Principles for protecting the natural diversity of insects at the regional level

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Abstract. Insects play a key role in the biodiversity of regional ecosystems. To effectively protect natural diversity at the regional level, it is important to adhere to certain principles. This article discusses the basic principles of protecting the natural diversity of insects at the regional level. These principles include an ecosystem-based approach, conservation of multiple habitats, protection of endemic species, mitigation of human impacts, Red List species assessment, public engagement, biodiversity research, sustainable land use, collaboration and partnerships, and adaptation to changing conditions. Compliance with these principles contributes to the conservation of insect biodiversity and promotes the health of regional ecosystems.

1 Introduction

According to experts from the World Conservation Union (IUCN), the Russian Caucasus is home to a minimum of 55 invertebrate species (including Gastropoda, Oligochaeta, Malacostraca, Insecta) that are listed on the Red List of Threatened Species (referred to as RL IUCN) with assessments of their risk of global-scale extinction [1]. Out of these species, 50 belong to 5 Insecta orders, primarily Odonata (31 species) and Lepidoptera (8 species). Additionally, many species are known in the North Caucasus, but they are not listed in the RL IUCN for Russia (examples include Allancastria caucasica, Hyles hippophaes, Esper, and Pallas).

In summary, five Insecta species (out of those present in the Russian Caucasus) are classified as "endangered" on a global scale and are labeled as Vulnerable [2]. This global redlisting practice does not align with the extensive entomofauna diversity of the Caucasus, the level of endemism, the current status of local populations of some endemic taxa, the ecological conditions of biodiversity and endemism centers, which are susceptible to the influence of alien phytophagous species, and the escalating impacts of agricultural or recreational activities, urbanization, and infrastructural fragmentation in the region.

The threat of extinction, whether local or complete, sudden or gradual, looms over entire community types, including those rich in endemic and relic species, such as troglobionts, sub-Mediterranean, subnival, Colchian, steppe, semi-arid, and petrophilic communities. In contrast, there are stable or even increasing trends in regional

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metapopulations of many Odonata species. These trends are inconsistent with the fact that the majority of local endemics in the Russian Caucasus are absent from the list of RL IUCN species [3].

2 Research Methodology

The legislative protection of threatened insect species in Russia, as reflected in the Red Book of the Russian Federation and regional Red Books, progresses slowly and conservatively. While there are 40 insect species included in the new Red Book of the Russian Federation, only 14 of them, or 35%, are primarily or exclusively found in the Caucasus region. The significance of the Caucasian entomofauna for Russia's overall biodiversity and the current threats to various representatives of this fauna are not adequately considered. Western Caucasian endemic species dominate the protection efforts.

The regional Red Books of most Caucasian regions in Russia provide limited lists of protected insect species without considering real limiting factors, population dynamics, and the status of these species in neighboring Caucasus regions. To address this, a concept for selecting insect species for legislative protection was developed. This concept involves assessing the probability of a regional metapopulation's extinction over a specified period (e.g., 20 years) to assign a species to one of the IUCN Red List "threatened" categories (CR, EN, VU, occasionally NT, DD) [4].

In the second stage, additional assessments consider the species' significance in the context of Russia's biota and its suitability as an indicator of the state of communities or as an umbrella species. The priority gradations for inclusion in regional Red Books are as follows:

1) Regional endemics (those with a range entirely within a specific Russian region).

2) Species with the only local population in the Russian Federation within a specific region.

3) National endemics (species with a range limited to Russia).

4) Relict species (limited to "threatened" species).

5) Species from international legal acts ratified by Russia.

6) Species from higher Red Data Books in Russia (with special categorization for relatively safe regional populations).

7) Species included in the IUCN Red List with global threat assessments (RE, CR, EN, VU, and exceptionally NT, DD).

8) Marker species serving as indicators of ecosystem health and potential umbrella species for ecosystem protection and monitoring.

Assigning a species to multiple priority categories underscores its importance and the collective efforts required for its conservation in Russia's biodiversity [5].

This review focuses on insect species found in the Russian Caucasus that are relevant to environmental programs and draws from various verified sources of information. These sources include scientific publications, regulatory legal acts, research and applied research reports, and electronic resources. The information was used from extensive faunal studies that cover broad territories, regional and local faunal reviews for various taxonomic groups, and these sources provide details on distribution, ecology, and other relevant data.

Data on global ranges of insects and their occurrence in the Russian Caucasus were obtained from specialized reviews of specific groups or the region as a whole. The North Caucasus region is particularly rich in endemic insect species, even though the full extent of endemism is not yet fully determined.

However, due to the limited knowledge of many local and regional insect faunas and a lack of expert opinions on their conservation status, not all species could be included in the review. While there are many endemic insects in the Central and Eastern Caucasus, the

review primarily focuses on species in the orders Coleoptera, Hymenoptera, and Diptera from the Russian Caucasus.

Materials from the Red Data Books of nine constituent entities of the Russian Federation were used, along with the legal framework of the Red Book of the Russian Federation [6]. These sources provided valuable information about habitats and assessments of the extinction risk for various insect taxa. Notably, the Red Books of the Krasnodar Territory, the Republic of Adygea, and the Republic of Dagestan provided relatively accurate information.

The review compiles information on 1,322 species from 17 insect orders, which represent potential candidates for territorial protection at the regional level. The information database includes factual data, expert assessments, and preliminary analyses. It particularly focuses on taxa such as Orthoptera, Odonata, Neuroptera, Mecoptera, Lepidoptera, and selected beetle families. These taxa are often the subjects of legal protection efforts. Conversely, some insect groups like Diptera, Hymenoptera, and Homoptera have been less studied, and the database includes information about Red Book species from studied local or regional faunas. In total, 1,200 species from 16 orders met the specified selection criteria for inclusion in the review.

3 Results and Discussions

The Central Ciscaucasia is a region of great interest in terms of its paleofauna. While literature provides limited data on fossil animals in this area, these findings still reveal a significant diversity of species from various taxa. These species have diverse origins, belong to different faunal complexes, and are adapted to specific environmental conditions. They successively replaced each other in the course of the Earth's evolutionary history. However, due to the limited and, in some cases, absent paleozoological data, constructing a comprehensive understanding of the region's fauna is challenging. Consequently, most interpretations remain hypothetical [7].

Various studies in paleogeography, paleoclimatology, and paleobiology have provided some insights into the formation of the region's fauna. These studies suggest that the beginning of the development of the Northern Caucasus' landscape was related to the uplift of the Greater Caucasus during the Upper Paleozoic era. This process contributed to the elevation of the central and western parts of Ciscaucasia, which were previously vast, flat, and minimally dissected with isolated elevations ranging from 200 to 700 meters.

The next phase of landscape development occurred at the end of the Triassic and the beginning of the Jurassic (Rhaetian-Leias). During this time, it is assumed that the Northern Caucasus became fully drained, and a significant peneplain developed during the Lias period. This Rhaetian-Liassic peneplain is regarded as the initial surface for shaping the Northern Caucasus' topography. The subsequent deformation of this surface was linked to the emergence of various morphostructural elements in the region.

By the Middle Jurassic, significant subsidence occurred in the Greater Caucasus region, while the western and central parts of Ciscaucasia experienced uplifts and erosional dissection. In the Late Jurassic, Ciscaucasia was peneplained to a low plain, and large rivers flowed through the region, with their sources located on the Russian Platform. This period was characterized by a humid subtropical climate.

The Southern Caucasus exhibited a strip of a shelf zone along its southern edge and the central Caucasus axis. Some parts of the Northern Caucasus were submerged by the sea, while others underwent uplift and erosional dissection. In the Early Cretaceous, island uplifts with mountainous relief formed in the axial part of the Caucasus. By the Upper Cretaceous, the Northern Caucasus region was primarily characterized by a marine environment, with some small flat islands [8].

At the boundary between the Cretaceous and the Paleogene, these islands began to merge into a single Oligocene Caucasian island. This island expanded over time, forming middle- and low-mountain landscapes in the axial region. These areas had moderately warm and humid climates, which supported deciduous and coniferous forests, as well as subtropical climates and flora in lowlands. The foothills and coastal plains featured a high number of deltas and lakes, with a subtropical and tropical climate and corresponding flora. The climate had a humid subtropical nature.

During the Lower Miocene (approximately 20 million years ago), the Caucasian Island was a low, flat, and minimally dissected land. Its further development involved increased elevation and greater topographical complexity, as demonstrated by pronounced vertical zoning in vegetation distribution. From subtropical coastal regions to broad-leaved forests in the middle zones and coniferous forests at higher elevations. This era marked the beginning of the formation of ancient mesophilic Mediterranean-Turgai vegetation.

In the Middle Miocene (around 14 million years ago), the island's relief gradually decreased, with low-mountain and mid-mountain areas becoming more prominent. Coastal regions featured low-lying alluvial plains. Periodically, the island was intermittently connected to Western Asian lands. The climate was subtropical and humid, with a gradual shift towards increased aridity.

This historical account provides insights into the geological and climatic factors that have shaped the fauna of the Central Ciscaucasia region over time.

The geological and climatic history of the Caucasus region is fascinating and has played a crucial role in shaping its landscape and flora. In the Upper Miocene, around 13.7 million years ago, the region experienced uplifts that covered the Greater Caucasus, Central Ciscaucasia, and Ergeni. During this time, the Caucasus Island merged with Transcaucasia through the Dzirul Isthmus, effectively turning into a peninsula that extended into Asia Minor. The Stavropol Isthmus, in the northern part of the region, began to form, leading to the creation of Pyatigorye [9]. The sea basin, which had previously occupied the entire Ciscaucasia, was split into two parts. These two areas were connected by a narrow strait that existed in the location of the Manych trough.

By the end of the Meotis era, the relief of the Greater Caucasus featured low mountains, middle mountains, and high mountains in the central region. In contrast, Ciscaucasia was a low, minimally dissected plain with shallow river valleys and low-lying swampy banks. During the Pontic transgression, which took place during the Late Miocene, this relief was leveled. The Sarmatian century saw a degree of climate cooling that introduced differentiation in climate and vegetation throughout the region. This included broad-leaved floodplain forests with deciduous trees typical of temperate climates in the Stavropol region, open savanna-like steppe areas, steppe-type vegetation, and tugai thickets along river valleys in foothill plains. In the eastern lowlands, semi-desert ecosystems and subtropical forests were present alongside coniferous and deciduous forests in the middle mountains. The western part of the North Caucasus featured broad-leaved and mixed forests, while highlands contained coniferous forests, alpine meadows, glaciers, and snowfields.

Towards the end of the Maeotis, around 5 million years ago, the land in the Caucasus continued to expand, leading to the introduction of boreal species into the flora and further development of mountain zoning. Climate cooling and the migration of drought-resistant plants and animals from the south of the region became apparent. During the Pliocene, the size of the sea basins surrounding the Caucasian land fluctuated significantly due to transgressions and regressions, which led to the transformation of the peninsula into an isthmus and vice versa. Middle Pliocene uplifts covered various areas, including the Greater Caucasus and parts of Ciscaucasia [8]. The laccolith mountains of Pyatigorye

finished forming. By the end of the Pliocene, the peninsular position of the Caucasus disappeared, and a continental regime was established across 90% of the North Caucasus.

The reduction in water levels led to the formation of an extensive plain in place of the northern and middle Paleocaspian. The Manych trough area featured a narrow strip of isolated and connected lakes and swamps. Two distinct river systems, the western and eastern, were found on the northern slope of the Greater Caucasus, separated by the Central Caucasus watershed. Western Ciscaucasia contained alluvial plains, while the lower reaches of the Kuban featured deltaic lowland plains with swamps and lakes. The Tersko-Kumskaya lowland included expansive deltaic swampy lowlands, desalinated lakes, and lagoons. Shallow bays, such as the Cimmerian and Kuyalnik basins, extended into the lower reaches of the Kuban, and the bays of the Balakhani basin reached the mouth of the Terek river. In Central Ciscaucasia, stratified elevated plains with a well-developed independent river network were present. The western part of the region featured high-mountain relief in the axial part, while the northern slopes of the Greater Caucasus included middle and low mountains, and sloping plains formed in the foothills.

This complex geological and climatic history has played a crucial role in shaping the landscape and ecosystems of the Caucasus region over millions of years.At this stage of information synthesis, the Western Caucasus regions, particularly the Krasnodar Territory, the Republic of Adygea, and the Republic of Karachay-Cherkessia, emerge as areas with the highest diversity of Insecta species identified for biodiversity conservation efforts. The Krasnodar Territory has 528 species, Adygea has 403 species, and Karachay-Cherkessia has 240 species [10]. This diversity aligns with the overall assessment of biodiversity in the Russian part of the North Caucasus. However, it is important to note that the entomofauna of the Republic of Dagestan is underestimated, and knowledge about insect diversity in Chechnya, Ingushetia, and North Ossetia is relatively limited. This is particularly evident when comparing information on endemics in well-studied Insecta groups like Rhopalocera, Noctuidae s.l., Carabidae s.l., or Tenebrionidae throughout the North Caucasus. Despite variations in the inventory of regional faunas, the collected data reveal distribution patterns of endemic species, which play a central role in shaping regional Red Data Books and guiding practical protection of natural communities in the Russian Caucasus.

The experience gained from studying regional insect faunas, developing lists of protected species, and establishing territorial protection and environmental monitoring in the North-West Caucasus has shown that not all endemic, subendemic, or rarely observed insect species designated as "Red Data Book" species require special protection measures. Some endemics are common and can be widely distributed in local or even extensive ecosystems. However, there are instances in the Russian Caucasus where the state of local populations of rare endemic species, protected species, metacommunities, and entire community types has significantly deteriorated. This decline can be attributed to the consequences of mass reproduction of alien phytophagous insects, large-scale measures to control their populations in protected areas, increased agricultural exploitation, or urbanization [11].

To correctly use information about endemic Insecta species when considering the introduction of territorial protection or assessing its adequacy, it is essential to evaluate the threat of extinction of local and regional populations using IUCN criteria. This approach encourages experts to analyze population trends over an extended period, moving beyond merely characterizing the current, often subjectively assessed rarity of species. Consideration should also be given to the sozological status of these species in the Red Book of the Russian Federation and adjacent regions. Special attention is required for intensively developing areas with high population densities, known development plans, and rich endemic fauna.

4 Conclusions

The study of the diversity of regional invertebrate animal faunas, particularly insects, is a crucial task in contemporary zoological research. Each region in the Central Ciscaucasia area has its unique natural and climatic characteristics, which influence the species composition of insects. Understanding the richness of local faunas is challenging without specialized entomological knowledge, and this becomes even more critical when examining rare insect species. It is well-established that properly chosen indicator species can offer valuable insights into environmental quality and ecosystem stability in ecological monitoring.

Recent estimates suggest that up to 5% of the insect fauna is currently at risk of extinction. This implies that at least 800 species should be included in the Red Book of Russia, highlighting the need for their protection. The compilers of the Russian Red Book in 2001 opted to include the most striking and large insect species, which are also sought after by collectors. However, many professional entomologists express skepticism regarding the actual threat of rare insect species being completely wiped out by collectors, except in some specific cases. They argue that the more pressing issue is the protection of ecosystems from chemical pollution and other anthropogenic influences.

The categories used in the Red Book are somewhat vague. They might be more suitable and reliable for vertebrates, given the higher level of knowledge about this group compared to insects. For many animal species in nature reserves and hunting areas, regular population counts are conducted. The Red Book categories don't necessarily reflect the causes but rather the result of a species being considered "rare." They were originally developed for the practical protection of vertebrates and were automatically extended to insects. In the book "Rare Invertebrate Animals," an attempt is made to provide a meaningful interpretation of the Red Book categories and adapt them for insects, taking into account the categories established by the International Union for Conservation of Nature (IUCN).

When examining the current state of biotechnology in Russia, several issues come to light.

References

1. A. A. Daukaev, R. Kh. Dadashev, L. S. Gatsaeva, R. A. Gakaev, IOP Conf. Series: Earth and Environmental Science, 378 (2019)
2. A. Yu. Apokin, D. R. Belousov, Scenarios for the development of the world and Russian economy as a basis for scientific and technological forecasting, **3(3)**, 12–29 (2009)
3. Bio-Economy Technology Platforms. The European Bioeconomy in 2030: Delivering Sustainable Growth by addressing the Grand Societal Challenges (2021)
4. C. Cagnin, E. Amanatidou, M. Keenan, Orienting European Innovation Systems towards Grand Challenges and the Roles that FTA Can Play, **39(2)**, 140–152 (2020)
5. E. Reynard, M. Panizza, Geomorphosites: definition, assessment, and mapping. Geomorphol Relief , 177–180 (2018)
6. EU-Russia Energy Dialogue, Energy Forecasts and Scenarios 2009–2010 Research. Final Report (2021)
7. K. Haegeman, F. Scapolo, A. Ricci, E. Marinelli, A. Sokolov, Quantitative and qualitative approaches in FTA: from combination to integration?, **80**, 386–397 (2021)
8. R. Kh. Ilyasov, Spline modeling and analysis of relationships in the economy with the possible presence of regression switching points, **11(4)**, 165-175 (2018)
9. K. M.-S. Murtazova, Ecological and economic assessment of sectoral agricultural technologies, **3(15)**, 68-71 (2021)

10. A. S. Salamova, Socio-economic factors in the fight poverty and hunger in the modern world: the scientific approach of Amartia Kumar Sen, **17(1)**, 237-245 (2023)
11. A. S. Salamova, Global networked economy as a factor for sustainable development, 03053 (2020)