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A Demographic Structure of Populations of *Salvia Lilacinocoerulea* Nevski, a Rare Species Endemic to the Western Pamir-Alay (Uzbekistan, Turkmenistan)

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Abstract

Salvia lilacinocoerulea Nevski (*Lamiaceae*) is an endemic to the Western Pamir-Alay mountain range. Usually it grows on eroded clay soils among sparse juniper forests in the middle mountain belt. Studied coenopopulations of *S. lilacinocoerulea* are normal, but are not complete. Coenopopulations self-maintenance is carried out by the seed of renewal. The characteristic spectrum of *S. lilacinocoerulea* coenopopulation is centered, with a peak in the middle-generative individuals. In most cases, specific developmental spectrum of coenopopulation does not coincide with the characteristic ones. The demography structure of mostly investigated coenopopulations is satisfactory. The population growing on the grey clay soil, on strongly eroded slope among sparse juniper woodland was evaluated as critical due to absence in ontogenetic spectrum young individuals and small percentage of generative plant as well.

Keywords

Salvia lilacinocoerulea, *Lamiaceae*, Western Pamir-Alay Mountain, Coenopopulation

1. Introduction

The genus *Salvia* L. is one of the largest member of the family *Lamiaceae*, comprising more than 700 species, many of them collected from the wild and a few of them cultivated [1]. In Central Asia this genus represented with 35 species [2].

Majority of species (23) occurring in the Central Asia are widespread in the Pamir-Alay mountain system; 14 of them are endemic to this region. Six species are endemics to the Tien Shan, and three species are endemic to the Kopetdag. Two species are common for Pamir-Alay and Tien Shan mountain systems. Four species (*Salvia aethiopis* L., *Salvia dumetorum* Andrz. ex Besser, *S. nemorosa* L., and *S. sclarea* L.) are widespread in Eurasia. In Uzbekistan, there are recorded 21 species of *Salvia*, and four of them are national endemics.

This work is devoted to the study of the demographic structure of cenotical populations (CP) of *Salvia lilacinocoerulea* Nevski, a species endemic to the Western Pamir-Alay included in the Red Data Book of Uzbekistan [3]. *S. lilacinocoerulea* is a perennial herbaceous plant 10 - 40 cm high (**Figure 1**) growing on red beds, stony slopes and eroded clay soils among sparse juniper forests in the middle mountain belt (**Figure 2**). It flowers in June-July, and bears fruits in July-August. The species is widespread in the southwestern spurs of the Hissar ridge (including Baysun and Kuhitang mountains) (**Figure 3**). The main part of its distribution area lies within the territory of Uzbekistan. Outside of Uzbekistan, *S. lilacinocoerulea* is found also in Turkmenistan on the western slope of Kuhitang ridge (*locus classicus*). Populations of *S. lilacinocoerulea* are considerably fragmented within its range.

Endemic plants with restricted and/or fragmented range often grow in stressful conditions. Their populations usually are characterized by unique internal organization, structure, morphology, and other biological features. Any anthropogenic impact (pollution, grazing, farming, recreation, etc.) exerts extremely negative influence on these populations, and can lead to their reduction or even

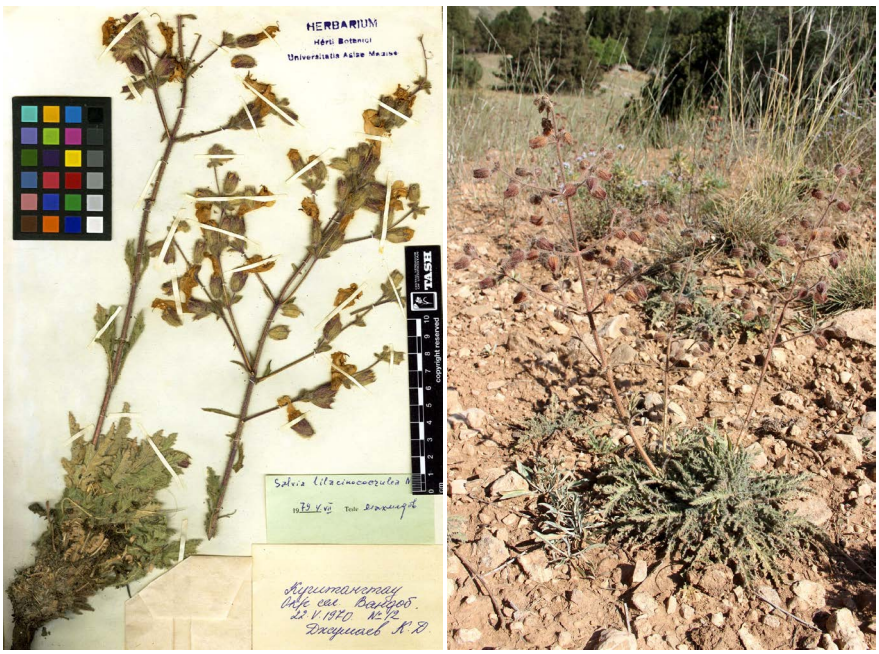


Figure 1. *Salvia lilacinocoerulea* Nevski. A representative mature specimen collected from the eastern slope of the Kuhitang ridge (22. V. 1970, Djumaev 12, TASH), and mature plants in the natural habitat (photograph by N.Yu. Beshko).

Figure 2. Typical habitat of *S. lilacinocoerulea.*Western spurs of the Hissar ridge, surroundings of the pass Tally. Photograph by N.Yu. Beshko.

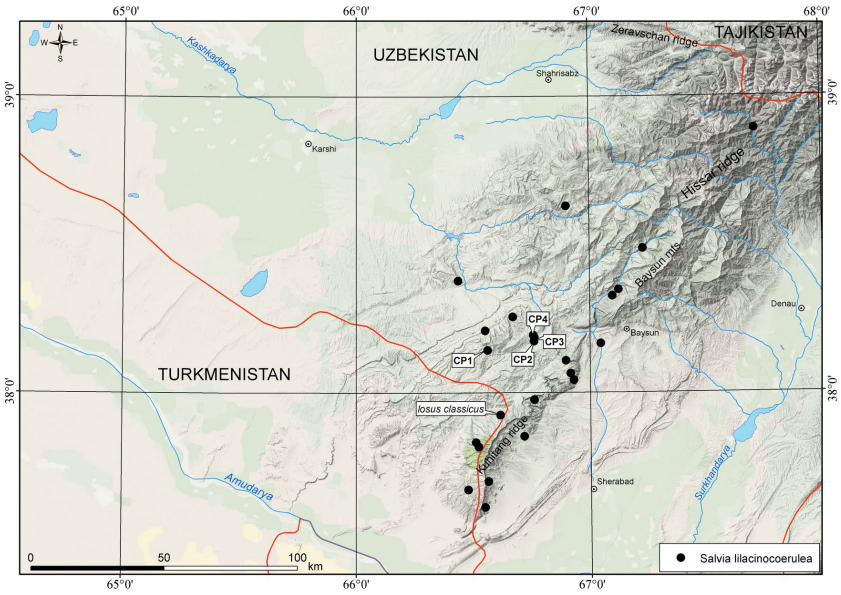


Figure 3. Distribution of *S. lilacinocoerulea* and localization of surveyed coenopopulations.

extinction. Considering these facts, we studied the structure of the coenotic populations of *Salvia lilacinocoerulea* within the framework of the project "Inventory of rare and endangered species of vascular plants and vertebrate animals of the Kashkadarya region of Uzbekistan". Knowledge on the biology of this species and the population structure are needed for prediction of population dynamics in particular habitats, for conservation and monitoring [4].

2. Materials and Methods

The area of research is situated in the western spurs of the Hissar ridge located

south of Guzar town and Dehkanabad village, on the left bank of the Kichik-Uradarya River and in Tarkapchigay river basin. This territory has been defined as the Tarkapchigay phytogeographical region of the Western Hissar district of the Central Asian Mountain Province [5]. There are several sub-latitudinal arid low ridges folded by red beds and gypsum with a very specific flora and gypsophilous vegetation. The southeastern boundary of the region runs along the left watershed of the Tarkapchigay basin, and the northern limit of this region is the Guzardarya River. The area ranges in elevation from 450 - 500 up to 2172 m above sea level. The peculiarity of landscapes of this region is the predominance of foothills and lowlands with rugged terrain, saline and plastered soils. Despite the arid conditions of these low mountains, vegetation is quite diverse. Foothills and the lower mountain belt are characterized by ephemeral-ephemeroid and sagebrush-ephemeroid communities, formations of halophytes and gypsophytes, fragments of xerophytic shrubs (*Amygdalus spinosissima* Bunge). Large areas are covered by rainfed crops and fallow lands with ruderal vegetation. Tall grass communities with domination of *Elymus hispidus* (*Elytrigia trichophora*) and sparse juniper woodlands are developed in the middle mountain belt.

The territory belongs to the temperate climatic zone. The climate is dry continental with long, hot and dry summer season; the winter season is short with mild frosts and little snow. The average annual temperature is 13˚C - 14˚C, the average temperature of January is 0˚C - 2˚C, average temperature of the July is 26˚C - 28˚C, the annual precipitation is 400 - 600 mm [6] [7].

Field research was performed during June 2016 by traditional phytosociological methods with description of plant associations, collection of herbarium and photographing of surveyed plots [8]. Demographic structure of populations was studied in accordance with T.A. Rabotnov [9], A.A. Uranov [10], L.A. Zhukova and E.V. Shestakova [11]. The age indexes were studied by A.A.Uranov [10]. The ontogenetic structure of coenopopulations in the different ecological and phytocenotical conditions was determined by the transect methods [12]. A total of 22 plots (10 × 10 m) were surveyed; habitat conditions (elevation, soil, disturbance, vegetation density and pattern, etc.) were recorded for each plot. All specimens of *S. lilacinocoerulea* were counted within the plot and categorized into stage classes. Gatsuk *et al.* [13] defined for trees, shrubs and perennial herbaceous plants 10 stage classes in 4 life stages: latent (seed-se), pre-reproductive (seedling-p, juvenile-j, immature-im, virginile-v), reproductive (young-g1, mature-g2, old-g3), and post-reproductive (subsenile-ss, senile-s). In our research, we used this classification of age stages widely applied in Russian botanical literature.

We assessed CP using "delta-omega" classification by L.A. Zhivotovskiy [14] based on the age index (Δ) [10] and efficiency index (ω) [14]. Standard statistical methods were used for data analysis: the mean value, its standard error, and coefficient of variation CV (%) were calculated.

Coordinates of studied cenopopulations were recorded using GPS. All herbarium specimens of *S. lilacinocoerules* stored in the Central Herbarium of Uzbe-

kistan (TASH) were studied and geo-referenced. Distribution map (Figure 3) was created by ArcGIS 10.0 software. A WGS84 geographic coordinate system was used as a reference datum.

3. Results and Discussion

All surveyed cenopopulations of *S. lilacinocoerulea* are situated in the middle mountain altitudinal belt; the vegetation type is juniper open woodland with tall grass cover. Coordinates and habitat details are described below (Table 1). The local people use this territory for pastures (mainly sheep farming); rainfed crops and gardens occupy relatively small plots in valleys and gentle slopes.

The first cenopopulation of *S. lilacinocoerulea* (CP 1) is situated near the watershed crest of the Kurukdagana ridge, approximately 1 km to the east of the pass Tally, at the altitude of 1619 m a.s.l., on the steep stony northern slope, in the juniper-sagebrush community. The canopy cover is about 42%. The floristic composition of community contains 26 species of vascular plants, majority of them are herbaceous plants (annual and perennial) (Table 2).

The second cenopopulation of *S. lilacinocoerulea* (CP 2) grows on the grey clay soil, on strongly eroded northwestern slope, among sparse juniper woodland. The site is located on the northern slope of Tyubere-Oland ridge, in the upper part of the Tarkapchigay river valley, 25 km to southeast from village Tarkapchigay, on the altitude of 1724 m a.s.l. The community is composed by 12 species of vascular plants, 78% of them are perennial herbs. The canopy cover is about 36% (Table 2).

The third cenopopulation (CP 3) of investigated species is defined among the

Table 1. Parameters of studied coenopopulations.

CP No	Location, habitat and disturbance	Dominant/codominant species	Parameters of *S. lilacinocoerulea* cenopopulation		
			Area occupied by CP, ha	Cover of species, %	Population density, plants/m^2
1	Kurukdagana ridge, 1 km to the east of the pass Tally, N38.14881' E066.56252', 1619 m a.s.l., N slope, strongly eroded stony soil, juniper-sagebrush community (cover 33%), moderate grazing	*Juniperus seravschanica, Artemisia tenuisecta*	0.5	2.0	3.5
2	Tyubere-Oland ridge, upper part of Tarkapchigay river valley, N38.17335' E. 066.76115', 1724 m a.s.l., NW slope, strongly eroded saliferous gray clay soil, sparse juniper community (cover 30%), intensive grazing	*Juniperus seravschanica*	0.1	+	1.2
3	Karatepa mts., middle reaches of the Maydanak stream, N38.18574' E.066.76237', 1821 m a.s.l., W eroded steep slope, fine soil with large stones, wheat grass-sagebrush-juniper community (cover 70%), moderate grazing	*Juniperus seravshanica, Artemisia tenuisecta, Elytrigia trichophora*	1.5	3.0	3.7
4	Karatepa mts., upper reaches of the Maydanak stream, N38.19420' E066.75664', 1941 m a.s.l., NE gentle slope, eroded red clay soil, wheat grass-juniper community (cover 50%), intensive grazing, dry-farming	*Juniperus seravshanica, Elymus hispidus (Elytrigia trichophora), Salvia lilacinocoerulea*	0.4	5.0	4.8

Table 2. Species composition of studied cenopopulations of *Salvia lilacinocoerulea.*

№	Name of plants	Life form	Cover, %			
			CP 1	CP 2	CP 3	CP 4
1	*Juniperus seravschanica*	Tree	15	30	30	25
2	*Lonicera stenantha*	Shrub	–	–	5	–
3	*Convolvulus fruticosus*	Shrub	1	–	–	–
4	*Rosa maracandica*	Shrub	–	3	–	4
5	*Ephedra equisetina*	Shrub	+	–	–	–
6	*Molucella fedtschenkoana (Otostegia glabricalyx)*	Shrub	2	–	–	–
7	*Cerasus erythrocarpa*	Shrub	1	–	–	–
8	*Acer pubescens*	Shrub	–	–	2	–
9	*Amygdalus spinosissima*	Shrub	2	–	–	–
10	*Amygdalus bucharica*	Shrub	–	–	5	–
11	*Acantholimon erythraeum*	Dwarf shrub	+	–	–	–
12	*Acantholimon majevianum*	Dwarf shrub	–	–	–	+
13	*Acantholimon butkowii*	Dwarf shrub	–	–	–	+
14	*Artemisia tenuisecta*	Semi shrub	6	–	15	–
15	*Elymus hispidus (Elytrigia trichophora)*	Perennial	–	2	8	10
16	*Salvia lilacinocoerulea*	Perennial	2	+	3	5
17	*Astragalus rumpens*	Perennial	+	+	+	–
18	*Allium barsczewskii*	Perennial	–	–	+	–
19	*Convolvulus pseudocantabrica*	Perennial	–	–	+	–
20	*Prangos pabularia*	Perennial	–	+	–	–
21	*Galagania fragrantissima*	Perennial	–	–	+	–
22	*Iris sogdiana*	Perennial	+	–	–	–
23	*Eremurus sogdiana*	Perennial	+	–	–	–
24	*Eremurus olgae*	Perennial	–	+	–	–
25	*Phlomis thapsoides*	Perennial		1	–	–
26	*Phlomis olgae*	Perennial	1	–	–	–
27	*Phlomoides kaufmanniana*	Perennial	–	–	1	–
28	*Inula helenium*	Perennial	1	–	–	–
29	*Inula macrophylla*	Perennial	1	–	–	–
30	*Ferula kuhistanica*	Perennial	1	–	+	–
31	*Cousinia radians*	Perennial	+	+	+	+
32	*Cichorium intybus*	Perennial	–	–	+	–
33	*Hedysarum magnificum*	Perennial	+	+	–	–
34	*Hordeum bulbosum*	Perennial	–	–	+	–

Continued

35	*Poa bulbosa*	Perennial	+	–	+	+
36	*Kughitangia knorringiana*	Perennial	–	–	–	1
37	*Kughitangia popovii*	Perennial	–	–	–	1
38	*Ziziphora pamiroalaica*	Perennial	–	–	–	1
39	*Stipa szowitsiana*	Perennial	–	+	–	1
40	*Euphorbia rapulum*	Perennial	+	–	–	–
41	*Jurinea trautvetteriana*	Perennial	+	–	–	–
42	*Tragopogon vvedenskyi*	Perennial	–	–	+	–
43	*Pterocephalus afghanicus*	Perennial	–	–	–	+
44	*Scrophularia xanthoglossa*	Perennial	–	–	–	1
45	*Silene kudrjaschevii*	Perennial	–	–	–	+
46	*Astragalus xanthomeloides*	Perennial	–	–	–	+
47	*Scabiosa songarica*	Perennial	–	–	–	+
48	*Alyssum campestre*	Annual	–	–	–	+
49	*Veronica campylopoda*	Annual	+	–	–	–
50	*Bromus danthoniae*	Annual	+	–	–	–
51	*Boissiera squarrosa*	Annual	+	+	+	–
52	*Diarthron vesiculosum*	Annual	+	–	–	–
53	*Polygonum aviculare*	Annual	–	–	+	–
54	*Ziziphora tenuior*	Annual	–	–	+	–
55	*Taeniatherum crinitum*	Annual	+	–	2	–

wheat-grass–sagebrush–juniper community in the Karatepa ridge (upper part of the Tarkapchigay river basin). The soil is fine, in places with large stones. The cenopopulation is found on the altitude of 1821 m on eroded stony plot of steep western slope. The canopy cover is about 70%. The floristic composition of the community contains 23 species of vascular plants with predominance of perennial herbs (Table 2).

The fourth cenotical population (CP 4) is situated in the upper part of the Tarkapchigay river basin, near the watershed of the mountain ridge Karatepa, in the upper reaches of the Maydanak stream, at the altitude of 1941 m a.s.l. The population grows on the red clay soil, on the eroded plot of relatively gentle northeastern slope, on brink of cliff. The canopy cover of vegetation is about 50%; and only 18 species of vascular plants were recorded for this wheat grass-juniper community (Table 2). Surroundings of the described plot are occupied with rainfed crops of wheat and oil-bearing cultures. Within whole studied area, intensive soil erosion and grazing are the main factors of disturbance for *S. lilacinocoerulea*. Plants damaged by livestock were recorded in all surveyed cenopopulations (Figure 4).

The demographic structure (age structure) of cenopopulations was defined;

Figure 4. A floral shoot of *S. lilacinocoerulea* grazed by domestic sheep.

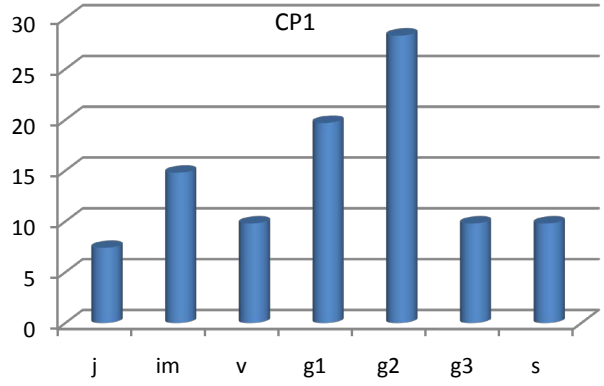
this feature has essential significance for population surviving, stability and regeneration [3].

An ontogenetic spectrum of investigated cenopopulationis is presented in **Figure 2**. According to the classification of A.A. Uranov and O.V. Smirnova [3], all studied CP can be assessed as normal and incomplete.

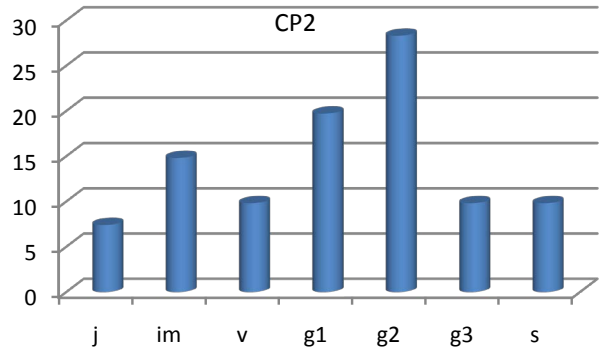
Cenopopulation 3 has a left-side type of the ontogenetic spectrum with well- defined prevalence of pre-reproductive stage (immature and virginal age classes). The ratio of other ontogenetic groups is low. The population grows on the stony substratum, on strongly eroded step slope; and low number of generative plants is related to the habitat conditions. Domination of immature and virginal individuals indicates good seed reproduction.

Ontogenetic structure of studied CP of *S. lilacinocoerulea* represents four types of the spectrum: left-side (CP 3), bimodal (CP 1), centered (CP 4), and right-side (CP 2) (**Figure 5**).

Cenopopulation 4 with centered type of the ontogenetic spectrum has maximal rate of the mature reproductive individuals (28 %). A number of young generative and immature plants is also significant (18% and 14% respectively), but a rate of juvenile specimens is low. This cenopopulation is situated on the uncharacteristic substratum (red clay); the area is notable disturbed by human activities (grazing and dry-farming). Apparently, not fully favorable habitat conditions resulted in a low germination, loss of seedlings and juvenile individuals. But the cenopopulation is able to self-maintenance by seed reproduction. As it



(a)



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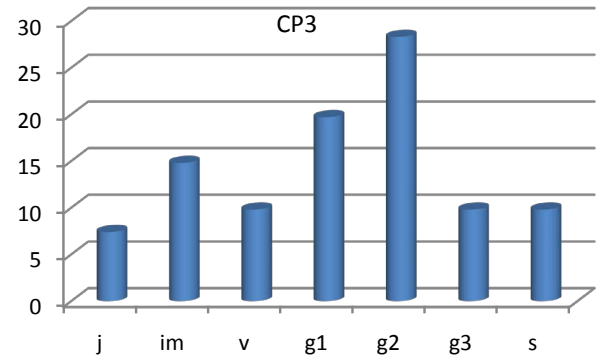

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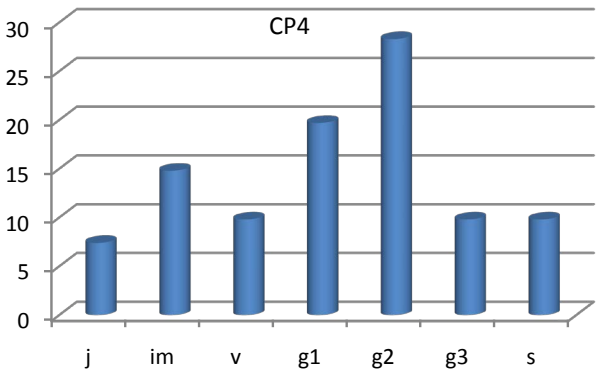

(d)

Figure 5. Demographic structure of *S. lilacinocoerulea* coenopopulations.

was mentioned in above, the characteristic spectrum of *S. lilacinocoerulea* coenopopulation is centered, with a peak in the middle-generative individuals. In contrast to other surveyed cenopopulations, CP 4 has coincides with the characteristic spectrum.

The demographic structure of cenopopulation CP 1 has a distinctive bimodal spectrum with two peaks in right and left parts of diagram that correspond with a high rate of senile and virginal individuals. Senile plants dominate in this population (40%). It appears that the germination is low on this population. In addition, CP 1 grows on the strongly eroded open stony slope, and seedlings washing away by spring rainfall each year.

A quite similar situation with prevalence of post-reproductive stage is observed in the cenopopulation 2 which has a right-side ontogenetic spectrum. Senile plants accounted for 75% of CP 2 growing in adverse environment, on a strongly eroded, almost bald steep slope with salt-bearing gray clay soil (Figure 6). This is a typical reaction of plans to stressful conditions that allows the population to survive: old generative plants inhibit life processes; by contrast, development of pre-reproductive individuals accelerated.

The age index (Δ) and efficiency index (ω) also shows that CP 1 and CP 2 situated in overgrazed pastures on strongly eroded substratum are cenopopulations of old type. The post-reproductive individuals dominate (CP 1: s = 40%, Δ = 0.56; ω = 0.40; CP 2: s = 75%, Δ = 0.80; ω = 0.54), and the rate of juvenile plants is low. CP 3 is the cenopopulation of young type (the rate of pre-reproductive individuals is 67.5%, Δ = 0.28; ω = 0.39). Reproductive individuals prevail in CP 4, and this is a cenopopulation of transitional type (Table 3).

4. Conclusions

Mostly investigated coenopopulations of *S. lilacinocoerulea* are incomplete. Absence of *S. lilacinocoerulea*'s young fractions in the CP2 and only juvenile indi-

Figure 6. Senile specimen of *S.* lilacinocoerulea on strongly eroded, almost bald steep slope with salt-bearing gray clay soil (CP 2). Photograph by N.Yu. Beshko.

Table 3. Age classes rate and demographic parameters of *S. lilacinocoerulea* cenopopulations.

CP No	Age classes rate, %							Demographic parameters		
	j	*im*	*v*	*g1*	*g2*	*g3*	*s*	Δ	ω	CP type
1	0	11.4	22.8	2.8	8.5	14.2	40.0	0.56	0.40	old
2	0	0	0	0	16.6	8.3	75.0	0.80	0.54	old
3	0	27.0	40.5	8.1	2.7	8.1	13.5	0.28	0.39	young
4	7.4	14.8	9.8	19.7	28.3	9.8	9.8	0.38	0.60	transitional

viduals in the CP1 connected with habitat conditions of these coenopopulations. Both of these coenopopulations are grow on the exposed slope and mudflow in early spring period leading to elimination of young not fully recovered plants. Among the investigated coenopopulations CP4 (growing on the red clay soil) differ with positive demographic spectrum. Here observed scale up number of individuals from juvenile (j) to mature generative (g2) and then phase-down to senile. Such ontogenetic spectrum reflect biological feature of *S. lilacinocoerulea.* Prevalence of matured generative plants in coenopopulation is result of long duration of plant life in this ontogenetic stage.

In general, the density and structure of populations of *S. lilacinocoerulea* indicates that their state is satisfactory with the exception of CP 2. Absence of plants in the left-side of ontogenetic spectrum (*j, im, v, g*1) and the small percentage of generative plants (*g*2 and *g*3) indicate critical state of this coenopopulation.

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