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Populations of *Orchis militaris*, *Epipactis palustris* and *Malaxis monophyllos* in the Republic of Mordovia (Central Russia)

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Abstract: Population-based studies of endangered plant species are key methods for assessment of the status for these plants at any territory. Plant species of the Orchidaceae family are sensitive components in natural ecosystems. That is why determination of the status for their populations can be considered as indicators for the status of natural ecosystem position as a whole. Investigations of three Orchidaceae species populations (*Orchis militaris* L., *Epipactis palustris* (L.) Crantz, *Malaxis monophyllos* (L.) Swartz) were carried out in Central Russia (Republic of Mordovia). Abundance, density, structure and dynamics of populations of these species were studied. Species composition of accompanying flora was established for each rare species. Some morphometrical parameters of individuals for the studied species were measured. Features of ontogenetic spectrum for *Orchis militaris* and *Epipactis palustris* populations were shown.

Key words: Orchidaceae, terrestrial orchids, population-based studies, age spectrum, morphometrics, population dynamics, Republic of Mordovia

1. Introduction

Plant species from Orchidaceae Juss. are study objects for many botanists and ecologists. This is confirmed by the appearance, in recent years, of a large number of review publications (Tatarenko 1996; Vakhrameeva *et al.* 2008; Perebora 2011; Frey 2014), publications devoted to the life cycle of orchids (Blinova 2007, 2013; Igosheva 2012; Betekhtina *et al.* 2013; Teteryuk *et al.* 2013), assessment of the status and structure of orchid populations (Gorchakovskii & Igosheva 2003; Blinova 2013; Valuiskikh & Teteryuk 2013; Korczyński & Krasicka-Korczyńska 2014; Khapugin *et al.* 2014), phylogeny and systematics of the Orchidaceae family (Averyanov 2014; Cameron 1999; Chase *et al.* 2015). Sustainability of orchid populations is determined by changes in the number of individuals within a population, the degree of completeness in ontogenetic spectrum of species, population age and sex structure, etc. (Zaugolnova *et al.* 1993; Gorchakovskii & Igosheva 2003; Blinova 2008, 2013; Valuiskikh & Teteryuk 2013, 2014; Jermakowicz *et al.* 2015). That is why determination of these parameters of orchid populations is an important component to assess their status.

At present, about 130 orchid species belonging to 42 genera are known in the Russian Federation (Vakhrameeva *et al.* 2008); 48 species belonging to 20 genera – in Central Russia (Averyanov 2014). Many orchids are endangered; 65 species are included in the Red Data Book of the Russian Federation (Bardunov & Novikov 2008). This can be attributed to (*i*) increasing anthropogenic influences and (*ii*) biological and ecological features of orchids. Orchids are considered as

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Fig. 1. Geographical position of the Republic of Mordovia in Eastern Europe
Explanations: ● – *Orchis militaris* population, ■ – *Epipactis palustris* population, ▲ – *Malaxis monophyllos* population

indicators of the disturbance degree of natural ecosystems due to their high sensitivity to various intrusions (Vakhrameeva 1992).

The aim of our study was to determine the structure and/or dynamics of populations, some morphometrical parameters of individuals for 3 orchid species occurring in the Republic of Mordovia.

2. Material and methods

Study objects were 3 plant species belonging to the Orchidaceae Juss. family: *Malaxis monophyllos* (L.) Swartz (=*Microstylis monophyllos* (L.) Lindley), *Epipactis palustris* (L.) Crantz, *Orchis militaris* L. The first 2 species are included in the Red Data Book of The Republic of Mordovia (Silaeva 2003); the last species is included in the Red Data Book of the Russian Federation (Bardunov & Novikov 2008).

M. monophyllos is a rhizomatous orchid with ovoid pseudobulbs. Its population is located in a wet, mixed (alder-birch-pine) forest 9 km south from Simkino village (Bolshie Berezniki district of the Republic of Mordovia) (54.18860478 N, 46.17414770 E) (Fig. 1).

O. militaris is a tuberous orchid with spherical tuberoids on short stolons. The population of this species is located in a wet railway roadside near the settlement of Komsomolskiy (Chamzinka district of the Republic of Mordovia) (54.441987 N, 45.839023 E) (Fig. 1).

E. palustris is a rhizomatous orchid with creeping rhizomes. *E. palustris* population occurs on a floodplain wet meadow in the neighborhood of Simkino village (Bolshie Berezniki district of the Republic of Mordovia) (54.24125609 N, 46.20597116 E) (Fig. 1).

Two-year field studies of *E. palustris* and *O. militaris* populations were carried out in 2012 and 2013. Field studies of the *M. monophyllos* population lasting seven years were carried out during the period from 2003 to 2008, and later in 2013. Investigations of population structures were carried out on square plots (1×1 m) established in habitats typical for the studied species according to geobotanical methods (Uranov & Serebryakova 1976; Serebryakova & Sokolova 1988). In studies of individual abundance in populations, each annual shoot was considered as one individual (counting unit) for *E. palustris* and *M. monophyllos*; each morphologically and physiologically single structure was considered as one individual (counting unit) for *Orchis militaris* (Rabotnov 1975; Uranov 1975). Assessment of orchid populations was carried out based on plant morphometrical parameters (height and number of leaves per each individual), size (length and width) of leaves, number of flowers and fruits per generative individual and species composition of flora accompanying rare species. Height of vegetative plants of *O. militaris* was not measured. Number of flowers per one plant was counted. The density (number of individuals per m^2) of orchids was compiled.

Based on the revealed morphometrical data, individuals of orchid species were divided into three

Table 1. Accompanying species of *Epipactis palustris*, *Orchis militaris* and *Malaxis monophyllos*

Orchis militaris	***Epipactis palustris***	***Malaxis monophyllos***
Achillea millefolium L. s. l.	*Achillea millefolium* L. s.l.	*Alnus glutinosa* (L.) Gaertner
**Angelica palustris* (Besser) Hoffm.	**Angelica palustris* (Besser) Hoffm.	*Betula pendula* Roth
Calamagrostis epigejos (L.) Roth	*Carex hirta* L.	*Carex pseudocyperus* L.
Campanula rapunculus L.	*Carex spicata* Hudson	*Carex vesicaria* L.
Cirsium canum (L.) All.	*Carex pallescens* L.	*Climacium dendroides* (Hedw.) F. Weber & D. Mohr
Crepis praemorsa (L.) Tausch	**Carex tomentosa* L.	*Potentilla palustris* (L.) Scop.
**Epipactis palustris* (L.) Crantz	*Equisetum arvense* L.	*Filipendula ulmaria* (L.) Maxim.
Equisetum arvense L.	*Equisetum fluviatile* L.	*Frangula alnus* Miller
Filipendula ulmaria (L.) Maxim.	*Filipendula ulmaria* (L.) Maxim.	*Galium palustre* L.
Galium spurium L.	*Galium mollugo* L.	*Lonicera xylosteum* L.
Hieracium umbellatum L.	*Galium spurium* L.	*Matteuccia struthiopteris* (L.) Tod.
Lathyrus pratensis L.	*Geranium palustre* L.	*Menyanthes trifoliata* L.
Lysimachia nummularia L.	*Glechoma hederacea* L.	*Mnium* sp.
Ranunculus auricomus L.	**Herminium monorchis* (L.) R. Br.	*Lysimachia thyrsiflora* L.
Sanguisorba officinalis L.	*Knautia arvensis* (L.) Coulter	*Phragmites australis* (Cav.) Trin. ex Steudel
Scirpus sylvaticus L.	*Lathyrus pratensis* L.	*Pinus sylvestris* L.
Taraxacum officinale Wigg. s.l.	*Lysimachia vulgaris* L.	*Populus tremula* L.
Tussilago farfara L.	*Medicago falcata* L.	*Scutellaria galericulata* L.
	Ophioglossum vulgatum L.	*Sorbus aucuparia* L.
	Parnassia palustris L.	*Thelypteris palustris* Schott
	Poa pratensis L. s.l.	
	Potentilla anserina L.	
	Pimpinella saxifraga L.	
	Sonchus arvensis L.	
	Trifolium pratense L.	

Explanation: *– species included in the Red Data Book of the Republic of Mordovia are indicated with an asterisk

age groups: immature (im), mature vegetative (v) and generative (g). Generative individuals without formed generative organs (i.e. they were in a vegetative age stage) in study years were considered as mature vegetative individuals. We determined the population type of orchids according to Gorchakovskii & Igosheva (2003): vegetative-oriented, generative-oriented, bimodal depending on the ratio of the age-groups in populations.

Statistical analyses were carried out using software PAST (Hammer *et al.* 2001) and R (R Core Team 2014).

The nomenclature used in this article follows Flora Europaea (Tutin *et al.* 1964-1980) and Cherepanov (1995).

3. Results and discussion

Accompanying floras in locations with participations of *E. palustris*, *O. militaris* and *M. monophyllos* comprised 18, 25 and 20 species, respectively (Table 1). As seen from the table, each of the investigated plant species grew in plant communities with species compositions typical for these orchids. This was confirmed by findings of other endangered plants in investigated locations. There were three species in the accompanying flora of *E. palustris* and two rare species in the accompanying flora of *O. militaris*.

Epipactis palustris (L.) Crantz

Total area of the investigated population covered 200-250 m^2. Density of individuals varied from 12 to 50 per m^2. Population spatial structure showed random type typical for perennial non-clonal plants. This investigated population was characterized by absence of young (juvenile and immature) individuals in its age structure (Fig. 2). Number of generative individuals varied from 10 to 14 per m^2, their percent in sex structure of the whole population varied within the limits 24.0-83.3%. The type of *E. palustris* population in all years of study was vegetative-oriented. While in 2012, the percent of vegetative individuals was 76.9%, advantage of vegetative individuals in 2013 was less pronounced (55.1%) (Fig. 2).

Based on investigations of plant individuals, some of their morphometrical parameters were determined (Table 2). Average height of plants, size (length/width) and number of leaves for generative and vegetative individuals in 2013 were relatively equal to values of these parameters in 2012. Our data were less than those

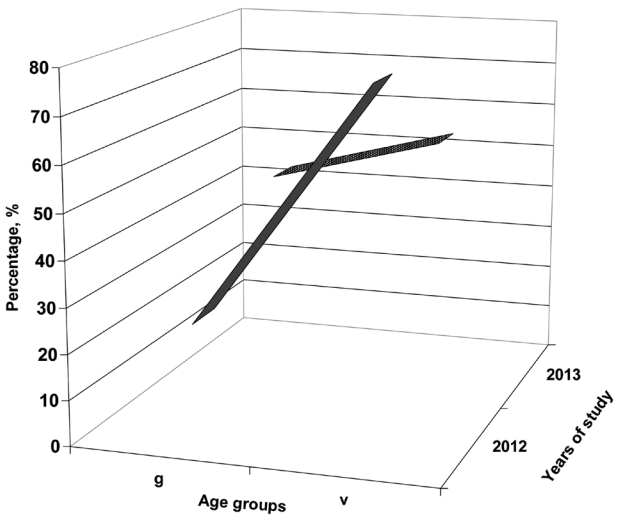

Fig. 2. Age groups in the investigated *Epipactis palustris* population
Explanations: v – mature vegetative, g – generative

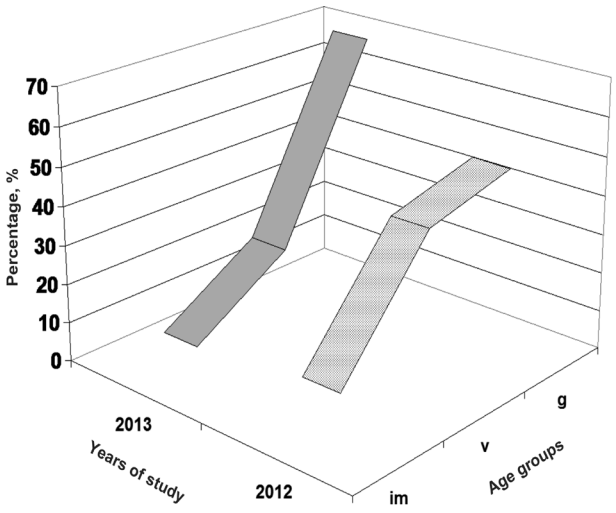

Fig. 3. Age groups in the investigated *Orchis militaris* population
Explanations: im – immature, v – mature vegetative, g – generative

reported by M. G. Vakhrameeva with co-authors (1997) for *E. palustris* populations in Moscow region

As seen from Table 2, average number of flowers per 1 individual in the investigated *E. palustris* population was significantly higher in 2013 than in 2012. We noted an almost twofold increase in this parameter in 2013 in comparison with 2012.

Orchis militaris L.

Total area of the investigated population was 150-200 m^2. Density of individuals varied from 10 to 17 per m^2. Population spatial structure was random type, typical for this plant. As evidenced from figure 3, the investigated population was characterized by absence of juvenile individuals in its age structure. According to the ratio of age groups, type of *O. militaris* population in 2012 year was bimodal, where the first peak accounted for vegetative individuals (52.9%, including 41.2% of mature vegetative) and the second peak accounted for generative plants (47.1%). In 2013, the age structure of the population was significantly changed: age spectrum became generative-oriented with percentage of generative individuals equalling 70%.

Based on investigations of mature vegetative and generative individuals at established plots, their morphometrical parameters were determined (Table 3). Height of generative plants slightly differed amongst 2012 and 2013. This parameter varied from 18 to 43 cm in 2012 and from 24 to 47 cm in 2013. Average parameters of size (width/length) and number of leaves for vegetative individuals were consistent

Table 2. Morphometrical parameters of *Epipactis palustris* individuals in 2012-2013

Parameter	Height [cm]		Number of leaves		Length of leaves [cm]		Width of leaves [cm]		Number of flowers per individual
	v	g	v	g	v	g	v	g	
					2012*				
M	18.0	49.7	5.3	4.5	9.3	9.5	2.0	2.3	8.6
m	1.4	2.5	0.2	2.5	0.2	0.3	0.1	0.1	1.5
min	8.0	36.5	3	1	2.0	3.0	0.5	0.5	1
max	31.0	69.0	7	11	18.0	17.0	3.5	4.0	19
					2013**				
M	21.5	61.5	6.1	6.7	10.5	10.9	2.0	2.3	19.4
m	0.7	1.3	0.1	0.1	0.2	0.2	0.1	0.1	1.2
min	7.0	46.0	4	5	3.0	4.0	0.5	0.5	7
max	30.0	77.0	8	8	17.5	19.5	3.5	4.0	36

Explanations: *M* – mean value, *m* – the standard error of the mean, *min* – minimal value, *max* – maximal value, g – generative individuals, v – vegetative individuals, * – n_{veg}=40, n_{gen}=12, ** – n_{veg}=59, n_{gen}=48

Table 3. Morphometrical parameters of *Orchis militaris* individuals in 2012-2013

Parameter	Height [cm]	Number of leaves		Length of leaves [cm]		Width of leaves [cm]	
	g	v	g	v	g	v	g
			2012*				
M	32.2	2.4	3.3	10.9	10.8	2.8	3.7
m	1.7	0.2	0.1	0.4	0.3	0.1	0.1
min	18.0	1	2	7.0	7.0	1.5	2.5
max	43.0	3	4	15.5	13.5	4.0	5.0
			2013**				
M	36.4	1.8	3.4	9.4	11.4	1.9	3.7
m	1.0	0.2	0.1	0.5	0.3	0.2	0.1
min	24.0	1	3	6.0	6.0	1.0	1.5
max	47.0	3	5	14.0	16.0	3.5	5.5

Explanations: *M* – mean value, *m* – standard error of the mean, *min* – minimal value, *max* – maximal value, g – generative individuals, v – vegetative individuals, * – n_{veg}=18, n_{gen}=16, ** – n_{veg}=12, n_{gen}=28

with literature data (Vakhrameeva *et al.* 1995; Efimov 2011), and these parameters for generative individuals were slightly less in comparison with the results of the same authors.

In order to reflect the number of flowers per individual and fruit set of *O. militaris*, all generative individuals at established plots were investigated (Table 4). It was shown that fruit set was less in 2013 (66.8±4.0%) than it was in 2012 (84.0±2.2%), despite the approximately equal average number of flowers per generative individuals (24.9 flowers in 2012, 24.1 flowers in 2013). Probably, this fact can be explained by the maldevelopment and withering of flowers on many generative plants in 2013.

Malaxis monophyllos (L.) Sw.

Total area of the investigated population was 250-300 m^2. Individuals were sparsely located. Population density was less than one plant per m^2. Population spatial structure showed random type. Only generative individuals were present in age structure of the investigated population in 2013. As a result of investigation, only 5 *M. monophyllos* generative individuals were found in this population in 2013. Values of some morphometrical parameters of *M. monophyllos* are presented in Table 5. They are consistent with literature data (Vakhrameeva *et al.* 1993, 2008). Thus, this *M. monophyllos* population was generative-oriented type in 2013.

Small number of *M. monophyllos* individuals in 2013 prevented us from comparing the obtained data with those in appropriate literature sources. Probably, a small number of individuals in the population in 2013 can be explained by population waves and features of biology of this species. Biology features are significant fluctuations in the abundance dynamics in the population. Population waves were presented by the alternation of periods with a significant number of adults with

Table 4. Characteristics of generative reproduction of *Orchis militaris* in 2012-2013

Parameter	Number of flowers per individual	Number of fruits per individual	Fruit set [%]
		2012*	
M	24.9	20.9	84.0
m	1.6	1.4	2.2
min	15	14	62.5
max	42	34	96.4
		2013**	
M	24.1	15.8	66.8
m	1.2	1.2	4.0
min	14	7	24.3
max	38	33	100.0

Explanations: *M* – mean value, *m* – standard error of the mean, *min* – minimal value, *max* – maximal value, * – n_{gen}=16; ** – n_{veg}=28

Table 5. Some morphometrical parameters of *Malaxis monophyllos* individuals in 2013

Height [cm]	Number of leaves	Length of leaves [cm]	Width of leaves [cm]	Number of flowers
22	2	4 9	1 6	66
22	1	6	4	47
21	1	7	5	40
21.5	1	8	5.5	35
12	1	5	3	15
Mean: 19.7	*Mean:* 1.2	*Mean:* 7.0	*Mean:* 4.7	*Mean:* 40.6

periods when the population consisted, predominantly, of juvenile individuals. This was supported by the fact that the number of individuals in this population varied considerably in period from 2003 to 2013 (Fig. 5).

Significant fluctuations in the number of individuals in this *Malaxis monophyllos* population (more than 26 times: from 2 individuals in 2003 to 53 individuals in 2008) indicated vulnerability of this orchid. Changes of the hydrological and/or light conditions in this habitat can lead to the disappearance of the population or transition of most individuals into the resting state.

4. Conclusion

The investigated *O. militaris* population did not contain juvenile individuals in the age spectrum. It can be explained by prolonged (until 2012) resting state of most individuals without formation of the aboveground organs. That is why we suggest that in near future, this population will be represented in all age groups. High percentage of young (juvenile and immature) individuals in populations of stem-root tuber orchids is observed under the influence of burrowing animal activities (e.g. wild boar) (Gornov 2007). Perhaps, absence of this factor was a reason of low percentage of young individuals in age spectrum of the *O. militaris* population during the study period.

E. palustris population was characterized by low percentage of young (juvenile and immature) individuals in the age spectrum. Perhaps, this was a result of a depressing effect of tall herbage and shrubs (*Salix* spp.) contributing to the habitat shading, as it was shown for *E. palustris* population in Bryansk region (Gornov 2011). High percentage of mature vegetative individuals in the population age spectrum indicated the predominance of vegetative (rhizome) propagation in ontogenesis of *E. palustris*. Consequently, this last fact helped to maintain a stable status of the population during the long period.

Small number of individuals in the *M. monophyllos* population in 2013 manifested its biological feature – ability for a transition of individuals into the resting state for a long time. This is supported by observations of study years, when the number of individuals in the population increased from 2-9 individuals (in 2003-2005) up to 47-53 individuals (in 2006-2008). That is why we predict the possibility of a sharp increase in the abundance of individuals in this population during next 1-3 years under favorable conditions.

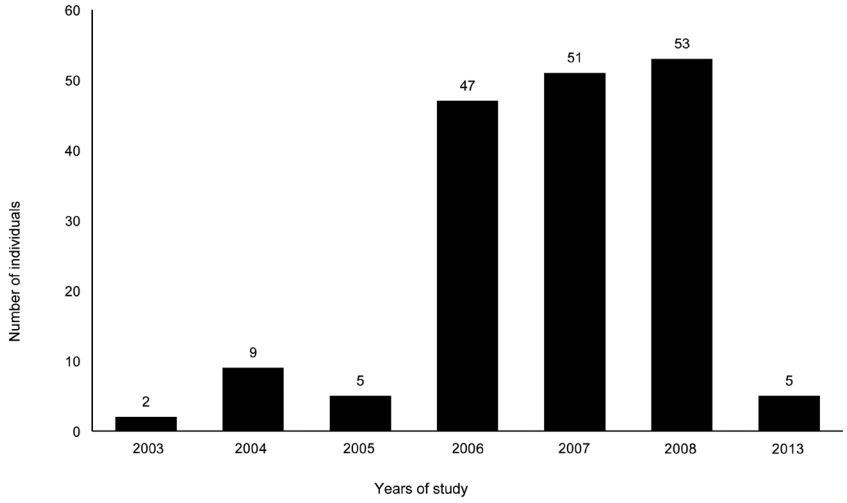

Fig. 4. Dynamics of the number of individuals in *Malaxis monophyllos* population in the period 2003-2013

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