GENERAL
BIOLOGY

Demographic Processes and Genetic Variability of Mouse Populations at the Ecological–Geographic Periphery

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Presented by Academician V.N. Bol'shakov August 14, 2014

Abstract—On the basis of the results of long-term monitoring, the peculiarities of demographic processes in *Sylvaemus uralensis* Pall. populations under the peripheral ecological–geographic conditions of the area have been studied. Data of the individual marking and ontogenetic history of animals are presented. Demographic parameters of population, reproduction efficiency, and progeny survival, as well as contributions of various structural groups in the population gene pool were analyzed. The low reproduction activity of the young and the considerable role of the senior age groups in population reproduction were revealed. We have established that changes occur at two structure levels of population: simplification of the age structure and reorganization of the generation structure transformed the genetic information transmission pathways. The transgeneration channel of the transfer of hereditary information is prevailing in pessimum habitats of murine rodents with low reproductive activity of the young stock. In depression years this channel is obligatory and it might cause a reduction in the population genetic heterogeneity.

DOI: 10.1134/S0012496615040031

A peripheral population (in not only geographical, but also ecological context) is a subject of many studies and reviews, which have often focused on genetic diversity as the basis of adaptive changes, stability, and evolutionary prospects of the central and peripheral populations [1–4]. On the other hand, investigation of environmental mechanisms for maintaining the genetic heterogeneity of populations has been under development [5–10]. Development of the general concept of peripheral populations linking these areas is constrained by the lack of factual material on the marginal settlements of different species [3], the contradictory information about the level of their genetic polymorphism, and insufficient investigation of association between genetic variability of populations and their ecology, including the genetic capacity of individuals [6, 11].

This has determined the goal of the present study: investigation of the possible transmission of genetic information in real natural populations of short-lived rodents in association with the peculiarities of their demographic structure in an ecologically suboptimal zone of the area.
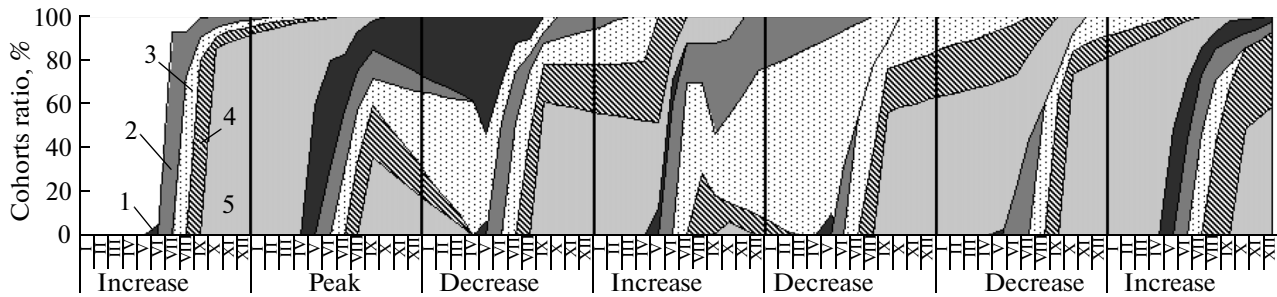
In the present study, environmental and genetic peculiarities of functioning of such populations were shown using marked rodents. Demographic processes leading to a simplification of the age structure and change of generational structure transform the way the transmission of hereditary information and can lead to a reduction of genetic heterogeneity of mice populations living in a pessimal habitat.

We analyzed the demographic processes in *Sylvaemus uralensis* Pall. (pygmy wood mouse) populations based on the results of nine-years monitoring under the conditions of the ecological and geographical periphery of the area (southern- and middle-taiga forests of the Urals). Our study presents unique data on individual marking and monitoring of the developmental history of the animal. In parallel, we studied the interior indicators for the age diagnostics and the establishment of structural and physiological status of the animals, followed by the reconstruction of the demographic transformation of their populations. The contributions of different structural groups to the gene pool of the population were evaluated based on the effectiveness of reproduction (the proportion of reproducing individuals and the actual fertility of females) and the survival of offspring, as we described previously [12].

Up to 10 age cohorts (overwintered and youngs-of-the-year) were annually recorded in the age structure of the population of model species in different proportions, depending on the phase of the cycle, season and/or climatic influences (figure). A cohort was defined as the basic structural intrapopulation groups of animals of the same age and numbered in accordance with the appearance from the beginning of the

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The age structure of *Sylvaemus uralensis* population with different levels of abundance (marked animals). The *x*-axis shows the time (years with different levels of abundance and months, roman numerals); Arabic numerals in the figure (1−5) are age cohorts; filled areas of different colors correspond to generation I; hatched areas, to generation II (or I + II).

breeding season. Deviation from the baseline cohort spectrum toward decreased complexity of the age structure was determined. Almost every year, death of the youngs-of-the-year of the first cohort (less frequently, death was detected in other cohorts) reduced the number of reproducing individuals in general and their genetic value for the population in particular. The low reproductive activity of the young was expressed by participation in the reproduction of only spring cohorts (with survival 0.10−0.77), and by the low proportion of their descendants (8.1−34.0%) in the population of the current year. Due to the high life expectancy (up to 16.5 months), overwintered mice provided an increased abundance in the late summer and autumn, while the youngs-of-the-year after one or two litters did not breed, they had morphological and physiological signs of reproductive failure and survived a maximum of 6 months (figure). In low-abundance phases, the reproduction of populations was mainly accounted for by older age groups (overwintered mice). During these periods, we recorded a significantly high (according to the Mann−Whitney *U* test) mortality rate of breeding youngs-of-the-year compared to overwintered animals: $U_{4;4} = 0.03$, $p = 0.02$ with a median (interquartile scope) for these groups 0.78 (0.75−0.84) and 0.31 (0.25−0.36), respectively.

We also investigated another level of structuring of the population, the generation structure, for the estimation of the genetic diversity of populations. Generations are intra-population groups including animals of different ages united by their degree of relation with a common ancestor.

For short-lived murine rodents of boreal bioclimatic zone, the generational structure of populations is usually represented by a series of three consecutive overlapping generations (referred respectively as I, II, and III), while summer and autumn cohorts of youngs-of-the-year have a "mixed" origin, including the descendants of different generations (I + II). In the population studied, due to the limited reproduction and high mortality rate of the first cohorts of the

youngs-of-the-year (generation I), generation II was limited, being represented by only one cohort, cohort 4 (sometimes, during years with increased abundance, it was represented partially by cohort 3) and III generation was not registered (figure). It was found that, during the prolonged breeding of wintering mice, autumn and spring cohorts were represented only by generation I; i.e., changes in the standard sequence of alternation of generations were observed: I, II, and again I.

The impact of the demographic structure of populations on their genetic diversity was repeatedly discussed in the literature for different groups of animals (mostly for short-lived animals). Wood mice, in contrast to many species of field mice, were characterized by the low reproductive activity of the youngs-of-the-year, clearly expressed under extreme environmental factors. Based on the ontogenetic development concept of bivariate cyclomorphic rodents [13], the ratio of ontogeny types in the structure of the population changed the age and generation spectra.

The fact that, under non-adequate environmental conditions, the modality of generation structure shifts toward generation I and generation II due to low reproductive activity. The high mortality of youngs-of-the-year is representative only during rare phases of increased abundancy of populations along with the simplification of the age structure was demonstrated for the populations studied (figure). The predominance of senile individuals in the effective (breeding) part of the population also has negative genetic consequences for descendants [14]. It is known that in rodents the genetic load can be transmitted from generation to generation not only sequentially, but also transgenerationally [15]. This variant occurred in rare cases in optimum zones of the area and in rodents with active reproduction of youngs-of-the-year [13], while in the population of the pygmy wood mouse studied, with significant suppression of young animals breeding, in contrast, it is advantageous.

Thus, in the present study based on data from marking, we established that, under pessimal condi-

tions, in murine rodents with low reproductive activity of young individuals with the simplification of age structure and fundamental changes in the structure of the generation, the transgenerational channel for transmission of hereditary information is the main channel, and it becomes an obligate channel during depression years. These demographic processes may lead to decreased genetic diversity in peripheral populations.

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Translated by V. Mittova