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SYSTEMATIC STUDY OF ARID TERRITORIES

Current State of the Cenopopulation of *Cynoglossum viridiflorum* Pall. Ex. Lehm. in the Karakalpak Part of the Ustyurt Plateau (Uzbekistan)

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Abstract—The current state of a rare medicinal species, the "green-flowered" hound's tongue (*Cynoglossum viridiflorum* Pall. ex Lehm.), of Uzbekistan growing in the Karakalpak part of the Ustyurt Plateau, based on the structure of its cenopopulations is examined. New data is reported with respect to the ontogeny and ontogenetic structure of cenotic populations of this rare endemic, and plant communities with its participation are characterized. In the Ustyurt conditions, the vegetation cycle of *C. viridiflorum* spans approximately eight months from March to October. The studied populations were shown to be normal and full-membered. The left-sided ontogenetic spectrum is characteristic of *C. viridiflorum* due to the high seed productivity and germination capacity. Altogether, this reflects the biological characteristics of *C. viridiflorum* and points to a stable state of the species population in the Ustyurt conditions.

Keywords: *Cynoglossum viridiflorum*, Karakalpakstan, Ustyurt Plateau, Eastern chink, desertification, ontogenesis, ontogenetic structure, cenopopulation

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Adverse processes, such as desertification and ecosystem degradation, have been developing in recent years in the Karakalpakstan natural environment. This is associated with a disturbance of the hydrological regime of the Aral Sea, as well as an increasing anthropogenic load. The decline in the level of the Aral Sea has had an impact on the regional biodiversity to varying degrees. Vegetation is observed to undergo transformation; mesophiles are the most strongly affected. As a result, some species became rare; while others live in a suppressed state. The global climate change and various local cataclysms pose a threat to existence of species with restricted ranges. Change in the parameters of the habitat environment can lead to a reduction and even extinction of particular species.

The Republic of Karakalpakstan is located in the northwestern part of Uzbekistan. The total area is 167000 km^2. It borders on Kazakhstan in the west, north, and northeast, shares borders with Bukhara Region in the east and southeast, and has a common border with Turkmenistan and Khorezm Region.

The flora of Karakalpakstan is rich in commercially valuable groups of plants, such as forage, medicinal, tinctorial, tanning, ornamental, nectar-source, nonfood, fines herbes, and other species (Erezhepov, 1978). Medicinal plants (or herbs) are particularly important.

The Karakalpak part of the Ustyurt Plateau is a barren waterless clayey plain. The total area of this part of the plateau is approximately 7.5 million hectares (Rakhimova et al., 2023). From the east, the plateau with alternating steep scarps and gentle slopes is bounded by the shrinking Aral Sea and is known in the literature as the Eastern chink, which is a huge morphologically rugged dry stony desert. Its escarpments are composed of limestone beds, strikingly standing out against the surrounding area and equally distinctive in constituting a flat plain on the plateau. The climate conditions of the Eastern chink are characterized by extreme or hyper continentality, that is, a hot summer, relatively cold winter, and a low amount of precipitation with rather frequent fogs and more humid air. The average monthly temperature peaks in July at 28.1°C in the northern half and 32–35°C in the south. The temperature drops to its absolute minimum in January (–40°C) and rises to the absolute maximum in July (+32.6°C). The chink features rather peculiar vegetation. Communities with a dominance of mesophiles occur together with the halophiles and xerophiles groups. The vegetation is basically formed of *Anabasis salsa*,[1] *Artemisia terrae-albae*, *Salsola arbusculiformis*, *S. orientalis*, *Phragmites australis*, *Agropyron*

[1] Latin names of plant species are reported based on the web resource *Plants of the World Online* (2023).

fragile, *Medicago sativa*, *Calamagrostis dubia*, and even *Corydalis schanginii* (Sherbaev, 1982). Vegetation of the Eastern chink is characterized by a high diversity of phytocenoses. Locally, 68 associations, belonging 18 formations and seven types, were recorded by B. Sarybaev (1981). The composition of these associations was reported to include 302 species of higher plants, belonging to 188 genera and 42 families. Recent studies showed that significant changes in vegetation cover have been observed on Ustyurt and other adjoining territories due to desiccation of the Aral Sea. They manifested themselves in a shift of species composition of the plant communities toward xerophytization and/or halophytization or, alternatively, restructuring of the entire community as a result of displacement of the dominant and subdominant species by drought- and salt-tolerant plants (Adilov et al., 2021).

Under the circumstances, due to recession of the Aral Sea, the ecological conditions primarily have an adverse effect on the state of populations of the regionally occurring locally confined and rare species. A series of studies are available concerning the current state of cenopopulations of rare species in the conditions of Uzbekistan (Rakhimova et al., 2020, 2021a, 2021b; Akhmedov et al., 2022, 2023; Beshko et al., 2023; Saribaeva et al., 2023). Considering the foregoing problems, a wealth of data was collected for the long-term monitoring on the state of populations of a number of rare species listed in the Red Book of Uzbekistan (*Malacocarpus crithmifolius*, *Euphorbia sclerocyathium*, *Astragalus holargyreus*, *Eremurus anisopterus*, *Xylosalsola chiwensis*, and *Scorzonera bungei*) and species recommended for inclusion in the Red Book (*Crambe edentula, Lagochilus acutilobus*, *Crataegus korolkowii,* and *Allium delicatulum* (Rakhimova et al., 2021a, 2021b, 2023; Rakhimova, T. and Rakhimova, N.K., 2022; Saribaeva et al., 2022). One of them is the green-flowered hound's tongue (*Cynoglossum viridiflorum* Pall. ex Lehm.), which is an extremely rare species for the Republic of Uzbekistan, growing in isolated clumps or (less commonly) small aggregations in ravines of the Ustyurt Eastern chink.

The genus *Cynoglossum* L. (*Boraginaceae*) includes approximately 50 species, which are largely distributed across Eurasian regions with temperate climate and tropical uplands and South Africa, with a smaller number of species in North America and Australia (Miller, 2005), while nine species are native to the Italian flora (Selvi and Sutory, 2012), which corroborates the fact that species of this genus are widely dispersed across the Old World.

In the flora of Central Asia, the genus *Cynoglosum* is represented by six species: *C. officinale*, *C. wallichii*, *C. seravschanicum*, *C. viridiflorum*, *C. capusii*, and *C. creticum*, of which the latter four grow on the territory of Uzbekistan (*Flora Uzbekistana*, 1961; *Opredelitel' rastenii*..., 2015). *C. viridiflorum* is the only species of the genus in Uzbekistan that grows in the condition of a desert.

MATERIALS AND METHODS

This study focuses on the green-flowered hound's tongue (*Cynoglossum viridiflorum*), a perennial plant of the family Boraginaceae (Fig. 4). The root is vertical, sparingly branched. Stem erect, 1–1.5 m high, in branching panicles in the upper half and glabrous in the lower part, sparsely villous above on bumps. Leaves pale-green at the top, grayish at the bottom, and with elliptically oblong cuspidate lamina cuneate on a long petiole (up to 35 cm) near the roots; leaves glabrous or covered with short bristle on the upper surface and almost pannose, grayish lanate on the abaxial surface. Sepal quinquepartite 3.5–4 mm long with elongated obtuse densely appressed hairs. Yellow–green corolla. Nutlets ovoid 6–7 mm long. In the Karakalpakstan Republic, blooms and fruits in May–June (*Flora Uzbekistana*, 1961).

Little data is available in the literature on the health benefits of *C. viridiflorum*, while data on the biological characteristics is almost nonexistent.

Based on data from D.K. Ges' et al. (1967), the roots and leaves of the green-flowered hound's tongue are used for medicinal purposes. Its roots contain the alkaloids cynoglossin and cynoglossofin, the bitter substance cynoglossoidin, dye substances, resins, and other things. In the past, hound's tongue was used in medicine practices. Doctors advised it as a remedy to relieve pain and remove spasms. In traditional medicine, it is recommended to drink a decoction of hound's tongue after bites from rabies-infected animals; the root grounded to powder is mixed with fat and applied for rheumatism (Nikolaeva, 1964), aches in bones, abscesses, and sucking lice; the tincture was poured on wounds.

Geobotanical descriptions of plants communities, the composition of which was found to include this species, were made using the standard procedure (*Polevaya geobotanika*, 1964). The plant species was identified using the *Opredelitel' vysshikh rastenii Karakalpakii* (*Identifier of Higher Plants of Karakalpakstan*) (Bondarenko, 1964).

The ontogeny age states were distinguished according to T.A. Rabotnov (1950). An individual plant was taken as a unit of counting. The population structure was characterized relying on the ideas about the characteristic ontogenetic spectrum (Zaugol'nova, 1994). Transects were laid out, 10 m long each, and divided into quadrants 1 m^2.

The state of the rare species populations was assessed based on the ideas about a characteristic ontogenetic spectrum, according to classifications by A.A. Uranov and O.V. Smirnova (1969) and "delta–omega" by L.A. Zhivotkovskii (2001). For mapping the location of the studied cenopopulation of the spe-



Fig. 1. General view of *Cynoglossum viridiflorum*.

cies, coordinates of the occurrence locations were imported into the geographic information system ESRI ArcGIS ArcView v.10.0 (2020).

RESULTS AND DISCUSSION

Two cenotic populations of *C. viridiflorum*, growing on the Eastern chink of the Ustyurt Plateau, were investigated in 2021–2022. The cenopopulations were detected under the chink on large debris (blocks, boulders) as a part of the Hound's tongue–medick (CP 1) and *Elytrigia*–medick community with the participation of Hound's tongue (CP 2) at 210 m a.s.l. in the Baltic height system. The Aral Sea, washing the Eastern chink, has an appreciable effect on its climate manifested by rather frequent fogs, more humid air, and richer vegetation compared to the other parts. The described sites are characterized by higher humidity, as well as more common wind occurrence. The chink scarps have excellent shielding properties due to the formation of cracks, void spaces, and hollows.

The geographic coordinates of the first cenopopulation (CP 1) are 44°14′35″ N, 58°16′29″ E. The plant community is dominated by *Medicago sativa*. The vegetation cover of the grass stand does not exceed 20% with the studied species accounting for 5%. Soil is gypseous with large stones. The floristic composition of the community is rather rich and diverse due to the herbaceous plants. It features the participation of 21 vascular plant species, of which 13 are perennials.

The geographic coordinates of the second cenopopulation (CP 2) are 44°74′56″ N, 58°23′37″ E (Fig. 2). Similarly, *M. sativa* individuals are dominant in the plant community. The vegetation cover of the grass stand amounts to 50%, while the studied species accounts for 1%. The soil is gypseous with large stones. This community comprises 19 vascular plant species, of which 13 are perennials (Table 1).

Three major periods and six age states were distinguished and described in *C. viridiflorum*: (j) juvenile, (im) immature, and (v) virginal within the virginal (pregenerative) period; (g_1) early generative, (g_2) mid-generative, and (g_3) late generative within the generative period; and (s) senile in the postgenerative period (Fig. 3).

Four nutlets ovoid, 6–7 mm long on the dorsal surface, with a flat or concave disc along the low unremarkable keel with isolated anchor-like spines at its edges; disk margins slightly raised, thickened rim, densely covered with short anchor-like spines (the latter also applies to the lateral and ventral surfaces (*Flora Uzbekistana*, 1961).

Seedlings (*p*) feature two lanceolate cotyledonary leaves 0.6–0.8 cm long and 0.3–0.5 cm wide. In seedlings, these leaves differ from adult plants in the sizes. The hypocotyl is unremarkable. Leaf lamina broad–lanceolate entire (smooth-edged); apex somewhat obtuse. Length of the seedling leaf is 2–2.5 cm; width, 1–1.2 cm. Tap root system. Thin root nonbranching; can grow to 8–9 cm deep.

Juvenile plants (j) retain two cotyledonary leaves 1–1.3 long and 0.5–0.8 cm wide. Up to three to five assimilating leaves develop in this state. First true leaves apetiolate. Leaf lamina lanceolate smooth-edged. Length of leaf lamina 3–4 cm; width, 1.8–2 cm. Pronounced reticulate venation. Primary root 12–13 cm long and 2–3 mm in diameter with fine second- and third-order lateral roots. Length of the second-order laterals 8–9 cm; third-order, 1–1.5 cm.

Immature plants (im) form up to five to eight leaves. In their size and shape, they approximate leaves of virginal plants. Cotyledonary leaves still retained in this state, but further acceleration of rates of leaf formation is observed. Leaf lamina broad-lanceolate, with smooth margins and well-developed midrib, 4–5 cm long, 5–6 cm including the petiole; width, 2–2.2 cm. Primary root about 4–5 mm in diameter and penetrates down to a depth of 15–18 cm.

Virginal plants (v) form 8–12 leaves, varying in shape and size. Large leaf lamina up to 20–23 cm long and 30–32 cm including the petiole; width, 4–7.5 cm. Length of a medium-sized leaf lamina up to 10–12 cm and 16–19 cm including the petiole; width, 6–7 cm. Small lamina up to 5–6 cm long and 7–8 cm including the petiole; width, 3–3.5 cm. These leaves retain a lanceolate shape with the entire margin. Up to 15 dead leaves were found from the previous year. Tap root sys-

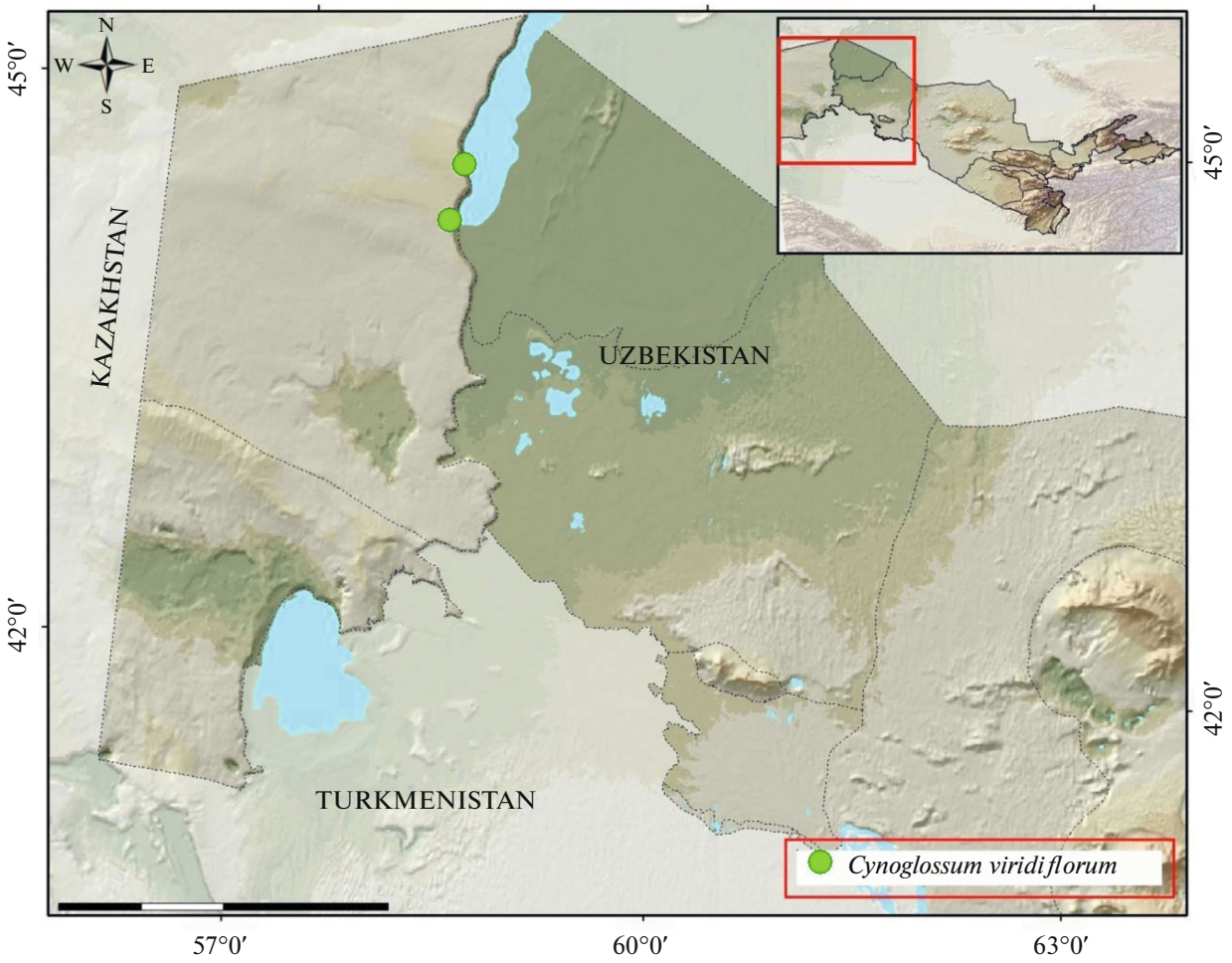


Fig. 2. Map of distribution of the studied *Cynoglossum viridiflorum* cenopopulations.

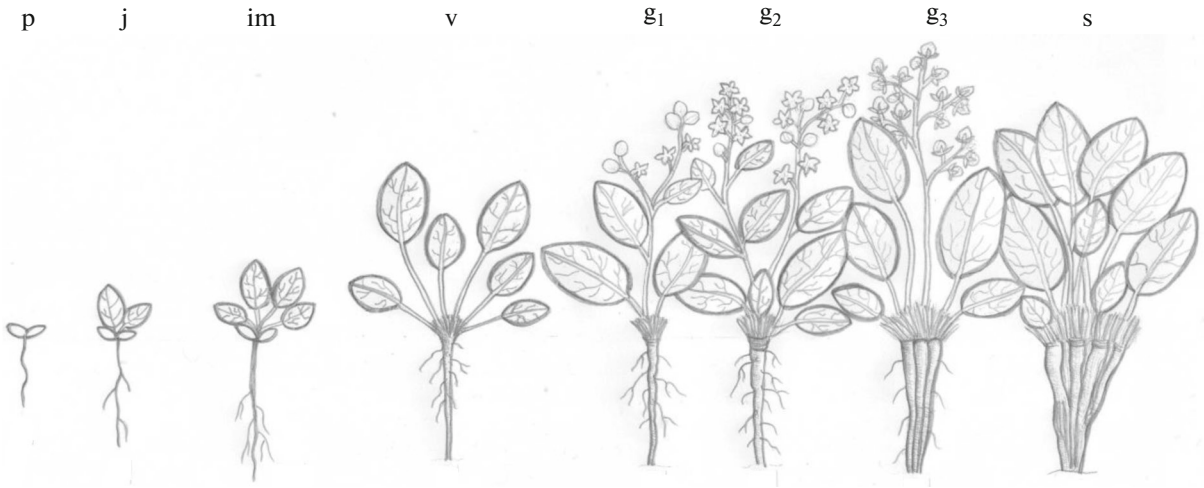


Fig. 3. Ontogenesis in *Cynoglossum viridiflorum*. (p) Seedling; (j) juvenile; (im) immature; (v) virginal; (g_1) early generative; (g_2) mid-generative, (g_3) late generative; (s) senile.

Table 1. Species composition and their abundance with participation of the studied *Cynoglossum viridiflorum* cenopopulations

No.	Plant name	Abundance of species communities, %	
		CP 1	CP 2
	Shrubs		
1	*Atraphaxis spinosa* L.	+*	+
2	*Ephedra intermedia* Schrenk & C.A. Mey.	2	–
	Subshrubs		
3	*Artemisia terrae-albae* Krasch.	2	–
4	*Anabasis brachiata* Fisch. & C.A. Mey. ex Kar. & Kir.	–	+
5	*Caroxylon orientale* (S.G. Gmel.) Tzvelev.	–	+
6	*Lagochilus inebrians* Bunge	–	+
	Herbaceous perennials		
7	*Agropyron fragile* (Roth) P. Candargy	1	20
8	*Asparagus breslerianus* Schult. & Schult. f.	+	+
9	*Capparis spinosa* L.	–	+
10	*Lepidium appelianum* Al-Shehbaz	+	–
12	*Calamagrostis dubia* Bunge	+	+
13	*Centaurea apiculata* Ledeb.	+	–
14	*Cynoglossum viridiflorum* Lehm.	5	1
15	*Ferula caspica* M. Bieb.	–	+
16	*Galium pamiroalaicum* Pobed.	–	+
17	*Limonium suffruticosum* (L.) Kuntze	–	+
18	*Medicago sativa* L.	10	28
19	*Onosma staminea* Ledeb.	+	+
20	*Poa bulbosa* L.	–	+
21	*Tragopogon marginifolius* Pavlov	+	–
22	*Thalictrum isopyroides* C.A. Mey.	+	+
23	*Rheum tataricum* L.	+	+
24	*Sisymbrium subspinescens* Bunge	+	–
	Annuals		
25	*Artemisia scoparia* Waldst. & Kit.	+	–
26	*Asperugo procumbens* L.	+	–
27	*Diptychocarpus strictus* (Fisch. ex M. Bieb.) Trautv.	+	+
28	*Eremopyrum bonaepartis* (Spreng.) Nevski	+	+
29	*E. triticeum* (Gaertn.) Nevski	+	–
30	*Polygonum aviculare* L.	+	–

+* member of the community.

tem reaches a depth of 18–20 cm and is 1.5–2 cm in diameter.

Early generative plants (g_1) retain the root rosette. Height of plants with the generative part is 50–55 cm. All lower leaves (up to 10–15) remain green, but particular leaves turn yellow in summer months. The generative sphere is formed from the apical part of the shoot. In generative shoots (1–2), phyllotaxy is of an alternate type. Lower leaves lanceolate; length with petiole 27–28 cm; width, 7–9 cm; medium-sized leaves 8–10 cm long including the petiole, and 3–3.5 cm wide; uppermost leaves sessile 5–8 cm long and 2–2.5 cm wide. Young lateral roots of the 2nd–3rd orders are formed from the primary root, which is up to 20–25 cm long and 1.8–2 cm in diameter.

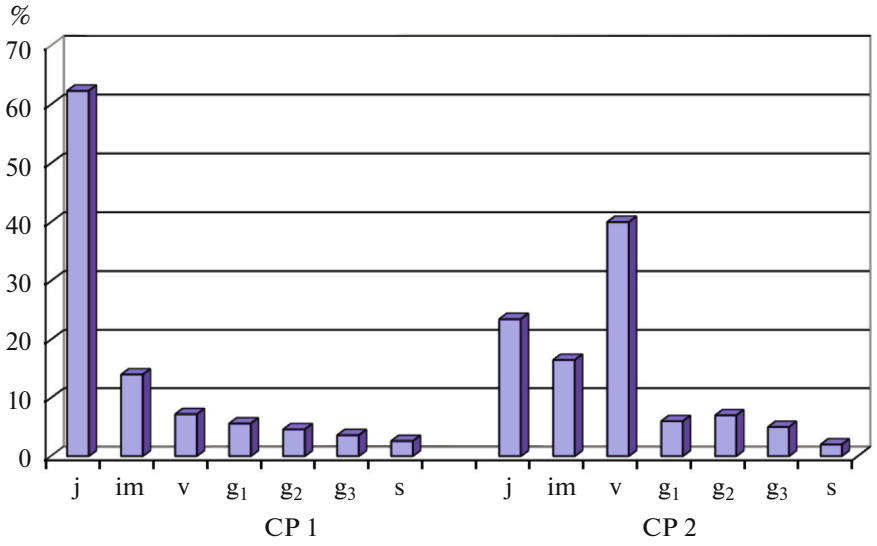


Fig. 4. Left-sided ontogenetic spectra in *Cynoglossum viridiflorum*. (j) Juvenile; (im) immature; (v) virginal; (g_1) early generative; (g_2) mid-generative, (g_3) late generative; (s) senile.

Middle-aged generative plants (g_2) can be as tall as 55–65 cm. In this age state, the number of shoots increases (feature 4–6 generative and 5–6 vegetative shoots), while the generative shoot ramifies. Length and width of leaf lamina are up to 13–15 and 6.5–7 cm, respectively. The number of live leaves increases to 20–25. Primary root up to 25–28 cm in length; 2–2.5 cm in diameter. Many dead leaves from the previous year (up to 20–25). "Particulation" (fragmentation) processes are observed on roots at the end of vegetation.

Late generative plants (g_3) can reach 30–35 cm in height and feature 1–3 generative and 4–5 vegetative shoots. Fragmentation is appreciable, but not yet complete. The plants separate into 3–5 partial clumps. Living leaves in this age–state number up to 12–14. Length and width of leaf lamina are 15–18 and 7–8.5 cm, respectively. The number of dead leaves increases up to 25–30 leaves. Dying processes are observed in the inner root tissue. Root crown 3.5–4 cm wide.

Senile plants (s) feature occasional dying fragments. The plant has five fragments, two of which have already died away. There are three to eight living leaves on each fragment. No generative or vegetative shoots are formed; only green leaves are present, 15–16 leaves in total, 15–18 cm long and up to 4–5 cm wide.

The ontogenetic structure of the C. viridiflorum cenopopulation has not previously been investigated. The *C. viridiflorum* cenopopulations studied by the classification of A.A. Uranov and O.V. Smirnov (1969) are normal and full-membered. Analysis of the ontogenetic structures of these cenopopulations revealed a left-sided type of the spectrum with the maximum in juvenile and virginal individuals. Considering the characteristics of the species biology (high seed productivity and germination capacity), the left-sided spectrum should be considered typical of the studied species cenopopulations (Fig. 4). The ontogenetic spectrum of the cenopopulations coincides with the typical spectrum. Cenopopulations occur on the prechink terrace (shallow ravines), that is, in the wetter places not accessible for grazing. Dominance of the juvenile (62.3%) and virginal (40.0%) individuals in the cenopopulations results from the intensive regeneration by seeds.

The number of individuals total 198 in the cenopopulations. The average density of individuals is high; species occurrence frequency is 9.7 plants per 1 m^2. The age state (Δ) and effectiveness (ω) of *C. viridiflorum* cenopopulations were assessed to determine their type; the studied cenopopulations were established to belong to the early type: CP 1 $\Delta = 0.11$, $\omega = 0.22$; CP 2 $\Delta = 0.15$, $\omega = 0.39$.

CONCLUSIONS

The studied species of *Cynoglossum viridiflorum* is a medicinal plant adapted to ecological conditions of the Eastern chink. Its vegetative cycle spans approximately eight months in these conditions, from March to October. The ontogenetic spectrum of the cenopopulations, growing in the composition of the Hound's tongue–medick (CP 1) and *Elytrigia*–medick community, is left-sided. The spectrum peaks in the juvenile and virginal states, which points to good regeneration by seeds. The cenopopulations are self-sustaining due to seed regeneration alone. The foregoing parameters suggest a stable state of populations in the studied species.

Importantly, many medicinal herbs occur rarely, but form large aggregations; whereas the others have a ubiquitous distribution, but their raw material stock is rather limited. The obtained new data on the distribution of the *C. viridiflorum* cenopopulations in the existing ecological conditions of the Eastern chink will assist in finding new ways of using the different groups of medicinal plants.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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