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SHORT COMMUNICATIONS

Long-term Trend toward Increase in the Proportion of Melanics in the Kurgan Population of Northern Mole Voles (*Ellobius talpinus* L.) against the Background of Climate Change in the Transural Region

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Northern mole voles (*Ellobius talpinus* L.) in the Urals and Transural region forms polymorphic colonies comprising animals of different coat color morphs: black, brown, and transitional (black-backed with brown belly and sides), and the ratio of these morphs may differ between years and localities [1]. The phenomenon of color polymorphism in invertebrates and vertebrates has been widely used in studies on the dynamics of population structure since the mid-20th century [2–9]. A well-known example is adaptive polymorphism of body color in in the two-spot ladybird (*Adalia bipunctata*) described by Timofeeff-Ressovsky and Svirezhev [10], with the ratio of morphs varying by seasons against the background of changes in ambient temperature. As hypothesized by the authors, changes in the vectors of seasonal selection of color morphs take place against the background of change in ecological conditions for their existence.

Smyshlyaev [5] revealed a trend of change in the ratio of color morph over a 12-year observation period in the Sayan population of red squirrels from dark conifer mountain forest of the Baikal region. The author noted a probable relationship between changes in the frequencies of color morphs and phases of squirrel population dynamics but did not find that they are correlated with environmental conditions. Our calculations showed that Pearson's correlation of change in frequency with the year of observation was $r = -0.87$ ($p = 0.0003$) for the black-tailed morph and $r = 0.84$ ($p = 0.0006$) for the brown-tailed morph. However, the corresponding correlation coefficients in another northern population of red squirrels, from dark conifer forest in the upper reaches of the Lena River, proved to be low and lacked statistical significance.

Gershenzon [2, 11] described the phenomenon of seasonal and interannual changes in the frequencies of melanistic coat color morph in the common hamster in the Southern Urals, which is also interpreted as a manifestation of adaptive polymorphism. Therefore, it appeared probable that northern mole voles from the same region would also be characterized by adaptive polymorphism involving changes in the ratio of color morphs in polymorphic populations in years with different climatic conditions.

Coat color polymorphism in northern mole voles inhabiting the Southern Urals and Transural region is manifested in Bashkortostan and Chelyabinsk and Kurgan oblasts. Their northern populations in Chelyabinsk oblast consist only of black animals (melanics), colonies in the south of the region and in the Naurzum Nature Reserve (Kazakhstan) contain only animals with brown fur, and geographically intermediate populations are usually polymorphic. Thus, the proportion of melanics in the populations increases in the south–north direction, along with increase in climate humidity. Therefore, a correlation could be expected between the proportion of melanics in in a local polymorphic population and interannual fluctuations of climate humidity (e.g., summer precipitation).

The purpose of this study was to analyze long-term trends of change in the ratio of coat color morphs in the model Kurtamysh population of northern mole voles with regard to fluctuations of climate humidity (moisture level) and temperature in key seasons.

The animals were trapped in 1985 to 1999 in the same locality near the village of Pes'yanoe (Kurtamysh district, Kurgan oblast; 55°01′ N, 64°43′ E). Live-trapping was carried out twice a year, in the same seasons. The animals were weighed, examined to record their sex and coat color type (morph), marked, and released. On the whole, 745 animals were marked, but some of them were recaptured and recorded again (2–13 times); therefore, the total number of animals examined over 15 years reached 2237 ind. Precipitation in early summer and low temperatures in late

The ratio of coat color morphs in the Kurtamysh population of *E. talpinus*, June precipitation, and October air temperature during the 15-year period of observations in Kurgan oblast

Year	Coat color morphs			Number of animals	Climatic parameters	
	black	brown	transitional (black-backed)		June precipitation, mm	October temperature, °C
1985	38.5	44.8	16.7	96	393	1.4
1986	37.5	40.8	21.7	152	518	2.8
1987	38.1	41.3	20.6	160	116	2.0
1988	41.8	40.3	17.9	134	283	3.8
1989	42.7	39.8	17.5	206	169	3.8
1990	48.6	34.7	16.7	245	648	2.8
1991	49.3	34.4	16.3	221	365	7.1
1992	49	34.3	16.7	210	304	3.4
1993	50.7	35.9	13.4	223	282	3.5
1994	51.2	27.4	21.4	84	561	6.9
1995	48.4	32.3	19.3	62	482	4.5
1996	55	28.8	16.2	80	561	2.0
1997	62.1	18.5	19.4	103	663	7.9
1998	50.8	21.2	28	118	565	4.7
1999	58.7	22.4	18.9	143	878	7.4

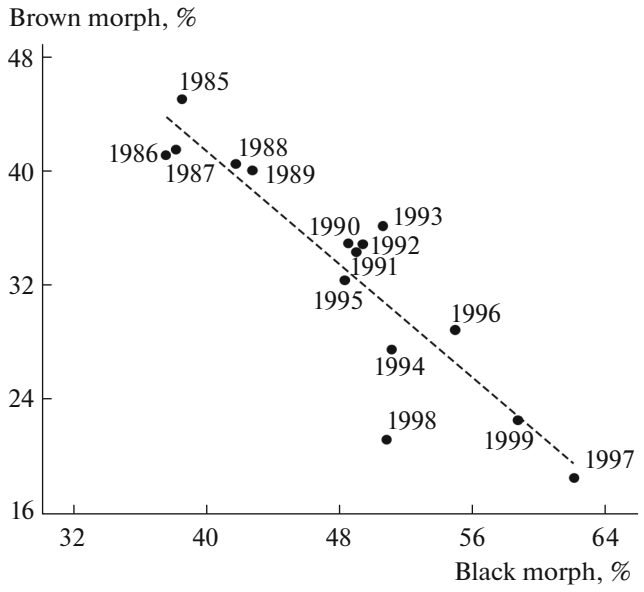
autumn are the most important climatic factors that have a direct effect on seasonal and annual fluctuations in the abundance of northern mole voles. Data on June precipitation and average October temperature in the study region over the period of 1985 to 1999 were obtained from the CRU TS 2.1 database [12].

The data on the ratio of three color morphs in the Kurtamysh population, and climatic parameters in different years are presented in the table. They show that the frequencies of black and brown morphs in the consecutive years of the late 20th century are inversely correlated with each other. Pearson's coefficient for this correlation is highly significant: $r = -0.94$, $p < 0.0001$. At the same time, change in the frequency of the transitional morph shows no trend in time and does not correlate with changes in the frequencies of the other two morphs ($p > 0.05$). Statistically significant positive correlation coefficients were obtained for changes in the frequency of black morph depending on June precipitation ($r = 0.68$, $p = 0.005$) and October temperature ($r = 0.67$, $p = 0.004$); correspondingly, statistically significant but negative correlation coefficients were obtained for changes in the frequency of brown morph depending on the same parameters: $r = -0.72$ ($p = 0.002$) and $r = -0.71$ ($p = 0.003$), respectively.

Thus, the study on the coat-color-polymorphic Kurtamysh population of northern mole voles has revealed a 15-year directed trend toward increasing proportion of melanics, which is correlated with year-by-year increase in climate humidity (precipitation) in early summer and average October temperature in the region during the late 20th century.

Changes in the ratio of color morphs similar to its geographic variation in the south–north direction were revealed in the northern mole vole population from the vicinities of Kuvandyk (Orenburg oblast), where the animals were trapped along a gradient from relatively moist biotopes (glades in forest in the Sakmara River floodplain) to xerophytic areas on the steppe slopes of the Guberlinski Hills. Family colonies in the relatively moist Sakmara floodplain consisted mainly of black-backed mole voles with dark brown belly; in the steppificated meadow on the Sakmara terrace, with more xerophytic vegetation, both black-backed and brown animals occurred in colonies; and colonies in the steppe on hillslopes consisted only of brow animals. In the same habitats with contrasting ecological conditions, biotopic variation (in the mandible shape) was previously revealed in other rodent species, the bank vole and pygmy wood mouse [13].

Thus, coat color polymorphism in the northern mole vole shows correlation with moisture level in the geographic region, year, and biotope. Therefore, the trend toward increasing proportion of the black morph in mole vole colonies (up to melanistic monomorphism) with an increase in environmental moisture reflects parallelism of the geographic, chronographic (interannual), and biotopic forms of variation in coat color. Biotopic (landscape–geographic) variation was revealed in the aforementioned population from Orenburg oblast. Data on chronographic variation is presented in the table for the Kurtamysh population from Kurgan oblast. Geographic variation in the south–north direction manifests itself in melanics in



Regression dependence of the proportion of brown-morph animals on the proportion of black-morph animals in the Kurtamysh population of *E. talpinus*, Kurgan oblast (1985–1999).

the common hamster is also observed at the northern boundary of the range and in relatively moist mountain landscapes of Bashkortostan [11]

Since it has been shown experimentally that variation in the expression of coat color morphs in the mole vole has a genetic basis [14], there are grounds to consider that positive selection for melanics takes place in colonies of these animals under conditions of increasing environmental moisture. However, genetic and probable epigenetic factors responsible for this phenomenon are as yet unclear and need further analysis. Nevertheless, from the traditional point of view on long-tern trends of changes in the ratio of color morphs in the mole vole, the increase in the proportion of melanics in the population against the background of directed climatic trends may be regarded as a typical instance of adaptive polymorphism (in Timofeeff-Ressovsky's interpretation).

It may be concluded that the correlation of change in the proportion of melanics in the mole vole population with increasing moisture in early summer and average October temperature and the parallelism of geographic, chronographic, and biotopic variation in coat color are directly evidence for the adaptive nature of its polymorphism in the Urals and Transural region.

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