

PRESENT FACTORS AND CRUCIAL TRENDS OF ANTHROPOGENIC TRANSFORMATION OF HERPETOFAUNA IN BELARUS

Sergey M. Drobenkov

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Extensive human agricultural activities, clear cutting and fragmentation of forests, drainage reclamation of wetlands, industrial and road construction, intensive road traffic and urbanization have most significant impact on the herpetofauna of Belarus in recent decades. Radical changes in natural landscapes lead to a reduction in the area of natural habitats of amphibians and reptiles, reduce their ecological capacity, increase the fragmentation of land and, as a result, to reduce the distribution and abundance of wild populations and the violation of the natural structure of their communities. The most important natural changes in habitats, species populations and communities occur in result of natural plant successions, as a rule, local and cyclical, but they do not lead several disorders and serious consequences for populations and communities as in landscapes disturbed by man. Most of amphibians and reptiles in Belarus, due to their ecological-morphological, physiological and other features, can be classified as high - and moderate-reagent species, showing, in general, increased sensitivity to environmental factors, therefore, the identified fairly clear trends of anthropogenic transformation of populations and herpetocomplexes may be indicators of disturbance of wild communities and ecosystems as a whole.

Key words: Amphibians, reptiles, ecosystem, anthropogenic transformation, Belarus.

Sergey M. Drobenkov. Ecological Centre on Biological Resources of the National Academy of Sciences of Belarus, ul. Akademicheskaya, 27, 220072, Minsk, Republic of Belarus, E-mail:bel_gerpology@rambler.ru

INTRODUCTION

The study of changes occurring in ecosystems under influence of external factors, both natural and anthropogenic, allows us to understand the mechanisms of adaptation of biological systems to the environment, to find out the patterns of their structural organization and complex processes of evolution, to develop measures of their use and conservation (Huijser et al. 1999, Gundling 2002).

Amphibians (Amphibia) and reptiles (Reptilia), due to their wide distribution in various habitats and high abundance, play an important role in the structure and functioning of terrestrial and water ecosystems of the European forest area (Gilmanov 1987). The species structure and the number of their communities under the impact of different anthropogenic factors is changing radically. The study of the variability the structure of faunistic complexes of amphibians and reptiles in man-transformed landscapes helps to

solve various theoretical problems and practical problems, to study the patterns the functioning of ecosystems, the organization of monitoring system, to predict the dynamics of biological diversity and its conservation (Herpetological communities 1982).

In the work the data of long-term research of anthropogenic transformation of natural ecosystems and dynamics of species diversity and number of amphibian and reptiles complexes in Belarus are analyzed.

MATERIAL AND METHODS

Field researches were conducted in Belarus in 1985-2016, in various geobotanical regions, landscape provinces and basins of the country's largest rivers (Dnieper, Pripyat, Berezina, Neman and Western Dvina). Long-term observations (up to 25 years) were carried out at 11 key fixed stations located in different geographical points of Belarus and representative of the all diversity its natural and climatic conditions, landscape heterogeneity and modern trends of anthropogenic transformation of ecosystems.

The species composition and abundance these groups of vertebrates were estimated in summer by the method of route accounting on a fixed-width band (Dinesman & Kaletskaya 1952; Chelintsev 1985, 2000, Measuring and Monitoring Biological Diversity 2003). To this end, 1108 route surveys were carried out at the observation points. The structure of amphibian and reptile communities was analyzed by 10 main groups of habitats corresponding to landscape-dominant phytocenoses, allocated on the basis of the classification plant associations adopted in Belarus (Yurkevich et al. 1979).

The description of ecological conditions of habitats was carried out according to the available recommendations (Cody & Diamond 1975, Diamond & Case 1986, Morin 2011) on a set of parameters characterizing the relief, temperature and humidity regimes, vegetation, microclimate, neighboring biogeocenoses,

remoteness and features of ecotones, the most important parameters of ponds, as well as the forms and degree of influence of anthropogenic factors.

RESULTS AND DISCUSSION

The analysis of the collected data has shown that anthropogenic factors related to various and economic human activities currently have the most significant impact on the herpetofauna of Belarus, much more than natural changes in the natural environment in the process of ecological successions.

Radical transformation of natural landscapes significantly alters species composition, structure and abundance of herpetocomplexes. The restructuring of populations and communities of the amphibians and reptiles is caused by the influence of many factors, but the important impact is caused by changes in environmental conditions of habitats (microclimate, hydrological regime, availability of trophic resources), the increase mosaic of habitats and insularization of populations, as well as outright extermination by human (deaths from road transport, etc.) (Pikulik 1989, Drobenkov et al. 2006).

In intensity of the impact of anthropogenic factors on its habitats, several successive stages of their degradation can be distinguished: 1) minor changes, 2) transformations leading to noticeable changes in environmental conditions, 3) destabilizations associated with radical restructuring of the environment, 4) destructions characterized by radical irreversible consequences and complete degradation of habitats.

The state of the amphibian and reptile habitats in Belarus varies widely, which is connected not only with the stage of their degradation, but also with the zonal and landscape features and economies of the region.

The most significant natural changes in habitats, species populations and communities occur in result of natural successions, as a rule, local and

cyclical, but the successions does not entail such severe disorders and serious consequences for populations and communities as in landscapes disturbed by man.

In Belarus in recent decades, there are intensive development of agriculture and industry, growth of cities and urban population, constant expansion of the network of highways, increase in road traffic and the number of cars, the growth of natural resources extraction, the expansion of ecological tourism and other forms of recreation (Suschenya & Pikulik 1991, Drobenkov et al. 2006).

Among the most significant factors stand out general, affecting all groups of animals, and specific, influencing only on amphibians and reptiles. The latter include, for example, the combined effects of chemical pollution and the destruction of small bodies of water used by amphibians for breeding; distribution of invasive

species dangerous for native herpetofauna from neighbouring countries territories, for example from Southern Latvia (Pupins 2007, Pupins & Pupina 2011, 2012, Pupina et al. 2015, Pupina & Pupins 2016).

Unfavorable conditions for life of amphibians are formed under the influence of combined effects of anthropogenic and natural factors (for example, weather fluctuations in breeding season), affecting the level of realization of the high reproductive potential of the populations.

The greatest negative impact on regional herpetofauna in recent decades has been caused by intensive human agricultural activities, clear-cutting and fragmentation of forests, drainage of wetlands, industrial and road construction, heavy traffic and urbanization (Fig.1). The general direction of anthropogenic transformation of natural landscapes and the main trends in the state of the studied groups of animals remain the

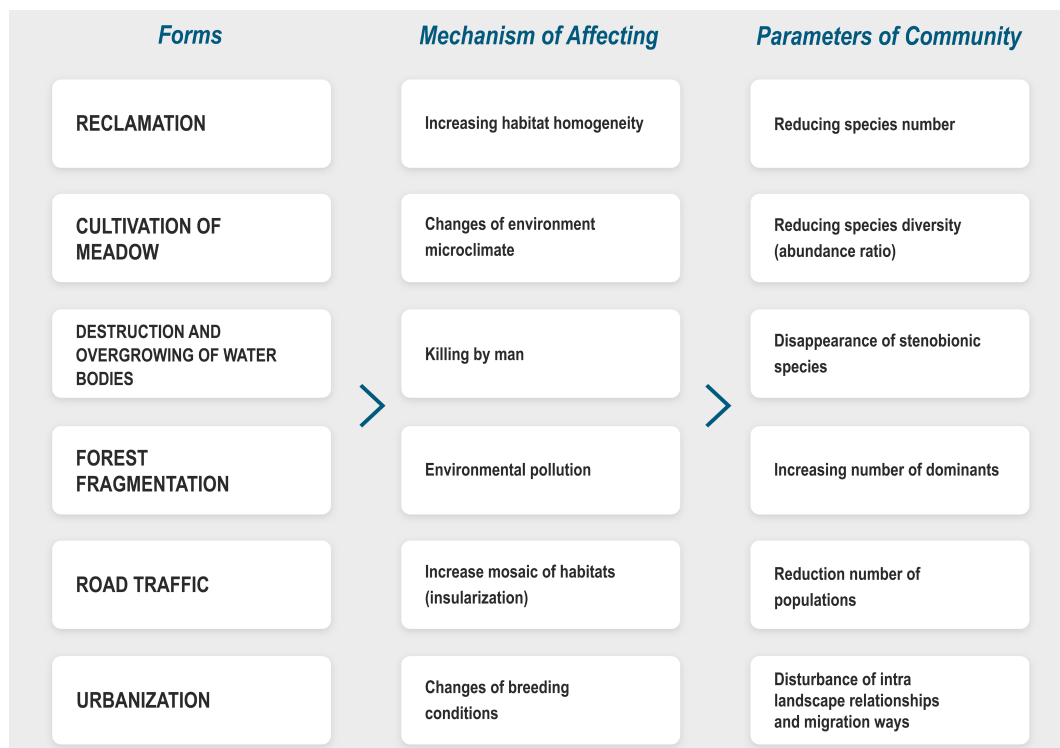


Fig. 1. Generalized scheme of impact anthropogenic transformation of ecosystems on the assemblies of amphibians and reptiles in Belarus.

same since the second half of the 20th century. The dynamics of herpetofauna is associated with a reduction in the area of their habitats, changes in its ecological capacity and the growth of mosaic environment.

As a result of exposure to anthropogenic factors, the disturbance the structure and reproduction of most species populations and reducing their numbers, which are reflected in the structure of herpetocomplexes as a whole, observed. The influence of many forms of economic activity has a regional specificity, manifested in significant differences in directions, intensity and duration of exposure (Drobenkov et al. 2005).

At the turn of XX-XXI centuries the impact of some previously very important factors, such as reclamation and chemical pollution of land considerably decreased, however, their contemporary implications remain highly visible. At the same time, the influence of some other, partly completely new forms of transformation of the natural environment, which have a negative effect on the animals, was manifested or sharply increased. Of particular importance, inter alia, the rapid growth of the number of cars and the intensification of road traffic, as well as high rates of suburban individual construction (summerhouses, cottages) have become.

It is also significant to reduce the occurrence of variants of species combinations formed as a result of long-term coadaptation of species, to varying degrees resistant to external factors and disappearing in a situation of exceeding the impact of extreme conditions. The anthropogenic influence on amphibians and reptiles is evident in changes in the qualitative and quantitative composition of herpetocomplexes, restructuring of species composition of assemblages, the transition from poly- to monodomination and to increase the spatial homogeneity of populations.

Land improvement

Over the past century, the radical reclamation of wetlands, which was especially active in the southern part of the country, in the heavily

swampy region of Polesie, had a greatest impact on the zoocenoses of Belarus. To date, specific communities of amphibians and reptiles have been formed and are functioning in the drained territories and their species composition and structure are radically different from the original marsh and more similar to the complexes of open meadow ecosystems (Fig. 2). In the area of reclamation, the spatial redistribution of populations and changes in the abundance of most species and, as a consequence, an irreversible restructuring of the natural structure of assemblages has occurred.

The data obtained indicate, on the one hand, the negative impact of reclamation on the state of herpetofauna, showed in the radical reconstruction or even complete destruction of communities, and, on the other hand, a sufficiently significant adaptive capacity of these groups of animals to restructure in the new environmental conditions.

At the same time, it should be noted that the responses of amphibians and reptiles to the impact of reclamation are not always unambiguously negative. For example, in some areas there has been an increase in the number of populations and species diversity of communities. Growth of abundance is found in eurytopic species, such as Moor frog (*Rana arvalis*), Common spadefoot (*Pelobates fuscus*), Common toad (*Bufo bufo*), viviparous lizard (*Zootoca vivipara*), which can able to increase number 2-5 times (up to 400-1200 ind./ha).

The increase in species diversity in communities of these groups of animals formed on reclaimed land, often related with the emergence of new, atypical for open marsh species (Sand lizard *Lacerta agilis*), which is distributed on the dams and embankments of hydro technical structures of an extensive system of drainage canals.

Urbanization

Urban growth is one of the most important factors of anthropogenic transformation of herpetocomplexes, which often leads to complete

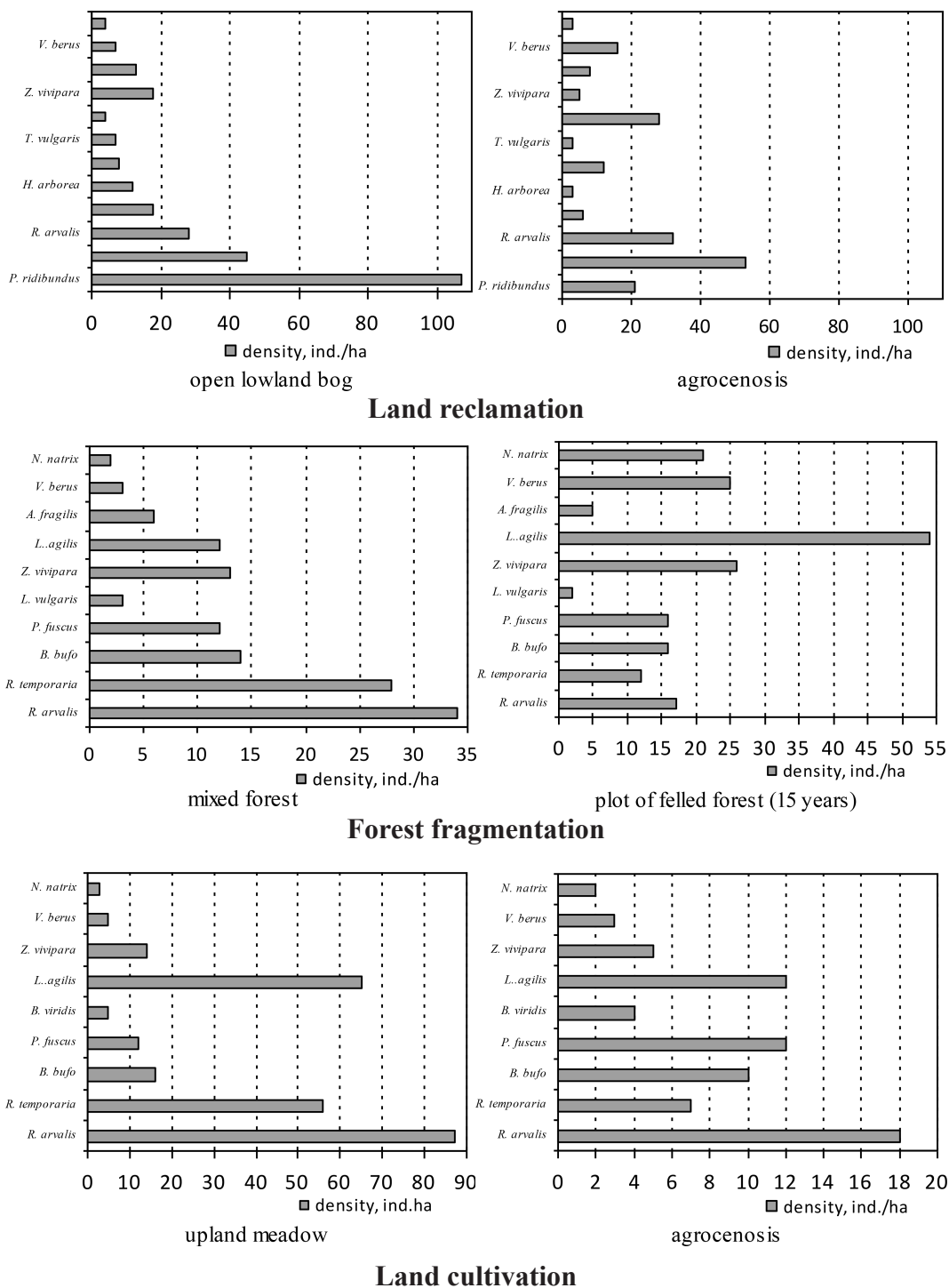


Fig. 2. Changes in the species structure of amphibian and reptile's assemblies as result of impact different anthropogenic factors.

degradation of habitats, disruption of reproduction processes most species populations and entails the disappearance of nearly all species of amphibians and reptiles at sites of the solid of housing and industrial construction.

Ecological and faunistic studies carried out in different types of settlements, both small and large such as the cities of Minsk, Brest, Mogilev showed that most species are characterized by low resistance to the influence of this factor. Green toad (*Pseudepidalea viridis*), brown frogs (Moor frog *Rana arvalis*, Common frog (*Rana temporaria*) and green frogs (*Pelophylax cl. esculentus*) had been most adapted to the modified habitats of the cities.

Among reptiles, in the cities of Belarus *L. agilis* and *Z. vivipara*, penetrating on the earthen embankments of railway lines and highways from neighboring suburban areas, most often met. Undeveloped floodplain and riverbed zones, ponds and lakes, as well as city parks and forest parks are the most favorable for the life of amphibians and reptiles in urban landscapes. Both urbanization and land improvement are negative factors that cause destruction of ways of genetic contacts between amphibians and reptiles populations in Belarus and in neighbouring countries, for example with populations of rare and preserved species in Southern Latvia and Lithuania (Meeske et al. 2006, Pupina & Pupins 2008, Pupins & Pupina 2008, Kuzmin et al. 2008, Pupins et al. 2017).

Deforestation and forest fragmentation

The reduction of forests and increase in their mosaic caused by the need for productive forestry, urbanization, road construction and other forms of economic activity have ambiguous and not always negative consequences for amphibians and reptiles.

In large forests after clearcut logging, the reduction of the habitat area of most amphibians (due to clarify), the restructuring of the spatial structure of their populations and, ultimately, the change in the structure of herpetocomplexes

occurs. At the same time, the increase in intra-landscape heterogeneity and the length of the ecotones for the majority of reptiles (*Z. vivipara*, Grass snake *Natrix natrix*, Slow worm *Anquis fragilis*), is certainly a favorable factor contributing to the growth of the populations. Nevertheless, despite the improvement of living conditions of some species, and in this case, a radical transformation of the community structure of these groups of animals takes place.

In the modern mosaic forests that appear after harvesting, changes in the spatial structure of populations and assemblages, more high density is observed, whereas for large, homogenous tracts of forest more uniform territorial distribution of populations is typical.

Dynamics of herpetocomplexes on the grounds of the forest felling associated with the gradual change of composition and ratio of species and is caused by transformation of the plant cover, changing the microclimate of the localities and structure of invertebrates and vertebrates that make up the food resources for amphibians and reptiles.

The most favorable conditions after forest felling are formed for the Sand lizard (*L. agilis*), which dominates in emerging communities at the early stages of succession.

Destruction, chemical pollution and eutrophication of ponds

The character of water bodies and the conditions they create for amphibious and near-water reptile species (Pond turtle *Emys orbicularis*) are one of the most important factors and requirements that often determine the reproduction of species populations in transformed landscapes.

Pond pollution from agricultural wastewater containing large amounts of fertilizers, insecticides and pesticides (mainly endosulfan, imazapir) has a global negative impact on amphibians, reproduction and larval development in the aquatic environment (Raloff 1998, Netting 2000).

Table 1. Species composition and the number of amphibians and reptiles dying on the roads in Belarus

Species	Numbers of registered corpses	
	<i>n</i>	%
<i>Bufo bufo</i>	165	25,1
<i>Rana arvalis</i>	132	20,1
<i>R. temporaria</i>	119	18,1
<i>Pelobates fuscus</i>	67	10,2
<i>Pseudepidalea viridis</i>	45	6,8
<i>Lissotriton vulgaris</i>	39	5,9
<i>Pelophylax cl.esculentus</i>	29	4,4
<i>Hyla arborea</i>	10	1,5
<i>Bombina bombina</i>	7	1,1
<i>Epidalea calamita</i>	6	0,9
<i>Triturus cristatus</i>	5	0,8
Species not defined	34	5,2
Total	649	100,0
<i>Lacerta agilis</i>	65	50,4
<i>Natrix natrix</i>	17	13,2
<i>Zootoca vivipara</i>	14	10,9
<i>Pelias berus</i>	12	9,3
<i>Anguis fragilis</i>	7	5,4
<i>Emys orbicularis</i>	6	4,7
Species not defined	8	6,2
Total	129	100,0

There is a large number of studies showing a serious disruptions in the reproduction and structure of populations of amphibians and reptiles in urban areas and large agro-industrial regions (Kuzmin 1999).

Automobile transport

Car movement on roads is one of the few anthropogenic factors, which is suitable for accurate quantitative estimate of the extent of impacts on fauna including the studied groups of animals.

According to the counting carried out on the roads of Belarus and characterized by different pavement, purpose and intensity of traffic, this reason is one of the leading positions in the list of modern threats to herpetofauna.

On some sites of roads per 1 km of roadway during season to 450-2500 50-110 amphibians and reptiles dies (Table 1). Due to the landscape heterogeneity of the territory and differences its

conditions, it is difficult to calculate the total pressure, which falls on the whole country, but it is obvious that every year a huge number of amphibians and reptiles die on the roads.

The highest mortality was observed in species characterized by mass spring migration to breeding ponds (Common toad *B. bufo*, Moor frog *R. arvalis*, Common frog *R. temporaria*, Common spadefoot *P. fuscus*).

Significant death rate on the roads is established for the majority of reptiles, excluding only the rarest species (Smooth snake *Coronella austriaca*). Major press on the populations of reptiles accounting on the season of migration oviparous species (*N. natrix* and *E. orbicularis*).

Intensive traffic and high density of road network lead to a decrease in the number and disruption of normal reproduction of populations, and in some areas even to the isolation of some population groups.

Radioactive pollution of the territory

As a result of the accident at the Chernobyl nuclear power station on 26 April 1986, a large part of the territory of Belarus, and especially its South-Eastern part, was contaminated with radioactive decay products. As was shown results of radioecological monitoring carried out in the 30-km zone closest to the nuclear reactor (Polesky Radiation and Ecological Reserve), the influence of this factor on herpetofauna was manifested in two main directions: 1. direct impact to ionizing radiation on organs, tissues and biological functions of animals (contamination with radionuclides of technogenic origin); 2. environmental consequences relating to a sharp decrease in the anthropogenic load on ecosystems, complete relocation of local residents and succession processes occurring intensively in the first decades (Pikulik & Drobenkov 1995).

Among the environmental consequences of the accident, changes in the spatial distribution of populations and their abundance, which affected almost all species, are most pronounced in the accident zone. On the territory of the largest radioactive contamination, covering 30 km around the nuclear reactor, in terms of the number (density) the most common species in Belarus dominated: green frogs *P. cl. esculentus* (66,7-2687,5 ind./ha) and Moor frog *R. arvalis* (22,2-240,0 ind./ha).

The main changes in the size and structure of herpetocomplexes in the zone of the Chernobyl accident was caused by successional processes – gradual bush encroachment of floodplains and meadows, the secondary bogging of drained marsh earlier, as well as the gradual degradation and transformation of agricultural land in meadow and forest ecosystems.

The ecological situation, formed as a result of the recession the impact of almost all the anthropogenic factors and the complete evacuation of the local residents from the region, has led to the growth of some species (Common toad *B. bufo*, Common spadefoot *P. fuscus*, Tree frog *Hyla arborea*), which gradually settled wide

range of habitats: overgrown pastures, fields and gardens, as well as in the abandoned villages. Besides the green frogs *P. cl. esculentus*, the number another aquatic species – Fire-Bellied Toad (*Bombina bombina*) has increased. The trend of population decline was observed only for one species of herpetofauna, for Green toad (*P. viridis*), expressing a tendency to synanthropization everywhere.

Commercial capture

Purposive catching of amphibians on the territory of Belarus is limited, which is explained by the low practical significance this group of vertebrates for the local people. For scientific research and as demonstration objects in the anatomical and physiological experiments in medical universities and in the biological faculties of universities *R. temporaria* and *R. arvalis* sometimes used.

Common adder (*Pelias berus*) is the only resource species of herpetofauna in the country, which is caught to produce poison. The annual removal of these snakes from nature does not exceed 0.3-0.5 thousand individuals, and the developed and applied protection measures are quite effective, so the damage to its population is minimal.

In addition to the above listed factors, some other forms of human economic activity have a negative impact on the herpetofauna of Belarus. The negative influence is manifested in overgrazing of cattle in meadow ecosystems, flooding of certain areas in the construction of storage reservoirs and ponds, clearing the bottom and coastal zone of reclamation channels. However, the scale and degree of their impact on amphibians and reptiles is less significant.

The distribution and degree of influence on regional batrachofauna pathogenic fungus *Batrachochytrium dendrobatidis*, that is actively spreading around the world and caused the extinction of populations of many species of amphibians, yet not undefined.

Anthropogenic transformation of ecosystems leads to the disruption of stable equilibrium in

the structure of herpetocomplexes, which is appear in the decrease in the number of species, changing trophic, spatial and other structures of communities. According to key ecological ideas of ecosystem disturbance, the diversity of communities determines their complexity and sustainability (Elton, 1960). Increasing the homogeneity of the natural environment leads to a decrease in the diversity of resources and the number of potential ecological niches, which adduct to the simplification of trophic networks and the structure of biotic communities, including the faunistic complexes of amphibians and reptiles. The structural complexity of communities, which is determined mainly by the level of their diversity, in anthropogenic ecosystems in most cases decreases.

Many of amphibians and reptiles living in Belarus, due to their ecological-morphological, physiological and other features, can be classified as high- and moderate-reagent species, showing, in general, increased sensitivity to environmental factors, therefore, the identified fairly clear trends of anthropogenic transformation of populations and herpetocomplexes may be indicators of disturbance of wild communities and ecosystems.

CONCLUSION

1. Intensive human agricultural activities, clear cutting and fragmentation of forests, drainage reclamation of wetlands, industrial and road construction, intensive transport movement and urbanization have most significant impact on the herpetofauna of Belarus in recent decades.

2. Radical changes in natural landscapes lead to a reduction in the area of natural habitats of amphibians and reptiles, reduce their ecological capacity, increase the fragmentation of land and, as a result, to reduce the distribution and number of populations and the violation of the natural structure of their communities.

3. The most significant natural changes in habitats, species populations and communities occur in result of natural successions, as a rule,

local and cyclical, but the successions not lead several disorders and serious consequences for populations and communities as in landscapes disturbed by man.

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