The State of the Cenopopulations of Botrychium Lunaria (L.) Sw. on the Territory of the Natural Park "Rybachy and Sredny Peninsulas" (Murmansk Region)

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Abstract. A survey of the rare relict fern Botrychium lunaria (L.) Sw was conducted in one of the recently created specially protected natural areas (SPNA) in the Murmansk Region – the natural park "Rybachy and Sredny Peninsulas". 6 cenopopulations were identified in various parts of the park. It has been shown that this species will grow in a variety of conditions both with respect to the totality of the intensity of the action of abiotic factors and with respect to the composition of the phytocenosis. It is shown that while the vitality of individuals varies within rather narrow limits and only in two cenopopulations is below 1, the density of individuals differs significantly. The results of the survey showed that when monitoring the condition of the cenopopulations of the moon-fern, it is necessary to use a set of parameters.

1 Introduction

The Rybachy and Sredny peninsulas are located in the extreme northwest of the Kola Peninsula, washed by the waters of the Barents Sea. On the Rybachy Peninsula there is an extreme northern continental point of the European part of Russia with coordinates 69°57′07″ N 31°56′26″ E. This natural park was created in 2014 [1] in accordance with the concept of development of protected areas of the Murmansk region developed in 2011 [2]. Tundra ecosystems, places of growth of rare species of vascular plants listed in the Red Book of the Murmansk region are protected here.

Mass tourism and reindeer husbandry on the Rybachy and Sredny peninsulas pose threats to natural objects. A number of rare plant species have an area boundary here. Tundra species are threatened by deer grazing and off–road vehicles, rock - extreme sports. Some species can be destroyed as valuable medicinal raw materials. Analysis of data on the distribution and status of populations of rare plant species using GIS will allow to identify critical areas for the conservation of components of biodiversity.

The Rybachy and Sredny peninsulas are visited annually by thousands of tourists, therefore, the regulation of tourist flow and the creation of an optimal network of routes

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that ensure the preservation of all components of biological diversity are the primary conservation tasks of the natural park.

Floristically, the territory of the peninsulas has been studied quite fully. The study of the flora of the Kola Peninsula began in the XVII century. In the middle of the XIX - early XX centuries, the flora and vegetation of the region was studied during geographical expeditions of the St. Petersburg Academy of Sciences, the St. Petersburg Society of Naturalists, as well as Finnish and Swedish scientists. Since 1931, research has been conducted by the Polar-Alpine Botanical Garden-Institute [3-6]. Population studies on the Rybachy and Sredny peninsulas were conducted by employees of the Polar-Alpine Botanical Garden. The results of these works formed the basis of the Biological flora of the Murmansk region. Thus, data on the density and age structure of the population were obtained for the northern fern on the bank of the Skorbeevka River on the Rybachy Peninsula [7].

The purpose of this study was to study the distribution and condition of the cenopopulations of the moon-fern on the territory of the natural park.

2 Materials and Methods

The moon-fern – Botrychium lunaria (L.) Sw. – is a plurizonal almost cosmopolitan species [8]. It is listed in the Red Book of the Murmansk Region as a species in need of special attention to its condition in the natural environment [9].

The determination of the number and age composition of cenopopulations of rare species was carried out on sample areas for which geobotanical descriptions were made. Temporary sites were laid inside the test areas, their number and size depended on the size of the population.

The assessment of the specifics of the ecological regime of each habitat was carried out on the basis of D.N.Tsyganov's ecological scales [10] by processing geobotanical descriptions according to indicative ecological scales. Taking into account the climatic, orographic and soil conditions of the studied territory, the following ecological and phytocenotic scales were selected: thermoclimatic, cryoclimatic, scale of humidification, aridity-humidity, richness of soils with nitrogen, trophic and acidity of soils.

To assess the viability of cenopopulations, the IVC vitality index was used [11]. The index is calculated using the alignment method of weighing averages [12]:

$$\text{IVC} = \frac{\sum_{i=1}^{N} xi / \overline{Xi}}{N}$$

where x i is the average value of the i-th trait in the cenopopulation, X i is the average value of the i-th trait for all cenopopulations (when monitoring one cenopopulation, the average value for all years of observations), N is the number of traits.

3 Results and Discussion

The results of the survey showed that the moon-fern is quite common both on the territory of the natural park and outside it. Cenopopulations of this species are confined mainly to the coast (Fig. 1).

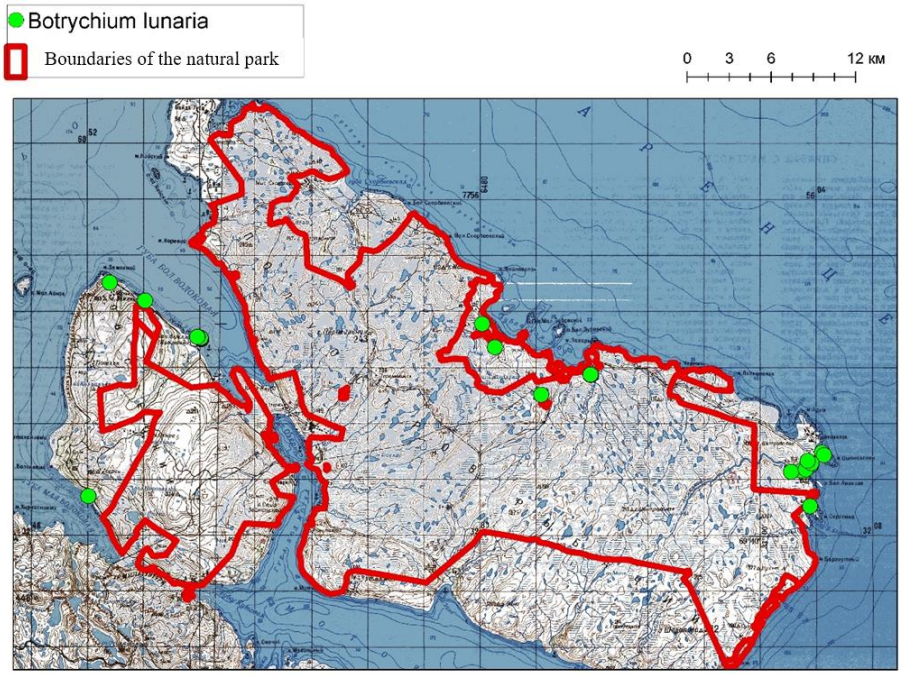

Fig. 1. Localization of the largest cenopopulations of the moon-fern on the territory of the natural park.

6 cenopopulations of this species were studied.

The moon-fern is found on the territory of the natural park in a wide variety of habitats. The species composition of phytocenoses with the participation of this species is presented in Table 1.

Table 1. The species composition of phytocenoses with the participation of the moon-fern.

Title	1	2	3	4	5	6
Allium schoenoprasum	–	–	–	–	–	cop1
Astragalus subpolaris	cop1	cop1	–	sp.	cop1	
Achillea millefoilia	cop1	cop1	–	sp.	cop1	sp.
Alchemilla alpina	–	–	–	sp.	–	–
Alcemilla sp.	–	–	–	–	sp.	–
Anthoxantum alpinum	–	–	–	–	sp.	–
Berteroa incana	–	–	–	–	–	sp.
Betula nana	–	–	–	–	–	–
Botrichium lunaria	sp.	sp.	sp.	sp.	sp.	sp.
Campanula rotundifolia	–	–	–	–	sp.	sp.
Coeloglossum viridiflora	–	–	–	–	–	–
Cerastium alpinum	sp.	–	–	–	–	–
Chamaenerion angustifolia	–	–	–	–	–	cop1
Cirsium heterofillum	–	–	–	–	cop1	–
Drias octapetala	–	cop1	–	–	–	–
Empetrum hermaphroditum	–	–	cop1	–	–	–
Euphrasia sp.	–	–	sp.	sp.	sp.	sp.
Festuca rubra	–	–	sp.	sp.	sp.	–
Hierochloe odorata	–	–	–	–	sp.	–

Gentianella aurea	–	–	–	cop1	–	–
Geranium sylvatica	–	–	–	–	sp.	–
Lathyrus aleuticus	–	–	–	–	–	cop1
Ligusticum scoticum	cop2	–	–	–	–	–
Leymus arenarius	cop1	–	–	cop2	–	–
Leontodon automnalis	–	sp.	–	sp.	–	–
Parnassia palustris	–	–	–	–	–	cop1
Pinguicula vulgaris	–	cop1	–	–	–	–
Poa alpina	–	–	–	sp.	sp.	–
Ranunculus glabriusculus	–	–	–	–	cop1	–
Rhinanthus minor	–	sp.	sp.	sp.	cop1	sp.
Rhodiola rosea	–	–	cop1	–	–	–
Rubus saxatilis	–	–	–	–	cop1	–
Rumex acetosella	–	–	–	cop1	sp.	–
Polygonum viviparum	–	cop1	sp.		sp.	–
Sagina	–	–	–	sp.	–	–
Salix lanata	–	cop1	cop1	–	–	–
S.polaris	–	cop1	–	–	–	–
Saussurea alpina	–	–	sp.	–	–	sp.
Solidago lapponica	–	sp.	–	sp.	–	cop1
Taraxacum sp.	–	sp.	sp.	–	–	sp.
Trientalis eurapaea	–	–	sp.	–	–	
Vicia cracca	–	–	cop1	–	–	sp.
Viola biflora	–	–	cop1	–	–	
Viola palustris	–	–	–	–	–	–

From the data given in Table 8, it follows that the moon-fern occurs in communities that are relatively poor in species. Often this fern lives in disturbed communities: by the roads, near the territories of abandoned military bases and warehouses. But it is also not uncommon in primary communities: tundra, small tundra meadows, and does not avoid ecotopes influenced by sea water.

Table 2. Characteristics of the habitat conditions of the cenopopulations of the moon-fern.

Number	Acidity	Trophicity	Humidity	Illumination	Moisture variability	Richness of soils with nitrogen	Continentality of climate	Aridity/humidity	Cryoclimatic component	Thermoclimatic
1	7.0	7.2	12.0	2.7	6.5	7.2	8.0	8.0	7.3	7.2
2	6.4	6.3	12.6	2.6	5.1	6.3	8.8	8.6	5.8	5.6
3	5.5	5.4	13.0	2.9	5.3	5.4	8.7	8.4	6.0	6.1
4	6.3	7.4	11.9	2.9	5.1	7.4	7.9	8.6	7.3	7.1
5	6.2	6.5	12.1	3.4	6.2	6.5	8.8	8.0	6.7	6.6
6	6.7	6.6	11.8	2.8	5.9	6.6	8.8	7.7	6.8	7.4

The habitat conditions for the studied cenopopulations of the moon-fern are given in Table 8. According to the cryoclimatic scale, winter conditions in the described habitats can be characterized as quite severe (t.2), severe with a transition to moderate (most CP) and moderate (t.1). Thus, the moon-fern prefers ecotopes with the most mild winter conditions for this area.

The characteristic of the conditions on the thermoclimatic scale also shows that the moon-fern is more demanding of the amount of heat than such species as rhodiola rosea or frog orchid. The coldest is the ecotope in t.2 (euboreal group), the warmest is in t.1 (subboreal group).

On the scale of the continentality of the climate in most habitats, conditions can be characterized as sub-continental.

According to the humidity scale, vegetation in most locations can be attributed to the fresh-forest-meadow and wet-forest-meadow groups. According to the aridity-humidity scale, the conditions are fairly uniform and vegetation can be attributed to the semiarid group.

According to the illumination scale, vegetation can be attributed to vegetation of open and semi-open spaces, which is a slight distortion of real conditions, which is associated with a large proportion of cloudy days in summer and problems with the application of the Tsyganov scale in the tundra zone.

When assessing habitats on the scale of nitrogen availability, attention is drawn to the fact that the moon-fern does not occur on nitrogen-free soils, in most locations vegetation can be attributed to the 1 or 2 geminitrophilic group. Thus, this species is quite demanding of nitrogen.

According to the trophic scale, soils can be characterized as poor (t.3) or rather rich (t.1).

Table 3. The vitality index and the density of the moon-fern in the studied cenopopulations.

Measured parameter	CP1	CP2	CP3	CP4	CP5	CP6
Vitality of individuals	0.85	1.18	1.03	1.17	1.31	0.95
Density of spore-bearing individuals (pcs/m^2)	26	4	2	13	2	3

The indices of the vitality of the moon-fern in the studied cenopopulations fluctuate within relatively narrow limits. The maximum value of the index is observed in t.5, where the ecotope is characterized by the highest nitrogen supply. The minimum value of the index is observed in t.1, where conditions are characterized by relatively high humidity and variable humidification.

The density of the moon-fern CP varies very widely. The maximum density is observed in CP 1, for which the minimum vitality is marked. Considering the above-mentioned increased demands of this species on the growing conditions, probably the reason for the low vitality is precisely that the conditions for spore germination and gametophyte development were quite favorable, while the resources for the formation of large sporophytes were insufficient, and the ability to self-destruct is uncharacteristic for this species.

4 Conclusions

1. On the territory of the natural park "Rybachy and Sredny Peninsulas", the moon-fern is represented quite widely and is found in a variety of phytocenoses

2. The vitality and density of populations is determined by the habitat conditions, the requirements of the species to the conditions change with the age of plants, which is reflected in the ratio of the values of these parameters

3. To monitor this species, it is necessary to use a set of parameters, since high numbers are not always combined with high vitality of individuals.

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