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The influence of environmental factors on caudate amphibians at the national, regional and european level: synthetic eco-evolutionary analysis

Tudor Cozari

Abstract. Based on the data obtained in the field and those selected from the specialized literature, there was carried out a synthetic eco-evolutionary analysis of the biology, ecology and ethology of the populations of caudate amphibians at the national, regional and European level. The data obtained can serve as a support scientific-methodological for the evaluation of the ecological status of the populations of caudate amphibians and their conservation.

Keywords: caudata amphibians, polyfactorial analysis, anthropogenic factors, ecological status, amphibian conservation.

Influența factorilor de mediu la amfibienii caudaţi la nivel național, regional și european: analiză sintetică eco-evolutivă

Rezumat. Pe baza datelor obținute în domeniu și a celor selectate din literatura de specialitate, a fost realizată o analiză sintetică eco-evoluționară a biologiei, ecologiei și etologiei populațiilor de amfibieni caudați la nivel național, regional și european. Datele obţinute pot servi drept suport ştiinţifico-metodologic pentru evaluarea stării ecologice a populaţiilor de amfibieni caudaţi şi conservarea acestora.

Cuvinte cheie: amfibieni caudaţi, analiza polifactorială, factori antropici, starea ecologică, conservarea amfibienilor.

1. Introduction

One of the primordial imperatives of contemporary society consists in the protection of the biodiversity of the ecosystems on Earth [4, 9]. However, the well-being of human communities, whether at the local, regional or global level, depends entirely on its beneficial ecological condition. This requires us to take urgent measures to investigate the intra- and inter-population mechanisms of the adaptation and perpetuation of amphibians, which constitute one of the indispensable and important components of the biodiversity of natural ecosystems. In the animal world, amphibians represent one of the indispensable components of ecosystems, they populate the most diverse natural and anthropogenic

terrestrial and/or aquatic habitats. By virtue of the amphibious way of life, this group of animals evaluates as consumers of the first, second and third degrees in the trophic networks of aquatic and terrestrial ecosystems, achieving a continuous and efficient exchange of matter and energy and contributing to maintaining the ecological balance of these natural ecological systems. Regrettably, out of the 3 thousand species of amphibians currently existing on the globe, about 60 species (2%) are threatened with extinction, and 2 species (0.1%) disappeared after the year 1600. It is not known accuracy the number of amphibian species that are today on the verge of extinction, but one thing is certain: in a number of countries of the world, dozens of the representatives of the batrachofauna are assigned to the last category of vulnerability - that of critically endangered species, i.e. those which present an extremely high risk of extinction. The main causes of the deplorable ecological situation in which many species of amphibians have found themselves consist, first of all, in the destruction of habitats and/or in the overexploitation of certain species; most frequently, however, the threat to amphibian species is represented by a complex of causes. And these, to the regret of the specialists in the field, are not always fully known, and sometimes they cannot even be established so easily [1,3].

2. Materials and methods

Following theoretical and practical investigations, there were collected materials regarding the spatial and temporal distribution of more than 25 populations of caudate amphibians within the species' range, both at the local and national, as well as the regional and European level. The data were collected from different aquatic and terrestrial ecosystems during the years 2016-2022. Limiting ecological and anthropogenic factors, acting in particular on population structure, biology, ecology and ethology of caudate amphibians, were assessed. As a result, there was established the current ecological status of the amphibian populations and there were proposed the necessary measures for their conservation in the short and medium term. The need for such research is more than timely, given the fact that only after the elaboration of an integral conceptual framework about the biological and ecological-ethological peculiarities of the populations throughout the entire annual life cycle is possible to evaluate the real ecological state of the amphibian species and to elaborate adequate and effective measures for their monitoring and conservation [2].

3. Results and discussions

The amphibian fauna of the Republic of Moldova, in its current configuration, is partly the result of historical or recent transformations of anthropic origin. Along with indirect

actions, conditioned by essential and unpredictable environmental changes, the negative anthropogenic impact exerted consciously or unconsciously had adverse repercussions on the specific diversity and effective populations. As a result, most of the species of the national batracofauna (except, perhaps, only the green ranid species in some habitats) in the last 20 years have drastically reduced their distribution area and population numbers in most of the natural habitats and, more chosen, in the strongly anthropized ones, the causes of this deplorable ecological situation being multiple. Among them we mention: the fragmentation of natural habitats, which resulted in the disruption of amphibian access routes between the terrestrial nutrition and wintering stations and the aquatic stations used for reproduction; compromising the nutritional base of amphibians in natural habitats due to the degradation of their biodiversity; the clearing of small river meadows, which caused the disappearance of temporary water pools used as breeding stations for amphibians; pollution or destruction of breeding stations, etc. A series of anthropogenic factors act on the spatial distribution, the population numbers and the general ecological state of the caudates within the area, the degree of influence and negative impact of which varies greatly from one region to another. Through long-term special researches, carried out in various European countries [6,7], it has been demonstrated that one of the strong factors of the decrease in the population of paedomorphic newts, along with the fragmentation of natural habitats, is the introduction of the species into water basins fish predators. The investigations carried out demonstrated that, according to the degree of adaptation to different living conditions of the environment, the caudate species are divided into the following three ecological groups: a) forest species; b) species of open habitats; c) amphibian species (with wide ecological plasticity). The distribution of species with wide ecological plasticity (potential) is in full agreement with the density of the lakes, their degree of insolation during the amphibian reproduction period and the presence of other syntopic amphibian species. The species of the genus Triturus, in certain periods of the year, use different habitats - forest and meadow; thus, after leaving the breeding ponds, the newts stay in the meadow habitats for more than a month. In spring and in the first half of summer, the individuals of these populations are in water basins, being active both during the day and at night; then, they go out on land, where they are already active only at dusk and at night. During the day on land they are only encountered in rainy weather or during breeding migrations. The given species, as characteristic habitats, use open grassy, rocky ones, burrows of other animals, etc., males prefer open habitats, and females prefer burrows (due to viviparity).

Through the method of polyfactorial analysis, there were evaluated the ecological factors that influence the spread of species. It has been established that caudate species

prefer lakes that are, at least partially, overgrown with bushes; that is, the population of certain lakes by this species depends on the quality of adjacent terrestrial habitats, where the common newt can live in terrestrial conditions after breeding. It has been found that species of the Triturus genus make extensive use of natural burrows to hide from predators and adverse environmental factors [5]. Females preferentially enter those burrows where males are already present, while for males the presence of females or other individuals in such burrows is of no importance. The problem with the use of temporary water pools by amphibians is that these pools, although they are favorable for the development of larvae, are also unstable as a hydrological regime: when they dry up, these pools lead to the death of larval populations. Thus, some caudates live, as a rule, in the aquatic habitats (78% of the individuals of the population) and only a part of them (22%) – on the moist terrestrial sectors around the aquatic habitats. Following the investigations, it was established that one of the determining factors of the spread of caudates is the presence and distribution of water bodies, which can ensure their successful reproduction [3,6,8]. One of the indispensable ecological parameters of the use of water basins as a place for reproduction is the presence of submerged aquatic plants. It has been established that the water basins where newts reproduce are rich in such vegetation, from which it follows that newts, in this sense, could serve as suitable biological indicators of a rich diversity of vegetation in them. All the amphibians found on the territory of our country hibernate; they appear in early spring immediately after the melting of snow and ice in the water bodies, the date of their appearance and the entire seasonal cycle of reproduction varies according to temperature [1,4,6]. The alternation of aquatic and terrestrial life phases is a typical phenomenon for salamander species [2,9]. It was found that the seasonal movements of the studied caudate and ecaudate species from lakes to terrestrial habitats and vice versa do not occur randomly: the amphibians use certain ”habitat corridors” for this. In relation to this particularity of migration, it is proposed that in cases where it is necessary to create so-called ”buffer zones” around the reproduction pools of the species, the specificity of the spatial location and the configuration of the ”corridors” should be taken into consideration habitats” of amphibian species in these habitats. Following the study of the migration capacity of salamanders, it was established that in 48 hours they can cover a distance of up to 200 m [7].

Another important aspect of the ecology of caudates is related to their ability to recognize (based on certain sense organs) and to return to their native terrestrial habitats after the end of the reproduction process that takes place in water basins. It has been established that caudates have a well-developed so-called ”sense of home” (”homing” - from English), which allows them to safely return to their native habitat after being

transferred to a distance of 213–230 m by this one. Their safe orientation towards their native place of living is due to the previous experience accumulated during the pre-reproductive and post-reproductive migrations, during which the individuals know and memorize the natural terrestrial habitats that are within 230 m of the breeding pool. In sympatric populations of newts, heterospecific crossings are not possible due to the existence of different, species-specific acts of nuptial demonstration. Thus, during homospecific crosses spermatophore transmission occurs in 34 percent of cases, while after heterospecific crosses - only in 4 percent of cases.

Chemoreception plays a primary role in achieving orientation and locomotor behavior by caudate amphibians. Following some special studies, it was found that in the species of the Salamandridae family, for example, while searching for burrows, individuals orient themselves by the smell emanating from other individuals, this allowing them to populate the same burrows with several individuals of the same species [1,6]. It is assumed that this tendency of individuals to aggregate presents an adaptation for survival in dry habitats, because, gathering several together in the same burrows, the integument of individuals resists drying much more easily. The diurnal activity of salamanders changes when the presence of predators is signaled, it obviously decreases [6].

It has been established that chemoreception plays an important role in newt communication [8]. Thus, in the Triturus helveticus species, the odors of conspecific individuals facilitate the process of association and formation of nuptial groups in the breeding pools. In the species Salamandra desmognatus ochrophaeus, the phenomenon of recognizing conspecific individuals based on the olfactory markings left on the substrate by different individuals was established: young males avoided the smell of mature males (to avoid cannibalism) [2, 4]. Depending on the degree of evolution of different species of salamanders, the process of chemical communication between conjugal partners is carried out differently [1, 8]. In the species of the most primitive group of the genus Plethodon - the ”cinereus” group, the males, in order to transmit the sexual pheromones, use the ”vaccination” procedure: strongly rubbing the skin of the females with the help of special premaxillary teeth, they then introduce this place the sexual pheromones that are produced by the submaxillary glands. The second group of species - ”gluinobius”, being more evolved, carries out the transmission of male sexual pheromones directly from the sexual glands to the nostrils of the females. However, there are also species, such as Plethodon dorsales, which occupy an intermediate position in terms of sexual behavior compared to the two groups of salamanders mentioned previously.

In laboratory conditions, the males of some species of caudates, such as those of Plethodon vehiculum and P. dunni, can determine by smell the chemical messengers

emitted by mature and young females [7]. While the females, unlike the males, were not able to distinguish the young males based on the sexual pheromones eliminated by them. In this way, it was demonstrated that males are able to choose females ready for reproduction, while females - only the largest males. Often, in order to successfully carry out some investigations related to the nuptial behavior of newts, along with the classical methods, it is also necessary to develop some original research methods. Thus, one of the effective methods of studying the behavior of caudate and ecaudate amphibians, along with photographing demonstration pictures of males and females, is the representation of these behavioral acts through schematic drawings. Schematic drawings have priority in that they allow highlighting and representing only those particularities of animal behavior that represent the ”quintessence” or ”key-particularity” of one or another behavioral act. In this way, the researcher has the opportunity to accumulate, systematize, analyze and expose these behavioral acts in a certain consecutiveness and interconnection that other illustrative research methods cannot provide. In many works, certain aspects of the territorial behavior of some species of Salamandridae, such as Eurycea wilderae, are analyzed [2,4]. In the territorial behavior of salamanders, which is quite original, certain specific behavioral acts are attested, such as ”aggression behavior” towards intruding individuals. It was found that the resistant individual, being disturbed, always shows an aggressive behavior, while the intruder avoids direct confrontations with him, regardless of his body size or previous experience of such confrontations. These behaviors once more prove to us that salamanders are strictly territorial animals during the breeding season. They show territorial antagonism not only towards related species, but even towards other foreign syntopic species of hydrobionts. In addition to the fact that both the forest salamander (Plethodon cinereus) and the centipede Scolopocryptos sexspinosus use similar hiding places (galleries under stones on the bottom of the water), these species show a negative spatial correlation. So, for example, only in 7 hiding places out of the 247 examined, under some and the same stones were both species. This is due to the fact that the salamander attacks this millipede and drives it out of its favorite hiding places [1,3]. Following some research, carried out both in laboratory conditions and in natural conditions, it was established that the nuptial behavior of different species, as expected, differs more obviously than in the cases of nuptial behaviors manifested by the subspecies of the same species [4 ,6,8]. Precisely because of this, subspecies hybridize much more frequently in nature than sympatric species. In the sympatric populations of T. vulgaris and T. montadoni, heterospecific crossings are not possible due to the existence of different, species-specific acts of nuptial demonstration [5,7]. Thus, during

homospecific crosses spermatophore transmission occurs in 34 percent of cases, while after heterospecific crosses - only in 4 percent of cases.

It is known that the reproductive behavior of caudate amphibians is stereotypical, from which it can be hypothesized that it is genetically coordinated. Following special research on the subject, it was established that the consecutiveness of the manifestation of certain behavioral acts by the partners during the nuptial games is not strictly regulated from a genetic point of view, this giving the species the opportunity to manifest a certain behavioral plasticity, which, in his opinion, has a certain adaptive importance in the conditions of unpredictable fluctuations of the environment. In the populations of Triturus vulgaris that are in unfavorable conditions of existence, the oviposition process of the females is directed towards the economy of the available vital energy. For this reason, females become fertile at a smaller body size than females in populations with optimal living conditions, lay smaller eggs and, at the same time, end their breeding season much earlier than in optimal living conditions. The survival strategies of the larvae depend on the altitudinal distribution of the biotopes; being strongly influenced by temperature, certain adaptations to these environmental conditions appear in larval populations. The larvae are resistant to frost for a short period of time and this resistance depends on the thermal capacity of the brood. Larvae in temporary pools, which have high water temperature but dry up every year, develop very quickly. In medium-sized pools, rich in vegetation, larval development, on the contrary, proceeds at a normal rate. The rate of larval development of newts also depends on the influence of the metabolites eliminated by the larvae of other syntopic caudate species. It has been established that in different breeding pools the size of the larvae depends on their density: in conditions with a high density, the larvae are small, while in populations with a low density the larvae are larger. When there are several generations of larvae in aquatic pools, the larger generations influence the smaller ones through cannibalism, the phenomenon in question being due to the different sizes of the larvae. There is the so-called priority effect: priority is given to larger larvae and then density regulation takes place to exclude cannibalism and intraspecific competition. As a result of the investigations, it was demonstrated that cannibalism is an effective mechanism for regulating the density of larval populations only in highly variable environmental conditions. The cannibals, consuming a large number of conspecific larvae, contribute, in this way, to the decrease of the density; and, on the other hand, they contribute, at the same time, to the intensification of the process of the individual development of the larvae and, as a result, to their earlier emergence on land.

Anthropogenic factors have a particular influence on the spread and reduction of amphibian populations. One of the anthropogenic factors with a strong negative action that

leads to the extinction of caudate species is deforestation; phenomenon reported in forest ecosystems: in all sectors cut from the forest, the density and diversity of salamanders has decreased a lot. Also, in a number of areas of Europe, the caudates, due to the destruction of their habitats, are disappearing, being ranked in the category of endangered species. Due to the damming works and the acquisition of gravel, various species of the genus Triturus have disappeared in a number of habitats of our country. Roads also have a negative impact on amphibians because they lead to the fragmentation of populations, preventing their free movement in the given natural habitat. During migrations, due to roads, up to 51% of individuals do not return to their natural habitat. One of the causes of the disappearance of the species Triturus vulgaris from a series of aquatic habitats is the introduction of predatory fish species. The predatory fish destroy the mature individuals and larvae of Triturus vulgaris, the eggs not being consumed because they are hidden in the leaves. It has been established that one of the causes leading to the demise of certain amphibian populations is the different degree of mortality of mature individuals; where it is higher, the total disappearance of populations is reached, because both in established populations and in those on the verge of extinction, the mortality of larvae and juveniles is approximately the same. In areas strongly affected by anthropogenic factors, some species of amphibians can be successfully used in testing the quality of the environment; first of all, of the degree of pollution of aquatic habitats [4]. In order to protect the caudates, it is proposed to create terrestrial buffer zones (with a width of 50 m on either side of the streams) where the species spend their lives after they have completed their reproduction in the water and have come out on land. The research carried out on this subject has shown that salamanders, once they are on land, do not move away from the water at a distance greater than 43 m. They use these adjacent areas as a characteristic habitat for life, along the streams of the hydrographic networks forming the so-called ”housing corridors”, which ensure the existence of species in the post-reproductive phase of life. Therefore, in order to protect the caudates, we must take under protection these habitat corridors of terrestrial habitats. During the formation of large lakes in spring, which, later, are accompanied by a partial separation following the drying of certain aquatic sectors, it is important to preserve their integrity by digging trenches that would ensure the connection between them to maintain a constant biotope. Some scientists believe that it is very important to study autecology in the development of effective protection methodologies, especially for the populations of little-studied species [3,6,7].

4. Conclusions

The level of research on caudate amphibians, with reference to the number of species examined and the problems addressed, is very different: many of the European caudate species are analyzed from a general point of view, without specifying the entire complex of particularities of their biology, ecology and behavior in the diverse and strongly fluctuating conditions of the environment. And autecological and long-term researches of many species of the genus Trirurus are completely missing. Caudata, as a result of the high degree of primitivism in morphological organization, are subject to much stronger environmental and anthropic influences than the other systematic groups of amphibians. The caudate species, at the same time, also show a certain level of morphological, physiological, ecological and ethological specialization, which, on the one hand, ensures their existence in different environmental conditions of natural habitats, and on the other hand, allows them to colonize to a certain extent and some anthropized habitats; especially those habitats that offer them, first of all, minimal but sufficient conditions for reproduction. The continuation of long-term ecological monitoring research of caudate amphibians is not only timely, but also of particular importance for the sustainable management and protection of their populations. For the successful conservation of caudate amphibians, it is strictly necessary:

a) to protect the natural habitats of the populations and, in particular, of the breeding ones;
b) to avoid the pollution of temporary and permanent stagnant water bodies;
c) to avoid the disturbance of breeders and to preserve amphibian wintering stations;
d) to collect amphibian eggs and larvae from lakes subject to drying or pollution and to transfer them to other water bodies;
e) to avoid the remediation of river meadows in order to preserve aquatic reproduction pools;
f) to provide ecological education for the population, including the young generation, etc.

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(Cozari Tudor) State Pedagogical University "Ion Creangă"