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Research Article

Populations of alpine lady's-mantle (*Alchemilla alpina* L.) within the territory of the State Natural Park Rybachy and Sredniy Peninsulas

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Abstract

Research of the populations of an arctoalpine amphiatlantic species *Alchemilla alpina* L. has been conducted in the State Natural Park Rybachy and Sredniy Peninsulas, which was established in 2014. This species is listed in the Red Data Book of the Murmansk region with status category 3 (rare in the Murmansk region, corresponds to category NT (Near Threatened) of the IUCN International Red List). The relevance of this research is based on the increasing tourist flow in the natural reserve, as well as the need to create a scientific basis for monitoring the status of populations located in the specially protected natural areas. The age structure, effective size and vitality of seven coenopopulations (CP) of *Alchemilla alpina* growing in the most popular tourist areas of the nature park were studied. It is shown that all CPs are dominated by generative specimens, and the majority of CPs plants of all ages are present. The vitality index according to Ishbirdin exceeds 1 only in two CPs. The predominance of generative specimens can be explained by the specifics of this species' life cycle, the different mortality rates at various age groups, and the high longevity of generative individuals. At the same time, the duration of the early stages of development is rather short, so the mortality rate may be much higher at these stages. Cohabiting plants with dense turf, as well as species with dense foliage shading sprouts, may also have a negative effect on the regenerative process of *Alchemilla alpina* populations.

Keywords: Coenopopulation, population age structure, vitality index, Red Data Book, Natural park

Introduction

Alchemilla alpina L. is an elegant plant of dry tundra, widely widespread in Scandinavia (Mossberg, 1995) and Greenland (Pokhilko, 1985). The species is listed in the Red Data Book (2014) as rare (in the Red List of Murmansk region), and corresponds to category NT (Near Threatened) of the IUCN International Red List (category 3). The goal of this research was to study and assess the population status of *Alchemilla alpina*, which is one of the species protected by the State Natural Park Rybachy and Sredniy Peninsulas. In the Murmansk region, the species is identified in various geographical locations, such as the Khibiny Mountains, the Lovozero Massif, Kildin island, Rybachy and Sredny Peninsulas (Filimonova, 2006), Teriberka, lake Notozero, the Iokangskiye islands, the Lavna-tundra hill, the Salnye Tundry and Volchya Tundra mountains, and the Bolshoi Nyall-tundra mountains (Demakhina, 2014). This is the eastern border of the range of this species; in other regions of the Russian Federation, the *Alchemilla alpina* does not occur in the wild.

On the Rybachiy and Sredny peninsulas, *Alchemilla alpina* grows quite often in disturbed areas of tundra communities, on slope detritus, seaside meadows, rocks, near roads, etc. (Menshakova et al., 2022). It avoids only swampy areas, tundras with high projective coverage of shrubs, mosses, and lichens, and areas with significant exposure to seawater. Although *Alchemilla alpin*a does not tolerate salinity, it gravitates to near-coastal areas, screes and slopes, in other words, this species is confined to places where the integrity of the vegetation cover is disturbed. The investigation of the phytocenotic features of *Alchemilla alpina* showed that this species cohabits with 44 species of vascular plants in the sample sites.

Martial and methods

Alchemilla alpina (Fig. 1) is a polycarpic herbaceous hemicryptophytic plant with a basal rosette of leaves, monopodial branching, and short plagiotropic rhizome (Petukhova, 1977; Filimonova, 2007). Notov (1993) registered some similarities of *Alchemilla alpina* with shrubby forms.

Figure 1. *Alchemilla alpina* L. (at the center)

The research of *Alchemilla alpina* coenopopulations (CPs) was conducted in July 2016 on the territory of the natural park Rybachy and Sredniy Peninsulas and in the adjacent areas by setting up sampling sites of 20 m^2. The number of specimens of various age groups was counted at each site, and the age of individual plants was determined according to the classification proposed by Filimonova (2006). The specimens are categorized as representatives of one of the following age groups: embryotic, germinating seedling (p), juvenile (j), immature (im), virginile or young vegetative (v), young generative (g1), mature generative (g2), old generative (g3), subsenile (ss), senile (s), withering (sc). Embryonic stages were excluded from the study.

Effective coenopopulation size appears to be a more representative parameter than total coenopopulation size due to *Alchemilla alpina* propagating in a specific way forming thick patches in which it is impossible to reliably divide individual specimens without damaging plants. The effective coenopopulation size was determined as the number of generative shoots in the sample area. The vitality of the coenopopulation was determined by Ischbirdin's method (2004). The index is calculated by aligning the average values of parameters across populations by weighing them by the average value of the parameter for all populations, followed by averaging the results:

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

To calculate the vitality index, a number of morphometric parameters (height of generative shoots, number of generative shoots per specimen, number of flowers per shoot, etc.) were used.

A geobotanical description of *Alchemilla alpina* phytocenosis was compiled at each site. The abundance of species in plant communities was determined based on their projective coverage by the O. Drude scale. Seven coenopopulations of this species, located mainly in the coastal zone, were surveyed. The coordinates and information on the geographical location are given in Table 1.

Table 1. Location of the studied *Alchemilla alpina* populations

CP number	Coordinates	Geographic location
1	69.711500°N 33.062717°E	Left bank of the Anikieva River (coastal slope)
2	69.710353°N 33.052379°E	Right bank of the Anikieva River (parched riverbed)
3	69.709031°N 33.071472°E	Right bank of the Anikieva River (coastal slope)
4	69.712815°N 33.089827°E	Coast of the Barents Sea (0.3 km to the N of the mouth of the Anikeeva River)
5	69.708500°N 33.076428°E	Right bank of the Anikieva River (0.3 km to the SW of the mouth)
6	69.786692°N 32.528726°E	Coast of Zubovskaya Bay (1 km to the SE of the mouth of the Zapadnaya Mayka River)
7	69.776678°N 32.683421°E	Coast of Zubovskaya Bay (1,6 km to the S of the Lazar cape)

The habitat conditions of each coenopopulation were evaluated based on the analysis of phytocenosis composition using Tsyganov's ecological scales (Tsyganov, 1983). The age structure, effective size and vitality of seven coenopopulations (CP) of Alchemilla alpina growing in the most popular tourist areas of the nature park were studied.

Results

The results of the study of the composition and structure of communities in which *Alchemilla alpina* grows are presented in Table 2. This species cohabits with 44 species of vascular land plants.

Table 2. Composition and structure of phytocenoses on sample plots

№	Name	CP number						
		1	2	3	4	5	6	7
1.	*Astragalus subpolaris* Boriss. & Schischk.	cop2	–	cop1	–	cop2	–	cop2

2.	*Achillea millefoliata* Grecescu	cop1	cop1	cop2	cop2	cop1	cop2	cop1
3.	*Alchemilla alpina* L.	cop1	cop2	cop2	–	soc.	cop2	cop2
4.	*Alchemilla* sp.	–	–	–	–	sp.	cop1	cop2
5.	*Anthoxanthum alpinum* Á. Löve & D. Löve	–	sp.	–	–	–	–	–
6.	*Avenella flexuosa* (L.) Drejer	–	cop1	–	–	–	–	cop1
7.	*Botrychium lunaria* (L.) Sw.	–	–	–	sp.	Sp.	–	–
8.	*Calamagrostis lapponica* (Wahlb.) Hartm.	–	–	–	–	–	–	sp.
9.	*Campanula rotundifolia* L.	–	–	–	–	–	–	cop1
10.	*Cerastium alpinum* L.	–	–	–	–	cop1	–	–
11.	*Cerastium holosteoides* Fr.	–	sp.	–	–	–	–	–
12.	*Chamaepericlymenum suecicum* (L.) Asch. & Graebn.	–	–	–	–	–	cop3	–
13.	*Deschampsia cespitosa* (L.) P. Beauv.	cop1	–	–	–	–	cop2	–
14.	*Dianthus superbus* L.	–	–	–	sp.	–	–	–
15.	*Empetrum hermaphroditum* Hagerup	–	sp.	–	sp.	–	–	–
16.	*Equisetum pratense* Ehrh.	–	sp.	–	–	–	–	–
17.	*Euphrasia* sp.	–	–	sp.	–	sp.	–	sp.
18.	*Festuca rubra* L.	–	–	cop1	–	–	–	–
19.	*Oxyria digyna* (L.) Hill	cop1	–	–	–	–	–	–
20.	*Geranium sylvaticum* L.	–	–	–	sp.	cop1	–	cop1
21.	*Linnaea borealis* L.	–	sp.	–	–	–	–	–
22.	*Luzula multiflora* (Ehrh.) Lej.	–	–	–	–	cop1	–	–
23.	*Leymus arenarius* (L.) Hochst.	–	cop2	cop2	–	–	–	cop1
24.	*Leontodon autumnalis* L.	–	–	cop1	–	cop1	–	–
25.	*Poa alpina* L.	–	–	cop1	–	–	–	–
26.	*Ranunculus glabriusculus* Rupr.	–	–	–	–	cop1	–	–
27.	*Rhinanthus minor* L.	–	sp.	sp.	sp.	–	–	sp.
28.	*Pyrola rotundifolia* L.	–	sp.	–	–	–	–	–
29.	*Pilosella* sp.	–	sp.	–	–	–	–	–
30.	*Rumex acetosa* L.	–	–	–	cop2	–	–	cop1
31.	*Rumex acetosella* L.	–	–	cop1	–	–	–	–
32.	*Polygonum viviparum* L.	cop2	cop1	–	cop1	cop1	–	cop2
33.	*Salix lanata* L.	–	–	–	cop2	–	–	–
34.	*Saussurea alpina* (L.) DC.	cop1	–	–	–	–	–	–
35.	*Sagina* sp.	–	–	sp.	–	–	–	–
36.	*Solidago lapponica* With.	–	cop2	cop1	cop2	cop1	–	cop1
37.	*Taraxacum* sp.	–	–	–	–	sp.	–	sp.
38.	*Trientalis europaea* L.	–	cop1	–	cop2	–	–	–
39.	*Tripleurospermum hookeri* Sch. Bip.	–	–	–	–	–	–	–
40.	*Trollius europaeus* L.	–	–	–	cop1	–	–	–
41.	*Vaccinium myrtillus* L.	–	–	–	–	–	–	–
42.	*Vaccinium vitis-idaea* L.	–	cop1	–	–	–	–	–
43.	*Vaccinium uliginosum* L.	–	cop1	–	–	–	–	–
44.	*Vicia cracca* L.	–	–	–	–	–	–	–
45.	*Viola biflora* L.	–	sp.	–	cop1	–	–	–

The species composition of communities with *Alchemilla alpina* is characterized by considerable diversity, comparable with that in the communities studied by T.V. Filimonova (2007).

Characteristics derived from the analysis of the composition and structure of plant communities are presented in Table 3.

Table 3. Habitat conditions for *Alchemilla alpina* coenopopulations

Parameter	CP number						
	1	2	3	4	5	6	7
Acidity	6.1	5.5	6.3	6.3	6.6	5.3	6.0
Trophicity	5.6	5.1	7.4	5.0	7.0	5.5	6.2
Moisture	12.5	13.2	11.9	12.8	12.2	14.8	12.2
Light-shading	2.6	4.0	2.9	3.6	3.1	3.5	3.3
Moisture uniformity	4.5	4.4	5.1	5.8	5.2	5.0	5.5
Nitrogen abundance in the soil	5.0	4.7	5.4	5.0	5.9	3.5	5.2
Climate continentality	9.0	8.3	7.9	8.5	8.4	8.0	8.1
Aridity/humidity	8.3	9.1	8.6	8.5	8.4	9.5	8.4
Cryoclimate component	5.3	6.4	7.3	6.5	6.7	7.0	7.1
Termoclimate component	5.1	6.3	7.1	6.3	6.6	6.5	6.9

The habitat conditions of *Alchemilla alpina* can also be described as rather diverse. On the thermoclimatic scale, the vegetation can be classified as euboreal (CPs №2 and №6) and subboreal, in other words, the *Alchemilla alpina* tends to inhabit the warmest ecotopes in the Subarctic. On a cryoclimatic scale, winter conditions range from fairly severe (CP №1), to moderate winters (CPs №3, №6, №7). On scale of climate continentality vegetation is differentiated from subcontinental (CP №3), to the continental group 2 (CP №1).

Light-shading conditions are typical for open spaces in the area, but in CP №2 the vegetation is attributed to the sparse forest group. This can be explained by the fact that this CP was formed on a steep slope above flood lands, so it is in the shade for much of the day.

On the aridity-humidity scale, the vegetation can be evaluated as semiarid or subhumid, *Alchemilla alpina* is not found in either waterlogged or very dry habitats.

Mineral nutrition in the described communities varies quite significantly, soils can often be classified as poor, but rich soils are also represented (CP №3). Salinized soils are avoided by *Alchemilla alpina*. At the same time, the conditions of nitrogen nutrition are rather sparse, the vegetation belongs to the subanitrophilous or heminitrophilous groups 1 and 2. Moreover, the moisture uniformity is quite low, which indicates unstable conditions.

Soils are classified as acidic in CP №2 and №6, and as weakly acidic in the rest.

Thus, *Alchemilla alpina* occurs in ecotopes with rather dry, nitrogen-poor soils, that are rich in other components of mineral nutrition. It tends to avoid bogs, tundras with a closed shrub or lichen cover, and coastal marshes. Data on the effective coenopopulation size is presented in Fig. 2.

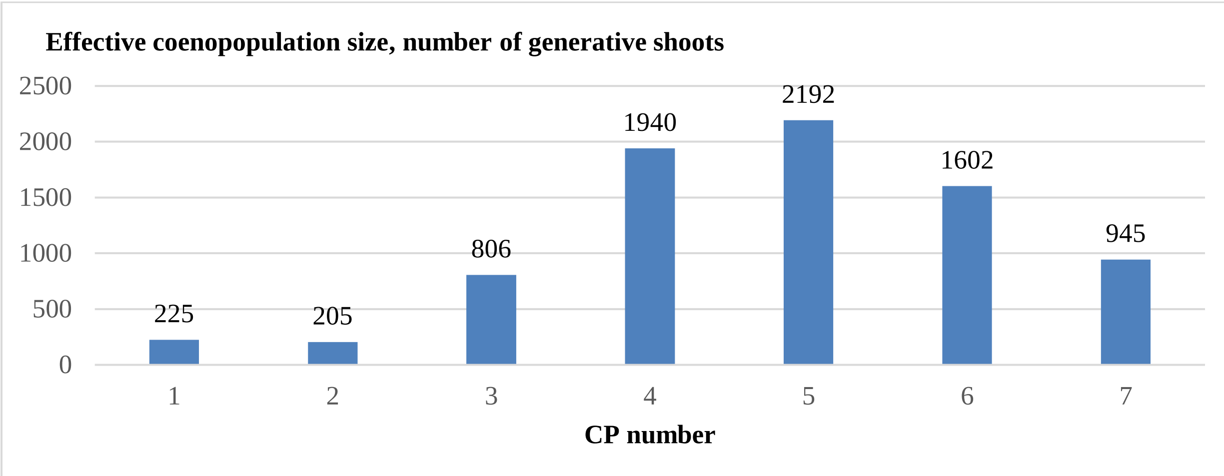

Figure 2. Effective coenopopulation size of *Alchemilla alpina*

The effective coenopopulation size in some of the CPs is quite high. It amounts to 2,000 or more generative shoots per 20 m^2. The object of study propagates in a very specific way forming thick patches, thus effective coenopopulation size appears to be a more informative parameter than total coenopopulation size. The highest value of this parameter is noted for CP №5. This area was recorded for the highest trophicity, nitrogen abundance, as well as the closest to the neutral acidity level of the soil. The results of the vitality index evaluation in *Alchemilla alpina* CPs are shown in figure 3.

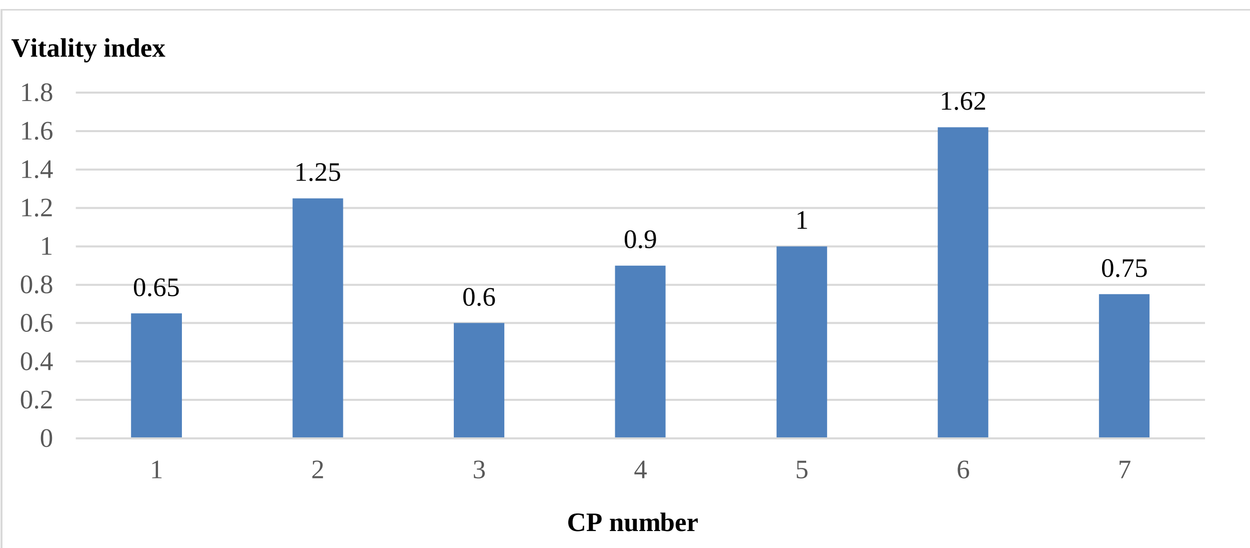

Figure 3. Vitality index of *Alchemilla alpina* coenopopulations

The histogram shows that the maximum vitality index is observed in CP №6, which can be explained by the higher moisture level (in the absence of bog formation) in this area. At the same time, this CP's effective size is very low due to the sparseness of individuals: this phytocenosis is sharply dominated by *Cornus suecica* which prevents the growth and regeneration of *Alchemilla alpina* coenopopulations.

Data on the age structure of *Alchemilla alpina* CPs are present in Figure 4. It can be seen that the studied CPs cannot qualify as complete, as there are no individuals of older ages. The absence of senile and old generative specimens in large and numerous populations is explained by the low life expectancy at these stages. In other words, plants perish shortly after the end of the generative phase, so they are rarely encountered. But it is worth noting that some senile and old generative specimens were nevertheless found in the state nature park Rybachy and Sredniy Peninsulas outside the sample areas.

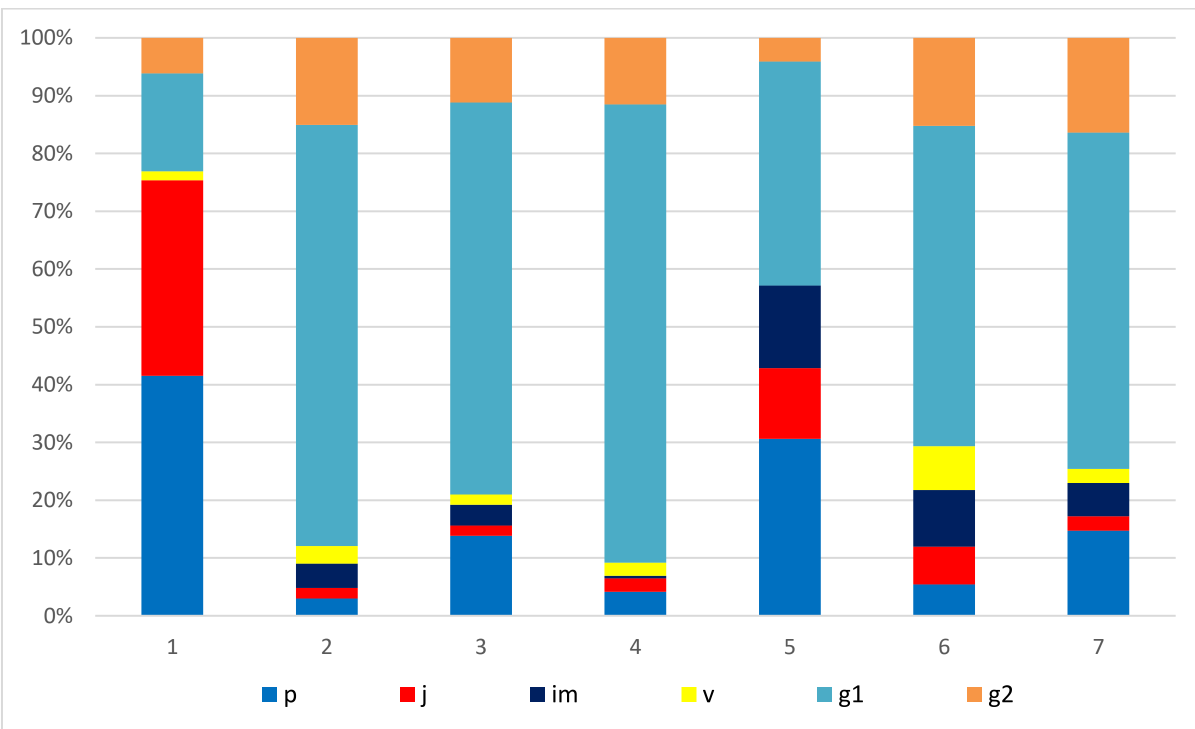

Figure 4. Ontogenetic spectrum of *Alchemilla alpina* coenopopulations

In general, the studied CPs are characterized by rather weak regeneration. Seed propagation is noted mainly in the periphery of CPs, where vegetation cover is more sparse. The existence of numerous large medium-aged generative individuals in the CPs often limits the opportunities for seed germination, as well as the survival of plants in the early stages of ontogenesis.

Discussion

Despite the diversity of plant species cohabitating with *Alchemilla alpina* on the territory of the state natural park Rybachy and Sredniy Peninsulas, it is important to note that this species avoids communities with high projective cover of crowberry and heath family plants, preferring to cohabit with perennial herbaceous plants.

In evaluating *Alchemilla alpina* CPs, it is difficult to identify a parameter that unambiguously indicates the sustainability and prosperity of a particular group of specimens. This species has little demand for abiotic resources, although it responds well to the increased soil moisture, as well as the abundance of minerals within the soil. On sites with more favorable conditions, *Alchemilla alpina* encounters competing plants, often significantly taller than it (*Geranium sylvaticum*, *Leymus arenarius*, *Rumex acetosa*). Such proximity can lead to a decrease in effective coenopopulation size or to a decline in regeneration.

The formation of large thick patches of middle-aged generative individuals merging into one another forms a continuous cover of vegetation, within which seeds cannot germinate. As a result, regeneration in such areas is obstructed. More intensive regeneration is observed in the areas where the integrity of the vegetation cover is disturbed, especially on slope detritus.

The low representation of young specimens in CPs may indicate the short duration of vegetative development stages. At the same time, the duration of the generative period can last for dozens of years, as a result, CPs have an ontogenetic spectrum similar to that of aging populations, which does not correspond to reality and is a characteristic feature of this species.

Population studies for *Alchemilla alpina* in the Murmansk region were conducted on Kildin Island, Rybachy Peninsula, in the Lovozero and Khibiny Mountains, and around the rural settlement of Teriberka. According to Blinova I.V. (2009), the object of research is referred to the type of species, populations of which have an average size and a high percentage of seed formation, which the author explains by successful autogamy and apomixis.

On the territory of the region the species is protected within the boundaries of the following Protected Areas (PAs): Laplandsky state natural biosphere reserve (Kolsky district, Monchegorsk urban district), national park Khibiny (Kirovsky district), state natural parks Rybachy and Sredniy Peninsulas (Pechengsky district) and Teriberka (Kolsky district), state natural reserve of regional significance Sejdjavvr (Lovozersky district).

According to the Regulations on the Red Data Book of the Murmansk region, for populations of species classified as Category 3, the necessary measure of protection is the designation of one most representative place of growth within the boundaries of SPNA in every municipal settlement and urban district in the area of habitat. Populations of *Alchemilla alpina* are protected by Protected Areas status in all municipal settlements, except for closed city Ostrovnoy (populations of the Iokangskiye islands). No analysis of the representativeness of the populations both within the boundaries of the existing PAs and during the creation of new ones was carried out. With the intensive recreational development of such popular areas as the state nature parks Rybachy and Sredniy Peninsulas and Teriberka, without taking into account the state of populations of protected species there is a threat to the populations growing within their boundaries (Huber et al., 2020; Huber et al., 2021).

On the territory of the state nature park Rybachy and Sredniy Peninsulas *Alchemilla alpina* CPs have a complete age spectrum with the predominance of generative specimens, which is explained by specifics of this species' life cycle, that being high longevity of generative specimens and differences in mortality in various age groups. The influence of other plant species included in phytocenoses with *Alchemilla alpina* on the populations regeneration process was detected. In the studied area, CPs are located in habitats with dry soils low in nitrogen but abundant in other components of mineral nutrition.

An analysis of the representation of *Alchemilla alpina* in protected areas of the Murmansk region showed that populations growing on the easternmost border of the species distribution do not have protected status at the moment. Taking into account the specifics of CP regeneration in the design of protected areas and ongoing planning of economic activities in the places of growth of *Alchemilla alpina*, it is necessary to preserve the CPs with various characteristics, not limited to the largest and most numerous.

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