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The structure of *Adonis wolgensis* Stev. coenopopulation in the conditions of Northern Kazakhstan

The article presents the study results made on the *Adonis wolgensis* coenopopulation in Northern Kazakhstan (2018–2019). The materials have been gathered in the course of field research taking into account the literary data. The age structure of the coenopopulations is provided on the basis of detailed route studies. There have been studied eight coenopopulations located in Akmola, Pavlodar, and Kostanay regions. *A. wolgensis* is a short-stem herbaceous polycarpic of Northern Kazakhstan. *A. wolgensis* coenopopulations are found in three main habitats: steppe, meadow-steppe, and forest communities. The study of *A. wolgensis* coenopopulations in the latitudinal direction from Ekibastuz in the east to the Kostanay region in the west has revealed a high recovery index in steppe ecotopes. In other coenopopulations it is less than one. It is especially low in forest habitats. Most coenopopulations have a normal character according to the spectrum of age conditions, and they are maturing. This fact proves no negative impact of environmental and anthropogenic factors on the structure of coenopopulations and ensures their recovery and preservation.

Keywords: *Adonis wolgensis* Stev., coenopopulation, Northern Kazakhstan, age structure, rare plants.

Introduction

Adonis wolgensis Stev. is in the Red Book of Kazakhstan (category III). Dying species) [1]. The species is protected in Ukraine, the Republic of Moldova, Bulgaria, Romania [2–5], as well as in 11 regions of the Russian Federation.

Material and research methods

Age structure is one of the essential signs of coenopopulation, as it provides the ability of the population system to maintain itself and to determine its stability [7]. The study of *Adonis wolgensis* Stev.'s age structure was held in Northern Kazakhstan in 2018–2019. There have been studied 8 coenopopulations of *A. wolgensis* located in Akmola, Pavlodar, and Kostanay regions. The area of maximal distribution of *A. wolgensis* was determined for each CP using GPS; 25 reference sites (1 m²) were made inside the CPs on which the number of all *A. wolgensis* specimens was counted and their age stages were determined.

The age stages were determined according to the guidelines of T.A. Rabotnov [8], A.A. Uranov [9–10], L.B. Zaugolnova and O.V. Smirnova [7], Plant coenopopulations... [11].

The type of coenopopulation was determined according to T.A. Rabotnov [8] and to the «delta-omega» classification of L.A. Zhivotovsky [12].

The age index of a coenopopulation (Δ) is calculated according to the formula

$$\Delta = \sum K_i m_i / \sum K_i,$$

i.e. $\sum K_i$ is a sum of the plants of all age stages; m_i is the age of individual plants [13].

The efficiency index was defined by the formula

$$\omega = \sum p_i e_i,$$

i.e. $p_i = n_i/n$ is the share of plants of an i -state in this population, n_i is the absolute number of i -state plants, $n = \sum n_i$ is the total number of plants, e_i is energy efficiency [13].

The recovery index (I) was calculated by the formula

$$I = \sum j \rightarrow v / \sum g1 \rightarrow g3,$$

i.e. $\sum j \rightarrow v$ is the sum of plants of all age stages of the pre-generative period; $\sum g1 \rightarrow g3$ is the sum of plants of all age stages of the generative period [13].

Results and discussion

A. wolgensis is a short-stem herbaceous polycarpic plant of Northern Kazakhstan represented by three morphotypes: steppe, meadow-steppe, and forest ones. They all have significant morphological differences in the height of shoots and the form of leaf blades.

CP-1. Pavlodar region, near Ekibastus, 51.66494°N, 75.28173°E, $h = 412$ m.a.s.l. Interslope lowland, northern slope, adonis-fescue community. The population area is 200 m², total projective cover (TPC) is 60 %, the TPC of *A. wolgensis* is 40 %, the community has 24 species. The vegetation is formed by *Adonis wolgensis*, *Alyssum desertorum*, *Androsace maxima*, *Artemisia austriaca*, *Festuca valesiaca*, *Potentilla humifusa*, *Ranunculus polyrhizos*, *Seseli ledebourii*, *Valeriana tuberosa*.

CP-2. Pavlodar region, near Ekibastus, «Three birches» tract, 51.57517°N, 75.13187°E, $h = 403$ m.a.s.l. Eastern slope of the hill, feather-grass and fescue steppes on alkaline soils. The population area is 300 m², TPC is 60 %, the TPC of *A. wolgensis* is 0.5 %, the community has 29 species. The vegetation is formed by *Artemisia nitrosa*, *Astragalus testiculatus*, *Draba nemorosa*, *Festuca valesiaca*, *Limonium gmelinii*, *Ranunculus polyrhizos*, *Spiraea hypericifolia*, *Tulipa patens*, *Valeriana tuberosa*.

CP-3. Pavlodar region, near Bayanaul, 50.2209° N, 75.8009° E, 406 m.a.s.l. The foot of the slope, the shrubs of a fescue-feather grass steppe. The population area is 500 m², TPC is 90 %, the TPC of *A. wolgensis* is 0,5 %, the community has 29 species. The vegetation is formed by *Allium nutans*, *Caragana frutex*, *Carex pediformis*, *Gagea granulosa*, *Poa angustifolia*, *Rosa spinosissima*, *Seseli libanotis*, *Stipa capillata*, *S. pennata*, *Thymus marschallianus*.

CP-4. Akmola region, near Ereimentau, the Ereimentau mountains, 51.65717° N, 73.19056° E, $h = 313$ m.a.s.l. The foot of the slope is the alkaline meadow. The population area is 400 m², TPC is 100 %, the TPC of *A. wolgensis* is 3.0 %, the community has 25 species. The vegetation is formed by *Agropyron cristatum*, *Artemisia dracunculus*, *Carduus nutans*, *Centaurea scabiosa*, *Glycyrrhiza uralensis*, *Potentilla bifurca*, *Ranunculus polyanthemus*, *Rumex acetosa*, *Tamarix ramosissima*.

CP-5. Akmola region, the Burabay region, near Kartakol, 52.93287° N, 70.49210° E, $h = 431$ m.a.s.l. Pine and birch forest. The population area is 300 m², TPC is 60 %, the TPC of *A. wolgensis* is 0.5 %, the community has 20 species. The vegetation is formed by *Achillea asiatica*, *Betula pendula*, *Calamagrostis epigeios*, *Equisetum hyemale*, *Filipendula ulmaria*, *Jacobaea erucifolia*, *Pinus sylvestris*, *Populus tremula*, *Rosa majalis*, *Solidago virgaurea*,

CP-6. Kostanay region, near Scherbakovo, 53.20453° N, 64.21550° E. The sparse pine forest is growing on sands. Population area is 1000 m², OPP is 30 %, the OPP of *A. wolgensis* is 0.5 %. The community has 22 species. The vegetation is formed by *Agropyron pectinatum*, *Carex supina*, *Genista tinctoria*, *Phragmites australis*, *Potentilla arenaria*, *Scorzonera ensifolia*, *Stipa capillata*, *Thymus serpyllum*, *Tulipa biebersteiniana*, *Veronica spicata*.

CP-7. Kostanay region, near Ozerny, the Novonezhensky forestry, sq. 21, 52.43971° N, 64.09279° E, $h = 213$ m.a.s.l. The secondary psammophyte steppe is at the site of an old fire. Population area is 300 m², OPP is 100 %, the OPP of *A. wolgensis* is 5.0 %. The community has 38 species: *Artemisia campestris*, *Echinops sphaerocephalus*, *Gypsophila paniculata*, *Medicago falcata*, *Oenothera biennis*, *Otites wolgensis*, *Potentilla arenaria*, *Pulsatilla uralensis*, *Sedum telephium*, *Xanthoselinum alsaticum*,

CP-8. Kostanay region, near Zarechny, «Stone Lake», 52.28013° N, 63.76616° E, $h = 134$ m.a.s.l. The northern slope towards the lake, shrub thickets. Population area is 400 m², OPP is 100 %, the OPP of *A. wolgensis* is 1.0 %. The community has 23 species: *Amygdalus nana*, *Calamagrostis epigeios*, *Filipendula vulgaris*, *Potentilla bifurca*, *Rosa acicularis*, *R. spinosissima*, *Spiraea hypericifolia*, *Stipa capillata*, *S. pennata*.

A. wolgensis coenopopulations are confined to three main habitats: steppe communities (CP-1, CP-2, CP-7), meadow-steppe communities (CP-3, CP-4, CP-8), forest communities (CP-5, CP-6). Many authors who studied the structure of *A. wolgensis* coenopopulations consider it to be a steppe species. Forest habitats are not peculiar to it [14–16]. Therefore, forest habitats should be considered secondary for *A. wolgensis*. In this regard, the presence of *A. wolgensis* in a pine-birch forest can be explained by some dynamic processes of «forest fighting with steppe» in the process of climatic fluctuations in the Kokshetau highlands.

By density (pcs./100 m²) all populations are divided into three groups: high > 800 pcs./100 m² (CP-1, CP-7), medium — 150–800 pcs./100 m² (CP-3, CP-4, CP-6, CP-8), low < 150 (CP-2, CP-5). Steppe CPs (except CP-2) have high density, meadow-steppe ones are medium, forest CPs are low or medium (Table 1).

Table 1

Characteristics of *A. wolgensis* coenopopulation

No.	TPC, %	TPC <i>A. wolgensis</i> , %	Area of CP, m ²	Density of plants, pcs./100 m ²	Number of plants in CP	Δ	ω	I
CP-1	60	40.0	200	1480	2960	0.47	0.62	0.65
CP-2	60	0.5	300	51	153	0.20	0.59	1.43
CP-3	90	0.5	500	169	845	0.30	0.77	0.32
CP-4	100	3.0	400	490	1960	0.29	0.75	0.32
CP-5	60	0.5	300	85	255	0.33	0.86	0.06
CP-6	30	0.5	1000	315	3150	0.32	0.81	0.31
CP-7	100	5.0	300	870	2610	0.22	0.64	1.07
CP-8	100	1.0	400	155	620	0.27	0.84	0.63

According to the age structure, mature (CP-1) and maturing (CPU-2) species grow only in steppe coenopopulations, all the rest are young (Table 2). By the «delta-omega» ratio, most populations are maturing, but CP-1 is the one which is transitive and CP-2 is young.

The recovery index (Table 1) in steppe ecotopes is very high 0.65–1.43. In other CPs it is less than one. It is especially low in CP-5 (forest habitats) where it is 0.06 (Table 1).

Table 2

Characteristics of *A. wolgensis* according to the age ratio and «delta-omega» (by Zhivotovsky, 2001)

No.	Age ratio	«delta — omega»
CP-1	Mature	Transitive
CP-2	Maturing	Young
CP-3	Young	Maturing
CP-4	Young	Maturing
CP-5	Young	Maturing
CP-6	Young	Maturing
CP-7	Young	Maturing
CP-8	Young	Maturing

All the coenopopulations of *A. wolgensis* are normal with slight deviations. The exception is CP-2 located on the eastern slope of the hill in the lowland. There is a long-lasting snow cover that provides favorable conditions for resumption. As a result, a large number of young vegetative plants and CPs has antropogenous invasive character. Inconsistency of the CP is bound to an extremely small number of senile plants and seedings.

Conclusion

Thus, the study of *A. wolgensis* CPs in a latitude direction from Ekibastus in the east to the Kostanay region in the west has found that the majority of CPs has normal character and belongs to maturing CPs according to the spectrum of age stages. This fact proves no negative impact of environmental and antropogenic factors on the structure of coenopopulations and ensures their recovery and preservation. The gathered data are consistent with the study results of *A. wolgensis* coenopopulations in the Saratov's region [17, 18].

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Солтүстік Қазақстан жағдайындағы *Adonis wolgensis* Stev ценопопуляциясының құрылымы

Мақалада Солтүстік Қазақстандағы *Adonis wolgensis* ценопопуляцияларын зерттеу нәтижелері келтірілген (2018–2019 жж.). Материалдар далалық зерттеулер нәтижесінде алынған, әдеби мәліметтер ескерілген. Егжей-тегжейлі бағыттық зерттеулер негізінде ценопопуляциялардың жас құрылымы келтірілген. Ақмола, Павлодар, Қостанай облыстарында орналасқан сегіз ценопопуляция зерттелді. *A. wolgensis* қысқа-өзекті шөпті поликарпик, ал Солтүстік Қазақстанда *A. wolgensis* ценопопуляциясы негізгі үш мекендейтін жерге: дала қоғамдастықтары, шалғынды-дала, орманды деп топтастырылған. *A. wolgensis* ценопопуляциясын шығыста Екібастұздан, батыста Қостанай облысына дейін ендік бағытта зерттеу барысында дала экотоптарындағы қалпына келтіру индексі өте жоғары екенін анықталды. Қалған ценопопуляция, ол бірліктен әлдеқайда аз. Әсіресе, орманды жерлерде аз кездеседі. Жас жағдайының спектрі бойынша көптеген ценопопуляциялар қалыпты сипатқа ие және піскендер қатарына жатады. Бұл ценопопуляциясының құрылымына экологиялық және антропогендік факторлардың теріс әсерінің жоқтығын растайды және популяциялардың жаңартылуы мен сақталуын қамтамасыз етеді.

Кілт сөздер: *Adonis wolgensis* Stev., ценопопуляция, Солтүстік Қазақстан, жас құрылымы, сирек өсімдіктер.

Г.Ж. Султангазина, А.Н. Куприянов, О.А. Куприянов, М.Ю. Стешенко

Структура ценопопуляций *Adonis wolgensis* Stev. в условиях Северного Казахстана

В статье даны результаты изучения ценопопуляций *Adonis wolgensis* в Северном Казахстане (2018–2019 гг.). Материалы получены в результате полевых исследований, учтены литературные данные. На основании детально-маршрутных исследований приведена возрастная структура ценопопуляций. Изучено восемь ценопопуляций, расположенных в Акмолинской, Павлодарской, Костанайской областях. *A. wolgensis* — коротко-стержневой травянистый поликарпик, в Северном Казахстане ценопопуляции *A. wolgensis* приурочены к трем основным местообитаниям: степные сообщества, лугово-степные, лесные. Изучение ценопопуляций *A. wolgensis* в широтном направлении от Экибастуза на востоке до Костанайской области на западе выявило, что индекс восстановления в степных экотопах очень высокий. В остальных ценопопуляциях он значительно меньше единицы. Особенно он мал в лесных местообитаниях. Большинство ценопопуляций по спектру возрастных состояний имеют нормальный характер и относятся к зреющим. Это свидетельствует об отсутствии негативного влияния экологических и антропогенных факторов на структуру ценопопуляций и обеспечивает возобновляемость и сохранность популяций.

Ключевые слова: *Adonis wolgensis* Stev., ценопопуляции, Северный Казахстан, возрастная структура, редкие растения.

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