the population;

Problem 5: calculate the initial number of individuals of wolf and lynx populations, in which the number of individuals of deer population will remain approximately the same (about 2 thousand) during the initial five years of life of the population.

The calculations were performed in Microsoft Excel. The results of the calculations are presented in Table 1.

Table1

Calculation results of the combined population in a discrete form

1828	0,387	15	33	0,126	5	21	0,218	14	11	
Deer (conditionally)		Wolves (conditionally)			Lynxes (conditionally)					
Years	Deer					Wolves				Lynxes
	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5
0	1828	1828	1828	1828	1828	15	15	14	11	5
1	2535,436	1848,871	1848,871	1894,642	1886,32	15	16,89	15,764	12,386	6,09
2	3516,65	1877,819	1791,312	1906,334	1872,023	15	19,01814	17,75026	13,94664	7,41762
3	4877,593	1917,97	1614,07	1831,638	1742,091	15	21,41443	19,9868	15,70391	9,034661
4	6765,222	1973,659	1258,556	1625,667	1434,344	15	24,11264	22,50513	17,68261	11,00422
5	9383,363	2050,901	641,9571	1224,718	859,5649	15	27,15084	25,34078	19,91061	13,40314
6	13014,72	2158,034		538,8103		15	30,57184	28,53372	22,41935	16,32502
7	18051,42	2306,629				15	34,42389	32,12897	25,24419	19,88387
8	25037,32	2512,729				15	38,7613	36,17722	28,42496	24,21856
9	34726,77	2798,59				15	43,64523	40,73555	32,0065	29,49821
10	48166,02	3195,079				15	49,14453	45,86823	36,03932	35,92881

Conclusion. The results of the calculations carried out under the given conditions showed that during the first five years the number of individuals of prey population (deer) will remain stable in all five problems. Thus, in the course of work the possibility of forming the balance of the combined population "predator-prey" on the basis of the discrete data calculation in the regulation of the initial population of

the predator was justified. For a detailed study of the model, it is necessary to conduct a differential analysis of the phase portrait of the combined population.

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