THE VULNERABILITY OF SPECIES AND HABITATS IN THE LOWER PRUT ZONE TO CLIMATE CHANGE

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Abstract. The Lower Prut area is home to meadow, aquatic and marsh ecosystems with numerous valuable species that are already threatened by climate change, facing a drier climate, water shortages in rivers and lakes, unpredictable floods and devastating forest fires. Many species in this area are particularly vulnerable to climate change and specific measures are needed to help them survive. Fragile habitats must be protected, if possible extended and connected to each other. Continued research and monitoring will allow a better understanding of threatened species and their habitat. Beleu and Manta lakes deserve special attention, which are the core of some protected areas, so that they maintain their optimal water level. 118 species of flora and fauna were included in our study, but the communication is focused on the most threatened, in particular, critically endangered and the main types of habitats and ecosystems.

Keywords: climate change, wetlands, species, habitats.

Rezumat. Vulnerabilitatea speciilor şi habitatelor din zona Prutului de Jos la scimbările climatice. Zona Prutului de Jos, adăpostește ecosisteme de luncă, acvatice şi palustre cu numeroase specii valoroase care deja sunt amenințate de schimbările climatice, confruntându-se cu o climă mai uscată, dificitul de apă în râuri şi lacuri, inundații imprevizibile şi incendii de pădure devastatoare. Multe specii din această zonă sunt deosebit de vulnerabile la schimbările climatice şi pentru a le ajuta să supraviețuiască sunt necesare măsuri specifice. Habitatele fragile trebuie protejate, dacă este posibil extinse şi conectate între ele. Cercetarea şi monitorizarea continuă va permite a înțelege mai bine speciile amenințate şi mediul lor de viață. O atenție specială merită lacurile Beleu şi Manta, care constituie nucleul unor arii protejate, pentru ca ele să-şi mențină nivelul optim al apei. În studiul nostru au fost incluse 118 specii de floră şi faună, dar comunicarea dată e axată pe cele mai amenințate, în special, critic periclitate şi principalele tipuri de habitate şi ecosisteme.

Cuvinte cheie: schimbări climatice, zone umede, specii, habitate.

INTRODUCTION

The climate changes of different geological periods were fatal for some organisms, but others survived, adapting to the new conditions or found refuge in restricted sectors, with specific living conditions, such as the aquatic, marshy, terrestrial environment. And so, the primary task that must be solved by the international organizations empowered with the rights and capacities of nature conservation is to carry out a complex (ecosystemic) study, in order to evaluate the current state of the organisms threatened with extinction. The results of such a study will create premises for the scientific argumentation of the sustainable implementation of integrated ecological monitoring, the reconstruction of degraded habitats, the creation of new National Parks, Nature Reserves etc., including protected areas for habitats and species where water is an important factor.

The purpose of the research is the analysis of the vulnerability of the most threatened valuable species in the Lower Prut Area to climate change and the prediction of scenarios for reducing the negative impact on them and their habitats. Based on the official information obtained from statistical reports, scientific publications, official documents etc., it was found that the total area of the protected areas (originally the Lower Prut Scientific Reserve - LPSR) underwent partial changes, from 1691 ha, in the year of foundation 1991, up to 1755 ha, in 2013 and 14771 ha, in 2015, with the creation of the Lower Prut Biosphere Reserve (LPBR).

That area was subjected to more pronounced fluctuations in the area covered by water, which, on the one hand, increased the area, but, on the other hand, also increased the water level. The effects of these long floods were manifested by the expansion, in particular, of the areas of pasture and forests, but also the increase in the number of species of birds and plants, and to a lesser extent, of mammals and fish. So, we assume that the maintenance of a water area of approx. 700-900 ha, provides an ecological optimum from a hydrological and biocenotic point of view for species vulnerable to the ecological factor humidity.

MATERIALS AND METHODS

The Lower Prut Area includes the Lower Prut Biosphere Reserve (Fig. 1), the Lower Prut Scientific Reserve, the Lower Prut Wetlands Ramsar Area (Fig. 2), which are part of the Emerald Network, the Reserve Natural Forest Isac's ford and the sector surrounding the Manta Lake (Fig. 3) with the adjacent territories. Scientific information on biodiversity reflects in more detail the representatives of many systematic groups of flora and fauna in the Lower Prut Scientific Reserve and, unfortunately, less is known about the biological diversity of forests, lakes (including Manta), steppe sectors etc. from the Lower Prut Area.

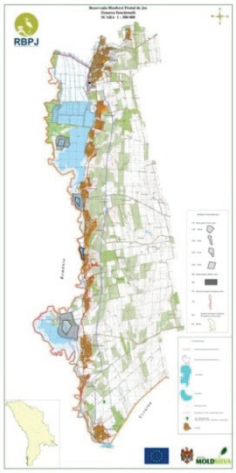

Figure 1. LPBR zoning (original).

Figure 2. Brânza Puddle (original).

Figure 3. Bird fauna of the Manta Lake (original).

In this study, the distribution of threatened species is represented in the following three geographic units: habitats, ecological systems, biomes.

Habitats. Worldwide, forests are the most important habitats for birds – 9,407 species and amphibians – 5,708 species, the latter registering here the largest number of threatened species. For amphibians, wet habitats are particularly important, especially for those species, which are in the larval stage. Recently, the tendency of both birds and amphibians to use artificial habitats was mentioned.

Ecological systems (ecosystems). The simplest assessment of the distribution of threatened species is to divide the surface of the planet into three ecological systems: terrestrial, freshwater and marine. On Earth, 1,388 species are listed as threatened for freshwater ecosystems. In our study we will analyze aquatic, marsh, meadow and forest ecosystems.

Biomes. Evaluating the distribution of threatened species on a finer scale is possible through biomes. Biomes represent global-scale variations in the structure, dynamics and complexity of terrestrial communities, which are conditioned by key global patterns such as temperature and precipitation. As a result of a classification in the interest of standardization, OLSON et al., (2001) identified 14 types of biomes worldwide. In our study we will operate with the deciduous forest biome type.

Classical research methods were used in the study of the flora: direct in the field - by covering transects on land, palustral sectors and water bodies (by boat) with direct counting of specimens on sample surfaces. The ecological conditions, the state of the biotopes were described, and data on the hydro-climatic regime were fixed. The collected material was analysed under laboratory conditions (species determination, maps/diagrams, etc.) and conclusions and recommendations were drawn up based on the analysis.

RESULTS AND DISCUSSIONS

According to personal research (BEGU et al., 2012; DENISOV et al., 2021), but also other bibliographic sources (POSTOLACHE et al., 2012), the vegetation of the Lower Prut Scientific Reserve is represented by a wide variety of communities of vascular plants, numbering about 270 species, especially hygrophytes and hydrophytes. In the north and northeast of the lake, where, through several tributaries, the flood waters enter, there is an intense accumulation of alluvium, which continuously clogs these areas and thus reduces the surface of the lake, creating favourable conditions for swamping and the development of reeds (*Phragmites australis*) and rushes (Typha angustifolia). Willows (*Salix alba*) and reeds (*Salix fragilis, S. viminalis, S. triandra*) are widespread, with the presence of the white and the black poplar (*Populus alba, P. nigra*).

Quite valuable are the hornbeam (*Trapa natans*), the floating fish (*Salvinia natans*), the white-water lily (*Nymphaea alba*), the marsh fern (*Thelypteris palustris*) etc. with protection status Endangered (EN) or Critically Endangered (CR).

The faunal complex is specific to aquatic ecosystems; they serve as a nesting place for birds and during seasonal migrations, and as a place of rest and food for migrating ones. Some bird species such as the common pelican (*Pelecanus onocrotalus*), curly pelican (*Pelecanus crispus*), great egret (*Egretta alba*), yellow heron (*Ardeola ralloides*), shoveler (*Platalea leucorodia*), gypsy (*Plegadis falcinellus*), european eel (*Anguilla anguilla*) are critically endangered (CR).

The dynamics of the area of habitats and the number of monitored species. Based on the official information, obtained from statistical reports, scientific publications, official documents, etc., it was found that the total surface of the protected area (originally the Lower Prut Scientific Reserve) underwent partial changes, from 1691 ha, in the year of foundation 1991, to 1755 ha, in 2013 (Fig. 4) and 14771 ha, in 2015, with the foundation of the creation of the Lower Prut

Biosphere Reserve. That area was subjected to more pronounced fluctuations regarding the surface covered by water (Fig. 5), which increases suddenly, from 446 ha in 1991, to 1255 ha in 1993, with a return from 1994 to 2001 to 650-628 ha , and from 2011, up to approx. 800 ha, with a decrease in 2016 to approx. 650 ha. Some variables of the surface of Lake Beleu can be explained by the fact that: the lake was completely dry in 1990, and in 1991 there were long floods, which increased both the surface and the water level, proven by the depth of 3-4m almost over the entire lake area. The effect of these long floods was manifested by the expansion, in particular, of the areas of pastures and forests (Fig. 6), but also the increase of the number of species of birds and plants, and to a lesser extent, of mammals and fish. So, we can assume that the maintenance of a surface of the water body of approx. 700-900 ha provides an ecological optimum from a hydrological and biocenotic point of view for species vulnerable to the ecological factor of humidity.

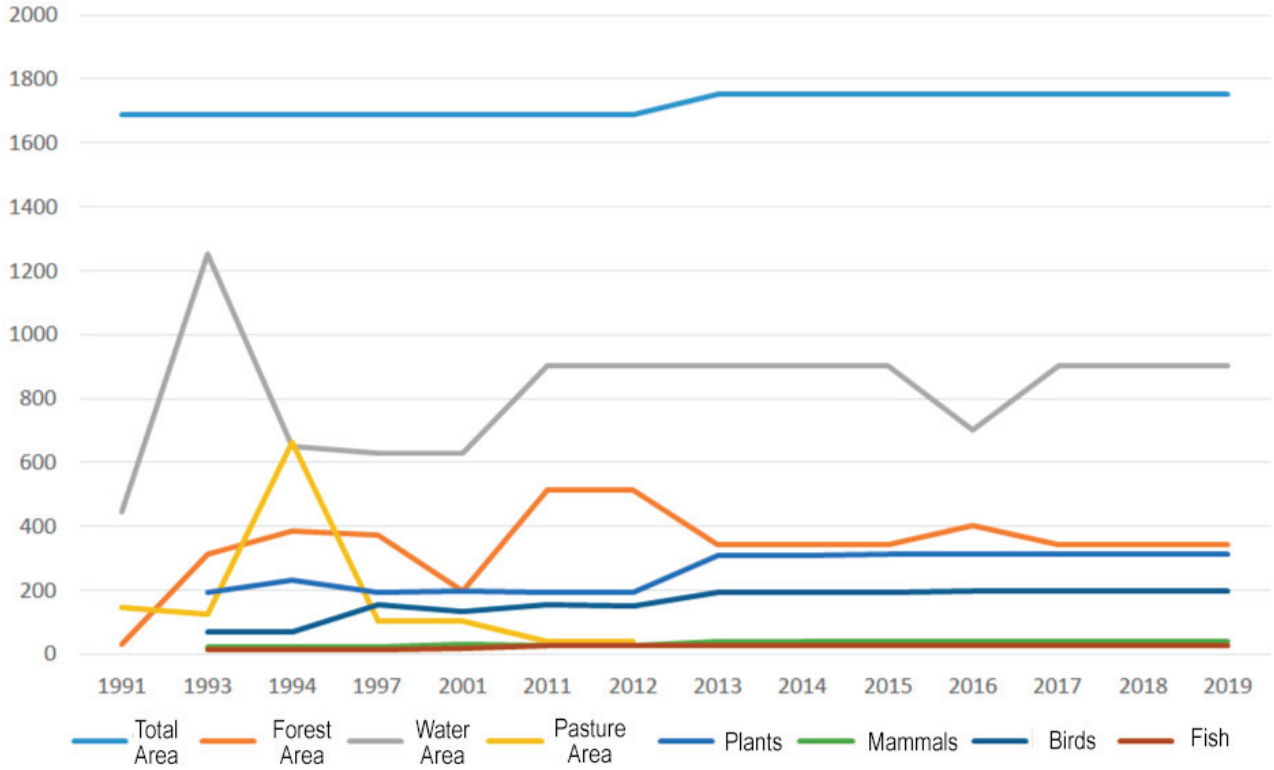

Figure 4. Modification of the surface area of habitats and the number of species in LPSR and LPBR.

Figure 5. The Beleu Lake after the floods (original).

Figure. 6. Extension of the forest towards the center of the lake (original).

Vulnerability of plants to climate change. Among the valuable species, we mention 3 species of higher plants with spores, which show increased vulnerability to climate changes, in particular, to humidity. The species *Equisetum palustre* from the Phylum *Equisetophyta*, in the event of prolonged drought conditions, will be significantly affected being a hygrophytic plant, a fact that requires us to place it in the Rare category (regrettably, it was not previously included in the List of species of rare plants (NEGRU, 2002) and inexplicably, no species of *Equisetaceae* is included in the Red Book of the Republic of Moldova (***. RB RM, ed. 3, 2015).

For the two endangered species (EN) of ferns, the limiting moisture factor will manifest itself differently. In the event of an increase in the water level, the floating species *Salvinia natans* will remain viable and its area will expand, and in the event of a decrease in the water level, the specimens that will appear on land will perish, while the species *Thelypteris palustris*, in the first case, will be covered of water, and in the second case it will remain on land and, according to the law of tolerance (Shelford, 1913), with time, both from excess and from insufficient water, will perish.

According to the Management Plan of the Lower Prut Biosphere Reserve (2019), 310 plant species are currently registered in this area. However, taking into account the fact that most of the described species have an increased abundance and have a fairly wide ecological value, a detailed analysis is not necessary, perhaps with only some exceptions (as food resources, breeding station, habitat for temporary refuge etc.).

Among the 24 species of threatened flowering plants, 2 species are critically endangered (CR) – the hydrophyte *Trapa natans* and the mesoxerophyte *Sternbergia colchiciflora*, the latter being recorded only around Văleni commune (***. CR RM, 2015). If for *Sternbergia colchiciflora* the main risk is the increase in temperature that will decrease the air and soil humidity, then for *Trapa natans* the basic threat is the decrease of the water level to minimum values, causing the retention of many plants on land, which will eventually dry out (Law of the critical values of the ecological factor DEDIU (1989): if at least one of the ecological factors approaches or goes outside the critical values, death awaits the individual).

Vulnerability of mammals to climate change. According to previously published studies (MUNTEANU & LOZANU, 2004; POSTOLACHE et al., 2012), as well as more recent ones (PALADI & NISTREANU, 2018), 40 species of mammals are registered in the Lower Prut Zone, one of which is threatened by climate change. Of these, only one species - the european mink (*Mustela lutreola*) is assigned to the critically endangered category (CR) in the Red Book of the Republic of Moldova (2015), at the same time being an endemic species for Europe. As mentioned in the aforementioned bibliographic sources, the frequency in the area is very rare (RR) and the reproductive population is at the critical limit. In the breeding areas, the species is very vulnerable to the drop of the water level below 0.5 m, and for the winter it inhabits only the pools that do not freeze. So, ensuring the optimal water level for reproduction and wintering is decisive in the survival of given species. According to the static data presented by LPSR, the number of individuals drops from 12-15 in 2011-2012 to 2-1 in 2013-2015, the cause being probably also related to the water level.

Vulnerability of birds to climate change. Research in the Lower Prut Area has its beginnings in the Lower Prut Scientific Reserve, founded in 1991, the strong argument being the richness and originality of the aquatic birdlife in the Beleu Lake. Birds were and remain the main valuable systematic group in this territory, at first more restricted (LPSR), then more extensive (ZUII Ramsar), and in the last variant extended to the Lower Prut Biosphere Reserve. Thus, one of the first official reports on valuable biodiversity monitored by LPSR collaborators is that from 1993, in which 68 species of birds are indicated. Later, the number of registered species increases to 132-157 - between the years 1997-2012, and with the foundation of the creation of the LPBR (with the absorption of new territories), in 2016-2018, 196-199-192 species of birds are registered (PALADI & NISTREANU, 2018).

Of course, the ecological importance of all the bird species recorded annually is very high, both in ensuring the functionality of the aquatic and swamp ecosystems in the LPBR, as well as a scientifically proven ecological management. However, most species have a rather broad ecological valence to the main environmental factors, so we cannot talk about an obvious direct or indirect threat. The basic attention, in our study, was directed towards the 34 species included in the Red Book of the Republic of Moldova (2015), many of them also being found on the lists of other international treaties regarding the conservation of biodiversity: RL IUCN – 6 species, Convention CITES – 7 species; Birds Directive – 18, Bern Convention – 31, Bonn Convention – 22 species. Of the 34 threatened species, 12 are classified as Critically Endangered (CR), 4 – Endangered (EN) and 18 – Vulnerable (VU). The Critically Endangered (CR) include: little cormorant (*Phalacrocorax pygmaeus*), also protected by IUCN RL, DP(I); CBr(II); CBn(II), which prefers the presence of shrubs or trees for rest and drying, but also sufficient fish resources. The curly pelican (*Pelecanus crispus*) is a more recently recorded species in the LPBR, and no more than 500 nesting pairs are recorded for southern Europe (SVENSON & DELIN, 1992: Romanian version by MUNTEANU (1999). For the first time the species is mentioned together with the common pelican (*Pelecanus onocrotalus*) in LPSR in 1993 (approx. 900 specimens), and in 1994 – approx. 600 specimens, following that approx. 1500-2500 specimens will be recorded annually after 2011. Since the curly pelican can also fish in deep waters, compared to the common one, it will be less threatened in the case of large-scale flooding over a long period (over 2 weeks); Species black stork (*Ciconia nigra*), shoveler (*Platalea leucorodia*), gypsies (*Plegadis falcinellus*), mallard white (*Oxyura leucocephala*), red duck (*Aythya nyroca*) catalogued as Red Book; DP(I); CBr(II); CBn(II); some - CITES (II) and RL IUCN - also prefer marshy habitats, where they acquire food consisting of invertebrates, amphibians, small fish, and some also need shrubs (the gypsy) or floating islands (the red duck) for reproduction. Birds of prey with CR status: white-tailed eagle (*Haliaeetus albicilla*), red jay (*Milvus milvus*), osprey (*Pandion haliaetus*), danube falcon (*Falco cherrug*) prefer forests, specifying

old forests with glades - for red jay, clear waters - for the fishing ruffian or high concrete pillars – for the danube falcon. These species are also threatened by illegal international trade, so that they are included in Appendix II of the CITES Convention (the red line was recently proposed by Switzerland).

Vulnerability of amphibians and reptiles to climate change. Amphibians and reptiles are among the most endangered organisms worldwide, a fact that leads the IUCN to include, as a priority, in the monitoring study all species known at the current stage. Among vertebrates, mammals and birds are fully evaluated, and amphibians – 99%. The share of threatened species is quite high in the case of amphibians – 30%, reptiles – 31% and fish – 37% of the number of assessed species (IUCN, 2008). Thus, the vulnerability of all amphibian species is related to the insufficiency of optimal ecological habitats (climatic, physical-chemical, biocenotic) for development and reproduction. They populate shady and humid places, because, if exposed directly to the sun's rays, they would immediately lose water from the body following evaporation through the skin (COZARI et al., 2003). Mature frogs live on land and take oxygen from the air, both through their underdeveloped lungs and through skin that must be constantly moist. It is known that all amphibians, during the reproduction period, are linked to the aquatic environment. Just these few exposed moments about the way of life of amphibians demonstrate their extreme vulnerability to climate change. In the Lower Prut Area, 9 species of amphibians are identified (PALADI & NISTREANU, 2018), which constitutes 69% of the number of species in the republic. Amphibians have favourable conditions for nutrition and reproduction throughout the LPSR territory, but less favorable in the rest of the territory, included in the LPBR. Among the 9 species – 5 are included in the Red Book of the Republic of Moldova (2015), and the crested triton (*Triturus dobrogicus*) may inhabit the waters of the Beleu Lake and its tributaries (POSTOLACHE & MUNTEANU, 2012). The brown bullfrog (*Pelobates fuscus*) is Critically Endangered (CR), it inhabits forests in river meadows and areas bordering water bodies. Pollution, but especially the drying up of lakes and ponds in the RBPJ, would lead to the extinction of the species, which is already very rare in the reserve.

Vulnerability of invertebrates to climate change. According to the data contained in the Red Book of the Republic of Moldova (2015), 9 valuable species of invertebrates can be found in the habitats of the LPBR area, which are catalogued as: Vulnerable (VU) – 8 species and Critically Endangered (CR) – one species. Aquatic, marshy, wet meadow habitats are preferred by the linden dragonfly (*Erythromma lindenii*) - Critically Endangered (CR), imperial dragonfly (*Anax imperator*) - Vulnerable (VU), which are threatened with extinction due to habitat destruction and watershed drying.

Vulnerability of valuable ecosystems to climate change. According to the SCIENTIFIC FOUNDATION STUDY FOR THE CREATION OF RBPJ (2015), of the total area of LPBR 14771.04 ha, 824 ha - are forest land, 356 ha - forests, 306 ha - reedbeds, 244 ha - swamps, 124 ha – meadows. The protected zones and areas constitute: ZUII Lower Prut Lakes - 19152.5 ha; LPSR – 1691 ha, Geological and Paleontological Nature Monument – the outcrop near the village of Văleni – 3 ha, the Vadul lui Isac Forest Nature Reserve – 68 ha.

Forest ecosystems (356 ha). The forest vegetation consists of 2 types of formations - willows and brambles, which predominate in higher places. Willow forests (*Salix alba*) are more common in the higher sectors of the northern LPSR, and in the South, along the Prut - there are only clumps or solitary trees. Răchitisurile (other species of *Salix*) – predominates in the NE, forming a belt on the shore of the lake. According to the FOREST MANAGEMENT OF THE PRUTUL DE JOS SCIENTIFIC RESERVE (2015), the territory has an average altitude of 5 m, is flat, meadow, with an inclination of 5 degrees. Geologically, the LPSR is located on leossiode deposits and fluvial-lacustrine or fluvial materials. Hydrologically, the Beleu Lake, with an area of 700.8 ha, is subject to intense clogging processes as a result of torrential rains. Climatologically, the factors with a negative impact are the floods related to the Beleu Lake, in particular, the late flooding of fields with marshes, then their freezing, as well as the long droughts of recent years, with very high temperatures, sometimes over 40 degrees. The soil is represented by only one type - alluvial gleic (401.9 ha), which is beneficial to poplar and willow trees. About 99.5% of the dendrological composition is white willow, the rest – wicker and white poplar.

All the forests in Moldova fulfill only the ecological role, not to mention those in LPBR. The average age of trees is 35 years. Age Class I (1-20 years) - 45%; II (20-40 years) -16%, III+IV (over 40 years) - 39%, so 39% of forests are in ecological decline. The reason - long floods, droughts accompanied by high temperatures. Totally affected by drying are 29%: stands with weak drying - 19%, medium - 9, strong - 1, very strong - 0.2 ha. With regard to hunting, fishing, collecting snails, acorns, mushrooms, plants, etc., but also recreation, tourism, sports - according to the State Protected Natural Areas Fund Law, Art. 26, p. e, f, g - these activities are banned for the next 10 years, probably until 2025 (exception – scientific research). The forest fund is affected by fires, especially the reeds, approx. 200 ha. Drought favours the emergence of diseases and pests, manifested by invasions of phytophages and xylophages. As measures to reduce the negative effects, it is recommended to stimulate the reproduction of insectivorous birds. In order to reduce the processes of erosion and swamping, measures are proposed to retain water on the slopes through afforestation, dams, dykes, etc. In the last decades, the clogging processes intensified, especially after the widening of the Manolescu gorge (the 60s of the 20th century), thus the islets disappear, the water depth decreases and the brambles and willows expand towards the center.

Marsh and aquatic ecosystems (306 ha - reed beds, 244 ha - ponds). The clogging processes, following the floods in the Prut River, as well as the erosion of the nearby slopes, as a result of the torrential rains, as well as the increasingly pronounced droughts, will accelerate the processes of lowering the water level in lakes and ponds, large sectors turning into swamp ecosystems, and the siltation and drying processes of swamp sectors, will lead to their

transformation into wet meadows, with the replacement of hydrophytic vegetation with hygro- and mesophytic ones. Thus, according to POSTOLACHE et al., (2012), in the years 2006-2008 the reed almost completely disappeared, its place being taken by other plants, especially by the marsh pepper (Persicaria hydropiper). On the sectors where the geological rocks contain soluble salts, salinization processes will occur, with the appearance of halophytic plants.

Meadow ecosystems (124 ha). They are represented by fragmented surfaces, arranged among the forested sectors of the LPBR or bordering the steppe lands around/or within the composition of the LPBR. They have higher stability due to the wider ecological valence of edifying grass species. In case of intensification of the aridization processes, the meadow vegetation can benefit from the groundwater reserves, through the well-developed root system, thickened roots or they can survive the critical period through metamorphosed stems (rhizomes, bulbs, tubers).

CONCLUSIONS

1• For valuable species, the most important, but also vulnerable, were the aquatic and marshy, meadow and forest ecosystems; and limnicolous habitats, muddy, with sandy-stony facies, thickets, sedges, reeds.

2. • Based on the fact that, unlike animals, plants, for the most part, are connected to the substrate, they are the most vulnerable to climate change, because they will not be able to react promptly to the impact of environmental factors, and survival through spores, seeds and vegetative organs offer minimal chances.

3. • Among animals, the most vulnerable to climate change are bird species, followed by amphibians and reptiles, then mammals, fish and invertebrates, assigned to both the IUCN threat categories - Vulnerable, Endangered, Critically Endangered, Low Risk, and other lists, annexes of Conventions or Directives.

4. •The richness of the specific diversity and quantity of natural biological resources in the RBPJ requires in-depth multilareral/systemic studies for all groups of organisms, including, bacteria, fungi, lichens, algae, mosses, invertebrates, etc., to ensure the functionality of ecosystems under conditions optimal, reduce the risk of vulnerability to climate change and give the possibility of rational, scientifically substantiated use of biological resources by the local population.

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