Ecological monitoring of aquatic and terrestrial ecosystems based on the distribution of model groups of living organisms

Sergey Kozminov[1*], *Elena* Krapivina[1], *Anzor* Paritov[1], *Svetlana* Khadzegova[1], and *Zuleikha* Lukyaeva[1]

[1]Federal State Budgetary Educational Institution of Higher Education "Kabardino-Balkarian State University named after H.M. Berbekov", Nalchik, 360004, Russian Federation

Abstract. The paper presents the results of the analysis of the use of living organisms as bioindicators and model groups in the ecological monitoring of natural ecosystems in various landscapes. The results of the analysis of the distribution of dragonflies and macromycetes in aquatic and terrestrial ecosystems, the taxonomic composition of populations and individual communities showed a relationship with physical-geographical and natural-climatic conditions. The distribution of dragonflies is heterogeneous, associated with the characteristic features of water bodies and terrestrial biotopes, the nature of saprobity and plant formations. The distribution of macromycetes is determined by substrate specialization, the composition of the dendroflora of mycobiotes of different altitudinal zones and belts. Features of the distribution, allows you to use these groups of organisms as model objects for the organization of environmental monitoring.

1 Introduction

Preservation of taxonomic richness and species diversity, ranges of populations of different regions, protection of specific species, requires the creation of methods for the rational use of biological resources. The search for model groups of living organisms as bioindicators of the habitat and physical and geographical conditions will significantly improve the quality of monitoring ecosystems of various ranks. Various technogenic and agro-economic processes indirectly or directly affect the composition and structure of natural populations, which determines, for a long time, the dynamics of development and functioning of ecosystems in various natural geographical zones [1]. Only specific taxa, characteristic of different regions, their natural and climatic conditions and landscapes, can be model objects and used as bioindicators, as well as organizing ecosystem monitoring. The definition of taxa of bioindicators and their complexes as model groups is based on the identification of ecological and biological features, life cycles, distribution and habitat, fully reflecting the picture of changes occurring in the structure and all levels of ecosystems. The defining task in assessing ecosystems disturbed and undisturbed by anthropogenic impact is the study of

* Corresponding author: s_g_k@mail.ru

specific regional faunistic, floristic complexes and mycobiots, which are not fully studied and their taxonomic appearance is not complete, with the existing opinion that they determine significant biogeocenotic work. Therefore, the study of taxa of insect populations and fungal complexes that exist for a long time in a particular area, associated with physiographic and climatic conditions, adaptive ecological and morphological plastic variability, is of great interest in identifying bioindicator species.

Among amphibiotic insects developing in aquatic and terrestrial environments, the most interesting are dragonflies (Odonata), among fungal organisms, macromycetes (Fungi), which have a substrate specialization for the main woody plants of terrestrial ecosystems. Imago and dragonfly larvae, known for their biological progress, inhabit various aquatic and terrestrial ecosystems and their biotopes of various types. Taxa of the order inhabit various aquatic, semi-aquatic and terrestrial biotopes, live in plains, foothills and mountain zones, inhabit stations with contrasting environmental factors of habitat conditions. Different life phases of dragonflies are characterized by the formation of interactions with specific complexes of habitat factors that determine adaptive ecological fitness [2-3]. The development of bioindication of ecosystems is based on model taxa of dragonflies, which are quite sensitive to changes in aquatic and terrestrial habitats, drying, drying up, or disappearance of aquatic biotopes, and deterioration of water quality in the larval stage of development [4-6].

The structure of the macromycete biota and the formation of the taxonomic composition are determined both by natural and climatic factors of landscapes and by the species composition of tree species. The natural composition of the dendroflora is the main link in the taxonomic structure of the mycobiota community. The distribution of macromycetes along the altitudinal vector and zones is associated with substrate specialization. Where a variety of climatic features, soil cover and flora create various unique complexes, there is created a species diversity of macromycetes, specific mycobiota and growing conditions for rare representatives of the group. Such taxa determine the uniqueness of natural landscapes, create the prerequisites for creating a number of definitive keys of species [7-8] with a complete list of ecological specialization and morphology of representatives of macromycetes [9-10]. Biotopes of ecosystems of open terrestrial, near-water and forest landscapes were studied, observations were made on ecological specialization, and the distribution of organisms along the altitudinal vector.

2 Materials and Methods

The study of two groups (macromycetes, dragonflies) as bioindicators and ecosystems was carried out on the territory of the Central Caucasus with a high level of specific and endemic fauna and flora. The territory, due to its unique regional geographic location (the central part of the North Caucasus), has diverse and even specific landscapes, ecological habitats with contrasting habitat conditions determined by mountain conditions. Geographically, the territory is differentiated according to the altitude vector, there are flat (up to 500 m above sea level), foothill (500-1000 m above sea level) and mountain zones (m above sea level). The vegetation is differentiated into altitudinal zones: semi-desert (up to 50 m above sea level), steppe (up to 200 m above sea level), forest-steppe (up to 300 m above sea level), oak forests (up to 1000 m above sea level), beech forests (up to 1600 m above sea level), pine-birch forests (up to 2250 m above sea level), subalpine (up to 2300 m above sea level), alpine (up to 3500 m above sea level) and nival (over 3500 m above sea level). During the field work, which was carried out during the growing season, the route method (100 m) was used. The actual collection, species identification, and cameral processing were carried out according to generally accepted methods [7–12]. The biotopes of ecosystems of open terrestrial, near-water and forest landscapes were studied.

Observations were made on ecological specialization, the distribution of organisms along the altitude vector. Refinement of original materials, adaptive features and verification of taxonomic affiliation were confirmed in the laboratory.

3 Results and Discussion

Diverse phytocenoses of the Central Caucasus provide a historically established complex and taxonomic composition of representatives of various groups and taxa inhabiting them. The river floodplain (up to 900 m above sea level) includes alder forests, which occupy significant areas of the river network. In the upper part of the forest belt, subalpine birch forests and rhododendron (Rhododendron caucasicum Pall.) are widespread. Characteristic oak forests are formed by Quercus robur L. The most common plant complex is mixed grass oak forest, the shrub layer is often dominated by Corylus avellana L., Euonymus europae L., Cornus mas L., Mespilus germanica L., as well as hops and forest grapes. Another plant formation of the oak forest is the hornbeam-hazel oak forest with dense undergrowth (hazel, mountain ash, European spindle tree) and grasses in the grass cover. In the flat part, often flooded with water during floods, there are forests in the first layer with a predominance of Populus alba L., P. tremula L., P. nigra L. The second layer is represented by species of the genus Alnus (taxa A. incana (L.) Moench, A glutinosa (L.) Gaertn., A. barbata (C.A. Mey.) Yalt.). The dense undergrowth consists of taxa: common viburnum (Viburnum opulus L.), Caspian willow (Salix caspica Pall.), cherry plum (Prunus divaricata Ledeb.), sea buckthorn (Hippophae rhamnoides L.), grasses dominate in the grass layer. The central part of the forests is formed by beech forests with a predominance of oriental beech (Fagus orientalis Lipsky). There are taxa: Caucasian hornbeam (Carpinus caucasica Grossh.), rough elm (Ulmus glabra Huds.), Caucasian lime (Tilia caucasica Rupr.), Norway maple (Acer platanoides L.), common ash (Fraxinus exselsior L.), sweet cherry bird (Cerasus avium (L.) Moench), hop hornbeam (Ostrya carpinifolia Scop.), . The black elder shrub (Sambucus nigra L.) is common in beech forests. The grass cover has great taxonomic diversity and a high degree of coverage. Pine forests consist of Pinus hamata D. Sosn. (within 1000-2000 m above sea level). Among the formations of pine forests, the following stand out: rocky pine forest, grass-forb pine forest, birch pine forest [13].

The mycobiota of the plain zone is characterized by macromycetes of the following species: Pholiots mutabilis Quel., Pluteus cervinus (Sch.: Fr.) Kumm., Rhodopolium abortivus (Berk.: Curt.) Sing., Daldinia concentrica (Bolt.: Fr.) Cesati: De Not., Hypholoma capnoides (Fr.: Fr.) Kumm, Kueheromyces mutabilis (Schaeff.: Fr.) Sing., K. vernalis (Peck.) Sing.: A.S. Sm., Collybia dryophylla (Bull.: Fr.) Kumm., C. acervata (Fr.) Kumm., Mycena galericulata (Scop.: Fr.) S.F. Gray, M. rosella (Fr.: Fr.) Kumm., Dedaleopsis confradosa (Bolton.: Fr.) Schrot., Inonotus hispidus (Bull: Fr.) Karst., Onnia tomentosa (Fr) Karst., Fomes fomentarius (Fr .) Fr., Polyporus squamosus (Huds.: Fr.) Fr., Fomitopsis pinicola (Sw.: Fr.) Karst., Paxillus involutus (Batsch.: Fr.) Fr., Pulmonaris erygii (DC.: Fr.) Quel., Alnicola scolecina (Fr.) Romagn. The dominant families among macromycetes are Tricholomataceae and Coriolaceae. The group of oak symbiotrophs includes Lactarius vellereus (Fr.: Fr.) Fr., L. volemus (Fr.) Fr., Xerocomus chrysenteron (Bull.: St. Amans) Quel., X. subtomentosus (L.: Fr.) Quel. These taxa are widespread in various types of deciduous and mixed forests. Armillaria mellea (Vahl.: Fr.) Kumm., Mycena galericulata (Scop.: Fr.) S.F. Gray and other wood-dwelling species of oaks and conifers found in broad-leaved forests. Leaf litter includes Marasmus alliaceus (Jacq. :Fr.) Fr., Festulina gepatica (Sch : Fr) With and 13 species of the genus Cortinarius (C. ceraceus (Pers.:Fr.) Fr., C. cereifolius (Mos.) Mos., C. crassus Fr., C. variecolor (Pers.: Fr.) Fr., C. pholideus (Fr.: Fr.) Fr., C. trivialis Lange, C. violaceus (L.: Fr.) S.F. Gray, C. bulliardii (Pers.:Fr.) Fr., C. malicorius Fr., C. odorifer Britz, C. semisanguinea (Fr.) Gill, C. pseudosulphureus Hry.:

P.D. Orton, C. collinitus (Fr. Fr.). Macromycetes taxonomically belonging to 16 genera (11 families) are found in the forest belt: Rhodopolium abortivus (Berk.: Curt.) Sing., Daldinia concentrica (Bolt.: Fr.) Cesati: De Not., Hypholoma capnoides (Fr.: Fr. .) Kumm, Kueheromyces mutabilis (Schaeff.: Fr.) Sing., Collybia dryophylla (Bull.: Fr.) Kumm., C. acervata (Fr.) Kumm., Pluteus cervinus (Sch.: Fr.) Kumm., Mycena galericulata (Scop.: Fr.) S.F. Gray, M. rosella (Fr.: Fr.) Kumm., Inonotus hispidus (Bull: Fr.) Karst., Dedaleopsis confradosa (Bolton.: Fr.) Schrot., Onnia tomentosa (Fr) Karst., Fomes fomentarius (Fr .) Fr., Paxillus involutus (Batsch.: Fr.) Fr., Fomitopsis pinicola (Sw.: Fr.) Karst., Polyporus squamosus (Huds.: Fr.) Fr., Naucoria semibicularis (St. Amans) Quel. In the mountain zone, which have contrasting habitat conditions, the dominant macromycete families are Tricholomataceae (69 taxa), Russulaceae (23 taxa), Agaricaceae (15 taxa), Cortinariaceae (46 taxa), Coprinaceae (11 taxa), Strophariaceae (13 taxa). In forests with a predominance of Caucasian beech among macromycetes, the dominant species are Armillaria mellea (Vahl.: Fr.), A. galica Merxm.: Romagn., Flammulina velutipes (Curt.: Fr.) Karsten, Oudemansiella mucida (Schrad.: Fr.) Hőhn., Pleurotus osteratus (Jacq.: Fr.) Kumm., P. pulmonarius (Fr.: Fr.) Quel. Destructive wood (the last stage of destruction) is inhabited by taxa of representatives of the genera Pluteus, Crepidotus, Lentinus, Mycena (Pluteus cervinus (Sch.: Fr.) Kumm., P. galeroides P.D. Orton), Mycena crocata (Schrad.: Fr.) Kumm. , M. galericulata (Scop.: Fr.) S.F. Gray, Crepidotus mollis (Schaeff.) Staude, Kueheromyces mutabilis (Schaeff.: Fr.) Sing.). Xylotrophs are represented by two taxa (Marasmus alliaceus (Jacq.:Fr.)Fr., Xerula radicata (Relhan: Fr.) Dörtelt). Oak symbiotrophic macromycetes can form bonds with deciduous and coniferous tree species and are quite common in broad-leaved and mixed forests (Lactarius vellereus (Fr.: Fr.) Fr., L. volemus (Fr.) Fr., Xerocomus chrysenteron (Bull.: St . Amans) Quel., X. subtomentosus (L.: Fr.) Quel.). Among the symbiotrophs of Caucasian pine (Pinus kochiana Klotsch), taxa of macromycetes of the genera Gomphidius, Lactarius and Russula (Gomphidius roseus (Nees: Fr.) Gillet, G. glutinosus (Sch.: Fr.) Fr., G. viseidus (L.) Fr.) ., G. rutilus (Schaeff.: Fr.) Miller, Lactarius deliciosus (L.: Fr.) S.F. Gray var. pini Vassilk., L. scrobiculatus (Scop.: Fr.) Fr., L. salmonicolor Heim: Leclair , L. pubescens (Fr.) Fr., L. torminosus (Sch.: Fr.) S.F. Gray, Russula veternosa Fr., R. decoloran (Fr.: Fr.) Fr, R. puellaris, R. vesca Fr. , R. paludosa Britz., R. adusta (Pers.: Fr.) Fr., R. eruthropoda Pelt., R. rosacea Pers.: S.F. Grey, Sulus luteus (L.: Fr.) Roussel).

When studying the structure of the taxonomic composition of populations and its distribution by stations, the composition of the community of individual biotopes, adaptive morphological and ecological indicators for living in aquatic and terrestrial environments, it is necessary to imagine the boundaries of the range of a particular species, which are a complex of various factors that have developed historically and are active currently. Most dragonfly taxa expand the boundaries of the space they inhabit, interact with the environmental factors of new habitats existing in new ecosystems and their biotopes. The distribution of dragonflies is limited by a variety of factors, which include both biotic and abiotic. The impact of anthropogenic factors is great, which are diverse and can both lead to the spread of any taxon and the disappearance of a species from the historically occupied territory [1]. The emergence of adaptive features and their speed, depending on the effects on dragonflies, are very diverse, they include both abiotic and biotic, and anthropogenic. The rapid response of larvae and adults of dragonflies to these factors is determined by the optimal developmental needs of the terrestrial and aquatic stages of development, the limits of the ecological response of taxa to the action of various factors (complexes). The taxonomic composition of adults and dragonfly larvae is heterogeneous in composition. Of all the species diversity, 13 species are characteristic of lowland ecosystems, 10 species of foothills and 6 species of mountains. The plain and foothill zones differ from the mountain ones in the factors of the aquatic and terrestrial environment in the direction of greater

availability of development conditions from the egg phase to adult dragonflies. Such differentiation is determined primarily by the availability of water stations suitable for the habitation and development of dragonfly larvae, as well as the adaptive capabilities of imago to go through a cycle of terrestrial development in various conditions of the ground-air environment with a provided natural food base. The river network of the Central Caucasus, with its complex hydrological system, ensures the specific development and taxonomic composition of dragonflies within geographical limits and distribution along the altitudinal vector. A distinctive feature of reservoirs and their stations of various types, for a long time, remains weak mineralization, as well as the division of altitudinal zonality according to the degree of presence of organic matter. The plain zone is characterized by polysaprobic biotopes and, to a lesser extent, mesosaprobic biotopes. Typical species for this level of saprobity are the taxa Orthetrum cancellatum L., O. albistylum Selys, Libellula depressa L., Crocothemis erythraea Brulle, Sympetrum meridionale Selys, S. depressiusculum Selys, Platycnemis pennipes Pallas, Erythromma najas Hansemann, Coenagrion puella L., C. pulchellum Vander Linden, Lestes dryas Kirby, Anax imperator Leach, A. parthenope Selys. The foothill zone is characterized by mesosaprobic and, to a lesser extent, polysaprobic biotopes. Dragonfly taxa O. albistylum Selys, L. depressa L., O. albistylum Selys, S. meridionale Selys, L. sponsa Hansemann, P. pennipes Pallas, Gomphus vulgatissimus L. are characteristic of this territory. development of dragonflies by stations, is characterized by representatives of the genus Aeshna, with the most indicative and frequently occurring species of Aeschna cyanea Müller. Oligosaprobic and mesosaprobic habitats are characterized by dragonflies Calopteryx splendens Harris, which develop in rare habitats of this type on the plains and foothills.

The definition of dragonflies as bioindicators is associated with indicators of morphological plasticity, many ecological and biological adaptations (seasonal variability, phenology, summer time, number of developmental stages, time of life cycles), which differentiate the taxonomic composition of adult dragonfly populations and the larval population of water stations. Dragonflies of various taxa form a complex under the influence of the physical and geographical conditions of the habitat and is deeply related to the biological characteristics of various species, their developmental capabilities from the egg and larval phase to the imaginal one. Such an influence primarily affects taxa of southern origin, which, moving into the mountains and settling in water and land stations, are subject to ecological restructuring of all life cycles. Taxa of northern origin develop only in mountainous landscapes, however, they can also inhabit the upper part of the foothill zone. The number of taxa in different geographic zones is heterogeneous, has its own core of populations, which determine the faunistic complex differentiated by altitudinal vector. The temperature factor is the most important in the differentiation of the structure of populations, ontogeny of larvae, breeding and development of adult dragonflies as a reproductive stage. According to the nature of habitat and duration of development, dragonflies are divided into ecological groups: taxa that live only in stagnant water habitats and their coastal terrestrial biotopes; living mainly in stagnant and low-flowing water habitats with coastal habitation of adult dragonflies, or a small departure from breeding sites to open areas of landscapes; living in flowing habitats with coastal habitation of adult dragonflies, sometimes making a small migration to herbaceous or shrubby plant communities. The qualitative composition of near-water terrestrial and aquatic vegetation has a direct impact on the taxonomic structure and quantitative indicators of dragonflies due to its substrate for metamorphosis, imago breeding, or shelter and rest. Dragonfly species of the suborder Anizoptera are practically not affected by the change of plant communities, but their larvae prefer the soil structure of water stations, consisting of coastal plant litter and bottom detrital sediments. At the same time, the natural food supply of dragonflies, in terms of its qualitative and quantitative indicators (species composition, abundance,

biomass), is directly dependent on the plant communities of landscapes of various geographical zones.

4 Conclusion

The results showed the dependence of the taxonomic composition of dragonflies and the distribution of individual species on the qualitative and quantitative indicators of aquatic and terrestrial ecosystems. Dragonfly taxa S. depressiusculum Selys, L. sponsa Hansemann, 1823, E. najas Hansemann, L. depressa L., O. cancellatum L., O. albistylum Selys, Ae. cyanea Müller, A. parthenope Selys can be used as bioindicators of the aquatic and terrestrial environment of ecosystems of various levels in ecological monitoring. The distribution of macromycetes is interconnected with the distribution of tree formations, reflecting the geographical zonality and altitudinal zonality. The taxonomic composition of the vegetation cover of landscapes forms the mycobiota of ecosystems with pronounced dominant species: P. erygii (DC.: Fr.) Quel. lives only in the plain zone, F. gepatica (Sch: Fr) With lives only in the foothill zone, and G. viseidus (L.) Fr. - only in the mountains and is specific to its food specialization. Thus, the distribution of macromycetes and dragonflies over altitudinal zones, their terrestrial and aquatic ecosystems is subject to adaptive ecological and biological indicators of different taxa and the physiographic complex of ecosystem conditions. The indicators of the distribution of dragonflies and macromycetes by zones and belts make it possible to use these living organisms as model groups for organizing ecological monitoring of aquatic and terrestrial ecosystems.

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