

The Striata Morph and Its Role in the Ways of Adaptation of the Genus *Rana* in the Modern Biosphere

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Polymorphism has been described in a great many species. This phenomenon is determined by genetic heterogeneity of individuals in populations [1]. This is the external expression of “[...] *the hidden intraspecific variability reserve* [...]” [2] and adaptation polymorphism related to phenological or other environmental fluctuations or reflecting the history of the geographic spread of the given species [3]. Neutral polymorphism, by its very nature, is extremely rare.

In this study, I used three species of tailless amphibians (Anura) from the genus *Rana*: *R. ridibunda*, *R. arvalis*, and *R. temporaria*. Most animals studied lived in an urban agglomeration. I distinguished the following urban zones in which the amphibian habitats were located: the zones of multistory and low buildings (zones II and III, respectively) and forest parks (zone IV). A plot located 23 km away from Yekaterinburg was used as control (C). The results of hydrochemical analysis confirmed that this typification was acceptable.

The so-called striata morph, which is phenotypically expressed as a light dorsomedian strip, has been found in several frog species of the genus *Rana*. The analysis of the genetics of this character has demonstrated that it is determined by a monogenic mutation. The dominant allele of the diallelic autosomal gene *striata* determines the presence of the strip (a complete dominance). This mode of inheritance has been established for *R. arvalis* [4] and *R. ridibunda* [5]. The specificity of the character inheritance make it a good marker of changes in population genetic structure.

Frogs from the striata morph are characterized by sensitivity to “frog kill” and a relatively high energy consumption [6]. Young-of-the-year *R. arvalis* belonging to the striata morph released 1.5–2 times more CO₂ per unit time than *R. arvalis* of the same age from the maculata morph [7], which the authors of the study [7] consider to be evidence for a high metabolic rate.

Young-of-the-year *R. arvalis* [8] of the striata morph have a low thyroxin sensitivity related to the primarily high rate of redox processes, which determines [9] their high migration activity and resistance to drought. Striata individuals of *R. macrocnemis* are characterized by a high mean hemoglobin content of blood [9]. Studies on *R. arvalis* from Ural populations [10] showed that the concentrations of some metals in the body of striata frogs were considerably lower compared to other individuals (only iron concentration was two times higher); therefore, it was assumed that the occurrence of this morph in the Urals was related to the environment geochemistry. Earlier, we often observed an increase in the proportion of the striata morph in frog populations living in anthropogenically affected areas. Early maturation and short life span were found [11] to be characteristic of striata individuals of *R. arvalis*. According to our data, the sodium permeability of the skin of striata *R. arvalis* is lower than in others by more than three times ($F = 5.39$, $p < 0.0023$). The mechanism of this decrease in permeability is unknown; however, a study on bioaccumulation in *R. arvalis* demonstrated that striata individuals accumulated 5, 3.5, 5, 4, 6, and 2.5 times less ⁹⁰Sr (our data), manganese, chromium, nickel, tin, and zinc [10], respectively, than other frogs did.

The observed characteristic feature of the skin of striata frogs offered an entirely new insight into the specificity of its physiology. 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 frogs. We found that young-of-the-year frogs belonging to this morph were characterized by an increased initial level of erythrocyte precursors in the blood, namely, 63.7 vs. 52.7% ($F = 6.5$, $p = 0.0134$, $n = 60$). Together with the high reactivity of the striata morph, this precluded hemopoietic depression (Figs. 1a, 1b) after burst release of erythrocyte precursors in response to drastic environmental changes [12].

The data on the proportion of neutrophils in striata young-of-the-year *R. arvalis* (Figs. 2a, 2b) ($F = 7.995$,

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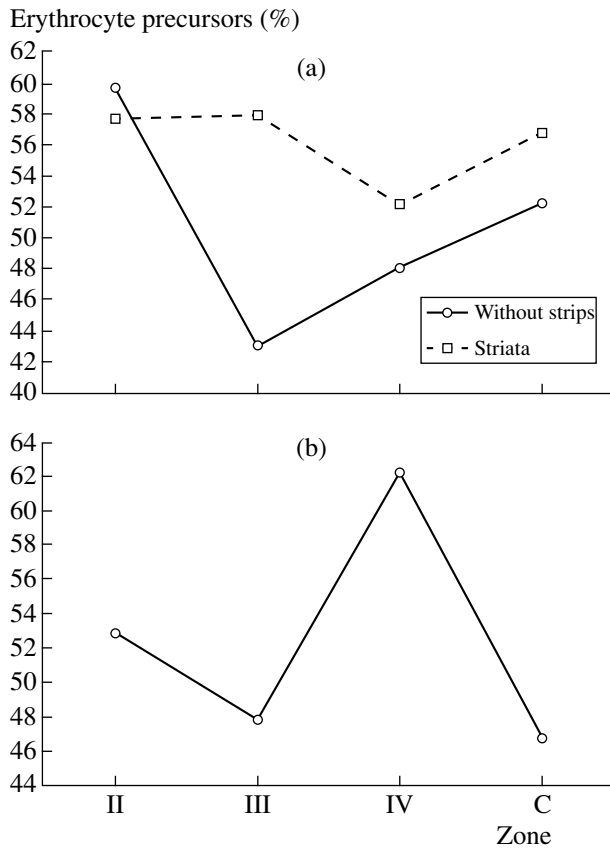


Fig. 1. Proportions of erythrocyte precursors in young-of-the-year frogs of different morphs: (a) *R. arvalis*; (b) *R. temporaria* (total for the period from 2000 to 2002).

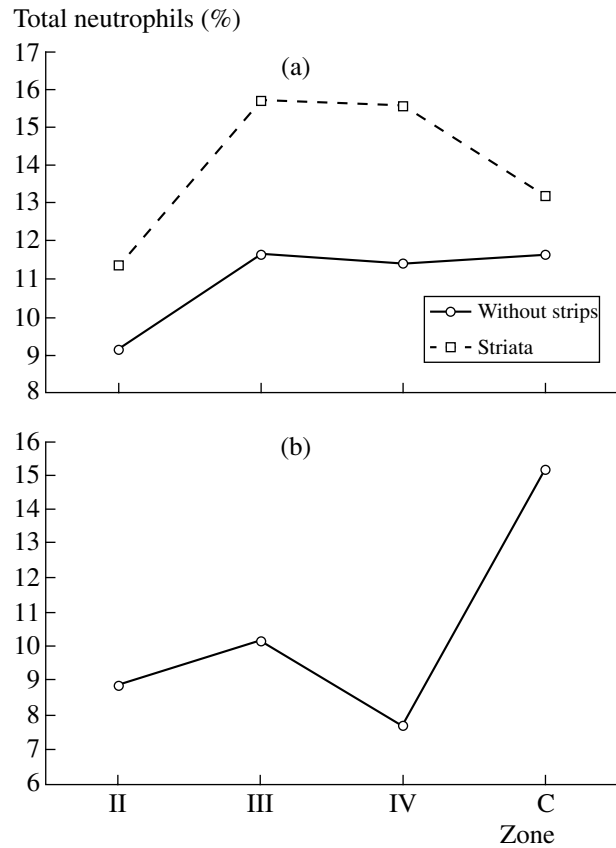


Fig. 2. Total neutrophil proportions in young-of-the-year (a) *R. arvalis* and (b) *R. temporaria* (total for the period from 2000 to 2002).

$p = 0.005$) and *R. ridibunda* ($F = 12.4, p = 0.0007$) indicate a high phagocytic capacity of the hemopoietic system of striata frogs from both species. The increased lung function intensity resulted in an increased metabolic rate and, hence, decreased life span of striata (2.8 ± 0.16 years ($n = 71$) vs. 3.3 ± 0.19 years ($n = 42$) in other frogs; $F = 4.11, p < 0.0451$) (Table 1). The shortened life cycle of striata frogs promotes an increase in evolution rate.

The high metabolic rate may have caused the decrease in nerve excitation threshold in striata frogs. The comparative analysis of the excitability of the nervous tissue in *R. arvalis* demonstrated that the excitation threshold of striata frogs ($0.39 \pm 0.04; n = 59$) was significantly ($F = 5.49, p = 0.02$) lower than in others (0.529 ± 0.035).

The relatively lower capacity for bioaccumulation determined the increased frequency of striata frogs in areas of natural and artificial geochemical anomalies. As noted before, the striata morph was usually rare among both *R. arvalis* and *R. temporaria* in areas with insignificant anthropogenic transformation of environment (Table 2).

The striata morph is absent in *R. temporaria*, which is sympatric to *R. arvalis* [9]. Apparently, the ancestors

of *R. temporaria* lost this morph; apparently, this was related to the fact that wintering *R. temporaria* tolerate hypoxia by using skin respiration [13]. Typically, *R. temporaria* spend winter on the bottom of water bodies and *R. arvalis*, on land [14]; and striata individuals are more vulnerable under the conditions causing “frog kill” [6].

High resistance to the anthropogenic transformation of the environment is characteristic of *R. arvalis* and *R. ridibunda*, i.e., the species in which the striata morph exists as a genetic variant. It may be assumed that frogs with the dorsomedian strip are preadapted to geochemical environmental anomalies.

Thus, differences in polymorphism between closely related species reflect the species specificity of the

Table 1. Mean age of mature *R. arvalis* (years)

| Zone | Without strips | N | Striata | N |
|------|----------------|----|----------------|----|
| II | 3.2 ± 0.33 | 14 | 2.7 ± 0.37 | 11 |
| III | 3.4 ± 0.41 | 9 | 2.7 ± 0.39 | 10 |
| IV | 3.3 ± 0.32 | 15 | 2.6 ± 0.37 | 11 |
| C | 3.1 ± 0.21 | 33 | 3.0 ± 0.39 | 10 |

Table 2. Occurrence of the striata morph in an urban area (in percent)

| Zone | II | III | IV | C |
|---------------------|---------------------|--------------------|---------------------|---------------------|
| <i>R. arvalis</i> | | | | |
| Adult | 42.05 (n = 88) | 42.86 (n = 42) | 34.65 (n = 127) | 22.02 (n = 109) |
| Young-of-the-year | 44.73 (n = 2611) | 37.55 (n = 514) | 29.26 (n = 3835) | 19.51 (n = 2466) |
| <i>R. ridibunda</i> | | | | |
| Adult | 89.36 (n = 47) | 92 (n = 25) | 0 (n = 19) | No data* |
| Young-of-the-year | 47.1 (n = 797) | 26.7 (n = 30) | 0 (n = 57) | No data* |

* *R. ridibunda* is an immigrant species; it does not occur outside the urban area.

ways of adaptation and may affect the survival and reproductive success of populations under the conditions anthropogenic landscapes, which substantially affects their further evolution under the current biosphere conditions.

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