POLISH ACADEMY OF SCIENCES
INSTITUTE OF ZOOLOGY

URBAN ECOLOGICAL STUDIES

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM WARSZAWA — JABŁONNA, 24—25 SEPTEMBER, 1986

WROCŁAW—WARSZAWA—KRAKÓW—GDAŃSK—ŁÓDŹ
ZAKŁAD NARODOWY IMIENIA OSSOLIŃSKICH
WYDAWNICTWO POLSKIEJ AKADEMII NAUK
1990

VLADIMIR L. VERSHININ

FEATURES OF AMPHIBIAN POPULATIONS OF AN INDUSTRIAL CITY

ABSTRACT

Results are discussed of long-term studies (1977—1985) in Sverdlovsk (USSR), a large city with 1.5 mln population. Changes in spatial and genetic structure of populations of brown frogs *Rana arvalis* (NILSS.) and *R. temporaria* (L.) were investigated. Their population dynamics and population characteristics in urbanized landscapes were revealed. Adaptative changes in *R. arvalis* urban populations and increased predation on invertebrates were noted in micropopulations of froglets.

Microevolutional changes in urban communities under conditions of industry growth and urbanization are interesting from the theoretical point of view, as their rate may be higher and the trends different from that under natural conditions (SCHWARTZ, 1976). Modes and origins of synantrophic fauna formation are still poorly studied. For city ecosystems characteristic are poor species composition and predominance of one or few species (DROZDOV, 1969).

Some species undergo a synurbanization (i.e. urbanization) process, i.e. adaptation to city environment at a populational level, and new regulating mechanisms appear (ANDRZEJEWSKI et al. 1978).

Rana arvalis is the most widespread urban species in the Urals (VERSHININ, TOPORKOVA, 1981). It is abundant as compared to other amphibians and more tolerant of man-induced environmental changes. Its quantitative predominance over *R. temporaria* is recorded in the anthropogenic landscape of the Urals and other regions

(TOPORKOVA, 1973). It is a good model species to study particular ways of adaptation to city conditions.

Since 1977, absolute counts of spawns in each pond of the observed area were made during the breeding period. From stage 41 (DABAGYAN, SLEPTSOVA, 1975) numbers of *R. arvalis* and *R. temporaria* larvae were studied by their staining with neutral red (COOKE, 1978). The larvae and froglets were marked and recaptured. Abundance of the latter was established twice — immediately after metamorphosis and at stage 54 by toe clipping (mass marking).

In 1984—85 *R. arvalis* and *R. temporaria* stomach content were studied at the beginning of terrestrial life — soon after metamorphosis, and 10—14 days later, by the time of full tail resorption.

In July—August 1984 amphibian numbers were estimated on 10×10 m^2 plots in the urban area and outside. After the plots were set up they were combed and the floor was examined by hand. Morphological aberrations among all amphibian groups were recorded.

Species composition and distribution changed with increased urbanization pressure. In the centre of the city, amphibians did not occur. In heavily urbanized biotopes, numbers of amphibian species was poor — 1, rarely 2 or 3 species. *Caudata* was nearly absent. *R. temporaria* was locally recorded — perhaps due to lack of ponds suitable for hibernation. The introduced species *R. ridibunda* was recorded. The degradation process affected suburban forests, too. In 1980—82 the number of *R. arvalis* spawns in the study area of the suburban forest was 3.1—3.5 times less compared to 1977. That of *Salamandrella keyserlingii* was 2—2.4 times less within the same period. Decreased average egg number in *S. keyserlingii* spawns was marked over 4 years, though the size of adult females was nearly the same for all years.

R. arvalis was the only species common through all urban habitats. Maximal density of adult *R. arvalis* outside the city metropolitan area was 113 individuals per ha. In the urban areas it was about 64 ind./ha around multi-story buildings (zone II), 38 ind./ha around low-story buildings (zone III), and 4 ind./ha in suburban forests (zone IV).

By "density per hectare" (urban areas) we mean local density in the habitat. The average density in the entire urban area was of course much lower.

The number of *R. arvalis* spawns per 10 m^2 water surface was the largest in the suburban forest (0.89) and the least in the multi-story building area ((0.13). That is while areas of breeding ponds were nearly the same (70—150 m^2 in the water table in all zones), there were significantly less suitable terrestrial areas in heavily urbanized zones. Annual counts of the young on the sampled plots gave similar results as for the adults (Table 1). The number of *R. arvalis* spawns per 10 m^2 water surface in zones of different urbanization pressure were calculated from the data of 1984 (Table 1). They generally agreed with the data for the several preceding years.

Table 1. Density of *R. arvalis* per ha and spawns per 10 m^2 water surface in zones of different urban pressure

Zone	Quantity				
	Adult per 1 ha	Froglets per 1 ha	Plot numbers	Spawns per 10 m^2	Ponds
multi-story buildings	64	317	6	0.13	5
low-story buildings	38	75	9	0.66	4
suburban forest	4	11	55	0.89	4
forest	113	—	15	—	—

Annual survival of the larvae and young of the years was earlier estimated only at stages 41 and 54. This revealed that offspring survival in the city areas was low at early developmental stages. However, in 1984 the results of our previous investigations were reconfirmed. From detailed calculations of the annual larvae and young we obtained curves of their number dynamics beginning from 41 stage. Thus, by stage 41 about 0.92% *R. arvalis* larvae from 28,000 eggs survived in multi-story building areas. In the zone of low-story buildings the value was 11.9% from 79,000 eggs. By

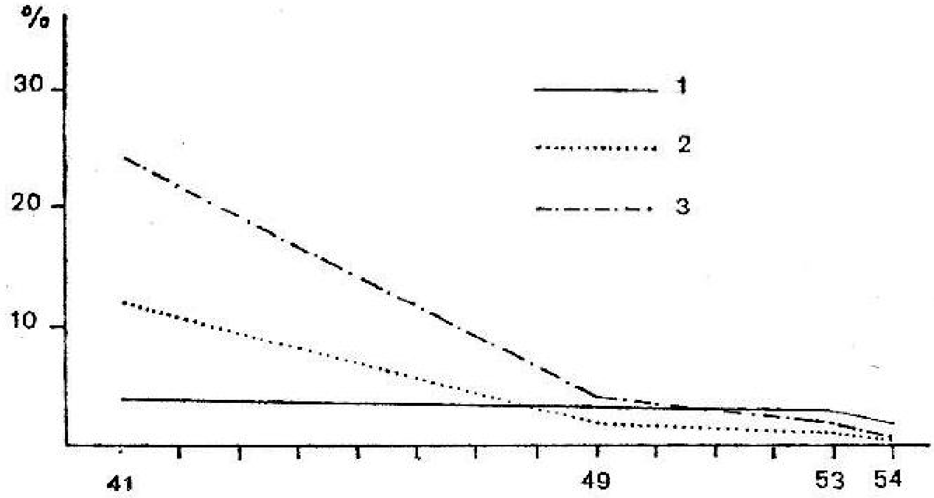

Fig. 1. *R. arvalis* survival at different stages of development against urban pressure 1 — multi-story building area, 2 — low-story building area, 3 — suburban forest

stage 49, 0.88% of the larvae survived in zone II, 1.8% in zone III, and 4.0% in zone IV (Fig. 1). High mortality at early stages in groups with strong urbanization pressure was compensated for by its decrease at later stages (even at metamorphic climax). By stage 53 the surviving froglets accounted for 0.76% in zone II, 1.42% in zone III, and 1.6% in zone IV. By stage 54 the estimates were 0.23, 0.11, 0.58% respectively.

The average quantity of food objects per stomach in *R. arvalis* and *R. temporaria* froglets significantly increased by stage 54, from 0.6—11.9 to 2.9—19.5. Althrough abundance of the young annually decreased with maturation, their predation on invertebrates in urban areas either remained the same or increased. In natural biotopes, froglet predation decreased due to postmetamorphic mortality of froglets at this period.

Studies into phenotypical peculiarities also revealed some specific features in *R. arvalis* populations in zone II. There was an unusually high proportion of the striata morph (Table 2) distinguishable of the metabolism level (DOBRINSKY, MALAFEEV, 1974). It is genetically determined by the dominant allele of the dyallel gene (SHCHUPAK, 1977).

Frequency of morphological aberrations also depended on the degree of anthropogenic impact on habitats. Among *R. arvalis* frog-

Table 2. The total frequency of striata morph in *R. arvalis* during 1977—1986

Zone	Adult %	Total	Froglets %	Total
multi-story buildings	39.3	61	43.3	406
low-story buildings	35.1	37	26.9	160
suburban forest	31.0	58	25.0	1106
forest	16.0	25	22.8	473

lets, they accounted for 1.5—15% in multi- and law-story building areas, 0—2.2% in suburban forests and natural populations. Aberrations among *R. temporaria* froglets made up 2.6—4.0% in the multi--story building areas, and 0.68—2.2% in the low-story. A similar trend was observed for *Triturus vulgaris* adults: 14.6% in the multi--story building areas, 10.3% in low-story, and 5.0% in suburban forests (data obtained in 1981).

In zone II the average body length of *R. arvalis* froglets was significantly greater ($p = 0.01$) than in other zones. The same was noted in even-year, old *R. temporaria* adults in heavily urbanized areas (USHAKOV et al., 1982).

Variation coefficients of the main morphological traits of froglets and adults in zones IV and III were low (relatively to natural populations). In populations from zone II, however, they increased, sometimes exceeding values for the natural populations. The lower variability was marked in populations with a high degree of anthropogenic pressure (Fig. 2). Data on variations of the main morphological features were recorded in 1981 from 542 *R. arvalis* froglets, 292 *R. temporarir* froglets, 30 *R. arvalis* adult males and 47 *S. keyserlingii* adult males. The above-mentioned regularity was recorded over 3 years.

Hence, amphibian density declined with rising urban pressure even when changes in suitable terrestrial habitats and degeneration of vegetation cover were insignificant. Further decline in amphibian abundance was accompanied by further restriction of the areas of terrestrial habitats. This led to local increase of animal density in

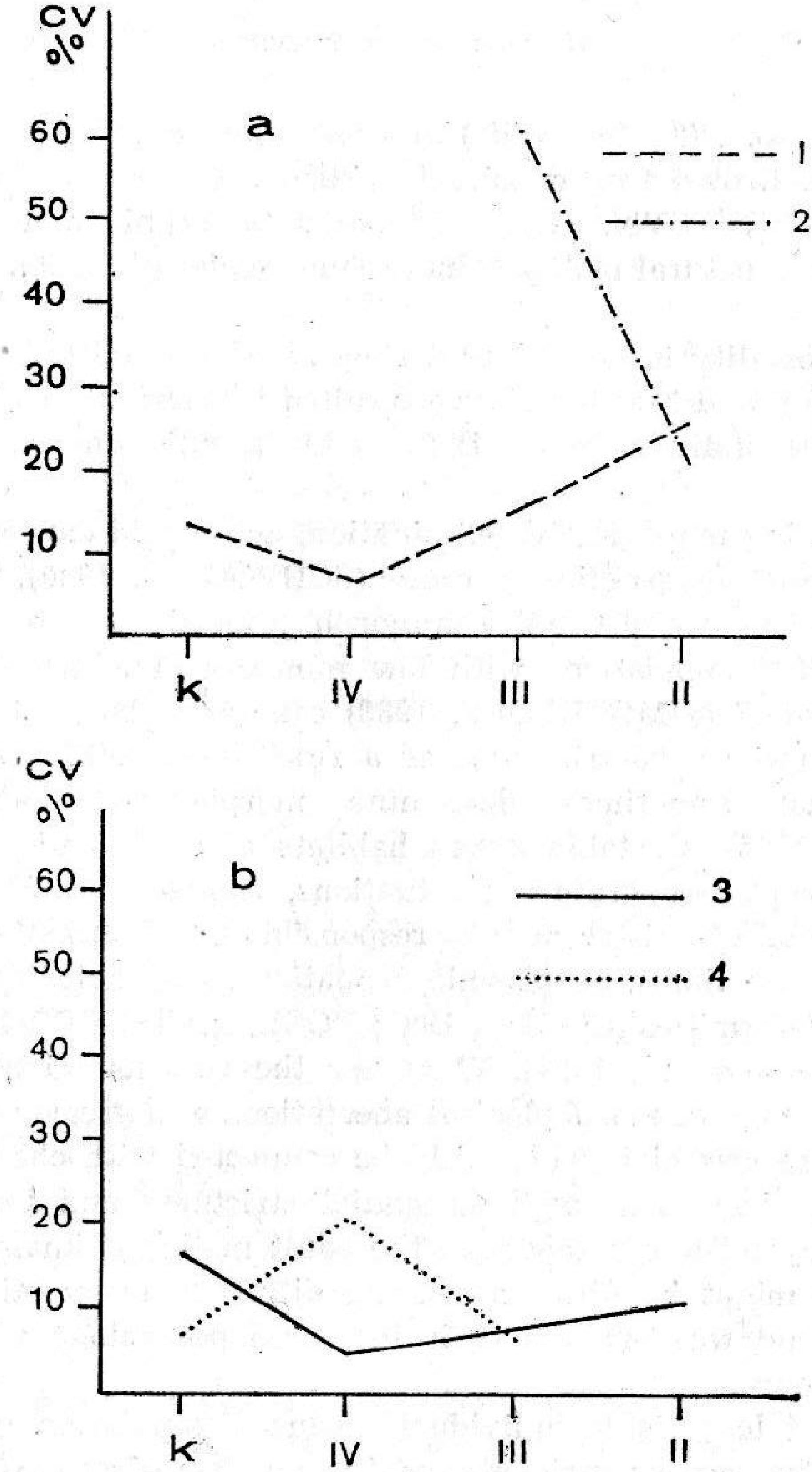

Fig. 2. Changes in coefficient of variation of the main morphological traits with rising urban pressure (data for 1981) K — forest, II — multi-story building area, III — low-story building area, IV — suburban forest: a: 1 — relative rostrum width of *R. arvalis* froglets, 2 — relative rostrum width of *R. temporaria* froglets b: 3 — body length of adult *R. arvalis* males, 4 — body length of adult *S. keyserlingii* males

the narrow zone (2—4 m wide) of vegetation near the pools in the city centre. Brown frog density in urban areas was higher (VERSHININ, KRINITSYN, 1985) and postmetamorphic mortality was lower than in natural biotopes, increasing froglet predation on invertebrates.

High mortality in early larval stages under conditions of pollution, isolation and low abundance resulted in survival of bigger and more viable individuals or those with peculiar metabolic processes.

Considering non-selective elimination, one would expect changes in the population genetic structure (SCHWARTZ, 1980). This was seen in the increase of the striata morph proportion.

In isolated populations with low numbers of adults, "inbreeding depression" (SIMBERLOFF, 1983) can take place. That is, recessive mutations, "detrimental as a rule" (GERSHENSON, 1985), appear that sometimes determine morphological aberrations (FLINDT, 1985). Unstable urban habitats of adult and amphibian larvae, abrupt temperature fluctuations, changes in pH and the environmental chemistry may be responsible for abnormal regeneration of the lost limbs, neoplasmic formations, morphological aberrations and deformities (COOKE, 1981; ROSE, HARSHBERGER, 1977; ZAVANELLA et al., 1984). Whatever the reasons might be, the total percentage of morphological aberrations was greater when urban pressure was high. This could be connected with chemical, environmetal changes as well as spatial strictness and isolation of populations, and low numbers of the adult mating animals. Aberration types might be different among different systematic groups, but the trend was towards their increased percentage with rising urban pressure.

Death of less viable individuals reduced population variability when habitats were restricted, and the number of groups of genetically similar animals was minimal.

"Inbreeding depression" would have promoted lower stability and fast disappearance of the isolates, but this was not seen. Experiments showed that genotypically close larvae (from one clutch) inhibited growth and development of each other as a result of the mechanism maintaining genetic heterogeneity in the group SCHWARTZ, PYASTOLOVA, 1970). Evidently, the mechanism contributed to higher variability in *R. arvalis* larval urban colonies, and, therefore their stability. Hence, adaptation at population level may be supposed. Populations which had experienced such adaptation became very resistant to anthropogenic impacts (evidenced by spot variations of morphological indices in populations from zone II) and could exist under new conditions for a long time (personal observations). It is transferable of a population to new adaptive zones other than natural conditions. However, adaptive peculiarities in *R. arvalis* populations in the multi-story building areas did not ensure their resistance to unlimited degradation of the environment, although isolates were more resistant to urban pressure than natural populations. They should be investigated and conserved for their important role in "ecological compartments" of urban ecosystems. Frequently they are the only terrestrial vertebrates represented in such habitats.

REFERENCES

ANDRZEJEWSKI R. et al. 1978. Synurbization processes in population of *Apodemus agrarius*. Characteristic of population in an urbanization gradient. Acta Theriol., Warszawa, 23: 341—358.

COOKE A. S. 1981. Tadepoles as indicators of harmful levels of pollution in the field. Environ. Pollut., Ser. A., Barking, Essex, 25: 123—133.

COOKE A. S. 1978. Marking tadepoles with neutral red. Br. J. Herpetol, 5: 701—705.

DABAGYAN N. V., SLEPSTOVA L. A. 1975. Travyanaya lyagushka *Rana temporaria* L. In: Obyekty biologii razvitiya, Moskva, 442—462.

DOBRYNSKY L. N., MALAFEEV U. M. 1974. Metodika izucheniya intensivnosti vydeleniya uglekislogo gaza melkimi poikilotermnymi zhivotnymi s pomoshchu optikoakusticheskogo gazoanalizatora. Ekologiya, Sverdlovsk, 1: 73—78.

DROZDOV N. 1969. Kulturnye landshafty kak arena synantropizatsii zhivotnykh. In: Synantropizatsiya i domestykatsiya zhivotnogo naseleniya. Moskva, 59—60.

FLINDT R. 1985. Untersuchungen zum Auftretem von misgebildeten wechselkröten (*Bufo viridis*) in einen Steinbruch in Vainingen.-Roswag. Jahresh. Ges. Naturk., Württemberg, 140: 213—233.

GERSHENSON M. S. 1985. Mikroevolutsiya, polimorfizm i dominantnye mutatsii. Priroda, Leningrad, 4: 73—78.

ROSE F. L., HARSHBERGER J. C. 1977. Neoplasmic and possibly related skin lesions in neotenic tiger salamanders from a sewage lagoon. Science, Washington, 196 (4287): 315—317.

SIBBERLOFF D. 1983. What a species needs to survive. Nature Conserv. News, 33 (6): 18—22.

SCHWARTZ S. S. 1976. Evolutsiya biosfery i ekologitcheskoe prognozirovanie. Vestn. Akad. Nauk SSSR, Moskva, 61—71.

SCHWARTZ S. S. 1980. Ekologicheskie zakonomernosti evolutsii, Moskva, p. 278.

SCHWARTZ S. S., PYASTOLOVA O. A. 1970. Regulatory rosta i razvitiya lichinok zemnovodnykh. 1. Spetsifichnost deistviya. Ekologiya, Sverdlovsk, 1: 77—82.

SHCHUPAK E. L. 1977. Nasledovanie spinnoi polosy osobyami ostromordoi lyagushki. In: Informatsionnye materialy Instituta ekologii rastenii i zhivotnykh, Sverdlovsk, 36—37.

TOPORKOVA L. Y. 1973. Amfibii i reptilii Urala. In: Fauna Severa, Urala i Zapadnoi Sibiri, Sverdlovsk, 84—117.

USHAKOV. A., LEBEDINSKYI A. A., GREFNER N. M. 1982. Analiz raznovozrastnoi struktury populyatsii travyanoi lyagushki na urbanizirovannoi territorii. Vest. Zool., Kiev, 2: 67—68.

VERSHININ V. L., TOPORKOVA L. Y. 1981. Amfibii gorodskikh landshaftov. In: Fauna Urala i Evropeiskogo Severa, Sverdlovsk, 48—56.

VERSHININ V. L., KRINITSYN S. V. 1985. Plotnost v gruppirovkakh ostromordoi lyaguschki v zavisimosti ot stepeni urbanizatsii. In: Problemy ekologicheskogo monitoringa i nauchnye osnovy ochrany prirody na Urale, Sverdlovsk, 9—10.

ZAVANELLA T., ZAFFARONI N. P., ARIAS E. 1984. Abnormal limb regeneration in adult newts exposed to the fungicide Maneb 80. A histological study. J. Toxicol. Environ. Health, Washington, 13 (4—6): 735—745.

Institute of Plant and Animal Ecology
Ural Scientific Centre
8-Marta, 202
620219 Sverdlovsk GSP-511, USSR

CECHY POPULACYJNE PŁAZÓW MIASTA PRZEMYSŁOWEGO

STRESZCZENIE

Dokonano przeglądu wyników badań (1977—1985) przeprowadzonych na zgrupowaniach płazów, zasiedlających terytorium wielkiej aglomeracji miejskiej Swierdłowska.

Stwierdzono szereg cech populacyjnych, pozwalających mówić o występowaniu zmian adaptacyjnych w zgrupowaniach *Rana arvalis* w obrębie miasta.

ПОПУЛЯЦИОННЫЕ ОСОБЕННОСТИ АМФИБИЙ ПРОМЫШЛЕННОГО ГОРОДА

РЕЗЮМЕ

Рассматриваются результаты исследований (1977—1985), проводившихся на группировках амфибий, населяющих территорию крупной городской агломерации Свердловска.

Установлен ряд популяционных особенностей, позволяющих говорить о наличии адаптивных изменений в группировках *Rana arvalis* NILSSON в пределах города.