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Protected areas in a large metropolis: the experience of the city of St. Petersburg (Russian Federation)

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Summary: St. Petersburg is the largest city in the world north of 60° N. It constitutes a top-level administrative unit of Russia and has a significant authority in the field of environmental protection. It has 15 protected areas (PAs) which cover 4.3% of the city territory and are governed by a special institution of the city government. Existing PAs secure the protection of a significant proportion of plant, fungus and animal species occurring in St. Petersburg. They provide important regulatory and cultural ecosystem services. There is a long practice of fruitful collaboration between the city authorities and academic scientists in providing comprehensive landscape and biodiversity surveys in order to justify the establishment of new PAs as well as wildlife monitoring of existing ones. PAs play an increasingly important role in the life of the city, especially as recreational and educational entities.

Keywords: conservation, protected areas, Russian Federation, St. Petersburg

St. Petersburg (1914–1924 Petrograd, 1924–1991 Leningrad) is the second most populated city in Russia with ca 5.4 million inhabitants. It is known worldwide for its cultural and historical heritage. During 1713–1918, it served as the capital of Russia and now is unofficially regarded as the 'northern capital' or 'cultural capital' of the country. It occupies 1439 km^2, which is approximately twice the territory of the state of Singapore or more than half of the territory of Luxembourg. St. Petersburg is the largest city in the world located north of 60° N latitude.

According to the Constitution of the Russian Federation, the city of St. Petersburg holds the status of a top-level administrative unit (federal subject of Russia or subject of the Russian Federation) and has significant authority in the field of its environmental protection and conservation. The aim of this paper is to present to a wide audience the results of the development of the system of protected areas in this city and the arising problems and challenges.

Natural conditions

St. Petersburg is located in the North-West of European Russia in the lower reaches of the Neva River (including its delta) and along the coasts of the Neva Bay in the Gulf of Finland (Baltic Sea). The main part of the city occupies lowlands with absolute heights from 0 m to 30 m. The maximum length of the city territory from northwest to southeast reaches 90 km. Ecologically, the city's land belongs to the southern subzone of the taiga zone of the East European Plain (Isachenko & Lavrenko 1980). However, the flora of the city possesses some similarities with Central Europe because of the proximity to the Baltic Sea. According to Takhtajan (1986: 18), the Central European floristic province includes "the western shores of the Karelian Isthmus, the environs of Leningrad [now St. Petersburg] and the entire southern shores of the Gulf" [of Finland]. Urbanised and industrial territories occupy about half of the area under the city administration. They are constantly growing due to the transformation of former agricultural

Figure 1. The general view of Yuntolovskiy sanctuary.

lands and the development of reclaimed areas in the Gulf of Finland. Nevertheless, at least 30% of the territory can be classified as natural landscapes because of the predominance of natural vegetation without significant human impact. About 20% of the city's area is occupied by forests, where mainly Scots pine (*Pinus sylvestris* L.) as well as European spruce (*Picea abies* (L.) Karst.) and birches (*Betula pendula* Roth and *B. pubescens* Ehrh.) prevail. Peatlands with mire vegetation and swamp forests occupy about 5% and smaller areas are classified as shrubland, meadow and riparian vegetation.

Categories of protected areas in the Russian Federation

According the Federal Act on Protected Areas[1] (1995, with several amendments adopted in 2001–2019), Russia has following categories of protected areas (PAs): strict state-governed nature reserve [zapovednik] (corresponds with category Ia according IUCN PAs system), national park or nature park (IUCN category II), state nature sanctuary [zakaznik] (category IV), state nature monument [pamyatnik prirody] (category III) and arboretum and botanical garden. Strict nature reserves and national parks must be under federal authority and others could be of federal, regional or local importance. Botanical gardens and arboreta comprise the special category of PAs, but they are not meant for wildlife conservation.

Development of protected areas in the city of St. Petersburg

The formation of a network of PAs in St. Petersburg began more than 30 years ago. Within the city there are two PA categories: nature sanctuaries and natural monuments of regional importance. The first PA, established in 1990, was Yuntolovskiy sanctuary (9.77 km^2) with forests, fens and mires located close to highly urbanised areas (Fig. 1).

After the adoption of the Federal Act on Protected Areas, the number of PAs in St. Petersburg has increased significantly (Table 1). At the beginning of 2021, fifteen PAs were of regional importance: 8 sanctuaries[2] and 7 natural monuments occupying 61.43 km^2 (4.3% of the

1 In literal translation from Russian: Federal Act on specially protected nature areas.

2 In 2021 another one (9th) state nature sanctuary 'Shungerovskiy' (0.33 km^2) has been established.

Table 1. Protected areas of regional importance in St. Petersburg.

Name of protected area	Area km^2	Year of establishment
1. 'Yuntolovskiy' state nature sanctuary	9.77	1990
2. 'Dudergofskie vysoty' [Duderhof heights] state nature monument	0.65	1992
3. 'Komarovskiy bereg' [Komarovo sea shore] state nature monument	1.80	
4. 'Strelninskiy bereg' [Strelna sea shore] state nature monument	0.40	
5. 'Park Sergievka' state nature monument	1.20	
6. 'Gladyshevskiy' state nature sanctuary	7.65	1996
7. 'Severnoe poberezhye Nevskoy guby' [North coast of the Neva Bay] state nature sanctuary	3.30	2009
8. 'Ozero Shchuchye' [Lake Shchuchye] state nature sanctuary	11.57	2011
9. 'Sestroretskoe boloto' [Sestroretsk mire] state nature sanctuary	18.77	
10. 'Petrovskiy prud' [Petrovskiy pond] state nature monument	0.03	
11. 'Elagin ostrov' [Elagin Island] state nature monument	0.97	2012
12. 'Zapadnyy Kotlin' [West part of the Kotlin Island] state nature sanctuary	1.02	
13. 'Yuzhnoe poberezhye Nevskoy guby' [South coast of the Neva Bay] state nature sanctuary	2.66	2013
14. 'Dolina reki Popovki' [The Popovka river valley] state nature monument	0.26	
15. 'Novoorlovskiy' state nature sanctuary	1.38	2015

total city area) (Fig. 2). They are administrated by a special institution established by the city government, the Directorate of Natural Protected Areas of St. Petersburg. The main objectives of this institution are the management of existing PAs and the organisation of new ones.

The Directorate supported the ideas proposed by researchers about the need for comprehensive studies of existing PAs as well as of territories beeing considered worthy for establishing of new ones. In 2005, the Regional Act 'On the General Plan of St. Petersburg' was adopted. It declares the organisation of a network of PAs as one of the major tasks to improve and protect the environment of the city. According to this Act, the number of PAs in St. Petersburg should reach 21 in 2025.

In 2011, the government of St. Petersburg adopted a decree on the procedure for interaction between authorities in the process of the establishment of regional PAs, which includes the following stages:

- comprehensive environmental survey (including biodiversity studies) of the territory in order to justify the status of PA;
- collection of necessary data from the executive bodies of the city government;
- development and approval of a draft decree by the Government of St. Petersburg on the establishment of the specific PA on the basis of a comprehensive environmental survey and other important information.

In 2014, the legislative assembly of St. Petersburg approved the Act 'On the list of territories on which comprehensive environmental surveys are to be conducted in order to assign to these

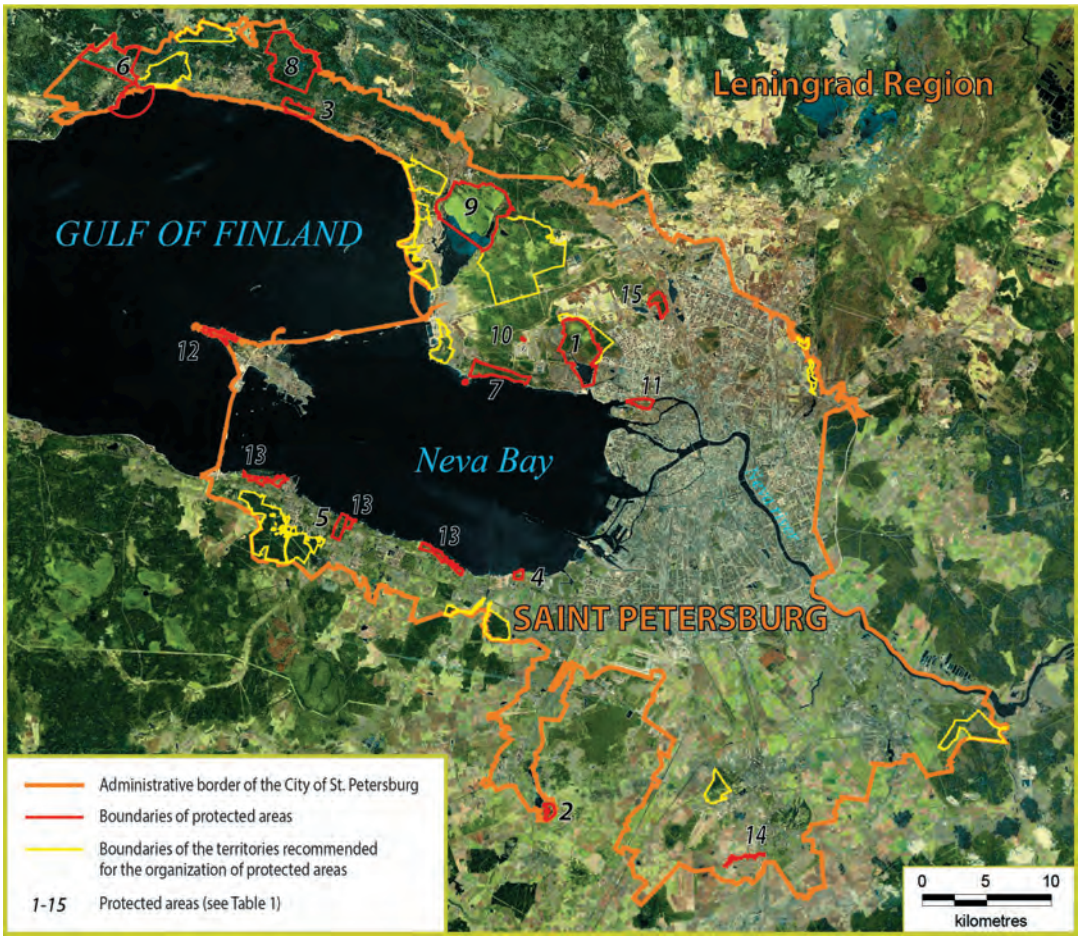

Figure 2. Protected areas of St. Petersburg.

territories the legal status of protected areas of regional importance'. Thus, the development of PAs is regulated by both by the general plan of the city and this Act.

During 2010–2016, almost all territories proposed for PAs by the General Plan were investigated. In 2016, surveys of territories stipulated by the Act of 2014 began; their total area is 160 km^2. In the case of the full implementation of the General Plan and the Act and the creation of PAs on all sites intended for survey, the area of PAs can reach about 20% of the city territory, which will ensure the safety of all of the main types of natural landscapes and plant communities and form a real environmental framework for the city, and at the same time provide for the recreational needs of its inhabitants.

However, the process of creating new protected areas is cumbersome and often takes many years, because it conflicts with the interests of investors and developers in setting up housing areas, recreation complexes, industrial enterprises, roads and other potential uses.

Landscapes and wildlife of PAs

The existing PAs in St. Petersburg cover almost all types of natural landscapes and vegetation characteristic of St. Petersburg and its surrounding territory as well as their modification under human influence.

A significant proportion of PAs (7 of 15) is located along the coast of the Gulf of Finland, mainly within the Littorina terrace formed by deposits of the Littorina Sea, which existed 8000–3000 years ago. Littorina terrace with altitudes up to 12 m s.l. is characterised by drained and bogged up plains on shingle-less sand and sandy loam, sometimes with ancient beach-ridges. Different types of spruce and deciduous forests grow here, including quite rarely black alder (*Alnus glutinosa* (L.) Gaertn.) forests in waterlogged sites.

Lake and glacial-lacustrine sandy and loamy terraces at elevations of up to 30 meters form the next level of Petersburg's landscapes. PAs located here include coniferous (mainly pine) and mixed forests (with spruce, pine and birch). Above a surface of glacial-lacustrine terraces, the kame[3] sandy hills tower over the northern part of the city; their altitude exceeds 100 m at some places. Kame hills, alternating with close hollows, are covered by pine and mixed pine-spruce forests. Kame landscapes are very picturesque and subjected to recreation loads.

Several protected areas include large mires with various types of oligotrophic, mesotrophic and eutrophic plant communities. The largest one is the Sestroretsk mire (more than 13 km^2), which is not disturbed by human influences and includes, among other mire types, ridge-hollow and ridge-hollow-pool complexes unique to St. Petersburg.

Some protected areas include historical parks created in the 18th and 19th centuries, where natural plant communities were enriched with exotic ornamental species of trees, shrubs and herbs that have adapted to local conditions. Most of them successfully reproduce; some species (e.g. ash-leaved maple, *Acer negundo* L.) have a tendency to be invasive, but in general the invasion of alien ornamental plants is not currently critical for PAs in the city.

As a result of dedicated research supported by the city budget, thematic maps of landscapes, vegetation maps, schemes of distribution of rare plant species were compiled, along with a complete inventory of the flora (vascular plants, bryophytes, lichens and for some PAs mycobiota and algae as well) and the fauna of vertebrates (Table 2).

The flora of vascular plants of St. Petersburg contains about 1080 species (Budantsev & Yakovlev 2006) including ca 200 alien species that mostly grow in urban areas, along the railways and highways. About 740 species of vascular plants occur in existing PAs. Thus, only 140–160 indigenous species have not been recorded in PAs yet. The flora of the city is significantly enriched with exotic species (about 100–180 in some PAs, which serve at the same time as parks).

Almost the entire bryoflora of St. Petersburg is represented in PAs, where currently about 300 species of bryophytes are known. Such high species diversity for a relatively small area of PAs is likely due to the fact that PAs include the majority of the typical landscapes and biotopes of the area.

Due to the diversity of natural and anthropogenic biotopes, 563 species of lichens are found within the boundaries of St. Petersburg. This is the richest urban lichen flora known in Russia, which has been studied for about 200 years. Almost the entire diversity of lichens (520 species) was found within existing PAs.

Over the entire history of research in St. Petersburg, 8 species of amphibians and 4 species of reptiles have been recorded there. Amphibians are found in forest parks, communal gardens, some city parks and in the coastal zone of the Gulf of Finland. Reptiles still occur but only in

3 Flat-topped mounds composed of sand and gravel deposited at places where the dead ice melts.

Table 2. Diversity of landscapes, plant communities and different groups of organisms in the protected areas of St. Petersburg.

Name of protected areas	Number		Number of species of plants and fungi				Number of species of terrestrial vertebrates			
	landscape sites	types of plant communities	vascular plants	bryophytes	lichens	macro-mycetes[1]	amphibians	reptiles	birds[3]	mammals
State nature sanctuaries										
Yuntolovskiy	15	67	380 (6)	160 (14)	146 (3)	320[1] (14)	4	3	172 (48)	27 (5)
Gladyshevskiy	27	61	450 (4)	139 (7)	310 (7)	168[1] (15)	4	3	122 (28)	34 (8)
Severnoe poberezhye Nevskoy guby	10	65	521 (12)	123 (5)	189 (9)	714[1] (30)	4	1	183 (54)	30 (8)
Ozero Shchuchye	21	39	397 (2)	138 (8)	204 (6)	>100[2] (9)	4	3 (2)	86 (12)	30 (7)
Sestroretskoe boloto	24	70	468 (1)	142 (11)	190 (5)	572[1] (29)	4	3	162 (35)	22 (7)
Zapadnyy Kotlin	13	42	454 (4)	78 (5)	164 (3)	26[2]	4	1	144 (32)	20 (6)
Yuzhnoe poberezhye Nevskoy guby	16	82	464 (1)	106 (3)	164 (12)	27[2]	5	1	173 (45)	33 (7)
Novoorlovskiy	3	27	355	74 (2)	109	n. i.	2	1	76 (6)	12
State nature monuments										
Dudergofskie vysoty	11	37	418 (4)	107 (12)	157 (3)	200[2] (7)	5	0	78 (10)	25 (9)
Komarovskiy bereg	20	49	405 (2)	120 (7)	160 (3)	100[2] (7)	3	1	143 (12)	20 (2)
Park Sergievka	15	76	541 (2)	70 (5)	186 (8)	~500 (3)	5	1	188 (29)	34 (9)
Strelninskiy bereg	8	16	268 (2)	49 (1)	34	40[2] (2)	5	1	131 (20)	17 (3)
Petrovskiy prud	3	8	152	62 (3)	30	n. i.	3	1	30 (2)	15 (2)
Elagin ostrov	7	51	520	66	87	113[2] (2)	2	0	144 (22)	17 (3)
Dolina reki Popovki	16	30	340 (1)	86 (2)	115 (1)	n. i.	2	1	60 (3)	15 (3)

[1] Ascomycetes, agaricoid, gasteroid, aphyllophoroid and heterobasidioid fungi have been studied.
[2] Not all systematic groups have been studied.
[3] All species, nesting and flying, including those staying in the water areas near the protected areas.
n. i. = no information.
The number of rare species listed in the Red Data Book of St. Petersburg (Geltman 2018) is given in brackets.

the natural landscapes. Due to intensive development and the resulting further fragmentation of natural landscapes, the number of amphibians and reptiles is steadily declining.

Features of the St. Petersburg's avifauna are determined by the location on the coast of the Gulf of Finland and the variety of landscapes and biotopes which are suitable bird habitats. Over the

duration of the study, 267 bird species have been recorded in the current limits of St. Petersburg. Birds are found everywhere in the city, but species diversity and abundance vary greatly. Forest species and those inhabiting aquatic and riparian biotopes are most widely represented at nesting sites. St. Petersburg is located on one of the branches of the White Sea-Baltic flyway. Vast areas of shallow water in the Neva Bay and the sand and pebble coasts of the Gulf of Finland are attractive migratory sites for dozens of species of waterfowl and shorebirds: grebes, swans, ducks, coots, gulls, terns and waders. Hundreds of thousands of birds do not only fly over the city, but also form mass migratory camps on its water areas and coastal territories during feeding and resting en route to nesting sites in northern Europe in spring and overwintering places in autumn. In the PAs of the city, 211 species of birds are registered. This high level of bird diversity and numerous rare species reflect the fact that all main types of regionally characteristic bird habitats are represented within the existing network of PAs.

The composition of the vertebrate animal world of St. Petersburg was directly and indirectly driven by human activity, which is associated with the appearance of synanthropic animal species. Today about 40 species of mammals live wild in St. Petersburg; almost all of these species are also represented in the protected areas. Some animals (e.g. lynx, elk, bear) only periodically visit the city area due to seasonal migrations or the resettlement of young individuals.

Monitoring studies on PAs

An important element of managing and maintaining the functions of protected areas within a large metropolis is the monitoring of their ecosystems and any changes due to natural causes and human influence. Since 2006, regular monitoring studies (every 2–5 years) of natural ecosystems at specially selected permanent sample plots have been carried out financed by the city. These studies include: a description of the soil profile; complete species listing, stand, young growth and shrub layer assessment; assessment of the condition of trees; recording of seedlings of forest-forming tree species; characterising and mapping of the horizontal structure of communities; compiling lists of vascular plants, bryophytes and lichens; recording and assessment of the state of populations of rare plant species; and detailed photography. Currently, such studies are carried out by researchers from the institutes of the Russian Academy of Sciences and St. Petersburg State University on 55 permanent sample plots in 12 PAs.

As a result of monitoring, data on the dynamics of several natural components (especially vegetation cover) and on trends in natural landscape as a whole were compiled. These changes include, e.g. the succession of tree species in forest communities (for example, replacing birch by spruce), the formation of forest and shrubland on former agricultural lands, waterlogging, erosion of the shore of the Gulf of Finland, retreat of the coastline, overgrowth of coastal vegetation, etc.

Monitoring observations have made it possible to determine the impact of climate change in recent decades (especially the increase in air temperature of 1–1.5°C during the cold period of the year) on the vegetation cover of PAs. At the moment, the increase of broad-leaved trees (especially common oak, *Quercus robur* L.) in the forests of different landscape conditions (including bogging forests with sphagnous cover) is evident; common oak usually is present in the young growth and occasionally forms a part of the forest stand. Another consequence of climate change is the lengthening of the ice-free period in the Gulf of Finland, which has led to an increased frequency of storms and coastal erosion.

Figure 3. Publications on landscapes and biodiversity of St. Petersburg's protected areas.

On the basis of monitoring data and routine observations, programmes are being developed to protect and conserve the natural protected areas. In accordance with the recommendations of researchers, restoration measures are being implemented, such as draining swampy areas of spruce forests, the construction of pedestrian stairs on steep slopes to prevent erosion and denudation, construction of barriers to control the passage of cars in the areas with high recreational loads, etc.

Data from comprehensive surveys of existing and planned PAs, including observations at permanent sample plots, provided important information for the new edition of the Red Data Book of St. Petersburg (Geltman 2018) which now contains 70 species of fungi, 68 lichens, 19 algae, 50 bryophytes, 47 vascular plants, 8 molluscs, 78 arthropods, 3 fishes, 2 amphibians, 3 reptiles, 71 birds and 17 mammals.

The results of interdisciplinary research by a large team of specialists (botanists, zoologists, landscape geographers, etc.) were compiled to produce a series of monographs devoted to the biodiversity and landscapes of many PAs (Volkova et al. 2004, 2005a,b, 2006, 2007, 2011, 2017, 2020) and two editions of the 'Atlas of protected areas of St. Petersburg' (Khramtsov et al. 2013, 2016) (Fig. 3).

Monographs provide comprehensive information about the landscapes and wildlife of PAs, which are important for the evaluation of their current condition and future monitoring; further, they also serve as a data source for environmental education and appeal to civil society to build support for nature conservation.

The Atlas (Khramtsov et al. l. c.) contains materials of 12 PAs: the characteristics of physical and geographical features, essays on the history of development in the territory, descriptions of landscapes, vegetation, characteristics of flora and fauna of vertebrate animals, lists of rare and protected species of vascular plants, bryophytes, lichens, fungi, terrestrial vertebrate animals as well as large-scale physical geographic maps (1 : 4000–1 : 25000), maps of landscapes, vegetation,

Figure 4. Educational walking trail in 'Sestroretskoe boloto' sanctuary. Photo from the archive of the Directorate of natural protected areas of St. Petersburg.

and a series of historical maps of the 18th to 20th centuries. Maps of modern processes in landscapes have been prepared for some PAs. The Atlas (Khramtsov et al. l. c.) has been widely distributed to the public and local authorities including various branches of the city government to inform environmental policymakers.

Ecosystem services and environmental education

PAs of St. Petersburg, like other PAs, provide significant regulatory ecosystem services: maintaining optimal atmospheric composition, retention of pollutants, regulation of surface and underground runoff, erosion control, maintaining biodiversity, etc.

It is impossible to overestimate the recreational and educational significance of PAs for St. Petersburg. Some PAs traditionally served as recreational areas for the city residents. Initially, just after the establishment of PAs, the introduction of some restrictions such as making open fires was in conflict with common recreation practice. Common habits have changed since then and the public became more interested in information on flora and fauna of PAs and its heritage. Five of the PAs have nature walks (educational trails) (Fig. 4), which are increasingly popular. The special feature of these trails is information which does not only concern natural history, but cultural and historical heritage as well. The Directorate of PAs has a special section responsible for education which organises lectures and educational courses, e.g. Zapovednaya shkola [conservation school], an open lecture course devoted to the nature and wildlife of St. Petersburg. Recently volunteer activity in PAs is increasingly popular.

PAs have become an important part of the city life as evidenced by the frequency of their mentions in the media and especially in social media. The condition of PAs sometimes gets in the focus of the city agenda. A public movement 'Save Yuntolovo' organised mainly via social media is monitoring the situation around Yuntolovskiy sanctuary; it was most active during nearby highway construction.

Conservation challenges in a large metropolis

It should be noted that the traditional conservation approaches applied to PAs in sparsely populated regions are clearly unfit for a large metropolitan area. Firstly, landscapes of the majority of PAs in St. Petersburg have been much transformed by human impacts (bog drainage, forest cuttings, agricultural use, parks layout, etc.) and continue to change rapidly during regenerative successions and as a result of human activity. Secondly, natural landscapes in the large city should also serve for recreational purposes of the inhabitants. One of the main goals of the creation of the network of PAs in St. Petersburg is to improve the quality of life of its residents.

The scientific potential of St. Petersburg allows researchers to carry out traditional inventory studies and to practice forecasting research offering different variants of PA management depending on planned targets. The methodological basis for the landscape management of PAs is the landscape-dynamic concept, according to which the characteristics of an elementary landscape are classified based on the attributes of the landscape site (relatively stable characteristics of relief and pedogenic bedrock) and the attributes of long-term landscape states (more dynamic parameters related to vegetation and soil). Thus, dynamics of landscapes are seen as a change of landscape states within a constant 'framework' of landscape sites (Isachenko 2007, 2020). A change of landscape states due to various influences is likely defined by the characteristics of a landscape site and the corresponding influence. Therefore, the design of management actions concerning PA landscapes can be carried out on the basis of the landscape site patterns.

Decisions on the management of PAs in a large city depend on being able to answer two principle questions:

What are our targets in the establishment of the PA? In each case, it is necessary to define whether we want to make a given PA more relevant to nature conservation goals (including conservation of rare plant and/or animal species) or a recreation area. A long-term state (or a set of states) of a landscape corresponding to its functions in the context of PA most closely, and consequently being the aim of the management, is what we call a 'target landscape state' like conservation and maintenance of an old-year spruce forest with minimal participation of other tree species.

What processes are taking place in a given PA and how will these respond to the preservation of present conditions? We examine the processes of landscape change caused by the present combination of natural factors and human impacts (including recreation) as spontaneous processes. Studies of these processes allow us to predict the future state(s) of each local landscape.

If the answers to these two questions above are received, the planned management actions in a PA should change the trajectory of landscape dynamics in such a way that it arrives at the predetermined (target) state. The general scheme of decision-making in the design of landscape management in city PAs is presented in Fig. 5.

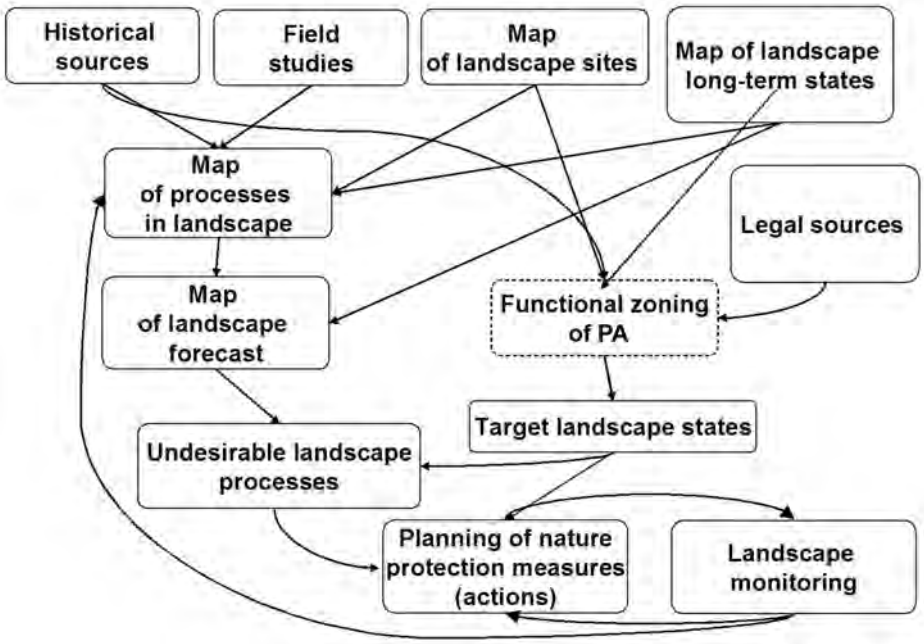

Figure 5. The algorithm of nature protected areas' management based on landscape-dynamical approach (Isachenko & Reznikov 2011).

Conclusion

Botanists and zoologists have studied the territory of St. Petersburg for at least 250 years, but its flora and fauna cannot be considered fully known, because it is constantly changing under the influence of natural factors and human impact. Developed areas are constantly expanding as well as their influence on natural ecosystems, and legislative mechanisms are being developed to control the increasing human impacts on nature and to preserve natural landscapes including unique natural ecosystems. Thus, this city could be proud not only of its cultural heritage, but also of significant successes in nature conservation. St. Petersburg's PAs could be a tourist attraction and draw visitors (especially foreign) to visit the city again. To achieve this, we need appropriate advertising campaigns, presenting St. Petersburg not only as a city with a rich cultural and historical heritage but also with natural sites that are well preserved by European standards.

Interdisciplinary studies provide a snapshot of the current state of PAs in the city and enable to predict future scenarios of change. This allows scientific justification for management decisions including minimising of unfavourable processes in PAs.

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