Acta Biol. Univ. Daugavp. 21 (2) 2021
ISSN 1407 - 8953

MULTI-YEAR DYNAMICS OF FAUNISTIC COMPLEXES OF AMPHIBIAN AND REPTILE IN NATURAL AND TRANSFORMED ECOSYSTEMS IN BELARUS

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Drobenkov S.M. 2021. Multi-year dynamics of faunistic complexes of amphibian and reptile in natural and transformed ecosystems in Belarus. *Acta Biol. Univ. Daugavp., 21 (2): 101 – 110.*

The analysis of field data collected in Belarus at several biological monitoring points over a 30-year period indicates a high diversity of trends in the variation of amphibian and reptile faunistic complexes in natural and transformed ecosystems. According to dynamics of species diversity and the abundance of herpetocomplexes, several main variants of their chronological changes are distinguished: (a) a state of relative stability, characterized by slight fluctuations in structural parameters and abundance over a long time, (b) fluctuating dynamics, indicative to periodic (irregular) reversible changes in species diversity and abundance over a wide range, (c) an unstable state, characterized by significant chaotic or directional changes, caused by strong external factors leading to a significant restructuring and changes in the number of faunistic complexes. The obtained data indicate the structural and functional stability of herpetocomplexes to external factors and their significant possibility for self-healing and maintaining the equilibrium state. In stable communities, the primary species composition, the rank of species, and their abundance are maintained for a long time without significant changes. The condition of the studied groups of animals in the short-term time scales (several decades) at the monitoring points was determined both by natural factors (fluctuations in weather and climatic conditions, flood processes in floodplain landscapes, gradual successions in forests) and by anthropogenic changes in the natural environment (forest logging, drainage reclamation, urbanization). Changes in the hydro-climatic conditions and processes associated with changes in the humidification of the territory, entailing a change in the wet and relatively dry phases are exerted the most significant influence on the state of herpetocomplexes. Long-term changes in the status of rare protected species are different and characterized by a gradual decline in numbers (crested newt *Triturus cristatus*, European pond turtle *Emys orbicularis*), fluctuating dynamics (natterjeck toad *Epidalea calamita*) and a relatively stable condition (smooth snake *Coronella austriaca*).

Key words: Amphibians, reptiles, faunistic complex, assemblages, structure, species diversity, anthropogenic factors.

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INTRODUCTION

The dynamic-temporal aspects of the structural organization of natural communities take an important position in the concept of the systemic all life (Whittaker 1980, Pianka 1981, Giller 1988). In accordance with modern concepts, biological systems are adapted to changes in environmental conditions, capable of constant autoregulation and maintaining integrity and stability in time and space (Razumovskij 1981, Gleason 1926). Any phenomena that occur in ecosystems are related to time, so time dynamics stands out as one of the most important issues in the analysis of the structural organization of natural communities.

The study of long-term chronological series provides the basis for the study the character and direction of the caenogenesis and changes occurring in communities, which makes it possible to assume the patterns of their formation in the past and predict their development in the future (Mirkin & Rozenberg 1978).

Amphibians and reptiles, characterized by a wide range of used habitats and a high population number, play an important role in the structural and functional organization of natural ecosystems in the temperate climate zone of Europe. Amphibians, due to a many of morphophysiological features – amphibious lifestyle, permeable skin, high reactivity to pollutants, are considered the most sensitive biological indicators of environment state and are widely used in biological monitoring (Bolschakov 2001, Hamer & McDonnell 2008, Hocking & Babbith 2014).

The temporal dynamics of the faunistic complexes of amphibians and reptiles in the forest zone of the temperate climate belt of Europe has been studied only in the most general terms, which is mainly due to the complexity of long-term chronological biological studies conducted using a single methodological basis (Drobenkov et al. 2006).

This work aimed to analyze long-term changes in the species structure and abundance of herpetocomplexes in current natural and transformed ecosystems of Belarus.

MATERIAL AND METHODS

The analysis was based on materials collected during long-term research conducted in 1991-2020 in different parts and different ecosystems of Belarus. The research area covered the western part of the East European Plain in the zone of conjugation of two geological botanical regions, the Eurasian coniferous forest (taiga) and the European broad-leaved forest, which are divided into three clearly defined subzones: oak-dark-coniferous southern taiga (broad-leaved spruce) forests, hornbeam-oak-dark-coniferous subtaiga (spruce-hornbeam oak forests) and broad-leaved pine forests (hornbeam oak forests) (Jurkevic & Geltman 1965).

The longest studies up to 25-30 years were conducted at 12 permanent observation plots, four of which are included in the State Register of Observation Points of the National Environmental Monitoring System of the Republic of Belarus. Model areas were getting out in various regions of the country and representatively reflected the diversity of its climatic and geographical conditions, landscape heterogeneity and features of anthropogenic transformation of ecosystems. Six model sites are located on the territory of specially protected natural areas (the Pripyatsky National Park and national and local nature reserves). As the monitoring points were selected relatively homogeneous areas of typical landscapes with formed vegetation (the structure of phytocenosis) and insignificant economic use of the territory.

The estimating of the species composition, structure (ranked of species by the number) and the relative abundance of herpetocomplexes was carried out according to generally accepted methods (Dinesman & Kaletskaja 1952, Darevskij 1987, Measuring and Monitoring Biological Diversity 2003). In total, more

than 650 route surveys were conducted at the monitoring sites during the observation period.

The monitoring was done in the spring-summer season (from the end of May to July) during the period of maximum terrestrial activity of the animals – in the morning (9-11 hours), favorable for accounting for reptiles, and in the evening (19-24 hours), at the highest activity of amphibians. The length of the assessing routes within the sample plots amounted 1-1.2 km. The counting was carried out repeatedly for 2-3 consecutive days for the registration of rare species and in order to obtain the most complete data on the number.

At the analysis the dynamics of the structural organization and the number of the studied groups of animals, traditional methods of statistical data processing and ordinary indexes of biological diversity were used (Puzachenko 2004, Borovikov 2008).

RESULTS AND DISCUSSION

The analysis of the data collected showed a significant diversity of the main trends of long-term changes in the faunal complexes of amphibians and reptiles in the biological monitoring sites located in various natural and disturbed ecosystems of Belarus.

Depending on the different annual variability of the studied community parameters – species composition and structure, and relative abundance, can be identified several major options of the dynamics of herpetocomplexes:

(a) State of relative stability, which is characterized by slight variations in structural parameters and abundance over a long time spanning several decades,

(b) Fluctuating dynamics, for which are typical periodic irregular reversible changes in the studied indicators over a wide range,

(c) Unstable state, characterized by chaotic or directional changes associated with the influence of strong external factors leading to significant changes in the species structure and number of herpetocomplexes.

A relatively stable state (option a), accompanied by some minor fluctuations in the qualitative and quantitative composition of herpetocomplexes over a long period, was observed in five monitoring points (Fig 1, a). Weak deviations from the initial state were observed, as a rule, in sample plots with a well-formed structure of phytocenosis and a low impact of human economic activity on natural ecosystems. This category includes almost all monitoring points in nature reserves, as well as some study areas in poorly transformed landscapes.

Species composition (number and taxonomy of species) remained the most stable parameter of the structure of herpetocomplexes at the sites for a long time. Even the rarest and least numerous species were regularly recorded at model sites monitored throughout the observation period (crested newt *Triturus cristatus*, natterjeck toad *Epidalea calamita*, smooth snake *Coronella austriaca*). On the other hand, single individuals some others species that are not characteristic for this habitat met frequently, what is explained by the search for new suitable place for living.

The ratio of different species and the total number of herpetocomplexes were more variable characteristic than their species composition. Dynamic processes in communities, according to general concepts, are the sum of the dynamics of various species populations and the result of inter-population relationships (Maksimov & Yerdakov 1985).

Some non-essential number fluctuations are noted for both dominant and rare species. The abundance of herpetocomplexes monitored at the testing plots also varied in a small range over a long observation period (σ=8.7-12.8).

Fluctuating dynamics of faunistic complexes (option b) during the long-term monitoring period was observed in sampled plots (3) located in floodplain ecosystems exposed to seasonal floods of different intensity. The species composition of the communities of the

studied taxa in river floodplains, represented by wet meadows flooded for a significant period (up to 30-45 days), was relatively stable, but the structure of species dominance and the number differed significantly over the years of observation.

The temporal dynamics of herpetocomplexes in floodplain landscapes had a reversible character and was characterized by a return to a close to the primary state. A characteristic feature that emphasizes the uniqueness of the natural communities of river floodplains is a radical seasonal restructuring of the spatial structure of the most species populations, due to changes in the water regime of floodplain territories. During flooding of a river, all species of reptiles, as well as almost all amphibians (excluding only aquatic forms – red-bellied toad *Bombina bombina* and three species of water frogs

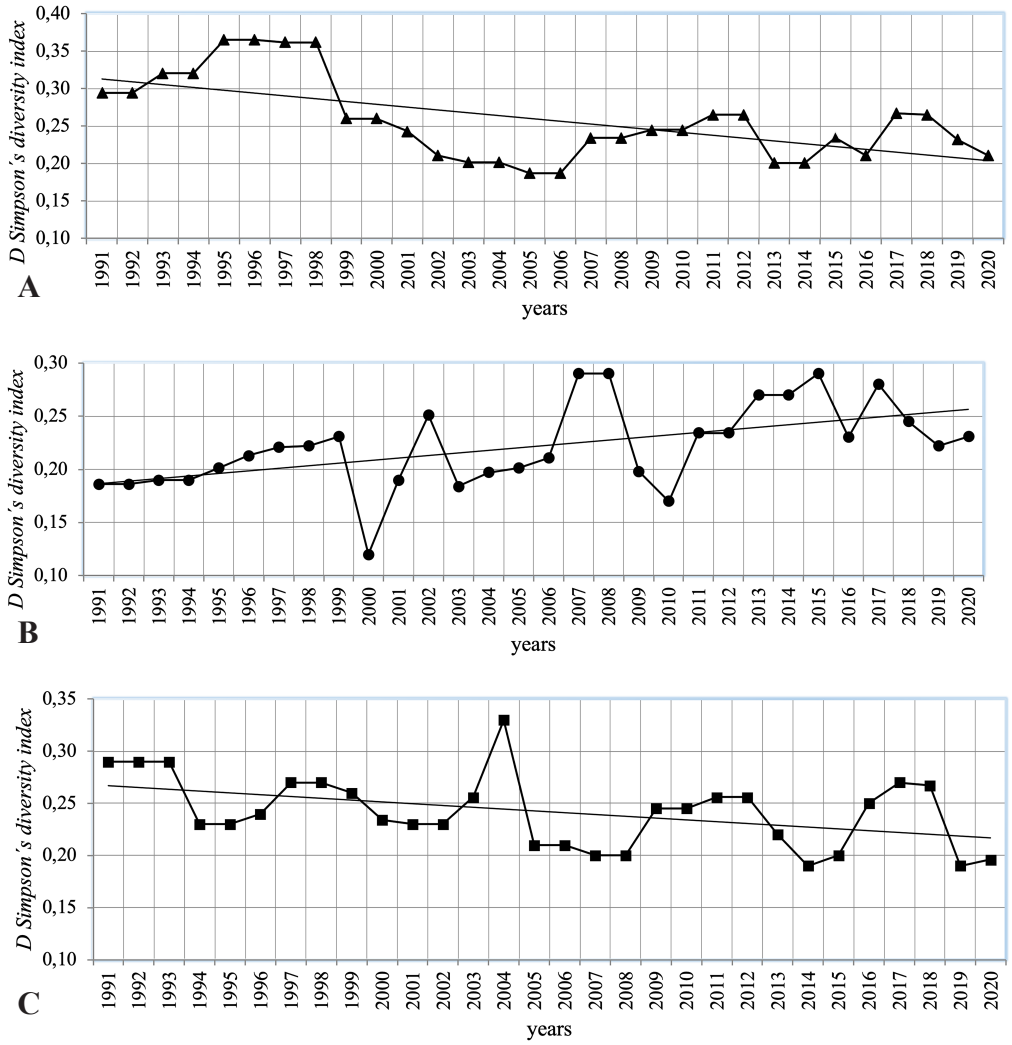

Fig. 1. Options of long-term dynamics of herpetocomplex species diversity in regular monitoring sites in Belarus

Notes: a-upland bog, natural reserve (stable state), b-floodplain meadow, poorly transformed territory (fluctuating dynamics), c-mixed coniferous-small-leaved forest, transformed landscape (unstable state)

Pelophilax esculentus complex) were located to the above-flood terraces and non-flooded hills, and then after the flooding was over, they were gradually again distributed over extensive floodplain meadows.

Regular floods have the most significant impact on the state of floodplain animal communities, the species structure of which is a consequence of their reaction to the natural environment (Maksimov & Yerdakov 1985). The very different environmental conditions that are formed under the influence of this factor give advantages to one or another species, affecting the structure of the community and determining the declines and rises in numbers. In favorable years, due to the huge fecundity and the successful realization of a high reproductive potential, the number of many amphibian species in floodplain ecosystems after metamorphosis increases many times, but quickly stabilizes at the same level.

Significant and often radical changes, indicating the unstable state of herpetocomplexes (option c), were observed in areas of natural and anthropogenic landscapes (noted in four monitoring points), which underwent a serious transformation in the process of intensive human economic activity. The main reasons for such changes are the violation of the natural water regime of the territory as a result of drainage reclamation, deforestation, urbanization, or a set of reasons. Some local factors also play a significant role, for example, the creation of small artificial ponds that contribute to the rapid increase of populations of many amphibian species. The number and structure of herpetocomplexes is largely determined by the state of populations of eurytopic numerous amphibian species that dominate in natural communities, such as common and moor frogs (*Rana temporaria* and *R. arvalis*) and common toad (*Bufo bufo*).

Anthropogenic factors entail major changes all the structural parameters of the faunal complexes of amphibians and reptiles that are formed in transformed ecosystems, such as the composition of species, their quantitative ratio, abundance, and others (Pikulik 1993, Drobenkov et al. 2006, Drobenkov 2018). The stressful conditions of the transformed environment lead to the formation of a more homogeneous structure, monodomination, equalization of the quantitative ratio of the remaining species (except for the dominants), as well as a decrease in the overall abundance value.

As a result of environmental changes, that are currently occurring under the influence of anthropogenic pressure, legitimate changes in the species structure and abundance are observed in herpetocomplexes (Fig. 2). Large-scale reclamation of lowland bogs, especially intensively carried out in the southern part of the country-in the Pripyat River basin in the Polesie region provided the most important impact on the herpetofauna. During the draining of lowland bogs and the creation of extensive agricultural landscapes on the drained lands, the species richness of amphibians and reptiles, in most cases, decreases, and the structure of herpetocomplexes changes from the predominance of hydro- and hygrophilous species to the dominance of meso- and psammophiles. Populations of some species, for example, *L. vulgaris*, *T. cristatus*, *B. bombina* and several others, due to the loss of suitable habitats, are reduced or even disappear, while others, for example, *L. agilis*, on the contrary, increase in number due to the colonization of new biotopes.

At the same time, the consequences of certain forms of human economic activity, that contribute to an increase in the heterogeneity (mosaic) of habitats, often are responsible to an increase in the species diversity of herpetocomplexes and an increase in the number of some species. A general pattern has been established both in natural and transformed landscapes of Belarus, the species richness of the herpetofauna positively correlates with the habitat diversity (Drobenkov 2017).

Vegetation cover and the features of the phytocenosis (humidity, shading, and other

conditions) are the most important, complex indicator of the habitat conditions of amphibians and reptiles, determining and displaying its microclimatic regime, protective properties, and abundance of trophic resources. Phytocenosis is the basis of zoocenosis, under its influence, certain conditions necessary for the life of different species are formed, and, ultimately, certain composition of species in communities (Drobenkov 2020).

The results of long-term monitoring have shown that the hydrological regime of the territory, spatial distribution and environmental conditions of water bodies have a major impact on the reproduction of amphibians, determining the reproductive success and the number of their populations. For reptiles that need daily basking, the light and temperature conditions of the habitat are most important.

Dynamic changes in the population state of rare species of regional herpetofauna included in the Red Book of the Republic of Belarus are also determined by the influence of natural and anthropogenic factors. The most threatened taxa currently include 4 of the 20 species of herpetofauna: crested newt – *Triturus cristatus* (Laurenti, 1768), natterjeck toad – *Epidalea calamita* (Laurenti, 1768), European pond turtle – *Emys orbicularis* (Linnaeus, 1758), and smooth snake – *Coronella austriaca* (Laurenti, 1768), the condition and dynamics of their populations are different.

The state of crested newt populations at monitoring sites in natural reserves and poorly transformed landscapes are relative stability or weak fluctuations. During the observation period, there were insignificant (maximum 1.5-2-fold) variations in the number, which can be considered the norm for this species. The greatest influence on the interannual dynamics

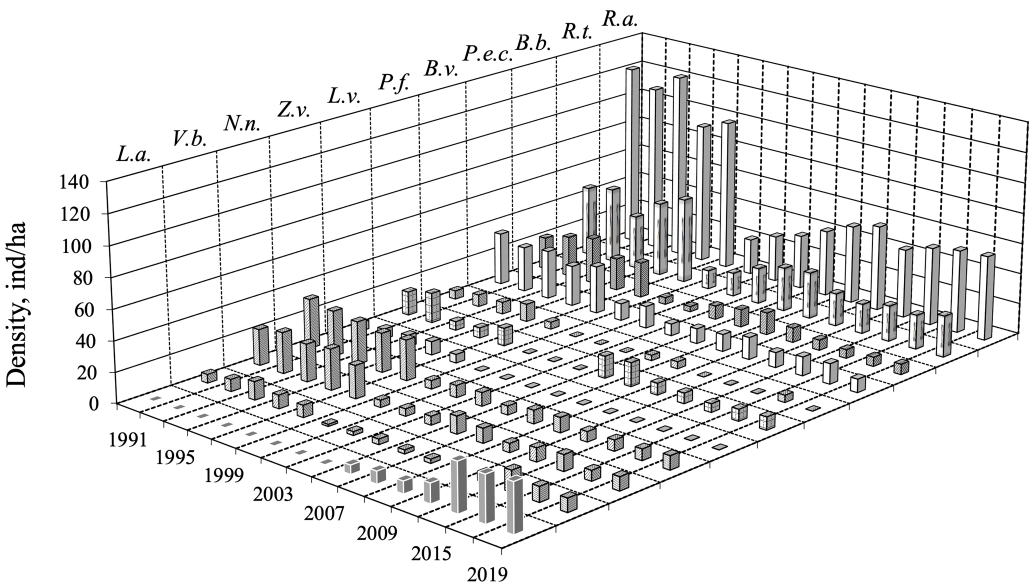

Fig. 2. Changes in the species composition and number of faunistic complexes of amphibians and reptiles in the long-term monitoring points on the site of a low-land bog transformed into farmland (drainage reclamation work was implemented in 2000)
Notes: *R.a. – Rana arvalis*, *R.t. – Rana temporaria*, *B.b. – Bufo bufo*, *P.e*.c. – *Pelophelax esculentus* complex, *B.v. – Bufotes viridis*, *P.f. – Pelobates fuscus*, *L.v. – Lissotriton vulgaris*, *Z.v. – Zootoca vivipara*, *N.n. – Natrix natrix*, *V.b. – Vipera berus*, *L.a. – Lacerta agilis*

was exerted by weather and climatic fluctuations, the height of snow cover and the level of atmospheric precipitation, on which the water regime of ponds depends, which determines the success of reproduction. At the same time, a significant part of the controlled groups of the species (about 40%) was in an unstable state. Much pressure in modern conditions is exerted by the illegal introduction of native fish and the spread of an alien species Amur sleeper (*Perccottus glenii*), eating eggs, larvae and adult newts. In general, the long-term dynamics of the population groups this species in the biological monitoring points is characterized by a clear trend of decline, which is typical for the entire regional population.

The natterjeck toad is characterized mainly a fluctuating variable type of long-term population dynamics, the number variation of which can be several tens of times. There are several phases of population dynamics, such as depression (in unfavorable years associated with the drying up of ponds), a sharp rise in the number, recovery (to the maximum) in optimal environmental conditions, and a gradual decline. The state of the population is determined mainly by natural factors and features of reproductive biology. The natterjeck toad nests in shallow open water bodies, the water level of which depends on the amount of precipitation during the breeding season. In this regard, in the summer, at hot weather, there is a mass death of the entire new generation. Due to the ephemeral of spawning ponds, the breeding strategy of this species is aimed at survival in unstable environmental conditions. Repeated dry weather for several years leads to the elimination of several major reproductive classes of the population, but under favorable conditions, the local groups are quickly restored. The number of *E. calamita* in the monitoring sites varied significantly, but in general, on a scale of decades, it remained relatively stable, which is typical for the entire regional population.

The data obtained indicate different trends in the population dynamics of the European pond turtle at different monitoring points: (a) relatively stable, (b) with fluctuating dynamics, and (c) unstable, with a clear trend of reduction. In areas characterized by a stable hydrological regime and low anthropogenic pressure, stable groups were observed for decades. At the same time, in some localities, a 2-5-fold decrease in the population was observed over the 30-year monitoring period. Among the natural factors that have a negative impact, there is a high pressure of oophage predators (Red fox, Raccoon dog, etc.), which annually destroy up to 25-40% of the new generation. Many forms of human economic activity (drainage reclamation, urbanization, automobile traffic, etc.) lead to a decrease in the population. Based on the state of the population in the monitoring points, the general trend of reducing the number of the European pond turtles, which manifested itself in the middle of the 20th century, continues presently.

The regional population of the smooth snake is characterized by relative stability state and slightly change in the number. The condition of the populations in the monitoring points, as well as in the whole in Belarus, was relatively steady within observation period. In some areas, the decline in the population is contribute by continuous logging, urbanization, and automobile traffic on the roads.

The analysis of the results of the studies allows us to make some generalizations concerning the main trends in the long-term dynamics of the structural organization and number of faunistic complexes of amphibians and reptiles in different ecosystems of Belarus.

According to the data obtained, herpetocomplexes controlled for a long period in monitoring points in natural and modified ecosystems were, in general, in a state of relative structural and functional stability, which indicates that herpetofauna is a fairly stable component of zoocenosis, which is significantly opportunities for self-restoration and support of a qualitative state.

In steady communities, the primary species composition, changes in the rank of species and their abundance remain at a close level for a long time. The data confirm the general ecological rule – a high level of stability is achieved either due to the low variability of the essential parameters, or due to the developed adaptive mechanisms of returning to the initial state (Giller 1988).

The condition of the studied groups of vertebrates in short-term time scales (ecological time covering the lifetime of several generations of animals) is determined both by natural factors (weather-climatic fluctuations, flood processes, successions) and by anthropogenic changes in the natural environment. The most significant impact on the state of herpetocomplexes is exerted by the dynamics of hydro-climatic conditions and processes associated with changes in the humidity of the territory, which leads to the alternation of relatively wet and relatively dry phases. Amphibians are one of the most hygrophilous groups of animals, the number of which is subject to natural changes associated with this factor.

The established structural and dynamic patterns concerning the temporal variability of herpetocomplexes and populations of rare threatened amphibian and reptile species have a certain prognostic value, which makes it possible to use them in the area of monitoring, biological indication and environmental protection.

ACKNOWLEDGEMENTS

The work was supported by the Belarusian Republican Foundation for Basic Research, project B20SRBG-009.

CONCLUSIONS

1. According to the data obtained in Belarus at the continuous monitoring sites during a 30-year observation period, depending on the features of the dynamics the species structure and number of faunistic complexes of amphibians and reptiles, several main options their chronological changes are distinguished: the state of relative stability, fluctuating dynamics and unstable state.

2. The data gathered indicate the structural and functional stability of herpetocomplexes and their significant potential for self-healing and maintaining the equilibrium state. In steady communities, the primary species composition, the rank of species, and their abundance are preserved for a long time without significant changes.

3. The condition of the studied groups of animals in the short-term scales at the monitoring points was determined by both natural factors and anthropogenic changes in the natural environment. The most significant influence on the temporal dynamics of herpetocomplexes is exerted by changes in the hydro-climatic conditions of habitats and processes associated with changes in the humidity content of the territory.

4. Long-term changes in the status of rare protected species of herpetofauna are characterized by different trends – a gradual decline in the number (crested newt *Triturus cristatus*, European pond turtle *Emys orbicularis*), fluctuating dynamics (natterjeck toad *Epidalea calamita*) and a relatively stable status (smooth snake *Coronella austriaca*).

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Received: 20.09.2021.
Accepted: 15.12.2021.