

The Population Diversity of *Chamaecytisus ruthenicus* (Fisch. ex Woloszcz.) Klaskova in the Mari El Republic

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Abstract

The paper describes the results of the study of the structure of Russian broom [*Chamaecytisus ruthenicus* (Fisch. ex Woloszcz.) Klaskova], a legume-family shrub, coenopopulations in the Mari El Republic. In this article, we determined its ecological valence and the species' tolerance with respect to climatic and soil factors; ontogenesis and the ontogenetic structure of coenopopulations are also described.

Keywords: Ontogenesis; Coenopopulation; Ontogenetic structure; Vitality structure; Vitality; Viability; Ecological scales; Valence; Tolerance; Russian broom; *Chamaecytisus ruthenicus* (Fisch. ex Woloszcz.) Klaskova

Introduction

Biological diversity is a unique quality of wildlife that plays an important part in sustaining life on the earth. It is an essential part of present-day ideas of relationships between the nature and the society. Although there is no generally accepted definition of biodiversity, it is recognized that "...it covers all the diversity of life manifestations at different levels of its organization" [1]. Biodiversity is studied not only in biology but also in many other sciences (geography, computer science, etc.). At present, the systemic approach to subjects of research is the basis for theoretical biology (an organism is not recognized as the only form of the matter organization) [2]. One of the basic research aspects in ecology is population-ontogenetic concept. The study of ontogenetic peculiarities and the structure of coenopopulations (CP) allows us to talk about proliferation or suppression of any species in a certain habitat. Thus, the aim of our article was to study the peculiarities of the ontogenetic structure of Russian broom CP on the territory of the Mari El Republic (MER).

Materials and Methods

In our study we used the generally accepted methods of geobotanical descriptions, and their processing was carried out with the aid of the EcoScaleWin program [3,4] according to D.N. Tsyganov's scales [5]. For both species ecological valences and tolerance indices [6-8] were calculated. The study of individual development is based on the concept of ontogenesis discrete description [2, 9-11]. In this study the following classifications of the plant populations were used:

- 1) The classification proposed by T.A. Rabotnov [9] who distinguished invasive, normal, and regressive CPs as well as the classification of normal CPs proposed by L.A. Zhukova, A.A. Uranov, and O.V. Smirnova [12] by the absolute maximum of ontogenetic groups of adult plants (virginile, young generative group—young normal CPs; middle-aged generative group—mature CPs; old generative group—ageing CPs; subsenile group—old normal CPs)

- 2) The classification proposed by L.A. Zhyvotovskiy [13]: "delta-omega," where delta is the age index proposed by A.A. Uranov [2], which evaluates the coenopopulation age level at any point of time and omega is the effectiveness of the plant of the i-ontogenetic state (the amount of "load" on the environmental energy resources expressed in fractions of the load produced by plants of middle-aged generative state of this population)—according to this classification, CPs can be young, maturing, transitional, ageing, and old
- 3) The classification proposed by O.V. Smirnova [14], who also distinguishes the invasive and normal, with subdivision into full-member spectrum, vegetative-full-member spectrum, and discontinuous spectrum as well as a regressive state of CP—the classification is added as a fragmentary spectrum represented only by certain ontogenetic groups

The restoration and replacement indices [11] were calculated. Statistical processing was carried out with the aid of the χ^2 -test.

Russian broom [*Chamaecytisus ruthenicus* (Fisch. ex Woloszcz.) Klaskova] is a Euro-Asian species. This is a small (50-150 cm high) perennial summergreen deciduous shrub with straight, branchy, orthotropic shoots; strong, limby xylorhizomes; and a taproot system. It comes into symbiosis with mycorrhiza-forming fungi. Russian broom belongs to the bushy form [15] or hypogeogenic-geoxile shrubs [16]. CPs of the studied species can be found in dry pine and oak forests, in the layer of shrubs, in felled areas, on open grassy slopes and clearings in the woods, on flow meadows, exposed chalk stone and limestone, and on sands [16-19].

The study was carried out on the territory of the Mari El Republic. We collected the material at four places: the central part of the MER (neighborhood of Yoshkar-Ola), the northern part (Orshansky district), the southern part (Volzhsky district), the western part (Mountain Mari district). At every point contrasting habitats were studied, and 18 CPs were studied in total.

Results and Discussion

Zhukova [7,8] determined ecological valence as a measure of adaptiveness of a species to any environmental factor, and the tolerance index is calculated for the group of factors. At the same time, stenovalent (SV) species are those taking up less than 1/3 of the scale, mesovalent

(MV)—from 1/3 to 2/3, and eurivalent (EV)—more than 2/3. Mesovalent species additionally are subdivided into hemistenovalent (HSV), mesovalent as such, and hemieurivalent (HEV). According to distribution by fractions, Russian broom is hemisteno-, meso-, or hemieurivalent according to soil scales and the light-shading scale. The exclusion is its eurivalence according to the scale of soil acidity. The tolerance index of the studied species is 48%, which allows us to assign it to mesobiont species [21]. Russian broom in the studied CPs realizes from 16.6 to 48.0% of their potential capacities by the studied factors (Table 1, Figure 1). The limiting factors are moistening and wealth of soils.

Ontogenesis of Russian broom was described by M.N. Gavrilova, L.A. Zhukova, and E.S. Zakamskaya [20]. At the early stages of individual development, monopodial growth of the leading shoot can be observed, which is changed by sympodial one in the juvenile or immature ontogenetic state. Formation of the hypogeogenic rootstock starts at the end of the immature period but it is completely formed in the virginile period. The completion of the life-form formation usually takes place in virginile plants. By this time xylopodia [15] has been formed in the underground part of plants. Initial dying-off processes are already noticed in middle-aged generative state (a part of shoots of two-three order is dying-off); in old generative state, dying-off processes

are more pronounced. Senile plants, as a rule, are short nonbranching plants with small sections of shoots. As a result of the study of Russian broom ontogenesis, we distinguished the following markers of ontogenetic states (j-ss): (1) replacement of the taproot system by the hybrid one; (2) formation of xylopodia and their subsequent dying-off; (3) the change of growth nature from monopodial to sympodial one; (4) intensity of dying-off and new growth processes in different ontogenetic states; (5) degree of shoot duraminization; (6) order of shoot branching [20].

As a result of our study we obtained the data supporting the fact that all the studied Russian broom CPs according to T.A. Rabotnov's classification [15] can be subdivided into invasive, represented only by the pregenerative fraction specimens (CP 6 of the central area of the MER), and normal CPs (the remaining 17 CPs). Regressive CPs, consisting of the postgenerative fraction, were not identified. Thus, virtually all the studied Russian broom CPs, besides an invasive one, are capable of self-renewal and do not depend on primordiums coming from outside.

According to A.A. Uranov's classification [10], the studied CPs are subdivided into full-member CPs represented by the specimens of all ontogenetic states (4 CP) and non-full-member CPs (14 CPs), in which specimens of certain ontogenetic states (j, im, ss or s) are absent. In most cases only senile specimens were not identified.

L.A. Zhukova in 1967 and A.A. Uranov and O.V. Smirnova in 1969 supplemented this classification and distinguished the subtypes of normal CPs. By the absolute maximum among adult plants we can distinguish the following Russian broom CPs:

- In normal young CPs the maximum is accounted for by the specimens of the virginile (7 CPs) or young generative state (five CPs).
- In normal mature CPs of Russian broom, middle-aged generative specimens are prevalent (three CP).
- Normal ageing CPs are characterized by the maximum on old generative specimens (two CPs).

According to L.A. Zhyvotovskiy's classification [13] based on the age index by A.A. Uranov [12] and effectiveness, all the studied Russian broom CPs are subdivided as follows:

1. Young CPs ($\Delta = 0.277$; $\omega = 0.519$)
2. Maturing CPs ($\Delta = 0.338$; $\omega = 0.629$)
3. Transitional CPs ($\Delta = 0.402$; $\omega = 0.495$)
4. Ageing CPs ($\Delta = 0.725$; $\omega = 0.486$)

According to O.V. Smirnova's classification [14], we distinguished the following types of the CP state:

- Invasive population of Russian broom, the ontogenetic spectrum of which is represented only by the species of the pregenerative period
- Normal CPs with left-side (nine CPs), unimodale (seven CPs), or right-side spectra (one CP)

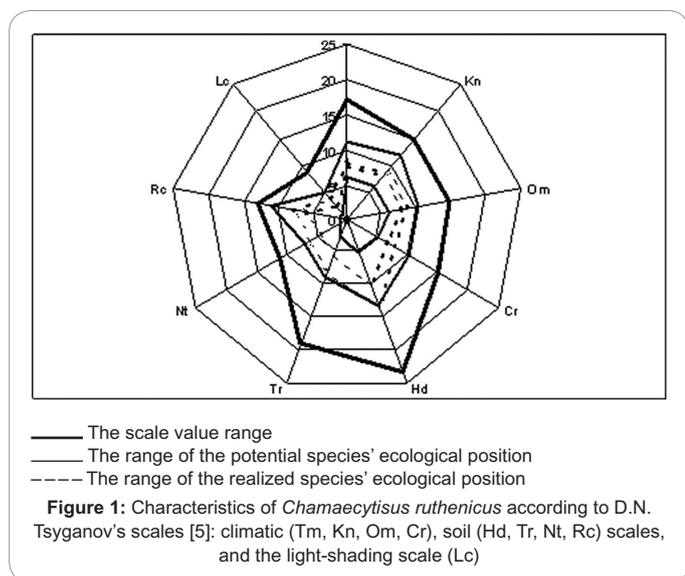
Let us consider the ontogenetic spectra of main types of Russian broom CPs.

Invasive CPs (Figure 2) are represented only by the specimens of pregenerative period. Here juvenile plants (on the average 73.2%) are prevalent, and the percentage of plants of immature and virginile state is 17.1 and 9.8%, respectively. We identified only one CP of this type, in the central area of the MER.

Ecological scale		PEV	REV	It	
Climatic scales	Tm	0.35 (HSV)	0.11 (SV)	It according to clim. scales 0.40 (MB)	It (total) 0.48 (MB)
	Kn	0.47 (MV)	0.10 (SV)		
	Om	0.33 (SV)	0.13 (SV)		
	Cr	0.4 (HSV)	0.13 (SV)		
Soil scales	Hd	0.39 (HSV)	0.21 (SV)	It according to soil scales 0.56 (MB)	
	Tr	0.37 (HSV)	0.18 (SV)		
	Nt	0.64 (HEV)	0.27 (SV)		
	Rc	0.85 (EV)	0.20 (SV)		
	Lc	0.56 (HEV)	0.26 (SV)		

Conventions: Tm—thermoclimal scale, Kn—continentality scale, Om—ombroclimatic scale, Cr—cryclimatic scale, Lc—light-shading scale, Hd—soil moistening scale, Tr—soil wealth scale, Rc—soil acidity scale, Nt—soil nitrogen abundance, SV—stenovalent, HSV—hemistenovalent, MV—mesovalent, HEV—hemieurivalent, EV—eurivalent.

Table 1: The characteristics of the potential (PEV), realized (REV) ecological valences and the tolerance index (It) according to D.N. Tsyganov's scales [5]



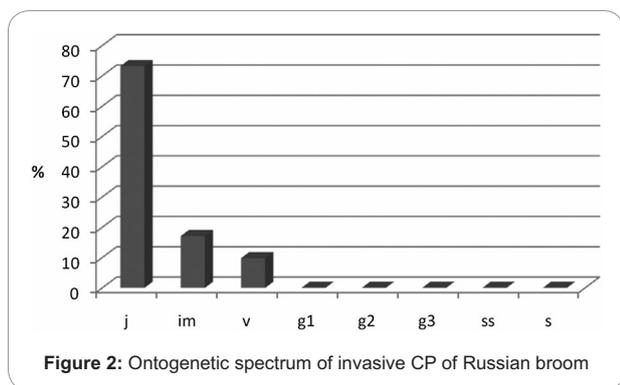


Figure 2: Ontogenetic spectrum of invasive CP of Russian broom

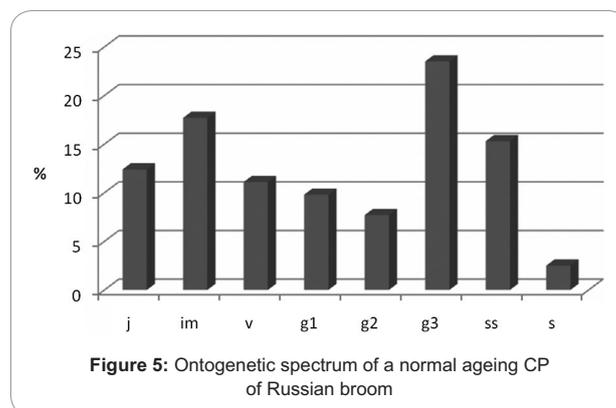


Figure 5: Ontogenetic spectrum of a normal ageing CP of Russian broom

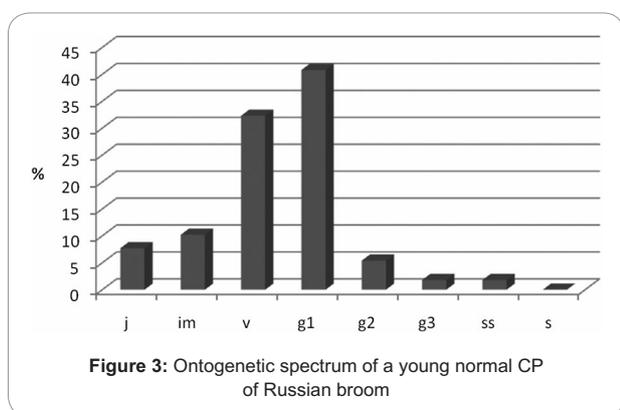


Figure 3: Ontogenetic spectrum of a young normal CP of Russian broom

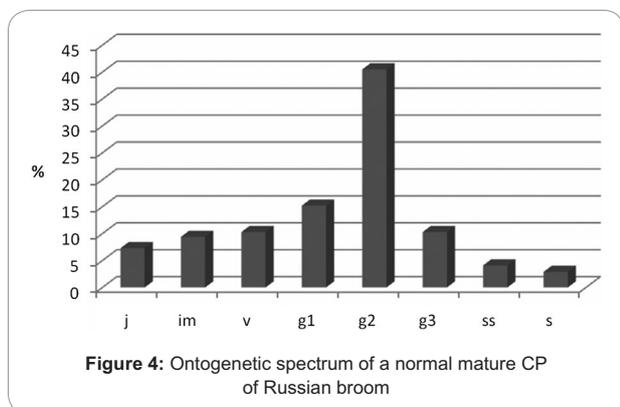


Figure 4: Ontogenetic spectrum of a normal mature CP of Russian broom

In young normal Russian broom CPs (Figure 3), the maximum is accounted for by the specimens of the virginile or young generative states (on the average 32.3 and 40.8%, respectively). In CPs of *Ch. ruthenicus* we observe a high percentage of generative fraction specimens (on the average 37.9 and 38.8%) and a low percentage of old generative and subnile plants (on the average 7.6 and 2.0%).

Normal mature CPs (Figure 4) are distinguished by the highest percentage of generative period plants (62.0-63.7%) with a maximum on the group of middle-aged generative plants (31.0-40.5%). The postgenerative fraction percentage is low (4.8-7.0%), as in the CP of the preceding type.

Ageing CP (Figure 5) is characterized by the presence of the maximum on old generative groups (up to 45.0%) or the two maximums

on the immature (17.7%) and old generative groups (23.5%). Therefore, the number of specimens of the pregenerative and generative fractions is nearly the same (41.2 and 41.0%).

If we consider the ontogenetic structure of Russian broom CPs depending on the study area, the youngest are northern and western ones (here all CPs of *Ch. ruthenicus* are young normal), and in the southern and the central areas, most studied CPs are young normal (60 and 71.4%, respectively) but ageing normal ones can also be found.

Thus, Russian broom CPs represented by most ontogenetic states are prevalent. This proves stability and self-renewal capability of its CP.

In young normal CPs of Russian broom, the restoration index is more than 1 ($I_n = 1.20-1.45$), i.e., CPs are stable, and a great amount of seeds is produced, which gives rise to viable specimens. The pregenerative fraction of these CPs can completely replace the generative fraction specimens. In mature CPs of *Ch. Ruthenicus*, these indices decrease ($I_n = 0.38-0.85$), which proves that the pregenerative fraction is less dense and these populations are less resistant because the undergrowth cannot provide a sufficient replacement for the generative fraction specimens. Ageing Cps are close to the critical condition ($I_n = 0.27-0.45$). If there is no new population wave, such CP of Russian broom can disappear.

According to L.A. Zhyvotovskiy's classification [13], we distinguished four types of the ontogenetic structure of Russian broom CP. The age index increases in the direction from young CPs to ageing ones, i.e., we observe a gradual increase in the number of the postgenerative fraction specimens which cannot be replaced by the undergrowth completely. The effectiveness does not change significantly. We can make the only conclusion that young and maturing CPs consume a great amount of energy and put great stress on the environmental energy resources.

Conclusion

As the habitats of the studied CPs of Russian broom do not differ significantly (2-4 degrees according to D.N. Tsyganov's scales, 1983), therefore, they have a similar ontogenetic structure, and most factors are not limiting for the studied species and are close to the optimal ones. This can be proved by the description of the vitality structure of the Russian broom CP [22]. In CPs of *Ch. ruthenicus* of various areas of the MER, the specimens of the third point of vitality (from 48 to 100%) are prevalent, which ensures their prevalence in the studied communities.

In northern areas of the MER, young normal CPs of Russian broom are prevalent. When comparing the distribution of specimens by ontogenetic groups with the aid of the χ^2 -test, we did not find out the difference between southern and northern CPs, i.e., the species *Ch. ruthenicus* spreads further north than its natural habitat. It can be a constant component of forest ecosystems, increasing their productivity due to nitrogen enrichment of the soil.

Thus, all the studied coenopopulations are located in habitats with similar environmental conditions close to the optimal values for this species, which allows us to trace the development of populations in the course of time. The restoration index gradually increases, starting with invasive populations, and decreases in maturing populations, which proves that such populations are less resistant because the species of the pregenerative period cannot provide a sufficient replacement of species of the generative period.

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