Amphibian Populations in the Commonwealth of Independent States: Current Status and Declines (Editors: S.L.Kuzmin, C.K.Dodd, Jr.,& M.M.Pikulik). Moscow: Pensoft,1995.

Types of Morphological Anomalies of Amphibiansin Urban Regions

Vladimir L. Vershinin

Abstract: Amphibian developmental anomalies in the Ekaterinburg City, Ural, have been studied. Five groups of anomalies have been discovered: limb anomalies, eye anomalies, deformations of the axial skeleton, skin anomalies (edema), and anomalies of internal organs. Frequencies of occurrence and probable causes of the anomalies are discussed.

Резюме: **Типы морфологических аномалий земноводных городских районов. *В.Л.Вершинин.*** — В г.Екатеринбурге, Урал, изучались аномалии развития земноводных в районах с разным уровнем урбанизации. Найдено пять групп аномалий: аномалии конечностей, аномалии глаз, деформации осевого скелета, аномалии кожи (опухоли) и аномалии внутренних органов. Обсуждаются частота встречаемости и возможные причины аномалий.

Individuals with morphological anomalies occur in almost all amphibian populations. The causes of such anomalies are varied: mutation processes, (Wittouck, 1980), partial neoteny (Breul, 1981), parasites (Ruth, 1987), habitat isolation (Reynolds and Stephens, 1984), hybridization (Gollmann et al., 1984), ontogenetic deviation (Obukhova, 1984), and anomalous regeneration. The same effect may be caused by different factors, from mutations and viruses to temperature influences (Van Vallen, 1971).

Along with natural causes, anomalies are induced frequently by such side effects of human activity as environmental pollution, industrial discharge (Hazelwood, 1970), pesticides (Cooke, 1973), changes in pH (Andren and Nilsson, 1988), radioactive contamination (Flindt, 1985), and by the formation of genetic isolates resulting from the fragmentation of natural habitats (Simberloff, 1983). These influences on amphibian morphology allow the use of amphibians as bioindicators because increases in anomalies in amphibian populations can be monitored (Vershinin, 1982; Pyastolova et al., 1981).

To understand the causes of morphological anomalies in anthropogenic landscapes, it is necessary to know the extent of anomalies in natural populations of various species. The data reported below comprise the mean results of long-term studies conducted at Ekaterinburg City, Middle Ural, from 1977 to 1993 on all resident amphibian species.

We outline the following types of morphological anomalies:

1. Limb anomalies: polydactyly, ectrodactyly (oligodactyly), syndactyly, clinodactyly, non-flexible limbs, hemimely, brachymely, taumely, polymely, ectromely.
2. Eye anomalies: anophthalmy, reduction of some eye components and/or eye-

lids, depigmentation of the iris.
3. Deformation of the axial skeleton: skull deformations, mandibular hypoplasia, vertebral column deformations.
4. Skin anomalies: pointed back pattern (fragmentation of pigmentation), albinism, pigment spots, skin neoplasia.
5. Edemas: edema of the bottom of the mouth cavity, edema of the abdominal cavity.
6. Anomalies of the internal anatomy.

Summary data on the occurrence of certain anomalies have been combined by us into one category. For example, deformations of the skull and vertebral column were included as deformations of the axial skeleton, albinism and pigment spots were included as defects of pigmentation, anophthalmia and eye component reduction were included as deformations of the eye, and edema of the bottom of the mouth cavity and edema of the abdominal cavity were classified as edemas.

More than a half of all the anomalies in adult *Salamandrella keyserlingii* in the forested park regions of the city were connected with limbs. The rest were pigment anomalies, deformations of the axial skeleton and eyes, and herniae (Table 12). Edemas were noted only in juveniles. The proportion of the types of anomalies was almost the same as in the control population. In the zone of multi-level houses, 3/4 of the anomalies of *Triturus vulgaris* were related to defects of the limbs with fewer individuals affected by skin neoplasms. In newt populations from other zones, herniae of the ovaries and lungs were found. Juvenile anomalies were recorded only in the zone of multi-level houses. These were all metamorphic edemas and herniae.

The most comprehensive data on developmental anomalies are available for the widespread species *Rana arvalis*. In populations living in the vicinity of the multi-level house zone, more than a third of all juvenile anomalies are connected with the pointed back pattern and other defects of skin pigmentation. A similar proportion exists for depigmentation of the iris, a condition which may be regarded as partial albinism. About 1/6 of the deformities are limb anomalies. The rest of the defects involve the eyes and axial skeleton, edemas, and mandibular hypoplasia. About half of the anomalies in the control group involve iris depigmentation, whereas approximately 1/4 involve mandibular hypoplasia with fewer limb anomalies. Among adult animals from the zone of multi-level housing, almost half of all anomalies are connected with limb and axial skeleton deformities and depigmentation of the iris. Only the latter was found in the control population.

Adult and juvenile *Rana ridibunda* possess anomalies of skin pigmentation. About a quarter of the anomalies involve animals with limb problems, whereas the rest involve edema and internal pathology. High percentages of morphological anomalies in *S.keyserlingii* may result from, in large part, anomalous regeneration after injuries accrued during courtship (Basarukin and Borkin, 1984). The percent-

Table 12. Occurrence of different types of anomalies in amphibians of the urban agglomeration.

Anomalies	*Salamandrella keyserlingii*							
	II		III		IV		K	
	ad.	juv.	ad.	juv.	ad.	juv.	ad.	juv.
polydactyly					1	1		
ectrodactyly					8	5	1	
syndactyly					4			
clinodactyly							1	
non-flexible limb								
hemimely								
brachymely					1	1		
taumely					1			
polymely					2			
ectromely								
eye defects					2			
depigmentation of iris								
deformation of axial skeleton			1		4		2	
mandibular hypoplasy								
pointed back pattern								
defects of pigmentation					4			
skin neoplasm								
oedemae						1		
defects of internal organs							1	
Total anomalies			1		28	8	5	0
N. general			6		382	300	55	8
Total percentage			16.7		7.3	2.7	9.1	0

Table 12 (continued).

Anomalies	*Triturus vulgaris*							
	II		III		IV		K	
	ad.	juv.	ad.	juv.	ad.	juv.	ad.	juv.
polydactyly	2							
ectrodactyly	3							
syndactyly								
clinodactyly	3		1					
non-flexible limb								
hemimely								
brachymely	1							
taumely					1			
polymely								
ectromely								
eye defects								
depigmentation of iris								
deformation of axial skeleton								
mandibular hypoplasy								
pointed back pattern								
defects of pigmentation								
skin neoplasm	3							
oedemae		1						
defects of internal organs		1	3				1	
Total anomalies	13	2	4	0	1	0	1	0
N. general	156	67	70	17	64	57	18	7
Total percentage	8.2	3	5.7	0	1.6	0	5.6	0

Table 12 (continued).

Anomalies	*Rana arvalis*							
	II		III		IV		K	
	ad.	juv.	ad.	juv.	ad.	juv.	ad.	juv.
polydactyly								
ectrodactyly	6	7				2		1
syndactyly	1							
clinodactyly	1					1		
non-flexible limb		1						
hemimely		1	1	2	1	1		2
brachymely								
taumely								
polymely								
ectromely	3	6				1		
eye defects		1			1			
depigmentation of iris	1	55		14	1	67	1	10
deformation of axial skeleton	1	2			2	1		1
mandibular hypoplasy		2		1		5		5
pointed back pattern	8	46	2	5		4		1
defects of pigmentation	3	9	2	2	2	3		1
skin neoplasm								
oedemae		1		2	1			
defects of internal organs								
Total anomalies	24	142	5	27	8	90	1	23
N. general	170	3422	53	1004	183	5309	57	2939
Total percentage	14.1	4.2	9.4	2.7	4.4	1.7	1.8	0.78

Table 12 (continued).

Anomalies	*Rana temporaria*							
	II		III		IV		K	
	ad.	juv.	ad.	juv.	ad.	juv.	ad.	juv.
polydactyly								
ectrodactyly			1	3				
syndactyly								
clinodactyly				1				
non-flexible limb								
hemimely				1				
brachymely								
taumely				1				
polymely								
ectromely				1				
eye defects		1	1	1				
depigmentation of iris			1	3				
deformation of axial skeleton								
mandibular hypoplasy								
pointed back pattern			1					
defects of pigmentation		3	5	2				
skin neoplasm								
oedemae		2						
defects of internal organs								
Total anomalies	0	6	9	12	0			
N. general	41	235	151	2239	203			
Total percentage	0	2.6	6	0.54	0			

Table 12 (continued).

Anomalies	*Rana ridibunda*							
	II		III		IV		K	
	ad.	juv.	ad.	juv.	ad.	juv.	ad.	juv.
polydactyly								
ectrodactyly		2						
syndactyly								
clinodactyly								
non-flexible limb		2						
hemimely								
brachymely								
taumely								
polymely								
ectromely								
eye defects								
depigmentation of iris								
deformation of axial skeleton								
mandibular hypoplasy								
pointed back pattern								
defects of pigmentation	1	28						
skin neoplasm								
oedemae		4						
defects of internal organs		2						
Total anomalies	1	44						
N. general	123	953						
Total percentage	0.8	4.6						

Notes: II, multistory house zone; III, small house zone; IV, forested park; K, control; ad., adults; juv., juveniles.

age of anomalous adults is higher than in juveniles because of the accumulation of both inherited anomalies and anomalous regeneration. Regeneration anomalies occur frequently with changes in water chemistry (Zavanella et al., 1984). In populations studied thus far, the total frequency of anomalies in adult animals varied between 5.9% and 16.6%. There is a direct correlation between increases in the frequency of anomalies and the level of environmental pollution.

As opposed to *S.keyserlingii, T.vulgaris* has skin neoplasms in addition to higher frequencies of limb anomalies. These neoplasms reflect the level of environmental pollution by carcinogens and are used in a special "newt test" (Pliss and Khudoley, 1979). The percentage of neoplasms of *T.vulgaris* living in the central part of Ekaterinburg City exceeds those from London by 3.66% (Roberts and Verrell, 1984), i.e., 8.22% vs 4.56%. 4.56%. This may reflect higher levels of pollution in the Ural. Frequencies of morphological anomalous occurrences in adult *T.vulgaris* also increase with increasing urbanization and changes in environmental chemistry.

The frequency of the occurrence of morphological anomalies in *Rana temporaria* is lower than in *R.ridibunda* both in juveniles and adults. Anomalies in adult *R.temporaria* were noted only in the zone of small houses, and there the proportion of different types of anomalies was similar to that in *R.arvalis*. Juveniles from the zone of multi-level houses, however, possess more pigment anomalies. The poor spectrum of anomalies and their relatively low frequency of occurrence probably is connected with high mortality in urban environments of anomalous individuals of this species, ecologically intolerant in Ural.

The unusual pigmentation of skin and eyes, which is one of the most frequent amphibian anomalies in the populations examined, has a genetic basis. Defects of the axial skeleton and limbs and some cases of lethal internal anomalies and tory has had mainly negative impacts on amphibian populations. Proportion of different anomalies varies between salamanders and frogs because a large percentage of the defects in salamanders is caused by anomalous regeneration. Cutaneous neoplasms occur in newts. The main morphological defects of anurans result from mutations and developmental anomalies.

Thus, analyzing the frequency of occurrence of different types of morphological anomalies in urban amphibian populations enables us to not only determine the extent of the transformation and pollution of the environment but also to discuss the ecological plasticity and microevolution of species in isolated urban populations.

References

(all references in Russian except those marked with an asterisk)

*Andren, C., and G.Nilson. 1988. Effects of acidification on Swedish brown frogs. — Mem.Soc.fauna et flora fennica 64 (3): 139-141.

Basarukin, A.M. 1988. [Addition to the morphological anomalies of *Rana chensinensis* in Sakhalin]. — Page 43 *in* 14 Konferentsiya Molodykh Uchenykh i Spetsialistov. Posvyashchennaya 40-letiyu Pobedy Sovetskogo Naroda v Velikoi Otechestvennoi Voine. Yuzhno-Sakhalinsk.

*Breul, M. 1981. Une anomalie de la metamorphose: la persistance dun intestin spirale chez une grenouille verte adulte (Amphibiens, Anoures). - In: Bull. Soc.Linn. Lyon. 50 (10): 322-327.

*Cooke, A.S. 1973. The effects of DDT, when used as a mosquito larvicide, on tadpoles of the frog *Rana temporaria*. - Environmental Pollution (5): 259-273.

*Flindt, R. 1985. Untersuchungen zum Auftreten von misgeildeten Wechselkröten (*Bufo viridis*) in einen Steinbruch in Vathingen-Roswag. — Jahersh. Ges. Naturk. Württemberg (140): 213-233.

*Gollmann, G., W.Hodl, and A.Ohler. 1984. A tadpole from a *Bombina* hybrid population: a hopeless monster. — Amphibia-Reptilia 5 (3-4): 411-413.

Obukhova, N.Y. 1984. [Influence of cooling on developing spawn of *Hynobius keyserlingii*]. — Page 30 *in* Vid i Ego Produktivnost v Areale, Voprosy Gerpetologii. Sverdlovsk.

Pliss, G.B., and V.V.Khudolei. 1979. [Oncogenesis and cancerogenic factors in lower vertebrates and invertebrates]. — Pages 167-185 *in* Ekologicheskoe Prognozirovanie. Moscow.

Pyastolova, O.A., E.A.Bugaeva, and V.N.Bolshakov. 1981. [Amphibian larvae as bioindicators of environmental pollution]. — Page 112 *in* Problems of Herpetology. Leningrad.

*Reynolds, T.D., and T.D.Stephens. 1984. Multiple ectopic limbs in a wild population of *Hyla regilla*. — Great Basin Naturalist 44 (1): 166-169.

*Roberts, J.M., and P.A.Verrell. 1984. Physical abnormality of the limbs of smooth newts (*Triturus vulgaris*). — British Journal of Herpetology 6 (11): 416-418.

Rostombekov, V.N. 1930. [Data on the fauna in the vicinity of Tbilisi]. — Zakavkazskii Kraevedcheskii Sbornik A (1): 129-140.

Rudik, A.M. 1989. [New herpetological records in the Caucasus]. — Pages 213-214 *in* Problems of Herpetology. Kiev.

*Ruth, S. 1987. Flukes produce legs in profusion. — New Scientist 113 (1551): 24.

*Simberloff, D. 1983. What a species needs to survive. — Nature Conservation News 33 (6): 18-22.

Vershinin, V.L. 1982. [Urban amphibian groups as criterion of the estimation of small ponds condition]. - In: Problemy Ekologii Pribaikalya 1. Irkutsk: 19-22.

*Van Valen, L. 1974. A natural model for the origin of some higher taxa. - J. Herpetol. 8: 109-121.

*Zavanella, T., N.P.Zaffaroni, and E.Arias. 1984. Abnormal limb regeneration in adult newts exposed to the fungicide Maneb 80. A histological study. — Journal of Toxicology and Environmental Health 13 (4-6): 735-745.