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Calligonum zakirovii (Polygonaceae), A NATIVE SPECIES IN UZBEKISTAN: POPULATION, HABITATS, AND THREATS

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Abstract

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One of the central issues in conservation today is identifying areas rich in biodiversity for priority conservation. The local population structure of endangered species is one of the main criteria for assessing their state in their habitats. The range of the genus *Calligonum* L. is Holarctic, ancient Mediterranean, continuous. *Calligonum* L. (Polygonaceae) is an ancient genus in the arid desert flora, and Central Asia is the place of its origin. *Calligonum* is distributed from southern Europe through northern Africa to central Asia, and is typically found in arid, desert regions. Some species migrated to the Middle Asia and Iran, developing into a second center there. There are 41 (80) species of *Calligonum* L. worldwide, 29 of which are in Uzbekistan. They play a key role in the stability of desert and gravelly desert ecosystem of Uzbekistan. *Calligonum zakirovii* (Khalk.) Czerep. is classified as 1 category, threatened species, in the Red Data Book of the Republic of Uzbekistan. During the research, three local populations of the species were studied. The number of individuals in 1 m^2 area is 0.85-1.25, and the ecological density is 0.94-1.66. Therefore, inventory of regional floras as well as single species and their populations is highly important and necessary.

Key words: *Calligonum zakirovii,* desert, Kyzylkum, conservation, endemic, population structure.

Introduction

Conservation of biological diversity of plants is a global task of preserving the human habitat. The strategy for the conservation of rare and endangered plants should be based on the identification of regularities in the existence of species in natural populations (Kupriyanov et al., 2019; Abduraimov et al., 2023a). The long-term objective of the Global Strategy for Plant Conservation is to halt the current and continuing loss of plant diversity (CBD, 2003). Improve long-term conservation, management and restoration of plant diversity, plant communities, and the associated habitats and ecosystems, *in situ* (both in more natural and in more managed environments), and, where necessary to complement *in situ* measures, *ex situ*, preferably in the country of origin (Fan et al., 2016). The climate forecast for Uzbekistan includes a 5%–10% decrease in mean annual precipitation and a 3.5 °C increase in mean temperature by the end of this century (Abduraimov et al., 2023b; Mitchell et al., 2017). Preservation of biological variety is an urgent problem of the present scenario, which should be solved first at the regional level, since the state of ecosystems and biosphere of earth depends on the environmental stability of regions (Zanina, Smirnova, 2020).

The genus *Calligonum* L. is a typical representative of the xerophytic flora of the deserts of the ancient Mediterranean. Species of the genus *Calligonum* L. – *juzgun* and the shrub–grass ecosystems formed by it are of fundamental importance in the ecology and economy of the arid regions of Central Asia (Borodina et al., 1989). In the genus *Calligonum*, since the publication of C. Linnaeus' work "Species Plantarum" (Linnaeus, 1753), four sections, 174 species, 42 varieties, and 4 forms have been described. There are at least 158 (161) accepted species names ascribed to *Calligonum* (Alaklabi, 2022; Taia, El-Etaby, 2006), but, of these, only ca. 40–85 may represent entities meriting species status (Sanchez et al., 2011; Soskov, 2011; Liu et al., 2021). Giant polymorphism and interspecific hybridization complicate the establishment of the volume and boundaries of its species. When starting to study a complex genus such as *Calligonum*, we naturally could not ignore the question of the volume and boundaries of the species, especially since botanists do not have a single point of view on this issue. It is characteristic that Popov (1925) called this genus, due to its dispersion into small systematic units, the true "botanicorum crux et scandalum" of Central Asia (Plant resources of the USSR, 1985; Bannour et al., 2016).

There is no alternative to *juzgun* species as irreplaceable sand

strengtheners. On dune sands, *Calligonum* develops powerful, branched, deeply penetrating root systems, occupying a large volume of soil (Purohit, Kumar, 2020). These natural fundamental multifunctional ecological functions and economically valuable properties of species of the genus *Calligonum* play an important role in the sustainable functioning of the biosphere and agrosphere.

Calligonum is the only C_4 genus within Polygonaceae (Liu et al., 2021). The species of *Calligonum* are mainly shrubs or subshrubs, much branched with woody branches without spines and herbaceous branchlets of the current year with leaves and flowers (Sabirhazi, Borong, 2009). The leaves are simple, opposite, nearly sessile, linear or scale-like, united with ocrea at the base or free (Bao, Grabovskaya-Borodina, 2003). Many *Calligonum* species are the dominant species in desert vegetation, where they typically have reduced (or absent) leaves, and the young branches are the chief organs for photosynthesis (Liu, 1985; Song et al., 2020).

Many authors pay special attention to the structural and functional features of plant species and their populations near the range margin (Abramova et al., 2014; Ilyina et al., 2021). A targeted study of plant populations helps to identify factors limiting the natural succession of plant populations and to propose appropriate conservation measures (Ilyina et al., 2022; Saribaeva et al., 2022a).

Many studies have been carried out about populations and the current status and conservation of rare and endangered species worldwide (Corlett, 2016; Clubbe et al., 2020; Dai et al., 2022; Julien et al., 2021; Hamilton et al., 2021; Gudzinskas, Taura, 2021; Barrios et al., 2021; Yang et al., 2022) and in Central Asian countries (Sennikov, Turdiboev, 2022; Usmonov et al., 2021; Khamraeva et al., 2023).

In recent years, several studies on the population of plants have been conducted in Uzbekistan (Abduraimov et al., 2022; Beshko et al., 2023; Saribaeva et al., 2022b; Rakhimova et al., 2020; Shomurodov et al., 2021). In these studies, the current status of many rare, endemic, and endangered species has been assessed.

Material and methods

The ontogenetic state and vitality were determined using a method developed for woody plants (Diagnoses and keys of …, 1989). Shrubs – the main trunk is present only at the beginning of the plant's life, and then it is lost among its equal or stronger aboveground skeletal axes of several orders, arising sequentially from dormant buds at the base of the maternal axes; with age, the main trunk completely dies off.

To determine the ontogenetic status of the species, we used herbarium samples collected during the field studies and the results of previous studies on this species (Rabotnov, 1950). Ontogenetic spectrum of the cenopopulations (henceforth CPs) was determined as the ratio of plants of different ontogenetic status, expressed as a percentage of the overall number of individuals (Smirnova et al., 1976, 2001; Mirkin et al., 2001). We

Fig. 1. *Calligonum zakirovii*. A – General appearance; B – fruiting; C, D – ripe fruits.

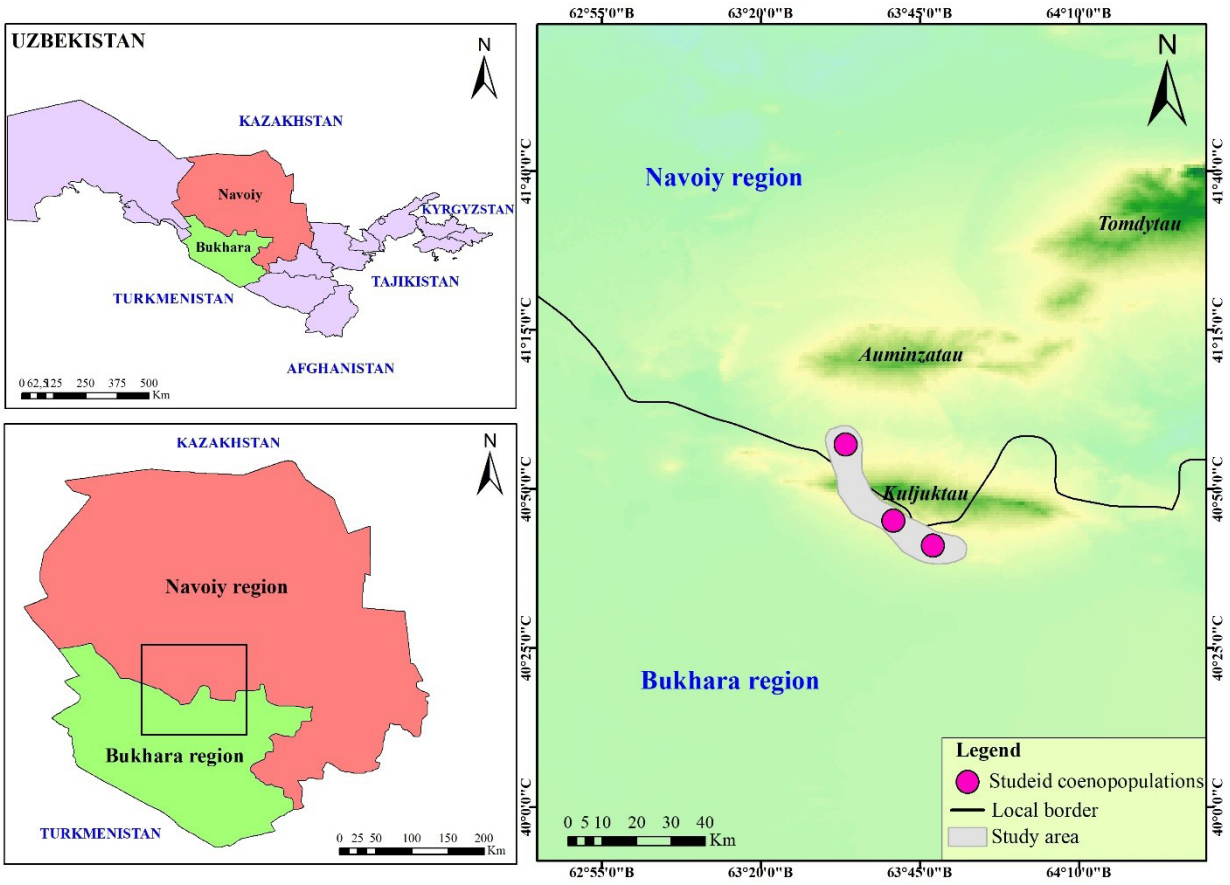

Fig. 2. Geographic range and distribution map of *Calligonum zakirovii* in Kyzylkum desert (Uzbekistan).

characterized the population structure based on the knowledge of the characteristic ontogenetic spectrum (Zaugolnova, 1994). According to the pattern of distribution of ontogenetic groups, four types of the spectrum are distinguished: left sided, centered, right sided, and bimodal. The characteristic spectrum depends on biological specifics of the species.

Characteristic type of CP range was determined according to Zaugolnova (1994). To characterize CPs, we used demographic parameters of indices of age and efficiency (Uranov, 1975; Zhivotovsky, 2001). They were analyzed in Delta-Omega software, kindly provided by Zhivotovsky (2001). The type of CP was determined according to Delta-Omega classification of Zhivotovsky (2001). Delta (Δ) is the age index (Uranov, 1975) that is used to evaluate the age level of a CP at each moment of time, and omega (ω) reflects the efficiency of plant of i-genetic condition (value of "pressure" on energy resources of the environment, expressed in shares of pressure imposed by plants of middle-age genera). According to the classification data, a CP may be young, mature, intermediate, aging, and old. Density of populations was determined by the number of individuals per unit area (Uranov, Smirnova, 1969; Smirnova et al., 1976). Counts were carried out on temporary sample plots of 10 × 10 m. The number of sample plots in the community was selected based on the degree of its horizontal heterogeneity and the need to take into account individuals of all ontogenetic groups represented in the community. At the same time, special attention was paid to the parameters of average density, that is, the number of individuals per unit of space (overall space), and ecological density – number per unit of inhabited space, which can be practically taken by a population (Odum, 1986).

Calligonum zakirovii (Khalk.) F.O. Khass. is classified as 1 category, threatened species, in the Red Data Book of the Republic of Uzbekistan (Fig. 1). It is included in The International Union for Conservation of Nature (IUCN) Redlist [B1ab (i, ii, iii, iv, v) + B2ab (i, ii, iii, iv, v)] (Fenu et al., 2023). This species was described by Khalkuziev, 1966 years (Khalkuziev, 1990) as *Calliphysa zakirovii* from southwestern Kyzylkum on the southern part of Kuldzhuktau mountains (Fig. 1), near the village of Churuk. Later, when dealing with the vascular plants of Russia and neighboring countries, Cherepanov (1995) renamed it as *C. zakirovii* (Fenu et al., 2023).

Study area

The basis for the development of measures for the protection and conservation of rare species is the assessment of their condition in modern plant communities at the population level (Egorova, Suleimanov, 2021). The observations were performed here in 2012–2023, and the main parameters of the age and structure of *C. zakirovii* (Khalk.) Czerep. populations were revealed for the

A B

Fig. 3. General aspects of the studied habitats. A – Kuldjuktau; B – Auminzatau.

first time. Our research was conducted in South-western Kyzylkum region. There are two remnant mountains (Kuldjuktau and Auminzatau) in this area (Fig. 2).

Kuldjuktau is the southernmost ridge of the Paleozoic hills of Kyzylkum. Kuljuktau is located on the territory of the Navoi and Bukhara regions of the republic. Its length is about 100 km, width is up to 15 km, and height is up to 785.6 m above sea level (Koshoshik – northwestern part of the ridge). In the northern and western parts of the mountain are Guzhumtau and Beltau, which together form the Kuldjuktau mountain system. The southern slopes of the mountains are gentle, dissected by dry canyons, while the northern slopes are rocky and steep. They are composed mainly of crystalline shales and limestones; along the margins there are Jurassic, Cretaceous, and Paleogene sedimentary strata and on the surface, there are blown sands in places.

Auminzatau – (Navoi region) are remnant mountains of relatively low height with smooth relief. Large rocky and gravelly slopes occupy a small area, stretching in a narrow strip in the southern part of the mountains. Its length is 62 km, width is up to 14 km, and the highest point (694.9 m, Auminzatau) is marked in the central part of the mountains. The western part of Auminzatau ends with its division into two mountains – Saryktau and Shokytau (Fig. 3).

Green-flowered wintergreen populations were studied. A bush part (ramet) was set as a counting unit. In total, nine subpopulations were surveyed, with 630 individuals registered. The age structure of populations was characterized using common demographic indicators: the recovery index and the population age index. The age structure of the population was associated with the efficiency of both seed reproduction. Generally, the share of pre-generative individuals was 34.3, generative individuals was 62.9, and senile individuals was 3.8%. The studied populations were stable due to low anthropogenic impact at the growth sites. Affected by livestock, their populations are damaged.

Results

C. zakirovii (Khalk.) Czerep. is one of the endemic species with a short range in Uzbekistan. It is distributed in the foothills of Kuljuktog and Auminzatog of Bukhara and Navoi regions. It is a 70–150 cm tall, slightly crooked branched bush. The flowers are white. As the safflower bears fruit, it bends downward. The fruit is almost spherical and 10–12 mm wide. It blooms in April–May and bears fruit in May–June. During the field research, two CPs were distinguished in the presence of the species. It should be noted that *C. zakirovii* dominates the phytocenosis, where three CPs of the species are distributed.

The initial CP was studied from the southern foothills of Kuljuktau, on the southern side of the Gujumli–Qoraqir (Kyzykum desert station 10 km) road (N 40O, 44 51 E 63O4010). CP is distributed partly in depressions, around areas where water accumulates after heavy rains, which are rarely observed in spring months, as well as on the slopes and tops of residual hills, the height of which does not exceed 4–5 m. The main vegetation of this area consists of wormwood (*Artemisia diffusa, A. turanica*). But there are also other plant communities in the form of small spots.

A clear example of this, as we noted above, is the community with the participation of zakirov sugar and white paint, or in highly exposed areas, it is possible to show jamalos consisting of 1-year sorghums (*Ceratocarpus arenarius* is dominant). CP of *C. zakirovii* is found in the mentioned area as part of the dye–sugar plant community. This community is distributed in gypsum soils covered with a thin layer of sand typical for Kyzylkum plains. The degree of soil coverage by plants is 18%. The percentage of the studied species was observed to be around 8%. The botanical composition consists of 24 tall plants.

CP grows on a pasture used by the local people in all seasons of the year. A large herd of shepherds is located 1–2 km west of the area where the CP is being studied. The vegetation of this area is in crisis not only because of trampling by cattle, but also because of cutting down of shrubs and bushes for firewood by shepherds.

The second CP was isolated from the southern slopes of Kuljuktau along the Churuq–Jongeldi road (40O,43 27 E 63 42 13). The CP grows in the ephemeral–mixed shrub community. The degree of soil coverage by plants is 22%, and the share of species is 10%. The floristic composition is quite rich; 34 species were registered. Two of them are shrubs, semi-shrubs, and semi-shrubs, eight are perennials, and 22 are annual grasses.

Table 1. Plants occurring in community of *Calligonum zakirovii*.

No.	Species name	Life form	Coverage rate, %		
			CP 1	CP 2	CP 3
1	*Calligonum zakirovii* (Khalk.) F.O. Khass.	Shrub	8	10	6
2	*Astragalus villosissimus* Bunge	Shrub	1	4	1
3	*Salsola arbuscula* Pall.	Semi-shrub	3	5	1
4	*Artemisia diffusa* Krasch. ex Poljakov	Sub-shrub	1	1	3
5	*Artemisia turanica* Krasch.	Sub-shrub	1	-	1
6	*Convolvulus hamadae* (Vved.) Petrov	Perennial	3	1	+
7	*Carex physodes* M. Bieb.	Perennial	1	1	3
8	*Poa bulbosa* L.	Perennial	+	+	1
9	*Eremurus korolkowii* Regel	Perennial	-	+	-
10	*Ferula foetida* (Bunge) Regel	Perennial	+	-	+
11	*Tulipa lehmanniana* Merkl	Perennial	-	+	+
12	*Acanthophyllum pungens* (Bunge) Boiss.	Perennial	-	+	-
13	*Peganum harmala* L.	Perennial	+	+	+
14	*Leontice incerta* Pall.	Perennial	-	+	-
15	*Salsola sclerantha* C.A. Mey.	Annual	+	+	+
16	*Salsola pestifer* A. Nelson	Annual	+	-	-
17	*Ziziphora tenior* L.	Annual	-	+	+
18	*Erodium cicutarium* (L.) L'Hér.	Annual	+	+	+
19	*Koelpinia linearis* Pall.	Annual	+	+	+
20	*Astragalus campylorhynchus* Fisch. et C.A. Mey.	Annual	-	+	-
21	*Astragalus bakaliensis* Bunge	Annual	-	+	-
22	*Amberboa turanica* Iljin	Annual	-	+	
23	*Eremopyrum bonaepartis* (Spreng.) Nevski	Annual	+	+	+
24	*Consolida camptocarpa* (Fisch.&C.A. Mey) Nevski	Annual	+	-	+
25	*Hypecoum parviflorum* Kar.&Kir.	Annual	+	+	+
26	*Onobrychis tavernierifolia* Stocks ex Boiss.	Annual	-	+	-
27	*Senecio subdentatus* Ledeb.	Annual	+	-	-
28	*Euphorbia turczaninowii* Kar.et Kir.	Annual	+	+	+
29	*Epilasia hemilasia* (Bunge) C.B. Clarke	Annual	+	+	+
30	*Arnebia decumbens* (Vent.) Coss.&Kralik	Annual	+	+	+
31	*Lallemantia royleana* (Benth.) Benth.	Annual	-	+	+
32	*Nonea caspica* (Willd.) G. Don	Annual	+	+	+
33	*Ceratocarpus arenarius* L.	Annual	+	+	+
34	*Anisantha tectorum* L.	Annual	-	+	+
35	*Alyssum desertorum* Stapf	Annual	-	+	+
36	*Climacoptera lanata* (Pall.) Botsch.	Annual	+	+	+
37	*Roemeria refracta* (Stev.) DC.	Annual	-	+	-
38	*Holosteum polygonum* C. Koch	Annual	-	+	-
39	*Strigosella africana* (L.) Botsch.	Annual	-	-	+
40	*Ceratocephala testiculata* (Crantz) Bess.	Annual	-	-	+
41	*Goldbachia laevigata* (Bieb.) DC.	Annual	+	+	+

Note: CP – cenopopulations.

The third CP was isolated from the foothills of Auminzatog, near the village of Chontiboy. The vegetation community of the area consists of a variety of herbaceous and sedges. The botanical composition consists of 30 tall plants. The degree of soil coverage by plants is 25%, and the share of species is up to 6%. This CP is located a little far from the other two CPs.

The analysis of the species composition of phytocoenoses in which the xenopopulation is distributed shows that 19 of the total 41 species are found in all three plant communities. Especially, the presence of *Astragalus villosissimus, Salsola arbuscula, Artemisia diffusa, Convolvulus hamadae,* and *Carex physodes*, which are considered dominant in desert communities, in both communities indicates that phytocenoses grow in ecologically close conditions (gypsum soils covered with thin layers of sand). Annual plants in the studied communities are not permanent (Table 1).

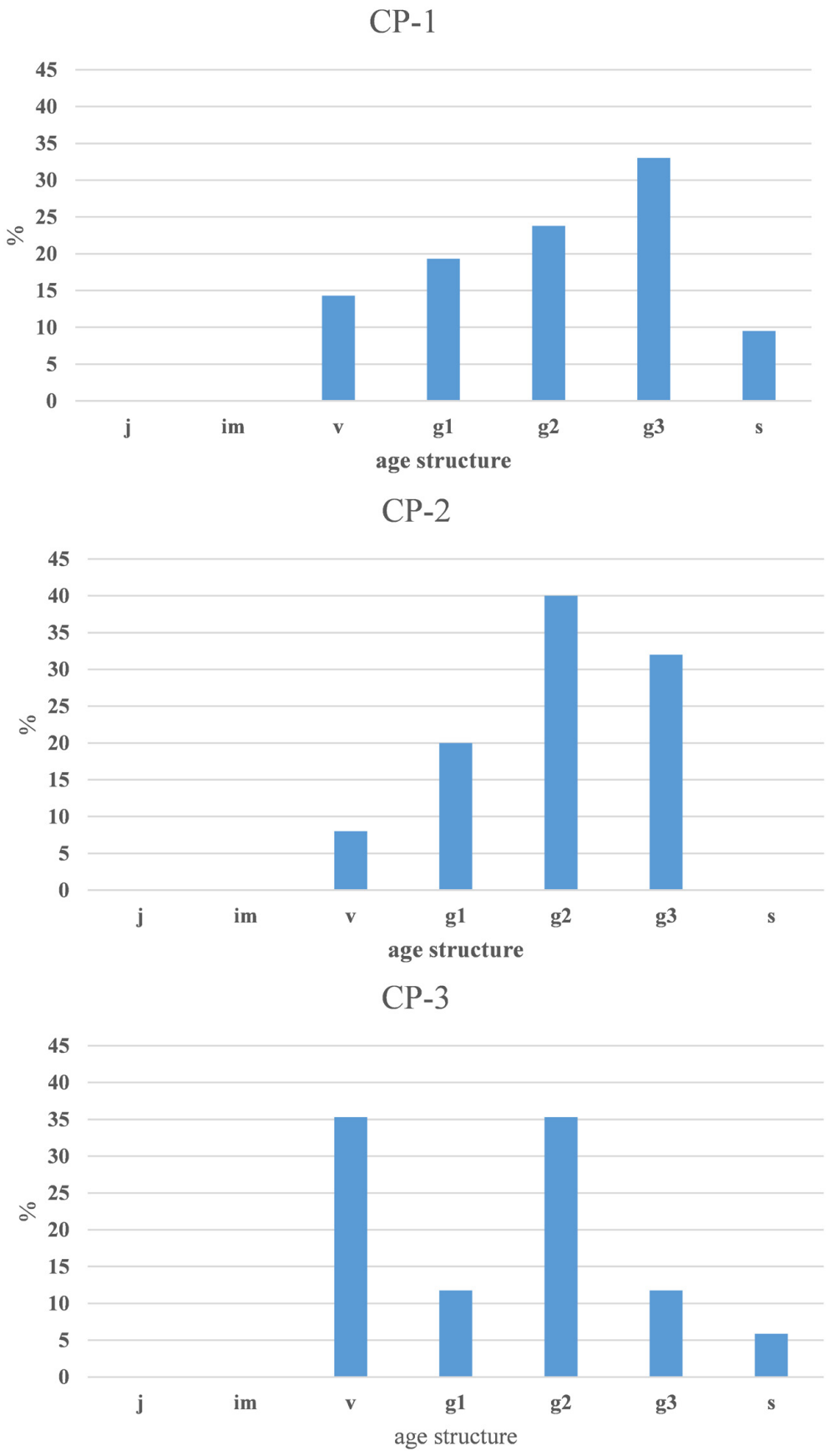

Fig. 4. Ontogenetic structure coenopopulations of *Calligonum zakirovii.*

Table 2. Demographic indicators of cenopopulations.

No. CP	Demographic indicators			I_r	I_p	I_{io}	I_e	Type of CP
	Total number of individuals	The number of individuals in 1 m^2 area	P_{ecol}, 1 m^2					
1	21	1.05	1.31	0.18	0.10	0.84	15.12	Mature
2	25	1.25	1.66	0.08	0	0.92	19.25	Mature
3	17	0.85	0.94	0.60	0.06	0.62	10.03	Transient

Notes: P_{ecol} – ecological density; I_r - recovery index; I_p - progress index; I_e - efficiency index; I_{io} - individual optimum index.

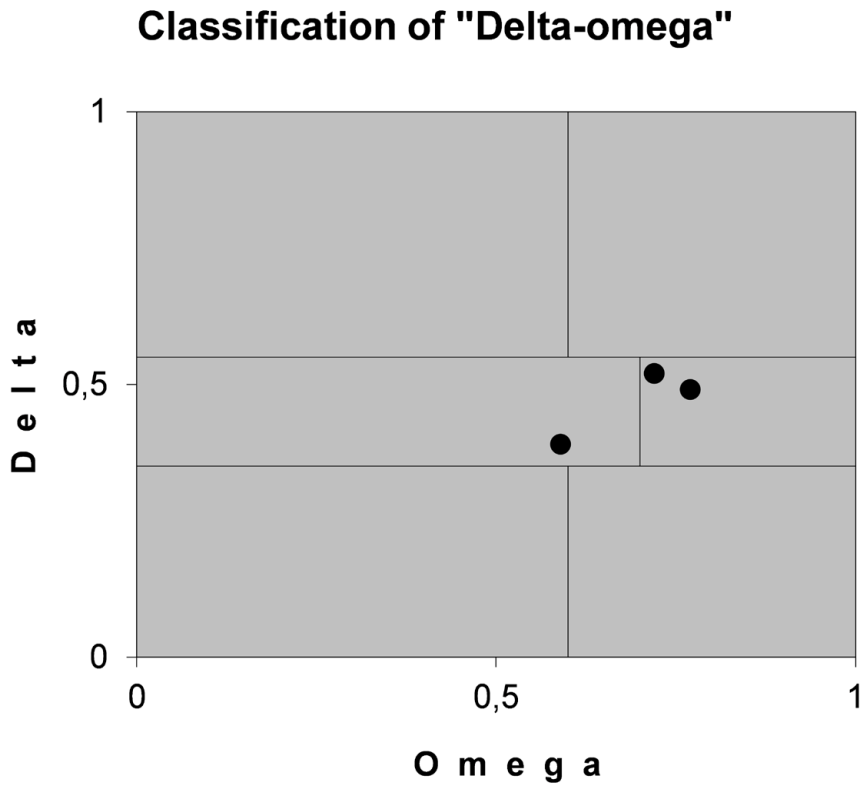

Fig. 5. Type coenopopulations of C*alligonum zakirovii*.

Discussion

Until now, there have been no studies on the ontogenetic structure of the species and their demographic indicators. During the research, the demographic status of two CPs of the species was studied in south-western Kyzylkum (in the southern foothills of Kuljuktau). Uranov and Smirnova according to the classification of (1969), the studied CPs were observed to be normal and completely limbless. The characteristics of the species are as follows: self-regeneration of xenopopulations by means of seeds, short duration of the pre-generative stages compared to the generative stages and long duration of the middle generative stage compared to the remaining stages, and most of the bushes do not reach the senile stage. These cases indicate that the characteristic spectrum for the species is centered.

The ontogenetic spectrum of studied CPs of *Calligonum zakirovii* is typical of two types: right sided (CP 1) and centered (CP 2). In the first CP, it was noted that the percentage of old generative trees has a high rate. The share of g3 age bushes was about 30.0%. It should be noted that this tenopopulation is distributed in the plains on the left side of the Churuq–Jongeldi road, and these areas correspond to the pastures that have been used by shepherds for a long time. A herd of shepherds is located 2–2.5 km west of this CP of *C. zakirovii*, and this is the main factor that negatively affects the state of the plant population. For almost a year, the shepherds chop down the large bushes of the plant (mostly g1 and g2 age bushes) as firewood. This, in turn, may have led to an increase in the proportion of old generative trees in CP (Fig. 4).

In the second CP, the absolute maximum indicator corresponds to the share of bushes of middle generative age (40%). In both CPs, no meeting of juvenile and immature stages was observed. This situation is related to the unevenness of seed reproduction and unfavorable weather conditions for their germination. In general, low seed germination is characteristic of

all types of sugarcane. Only in years of abundant precipitation (especially more winter precipitation) do seeds undergo natural scarification and germination increases. In practice, sugarcane seeds are left in running water for 1–2 days before planting, and this increases the germination of the seeds. The third CP is characterized by a bimodal spectrum, and it was found that the percentage of virginal and mid-generative stage bushes is high. In this CP, there was no meeting of juvenile and mature trees. As mentioned above, the germination of *C. zakirovii* seeds is very low. Demographic indicators of the species were also analyzed during the research. According to this, recovery index, progress index, efficiency index, and individual optimum index were determined. The demographic indicators of CPs are as follows: the total number of individuals in the population ranges from 17 to 25. The density of individuals per square meter ranges from 0.85 to 1.25, while the ecological density ranges from 0.96 to 1.66. It was observed that the remaining indicators also correspond to the number of individuals in CPs (Table 2).

According to the delta-omega classification, it was determined that the noted CPs are of the transitional and established type (Fig. 5).

Conservation of Calligonum zakirovii (ex situ)

It is very important to preserve rare species in *ex situ* and *in situ* conditions. During the research, the seeds of the species were collected. Currently, these seeds are storedin the area of Kyzylkum desert station. This area is very close to the CPs of the species. Plant seeds are stored in special boxes (Fig. 6).

During the research, cattle grazing was also observed in this area. This, in turn, affects the state of populations and the density of bushes. In addition, it was observed that geological exploration works and road construction works have a negative impact on the condition of populations In this case, although the plants were not consumed by livestock, instances of their fruits falling off before reaching maturity were observed (Fig. 7).

Utilization

Most species of the genus *Calligonum* are distributed in the Kyzylkum region. Some species of *Calligonum*, such as *C. microcarpum* I.G. Borshch., *C. caput-medusae* Schrenk ex Fisch. & *C. leucocladum* (Schrenk) Bunge, *C. eriopodum* Bunge etc., are dominant species in deserts; this must be remembered when restoring desert ecosystems. According to different natural conditions, we should choose suitable plants for introduction from different vegetation types and pay attention to the character of genetic diversity of plants.

Conclusion

Arid regions represent about 40% of the global land area, in which environmental conditions are known to exert a strong

Fig. 6. Sorting of seeds in laboratory conditions. A – seeds collected from CP 1; B – seeds collected from CP 2; C – seeds collected from CP 3; D – seeds stored in special boxes.

A B

Fig. 7. Factors affecting populations. A – livestock grazing; B – livestock grazing and road construction.

influence on organisms to the extent of hindering their growth and development. To overcome desertification in these habitats, shrubs that are able to survive in such conditions can be used to restore vegetation as they create more mesic spots for other understory plants. Such plants are termed as nurse plants, and the phenomenon that is represented by plant–plant positive interactions is called plant facilitation.

In conclusion, *C. zakirovii* CPs are normal. The ontogenetic spectrum of the species differs due to various ecological–phytocenotic conditions and certain levels of anthropogenic factors.

The ontogenetic spectra of *C. zakirovii* CPs are normal and not full membered (there are no young individuals). Two out of three CPs of the species do not coincide with the theoretically established (centered) ontogenetic spectrum characteristic of monocentric biomorphs and do not reflect the biological characteristics of the species.

The protection of rare species is impossible without knowledge of their bioecological characteristics. In this regard, population-age methods are relevant and serve as the basis for assessing the current state of vulnerable plant species populations. These populations are studied as a part of the monitoring of rare species included in the Red Data.

Monitoring populations of rare species allows determining trends in their development and proposing measures for their conservation. Protective measures should be based on studies of biology, environment, geography of the species in the region, state of the populations, and dynamics of age structure. It is necessary to create micro-reserves in these habitats, prohibiting business activities in them, and the recreational load should be controlled. It plays an important role in the productivity and stability of the desert environment.

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