The ontogeny and the demographic structure of the coenopopulations of the species *Oxytropis chakassiensis (Fabacaea)* in the steppe communities of Khakhassia (Russian Federation)

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Abstract. The article presents the results of the analysis of the demographic structure of ten coenotic populations of *Oxytropis chakassiensis* in near-Yenissei steppes (Khakassia and Krasnoyarsk krai). Most part of studied species coenopopulations are not complete and definitive, normal, mature, have a bimodal developmental spectrum with peaks at g1 (v)- and g3-individuals. Changes in the structure of the ontogenetic spectrum (increasing the share of young plants) depend mainly on the environmental conditions and the degree of human disturbance of habitats: rocky slopes and decrease in pasture digression create more favorable conditions for the survival of juveniles. The ontogeny of *O. chakassiensis* (the rare species of near-Yenissei steppes) was studied and its life- form was described. Four periods and nine ontogenic stages were distinguished. The results of our study showed that *O. chakassiensis*is was a petrophyte steppe species with strict ecological and cenotic propensity to petrophytic steppe with the prevalence *Koeleria cristata*, *Festuca valesiaca*, *Arctogeron gramineum*, *Hedysarum turczaninovii, Alyssum obovatum* and *Thymus minussinensis*. Due to long generative period *O. chakassiensis* is successfully renewed and is stable during long periods of extreme conditions of petrophytic steppes with high pasture digression.

It is well-known that, in order to evaluate the state and the possibility of preservation of rare species, it is necessary to study their biological characteristics and the structure of their populations. Yu. A. Zlobin [1] identified the study of the populations of the rare, endangered and protected species as one of the major tasks of the population ecology, with the purpose of developing of effective methods of maintaining their stable existence. The use of the population and ontogeny assessment approach is required to evaluate the state of species in plant communities [2, 3].

O. chakassiensis Polozhij is a rare species, endemic of the near-Yenissei steppes (the south of Middle Siberia), which is registered in the Red Books of the Republic of

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Khakassia [4] and of the Krasnoyarsk krai [5]. It is protected in the Khakasskiy reserve in the areas of Lake Itkul and Lake Bele. Outside the reserve, the species is found in steppe communities, which are being intensely used in farming and are exposed to pasture of cattle and to recreational damage. The ecological and coenotic optima of *O. chakassiensis* are within a narrow range; therefore, this species is primarily endangered.

The ontogeny and the demographic structure of ten (10) coenotic populations (CP) of *O. chakassiensis* were studied in the steppe regions of the Republic of Khakassia. The studies were carried out on the territories of the reserve clusters of Lake Itkul and Lake Bele and outside the reserve. The ontogenetic states were identified according the concept of discrete description of ontogeny [3, 6, 7, 8, 9]. The life form (biomorph) was determined by studying the adult plants of the middle generative age [10, 11]. The ontogenetic structure of the coenopopulations were analyzed using delta-omega (Δ-ω) criterion proposed by L.A. Zhivotovsky [12]. The effective [12] and ecological density of plants in the coenopopulations were determined [13]. A plant was a unit of study. For integrated characteristics of the population structure, the following demographic characteristics were used: Δ – the age index [8], ω – the effectiveness index [12], the recovery index (I_r) and the ageing index – I_a [14].

O. chakassiensis belongs to *Xerobia* section. The area of this endemic species of the Yenissei steppes (Abakan, Iyus-Shira and Minusinsk regions) is small, and the species is known to exist only in 5 locations: near the Charkova ulus and the Kapchala station of the Ust-Abakan district, Lake Itkul, Lake Bele and Lake Vlasyevo in the Shira district and in the vicinity of Lake Uchum in the Krasnoyarsk krai [4, 5]. *O. chakassiensis* grows on flat hill tops or on southern and south-eastern hill slopes, more rarely, on south-western and western hill slopes up to 12° steep, within the range of altitudes varying from 430 to 650 a. s. l. The species is found among petrophytes of typical steppes, their cover range from 40 to 90%. The projective cover of *O. chakassiensis* is small, mostly less than 1%, and much more rarely varies from 1% to 3%. *O. chakassiensis* is found in low-grass steppes, where bunch grasses (*Koeleria cristata* (L.) Pers., *Festuca valesiaca* Gaudin), as well as petrophytic low herbs (*Arctogeron gramineum* (L.) DC., *Hedysarum turczaninovii* Peschkova*, Alyssum obovatum* (C.A. Meyer), *Thymus minussinensis* Serg.) dominate.

O. chakassiensis is a taproot polycarpic hemicryptophyte herb with a pauciramose immersed caudex, vegetative polycyclic rosette shoots and elongated monocarpic generative axil shoots.

Multicipital perennial taproot herbs with polycarpic shoots of a rosette type are biomorphs of a monocentric type, incapable for vegetative reproduction. They reproduce only by seeds.

To identify the ontogenetic states of the plants, we used the following features: the presence of cotyledons, the structure of leaves and their number, formation of a caudex, the ratio of the processes of growth and destruction and the number of vegetative and generative shoots. Based on these features, 4 ontogenetic periods and 9 ontogenetic states were identified (Fig.1).

The stage of latency. The seeds are rounded and have the shape of a bud, they are brown colour, about 2 mm long and 1.5 mm wide. The fruit is unilocular, has a rounded shape tapering on top.

The pre-generative stage.

Sprouts. For *Oxytropis chakassiensis*, above-ground germination of seeds is characteristic. Sprouts have the main rosette shoot with two rounded cotyledons (3-4 mm long and 5-7 mm wide) and a root 3-4 mm long. The first true leaves are simple, ellipsoid, plain, 8-15 mm long and 2-4 mm wide.

The juvenile adult state. The plants in this state have one rosette shoot 1,5-1,7 cm tall, with one-three simple leaves of a lanceolate or ellipsoid shape. The length of the main root

is about 8 cm.

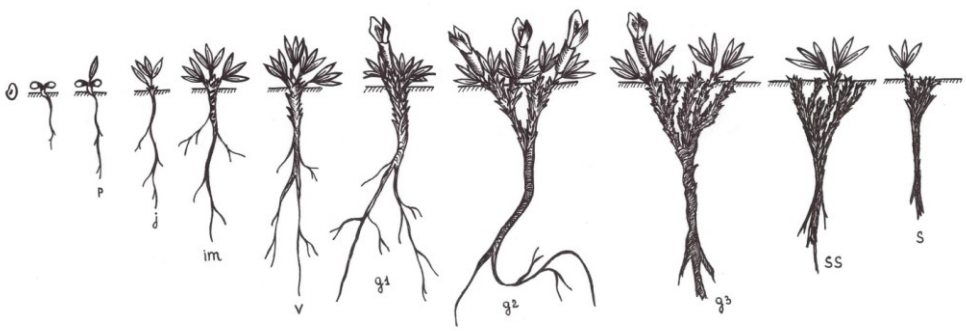

Fig. 1. The ontogeny of *Oxytropis chakassiensis*.

The immature state. Plants have the primary mopodially growing rosette shoot with 2-4 simple and ternate parted leaves, they are 1.5-2 cm long and 1-1.2 cm wide, the stalks of them are 1-1.5 cm long. In immature plants, lateral buds are formed in the leaf axils; a caudex begins to be formed, its main root reaches 11cm. The virginal state. The virginal plants have one or, more rarely, two vegetative rosette shoots with 2-5 ternate leaves of an adult type up to 1.8 cm long. The plants develop a multicipital caudex, the taproot of which reaches 18 cm.

The generative stage. Young generative plants have one or two monopodial vegetative shoots, with 2-5 ternate leaves on the shoot; the length of a leaf varies from 1.2 to 2 cm. 1-4 generative shoots are formed in a plant. The caudex is one- or two-headed, up to 1-3 cm in diameter. The length of the taproot reaches 20 cm. Middle-aged generative plants have a well-developed multicipital caudex, from 3 to 11 cm in diameter, on which 3-6 vegetative rosette shoots and up to 12 generative shoots are formed. From 2 to 6 leaves, the mean length of which is 2.1±0.2 cm, grow on the vegetative shoot. Old generative plants are characterized by 5-6 vegetative shoots and 2-4 generative shoots. The caudex is divided into individual particles, up to 50 of which are dead particles.

The postgenerative stage. The subsenile age state. Subsenile plants have vegetative rosette shoots with 1-2 leaves located on the periphery of the caudex, of an adult and immature types. Senile plants occur extremely rarely and are represented by a single vegetative shoot with leaves of immature or juvenile types.

The study of the ontogenic structure of the plants revealed that all studied coenopopulations of *O. chakassiensis* are normal, definitive, and in most cases, incomplete (7 incomplete CP out of 10 studied populations). Plants in a senile state were absent most often, followed by those in the pregenerative state. For the coenopopulations of the studied species, the domination of dextral ontogenetic spectra is characteristic, with the absolute maximum in g3-plants, in six CP. The coenopopulations with sinistral and centered spectra (two of each type) were equally represented. Based on Zhivotovsky's classification, the coenopopulations of the studied species mostly refer to mature (60 % CP) and ageing 18 %) types, and the young and transitional types characterize one coenopopulation each.

For all studied CP, significant dominance of the share of the generative plants is characteristic, 40.3-96.5 % (Table 1). The fraction of pregenerative plants varies rather much, primarily due to the pressure of pasture and secondly, due to the environmental and coenotic situation. The fraction of plants at the pregenerative stage varies within 2.6–52.2 %, but in most cases, the fraction of the young plants is low and constitutes 2.6–14.9 %. The percentage of virginal plants ensuring continuous replenishment of the

generative fraction is low too (2.7 – 8.6 %), and in two CPs virginal plants are absent. The values of the recovery index (I_R) vary from 0.03 to 0.12. This indicates insufficiently favourable conditions for recovery of *O. chakassiensis* in its populations. The share of the postgenerative plants in the ontogenic ranges of *O. chakassiensis* varies from 2.7 to 13 %. The plant density in the coenopopulations of *O. chakassiensis* fluctuates from 1.6 to 7 plants/m^2, with the values of effective density (density of generative plants) varying from 0.2 to 5.1 plants per 1m^2.

Table. Demographic characteristics of coenotic populations of *Oxytropis chakassiensis*

Name of coenotic populations	Plant density		Absolute and local maximums	Ontogenetic groups, (%)			Δ	ω	Ir	Ia
	individuals/ m2	generative individuals/ m2		j- v	g1 - g3	ss, s				
Vlasyevo	3,4	2,6	g1 , g3	11,8	85,3	2,9	0,53	0,76	0,12	0,03
Malyy Kobezhikov	2,0	1,5	g1, g3	3,1	86,1	10,8	0,63	0,75	0,03	0,11
Tus	0,3	0,2	g3	2,6	84,2	13,2	0,63	0,76	0,03	0,13
Chalpan	4,9	3,8	g2	14,9	82,4	2,7	0,41	0,78	0,15	0,03
Itkul 1	3,3	2,2	g1 , g3	21,4	68,6	10,0	0,42	0,66	0,24	0,1
Itkul 2	4,8	2,2	im, g1	52,2	40,3	7,5	0,23	0,46	0,56	0,07
Itkul 3	4,5	3,3	g1, g3	11,1	78,8	10,1	0,51	0,74	0,12	0,10
Itkul 4	7,0	5,1	g1, g3	7,2	84,8	8,0	0,53	0,73	0,08	0,08
Itkul 5	1,6	1,3	g2	0	91,0	9,0	0,50	0,83	0	0,09
Itkul 6	2,0	1,6	g1, g3	3,5	96,5	0	0,54	0,82	0,04	0

Note: Δ – the age index [8], ω – the effectiveness index [12], the recovery index (I_r) and the ageing index – I_a [14].

The basic (most common) ontogenetic range for this species is dextral with the absolute maximum in g3-plants and the local maximum in g1-plants. Plant density in the coenopopulations of *O. chakassiensis* ranges within 1.6 to 7 plants/m^2, with the values of effective density varying from 0.2 до 5.1 plants per 1m^2.

The conducted studies led us to conclude that the ontogeny of *O. chakassiensis* is simple, complete (p-s), and remains permanent in all habitats. The ontogenetic structure of most part of studied coenopopulations is characterized by a large share of generative plants and, in combination with a lengthy generation period, creates a possibility of regular regeneration and sustained existence of populations. Evaluation of the status of the coenopopulations has shown that the condition of studied species is stable and that moderate recreational load does not negatively affect the structure of its coenopopulations. As the anthropogenic load increases, the viability of coenopopulations goes down, the plant density decreases, the ontogenetic ranges become incomplete and dextral, and the populations acquire regressive traits.

Based on the conducted studies, we may conclude that, due to the scantiness and the small number of plants in them, the small share of pregenerative plants and the prevalence of g3-plants, the coenopopulations of *O. chakassiensis* need more thorough protection. *O. chakassiensis* should be recommended to be included into the Red Book of Endangered Species of the Russian Federation.

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