M. Vences, J. Köhler, T. Ziegler, W. Böhme (eds): Herpetologia Bonnensis II.
Proceedings of the 13th Congress of the Societas Europaea Herpetologica. pp. 197-200 (2006)

Significance of recessive and dominant mutations in adaptive processes of the genus *Rana* in the modern biosphere

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Abstract. The frequency of striata morph individuals in *R. arvalis* (44.9%) and *R. ridibunda* (92%) populations in Yekaterinburg increases along with the degree of urbanization. The reason of this process lies in the physiological specificity of the genotype. According to our data, the sodium permeability of the skin of the striata morph in *R.arvalis* is more than three times lower than in others. The frequency of iris depigmentation in the city populations of moor frogs was higher than in the forest population – 1.62% and 0.39% respectively. The probably underlying genetic mechanisms and the adaptive significances of these characters is discussed.

Introduction

From the orthodox point of view on processes of microevolution, it is supposed that during the process of mutating, recessive alleles usually accumulate in populations in heterozygotic state and later, when some environmental changes occur,, can be used in adaptational processes as a hidden resource of internal variability (Chetverikov, 1926). Vice versa – dominant mutations usually are eradicated by natural selection because of their immediate appearance in phenotype and their harmful influence on surivalship of the specimens.

During a long study (1976-2005) of city and forest populations of three anuran amphibian species we found some facts that show a different destiny of some dominant and recessive mutations and their different role in the adaptation process under the effect of urbanization.

Materials and Methods

The work was done on the territory of city agglomeration (Yekaterinburg) that is situated in Middle Ural - right on the border of Europe and Asia. Control sites were located 23 km from the city.

I studied populations of three species of anuran amphibians from the genus *Rana*: *R. ridibunda* Pall., *R. arvalis* Nilss., and *R. temporaria* L. that lived in an urban agglomeration. Frequencies of two characters were investigated – striata morph and iris depigmentation. The first so-called striata morph, which is phenotypically expressed as presence of a light dorsomedian stripe, has been found in several species of the genus *Rana*. It is determined by the dominant allele of the dialleleic autosomal gene "striata" with complete dominance (Schupak, 1977; Berger and Smielowski, 1982).

The second feature, absence of normal iris pigmentation in one or both eyes, is widespread in many amphibian species, both anuran (Cain and Utesch, 1976) and urodelean (Dubois et al., 1973; Engelmann and Obst, 1976). Hybridization experiments with *Rana esculenta* (Rostand and Darre, 1970) have shown that this anomaly is determined by a recessive mutation (Rostand, 1953). It has also been described in the brown frogs *R. temporaria* (Rostand, 1953) and *R. arvalis* (Vershinin, 2004a). In fact, it may be regarded as partial albinism.

Results and Discussion

It has repeatedly been noted that the frequency of striata morph individuals in *R. arvalis* (44.9%) and *R. ridibunda* (92%) populations in Yekaterinburg increased ($p<0.01$ by chi-square) along with the degree of urbanization (Fig. 1).

The reason of this process lies in the physiological specificity of the genotype. According to our data, the sodium permeability of the skin of the striata morph in *R.arvalis* is more than three times lower than in others ($F=5.39$, $p<0.0023$). The decrease in the skin permeability for many substances (including oxygen) favors an increase in the importance of lung respiration, which leads to an increase in the blood oxygen capacity due to an increased amount of hemoglobin. The high hemoglobin concentration accounts for the high amount of iron in the body of striata morph frogs. The increased lung function intensity resulted in an increased metabolic rate and, hence, decreased

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life span of striata morphs (2.8±0.16 years (n=71) vs. 3.3±0.19 years (n=42) in other frogs; F=4.1, p<0.045). The shortened life cycle of striata frogs promotes an increase in the rate of evolution. Frogs with this dominant mutation are preadapted to natural and artificial geochemical environmental anomalies (Vershinin, 2004b). The second feature, recessive mutation, is the evidence for inbreeding depression in urban populations and high mutagenesis in the urban environment (Vershinin, 2004a).

The frequency of iris depigmentation in the city populations of moor frogs was higher (chi-square=28.9; p<<0.001) than in the forest population – 1.62% and 0.39% respectively. We found that among the probable factors responsible for fluctuations in the frequency of this anomaly, attention should be focused on ambient temperature in the period of spawning and embryonic development: in the years characterized by the absence of frogs with iris depigmentation no frosts occurred in this period. Apparently, cold spells in spring promote the phenotypic manifestation of this anomaly (Vershinin, 2004a). In the city and in the forest populations of moor frogs, the frequencies of this deviation decreased in adults compared with young of the year animals (Fig. 3).

The total frequency of the feature in all juveniles is 4.9 times higher than in all adults (chi-square=12.39; p<0.001). We suppose that homozygosity of these specimens can negatively influence survivalship. Apparently, there is a complex of recessive traits that, being in the homozygous state, may be responsible for a low survival due to inbreeding depression (Simberloff,

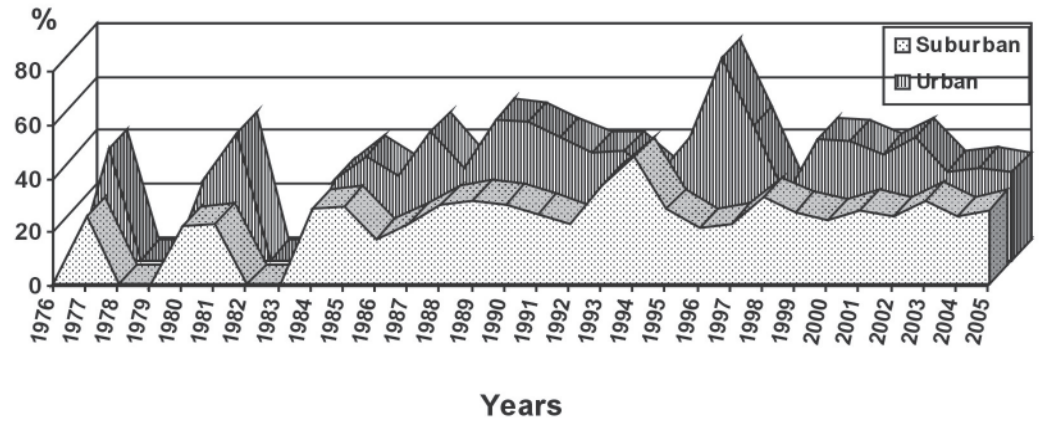

Figure 1. Frequency of striata morph in urban and suburban populations in juvenile *R.arvalis*

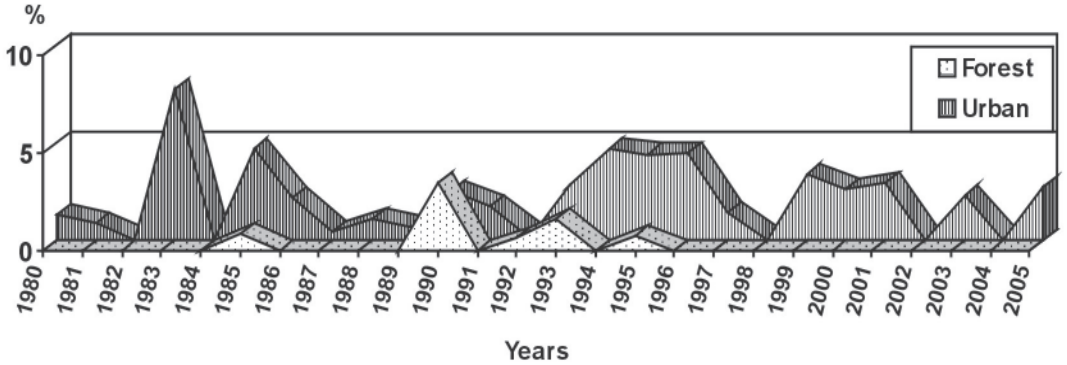

Figure 2. Frequency of iris depigmentation in urban and forest populations in juvenile *R. arvalis*

1983). It appears that striata morph frequency in the city populations slightly increases in mature animals (Fig. 4).

The relatively lower capacity for bioaccumulation determined the increased frequency of striata frogs in areas of natural and artificial geochemical anomalies. The striata morph is absent in *R. temporaria*, which is sympatric to *R. arvalis*. Apparently, the ancestors of *R. temporaria* lost this morph; this was related to the fact that wintering *R. temporaria* tolerate hypoxia by using skin respiration.

High resistance to anthropogenic transformation of environment is characteristic for *R. arvalis* and *R. ridibunda* - the species in which the striata morph exists as a genetic variant. Phenotypic manifestation of dominant – striata differs from recessive iris depigmentation (Fig.1, 2) by more stability and its penetrance is independent from seasonal factors. Thus, dominant mutations can immediately increase adaptive success of their carrier. On the contrary - recessive mutations reduce chances of individual to survive.

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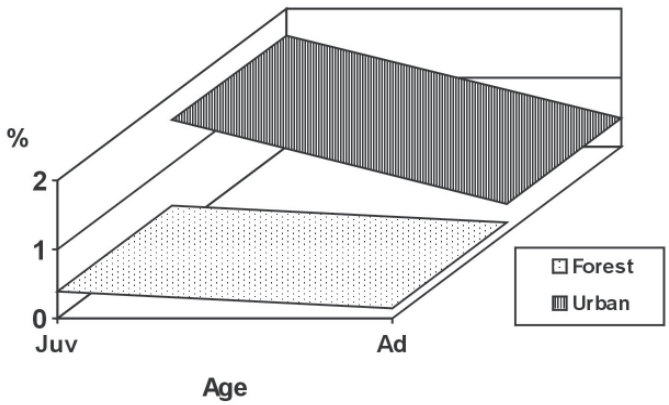

Figure 3. Age changes in iris depigmentation frequency in city and forest populations *R.arvalis*

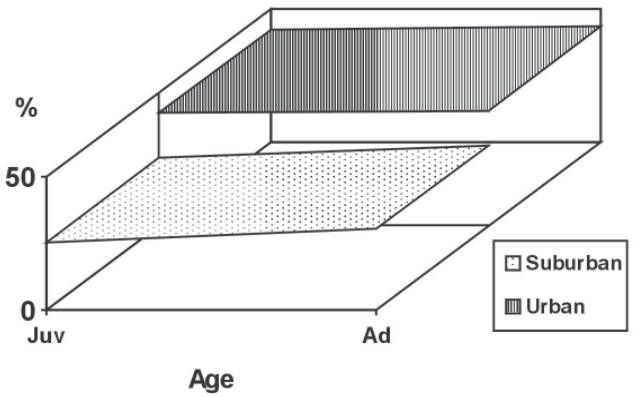

Figure 4. Age changes in frequency of the striata morph in urban and suburban populations *R.arvalis*

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