

Conservation of forest ecosystems in regional complex nature reserves

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Abstract. Based on the analysis of expedition, stock, published and official cadastral materials on the specially protected natural areas, the article characterizes complex (landscape) nature reserves of the Vologda region in the context of the landscape concept of formation of the network of specially protected natural areas in the region, and gives assessment of the compliance of the nature reserves with biodiversity conservation tasks under the taiga zone conditions. The history of establishment of nature reserves, the species and age composition of forests, the typological diversity of forests, availability of valuable natural areas, rare and protected species of plants and animals in 75 nature reserves were analyzed.

1 Introduction

Fragmentation of natural complexes is one of the main factors contributing to loss of biological diversity. For such a forested country as Russia conservation of forest ecosystems seems to be one of the priority tasks under the conditions of intensive forest exploitation [1]. In our opinion, the Vologda Region plays a key role in conservation of taiga biodiversity, since there is a vast area of taiga landscapes of the East European Plain belonging to the subzones of the middle and southern taiga within its borders. In addition to the Vologda Region, only in the Kirov and Leningrad regions there are also middle and southern taiga forests, which represent, respectively, the eastern and western outskirts of the Eastern European taiga, whereas the Vologda taiga stretches for 650 kilometers in its central part.

Establishment of specially protected natural areas (SPNA) is the most well-known biodiversity conservation way [2]. Formation and development of the system of specially protected natural areas of the Vologda region is aimed at assurance of conservation of natural ecosystems, natural landscapes and complexes and is one of the strategic objectives of development until 2030 [3]. At the same time, special attention is paid to conservation of typical taiga landscapes, since there are extremely few forest areas that are not affected by economic activity.

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Protection of forest ecosystems is implemented, first of all, within the complex (landscape) nature reserves (LNR), which take a special place in the system of specially protected natural areas of the Vologda region. Active formation of the network of regional landscape nature reserves began in the Vologda region in the 1980s as a result of expeditions of the Vologda State Pedagogical Institute (since 1995 - University). Materials from the very first years of the expedition in specially protected natural areas and the lake and soil expeditions preceding it showed that it is required to establish complex (landscape) state nature reserves for genetic conservation of primary taiga biogeocenoses and typical natural complexes disappearing under the pressure of economic activity. At the same time, the landscape concept of formation of the network of specially protected natural areas took shape, in accordance with it the network should be based on landscape nature reserves, including significant and little-modified forest areas, represented in all landscape districts of the region.

Currently, 75 complex nature reserves account for almost 48% of the total number and 58% of the area of specially protected natural territories of the region. The state of forests within other category of specially protected natural areas of the Vologda region had already become the subject of research [4]. A series of anthropogenic violations and risks of loss of protection sites were revealed as a result of the research. The information on conservation of forest ecosystems of the complex nature reserves in the Vologda Region, existing as of October 1, 2022, was generalized for the first time.

2 Materials and methods

The work is based on the analysis of the regional cadaster of specially protected natural areas, resolutions on establishment of the landscape nature reserves, forestry regulations of the Vologda region, the Public Cadastral Map of the Federal Service for State Registration, Cadaster and Cartography, published scientific papers devoted to description of specially protected natural areas, the Red Book of the Vologda region, reports on expeditions (stock materials of the Department of Geography and Sustainable Environmental Management of VSU) [5, 6-9].

Based on GIS application, the distribution of landscape nature reserves by landscape areas was studied, taking into account the fourfold change in the grids of landscape zoning of the region over the past 50 years. Working databases were made to analyze the species and the age composition and the typological diversity of forests, availability of valuable natural territories, rare and protected plants and animals, with involvement of the above sources.

3 Equations and mathematics

Most of the landscape nature reserves (65 out of 75) in the region were organized in the 1980s and 1990s as a result of the environmental expeditions of the Vologda Pedagogical Institute. "Atleka", "Mologa", "Karpovo", "Chernoozersky", "Bolshaya Pokhta", "Druzhinnoye Lake", "Eyugsky Bor", "Lakes of the Megorskaya group", "Dobroozerskoye Swamp" landscape nature reserves were established in the 2000s. At each stage, the newly formed nature reserves were "tied" to the landscape zoning scheme existing at that time, when it was changed (1970, 1993, 2006, 2007), as information was accumulated, peculiar gaps in the network of landscape nature reserves were revealed, indicating that some landscapes were not included in the network of specially protected natural areas of natural complexes.

Currently, the Vologda Region landscape zoning grid published in the Vologda Region Atlas (2007) includes four landscape areas and 33 landscape districts. The analysis of the network of landscape nature reserves as of October 1, 2022 showed that complex nature reserves were formed in all four landscape areas of the region: in the Sukhonsko-Dvinsk area – 30, in the Upper Volga area – 23, in the North-Western area – 14, in the Severnye Uvaly area – 8. All 6 genetic types of landscapes common in the region are represented within the landscape nature reserves. The lake-glacial landscapes are most widely represented in the network of nature reserves (32 nature reserves). Landscapes of the moraine and steeply-sloping type are protected in 15 nature reserves, moraine-hilly type – in 13 nature reserves, moraine-plain type – in 11 nature reserves. "Melgunovsky", "Ring structure "Chermzha" and "Druzhinnoye Lake" nature reserves were arranged in Kovzhinsko-Belozersky, Kirillovsky and Belozersky landscapes, and "Unzhensky forest" and "Ikonnny Bor" nature reserves were arranged in Verkhneunzhensky landscape district, respectively, in order to conserve rare moraine-lake-hilly and water-glacial landscapes in the region.

Complex nature reserves were organized in 25 landscape districts. The largest number of landscape nature reserves were organized within Mologo-Sudsky landscape (16). There are a lot of landscape nature reserves within Kuloysky (8), Verkhneyugsky (6), Kichmengsky (5), Kovzhinsko-Belozersky (5) landscapes. There are 4 landscape nature reserves in Andomsky landscape and 3 landscape nature reserves within Verkhnesukhonsky landscape – 3. There are 2 nature reserves in ten landscapes, and 1 nature reserve in eight landscapes. There are no complex nature reserves in 8 landscapes within the Vologda region: Vozheozersky, Kemsky, Kubenoozersky, Megorsky, Konoshsko-Verkhnevazhsky, Avnigsky, Pyschug-Vetluzhsky, Ustyansky. The last four landscapes are mainly located within the borders of neighboring regions. The natural complexes of Vozheozersky landscape are partially conserved in "Russian North" National Park, and the natural complexes of Megorsky landscape are conserved within 4 hydrological nature reserves. The natural complexes of Kemsky and Kubenoozersky landscapes are not covered by the system of landscape nature reserves or other categories of specially protected natural areas significant by area, characterized by the required protection regime.

67 nature reserves out of 75 were established as "forest" ones, and zonal vegetation (including forests in swamps) is one of the main protection sites in all nature reserves. 73 landscape nature reserves are fully or partially located on the designated forest lands. The forest nature of almost half of the landscape nature reserves is reflected in their official names ("Kudrinsky Bor", "Shilengsky Bor", "Gladky Bor", "Verkhovsky Forest", "Palemsky Forest", "Azletsky forest", etc.). The area of the landscape nature reserves in the region varies from 150 to more than 25 thousand hectares, and the average area amounts to almost 3000 hectares.

First of all, the primary types of forests – pine forests and spruce forests - are conserved within the boundaries of complex nature reserves. Pine forests prevail in 37 landscape nature reserves. Mainly green-moss cowberry and blueberry forests, as well as green-moss-lichen and lichen forests are represented among the pine forests in the nature reserves, sphagnum forests (for example, in "Shichengsky", "Sondugsky" landscape nature reserves) and long-moss forests ("Chuchkin Bor", "Verkhnyaya Strelna") are less common. Green-moss sorrel pine forests ("Nyushmensky Bor", "Kozlikha Bor") and grass-marsh pine forests ("Zaozersky", "Sysoevsky Bor") are quite rare. "Sholsky Forest", "Spassky Bor" and "Mazsky Bor" are distinguished for the greatest variety of types of pine forests. Almost the entire range of pine forests found in the region is represented in them.

Spruce forests are mainly protected within 24 nature reserves, among which green-moss blueberry and sorrel forests prevail. Sphagnum spruce forests ("Atleka", "Selmengsky forest"), long-moss ("Atleka", "Yansorsky", "Strelkinsky Forest") and grass-marsh

("Verkhne-Andomsky", "Ramensky Forest", "Verkhovsky Forest") are represented on the territory of the landscape nature reserves to a lesser extent. Green-moss cowberry spruce forests ("Entalsky Forest", "Soydozersky", "Urochishche Sharma") occur rarely. The territories of "Atleka" and "Ramensky Forest" nature reserves are distinguished for the greatest variety of types of spruce forests.

Let's specially distinguish those landscape nature reserves, in which broad-leaved tree species are conserved. *Tilia cordata* Mill, *Ulmus glabra* Huds. and *Acer platanoides* L., located on the northern border of the range are resumed in spruce forests in "Andogsky Forest" and "Voronovo" nature reserves. Forest stands with rich lime undergrowth are represented in Unzhensky Forest nature reserve. There occur broad-leaved species in "Gladky Bor" and "Bobrishny Ugor" nature reserves.

Siberian species, rare for the Vologda Region, are also protected in the forest stands of the landscape nature reserves. *Larix sibirica* Ledeb. is conserved on the western border of the range in "Melgunovsky" nature reserve – up to 10-20% in the forest stand. Pine forests with admixture of *Larix sibirica* Ledeb. occur in "Shilengsky Bor" and "Listvenichny Bor" nature reserves. *Abies sibirica* Ledeb. (with a 10-20% stake) is present in the spruce stand in "Talitsky forest" and "Urochishche Orlovskaya Roshcha" nature reserves. Areas of sub-primary southern taiga forests, unique for the region, similar in composition to the fir-spruce forests of the Middle Urals, are conserved in Verkhovinsky Forest landscape nature reserve [5].

Conservation of low-disturbed old-age forest stands is one of the goals of establishment of the landscape nature reserves. For example, in some places pine forests in "Sondugsky", "Bolshaya Pokhta", "Verkhnyaya Strelna" nature reserves are older than 180 years. In "Olenevsky Bor" nature reserve the age of individual specimens of pine trees exceeds 200 years. Spruce forests in "Strelkinsky forest", "Brusensky forest", "Voronovo" nature reserves are 120-150 years old. Spruce stands at the age of 150-180 years old prevail in "Ikhaltitsky", "Atleka", "Verkhovsky Forest", "Entalsky Forest" nature reserves. Spruce forests aged 180-200 years or more are represented in "Verkhne-Andomsky" nature reserve. In "Koloshemsky Forest" nature reserve there are individual specimens of spruce aged 250-280 years old.

Landscape nature reserves differ not only in forest types, but also in the species diversity of plants and animals. The largest number of officially registered plant species is recorded in "Chagodoshchensky" (about 400), "Ramensky Forest" (300-400), "Melgunovsky" (330), "Vanskaya Luka" (about 300), "Yarbozersky" (277), "Gladky Forest" (more than 250), "Shichengsky" (223) landscape nature reserves.

Populations of rare plant and animal species listed in the Red Book of the Vologda Region and subject to protection in the region (protected species) or those that need scientific monitoring in the region are conserved within many complex nature reserves [4]. Most of all protected plant species are found in "Sudsky Bor" (55), "Soydozersky" (37), "Lakes of the Megorskaya group" (30), "Chernoozersky" (28), "Verdensky" (27), "Melgunovsky" (25), "Atleka" (23), "Vanskaya Luka" (22), "Chagodoshchensky" (22) landscape nature reserves. Plant species that need monitoring are found in all landscape nature reserves except Chernoozersky. Most of all such species are found in "Chagodoshchensky" (40), "Sudsky Bor" (31), "Unzhensky Forest" (30), "Vanskaya Luka" (29), "Padun" (25), "Verdensky" (24), "Listvenichny Bor" (23) landscape nature reserves. "Sudsky Bor" is especially distinguished by the aggregate of protected plant species and plant species that need monitoring (86 species), which is explained by a significant area (2780.5 hectares), presence of three remote sites and 7 clusters, besides, it is well studied due to allotment of lands for the North European gas pipeline. More than 50 protected plant species and plant species that need monitoring are found within "Chagodoshchensky" (62),

"Soydozersky" (58), "Verdengsky" and "Vanskaya Luka" (51 each) landscape nature reserves.

Out of the protected tree species, *Abies sibirica* Ledeb., *Larix sibirica* Ledeb., *Ulmus laevis* Pall. and/or *Ulmus glabra* Huds are found in the landscape nature reserves. *Quercus robur* L is protected only in "Vanskaya Luka" landscape nature reserve. Out of the woody species that need monitoring, *Tilia cordata* Mill and *Acer platanoides* L. are represented in landscape nature reserves.

Populations of 6 plant species listed in the Red Book of the Russian Federation are conserved within the complex nature reserves. For example, *Cypripedium calceolus* L. is protected in more than 15 landscape nature reserves ("Eyugsky Bor", "Verkhnyaya Strelna", "Atleka", etc.), *Dactylorhiza traunsteineri* (Saut.) Soo s.l. is taken under protection in "Melgunovsky", "Chagodoshchensky" and "Soydozersky" and other landscape nature reserves, *Dactylorhiza baltica* (Klinge) N.I. Orlova – in "Koloshemsky forest", "Pochinkovsky forest" and other landscape nature reserves, *Isoetes lacustris* L. – in "Yansorsky", "Kharinsky", "Soydozersky" landscape nature reserves, *Epipogium aphyllum* (F.W. Schmidt) Sw. – in "Ramensky Forest", "Atleka" landscape nature reserves, *Lobelia dortmanna* L. – in "Yansorsky" landscape nature reserve.

Populations of such rare species as *Isoetes echinospora* Durieu, *Dianthus fisheri* Spreng. u *D. superbus* L., *Dracocephalum ruyschiana* L., *Delphinium elatum* L., *Hepatica nobilis* Schreb., *Veratrum lobelianum* Bernh., *Ranunculus subborealis* Tzvel., *Pulsatilla patens* (L.) Mill., etc. are represented only in 1-3 landscape nature reserves. Populations of such steppe species as *Koeleria glauca* (Spreng.) DC. are found only in "Vanskaya Luka" and "Chagodoshchensky" landscape nature reserves, *Phlum phleoides* (L.) H. Karst. is found in "Chagodoshchensky" landscape nature reserve.

Typical taiga species of *Ursus*, *Canis*, *Vulpes*, *Lepus* genera and others are common among mammals within the landscape nature reserves. Many landscape nature reserves are distinguished by a high diversity of birds. Thus, 100 or more bird species are registered in "Lakes of the Megorskaya group" (182), "Soydozersky" (124), "Atleka" (107), "Vanskaya Luka" and "Sodugsky" nature reserves (100 each).

There are few rare animal species listed in the Red Book of the Vologda Region and in the list of those that need monitoring, as a rule, in the landscape nature reserves, maximum 5-7 species. The most rare animal species are found on the territory of "Atleka" (29), "Lakes of the Megorskaya group" (22), "Vanskaya Luka" (16), "Sondugsky" (13), and "Dobroozerskoye Swamp" (12) landscape nature reserves.

The habitats of 15 bird species listed in the Red Book are protected within the landscape nature reserves. For example, *Pandion haliaetus* is protected in more than 10 landscape nature reserves, *Haliaeetus albicila* – in 8, *Aguila chrysaetos* – in 6, *Gavia arctica* – in 5, *Lagopus* – in 6 landscape nature reserves. The habitats of the following mammal species protected in the region: *Vespertilio murinus* ("Atleka", "Chernoozersky"), *Myopus schisticolor* ("Sondugsky") and insect species: *Ceruchus chrysomelinus* ("Atleka"), *Saturnia pavonia* ("Shelomovskoye Swamp"), *Limenitis camilla* ("Bobrishny Ugor") are found.

Among the species that need monitoring, for example, *Lutra*, *Tamias sibiricus*, *Mustela lutreola*, *Meles meles*, *Lacerta agilis*, as well as *Natrix natrix* and *Rana lessonae* found on the northern border of their distribution range are represented in the landscape nature reserves [5, 7, 10].

4 Conclusion

The position of the Vologda Region in the taiga zone determined the forest character of landscape nature reserves (67 out of 75). Middle taiga forest biogeocenoses are protected in 30 landscape nature reserves, southern taiga forest biogeocenoses are protected in 45 landscape nature reserves. The total number of complex landscape nature reserves generally complies with the landscape concept of formation of the network of specially protected natural areas of the Vologda region, but there are no complex landscape nature reserves in 8 landscapes within the boundaries of the region: Vozheozersky, Kemsky, Kubenoozersky, Megorsky, Konoshsko-Verkhnevazhsky, Avnigsky, Pyshchug-Vetluzhsky, Ustyansky. All 6 genetic types of landscapes common in the region are represented within the complex nature reserves. Moraine-lake-hilly and water-glacial landscapes are rare for the region. 5 nature reserves are organized in Kovzhinsko-Belozersky, Kirillovsky, Belozersky and Verkhneunzhensky landscape districts in order to conserve them.

Primary types of forests are conserved within the complex nature reserves, in general – all types of pine forests and spruce forests represented in the region and rare areas of mixed coniferous-broad leaved forest, forests with admixture of *Larix sibirica* and *Abies sibirica*. In order to conserve rare spruce forests and sphagnum, long-moss, grass-marsh pine forests, green-moss cowberry spruce forests and green-moss sorrel pine forests, represented in the landscape nature reserves, it is required to reveal new territories.

A significant part of complex nature reserves includes conserved areas of old-age coniferous forests, low-disturbed woodlands and territories and other types of valuable natural territories.

The species diversity of plants and animals in complex landscape nature reserves is significant. It is not possible yet to estimate the share of conserved diversity from all species revealed in the region, as it required to make a consolidated database that allows for species sampling. The same applies to protected species and species that need monitoring. Formation of the network of landscape nature reserves cannot be considered as completed. The prospects for expansion of the network are related to organization of complex nature reserves within all landscape districts, which requires additional field research.

Monitoring of the state and operation of the network of nature reserves requires regular (for example, once per 20-25 years) comprehensive field survey of the protected areas and maintenance of extended databases. Most of the landscape.

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