Online ISSN: 2588-3526

Journal of Wildlife and Biodiversity

Volume 9(3): 223-236 (2025) (http://www.wildlife-biodiversity.com/)

Research Article

Castilleja lapponica Gand. (Orobanchaceae) Coenopopulation status ecological assessment in the Lovozero Massif (Murmansk Region)

Marija Yu. Menshakova[1]*, Ramzia I. Gainanova[1], Konstantin K. Moskvin[2], Anastasia A. Nizikova[1]

[1]Murmansk Arctic University, Murmansk 183010, Russia
[2]Murmansk Marine Biological Institute, Murmansk 183038, Russia
*Email: dendrobium@yandex.ru

Received: 29 May 2025 / Revised: 19 September 2025 / Accepted: 15 October 2025/ Published online: 18 October 2025.

How to cite: Menshakova, M.Y., Gainanova, R.I., Moskvin, K.K., Nizikova, A.A. (2025). *Castilleja lapponica* Gand. (Orobanchaceae) Coenopopulation status ecological assessment in the Lovozero Massif (Murmansk Region), Journal of Wildlife and Biodiversity, 9(3), 223-236. DOI: https://doi.org/10.5281/zenodo.17386451

Abstract

This article presents the results of *Castilleja lapponica* Gand. populations status monitoring in the Lovozero mountain range. The monitoring framework was established in 1999-2000, and in 2025, previously studied cenopopulations were surveyed. This species is recognised as protected in the region but is poorly studied due to its fragmented distribution, small population size, and limited natural habitat, which makes it difficult to conduct representative studies of population dynamics and ecological prerequisites for survival. The study provided data on the ontogenetic structure (the ratio of individuals at different stages of ontogenesis) and effective population size of six *Castilleja lapponica* coenopopulations growing in different types of biotopes, including anthropogenically transformed ones, as well as the proportion of young individuals, effective abundance (the number of generative shoots), and vitality indices determined based on the size characteristics of individuals. It has been established that all studied coenopopulations are characterised by an incomplete ontogenetic spectrum and an extremely low recovery index, which indicates an inability to self-sustain under current conditions. Despite the high density of specimens in habitats disturbed by human activity, a general trend towards a decline in abundance has been observed, compared to previously recorded data. The results obtained confirm the risks to *Castilleja lapponica* populations and indicate the need to develop targeted conservation strategies whilst considering its apophyte-specific renewal strategy.

Keywords: Coenopopulation, population age structure, Red Data Book, C*astilleja lapponica* Gand.

Introduction

When assessing the stability of biodiversity, it is necessary to take into account not only the presence of rare species, but also the demographic structure of populations and the vitality of individuals.

Studying the dynamics of populations of rare species is often complicated by the fact that such studies are very time-consuming and expensive due to the fact that these species grow in hard-to-reach places and, as a rule, are few in number. The dynamics of plant populations is determined primarily by internal factors, the most important of which is the age of the population. At the same time, ecosystems are also susceptible to climate change. Thus, it is challenging to identify the risk factors that determine the dynamics of rare plant populations.

Climate change is one of the most difficult factors to assess. At the same time, it is believed that the mechanisms determining changes in vegetation under the influence of climate may include not only factors such as direct temperature influence, permafrost zone shift or carbon flow, but also plants' phenological development dissociation and seasonal development of their pollinators and other animals associated with trophic and choric interactions (Box, J. E. et al. 2019). The last few decades in high latitudes have been characterised by significant climate change. In Arctic and subarctic regions, temperatures have risen by 1–2 °C, with further increases predicted throughout the 21st century (Arctic Council and the International Arctic Science Committee (IASC) 2005; Intergovernmental Panel on Climate Change (IPCC) 2007).

Previously, a widely accepted view of the future of the Arctic was outlined in an article by Pearson, R. G. et al. (2013), which argued that documented climate change in the Arctic would lead to the northward expansion of forest vegetation, which could further exacerbate climate change due to changes in albedo and evapotranspiration. However, alongside this scientific idea, another was also developing. In particular, as early as 1993, Crawford, R.M. and his co-authors emphasised that the high degree of Arctic plants polymorphism makes them quite resistant to climate warming, and a change in the occurrence frequency of different ecotypes of the same species is observed over time, while the species composition remains stable. An international tundra experiment also showed that, as the climate warms, plants can react in various ways (Henry & Molau, 1997).

In our opinion, the influence of climatic changes on the well-being of the species we are studying may be related to the death of seedlings during heat and drought in early summer, the acceleration of the passage of phenophases, and changes in the biotic relationships of rare species in the phytocenosis, including the change of dominant species.

Studying the status of rare plant populations is a pressing scientific task, necessitated by the need to obtain reliable data for developing effective biodiversity conservation strategies in dynamically changing natural systems.

The purpose of this study is to analyze the dynamics of previously surveyed populations and assess the current status of *Castilleja lapponica* Gand. in the Lovozero Massif. The main aim was to identify and analyze the structure of coenopopulations of Castilleja lapponica in the Lovozero Massif. A coenopopulation was defined as a part of the total population inhabiting a specific phytocenosis, with groups of individuals growing in communities that differed in composition and structure being classified as different coenopopulations. For one of the cenopopulations surveyed earlier, a comparison was made with previously obtained data. The remaining cenopopulations were surveyed for the first time. This species remains poorly studied in the Murmansk Region, with research into population structure being sporadic. The most recent surveys were conducted in the Seydyavvr Nature Reserve in 2009 (unpublished data by the authors) and on the Svyatoy Nos Peninsula in 2024 (Menshakova, Gainanova, 2024).

Material and methods

Castilleja lapponica (Fig. 1) is an endemic Arctic North European species, distributed from the Kola Peninsula to the Yugorsky Strait. The western border of the species' range is located in the Murmansk Region, where it has been identified in various geographic locations, such as the Salnye Tundry and Volchya Tundra mountains, Lake Notozero basin, on the slopes of Mount Chiltald in the Tuadash-Tundra massif, and the Lovozero Massif, growing mainly in the tundra zone up to the Iokanga River in the east (Demakhina, 2014). *Castilleja lapponica* belongs to the Orobanchaceae family, which includes parasitic and semiparasitic plants (Wolfe et al, 2005). This is a perennial herbaceous plant that can be considered decorative due to the whitish (sometimes yellowish or reddish) colouring of the bracts in spicate inflorescences. The specimens are usually identified in tundra meadows, as well as lake, river, and stream banks, or rocky and gravelly slopes (Belkina, Konstantinova, Kostina, 1991; Bubenets, Pokhilko, Tsareva, 1993).

Castilleja lapponica is listed in the Red Data Book of the Murmansk region as a rare near-threatened species (Demakhina, 2014; Report, 2024). It is a subspecies of the larger *Castilleja pallida* (L.) Spreng., which is widespread in Siberia, the Far East, Mongolia, northern China, and is subject to protection in the Perm Krai (the Red Data Book of the Perm Krai, 2018), Sverdlovsk Region (the Red Data Book of the Sverdlovsk Region, 2018), Tyumen Region (the Red Data Book of the Tyumen Region, 2020), and Chelyabinsk Region (the Red Data Book of the Chelyabinsk Region, 2017).

Figure 1. *Castilleja lapponica* Gand.

During the research, the same methodological approach was used as in previous years: trial areas were laid in each location, within which 20 contours with an area of 1m2 were made. All individuals were counted in each contour, their age status was determined, and the number and length of shoots were measured. The research was conducted in the vicinity of the village of Revda, since in this part of the Lovozero Mountains the studied species is the most numerous and is represented by many populations.

Embryonic stages were excluded from the study, and the following were distinguished: p – plantlets and sprouts (at this stage, plants have only cotyledonous leaves); j – juvenile individuals (at this stage, plants have their first true leaves); im – immature (at this stage, the plants begin to branch); v – virginal (at this stage, the plants have well-developed vegetative organs, but they do not bloom); g_1 – young generative (plants bloom for the first time at this stage); g_2 – medium or mature generative (mature individuals with many generative shoots); g_3 – old generative; for some species, latent generative plants were also distinguished – g_0 (at this stage, many shoots die off), ss –

subsenile individuals (at this stage, the death of shoots sharply prevails over their growth); s – senile (dying individuals); (Uranov, 1975; Coenopopulation…, 1976; Coenopopulation…, 1988; Uranov, 1977). The age of the plants was determined based on the criteria provided by V. N. Bubenets et al. (1993). It should be noted that the stage of germination in this species is very short and by the beginning of flowering all seedlings usually already develop into juvenile individuals.

Effective population number was determined as the number of generative shoots in the sample area.

The following parameters of the ontogenetic spectrum of *Castilleja lapponica* coenopopulations have been calculated:

1. age index (Uranov, 1975):

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

m_i – number of individuals in ontogenetic i-state, k_i – age coefficient of ontogenetic i-state.

2. efficiency index (Zhivotovsky, 2001):

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

$p_i = n_i/n$ – proportion of plants in i-state in a population, n_i – absolute number of plants in i-state, $n=\Sigma n_i$ – total number of plants,

e_i – energy efficiency.

3. recovery index (Zhukova, 1987):

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

$\sum j \rightarrow v$ – sum of specimens in the pre-generative period,

$\sum g_1 \rightarrow g_3$ – sum of specimens in the generative period.

The coenopopulation type was determined according to L.A. Zhivotovsky's ‘delta-omega’ classification (Zhivotovsky, 2001).

The criteria proposed by G.O. Osmanova and L.A. Zhivotovsky (2020) were used to assess the coenopopulation self-sustainability. Per these criteria, coenopopulations are classified into effectively self-sustaining ($Ir > 2$), moderately self-sustaining ($1 < Ir < 2$), and poorly self-sustaining ($Ir < 1$).

The vitality index (IVC) was used to assess the viability of coenopopulations (Zlobin, 1989). The index is calculated using the weighted average method (Ishbirdin & Ishmuratova, 2004):

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

x_i — average value of the parameter i in the coenopopulation, X_i — average value of parameter i for all coenopopulations (when monitoring a single coenopopulation — average value for all years of observation), N — number of parameters. The index was calculated based on two parameters (length of generative shoots, number of generative shoots).

To describe the phytocenotic affiliation of coenopopulations for each location, a geobotanical description was compiled, taking into account the abundance of species according to the Braun-Blanquet scale.

The climatic variables of the growing conditions were established based on data from the Krasnoschelye weather station and are presented in Table 1 (Bulygina et al).

Table 1. Climatic variables characteristics for the period 2000-2023.

Year	I	II	III	IV	V	VI	VII	VII	IX	X	XI	XII	Annual average
2000	-12.4	-11.4	-6.8	-0.6	4.7	11.4	15.6	11	6.3	4.1	-3.1	-10.7	0.7
2001	-6.4	-17.4	-14.4	-1.1	2.4	11.5	14.7	10.7	7.7	-1.1	-8	-12.3	-1.1
2002	-15.1	-11.8	-9.5	-1.6	3.3	10.2	14.8	9.5	4.6	-2.1	-12.8	-12.7	-1.9
2003	-19.7	-7.6	-5	-3.3	5.3	5.7	16.9	12.2	6.9	1	-3.3	-10	-0.1
2004	-11.2	-15.1	-7.5	-2	3.7	9.7	16.8	11.6	6.9	0	-7.2	-6.5	-0.1
2005	-7.6	-11.6	-12.3	-2.6	3.8	11.3	14.3	13.7	7.3	2.3	-0.4	-8.3	0.8
2006	-12	-15	-11.7	-0.3	4.7	12.5	12	11.4	6	-1.4	-5.9	-5.5	-0.4
2007	-9.3	-20	-2.4	-1.4	3.4	8.5	13.1	13.4	6.6	4.2	-4.6	-3.1	0.7
2008	-8	-8.9	-10.4	-3.9	1.4	10.2	12.4	9.3	5.1	2.2	-4.5	-3.8	0.1
2009	-11.4	-13.9	-8.1	-3.5	4.3	8.9	12.3	11	8.7	-1.3	-3	-11.2	-0.6
2010	-16.6	-16.1	-10.5	0	5.6	9.4	16.6	10.5	7.4	1.6	-8.4	-13.3	-1.2
2011	-14.8	-19.1	-6.1	0.8	5.4	12.1	14.9	10.3	8	2.9	-3	-3.2	0.7
2012	-10.6	-14	-7.9	-2.3	5.4	11	12.8	10	6.9	1.2	-4.4	-13.7	-0.5
2013	-10.6	-8.2	-15	-1.7	6.6	13.8	14.9	13.9	7.7	-0.7	-4.6	-8.3	0.7
2014	-15.7	-6.6	-5.1	-1.9	3.1	8.5	14.5	13.5	6.8	-2.1	-4.5	-8.8	0.1
2015	-14.2	-8.6	-3.1	-0.9	6.7	9.8	9.8	11.1	8.8	1.5	-4.3	-8.2	0.7
2016	-19	-5.2	-4.7	0.3	8.2	10.6	16.9	13.1	7.4	2.2	-6.2	-7.1	1.4
2017	-10	-9.3	-5	-4.4	0.5	6.4	15.1	11.7	6.1	1.4	-4.6	-7.5	0.0
2018	-9.3	-11.8	-13.1	-1.2	6.6	9.7	18.1	12.8	8.1	0.3	-2.2	-7.4	0.9
2019	-14.4	-10.6	-7.7	0.2	4.3	9.7	10.9	10.3	7.6	-2.1	-5.4	-6	-0.3
2020	-10.6	-8.2	-4.6	-2.2	3.7	12.4	15.7	11.2	8.2	1.9	-0.5	-6.2	1.7
2021	-13.1	-19.4	-7.9	0.6	4.1	14.1	14.1	11.8	4.8	1.2	-7.3	-12.2	-0.8
2022	-11	-9.3	-5.9	-1.9	2.8	11.6	17	14.7	6.5	2.8	-2.4	-7.6	1.4
2023	-6.2	-9.5	-10.2	-1.4	7.7	9.7	13.8	14.2	10.6	-1.1	-10	-9.8	0.7

The above data on average monthly and average annual temperatures allow us to conclude that it is premature to talk about a pronounced warming of the climate in this area. The temperatures of June (when the seeds germinate), July (when the seeds bloom) and August (when the seeds ripen) are most important for the development of the studied species. It follows from the table that the temperature varies quite widely during these months. Most likely, temperature cannot play a decisive role in the dynamics of populations of this species, since there are no pronounced trends.

Results

The study analysed data on six coenopopulations of *Castilleja lapponica* in habitats that differ significantly in terms of growing conditions, including the degree of biotope anthropogenic disturbance. Geographical coordinates and brief descriptions of habitats are provided in Table 2.

Table 2. Characteristics of *Castilleja lapponica* locations.

CP number	Geographical coordinates	Location	Presence of threat factors
1*	-	A meadow in a birch forest near the Karnasurt mine.	*Castilleja lapponica* grows exposed to dust from the tailings pond of the Karnasurt mine.
2	67º54.34.8′ N 34º35.57.3′ E	Meadow phytocenosis on the roadside leading to the Karnasurt mine.	*Castilleja lapponica* grows in an area directly adjacent to the road, where there is a risk of chemical contamination, soil compaction, and mechanical damage caused by vehicles driving onto the roadside. Sparse vegetation cover.
3	67º55.11.3′ N 34º35.34.4′ E	Birch forest on the roadside leading to the Karnasurt mine.	*Castilleja lapponica* grows a short distance from the road. Dense vegetation cover.
4	67º52.02.5′ N 34º25.32.4′ E	Meadow phytocenosis of a vacant land on the roadside leading to the Umbozersky mine.	*Castilleja lapponica* grows in an area directly adjacent to the road, where there is a risk of chemical contamination, soil compaction, and mechanical damage resulting from the use of vacant land as a parking area for vehicles. Sparse vegetation cover.
5	67º52.54.3′ N 34º38.25.4′ E	The bed of a mountain stream on the western slope of Mount Karnasurta, in the Ilmayok River valley.	*Castilleja lapponica* grows on rocky ledges along a stream bed formed by snowmelt on the slopes of Mount Karnasurta, which dries up completely in summer when there is insufficient rainfall. Sparse vegetation cover.
6	67°52'48.87"N 34°38'27.90"E	Tundra meadow on the western slope of Mount Karnasurta, in the Ilmayok River valley.	*Castilleja lapponica* grows on overgrown rocky scree slopes. The scree slopes of the studied part of Mount Karnasurta are unstable due to blasting operations carried out during the extraction of loparite ore at the Karnasurt mine. Dense vegetation cover.

*Coenopopulation 1 was investigated in 2000 near the Karnasurt mine under conditions combining the impact of the Lovozero mining and processing plant on the one hand, and recreational pressure associated with growth near the road leading to a popular tourist route on the other (Vasilevskaya, 2006). Cenopopulation 2 is the result of the development of cenopopulation 1.

Data on the composition and structure of communities with *Castilleja lapponica* are presented in Table 3. Data on the composition of phytocenoses were obtained by compiling geobotanical descriptions.

Table 3. Composition and structure of phytocenoses on sample plots. Abundance was assessed on the Brown-Blanke scale

№	**Name**	**CP number**					
		1*	**2**	**3**	**4**	**5**	**6**
1.	*Achillea millefolium* L.	+	1	1	1	1	
2.	*Alchemilla* sp.					2	
3.	*Amoria repens* (L.) C. Presl	+					
4.	*Antennaria dioica* (L.) Gaertn.					1	
5.	*Archangelica officinalis* Hoffm.					1	
6.	*Arctous alpina* (L.) Nied.	+		1			
7.	*Arctostaphylos uva-ursi* (L.) Spreng.	+		2			
8.	*Astragalus subpolaris* Boriss. & Schischk.	+		2	1		
9.	*Arenaria pseudofrigida* (Ostenf. & O.C. Dahl) Juz. ex Schischk. & Knorring	+					
10.	*Bartsia alpina* L.	+				1	1
11.	*Betula pubescens* Ehrh.		1	2	1		
12.	*Betula nana* L.		1				
13.	*Bistorta vivipara* (L.) Delarbre					1	1
14.	*Botrychium lunaria* (L.) Sw.	+					
15.	*Calluna vulgaris* (L.) Hull	+					
16.	*Campanula rotundifolia* L.		1				1
17.	*Castilleja lapponica* Gand.	4	2	2	2	1	1
18.	*Cerastium alpinum* L.				1		
19.	*Cetraria islandica* (L.) Ach.			+			1
20.	*Cetraria nivalis* (L.) Ach.			+	1		
21.	*Chamaenerion angustifolium* (L.) Scop.		2		1	2	
22.	*Cladonia mitis* Sandst.			+	+		
23.	*Coeloglossum viride* (L.) Hartm.	+					
24.	*Dichodon cerastoides* (L.) Rchb.	+	+				
25.	*Dryas octopetala* L.	+	1			2	2
26.	*Empetrum hermaphroditum* Hagerup	+		2	1	2	3
27.	*Euphrasia frigida* Pugsley	+	1				
28.	*Galium mollugo* L.				+		
29.	*Gentianella lingulata* (C. Agardh) N.M. Pritch.	+					
30.	*Geranium sylvaticum* L.					2	
31.	*Festuca ovina* L.	+	1	1	1	2	

32.	*Festuca rubra* L.		2		2		
33.	*Juncus trifidus* L.	+		1			
34.	*Luzula spicata* (L.) DC.	+					
35.	*Melampyrum sylvaticum* L.	+					
36.	*Oxytropis sordida* (Willd.) Pers.		2	2	1	2	2
37.	*Pedicularis lapponica* L.	+					1
38.	*Pinguicula vulgaris* L.	+					
39.	*Pleurozium schreberi* (Willd. ex Brid.) Mitt.				1		
40.	*Phyllodoce caerulea* (L.) Bab.					2	3
41.	*Poa alpina* L.	+			2		
42.	*Potentilla crantzii* (Crantz) Beck ex Fritsch				1	1	
43.	*Pyrola rotundifolia* L.					1	
44.	*Racomitrium canescens* (Hedw.) Brid.		3	3	1		1
45.	*Rubus saxatilis* L.					2	
46.	*Salix lanata* L.		1	1	1	2	1
47.	*Salix phylicifolia* L.		2		2	2	
48.	*Saussurea alpina* (L.) DC.					1	1
49.	*Solidago virgaurea* L.		1	1	1	2	
50.	*Taraxacum* sp.				1		
51.	*Solorina crocea* (L.) Ach.				+		
52.	*Trientalis europaea* L.					1	
53.	*Trifolium pratense* L.	+	2		1		
54.	*Trollius europaeus* L.					1	
55.	*Vaccinium uliginosum* L.	+		2		3	2
56.	*Vaccinium vitis-idaea* L.	+		2			
57.	*Vaccinium myrtillus* L.			1			
58.	*Vicia cracca* L.	+					

* In the description by N.V. Vasilevskaya (2006), data on species abundance was not provided (except for *Castilleja lapponica*); therefore, the '+' sign in the column indicates the presence of the species.

The demographic parameters of the investigated coenopopulations are presented in Table 4.

Table 4. Demographic parameters of *Castilleja lapponica* coenopopulations

Indicator	CP number					
	1*	2	3	4	5	6
Effective coenopopulation number, pcs/m^2	-	9.3	4.4	20.3	7.9	3.6
Density, exv./m^2	19	2.5	1.2	7.8	2.2	1.4
Recovery index (Ir)	3.50	0.54	0.09	0.26	0.03	0.04
Efficiency index (ω)	0.25	0.71	0.88	0.73	0.85	0.79
Age index (Δ)	0.10	0.31	0.40	0.30	0.35	0.28
Type of coenopopulation according to "delta-omega" classification	young	maturing	mature	maturing	mature	maturing
IVC	-	1.07	0.71	1.75	0.89	0.59

*Data from coenopopulation monitoring conducted in 2000 (Vasilevskaya, 2006) is provided.

Ontogenetic spectra (the proportion of each age-related condition in %) of coenopopulations were determined during the study. The results of the age structure study are shown in Fig. 2.

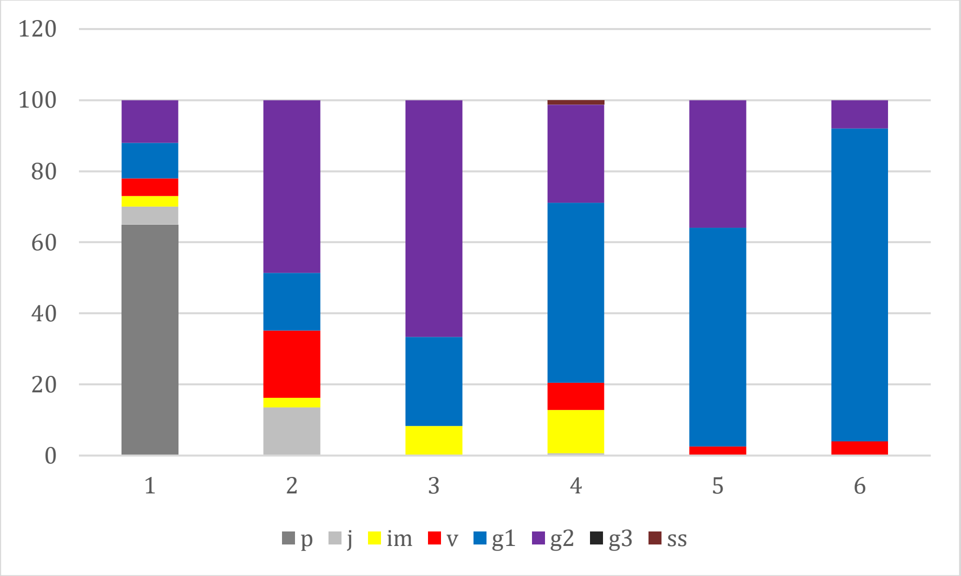

Figure 2. Ontogenetic spectra of *Castilleja lapponica* coenopopulations

Discussion

A composition study of the host phytocenoses showed that *Castilleja lapponica* grows together with 58 species of plants and lichens in the sample areas. Among the accompanying species, meadow plants are highly prevalent. The species composition of phytocenoses is largely similar. In our opinion, the slight differences in species composition in coenopopulations 1 and 2 are related to natural processes of succession. Most of the species are typical inhabitants of tundra, tundra meadows and small-leaved forests. There are no invasive species. The small presence of synanthropic species is not critical. This species has an apophytic nature, that is, it is confined to places with vegetation disturbances. Therefore, during succession, when moss sods, lichen layers, and curtains of grasses and heaths grow, the conditions for seed germination and the development of juvenile plants for castilla may worsen. It is these patterns that can be traced when comparing different price populations in 2025.The anthropogenic impact on the studied locations was mainly expressed in trampling, damage to vegetation cover when parking or turning vehicles around, and it turned out to be beneficial rather than harmful for castilla, since vegetation damage freed up areas where seeds from the soil bank could germinate.

Since observations were made at the same location over the years, coenopopulations 1 and 2 should be considered as different stages of the same coenopopulation development. It can be argued that CP5 inhabits an environment where anthropogenic impact (from industrial enterprises, motor vehicles and tourist traffic) is minimal.

Plants in CP4 are most intensively affected by human activity. At the same time, it is in CP4 that the highest effective population size, density, and vitality index are observed.

In all coenopopulations surveyed in 2025, low density was recorded. The density we calculated turned out to be slightly lower than that indicated by colleagues for other populations in the birch forest on the slopes of the Kuivchorr and Kuamdespakh mountains of the Lovozero Massif (Bubenets et al., 1993). The exception is CP4, where this parameter is twice as high. In the vicinity of the Karnasurt mine, the coenopopulation density has decreased almost eightfold since 2000. But to understand these differences, it is necessary to take into account that in 2000, the research was conducted in June, when the seedlings still existed. This apophytic species is characterized by high mortality at the stage of germination. In 2025, the measurements were carried out in early July, when most of the seedlings died, and a small part of them developed into juvenile plants.

Studies of *Castilleja lapponica* coenopopulations have shown low self-sustainability, with a high recovery index observed only in CP1 based on data from 2000. Currently, renewal is insufficient in all studied coenopopulations.

As a result of studying the age structure of coenopopulations, it was established that the full spectrum of ontogenetic states is not represented in any of the coenopopulations of *Castilleja lapponica*. The coenopopulations of this species are incomplete, with no plantlets, old generative, subsenile, and senile specimens. Immature and virginal specimens are either absent or present in insignificant proportions. All this indicates unstable reproduction of *Castilleja lapponica* and the death of plants before they reach the late stages of ontogenesis.

In terms of age spectrum, the studied coenopopulations are similar to those previously studied in the Lovozero Massif (Bubenets et al., 1993). In most coenopopulations, young and medium generative individuals are particularly prevalent. Based on previous research, it can be assumed that this population structure reflects the biological characteristics of the species rather than the stage of population development, as previously assumed (Vasilevskaya, 2006). The largest number of young specimens is observed in CP4, located in conditions of aggressive anthropogenic impact, as the roadside is used for parking and turning vehicles, which causes soil displacement and disturbances to the vegetation cover.

To understand the specifics of the population structure of this species, it is necessary to consider its apophytic structure (Bubenets et al., 1993). Seed renewal of *Castilleja lapponica* is more successful in the presence of damage (rockslides, fire sites, soil displacement). Seed regeneration is difficult in areas where the soil is stable and the vegetation cover is dense.

Conclusion

The study revealed the endangered status of *Castilleja lapponica* coenopopulations in the Lovozero Massif. Analysis of demographic parameters demonstrated the incompleteness of this species' coenopopulations, which reflects the biological characteristics of the species rather than being a consequence of intensive anthropogenic impact. The most intensive seed renewal of *Castilleja lapponica* occurs in habitats where the vegetation cover is disturbed and sparse, which is due to the apophytic nature of the species.

Thus, a detailed study of *Castilleja lapponica* coenopopulations allows us not only to assess the current status of the species, but also to obtain model data for understanding the mechanisms of biodiversity conservation in the context of global ecosystem transformations. The results of the study confirm the need to review approaches to the conservation of rare Arctic species, taking into account their specific biological strategies, and emphasise the importance of integrating population biology into nature management and territorial nature conservation practices.

Acknowledgments

The research was conducted with funding from Russian Science Foundation grant No. 25-24-20174, https://rscf.ru/project/25-24-20174/, and with financial support from the Ministry of Education and Science of the Murmansk region under Agreement No. 30-2025-000856 dated April 18, 2025.

References

Arctic Council and the International Arctic Science Committee (IASC) (2005). Arctic climate impact assessment. Cambridge University Press, Cambridge.

Belkina, O. A., Konstantinova, N. A., & Kostina, V. A. (1991). Flora vysshikh rasteniy Lovozerskikh gor [Flora of higher plants of the Lovozersky Mountains]. St. Petersburg.

Box, J. E., Colgan, W. T., Christensen, T. R., Schmidt, N. M., Lund, M., Parmentier, F. J. W., ... & Olsen, M. S. (2019). Key indicators of Arctic climate change: 1971–2017. Environmental Research Letters, 14 (4), 045010. https://doi.org/10.1088/1748-9326/aafc1b

Brochmann, C., Edwards, M. E., & Alsos, I. G. (2013). The dynamic past and future of arctic vascular plants: Climate change, spatial variation and genetic diversity. In The balance of nature and human impact (pp. 133–152). Cambridge University Press. https://doi.org/10.1017/CBO9781139095075.015

Bubenets, V. N., Pokhilko, A. A., & Tsareva, V. T. (1993). Biologicheskaya flora Murmanskoy oblasti [Biological flora of Murmansk Oblast]. Apatity: Kola Science Centre, Russian Academy of Sciences.

Bulygina O.N., Razuvayev V.N., Trofimenko L.T., Shvets N.V.: Description of the air temperature data array at stations in Russia. Certificate of database state registration № 2014621485. http://meteo.ru/data/156-temperature#описание-массива-данных

Crawford, R. M., Chapman, H. M., Abbott, R. J., & Balfour, J. (1993). Potential impact of climatic warming on Arctic vegetation. Flora, 188 (5–6), 367–381. https://doi.org/10.1007/978-3-642-78966-3_11

Demakhina, T. V. (2014). Castilleja lapponica Gand. In N. A. Konstantinova, A. S. Koryakin, O. A. Makarova, & V. V. Bianki (Eds.), Red Data Book of the Murmansk Region (pp. 460–461). Asia-print Publishing.

Henry, G. H. R., & Molau, U. (1997). Tundra plants and climate change: The International Tundra Experiment (ITEX). Global Change Biology, 3 (S1), 1–9. https://doi.org/10.1111/j.1365-2486.1997.gcb132.x

Intergovernmental Panel on Climate Change (IPCC) (2007). Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., and Miller, H.L. (eds). Cambridge University Press, Cambridge.

Ishbirdin, A. R., & Ishmuratova, M. M. (2004). Adaptive morphogenesis and ecological and cenotic survival strategies of herbaceous plants. In Methods of population biology: Proceedings of the VII All-Russian Population Biology Seminar (Vol. 2, pp. 113–120). Syktyvkar.

Menshakova, M. Y., & Gainanova, R. I. (2024). Rasprostranenie redkikh vidov rasteniy na territorii ZATO g. Ostrovnoy (Murmanskaya oblast') [Distribution of rare plant species in the territory of the closed administrative-territorial formation of Ostrovnoy (Murmansk Oblast)]. Estestvennye i Tekhnicheskie Nauki, (1) , 134–140. https://doi.org/10.25633/ETN.2024.01.22

Osmanova, G. O., & Zhivotovsky, L. A. (2020). Ontogenetic spectrum as an indicator of the state of coenopopulations of plants. Izvestiya Rossiiskoi Akademii Nauk. Seriya Biologicheskaya , (2) , 144–152.

Pearson, R. G., Phillips, S. J., Loranty, M. M., Beck, P. S., Damoulas, T., Knight, S. J., & Goetz, S. J. (2013). Shifts in Arctic vegetation and associated feedbacks under climate change. Nature Climate Change, 3 (7), 673–677. https://doi.org/10.1038/nclimate1858

Red Data Book of Chelyabinsk Oblast: Animals, plants, fungi (2nd ed.) (A. V. Lagunov, Ed.). (2017). Moscow: ReArt.

Red Data Book of Perm Krai / Ministry of Natural Resources, Forestry and Ecology of Perm Krai [et al.]; M. A. Baklanov (Ed.). (2018). Perm: Aldari.

Red Data Book of Sverdlovsk Oblast: Animals, plants, fungi (N. S. Korytin, Ed.). (2018). Yekaterinburg: Mir.

Red Data Book of Tyumen Oblast: Animals, plants, fungi (2nd ed.). (2020). Kemerovo: Tekhnoprint.

Report on scientific and research work on the preparation of the Red Data Book of the Murmansk Region (2024) [Contract No. 004, July 29, 2022]. Chief researcher: E. A. Borovichov. https://mpr.gov-murman.ru/files/kniga_1_spiski_vidov_tekst.pdf

Serebryakova T. I. (Ed.), & Sokolova T. G. (Ed.). (1988). Coenopopulations of plants (essays on population biology). Moscow.

Uranov, A. A. (1975). Age spectrum of phytocoenopopulations as a function of time and energy wave processes. Biologicheskie Nauki, (2), 7–33.

Uranov, A. A. (Ed.), & Serebryakova, T. I. (Ed.). (1976). Coenopopulations of plants (basic concepts and structure). Moscow.

Uranov, A. A. (1977). Questions of studying the structure of phytocenoses and species coenopopulations. In Coenopopulations of plants: Development and relationship (pp. 8–20). Moscow.

Vasilevskaya, N. V. (2006). Polivariantnost' razvitiya rasteniy raznykh zhiznennykh form v usloviyakh Severa [Developmental polymorphism of plants of different life forms in northern conditions] (Doctoral dissertation). Murmansk.

Wolfe, A. D., Randle, C. P., Liu, L., & Steiner, K. E. (2005). Phylogeny and biogeography of Orobanchaceae. Folia Geobotanica, 40, 115-134. https://doi.org/10.1007/BF02803247

Zhivotovsky, L. A. (2001). Ontogenetic states, effective density and classification of plant populations. Ekologiya, (1) , 3–7.

Zhukova, L. A. (1987). Dynamics of coenopopulations of herbaceous plants. In Naukova Dumka (pp. 9–19). Kiev.

Zlobin, Yu. A. (1989). Principles and methods of studying cenotic populations. Kazan: Kazan University.