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Research Article

State of *Pseudorchis albida* (L.) A. Love & D. Love coenopopulations on the Rybachy Peninsula (Murmansk Region, Russia)

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Abstract

The research article explores the state of Orchidaceae *Pseudorchis albida* (L.) A. Love & D. Love species' coenopopulations on the Rybachy Peninsula, located in the north of the Murmansk region (Russia). The species is included in the Red Book of the Russian Federation. Morphometric and demographic parameters of *P. albida* have been studied in two coenopopulations during the 2016 and 2025 field seasons. We assessed the ontogenetic structure, density, recovery index (Ir), and vitality index (IVC) of the coenopopulations, as well as their effective size (CP) and capacity for self-maintenance. Based on monitoring results, the coenopopulation in the eastern part of the Rybachy Peninsula was recorded in 2016 as the largest known in the Murmansk Region, while the remaining surveyed populations were few in number. Between 2016 and 2025, the total area occupied by *P. albida* coenopopulations decreased by more than sevenfold, accompanied by a 3.4–4-fold reduction in density, a sharp decline in the number of generative individuals, and a marked drop in the recovery index. The plant species is characterized by differences in vegetative and generative individual ratios; the self-maintenance ability is defined as weak and moderate. The studied populations are located outside the "Rybachy and Sredny Peninsulas" nature park boundaries, where there are no special protection measures taken. Hence, with the growing tourist inflow, there is a direct threat to the extinction of *P. albida* in the area under consideration.

Keywords: Arctic, climate stress, demographic structure, orchid**,** tundra

Introduction

Orchids (Orchidaceae) are one of the most diverse and highly specialised plant families; however, they can be particularly vulnerable in subarctic and arctic conditions (Blinova, 2009; Evans et al., 2020; Vakhrameeva et al., 2014). In high-latitude regions characterised by a short

growing season, low temperatures, and poor soils (which are often subject to the influence of permafrost), orchids frequently exhibit lower vitality: smaller plant size, smaller inflorescences, and reduced reproductive capacity compared to their counterparts in temperate or alpine zones (Kirillova, 2015). The orchids' life cycles are closely linked to specific mycorrhizal symbionts, which are essential for seed germination and nutrient uptake; this makes their establishment and survival highly sensitive to fluctuations in soil moisture, temperature conditions, and the composition of microbial communities (Pujasatria et al., 2020; Jolman et al., 2022; Li et al., 2021; Ponert, 2013). In Arctic and Subarctic regions, orchids face additional constraints linked to the low numbers and activity of pollinators (Koch et al. 2020; Kolanowska et al. 2024). They are also highly vulnerable to climatic stress factors, of which prolonged droughts, extreme temperature anomalies, and changes in the duration and stability of snow cover are of particular significance. The negative impact of abiotic factors can be exacerbated by human activities associated with the development of tourism. Such factors include habitat fragmentation, trampling by tourists and vehicles, off-road traffic, and the development of recreational infrastructure. This can lead to direct mechanical damage, soil compaction, and increased invasion of competing species into disturbed areas.

Hypoarctic Euro-American *Pseudorchis albida* (L.) A. Love & D. Love vegetates in Canada, Greenland, mountainous regions of Europe, the European part of Russia, and Siberia (Klein, 2000; Borovichev et al., 2025; Zolotareva et al., 2021). The southern border of the species' distribution in Russia lies in the Arkhangelsk region (Kravchenko, 2019; Anufriev et al., 2020). On the territory of the Murmansk region, the species grows quite widely in the north-west and central parts, as well as certain territories on the Kola Peninsula White Sea coast in the south (Borovichev et al., 2025). In Russia, *P. albida* is listed in several regional Red Data Books, including those of the Murmansk Region (Borovichev et al., 2025), Arkhangelsk Region (Anufriev et al., 2020), Komi Republic (Dyogteva et al., 2019), and Khanty-Mansi Autonomous Okrug–Yugra (Vasin et al., 2013), as well as in the Red Data Book of the Russian Federation as a vulnerable species (VU) (Orde, 2023).

The habitat of *P. albida* is quite diverse: tundra and mountain tundra, birch and coniferous forests, sparse woodland, damp meadows and forest edges, and sphagnum mires (Borovichev et al., 2025; Kirillova, 2015; Zolotareva et al., 2021). The maximum altitude of species distribution is 2700 m above sea level and is noted for the Apennine Mountains. In Scandinavian mountainous areas, *P. albida* is found up to an altitude of 1,100 m (Jersáková et al., 2011). On the Sredny and Rybachy Peninsulas, *P. albida* is confined to tundra meadows located on the Barents Sea coast (Menshakova et al., 2022). The studied coenopopulations are

located outside the boundaries of the state natural park "Peninsulas Rybachy and Sredny", and hence for habitat protection, there are no special measures applied in accordance with the Regulations on Protected Natural Areas. Considering the obscurity of plants outside the flowering period, small populations, and their growth near dirt roads, there are direct threats of *P. albida* coenopopulations' extinction associated with the intensive recreational development of the Rybachy and Sredny Peninsulas. According to the Directorate of Specially Protected Natural Areas, visitor numbers in the "Rybachy and Sredny Peninsulas" Nature Park exceed 60,000 people per year.

Studies on *P. albida* have been conducted throughout its area of habitat. In Scandinavia and the British Isles, research has focused on the biology of pollination and the ecology of the species, revealing a preference for open habitats with low competition (Jersáková et al., 2011). It was shown that populations of *P. albida* are characterized by predominantly seed propagation, while the role of vegetative reproduction in their self-maintenance is quite low (Kolanowska et al., 2022). Reinhammar et al. (2002) conducted morphometric, genetic diversity, and conservation biology investigations, documenting declines and protected status in Norway and Sweden. Some authors note that this species is confined to rock outcrops with a high calcium content (Klein, 2000; Jersáková et al., 2011; Blinova, 2016). In the Murmansk region, *P. albida* is particular for tundra, low-grass damp meadows, birch sparse woodland, and forests (Borovichev et al., 2025). In Russia, a fundamental contribution was made by I.V. Blinova, who studied the population dynamics of orchids along the northern border in the Murmansk Region and neighbouring areas (Blinova, 2009; Blinova, 2016), as well as Kirillova and her colleagues from the Subpolar Urals and the Komi Republic, who described the ontogenetic structure of coenopopulation communities and seed productivity (Kirillova, 2015; Kirillova, Kirillov, 2025). Earlier data (Borovichev et al., 2019) indicate small, fluctuating populations, often numbering fewer than 50 individuals.

Despite the research that has been carried out, significant gaps in our knowledge remain, particularly regarding long-term population trends at the northern limits of the species' range. Demographic data on *P. albida* are fragmented. Nevertheless, they are essential for distinguishing natural fluctuations (including secondary dormancy) from population declines caused by climate change and increased human impact. This study aims to fill this gap by assessing the status of *P. albida* populations on the Rybachy Peninsula in 2016 and 2025 in the context of increasing tourism pressure. This study aimed to assess the demographic structure, the number of generative individuals, the recovery index, and the vitality of *P. albida*

coenopopulations on the Rybachy and Sredny Peninsulas in 2016 and 2025, in order to evaluate population trends and determine the risk of extinction under increasing anthropogenic pressure.

Materials and methods

The study of *P. albida* coenopopulations (Fig. 1) was carried out in July 2016 and 2025 on the Rybachy Peninsula by means of establishing 1-square-meter test sites in order to estimate the vegetation, namely the total number of plant shoots. The survey was conducted across the entire area occupied by each coenopopulation. The total area of the surveyed territory is provided in Table 3. During the 2025 monitoring period, the same permanent plots were resampled to ensure data consistency. The authors did not conduct a detailed analysis of their early vegetative development, since counting protocorms would inevitably lead to individuals' death, followed by a reduction in population size. Instead, one-year-old individuals were taken as a counting unit (Blinova, 2009).



Figure 1. European small-white orchid - *Pseudorchis albida* (L.) A. Love & D. Love.

When assessing the age structure of coenopopulations, juvenile (j) plants were defined as those with a single leaf in the middle layer; immature (im) plants as those with two leaves in the middle formation bearing 4–6 veins; virginile (v) – plants with 2–4 leaves with 8 or more veins; and generative (g) plants as flowering plants (Tatarenko & Batalov, 1999). The study determined the proportion of plants in each age state.

The recovery index was calculated for the studied cenopopulations (Zhukova 1987):

$Ir = \Sigma j \rightarrow v / \sum g_1 \rightarrow g_3$ (Eq. 1)

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

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

To assess the vitality of coenopopulations, the authors used the vitality index IVC (Zlobin, 1989). This index is calculated by using the means weighting method (Ishbirdin, Ishmuratova, 2004):

$$IVC = \frac{\sum_{i=1}^{N} xi/\overline{Xi}}{N} \text{ (Eq. 2)}$$

where "x_i" indicates the mean value of "i" attribute of coenopopulation, and "X_i" represents the mean value of "i" attribute of all coenopopulations (if monitoring one coenopopulation – the mean value for all years of observation); "N" is the number of attributes. The index was calculated by using two parameters (length of the generative shoot (sm) and number of flowers per inflorescence (pcs)). These parameters were selected as the most informative indicators of the overall vitality and reproductive potential of *P. albida* individuals under extreme subarctic conditions. Because of the small size of the studied coenopopulations, shoot length and flower number were recorded for every generative shoot encountered. Although leaf length and leaf width are frequently used in IVC calculations for orchids in temperate and boreal zones, these parameters were deliberately excluded from the analysis. Measurement difficulties and risk of damage — leaves of *P. albida* are small, often pressed to the ground or partially damaged by wind, frost, or herbivores, which complicates accurate non-destructive measurement.

Vegetation of the surrounding phytocenoses was described using the Braun-Blanquet phytosociological approach. At each 1 × 1 m sample plot (established according to the minimal area principle), all vascular plant species were recorded, and their abundance was visually estimated using a modified Braun-Blanquet cover-abundance scale: r—solitary individuals; + – cover <1%, few individuals; 1—species abundant but covering <5% of the area; 2 – cover 5–25%; 3 – cover 25–50%; 4—cover 50–75%; 5—cover 75–100% (Westhoff, van der Maarel, 1973; Mirkin, Naumova, 2009). The study covered two coenopopulations of *P. albida*, all of which are located outside the boundaries of the "Peninsulas Rybachy and Sredny" natural park. This species is quite rare in the surveyed area. Two coenopopulations of *P. albida* on the eastern coast of the Rybachy Peninsula have been described. The studied coenopopulations are confined to the coastal crowberry tundra. All the described locations are in the areas near the dirt roads. Characteristics of the areas are provided in Table 1.

Table 1. Characteristics of *P. albida* locations.

№	CP	Coordinates	Location	Threats

1	1	69.697289°N 33.079347°E	Rybachy Peninsula, coast of Bolshaya Korabelnaya bay, low-grass meadow in the dwarf birch-crowberry tundra	Separated by a dirt road; vehicle damage risk
2	2	69.697685°N 33.079519°E	Rybachy Peninsula, coast of Bolshaya Korabelnaya bay, meadow in dwarf birch-crowberry tundra with sparse plant cover	Immediately adjacent to a dirt road

Results

Two coenopopulations of *P. albida* on the eastern coast of the Rybachy Peninsula were monitored in 2016 and 2025. The species composition and communities' structure where *P. albida* was found are very similar: these are shrub tundras dominated by crowberry and heather. This species grows near another 26 species of plants and lichens. The studied coenopopulations of *P. albida* occur in crowberry–dwarf birch tundra communities dominated by *Empetrum hermaphroditum*, with significant participation of *Betula nana*, *Vaccinium uliginosum*, *V. vitis-idaea*, Dryas octopetala, and *Arctous alpina*. The vegetation under study is assigned to the association Arctostaphylo alpinae–Empetretum hermaphroditi (Koroleva, 1994). This syntaxon is widespread in the coastal tundras of the Kola Peninsula, particularly on the Rybachy and Sredny Peninsulas, and is one of the characteristic shrub tundra communities in the hypoarctic sector of the Barents Sea coast (Popova et al., 2017).

It is noteworthy that *P. albida* grows here with another rare orchid species – *Coeloglossum viride*. The results of studying the composition and structure of phytocenoses with *P. albida* are presented in Table 2.

Table 2. Composition and structure of phytocenoses on sample plots (morphometric parameters are presented as mean ± standard deviation)

№	Species	CP 1	CP 2
1	*Andromeda polifolia L.*	3	
2	*Arctous alpina (L.) Nied.*	3	1
3	*Astragalus subpolaris Boriss. & Schischk.*	2	
4	*Bartsia alpina L.*	2	
5	*Betula nana L.*	3	2
6	*Bistorta vivipara (L.) Delarbre*	2	1
7	*Campanula rotundifolia L.*	2	
8	*Carex bigelowii Torr. ex Schwein.*	2	1
9	*Coeloglossum viride (L.) Hartm.*	2	
10	*Dryas octopetala L.*	2	
11	*Empetrum hermaphroditum Hagerup*	3	2
12	*Equisetum palustre L.*		+

13	*Festuca ovina L.*	2	
14	*Flavocetraria nivalis (L.) Kärnefelt et A. Thell*	1	
15	*Hieracium sp.*	1	
16	*Huperzia selago (L.) Bernh. ex Schrank & Mart.*	2	
17	*Pinguicula vulgaris L.*	2	
18	*Pseudorchis albida (L.) A. Love & D. Love*	1	1
19	*Salix lanata L.*	3	
20	*Salix reticulata L.*	1	
21	*Saussurea alpina (L.) DC.*	2	1
22	*Silene acaulis (L.) Jacq.*	1	
23	*Thalictrum alpinum L.*	1	
24	*Tofieldia pusilla (Michx.) Pers.*	1	1
25	*Vaccinium uliginosum L.*	3	2
26	*Vaccinium vitis-idaea L.*	3	

Table 3. Results of *P. albida* coenopopulation monitoring.

Parameter	2016 CP1	2016 CP2	2025 CP1	2025 CP2
Area of CP, m²	37	5	77	10
Density, ind./m²	3.2	5.8	0.8	1.7
The number of generative individuals, pcs	50	4	34	12
Recovery index (Ir)	1.3	12.1	0.0	0.4
Generative shoot height, cm	7.5 ± 2	6.8 ± 1.9	7.2 ± 0.6	6.7 ± 2.1
Number of flowers per inflorescence, pcs	20 ± 10	18 ± 9	19 ± 5	21 ± 12
Vitality index (IVC)	1.02	0.87	1.22	0.92[12]

The results of assessing age structure of coenopopulations are presented in Figure 2.

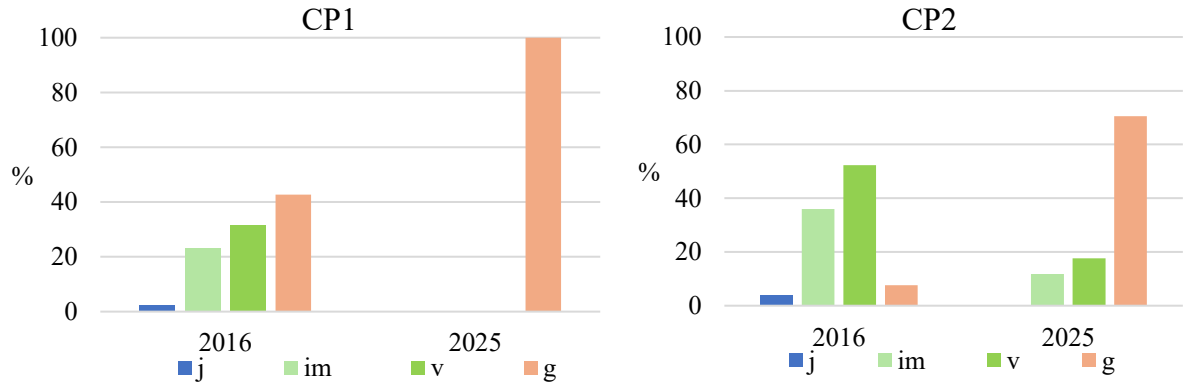


Figure 2. Demographic structure of *P. albida* coenopopulations (j – juvenile; im – immature; v – pre-reproductive vegetative (virginal); g – generative).

Discussion

Coenopopulations of *P. albida* are few in most habitats; this was noted when justifying the species' preservation status (Borovichev et al., 2025; Jeřábková, 2006). In the Arkhangelsk region, populations account for up to 5 individuals, often represented by single plants (Kravchenko, 2019). However, on the Rybachy Peninsula, the total number of species significantly exceeds previously known data and comprises 447 individuals, while the size of previously observed populations was estimated in the range from 6 to 39 plants (Borovichev et al., 2025). According to A.V. Razumovskaya and K. Popova (in 2015, the total number of *P. albida* on the coast of Malaya Volokova bay was at least 50 individuals (Borovichev et al., 2019). At the time of the survey in 2016, a smaller number of plants was documented. It is too early to conclude the population decreases in this location due to the ability of *P. albida* to enter a state of secondary dormancy for 1–2 years in case of unfavorable conditions.

The coenopopulation density is low. The highest density was recorded in CP 2, where *P. albida* grows in a patch of crowberry tundra with less dense vegetation cover and the least competitive pressure. The study found no evidence of a clustered spatial distribution of individuals, suggesting that each reproductive individual requires a considerable area, particularly when resources are scarce. A random distribution of specimens may indicate the suppressed state of coenopopulations (Fardeeva, 2018). Monitoring results have revealed a significant reduction in density by a factor of 4 and 3.4 in CP 1 and CP 2, respectively, in 2025, compared with 2016. This is likely due to periods of high temperatures and low rainfall (with no rainfall at all in August 2024) during the vegetation seasons of 2018 and 2024, which contributed to plant mortality in the early stages of development.

According to data from the Murmansk Department for Hydrometeorology, the summer of 2018 in the Murmansk Region was very warm, with the average seasonal air temperature exceeding the climatic norm by 2.4 °C. The amount of precipitation during the summer months was below normal; in July, it reached only 44% of the monthly norm (Report on Climate Features, 2019; Report on the State…, 2019). The summer of 2024 was recognized as the warmest on record in the Murmansk Region (since 1936). During the first ten days of August, periods of drought were recorded in the region, with precipitation ranging from 0 to 20% of the norm (Review…, 2024). Another reason for the decline may be *P. albida*'s ability to enter a state of secondary dormancy for 1–2 years under unfavourable conditions. This species is characterised by

significant yearly fluctuations in population size (Kirillova & Kirillov, 2025; Reinhammar et al., 2002).

A sharp decline in the number of generative individuals of both coenopopulations was also noted. In 2016, the highest number of generative individuals was recorded in CP 1, where conditions were more suitable for the formation of generative shoots. By 2025, only a few generative shoots had been observed. At the moment, the minimum population size of *P. albida* has not been determined, which would be needed to ensure the sustainable existence of the species in the studied area. To assess the long-term persistence of small and isolated populations, the concept of a minimum viable population (MVP) is widely applied. MVP is defined as the smallest population size required to ensure a specified probability of survival over a given time period, taking into account demographic, environmental, and genetic stochasticity (Shaffer, 1981; Frankham et al., 2012). MVP thresholds are species-specific. At the moment, the minimum population size of *P. albida* has not been determined; however, the low abundance, pronounced interannual fluctuations, and decline in the recovery index observed in the studied coenopopulations suggest that they may be approaching critically low population sizes. Under such conditions, the risk of local extinction increases due to reduced reproductive success, limited recruitment, and potential loss of genetic diversity. This allows the coenopopulations in the eastern part of the Rybachy Peninsula to be classified as vulnerable and indicates the need for precautionary conservation measures, particularly in the context of ongoing climatic stress and increasing anthropogenic pressure.

The age structure analysis of *P. albida* coenopopulations on the Rybachy Peninsula revealed a predominance of generative specimens, whilst specimens at vegetative stages of development were completely absent in CP1 and constituted an extremely low proportion of the total abundance in CP2, illustrating a transition to a depressed population structure, most likely caused by climatic stress factors (periods of high temperatures and precipitation deficit in 2018 and 2024) and population fluctuations distinctive of the species. Senile individuals (s) were not recorded during the surveys, which is typical for *P. albida* at the northern limit of its range due to the short life cycle and high environmental stress. The noted instability of the ontogenetic spectrum is also reflected in the dynamics of the recovery index. In 2016, the high Ir value in CP 2 (12.1) indicated a significant predominance of pre-generative plants over generative specimens. Populations of this species are characterised by predominantly seed propagation; vegetative reproduction plays a minor role in their self-sustainment (Kolanowska et al., 2022). *P. albida* is well adapted to surviving in open habitats with dwarf vegetation, a thin layer of detritus, and some irregularities that create open areas for seed germination (Jersáková et al., 2011). The high recovery index in CP 2 indicates active seedling regeneration under conditions

of sparse vegetation cover and low competition, whereas in CP 1, Ir = 1.3 suggests a moderate capacity for self-sustainment. In 2025, the Ir had decreased by almost 30-fold in CP 2, whilst no recovery was observed in CP 1; this was accompanied by a 3.4–4-fold decline in density and a reduction in the number of generative individuals. In comparison with the results of studies conducted in the Komi Republic, where complete populations predominate and maintain a stable ontogenetic structure (Kirillova & Kirillov, 2025), the *P. albida* coenopopulations on the Rybachy Peninsula are incomplete and show a decline in self-sustaining capacity between 2016 and 2025.

Kirillova and Kirillov (2025) note that on the western macroslope of the Subpolar Urals and the southwestern slope of the Southern Timan, *P. albida* typically occurs in habitats of the forest and forest–tundra zones, which are characterized by a relatively milder climate, a longer growing season, and more developed soil profiles with higher moisture retention capacity. Such conditions are more favorable for seed germination, the development of young individuals, and the maintenance of a balanced ontogenetic structure (Kirillova, 2015; Kirillova & Kirillov, 2025).

In contrast to the territory of the Komi Republic, the coastal tundras of the Rybachy Peninsula exist under harsh environmental conditions, including low temperatures, strong winds, shallow and poorly developed soils, as well as pronounced interannual variability in moisture availability. In addition, these habitats are increasingly affected by anthropogenic pressure associated with off-road vehicle traffic and growing tourism, which leads to mechanical damage to vegetation and soil compaction. Such conditions are likely to limit plant survival at early ontogenetic stages, resulting in the observed deficit of vegetative individuals and a shift toward a regressive population structure.

The habitus of *P. albida* appears to depend more on temperature than on soil conditions. Orchids growing above the Arctic Circle are characterized by a reduction in the number of flowers per inflorescence (Blinova, 2009). In all investigated CPs, the number of flowers is considerably lower than that recorded for *P. albida* in the British Isles, where inflorescences contain up to 60 flowers (Blinova, 2016). Similar differences have also been observed in the height of the generative shoots. The vitality indices analysis showed that CP 1 and CP 2 differ by this parameter; the most favourable conditions for *P. albida* are found in communities with sparse vegetation cover. It appears that vitality is less dependent on the abiotic conditions of the ecotope. A decline in vitality was observed in both habitats in 2025.

The increase in CP1's vitality from 2016 to 2025, despite a fourfold decline in density and a reduction in generative plant numbers, can be attributed to reduced intraspecific competition

and compensatory resource allocation among surviving individuals. Due to the decrease in the number of individuals using limited soil moisture and nutrients, the remaining generative plants demonstrate positive dynamics of morphometric indicators. Furthermore, because IVC is a relative index normalized against the overall population mean, the pronounced morphometric decline in CP2 during the 2024 drought likely depressed the baseline mean, causing CP1's more stable individual performance to register as a relative increase. The obtained data indicate the need for long-term monitoring to track the status of coenopopulations under changing climatic conditions and increasing recreational pressure. This will enable the timely implementation of measures to restrict off-road vehicle traffic and establish designated tourist camping areas during the peak growing season (June–August), thereby preserving the sparse vegetation cover and soil structure that support individual plant viability.

Conclusion

The present study provides data on the status of coenopopulations of a species rare in the Russian Federation. *P. albida* has been studied in the tundra communities of the Rybachy Peninsula, which are characterised by harsh climatic conditions and nutrient-poor, acidic soils. Coenopopulations of *P. albida* occupy small areas situated in the immediate vicinity of soil roads. The largest population of *P. albida* known in the Murmansk region was documented on the Rybachy Peninsula in 2016. The population density in all studied locations is low, the spatial distribution of individuals is random, which may indicate unfavorable growing conditions. The assessment of the recovery index showed the species' low self-maintenance ability due to the small proportion of vegetative plants. The most favorable in terms of self-maintenance is a CP in the eastern part of the Rybachy Peninsula, where sparse vegetation promotes seed growth and plant survival in the early stages of ontogenesis. Coenopopulations of *P. albida* in the studied area are very vulnerable, which is due to the ecological characteristics of the species associated with weak renewal, as well as the presence of direct threats of habitat destruction. This monitoring study reveals a pronounced demographic decline in *P. albida* coenopopulations on the Rybachy Peninsula, characterized by a 3.4–4-fold reduction in density, a sharp loss of generative individuals, and critically low recovery indices. These results underscore the extreme vulnerability of subarctic orchids at the northern margins of their range, where they grow under less favorable conditions, making populations highly sensitive to environmental fluctuations and anthropogenic impacts. Consequently, priority

conservation measures for *P. albida* on the Rybachy Peninsula should include legally enforced seasonal access restrictions, the relocation of tourist infrastructure away from sensitive tundra areas, and formal consideration of establishing a designated protected area. Future research should focus on studying soil conditions at the species' habitats, seed viability, and population genetic structure to elucidate the mechanisms underlying failed regeneration and interannual dormancy cycles. We recommend the establishment of a temporary buffer zone around these coenopopulations during the tourist season (June–August) and regular monitoring every 3–5 years to track population trajectory.

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