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СКВЕРЫ В ГОРОДАХ РОССИЙСКОЙ АРКТИКИ: ПРИОРИТЕТНЫЕ ЭКОСИСТЕМНЫЕ ФУНКЦИИ И УСЛУГИ, СПОСОБСТВУЮЩИЕ АДАПТАЦИОННОМУ РАЗВИТИЮ И УСТОЙЧИВОСТИ ГОРОДОВ

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Раскрывается роль городских скверов/небольших городских парков в повышении устойчивости городов в Арктическом регионе России. Модельными городами являются: Мурманск, Кировск, Воркута, расположенные на Европейском Севере России. Их современные эколого-географические характеристики различны, но зеленая инфраструктура имеет много общих черт, характерных для большинства арктических городов. Целью исследования явилась выявление специфических региональных экосистемных функций скверов/небольших городских парков, отличающиеся от таковых в более крупных парках в этом регионе. Скверы/небольшие городские парки в настоящее время в основном рассматриваются как рекреационные территории, хотя их функции одновременно создают важный баланс между социальными и природными городскими системами, поддерживая социальную ветвь городской устойчивости в некомфортных условиях проживания в Арктике. При этом информационные услуги экосистем (цветовые, эстетические, духовные и др.) имеют особое значение. Они обеспечивают условия для развития социальной сплоченности и формирования “чувства места”, позволяющего противостоять негативным социальным процессам, связанным с интенсивной миграцией, характерной для многих городов Российской Арктики. В условиях монохромных ландшафтов на протяжении долгой зимы, скромной цветовой палитры растительности летом, они снижают цветовое голодание у горожан, повышая комфортность условий проживания. Скверы/малые городские парки нуждаются в особом внимании муниципальных органов при развитии зеленой инфраструктуры.

Ключевые слова: Российская Арктика, зелёная инфраструктура городов, экосистемные функции, адаптационное развитие, социальная сплоченность

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INTRODUCTION

Nowadays, urbanization is one of the leading processes in environmental transformation. The share of the urban population is about 56% and continues to increase. According to the UN forecast, 68% of the global population will live in cities by 2050. The urbanization process is underway on all continents with the only exception of the Antarctic. Arctic regions are involved in this process as well [17, 25, etc.] Sustainable urbanization is included in the sustainable development goals (sustainable cities and communities) adopted by the UN in 2015. The

New UN Urban Agenda pointed out the necessity to maintain and develop the social and ecological functions of cities, reduce their vulnerability to natural and anthropogenic disaster risks and mitigate climate change [27].

Recently this system approach was transformed to recognize the existence of socioeconomic, natural and technical systems, drawing attention to modern technical achievements in promoting city resilience (green energy use, green roofs, devices for absorption of street air pollutants, etc. [4, 34, etc.]. The natural component of such systems is presented by the blue-green infrastructure which supplies a variety of ecosystem services both increasing the resilience of urban areas and providing better living conditions for citizens.

The studies of green infrastructure within urbanized territories are a primary focus of ecologists and municipal authorities in the majority of the developed countries, especially in the EU. Since 2010, the European green infrastructure became a part of the EU strategy for biodiversity and biodiversity policy. Target 2 of the EU Biodiversity Strategy is directed to maintain and enhance ecosystems and their services by establishing green infrastructure. In 2020, the European Commission established the Urban Greening Platform within the Green City Accord initiative directed "to mobilize European mayors committed to safeguarding the natural environment" [15]. One of the central goals of this initiative was to increase the extent and quality of green areas in cities [8]. Scientific support for these plans nowadays is provided by a large number of institutions, including the international TEEB program studies, urban ecology research programs of the Helmholtz Centre for Environmental Science (Germany), the Ecological Research Network (Ecornet), US Long-Term Ecological Research Network etc., and is also presented in recent monographs [14, 33], etc.

However, modern studies of the urban green infrastructure are still geographically limited and mainly concern the temperate zone cities in Europe and North America. Relevant research for more southern regions is also underway in Brazil, China, and India. As a result, there is an obvious gap in these studies for the Arctic zone where the existence of urban green infrastructure remains "unnoticed" by the scientific community [1, 13, 20]. Meanwhile, several large cities such as Murmansk, Norilsk, Vorkuta and Tromso with a population of 60000–310000 citizens are located beyond the Polar circle! The functions of green infrastructure promoting sustainable development here have features different from those in the temperate zone. For example, in terms of microclimate regulation ecosystem services, wind protection becomes more important than urban heat mitigation and information/cultural ecosystem services acquire special significance [19]. This idea supports the exclusivity of Arctic cities as they are bases for regional development. Arctic cities have specific public institutions that exist in extreme conditions as well as a specific internal structure and functioning. [25]. The following municipal priorities for strategic sustainable development goals have been recently outlined for Arctic cities: prevention and reduction of pollution, rehabilitation of damaged natural environmental systems, elimination of accumulated ecological damage, and protection of endangered species [16]. These goals may refer to many temperate zone cities as well. An innovative approach to the role of green infrastructure in Arctic cities was demonstrated in Green Arctic Building Project (GRAB) launched by Russia, Sweeden, Norway and Finland in 2019-2021[1], which focused on green building as the main topic. Arctic TEEB studies within the CAFF program of the Arctic Council are limited to biodiversity aspects [30]. Major research on green infrastructure in Arctic cities concerns agrotechnical and horticulture practices. Thus, a certain gap in studies devoted to the ecosystem functions of green infrastructure in Arctic cities is evident. The goal of this research is to reveal the main differences in the functions of green infrastructure in the Russian Arctic cities that support their resilience and demonstrate the important role of small city parks (pocket parks and squares) as elements of green infrastructure in this region.

[1] Green Arctic Building. www.site.unit.no

Fig. 1. Study area.

MATERIALS AND METHODS

This study focused on the cities of Murmansk, Kirovsk, and Vorkuta, which are located beyond the Polar Circle in the European part of the Subarctic zone and the Arctic administrative zone of Russia (Fig. 1). The first two cities belong to Murmansk region, while the third is located in the Komi Republic of the Russian Federation. Their modern ecological and geographical characteristics are different, but green infrastructure has many common features typical for the majority of Arctic and Subarctic cities and different from those of more southern cities of the Temperate zone.

Murmansk is situated at the northern limit of the forest-tundra zone, Kirovsk is located at the northern limit of the taiga zone on the Kola peninsula, and Vorkuta is located in the tundra zone at the North-Eastern marginal part of the Russian plain. All the studied cities are characterized by Subarctic climate, but with significant differences in their regional characteristics. In Murmansk region, the climate is Subarctic marine, while in Kirovsk it has many features of the continental climate. The climate in Vorkuta belongs to the Subarctic moderate continental type. Winters are long, but not as harsh as in Siberia, especially in the Murmansk region which is heated by the North Atlantic current. Summers are short and cool. Excessive hydration and snow cover period of more than 6 months are typical, strong winds are often and permafrost is found in Vorkuta. According to the first world classification of the Arctic zone cities [36], the city of Murmansk belongs to the category of key multifunctional centers, while Kirovsk and Vorkuta represent industrial inland centers. Their major socioeconomic and ecological characteristics are shown in Table 1.

All three cities have a well-developed green infrastructure which partly inherits forest and shrub natural remnants and partly was designed and planted over several decades. Thus, it combines initial planning and preservation of "green patches" within cities.

Our methodology was based on a combination of general official information from different regional and Federal sources, along with the analysis of scientific publications and field research data relevant to this study. This complex approach helped to reveal the problem and highlight its regional aspects. We used official data from the Federal Statistics Service, the information from the municipal Internet sites of the model cities, relevant international sites, OpenStreetMap and our field data. The field data included visual landscape studies and selective observations of the attendance to central small squares in summer and winter time, qualitative evaluation of visiting activities in daytime and during city festivals, and age composition of visitors at different times of the year. For Murmansk and Vorkuta, we also analyzed relevant information from local Internet sources, such as the frequency of appearance of popular parks' photos and sometimes information from selective interviews with citizens. Ranking of the ecosystem services was adopted from our previous studies [10] where their efficiency was evaluat-

Table 1. Principle socioeconomic and ecological characteristics of the model cities

	Characteristics	Murmansk	Kirovsk	Vorkuta
1	Time of city foundation	1916	1929	1936
2	Population (2021)	307723	25655	70551
3	Planning structure	The city stretches along the Kola Fiord, it has a historical center, regular central urban planning structure and scattered new neighborhoods on the surrounding hills	The city is located on one side of the terraces of the mountain lake Big Vyd'yavr. The city has limited space for the development. It preserves regular compact structure	The city has a regular, compact and elongated character (from north to southwest)
4	Economic activities	Transport and manufacturing industry	Apatite ores mining and initial processing, tourism	Coal mining
5	Main ecological problems	Air pollution	Air pollution and mechanical disruptions	Mechanical disruptions
6	Green infrastructure, %	30.7	42	14.1*
7	Dominating types of green infrastructure	Forest parks, public parks, pocket parks, street greening	Forest park, pocket parks, street greening	Forest parks, pocket parks

* For the municipal district.

ed based on field studies which revealed their influence on erosion, microclimate, recreation resources, etc. The principal research methods were landscape ecological and system analysis supplemented by the study of cultural landscapes. Cultural landscapes were defined as social-ecological systems in which both parts were equally important for the resilience effect studies [18].

RESULTS AND DISCUSSION

Social-ecological systems of Arctic cities

Arctic cities represent complicated social-ecological systems with many specific features in their composition [2, 17, 19, 26]. Dense urban development connected with difficulties in green infrastructure construction and maintenance, patterns of green infrastructure development, pools of ecosystem services that provide resilience, and specific images of cultural landscapes present key points to consider in city planning practice to provide the resilience of social-ecological systems to modern socio-economic and climatic changes [28, 20, etc.]. Green infrastructure is one of the most important elements of this resilience and its studies in Arctic cities are still new and rare [11, 13, 23]. Most often they only concern planning and climate change aspects, but not system analysis of green infrastructure functions that support resilience.

Specific features of green infrastructure in Arctic cities.

Green infrastructure in the majority of Arctic cities consists of relatively large park zones, small city parks, and street greening, often supplemented by small lakes and rivers with riparian territories. Large park zones in the model cities are represented by the patches of natural forests or shrubs in the form of city parks (with lighting, alleys, etc.), such as Kirovsk central park, Dolina Ujuta ("The valley of comfort") and Ogni Murmanska ("Lights of Murmansk") in Murmansk, Central and Pioneer parks in Vorkuta (former bogged shrubs), etc. Long snow cover and Polar night periods, extreme meteorological events during the cold period which lasts for more than half a year (strong winds and frosts, heavy snowfalls), remoteness from the central residential areas, and difficulties in clearing paths from snow limit the attendance of these parks mainly to weekends.

Fig. 2. Small city parks: central squares in Kirovsk (1); Vorkuta (2); Murmansk (3).

Alongside such large elements of green infrastructure, there are also small city parks in the model cities: 11 in Kirovsk, about 22 in Murmansk, and 3 in Vorkuta (Fig. 2). They occupy not more than 2 ha, but usually are much smaller. They may also be represented just by small patches of secondary vegetation (birch, willow, shrubs) remaining within city blocks. Another type of small parks is specially designed spaces decorated by trees, shrubberies, flowerbeds, and lawns. They are popular among citizens of different ages as places for rest, socializing and contact with nature.

Small parks are situated close to residential areas. During winter time paths and benches are regularly cleared from snow making these spaces reachable for citizens. In summer time parks are attractive because of flowering herbaceous plants and shrubs (*Syringa josikaea*, *Spiraea* sp., *Lonicera* sp., *Primula* sp., *Aconitum* sp., *Potentilla* sp., *Viola tricolor*, etc.) that are well-adapted to local conditions. The recommended types of ornamental plants include trees, shrubs, perennial, annual and biennial flower plant species. Tree species are mostly local and include birch (*Betula pubescens*), willow (*Salix* sp.), mountain ash (*Sorbus gorodkovii*), aspen (*Populus tremula*), larch (*Larix sibirica*), etc. These features of small urban parks to some extent provide the citizens with everyday contact with nature [22] and break the monochromic image that creates visual discomfort for citizens, especially during a long winter.

Priority ecosystem services of small city parks.

Pools of ecosystem services reflect the contribution of the social-ecological system to sustainable development [6]. There is no doubt that green infrastructure in Subarctic cities provides the traditional spectrum of ecosystem services, which includes regulating, supporting, information and even productive (berries and mushrooms in large parks attract people) services. At the first glance, they may not differ from those of the more southern regions, but this

Table 2. Prioritization of ecosystem services of green infrastructure in Murmansk, Kirovsk, Vorkuta

	Ecosystem service	Structure	Murmansk	Kirovsk	Vorkuta
			Importance (rank)*		
1.	Regulating	Runoff regulation	2	2	3
		Wind cooling protection/microclimate regulation	2	3	2
		Polluted air and runoff purification	1	1	1
		Noise mitigation	2	2	2
		Permafrost stabilization	–	–	3
2.	Supporting	Biodiversity support	2	2	2
3.	Productive	Berries, mushrooms, etc. production	1	3	1
4.	Information	Chromatic (different colors), aesthetic resources	3	3	3
		Recreation resources	3	3	3
		Spiritual (social cohesion)	3	3	3

* 1—the highest, 3—the lowest.

is only partly true. We argue that there may be certain differences important for the well-being of citizens and green infrastructure management practice. In our previous study [10] we revealed that the weight (importance) of principal regional ecosystem services for environment stabilization and city resilience in Murmansk and Tromso Subarctic cities were different and depended on different combinations of natural and socioeconomic factors. We extended this ranking based on a system analysis of our field data for the study area which included the analysis of ecological factors, a sociological survey and a review of relevant Internet publications. This data processing allowed us to develop a qualitative (expert) ranking of ecosystem services for the studied cities (Table 2).

The ranking revealed the higher importance of information ecosystem services supplied by local green infrastructure. It becomes even more evident for small city parks which reflect the specific nature of connection within the city area, especially in winters, thus creating images of Arctic cities [35]. Very often small city parks become iconic communication places in the cultural landscapes of Arctic cities. The most vivid example is “The Five Corners”, a small city park in the center of Murmansk (Fig. 2). It is situated at the crossroad of 5 main streets, close to the Central Palace of Culture, the biggest hotel, and the railway terminal. Its name reminds of the close connections between Murmansk and Leningrad (currently St. Peterburg) during the city’s construction period as the same toponym also exists in St. Peterburg. This place is used for city festivals, it is carefully managed and became one of the city’s symbols. It attracts both citizens and tourists visiting Murmansk all over the year. Creating a sense of place is one of the most important functions of small urban parks contributing to city resilience [3, 21, 31].

System approach to green infrastructure studies in the urban resilience context.

City resilience explains the long-term ability of a social-ecological system to cope with social, climatic etc. changes and to continue its development. A resilience discourse incorporates two important directions: socioeconomic and ecological which depend on different factors that in some cases produce a joint effect (Fig. 3).

The important socioeconomic factors for green infrastructure include its size, geographical location, city economy and management practice, local cultural traditions and social cohesion. A combination of ecological and socioeconomic factors implemented into nature-based solutions in management practice result in livable cities [8]. Small parks in Arctic cities provide community-level resilience. For example, a small city park in Kirovsk center (Fig. 2) exists for

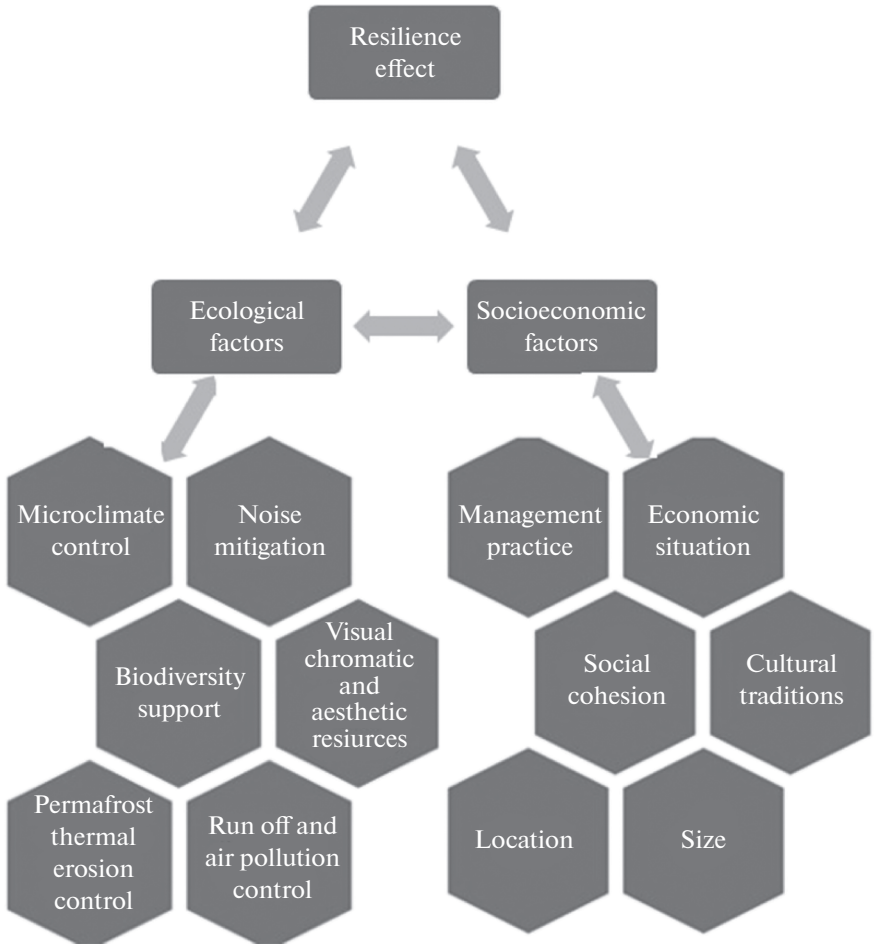

Fig. 3. The Joint effect of ecological and soicioeconomic factots in city resilience.

about 7 decades and becomes more and more maintained thus demonstrating its role in supplying specific ecosystem services of primary importance for citizens (Table 2). Industrial economic development and high anthropogenic pollution along with harsh climate and need for manpower launched green infrastructure development in Arctic cities to improve living conditions and create an attractive image of industrial cities. Small parks in historical centers of such cities became favorite places for citizens. At the same time, ensuring social stability in the conditions of high migration activity generates a need for social cohesion which is stimulated by comfortable communication in small city parks as well as during popular volunteer activities for their maintenance. Decorative plants (demanding frequent refreshing because of climatic conditions), snow removal, benches, and lighting make comfortable places for communication and reflect a cultural tradition of establishing attractive small parks in northern industrial cities to bridge the gap for everyday communication with nature, which is especially important for citizens in local conditions. The example of Kirovsk demonstrates close links between the mentioned factors. At the same time, small parks being an element of green infrastructure provide ecological resilience common for green infrastructure in general (Table 2), including

noise mitigation, wind and air pollution protection, biodiversity support, runoff control, etc. (Fig. 3).

Practical approach

The achievement of resilience in Arctic cities related to small parks is based on the consideration of the joint effect of the mentioned above factors, supplemented by appropriate technologies and actions [34]. Practical actions for supporting relevant ecosystem services were outlined in TEEB Manual for cities [29]. The goal of the TEEB-Urban project was to make a tool to integrate ecosystem benefits in the management process, including financing for municipalities. But as it was mentioned earlier relevant ecosystem services are geographically specific. Because of this, different practices and activities were suggested for "northern" regions [13, 17, 22, 23, etc.]. Most often regulatory services such as air pollution, runoff control and noise mitigation and recreation ecosystem services were mentioned as key points for management financing. This is true for the small Arctic city parks as well. For the biodiversity and aesthetic value support, there is no existing research, though such practice is known for more southern latitudes [5, 14, etc.], while the spiritual ecosystem service is still unquantifiable and is not discussed. The joint analysis of ecological and socioeconomic factors however suggests that it is relevant to the majority of ecological ecosystem services (the so-called indirect evaluation).

Appropriate technologies for the model cities were developed for many decades by the Polar Arctic Botanical Garden (institute) of the Kola Scientific Center and Biological and Agrobiotechnological institutes of the Ural Scientific center of the Russian Academy of Sciences. They may be referred to as nature-based solutions by ecosystem-based adaptation valuable for management practice [8, 24].

Small city parks are often used by municipal authorities as a place to demonstrate achievements in municipal development, exhibit paintings of local artists (in summer), and hold different festivals.

The development and improvement of green infrastructure were included in municipal development plans of the model cities adopted for 2017–2030. However, planning activities there concern mainly large city parks and generally lack a joint approach to address socioeconomic and environmental aspects of sustainable development. Nevertheless, citizens participate in this process by discussing acute problems of small city parks with local municipal authorities using different Internet platforms and mass media. Relevant ecological volunteer activities are popular among citizens of all ages as well, especially in the groups of older people and school children.

Conclusion

Small urban parks nowadays are mainly regarded as recreational territories, even though they provide "social production", which creates a certain balance between social and natural systems and supports resilience. The research highlighted the role of small city parks in promoting the resilience of cities in the Arctic region. Special attention was given to their specific regional ecosystem functions.

• Adequate management of urban green infrastructure nowadays is an essential part of implementing nature-based solutions, but the existing practice is still limited geographically. The management of small urban parks in Arctic cities based on the studies of their ecosystem services plays an important role in achieving city resilience in uncomfortable living conditions.

• The functions of ecosystem services in Arctic cities differ from those in more southern latitudes. Information ecosystems services (chromatic, aesthetic) become particularly important as they help to improve the quality of life in the conditions of harsh climate accompanied by local ecological problems. Nowadays, partial monetary assessment of these services can be done in order to consider them in the city management plans. Their effective management

patterns for the model Arctic cities were developed by regional scientific and practical institutions.

• For the spiritual ecosystem services of small city parks, there is currently no method of monetary assessment. However, further studies are needed because they provide a platform for developing social cohesion and creating a sense of place. This function helps to prevent many negative social processes typical for industrial Arctic cities, such as increased migration, indifference of new settlers to municipal development problems, etc.

• Modern nature-based solutions in Arctic cities are mainly directed at regulating ecosystem services of urban green infrastructure presented by large park territories. These solutions are typical for other geographical zones as well. Small urban parks contribute to the resilience of urban social-ecological systems by providing specific spiritual ecosystem services. Some of them form links with the past historical events associated with the economic development of the Arctic, generating a sense of pride. Besides, they provide new settlers with the enjoyment of close contact with small patches of nature that resemble their native places in more southern regions. Spiritual ecosystem services are especially important for the model Arctic cities and require careful maintenance.

Green infrastructure management in small city parks of the Arctic region requires special attention from municipal authorities because they produce a valuable social footprint. They promote the inclusive social development of Arctic cities, which is important for the resilience of the social-ecological system. Very often they create the image of Arctic cities. Scientific support for this process needs further investigation, especially this concerns large-scale studies of small city parks under different environmental conditions.

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Small urban Parks in the Russian Arctic Cities: Priority Ecosystem Functions and Services Promoting City Resilience

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Abstract—The research highlighted the role of small city parks (pocket parks, squares) in promoting the resilience of cities in the Arctic region of Russia. The model cities were Murmansk, Kirovsk, and Vorkuta situated in the European North of Russia. Their modern ecological and geographical characteristics are different, but their green infrastructure has many common features typical to the majority of Arctic cities. Special attention was given to specific regional ecosystem functions of green infrastructure, which are different from more southern regions. Studies of these functions are needed to develop nature-based solutions for providing urban population well-being and biodiversity support, effective management of urban green infrastructure, and ensuring the resilience of social-ecological systems. This is proven by the existing practice which is still limited geographically and mainly concerns large parks. The goal of this research was to demonstrate specific regional ecosystem functions of small city parks, which are different from the ones of large parks in this region. Small urban parks nowadays are mainly regarded as recreational territories, even though they can contribute to creating an important balance between social and natural systems and support the social branch of urban resilience in uncomfortable living conditions. Their ecosystem services differ from those in more southern latitudes. Information ecosystems services (chromatic, aesthetic) are particularly important. They provide a platform for developing social cohesion and creating a sense of place, which allows to withstand negative social processes typical for many cities in the Russian Arctic. Further studies are needed for spiritual ecosystem services as well as for possible ways of monetary assessment of information/cultural ecosystem services. Green infrastructure management of small city parks in the Arctic region requires special attention from municipal authorities.

Keywords: Russian Arctic, urban green infrastructure, ecosystem functions, resilience, social cohesion

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