Salt Lake as a natural monument terrestrial and aquatic biological diversity

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Abstract. The article provides data on biological diversity of plants, animals, and fungi inhabiting Salt Lake Natural Monument and its surroundings (Tyumen Oblast, Russia). The authors used route and sample plot census methods. The natural monument area is situated within the forest steppe ecotone of the West Siberian Plain. Thus species typical for the adjoining boreal and steppe zones are also registered in the biological communities under study. Aquatic ecosystems of the area include two instances opposed from the species diversity and abundance point of view: the poor one of mineralized Salt Lake and the rich one of fresh water Dolgoye Lake. The total of 166 vascular plant species, 110 vertebrate and 95 invertebrate species, as well as 60 fungi species were registered on the territory. Among these, two plant and eight animal species are listed in different Red Data Books. Recreational use of the territory makes the composition and structure of flora and fauna complexes unique, as the species intolerant to anthropogenic load are depressed, and synanthropes are implanted in the assemblages. Biological diversity transformation accelerates due to an increase of the investigated territory aridity.

1 Introduction

The National Strategy of Biodiversity Conservation in Russia includes development of the network of specially protected natural territories (SPNT) spanning all landscape zones and major regions of the country. It aims at the fullest preservation of species characteristic of different Russian regions in their natural habitats. SPNT located on the borders of natural zones, in the zonal ecotones, are of particular interest. In such environments, a border effect can manifest a considerable increase in species diversity in all groups of organisms. In the south of Tyumen Oblast, it is the forest steppe zone that is distinguished as a zonal ecotone

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[1]. A narrow strip, it spans along the border between the boreal (taiga) and steppe natural zones of the West Siberian Plain [2]. In Tyumen Oblast forest steppe zone, there is one federal and 15 regional zakazniks and 13 natural monuments. The latter include Salt Lake Natural Monument. No full-scale research of flora or fauna has been performed so far. The importance of such research into reference protected territories is driven not only by biological diversity appreciation, but also by the need to monitor its evolution under the influence of the external and internal development factors [3]. In Tyumen Oblast southern part, such transformations are often connected with the ongoing global climate change accompanied by climate aridization, resulting in the southern species spreading to the north, as we have previously discussed the increasing role of the forest steppe species in West Siberian subtaiga [4].

The current work aims at assessing biological diversity of Salt Lake Natural Monument and its surrounding territories.

2 Materials and methods

The total area of Salt Lake Natural Monument is 109.9 ha. It is situated in the southern part of Tyumen Oblast, in Berduzhsky District, to the south of Okunevoye Village (Figure 1).

Salt Lake takes 72% of the monument total area. Its salt brine is a 87.3 g/dm³ sodium chloride solution with a weak alkaline reaction. Its water contains a balneotherapeutic component, bromine, and its benthal deposits are therapeutic muds. Every summer, a lot of unorganized tourists come here for recreation and mudtherapy purposes. What also attracts people is a near-by fresh water Dolgoye Lake. The two lakes are divided by a narrow isthmus of land. There is some recreational space with sanitary facilities on it.

![Fig. 1. The area under study on West Siberia map.](image-url)
The natural monument biological diversity was studied in July and August, 2022. Floristic studies were performed using route censuses going through all plant associations. On the route, the vegetation cover was assessed, all types of vascular plants within sight were registered.

The summer species composition of macromycete fungi, their distribution and abundance were registered with the help of census shuffling across the route; the flora of the area under investigation was studied along. When found, a fungal fruit was photographed, and if needed taken samples of to be further scrutinized in a laboratory setting.

Terrestrial vertebrates were registered using route censuses (6.214 mi (10 km) for birds and 3.107 mi (5 km) for other groups); data obtained from route censuses were supplemented with trail camera evidence. Encounters of animals, their tracks and traces of life activity were registered. Invertebrates were registered along the routes and captured with a sweep-net method, aquatic organisms were sampled using a Petersen dredge and a Jedi plankton net.

### 3 Results and discussion

**Flora Examination.** The vegetation cover of the territory under study is a composition of meadow and forest plant assemblages. Meadow vegetation is made of motley grass-grasses assemblages of steppe meadows. They feature a charastically large amount of meadow-steppe and steppe species, xeromesophytes dominating the grassland, and a comparatively small number of meadow-forest mesophytes whose share grows along with the distance from the Salt Lake shore. Meadow grasses show high species diversity and abundance (grass canopy cover of 65-80%). The following grass species are dominant: *Calamagrostis epigeios* (L.) Roth, *Poa angustifolia* L., *Festuca pseudovina* Hack. ex Wiesb. In the forbs group, the most constant and abundant are: *Filipendula vulgaris* Moench, *Seseli strictum* Ledeb., *Eryngium planum* L., and other species. The following halophilous plants are characteristic: *Artemisia pontica* L., *Plantago maxima* Juss. ex Jacq. Other common species with a low abundance are xeromesophilous *Carex praecox* Schreb., *Astragalus danicus* Retz., *Vicia tenuifolia* Roth. A rare species, *Stipa pennata* L., listed in the Red Data Book of Tyumen Oblast was registered on such meadows. Among the described meadow assemblages, there are fragments of halophytic ones with the following xerohalophilous species dominating: *Puccinellia tenuissima* Litv. ex V.I. Krecz., *A. laciniata* Willd., *Plantago salsa* Pall. The herbaceous cover on such areas is sparse, the projective cover is 35-50%. Annual succulent halophytes, *Salicornia perennans* Willd. and *Suaeda prostrata* Pall., grow on the mineral outcrops of the Salt Lake shoreline.

Human recreational activities appreciably affect meadow vegetation on the isthmus between the two lakes. This is conductive to an overall deterioration of flora and to original community species structure change: plants that are not resistant to trampling disappear, synanthrope species proliferate. Picking bunches of flowers is another potential threat for diversity of flowering species first of all, which can ultimately lead to their loss and aesthetic deterioration of the meadow plant assemblages.

The old-growth forest on the territory under consideration includes a steppificated grass-forb birch forest adjoining the lake from the south. The birch forest understory is sparse and is not diverse in species. Another rare species listed in the Red Data Book of Tyumen Oblast was registered in it − *Cerasus fruticosa* Pall. The forests' grass stand is tall (up to 1 m high) and thick (90-100% projective cover), and features plants from different ecological groups. There are a lot of subtaiga mesophiles: *Brachypodium pinnatum* (L.) Beauv., *Rubus saxatilis* L., *Polygonatum odoratum* (Mill.) Druce; and not so many of *Pleurospermum uralese* Hoffm., *Silene nutans* L., *Lathyrus pisiformis* L. There are the following hygromesophiles: *Filipendula ulmaria* (L.) Maxim., *Kadenia dubia* (Schkuhr) Lavrova & V.N. Tikhom.,
Lysimachia vulgaris L. The following meadow-forest mesophiles are common: Hieracium umbellatum L., Galium boreale L., Trifolium lupinaster L., Solidago virgaurea L., and other species. Xeromesophilous motley grasses feature Filipendula vulgaris Moench, Phlomoides tuberosa (L.) Moench, Seseli libanotis (L.) W.D.J. Koch. The following grasses were also registered: Calamagrostis epigeios (L.) Roth and Festuca ovina L. Xeromesohalophilous Artemisia pontica L. is common in grass stands.

Forests of the area under study also include birch, pine, and larch plantations (1992-2000) on the lake-side terrace. The total grassland vegetation abundance and diversity is low here due to high canopy density. But these plants are an interesting natural object in themselves, especially the coniferous plantations that grow here outside their main range. The anthropogenic load on the forest ecosystems in the study area is less pronounced then that exercised on the meadow ones.

Over the course of research, we registered 166 vascular plant species from 128 genera and 40 families. Top five families (Asteraceae, Rosaceae, Poaceae, Fabaceae, Apiaceae) account for 57% of the entire floristic list.

A wide diversity of habitats varying in their ecotope properties gives rise to heterogeneous ecological and cenotic groups of plants on the territory under study (Figure 2). On the whole, open habitats species predominate, all in all their share is around 70%. Active recreational use of the natural monument territory and a big adjacent built-up area and farmland condition the presence of a considerable share of synanthrope (ruderal and segetal) vegetation in the meadow assemblages. The most frequent are Elytrigia repens (L.) Nevski, Rumex confertus Willd., Polygonum aviculare L., Convolvulus arvensis L., Fallopia convolvulus (L.) Á. Löve.

Fig. 2. Salt Lake Natural Monument Vascular Plant Distribution into Ecological and Cenotic Groups (%).

Being located within the forest steppe ecotone, on the border between the boreal and steppe natural zones, the natural monument vegetation assemblages feature different latitude groups of plants (Figure 3). The group of forest steppe species predominates. Nemoral-boreal and boreal group plants are almost exclusively connected with forest communities. The plurizonal plant group (widespread species not limited to a certain natural zone) includes a large amount of species with synanthropes playing a considerable role in it.
Fungi Species Examination. Fungi are an integral part of an ecosystem diversity, they recycle and put detritus elements back into use; symbionts (often mycorrhiza-forming fungi) and parasites, they also regulate plant assemblage conditions. The Red Data Book of Tyumen Oblast (2020) includes 20 fungi species. SPNTs play a crucial part in their preservation. Previously undetected fungi species have recently been found in the south of Tyumen Oblast [5].

Over the course of our research, 60 fungi species were registered, most of them are widespread in Tyumen Oblast. In the Ascomycota phylum, only Legaliana badia (Pers.) Van Vooren was registered. Basidiomycetes are represented by ecological and morphological groups of aphylloraphores (poliope) fungi comprised of 24 species; piliate fungi – 33 species (27 ground species and 6 wood species); puffballs – 2 species. The total of 30 wood-decay (xylophagous) fungi species were registered. Together with forest ground fungi, they exhibit predominantly forest character of the fungal biota.

Five species were registered on the steppificated plots, 20 in the pine, larch, birch plantations, 42 species in the natural birch forest. In the steppificated areas, Marasmius oreades (Bolton) Fr. and Agrocybe praecox (Pers.) Fayod are most common. Agaricus campestris L. is rarer along roadsides, and Calocybe gambosa (Fr.) Donk on the forest edges. Tricholoma terreum (Schaeff.) P. Kumm., T. argyraceum (Bull.) Gillet are particularly common in the plantations; Paxillus atrotomentosus (Batsch) Fr. is common in the birch plantations, Suillus granulatus (L.) Roussel – in the pine plantations, S. grevillei (Klotzsch) Singer and S. viscidus (L.) Roussel – in the larch plantations. The following xylophagous fungi species common for forest steppe forest outliers are typical of the natural birch forest: Fomes fomentarius (L.) Fr., Trichaptum biforme (Fr.) Ryvarden, Daedaleopsis tricolor (Bull.) Bondartsev & Singer, Pleurotus pulmonarius (Fr.) Quéz., Pluteus hongoi Singer, and other species, so are the following ground fungi: Leccinum scabrum (Bull.) Gray, Boletus edulis Bull., Russula foetens Pers. (stinking russula), and other species. Although there are very old trees (a birch of up to 130 years old), tree-trunk parasites characteristic for them are few: Inonotus obliquus (Fr.) Pilát on a birch tree and Phellinus tremulae (Bondartsev) Bondartsev & P.N. Borisov on a larch tree.

Almost all of the registered species are quite tolerant to moderate anthropogenic load, not causing any radical ecosystem transformation. The most antropophilous species include Agaricus campestris, Paxillus atrotomentosus, Trametes versicolor (L.) Lloyd, Stereum hirsutum (Willd.) Pers.; it is only the second of these that is widespread.

There are 4 mass species, 32 common species, 19 low-numbered species, and 5 sporadic species. Two of the mass species are abundant on the meadows: Marasmius oreades and Agrocybe praecox; in all the tree plantations, Tricholoma terreum is widespread, Paxillus atrotomentosus is widespread in birch plantations. Single specimens of the following species were registered: Climacodon pulcherrimus (Berk. & M.A. Curtis) Nikol., Hericium

Fig. 3. Salt Lake Natural Monument Vascular Plant Distribution into Latitude Groups (%).
coralloides (Scop.) Pers., Postia tephroleuca (Fr.) Jülich, Leccinum versipelle (Fr.) Snell, Amanita rubescens Pers. The first three species develop on the trees, and the latter two are mycorrhiza-forming fungi. It is noteworthy that two mycorrhiza-forming piliate fungi species new for the forest steppe zone were registered in the larch plantations: Suillus grevillei (Klotzsch) Singer and S. viscidus (L.) Roussel, and it was the first time that Paxillus atrotomentosus was registered in this zone. All these newly recorded species pertain to the category of common or mass species of the territory, the latter species is anthropophilic everywhere.

Our prior hands-on experience of the forest steppe zone shows that the seasonal abundance of Inonotus obliquus (chaga fungus), a birch trunk parasite infecting mostly thin trees, was comparatively low, so was the one of Stecherinum ochraceum (Pers. ex J.F. Gmel.) Gray, a species preferring optimum water and temperature regimes, and of Stereum subtomentosum Pouzar, a species common after ground fires. It is worthwhile to mention that up to the 2000s Cerrena unicolor (Bull.) Murrill, a wood fungus, was very widespread in the Tyumen Oblast forest steppe zone, and now it is comparatively rare in the Oblast south.

Fauna Examination. The biological diversity of vertebrates is set out in Table 1.

Table 1. Species Diversity and Relative Abundance Indices for Salt and Doloye Lakes and their Vicinities.

<table>
<thead>
<tr>
<th>Species Diversity Indexes</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Mammal Species</td>
<td>16</td>
</tr>
<tr>
<td>Number of Bird Species</td>
<td>87</td>
</tr>
<tr>
<td>Number of Reptile Species</td>
<td>1</td>
</tr>
<tr>
<td>Number of Amphibian Species</td>
<td>1</td>
</tr>
<tr>
<td>Number of Fish Species (Dolgoye Lake)</td>
<td>5</td>
</tr>
<tr>
<td>Relative Abundance of Mammals, sp. per 1 km of route</td>
<td>6.2</td>
</tr>
<tr>
<td>Bird Density, sp. per 1 sq. km</td>
<td>118.92</td>
</tr>
<tr>
<td>Reptile Density, sp. per 1 km of route</td>
<td>0.2</td>
</tr>
<tr>
<td>Amphibians Density, sp. per 1 km of route</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Birds (Aves) are the most numerous class of the vertebrate animals. In the summer of 2022 around Salt Lake, 87 bird species coming from 18 orders, 65 species were registered in June, and 51 species both in July and August. June (in the breeding season) was the month of maximum density. In July (for a number of species, a molting period), the bird density went down to reach a minimum in the second half of August when some species migrated from the study area to their wintering sites [6]. Forest bird species are numerous (Dryocopus martius L., 1758; Dendrocopos major L., 1758; Parus major L., 1758; P. montanus Baldenstein, 1827; Sitta europaea L., 1758; Phoenicurus phoenicurus L., 1758; Erithacus rubecula L., 1758; Cuculus canorus L., 1758; Turdus viscivorus L., 1758; Phylloscopus collybita Vieillot, 1817; Anthus trivialis L., 1758; Fringilla coelebs L., 1758; Fringilla montifringilla L., 1758, and other species), so are open habitats species (Buteo buteo L., 1758; Milvus migrans Boddaert, 1783; Falco tinnunculus L., 1758; Chettusia gregaria Pallas, 1771; Saxicola rubetra L., 1758; Saxicola torquata L., 1766, and other species), as well as bird species of water and semi-aquatic habitats (Podiceps cristatus L., 1758; Pelecanus crispus Bruch, 1832; Phalacrocorax carbo L., 1758; Ardea cinerea L., 1758; Cygnus cygnus L., 1758; Tadorna tadorna L., 1758; Anas platyrhynchos L., 1758; Circus aeruginosus L., 1758; Fulica atra L., 1758; Actitis hypoleucos L., 1758; Xenus cinereus Guldénstädт, 1775; Larus ridibundus L., 1766; Sterna hirundo L., 1758; Luscinia svecica L., 1758; Motacilla flava L., 1758, and other species). Built-up area being close, anthropophilic and even
synanthropic species are almost intrinsic here (*Passer domesticus* L., 1758; *P. montanus* L., 1758).

16 species Mammals (Mammalia, or Theria) coming from 6 orders were registered in the summer of 2022. This is the minimum value in the 21st century. The mammal abundance was also at the minimum. In Rodentia, the most numerous were *Spermophilus erythrogenys* Brandt, 1841; *Apodemus agrarius* Pallas, 1771; *Sylvaemus* (=*Apodemus*) uralensis Pallas, 1811; *Clethrionomys* (=*Myodes*) rutilus Pallas, 1779; *Microtus arvalis* Pallas, 1778; *Lasiopodomys* (=*Microtus*) gregalis Pallas, 1779; *Ondatra zibethicus* L., 1766 and other species, in Carnivora – *Nyctereutes procyonoides* Gray, 1834; *Vulpes vulpes* L., 1758; *Meles leucurus* Hodgson, 1847; *Neovison* (=*Neogale*) vison Schreber, 1777 and in Cetartiodactyla – *Capreolus pygargus* Pallas, 1771; *Sus scrofa* L., 1758. Representatives of Chiroptera and Eulipotyphla (Insectivora) orders were rare. *Cricetus cricetus* L., 1758, a rodent species, is a particularly interesting species for monitoring. The species was registered at the study area at the beginning of this century, but ever since only its old burrows were found. A drastic decline of the species number across its whole range (expecially in its European part) will obviously necessitate adding the species into the Red Data Book of Tyumen Oblast.

In 2022, seven vertebrate species red-listed in the Russian Federation and Tyumen Oblast were registered: *Lepus europaeus* Pallas, 1778; *Vulpes corsac* L., 1768; *Pelecanus crispus* Bruch, 1832; *Aquila clanga* Pallas, 1811; *Tadorna tadorna* L., 1758; *Chettusia gregaria* Pallas, 1771 and *Strix aluco* L., 1758.

Invertebrates of the area under scrutiny may be devided into terrestrial and aquatic. In the collection, the terrestrial invertebrates are mostly insects coming from 67 species, 8 orders, and 26 families. Three Lepidoptera species were registered: *Vanessa atalanta* L., 1758; *Argynnis Niobe* L., 1758 and *Melanargia russiae* Esper, 1783 are rare, but only the former is listed in the Red Data Book of Tyumen Oblast.

The two lakes' hydrobiocenoses are fundam entally different. The Salt Lake complex features the only species of the parthenogenetic forms with an ambiguous status under an umbrella term *Artemia parthenogenetica* Bowen & Sterling, 1978. There are accounts of *Cletocamptus retrogressus* Schmankevitsch, 1875 copepod encounters in hypersaline lakes [7], but it was not registered in Salt Lake.

Lake Dolgoye aquatic organisms assemblage comprise the total of 27 plankton and benthos species. Thirteen representatives of zooplankton coming from three majoir taxa (3 Rotifera, 4 Cladocera, 5 Copepoda) were registered. In terms of numbers and biomass, a large representative of Cladocera, *Daphnia magna* Straus, 1820, tops the list. In the samples, the benthic animals mostly included larvae of Chironomidae and to a lesser extent specimen of other taxa: Chaoboridae, Ceratopogonidae, Oligochaeta, Mollusca. In the first half of the summer, a lot of breeding *Gammarus lacustris* G.O. Sars, 1863 from Amphipoda were registered.

### 4 Conclusion

Salt Lake Natural Monument is home to a wide array of vascular plants (166 species), fungi (60 species), and animals (205 species). As for the fungi, the species first registered in the forest steppe zone in the larch, pine, and birch plantations are of interest. Two plant species and eight animal species listed in different Red Data Books were registered. High recreational load affects meadow plant assemblages of the natural monument, promotes their species structure change, and general flora degradation as plants that are not resistant to trampling disappear while synanthrope species proliferate. Further research will make it possible to supplement lists of plant, animal, and fungi species of the natural monument, to conceive trends in the biota change induced by man-caused load and global climate change, as well as ecosystem dynamics of this specially protected natural territory as a whole.
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