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SYSTEMATIC STUDY OF ARID TERRITORIES

The Status of Coenopopulations of *Xylosalsola Chiwensis* (Popov) Akhani & Roalson and *Scorzonera Bungei* Krasch. & Lipsch. on the Ustyurt Plateau (Uzbekistan)

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Abstract—Environmental monitoring, protection of rare plant species, research to assess the status of populations of rare and endangered plants by coenopopulation approaches, and preservation of plant communities with their participation are priority tasks. The aim of this work was to study the ecological and phytocoenotic parameters of coenotic populations of rare species of the Ustyurt Plateau: *Xylosalsola chiwensis* and *Scorzonera bungei* listed in the Red Data Book of Uzbekistan (2019). Plant communities with the participation of coenopopulations of the studied species are characterized. The ontogenetic structure of these species has been studied. The results show that coenopopulations under the ecological and coenotic conditions of Ustyurt are normal and incomplete. The basic ontogenetic spectrum is centered with a peak of middle-aged generative plants. The spectra of particular coenopopulations are centered and left-sided, which is related to ecological conditions of habitats and fluctuations in weather conditions. The protection of these species should be continued during the development of free-range animal husbandry and the planning of linear infrastructures. The results we obtained will be used in subsequent editions of the Red Data Book of the Republic of Uzbekistan.

Keywords: *Xylosalsola chiwensis*, *Scorzonera bungei*, Aral Sea, Ustyurt Plateau, biodiversity, ontogenetic structure, coenopopulation

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INTRODUCTION

The urgency of studying rare and endangered plant species is determined by the importance of the tasks of their preservation as elements of biodiversity. This problem may be solved on the basis of a comprehensive study of rare and endangered plant species, their bioecological features, and survival strategy. Such studies are necessary for protecting rare and economically valuable plant species, as well as for the rational use of natural communities and creation of artificial plant communities (Baktasheva and Indzheeva, 2014).

The coenopopulation approach is the optimal method for assessing the current status of populations of rare and endangered species. Such studies are widely used in Russia, Belarus, Ukraine, the Baltic states, and in Central Asia. Systematic research to assess the status of populations of rare and endangered species using coenopopulation approaches was started in Uzbekistan not long ago. Since 2012, employees of the Laboratory of Geobotany of the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan have performed studies to identify rare plant communities in the plant cover of Uzbekistan (including the Ustyurt Plateau) that need protection to assess their current status, and to develop protection measures.

The territory of the study. The Ustyurt Plateau is represented by dry clay desert located in the area of three Central Asian states: Uzbekistan, Kazakhstan, and Turkmenistan. The plateau is bordered on almost all sides by cliffs. Ustyurt is surrounded by the Caspian Lowland from the north, by the drained bottom of the Aral Sea from the east, by the Amu Darya delta and the Sarykamysh depression from the south, and by the Caspian Sea from the west. The total area of Ustyurt is 21.2 million ha, and the Karakalpak part comprises 7.2 million ha.

The flora of the Ustyurt Plateau includes 724 species assigned to 295 genera and 60 families (Sarybaev, 1994). The plant cover includes a few species, forming monodominant communities: *Salsola arbusculiformis, Anabasis salsa, Artemisia terrae-alba, Haloxylon aphyllum,* and *Salsola orientalis*. Less often, the dominants and subdominants of plant communities are represented by *Salsola arbuscula, Atraphaxis spinosa, Stipa richteriana, S. hohenackeriana, S. gemmascens,* and *Nanophyton erinaceum*. Endemics of the Ustyurt and of the drained bottom of the Aral Sea include species of gypsum deserts: *Salsola chiwensis* and *Sisymbrium subspinenscens*, as well as *Crataegus korolkowii*, *Artemisia austriaca*, *Atriplex pratovii,* and *Crambe edentula*. Among species listed in the Red Data Book of Uzbekistan (2019) are *Malococarpus crithmifolius*, *Climacoptera ptiloptera*, *Euphorbia sclerocyathium,* and *Xylosalsola chiwensis*. The species composition of the Karakalpak Ustyurt has not yet been completely studied.

Despite the fact that the Ustyurt is the least populated region of Uzbekistan (2.3 person/km^2), the anthropogenic load on natural biocenoses of the region has constantly increased from the beginning of industrial development. The oil and gas and chemical industries, railways and highways, animal husbandry, forestry and fishing are now the main economic activities on the Uzbek part of the plateau. In addition, the Ustyurt is affected by the Aral Sea, which is a kind of natural thermoregulator. Moisture evaporated by this means increases the humidity of the air at a distance of 350–400 km. The rate of the impact of the sea level drop on the biodiversity of the region is different, but mesophilic species suffer the most.

It is interesting to study the ecological-phytocoenotic status of coenotic populations of rare species *Xylosalsola chiwensis* and *Scorzonera bungei* under difficult environmental conditions of the Ustyurt. There are some works devoted to the modern status of rare species in Kyzyl Kum and on the Ustyurt Plateau (Rakhimova et al., 2020; Shomurodov et al., 2020; Rakhimova et al., 2021a, b; Saribaeva et al., 2022).

The genus *Salsola* L. (saltwort) is represented by annuals, semi-shrubs, shrubs, and small trees. There are about 120 species in the genus, and forage data are available for 43 species (Larin et al., 1951). Representatives of this genus are common in semi-deserts and deserts, and only a few species grow in forest-steppes and steppes. Saltwort plants contain to 10–12% protein. They are most eaten in autumn and winter, more readily by camels and small cattle and less readily by horses and other animals. The genus *Salsola* is represented by 60 species in the flora of Central Asia (Khasanov, 2015); 48 of them grow in Uzbekistan (*Flora Uzbekistana,* 1953). *Xylosalsola chiwensis* is a relict species of Northern Uzbekistan with status 2 and is included in the Red Data Book of Uzbekistan (2019).

The genus *Scorzonera* L. (salsify) includes 175 species spread from Central Europe and the Mediterranean region to East Asia. Species of this genus are especially numerous in Iran, Asia Minor, the Caucasus, and Central Asia and occur under arid ecological conditions (Makbul et al., 2011). Plants of the genus *Scorzonera* are mainly represented by perennial grasses and less often by biennials, semishrubs, and dwarf semishrubs (Tagaev, 2019). All species are valuable forage plants that are eaten by any type of livestock. There are no harmful or poisonous plants among them. Their roots are rich in starchy substances and are eaten. Some species contain rubber (Larin et al., 1952). According to the latest data by F.O. Khasanov (2015), 33 species grow in Central Asia, and 17 of them occur in Uzbekistan (*Flora Uzbekistana,* 1962). *Scorzonera bungei* is a rare endemic of Kyzyl Kum with status 2 and is also included in the Red Data Book of Uzbekistan (2019).

The ontogenetic structure of the coenopopulations of the species analyzed in this work has not been studied by anyone anywhere, including the Ustyurt Plateau.

OBJECTS AND METHODS

The objects of the study were rare species listed in the Red Data Book of the Republic of Uzbekistan (2019): *Xylosalsola chiwensis* and *Scorzonera bungei* (Fig. 1).

Xylosalsola chiwensis of the family Amaranthaceae is a semishrub 30–60 cm tall. It occurs in Uzbekistan on the Ustyurt Plateau and in the Kyzyl Kum Desert and is also found in Turkmenistan. It grows on gray-brown gypsum and marl soils. It occurs both separately and in groups and is reproduced by seeds. The factors for the change in the number and area include cattle grazing and cattle pass. This is a forage plant in Karakalpakstan (Erezhepov, 1978).

The second species we studied, *Scorzonera bungei* of the family Asteraceae, is a perennial herbaceous plant, an ephemeroid to 10–12 cm tall. It is spread in Karakalpakstan, Kyzyl Kum, and the Sultan-Uvais-dag outlier mountains on rocky slopes and rocks. It is reproduced by seeds and grows on slopes, where the young fraction of plants of seed renewal is eliminated by spring flows.

The climate of the Ustyurt is sharply continental and is characterized by hot and dry summer, rather severe winter with strong winds, low precipitation, high evaporation, and a sharp change in temperatures from season to season and during a day. The absolute maximum temperature is +45.5°C (July), and the minimal temperature is –37.0°C (January). The mean annual precipitation does not exceed 120 mm. Less favorable environmental conditions result in long severe winters and hot dry summers. The precipitation amount has decreased by 20–30 mm in comparison with the period of 1970–1980. The soil salinity increased 1.2–1.5 times (Rakhimova et al., 2020).

Geobotanical descriptions were performed in all communities, where the population structure of species was studied according to the conventional method (*Polevaya geobotanika,* 1964). Plant species were identified by *Opredelitel' vysshikh rastenii Karakalpakii* (Bondarenko, 1964). Three transects 10-m long and 1-m wide were laid in each coenopopulation. They were divided into sites of 1 m^2 each. The ontogenetic structure of coenotic populations was calculated as the ratio between plants with different ontogenetic status. The counting unit was a plant for *S. bungei* and a par-

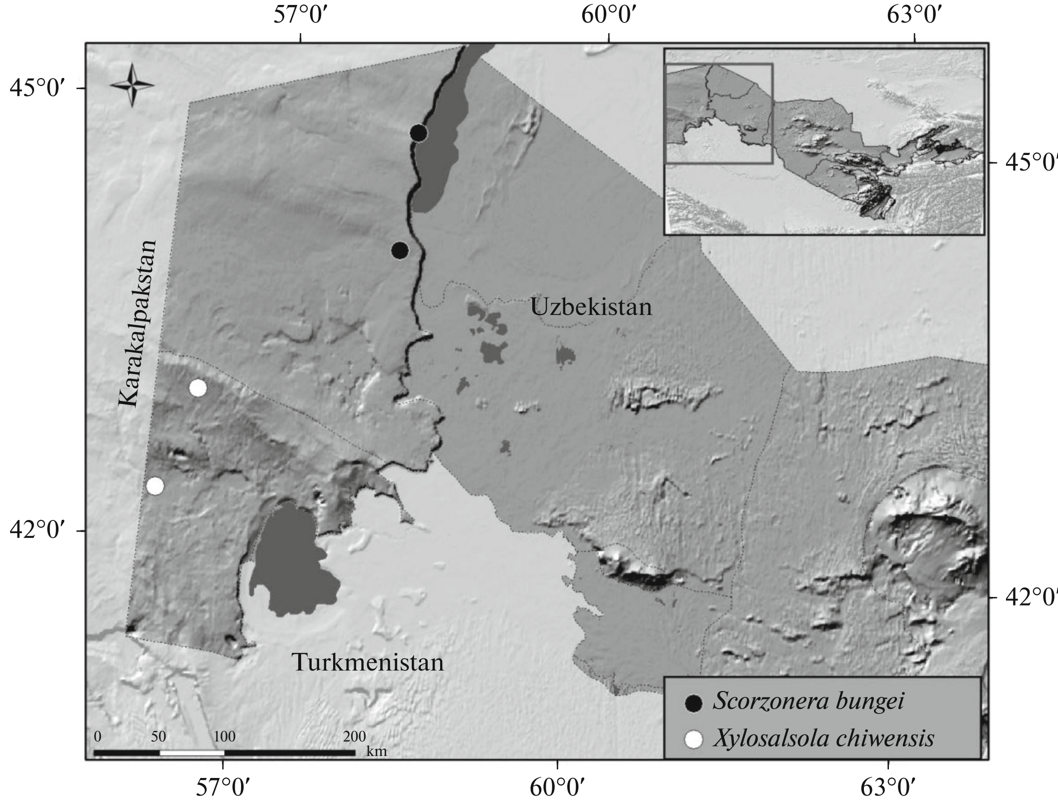

Fig. 1. A map of the distribution of *Xylosalsola chiwensis* and *Scorzonera bungei* on the Ustyurt Plateau (within Karakalpakstan, Uzbekistan).

tial shrub for *X. chiwensis*. Characterization of the population structure was based on the idea of a typical ontogenetic spectrum (Zaugol'nova, 1994). Four types of spectra were distinguished according to the distribution of ontogenetic groups: left-sided, centered, right-sided, and bimodal. The typical spectrum depended on the biological features of the species. We described coenopopulations according to the classifications by A.A. Uranov and O.V. Smirnova (1969) and the type of coenopopulation by the classification of delta–omega (Δ–ω) by L.A. Zhivotovskii (2001). According to this, coenopopulations may be young, maturing, transitional, aging, or old. To compile a map of the studied coenopopulations of the analyzed species, the coordinates of the locations were imported into the ESRI ArcGIS ArcView v.10.0 geographic information system (2020).

The current status of the species *Xylosalsola chiwensis* and *Scorzonera bungei* was assessed in parallel to other rare species (*Malacocarpus crithmifolius, Euphorbia sclerocyathium, Astragalus holargyreus, Crambe edentula, Lagochilus acutilobus,* and *Crataegus korolkowii*) during the terrain expeditions of 2019–2021 on the Ustyurt Plateau.

RESULTS AND DISCUSSION

Two communities with the participation of *X. chiwensis* have been identified on the Ustyurt Plateau. A brief ecological-phytocoenotic characteristic of these coenopopulations (CP) is given below.

X. chiwensis occurs as a member of the *Artemisia–Salsola* community in the Karabaur region (43°06′44″ N, 56°40′11″ E). The soil of the described territory is sandy loamy, and there are outcrops of parent rocks in places. The first CP grows along a dry river, where *Salsola arbusculiformis, Artemisia diffusa,* and *Convolvulus fruticosus* are dominants and subdominants of the plant community. The projective cover is 20%. The botanical composition of the community is represented by 12 species of flowering plants. The second CP of the studied species is found in Shakhbakhty region, 5 km to the northeast of the wells, in the *Calligonum–Artemisia* community (42°37′51″ N, 56°01′94″ E). The soil of the described area is sandy loamy and the topography is level. The plant community is dominated by *Artemisia terrae-albae*. The projective cover is 25% and the portion of the studied species in it is 1%. The community consists of 11 species (Table 1).

The ontogenetic structure of two *X. chiwensis* CPs has been studied to assess their status in various habi-

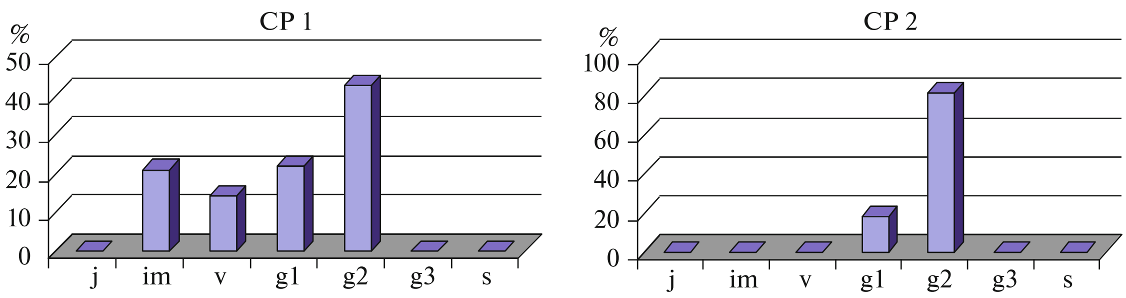

Fig. 2. Ontogenetic spectra of *Xylosalsola chiwensis* coenopopulations. j, Juvenile plants; im, immature plants; v, virginal plants; g1, young generative plants; g2, middle-aged generative plants; g3, old generative plants; s, senile plants.

tats. According to the classification by A.A. Uranov and O.V. Smirnova (1969), the studied coenopopulations of *X. chiwensis* are normal, but incomplete. Only juvenile plants are absent among pregenerative ones in CP 1, and other pregenerative representatives are present. CP 2 is characterized by the complete absence of pregenerative plants. Old generative and senile plants are absent in both CPs. The total number of representatives of the species is 18 in CP 1 and 12 in CP 2. The mean density of the plants is low: the occurrence of the species is 1.0 plants/m^2 in CP 1 and 0.6 plants/m^2 in CP 2. The absence of the pregenerative fraction in CP 2 is related to environmental conditions (arid climate, strong wind, and soil salinization). Irregular seed renewal of the species is another factor that determines the absence of the young fraction of its representatives during the survey period. Both studied CPs are characterized by the same centered type of ontogenetic spectrum (Fig. 2). The accumulation of middle-aged generative plants in the CPs is explained by long-term development and the smallest elimination of representatives of this ontogenetic group. According to our observations, *X. chiwensis* is characterized by poor seed reproduction and a long-term middle-aged generative stage. This biological status indicates that the centered spectrum is typical for this type of CP. The ontogenetic spectra of both CPs coincide with the typical one.

The age spectrum and the efficiency of the *X. chiwensis* coenopopulation were evaluated to identify the types of CPs. Based on the delta–omega parameter, the first CP of *X. chiwensis* is evaluated as maturing ($\Delta = 0.30$; $\omega = 0.71$), and the second one is mature ($\Delta = 0.42$; $\omega = 0.92$).

We also identified two CPs of *S. bungei*. A brief ecological-phytocoenotic characteristic of these CPs is given below.

The first CP is identified in the Aktumsuk region as part of the *Salsola-Artemisia* community (44°14′50″ N, 58°16′14″ E). The soil of the described site is sandy loamy. The projective cover is 15%. The floristic composition of the community includes 18 species of vascular plants, where *Salsola arbusculiformis* and *Artemisia terrae-albae* predominate. The subdominants are represented by *Anabasis brachiata*. The second CP is revealed in the Zhiidelibulak region in the *Atraphaxis–Salsola–Artemisia* community (44°96′30″ N, 58°23′00″ E). The soil here is also sandy loamy. The total projective cover is significantly higher as compared to CP 1: 30%. There are 13 species in this community. The grass layer is dominated by *Artemisia terrae-albae, Salsola arbusculiformis,* and *Atraphaxis spinosa*. The studied species occurs as a member of both communities (Table 2).

According to the classification by A.A. Uranov and O.V. Smirnova (1969), the studied coenopopulation of *S. bungei* is normal, but not complete. There are no juvenile and senile plants in CP 1. The total number of the species representatives is 16 in CP 1 and 22 in CP 2. The mean density is 0.8 plants/m^2 in CP 1 and 1.1 plants/m^2 in CP 2. Taking into account the specific features of the species biology (poor seed germination, rapid transition to flowering, and slow rates of development of plants at the middle-age generative stage), it may be concluded that the centered spectrum type with a peak on middle-aged generative plants is typical for the coenopopulations of this species. The absence of juvenile representatives in the ontogenetic spectrum of CP 1 is related to the fact that it is dominated by plants of vegetative origin and is formed on a slope, where the young fraction of plants of seed origin is eliminated by spring flows. The ontogenetic spectrum of the studied CP coincides with the typical one: it is centered with an absolute maximum of plants of the middle-aged generative stage. The portion of plants of this age group in the CP is 37.5% (Fig. 3). The domination of mature generative representatives in the coenopopulation is determined, on the one hand, by a gradual increase in the lifespan of plants of this ontogenetic status, and on the other hand, by a strong elimination of juvenile and immature representatives due to insufficient moisture.

The study of the ontogenetic structure of CP 2 shows that its spectrum is left-sided and does not coincide with the typical one. A high portion of virginal representatives (36.36%) in some coenopopulations is related to good seed regeneration and to a longer life period of this ontogenetic status in drier habi-

Table 1. The characteristics of plant communities with the participation of the analyzed populations of *Xylosalsola chiwensis*

No.	Plant species	Life form	Projective cover of species, %	
			CP 1	CP 2
1	*Haloxylon ammodendron* (C.A. Mey.) Bunge ex Fenzl	Tree	–	1
2	*Salsola arbusculiformis* Drobow	Shrub	8	+
3	*Convolvulus fruticosus* Pall.	Shrub	4	–
4	*Astragalus ammodendron* Bunge	Shrub	1	–
5	*Calligonum leucocladum* (Schrenk) Bunge	Shrub	–	3
6	*Xylosalsola chiwensis* (Popov) Akhani & Roalson	Semishrub	+	1
7	*Haplophyllum obtusifolium* (Ledeb. ex Eichw.) Ledeb.	Semishrub	+	–
8	*Artemisia diffusa* Krasch. ex Poljakov	Dwarf semishrub	5	–
9	*Artemisia terrae-albae* Krasch.	Dwarf semishrub	–	20
10	*Limonium suffruticosum* (L.) Kuntze	Perennial	1	–
11	*Zosima absinthiifolia* (Vent.) Link	Perennial	+	–
12	*Onosma staminea* Ledeb.	Perennial	+	–
13	*Eremopyrum orientale* (L.) Jaub. & Spach	Perennial	+	–
14	*Leontice inserta* Pall.	Perennial	+	–
15	*Anabasis brachiata* Fisch. & C.A. Mey. ex Kar. & Kir.	Perennial	–	+
16	*Stipa caucasica* Schmalh.	Perennial	–	+
17	*Euphorbia sclerocyathium* Korovin & Popov	Perennial	–	+
18	*Eremopyrum bonaepartis* (Spreng.) Nevski	Annual	–	+
19	*Ranunculus falcatus* L.	Annual	+	+
20	*Ceratocarpus arenarius* L.	Annual	–	+

tats. These coenopopulations are characterized by a gradual increase in the portion of a particular ontogenetic group compared to the previous one. This is explained by the greater duration of subsequent states of plants and a decrease in the number of dying representatives. The sharp decrease in the number of immature plants is related to their death due to trampling by small cattle. Low parameters in the ontogenetic spec-

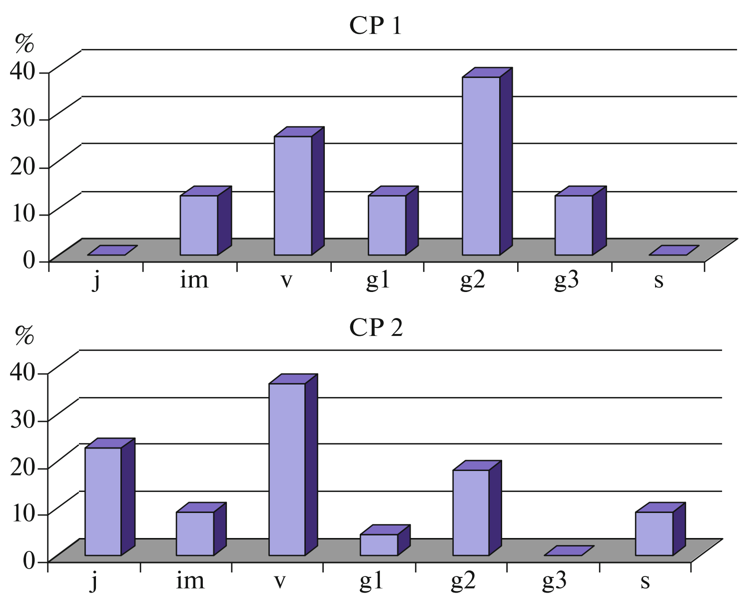

Fig. 3. The centered (CP 1) and left-sided (CP 2) ontogenetic spectrum of *Scorzonera bungei*. Designations are given in Fig. 2.

Table 2. The characteristics of plant communities with the participation of the studied coenopopulations of *Scorzonera bungei*

No.	Plant species	Life form	Projective cover of species, %	
			CP 1	CP 2
1	*Haloxylon persicum* Bunge	Tree	+	–
2	*Salsola arbusculiformis* Drobow	Shrub	4	8
3	*Nitraria sibirica* Pall.	Shrub	1	–
4	*Atraphaxis spinosa* L.	Shrub	–	5
5	*Artemisia terrae-albae* Krasch.	Semishrub	6	10
6	*Krascheninnikovia ceratoides* (L.) Gueldenst.	Semishrub	1	–
7	*Anabasis salsa* (Ledeb.) Benth. ex Volkens	Semishrub	+	3
8	*A. brachiata* Fisch. & C.A. Mey. ex Kar. & Kir.	Perennial	2	–
9	*Astragalus erioceras* Fisch. & C.A. Mey. ex Ledeb.	Perennial	–	+
10	*Zygophyllum turcomanicum* Fisch. ex Boiss.	Perennial	+	–
11	*Scorzonera bungei* Krasch. & Lipsch.	Perennial	+	+
12	*Haplophyllum obtusifolium* (Ledeb. ex Eichw.) Ledeb.	Perennial	+	–
13	*Lagochilus acutilobus* (Ledeb.) Fisch. & C.A. Mey.	Perennial	+	1
14	*Rheum tataricum* L.f.	Perennial	+	–
15	*Ferula caspica* M. Bieb.	Perennial	+	–
16	*Poa bulbosa* L.	Perennial	–	+
17	*Allium sabulosum* Steven ex Bunge	Perennial	–	+
18	*Onosma staminea* Ledeb.	Perennial	–	+
19	*Zosima absinthiifolia* (Vent.) Link	Perennial	–	+
20	*Eremopyrum orientale* (L.) Jaub. & Spach	Annual	+	1
21	*Ceratocarpus arenarius* L.	Annual	+	–
22	*Climacoptera lanata* (Pall.) Botsch.	Annual	+	–
23	*Arnebia decumbens* (Vent.) Coss. & Kralik	Annual	+	+
24	*Strigosella africana* (L.) Botsch.	Annual	+	–

trum of senile individuals are one of the biological features of this species (Fig. 3).

The age status (Δ) and the efficiency (ω) of the *S. bungei* coenopopulation were evaluated to identify the types of coenopopulations: CPU 1 is assigned to the maturing type (Δ = 0.34; ω = 0.69), and CPU 2 is of the young type (Δ = 0.24; ω = 0.41).

CONCLUSIONS

The current status of coenopopulations of two rare species of Uzbekistan, *X. chiwensis* and *S. bungei,* on the Ustyurt Plateau is evaluated on the basis of their structure. The studied coenopopulations of *X. chiwensis* are normal, but incomplete, due to the lack of a fraction of young plants. This is evidenced by the types of coenopopulations, which are evaluated as maturing and mature. The basic ontogenetic spectrum is centered with a peak on middle-aged generative plants and coincides with the typical one. The similarity of biological features in real ontogenetic spectra with the typical spectrum indicates the stable status of the studied coenopopulations of *X. chiwensis* in the Karakalpak part of the Ustyurt.

The studied coenopopulations of *S. bungei* are normal and incomplete and there are no juvenile and senile plants. The ontogenetic spectrum of CP 1 coincides with the typical one. It is centered with an absolute maximum for plants of the middle-age generative status. This is related to the gradual increase in the lifespan of plants at the generative stage and to the elimination of individuals at the juvenile stage. The ontogenetic spectrum of CP 2 is of the left-sided type with an absolute maximum for individuals of virginal groups. Its ontogenetic spectrum does not coincide with the typical one. *S. bungei* is characterized by seed and vegetative self-maintenance of coenopopulations and a long period of the middle-aged generative state. These biological features indicate that the centered spectrum of coenopopulations is typical for it. These species should be protected during the development of free-range animal husbandry and the planning of linear infrastructures. The results of this work will be used in the next editions of the Red Data Book of the Republic of Uzbekistan.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest. The authors declare that they have no conflicts of interest.

Statement on the welfare of animals. This article does not contain any studies involving animals performed by any of the authors.

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