STUDY OF *POTENTILLA POPULATIONS ARCTIC* ROUY ON THE COAST OF KANDALAKSHA BAY OF THE WHITE SEA

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Annotation

The article presents the results of a study of the structure and assessment of the state of Potentilla coenopopulations Arctic Rouy on the coast of Kandalaksha Bay of the White Sea. Population monitoring of this plant species, listed in the regional Red Book, is relevant due to its vulnerability, poor study, range fragmentation, and growth in areas subject to intense recreational impact. Morphometric and demographic parameters were studied for five cenopopulations, and their absolute and effective abundance, density, self-sustainability, and vitality were determined. It was found that the cenopopulations are predominantly sparse; in areas with minimal anthropogenic impact, abundance and density increase sharply. According to the "delta-omega" classification, they are considered young and maturing. Analysis of recovery index values allowed us to classify CP3 as stable, CP1 and CP5 as relatively stable, CP4 as unstable, and CP2 as critical. Factors that influence the vitality of individuals include the density of the vegetation cover and the immediate threat of mechanical damage to the plants. Given the increasing tourist flow and the lack of special conservation measures due to the location of cenopopulations outside the boundaries of existing protected areas, it can be concluded that P. arctica in the area under consideration is at risk of population decline and extinction.

Keywords: *Potentilla Arctic* Rouy , Kandalaksha coast, cenopopulations, recovery index, monitoring, conservation, Red Book.

I. Introduction

Studying populations of rare plant species, analyzing their viability and ability to reproduce independently, and identifying factors that may negatively impact their existence play a key role in developing effective approaches to their protection and conservation within a specific region.

The study was conducted to study the structure and assess the state of Potentilla cenopopulations arctica on the coast of the Kandalaksha Gulf in the vicinity of the city of Kandalaksha.

The object of the study is the *Potentilla cenopopulation Arctic* Rouy (hereinafter *P. arctica) is a perennial herbaceous plant with a woody* , dark-brown taproot and odd-pinnate basal leaves, the segments of which are deeply dissected into pinnately divided lobes. The flowers are yellow, collected in complex corymbose inflorescences [1].

The relevance of population monitoring is primarily due to the lack of data on the population ecology of the species, significant fragmentation of the range and limited distribution of the species in the Murmansk region.

P. arctica is endemic to Fennoscandia, distributed along the Karelian and Kandalaksha coasts of the White Sea and on the islands of the Kandalaksha Gulf from Veliky Island to Cape Turiy [1]. The species is also found in Sweden [2, 3]. *P. arctica is listed* in the Red Data Book of the Murmansk Region as a "vulnerable, including declining in numbers" species.

Typical habitats for *P. arctica include fissured* coastal cliffs, rocky ledges, and sandy-rocky placers covered with mosses and grasses. It prefers well-warmed areas enriched with ornithogenic nitrogen [4].

current data on the population ecology and biology *of P. arctica* in the literature. The age structure and seasonal development of the species have been studied in the vicinity of Kandalaksha and on the protected islands of the Kandalaksha Gulf. An experiment on growing it in culture was conducted on the territory of the Polar-Alpine Botanical Garden [5]. It is known that in culture, under the conditions of the Arctic flora exhibition in the Main Botanical Garden named after N.V. Tsitsin of the Russian Academy of Sciences, *P. arctica is* weakly stable, bears fruit irregularly, and survives for up to 6 years [6].

In the research report on "Preparatory Work for the Red Data Book of the Murmansk Region (2024)" [7], the species' habitat in the region is estimated to be less than 500 square kilometers, with populations reported to be highly viable. The population structure and population trends remain unstudied, and this work aims to fill this gap.

Fig. 1. *Potentilla arctica Rouy*

II . Methods

of P. arctica cenopopulations (Fig. 1) was conducted in August 2017 at sites along the coast of Kandalaksha Bay near the city of Kandalaksha. Sample plots were established on the eastern shore of the Savino-Kanozero Lagoon, on the seashore near the Nivskaya Hydroelectric Power Station outlet canal, and at Cape Monastyrsky Navolok. All generative and vegetative plants were counted in 1-m² sample plots, the number of plots in each case determined by the size of the cenopopulation.

Individuals were registered taking into account their ontogenetic state. The identification of age states was carried out in accordance with generally accepted concepts of the discreteness of plant ontogenesis [8-10].

Embryonic stages were excluded from the study and the following were distinguished: p – sprouts and seedlings; j – juvenile individuals; im – immature; v – virginile, or young vegetative; g_1

– young generative; g_2 – middle- or mature generative; g_3 – old generative; in some species, latent generative plants were also distinguished – g_0, ss – subsenile individuals; s – senile; sc – dying [8-11]. Age states were determined on the basis of available ontogenetic keys [5, pp . 190-199].

for the P. arctica cenopopulations :

1. age index [8]:

$$\Delta = \Sigma k_i m_i / \Sigma k_i,$$

where m_i is the number of individuals in the ontogenetic state with number i , and k_i is the age coefficient of the ontogenetic state with number i .

2. efficiency index [12]:

$$\omega = \Sigma p_i e_i,$$

where $p_i = n_i / n$ is the proportion of plants of the i -th condition in a given population, ni is the absolute number of plants of the i -th condition,

$n = \Sigma n_i$ – total number of plants,

e_i – energy efficiency.

3. Recovery index [13]:

$$I v = \Sigma j \rightarrow v / \sum g_1 \rightarrow g_3,$$

where $\sum j \rightarrow v$ - sum individuals pregenerative period ,

$\sum g_1 \rightarrow g_3$ - sum individuals generative period .

The obtained values of I in were interpreted using the criteria proposed by G.O. Osmanova and L.A. Zhivotovsky (2020), according to which when I in> 2 the cenopopulation self-sustains effectively; when 1 < I in< 2 the cenopopulation self-sustains moderately; when I in< 1 the cenopopulation self-sustains weakly [14].

The type of cenopopulation was determined according to the “delta-omega” classification of L.A. Zhivotovsky [12].

The vitality of individuals was assessed using the IVC vitality index [15]. The index is calculated using the mean weighting method [16]:

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

where x_i is the average value of the i -th characteristic in the cenopopulation, X_i is the average value of the i -th characteristic for all cenopopulations (when monitoring one cenopopulation, the average value for all years of observation), N is the number of characteristics.

III . Results

of P. arctica were studied in different areas of the Kandalaksha coast .

, *P. arctica* is found primarily in sandy and rocky areas. Its habitats are located within the city of Kandalaksha and have been significantly transformed by human activity and are subject to recreational pressure. The least impactful habitat of those studied is the shore of the Savino-Kanozero Lagoon, where *P. arctica is* confined to grass beds at the water's edge. Characteristics of the species' habitats are presented in Table 1.

Table 1. Brief description of *P. arctica locations* .

Table 1. Brief description of *P. arctica* sites.

Item No.	CPU number	Geographic coordinates	Location	Presence of threat factors
1.	1	67.129713°N 32.426234°E	Cape Monastyrsky Navolok, a sandy and rocky section of the coast adjacent to a dirt road	There is a high risk of trampling, mechanical damage or destruction of plants when vehicles leave the road.

2.	2	67.129725°N 32.424734°E	Cape Monastyrsky Navolok, an overgrown path to the monument	There is a high probability of trampling
3.	3	67.159750°N 32.378206°E	eastern shore of the Savino-Kanozero lagoon	The probability of displacement due to overgrowing of the shore with dense grasses with turfs
4.	4	67.156966°N 32.376491°E	the coast of Kandalaksha Bay to the west of the mouth of the Nivskaya hydroelectric power station's bypass canal, a section of the coastal strip above the cliff	There is a high probability of trampling
5.	5	67.157096°N 32.375975°E	the coast of Kandalaksha Bay to the west of the mouth of the Nivskaya hydroelectric power station's bypass canal, the rocky shore of the bay	There is a high probability of trampling

The results of the study of the phytocenotic association *of P. arctica* are presented in Table 2. The enclosing phytocenoses include 27 plants. In all communities, *P. arctica coexists* with *Achillea millefolium* , *Festuca ovina* and *Trifolium repens* .

Table 2. Composition and structure of phytocenoses in test plots.

Table 2. Composition and structure of phytocenoses on sample plots.

Item No.	Species name	CPU number				
		1	2	3	4	5
1.	*Achillea millefolium* L.	2	1	2	2	2
2.	*Betula pubescens* Ehrh. sl	-	-	1	-	-
3.	*Botrychium lunaria* (L.) Sw.	+	-	-	-	-
4.	*Campanula rotundifolia* L.	1	-	-	1	-
5.	*Cerastium alpinum* L.	2	-	-	-	-
6.	*Cerastium holosteoides* Fr.	-	-	1	-	-
7.	*Equisetum arvense* L.	-	-	-	1	-
8.	*Erigeron acer* L.	-	-	-	1	-
9.	*Euphrasia* sp.	1	-	1	2	-
10.	*Festuca ovina* L.	3	3	2	3	3
11.	*Festuca rubra* L.	-	-	3	2	2
12.	*Geranium pratense*	1	2	-	-	-
13.	*Hieracium umbellatum* L.	1	-	2	-	-
14.	*Leontodon autumnalis* L.	-	-	3	2	-
15.	*Matricaria suaveolens* (Pursh) Buchenau	-	1	-	-	-
16.	*Pinus sylvestris* L.	-	-	+	-	-
17.	*Plantago major* L.	-	2	-	-	-
18.	*Plantago media* L.	-	-	-	1	2
19.	*Poa annua* L.	-	2	-	-	-
20.	*Potentilla arctica* Rouy	2	2	2	1	2
21.	*Rhinanthus serotinus* (Schonh.) Oborny	1	2	-	-	-
22.	*Taraxacum* sp.	-		1	1	-

23.	*Thymus serpyllum* L.	3	-	-	-	-
24.	*Trifolium pratense* L.	-	2	-	-	-
25.	*Trifolium repens* L.	2	3	2	3	3
26.	*Solidago virgaurea* L.	1	-	-	-	-
27.	*Polytrichum* sp.	+	-	-	-	-

Table 3 shows the demographic and morphometric parameters of the studied cenopopulations.

Table 3. Results of monitoring of *P. arctica cenopopulations on* the Kandalaksha coast of the White Sea.

Table 3. Results of monitoring of cenopopulations of *P. arctica* on the Kandalaksha shore of the White Sea.

Indicator	CPU number				
	CPU 1	CPU 2	CPU 3	CPU 4	CPU 5
Area, m2	5	7	5	10	6
Absolute number, specimens	29	23	344	8	6
Density, specimens/ m2	5.8	3.3	68.8	0.8	1.0
Effective numbers	7	90	67	56	36
Recovery index (Iв)	6.3	0.4	17.1	1.0	2.4
Age index (Δ)	0.07	0.33	0.03	0.18	0.31
Efficiency index (ω)	0.22	0.77	0.10	0.48	0.76
Cenopopulation type according to the delta-omega classification	young	ripening	young	young	ripening
Height of generative shoot, cm	1 0.8±5.1	16.0±8.2	25.2 ± 10.7	21.7 ± 6.3	12.8 ± 4.2
Number of flowers in inflorescence, pcs.	3.0±3.0	10.4±9.5	10.4±6.2	7.4 ± 3.8	5.9 ± 4.3
Vitality Index	0.39	1.36	1.39	1.12	0.75

The results of the study of the age structure of cenopopulations are shown in Fig. 2.

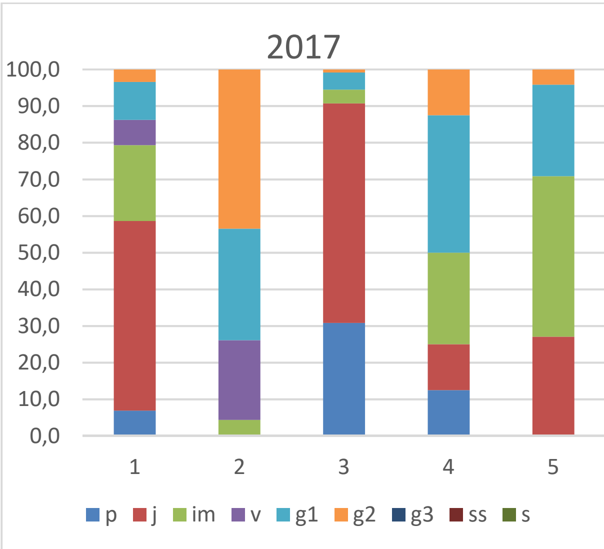

Fig. 2. Ontogenetic spectra *of P. arctica* .

Fig. 2. Ontogenetic spectrum of *P. arctica* cenopopulations.

IV. Discussion

In the studied habitats, the coenopopulations of *P. arctica are predominantly* small in number, which confirms that the state of the populations of this species corresponds to the established category of rarity [1].

The highest absolute abundance of individuals was recorded on the coast of the Savino-Kanozero Lagoon (CP3), a biotope least susceptible to recreational pressure. The lowest abundance *of P. arctica* was found in CP5, near the mouth of the Nivskaya Hydroelectric Power Station's outlet channel—a popular recreational area used for dog walking, picnicking, and observing harp seals in the bay during the spring. Local residents fish from this stretch of coastline, both from the shore and in small boats. Thus, anthropogenic pressure on vegetation in this part of the coast is significant.

The effective population size in the studied cenopopulations varied significantly, with the highest and lowest values observed in two habitats on Cape Monastyrsky Navolok, located a short distance apart but with different growing conditions. The lowest effective population size was found in Cenopopulation 1, a site where recreation occurs, with vehicle traffic and parking, making *P. arctica susceptible to trampling and mechanical damage. In Cenopopulation 2, on the overgrown path to the Victims of the Intervention Monument* , conditions appear to be more conducive to the formation of generative shoots; the effective population size was highest here. A high value for this indicator was found in Cenopopulation 3, which is least affected by recreation.

This cenopopulation is also characterized by its highest density under closed vegetation cover; in other habitats, the density is low. Cenopopulation density is influenced more by the presence of anthropogenic threats than by competitive interactions between plants.

The minimum population size of *P. arctica required for* the species to survive in the study area has not yet been determined. Threats related to recreation and potential damage from vehicle traffic, as well as the small population size, pose risks of population decline or extinction.

The age structure of the coenopopulations under consideration differs somewhat from those studied previously. Thus, the authors of the Biological Flora of the Murmansk Region demonstrated that the ontogenetic spectra *of P. arctica* are left-sided, unimodal, with a predominance of vegetative individuals over generative ones by almost 4 times [5]. In the two studied populations, the proportion of young and mid-generative plants was higher. In CP2, under conditions of a heavily overgrown path, this is probably due to the death of young plants as a result of trampling. For CP4, growing under the influence of strong winds, on fine soil at the edge of a cliff along which recreationists descend to the sea, and also small boats are launched into the water, a higher mortality of plants in the juvenile stage of development is apparently characteristic; the ontogenetic spectrum can be classified as bimodal. In the remaining coenopopulations, the age spectra are left-sided with a predominance of plants in the pregenerative period. The highest proportion of vegetative plants was observed in CP3, where growing conditions were more conducive to regeneration. Old generative, subsenile, and senile individuals were absent from all cenopopulations.

P. *arctica* on the coast of Kandalaksha Bay reproduces exclusively by seed, with seed germination lasting for 2-3 years [5]. Analysis of recovery index values showed that all cenopopulations, with the exception of CP2, are capable of self-sustaining. CP3 has the highest capacity for recovery and is stable and resilient. CP1 and CP5 are also relatively stable. CP4 can be classified as an unstable cenopopulation. The condition of CP2 can be assessed as critical.

According to the delta-omega classification, CP 2 and CP5 are considered maturing, while the others are considered young. The authors of a study conducted in the 1980s classified *P. arctica cenopopulations* on the rocks of Kandalaksha Bay as young populations with seed reproduction [5].

The vitality index values of the cenopopulations vary significantly: maximum vitality was observed in CP3, while minimum vitality was observed in CP1. These data differ by more than threefold. In CP3, high vitality is combined with high absolute and effective abundance, density, and recovery index values, which may indicate that the growing conditions on the coast of the Savino-Kanozero lagoon are most favorable for this species. In general, vitality is higher in habitats where

P. arctica grows in close contact with other plants. Low vitality is characteristic of individuals under direct recreational influence. The vitality *of P. arctica* was previously studied in culture in the Murmansk region. The authors of the study showed that the plants had high vitality, but fruiting did not occur [5].

The studied cenopopulations are located outside the boundaries of existing protected areas, and therefore no special habitat protection measures are implemented. Given the increasing recreational pressure on natural areas in the Murmansk Region [17, 18], four of the five studied cenopopulations are directly threatened with population decline or complete extinction.

Conclusion

The study yielded up-to-date data on the status of *P. arctica cenopopulations , a vulnerable species with an* extremely limited distribution. Monitoring of the status of cenopopulations was conducted in five biotopes on the Kandalaksha coast of the White Sea. *P. arctica cenopopulations* occupy small areas. The abundance and density of plants in all studied habitats directly impacted by recreation are low.

The surveyed area is dominated by cenopopulations with left-handed ontogenetic spectra; under conditions of trampling, which causes high mortality of pre-generative plants, a cenopopulation with a right-handed age spectrum has formed. In a habitat with significant recreational pressure, the ontogenetic spectrum is bimodal.

A recovery index assessment demonstrated the ability to sustain itself for four of the five cenopopulations studied. The condition of the cenopopulation associated with the overgrown trail was assessed as critical based on the recovery index. Cenopopulation recovery is limited more by anthropogenic impacts than by competitive pressure within plant communities. Individual viability is high when the biotope is overgrown by other plants and declines in areas with high recreational pressure.

In a biotope where the impact of anthropogenic factors is practically excluded, the indicators of abundance, density, recovery index and vitality index are maximum, which indicates favorable conditions and confirms the fact that the recreational load on the habitats of the species is a limiting factor for cenopopulations.

In general, the P. arctica cenopopulations *in the studied* area are vulnerable, which is associated with the species' confinement to a limited number of biotopes and the presence of direct threats of damage and destruction of plants as a result of uncontrolled recreation.

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