Assessment of coenopopulations *Epipactis atrorubens* in nature reserves of Republic of Bashkortostan

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**Abstract.** The effective conservation of rare species is possible in specially protected natural areas. The article presents the results of coenopopulations monitoring and assessing the state by demographic and vitality indicators of dremlik dark red (*Epipactis atrorubens*) family *Orchidaceae* in three reserves of the Republic of Bashkortostan. The geobotanical descriptions were carried out on a nine-point modified scale of Brown-Blanke. The ecological conditions of the habitats were assessed by the composition of species in plant communities using the ecological scales of Ellenberg. The assessment of the vitality of coenopopulations was carried out according to the size range of individuals (IVC). The studied coenopopulations grow on steep slopes, underlain by carbonate rocks, in dry pine forests and pine-birch forests. The number of individuals in coenopopulations is small, from 76 to 600 individuals; more than 4 thousand individuals were recorded in a favorable year in the Bashkir State Nature Reserve. Over a number of years for coenopopulations are characterized by significant fluctuations in the number, density, vitality of individuals and age spectra, which is associated with the prevailing influence of weather conditions on the growth and development of individuals. The average age spectra of coenopopulations are complete and incomplete, right-sided, with a predominance of generative and vegetative individuals. A decrease in the total number of individuals in some years by 3.0-6.5 times for *E. atrorubens* is not critical. Under protection conditions coenopopulations are in a satisfactory and stable condition.

1. **Introduction**

The species of the family *Orchidaceae* Juss. are the most protected representatives of the flora of most reserves in Russia and the Republic of Bashkortostan (RB). To date there are 38 taxa of the family *Orchidaceae* in the RB [1], in the Bashkir State Nature Reserve (BSNR), the South Ural State Nature Reserve (SUSNR) and the Shulgan-Tash State Nature Biosphere Reserve are protected in all 27 taxa [2].
Epipactis atrorubens (Hoffm.) Besser. a rare plant in the Urals forest zone (Subpolar, Northern, Middle, South Ural) and the Urals, s included in the Red Book of the RB [3] with the category of rarity – III, is protected in all reserves of the RB. It is very rare in RB. 4 habitats are known in BSNR, SUSNR, Shulgan-Tash Reserve – 9 [7].

The effective conservation of rare species is possible in Specially Protected Natural Areas. The long-term monitoring studies of rare plant species conducted by us in the reserves of the RB, they are aimed at assessing the state of coenopopulations (CP), identifying the viability potential and developing protection measures, including outside Protected Areas [2, 8, 9, etc.]. It is shown that the successful of species correlates with the chosen of method and method of protection. It is important to take into account the belonging of the studied taxa to certain ecological groups, phytocenoses, the manifestation of the types of life strategies, as well as the degree of their resistance to anthropogenic impact in terms of anthropotolerance.

The monitoring studies of the Epipactis atrorubens coenopopulations state are conducted on the territories of three reserves of the RB (BSNR, SUSNR, Shulgan-Tash reserve) located in the mountain-forest zone.

The aim of this work is to assess the coenopopulations (CP) Epipactis atrorubens state on demographic and vitality indicators in the Protected Natural Areas of the RB.

2. Materials and Methods

2.1. Description of the research object

Epipactis atrorubens is a perennial herbaceous short-rhizome plant with adventitious roots up to 40-50 cm. The stem is 25-60 cm high, dense, straight, short and densely pubescent in the upper part, purple in color. The leaves 5-9 pcs., hard, slightly rough along the veins, oval, pointed, 4-8 cm long and 1.5-4 cm wide. Inflorescence is a loose one-sided raceme, 7-20 cm long, the axis of the inflorescence is densely pubescent. The bracts are lanceolate, the lower bracts are longer than the flowers. The flowers 5-23 pcs., dark purple, twisted stalks. The fruit is a capsule. Propagated mainly by seeds.

2.2. Description of study areas

The BSNR, the SUSNR and the Shulgan-Tash Reserve are located in the mountain-forest zone of the Southern Urals.

The climate of BSNR is continental, here are observed a rather sharp temperature regime. The territory of the reserve is characterized by late spring and early summer frosts which again begin from mid-August [5]. In the Bashkir Reserve dominate forests, which occupy more than 80% of the area, post-forest meadows and steppes are also widespread. The forests here are formed mainly by Pinus sylvestris L.

The South Ural Reserve is located in the central and most high belt of the South Urals. Here the altitudinal zonality determines the mountain forest (mountain taiga), subalpine and mountain tundra belts of vegetation. The basis of vegetation is represented by forests, which cover almost 90% of the territory of the reserve. The main forest-forming species of the reserve are Picea obovata Ledeb., Abies sibirica Ledeb., Pinus sylvestris L., Larix sibirica Ledeb.

According to A.I. Kaigorodov [10] the climate of the SUSNR is moderately continental. On a 10-point continentality scale of N.N. Ivanov the indicator of continentality is 7 points. According to the climatic zoning of the country the reserve is located on the South-Eastern edge of the Atlantic-continental forest climatic region [11]. The growing season lasts 164 days; the active growing season is 121 days (from May 11 to September 9). The period of active vegetation is reduced to 95 - 105 days against the background of spring and autumn frosts, which reduces the thermal resources of the territory. Thermal resources (sum of temperatures above 10°C) are 1800 °C. The climate of the reserve is characterized as moderately cold [11].

Shulgan-Tash State Reserve is located in the mountain-forest belt of the western foothills of the South Urals. The landscape background of the reserve was formed due to the border location between
the broad-leaved and light-coniferous forests of the western macroslope and the central part of the South Urals [12].

The climatic peculiarity of the Shulgan-Tatsh Reserve is determined by its location in the temperate zone. Here is a zone of moderate cold humid climate: Atlantic-continental, with relatively hot summers, cold winters, sharp fluctuations in daily and annual temperatures [13]. The peculiar shape of the relief forms a mosaic temperature regime. On vegetation in open areas begins around May 15 and lasts 106-110 days. The duration of frost-free days is on average 90-100 days [14].

2.3. Research methods

The geobotanical descriptions were performed according to the method; where the abundance of species was taken into account according to the nine-point modified Braun-Blanquet scale [15]:

- r - 1-3 individuals of the plant species on the site;
- + - up to 10 individuals of the plant species on the site;
- 1 - up to 100 individuals of one plant species on the site;
- 2m - > 100 individuals of one plant species on the site;
- 2a - 5-12.5% - projection coverage 5-12.5%;
- 2b - total projective cover in the range from 12.5 to 25%;
- 3 - total projective cover in the range from 25 to 50%;
- 4 - total projective cover in the range from 50 to 75%;
- 5 - total projective cover in the range from 75 to 100%.

The Latin names of plants in the article are given from the international database An Online Flora of All Known Plants [16].

The ecological conditions of the CP habitats were assessed by the composition of species in plant communities using the ecological scales of Ellenberg [17]. When assessing to the ecological regime of habitats were taken the following factors: light (L), moisture (Fe), temperature (T), soil richness (N), and soil reaction (R).

The monitoring studies have been conducted according to the recommendations of A.R. Ishbirdin et al. [8] since 2005. The population studies were carried out according to generally accepted methodological developments [18]. When studying the CP structure the overground sprout was considered the counting unit. During monitoring the number of generative individuals was counted over the entire CP territory. The number of pregenerative individuals was counted on permanent plots of 1 m². To take into account the age structure of CP the following ontogenetic states were distinguished: juvenile (j), immature (im), vegetative (v), and generative (g).

The assessment of CP vitality (IVC) was carried out according to the size range of individuals [19].

\[
IVC = \sum_{i}^{n} \frac{X_i - \bar{X}}{X_0}
\]

where \(X_i\) is the average value of the i-th feature in the CP, \(\bar{X}\) is the average value of the i-th feature for all CP (when monitoring one CP – the average value for all years of observation), \(n\) is the number of analyzed features.

High IVC values corresponded to favorable growth conditions of individuals, low IVC values – to unfavorable growth conditions.

3. Results and Discussion

3.1. Ecological and phytocenotic characteristics of habitats

*Epipactis atrorubens* is characterized by a wide phytocenotic amplitude, forest-meadow, craggy species, xeromesophyte. The species is found in coniferous and mixed forests, mostly along riverine limestone slopes [20].

In the Bashkir State Nature Reserve *E. atrorubens* occurs in communities of pine-larch green moss forests belonging to the union *Dicranio-Pinion sylvestris*. The one CP is described on slag rocks from an old chromite mine (area 104). According to the composition of the herbaceous layer (27 species per
100 m², total projective cover 15%) this community can be characterized as poor; it is dominated by Orthilia secunda (L.) House [8, 21]. There are mosses sporadically – Pleurozium schreberi (Willd. ex Brid.) Mitt., Abietinella abietina (Hedw.) M. Fleisch., Dicranum flexicaule Brid., Ptilium cristasta-crensis (Hedw.) De Not., Hylacomium splendens (Hedw.) Schimp., Dicranum polysetum Sw. [4].

In the SUSNR E. atrorubens occurs in a dry mixed pine-birch forest. The tree layer of the community is dominated by Pinus sylvestris L. also found Betula pendula Roth and Tilia cordata Mill., in the herbaceous layer – Origanum vulgare L., Fragaria vesca Benth., Viola canina L., Rubus saxatilis Michx., Melica nutans Lam., Galium mollugo L., Leucanthemum vulgare (Vaill.) Lam., Achillea millefolium L., Cephalanthera rubra (L.) Rich., Glechoma hederacea L. [6]. Community belongs to the class Brachypodio pinnati-Betuletea pendulae Ermakov, Koroljuk et Latchinsky 1991 [22].

In the Shulgan-Tash Reserve of E. atrorubens 2 CP live on steep slopes of the southern and eastern exposures, on outcrops of carbonate rocks, in dry steppe pine forests. The herbaceous layer of the communities is poor; the total projective cover is from 15 to 30%. In both communities undergrowth is formed by species Betula pendula Roth, Populus tremula L., Sorbus aucuparia Maxim. The herbaceous layer contains such species as: Centaurea sibirica L., Dianthus versicolor Fisch. ex Link, Fragaria vesca Benth., Galium boreale L., Inula salicina Bunge, Poa angustifolia Elliott, Polygonatum odoratum (Mill.) Druce, Rubus saxatilis Michx., Vincetoxicum stepposum (Pobedimova in Komarov) Popescu, Viola ambigua Waldst. & Kit.

Epipactis atrorubens populations of can occur in disturbed habitats in anthropogenic derivative of natural communities.

The ecological characteristics of the habitats of E. atrorubens in the SPNA of the RB are presented in Table 1. In general in the studied territories E. atrorubens occurs in conditions from partial shade to half light (5.9–6.5 steps of the Ellenberg scales) and moderate warmth (4.8–5.2). Epipactis atrorubens is found on soils from dry to moderately moist (3.8–4.5), from slightly acidic to slightly alkaline (6.0–6.6), more often poor (3.2–4.1) (in relation to the soil richness in mineral nitrogen).

| SPNA of the RB     | L   | T   | Factors soil characteristics | Fe  | R   | N   |
|-------------------|-----|-----|-------------------------------|-----|-----|-----|
| SUSNR             | 5.9 | 4.8 |                               | 4.4 | 6.0 | 4.1 |
| BSNR              | 6.1 | 5.0 |                               | 4.5 | 6.2 | 3.9 |
| State Shulgan-Tash | 6.5 | 5.2 |                               | 3.8 | 6.6 | 3.2 |
| Min-max           | 5.9-6.5 | 4.8-5.2 |                             | 3.8-4.5 | 6.0-6.6 | 3.2-4.1 |

3.2. Population characteristics
The high abundance (4270 shoots) and the maximum density (23 specimens/1 m²) of E. atrorubens CP were noted by T.V. Zhirnova [23] on the territory of BSNR.

The demographic characteristics and vitality of E. atrorubens in the SUSNR and in the Shulgan-Tash Reserve are presented in Table 2.

On the territory of SUSNR the abundance of E. atrorubens CP varies from 76 to 600 individuals with a maximum density of 5-23 specimens per 1 m² (Table 2). This large CP lives on a steep slope in the valley of the Kushelga stream. The CP area is about 20000 m². During the years of observations the abundance and density of E. atrorubens individuals in the CP are relatively high; however these parameters are characterized by significant fluctuations. The maximum number of CP (from 593 to 600 pcs.) was revealed in 2009 and 2014. In 2006 and 2015 were recorded relatively low number (76 and 93, respectively) and density of individuals, in the age spectrum – the absence of juvenile and immature individuals. Apparently the relatively cool conditions with abundant rainfall during the
growing season influenced the low abundance and absence of individuals of young age groups. In the dry years of 2007 and 2010 was also recorded a relatively low total number of individuals in the CP. In subsequent years (2016-2020) the total number is relatively high (from 273 to 412), juveniles were absent in the age spectrum of CP. At the same time the minimum indices of the number of individuals and the incomplete age range allows stably exist CP, and are not critical for it.

Table 2. Demographic characteristics and vitality of Epipactis atrorubens in the SUSNR and Shulgan-Tash Reserve.

| Year  | Total | Age groups, % | Maximum | IVC  |
|-------|-------|---------------|---------|------|
|       |       |   |         |     |       |
| SUSNR |       |   |         |     |       |
| 2005  | 246   | 0:1.2;59.3;39.4 | 10      | 1.01 |
| 2006  | 76    | 0:0;57.8;42.1   | 7       | 1.00 |
| 2007  | 101   | 0;0:63.3;36.6   | 12      | 1.02 |
| 2008  | 367   | 1.4:2.9;42.7;52.8 | 23      | 0.90 |
| 2009  | 600   | 4.8;17.3;52.0;25.8 | 18      | 0.89 |
| 2010  | 283   | 0.35:10.2;87.9:1.4 | 13      | -    |
| 2011  | 518   | 0:9;1.2;95.5:2.3 | 17      | 1.23 |
| 2012  | 212   | 1.4:3.3;56.6;38.6 | 21      | 0.98 |
| 2013  | 179   | 0:3:9;67.0;29.0  | 11      | 1.04 |
| 2014  | 593   | 0:25.3;42.3;32.7 | 10      | 1.07 |
| 2015  | 93    | 6.4:11.8:32.2:49.5 | 7       | 1.03 |
| 2016  | 317   | 0:4.2;2:38.1:59.3 | 12      | 1.06 |
| 2017  | 412   | 0:6.1;82.2;11.6  | 6       | 1.12 |
| 2018  | 236   | 0:2:9;73.3:23.7  | 5       | 0.79 |
| 2019  | 275   | 0;10:2;74.9:14.9 | 11      | 0.84 |
| 2020  | 273   | 0:5.1;60.8;34.1  | 6       | 1.02 |
| Shulgan-Tash |       |   |         |     |       |
| 2017  | 366   | 6.3:13.1;40.4;40.2 | 10      | 1.06 |
| 2018  | 252   | 5.2:11.9;24.2;58.7 | 3       | 1.02 |
| 2019  | 276   | 6.2:19;9;52.9;21.0 | 8       | 0.96 |
| 2020  | 233   | 8.2:16.3:27.9:47.6 | 18      | 0.96 |

The number of E. atrorubens is relatively high in the Shulgan-Tash Reserve, ranging from 233 to 366 pcs. (table 2). The density of individuals in the CP is low – from 3 to 18 individuals per 1 m². The maximum number of individuals was observed in warm and humid 2017, and the minimum – in 2020. In 2019 the late spring frosts led to a sharp decrease in the proportion of flowering individuals. A decrease in the total number due to prolonged drought was observed at the beginning of the 2020 growing season.

The comparative analysis of the E. atrorubens CP state in the SUSNR and the Shulgan-Tash Reserve from 2017 to 2020 (table 2) indicates a similar dynamics of the number of individuals in different CP on the territories of two SPNA, which, apparently, is associated with the prevailing influence of weather conditions on the processes of reproduction and death of individuals in the mountain-forest zone of the Southern Urals. However the age spectra of CP are incomplete in SUSNR.

The averaged age spectra of E. atrorubens CP in the SPNA of the RB are shown in figure 1.

The averaged age spectrum of E. atrorubens during monitoring studies is right-sided on the territory of the SUSNR, where are young vegetative and generative individuals a high proportion (j: 0.98; im: 6.48; v: 61.64; g: 30.81) (figure 1). Here observed there are mainly the absent juvenile individuals in the age spectrum.
The averaged age spectra of coenopopulations are of the same type in BSNR and the Shulgan-Tash Reserve: one-peaked, right-sided, with a predominance of individuals of the generative age state (Figure 1). The averaged age spectra of coenopopulations are as follows in BSNR: in 104 sq. CP: j: 0; im: 11; v: 39; g: 50; in 123 sq. CP: j: 0; im: 3; v: 30; g: 65. In the BSNR are absent juveniles in the age spectrum. In the Shulgan-Tash Reserve the average age spectrum of *E. atrorubens* is complete: j: 6.5; im: 15.3; v: 36.4; g: 41.8.

![Figure 1. Average age spectra (% of *Epipactis atrorubens* coenopopulations in the SPNA of the RB.](image)

The averaged base spectrum shows that *E. atrorubens* in more favorable conditions grows on the territory Shulgan-Tash Reserve. Are shown [24] that the number of juvenile and generative individuals of *E. atrorubens* decreases under stress conditions, and the number of vegetative ones increases, including due of the species to the vegetative reproduction.

### 3.3. Assessment of the coenopopulation vitality.

In coenopopulations was assessed the vitality of individuals using the vitality index (IVC) calculated for each CP for a number of years. This analysis showed that the conditions of 2011 and 2017 in the SUSNR were the most optimal for plant growth (IVC – 1.23 and 1.12, respectively). Also favorable for achieving the organismic optima were: 2005-2007, 2013-2016, 2020, in which high IVC indicators were noted (1.00-1.07). During these years the CP also had the highest indicators of demographic characteristics (table 2). The years 2008, 2012, 2018 and 2019 were unfavorable for plant growth. In these years the vitality of individuals in CP was the lowest (IVC – 0.79 and 0.98). In 2009 although the highest numbers were recorded (600 pcs.) the viability of individual remained low (IVC – 0.89).

In the Shulgan-Tash Reserve the most favorable weather conditions were 2017 and 2018 (IVC – 1.06 and 1.02, respectively). 2019 and 2020 turned out to be unfavorable and the IVC values decreased to 0.96 (table 2).

In general the dynamics of the vitality of individuals (in terms of IVC indicators) in the CP of the SUSNR and the Shulgan-Tash Reserve demonstrate the same type of changes (table 2). The high vitality of individuals in 2017 is replaced a per years decrease (2018-2019) and then an increase in 2020. Apparently this is due first of all to the influence of weather factors on the state of populations.
4. Conclusion

Thus monitoring of the *E. atrorubens* coenopopulation in BSNR, SUSNR and the Shulgan-Tash Reserve testifies to their satisfactory and stable condition. The *Epipactis atrorubens* coenopopulations are not exposed to anthropogenic impact in the territories of the three reserves. Despite the fact that all SPNA are located in the mountain-forest zone of the Southern Urals, unique conditions are formed in the habitats of coenopopulations associated with weather-climatic, ecological-phytocenotic and orographic environmental factors. *Epipactis atrorubens* coenopopulations are characterized by significant fluctuations in density, abundance, vitality of individuals, and age spectra. A decrease in the total number of individuals by 3.0-6.5 times in some years is not critical for the state of *E. atrorubens* coenopopulations.

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