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RESEARCH ARTICLE

# Analysis of *Glycyrrhiza glabra* L. coenopopulations in the Amudarya River basin under global climate change

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## Abstract

This paper unveils the outcomes of an extensive research endeavor investigating the impact of climate change on the state of *Glycyrrhiza glabra* L. (Fabaceae). coenopopulation. The ontogenetic structure of the coenopopulation was studied using the generally accepted method. Coenopopulations were classified based on the systems developed by A. A. Uranova and O. V. Smirnova, L. A. Zhivotovsky utilizing the "delta-omega" concept. Ecological density was determined according to the method outlined by W. Odum. Geobotanical descriptions were carried out using standard 100 m$^2$ plots by established protocols as outlined in Field Geobotany methodologies. The representative ontogenetic spectrum is left-sided and has an absolute maximum in one of the pre-reproductive groups. The coenopopulations deviated from the typical left-sided spectrum culminating in the senile stage. Individual density within the studied coenopopulations ranged from 0.6 to 7.17 individuals/m$^2$. In comparison, ecological density varied from 0.85 to 8.1 individuals/m$^2$. According to the "delta-omega" classification, *G. glabra* coenopopulations comprised mature (CP 5), transitional (CP 4) and old individuals (CP 1, 2, 3, 6). The decline of *G. glabra* along the Amu Darya River appears primarily attributable to factors: intensive changes in water availability, potentially including significant shifts in channel location and the extensive utilization and economic development of tugai forests for agricultural purposes.

**Keywords:** biodiversity; climate dynamics; tugai; phytocenosis; ontogenetic structure

## Introduction

The ongoing anthropogenic modification of plant communities necessitates the prioritization of natural ecosystem conservation. Among the diverse threats to the planet's biological diversity, climate change manifested predominantly through warming, stands out as the most prevalent (1-3). In this context, irreversible natural occurrences are anticipated, including the thawing of permafrost and glaciers, as well as a climatogenic shift affecting not only the distribution boundaries of individual animal and plant species but also entire ecosystems (4). An ongoing challenge in ecology involves discerning the responses of species and ecosystems to climate change. However, there remains a scarcity of studies investigating the tangible impact, as opposed to the projected climate warming, on terrestrial ecosystems and individual species (5 -8). The limited availability of long-term datasets on natural resources, spanning several decades, appears to be the primary reason for the dearth of studies on actual climate change impacts (9).

Tugai vegetation covers approximately 18.2% of Uzbekistan's territory, with tugai forests constituting roughly 5% of this area. Notably, the Amu Darya's lower and middle reaches harbor the primary naturally occurring tugai vegetation, of which an alarming 80% face imminent extinction (10).

An investigation of the Amu Darya River valley's vegetation cover (11) revealed 84 distinct plant associations. *G. glabra* exhibits dominant status within 14 of these communities.

The area of licorice thickets in the Aral Sea region has decreased (12). Tugai vegetation, which once thrived across over 41740 ha (13), now faces widespread thinning and desertification (14). Reports are on a more than 50% decline in tugai area. This alarming trend is further compounded by the encroachment of xeric shrubs into the remaining tugai patches, coupled with a lack of tree species regeneration, leading to a shrinking range and the potential complete disappearance of these vital ecosystems (14).

This study investigates the response of *G. glabra* coenopopulations to climate change. In recent decades, population studies have been carried out in Uzbekistan on rare and endangered species (15-20) and wild relatives of cultivated plants (21-23). The preservation of plants in Uzbekistan has emerged as a significant concern amid the degradation of environmental conditions. It is pertinent to examine the natural plant populations and assess the impact of environmental factors.

## Materials and Methods

*G. Glabra* L. is a perennial plant 30-80 (sometimes 150) cm high, which grows in steppes, semi-deserts and deserts, on saline meadows and in tugai forests with shallow groundwater (24).

*G. glabra L* has been known in Chinese and Tibetan medicine for over 5000 years as a highly valuable medicinal plant. Since the time of Homer, licorice has been mentioned in all European medical writings. The licorice root has been used for centuries by the people of our country and is included in all herbals. It is included in all domestic pharmacopeias. The medicinal use of licorice is mentioned in the oldest Chinese medical monument, the "Book of Herbs," written 3000 years before our era. Licorice came to Tibetan medicine from China. Licorice roots were used in Sumer and Assyria, from where they were borrowed by the physicians of Ancient Egypt (35).

In modern medicine, *G. glabra* is used in the treatment of respiratory diseases. It has a mucolytic (sputum thinning) and antitussive effect (26 -28).

To study the coenopopulation of *G. glabra*, route surveys were conducted in the lower reaches and delta of the Amu Darya River. Six coenopopulations were identified within various plant communities situated in the mid-mountain zone (Fig. 1).

We compared data from Amu Darya meteorological stations for the period 1930-2020 and investigated monthly and annual time series of mean temperature, maximum temperature, minimum temperature, precipitation and relative humidity. The processed method (Mann-Kendall trend test) was applied to determine the trends of temperature and precipitation over the observation period (29-31 ).

Geobotanical descriptions were performed using a generally accepted methodology on plots of 100 m$^2$ (32). Latin names of plant species are given by the international taxonomic database POWO (33). When studying the ontogenetic structure of coenopopulations, generally accepted methods were used (34, 35). The ontogenetic state of the species was determined using herbarium samples collected during field research. The ontogenetic spectrum of CP is described as the proportion of plants in various ontogenetic states, expressed as a % of the total number of individuals (36). The characteristic type of the CPU spectrum was identified following the Standard principles (37). To characterize the CP, demographic indicators such as the age and efficiency index were employed (37, 34), along with the classification proposed (38). The coenopopulation type was determined based on the "delta-omega" classification system (34). Population density was determined by the number of individuals per unit area (39). In this instance, particular emphasis is placed on average density indicators, which represent the number of individuals per unit of total space (total area) and ecological density, denoting the number per unit of inhabitable space actually available to the population (40).

The aging index and recovery index were determined utilizing the standard method proposed by Gustov (41). Statistical analysis of the data was conducted using Microsoft Excel 2016.

## Results and Discussion

### Long-term climate characteristics

The climate dynamics in the Amu Darya basin in recent decades are reflected in the increasing frequency of extreme events such as droughts and permanent changes in the hydrological regime of water (42).

From 1930 to 2020, a slight increase in temperature was recorded at a rate of 0.11°C/year at the Amu Darya station (Fig. 1b). The warmest year was 1981 when the temperature reached 18.82°C. The coldest year was 1974 with a temperature of 14.24°C. Among the four seasons, only spring is characterized by a significant increase in temperature. The greatest warming occurred in spring, followed by winter. This indicates that the most significant warming was recorded at the Amu Darya station in the cold season.

The maximum temperature recorded at the Amu Darya station exhibited a significant increase at a rate of 0.15° C/year (Fig. 1c). The warmest year was 1954 when the temperature reached 27.08°C. The coldest year was 1972, with a temperature of 22.13°C. The minimum temperature recorded at the Amu Darya station also exhibited a significant increase at a rate of 0.31°C/year (Fig. 1d). The increase in the minimum temperature is primarily concentrated in the warm season.

The average annual precipitation from 1930 to 2020 was 146.09 mm, the maximum precipitation was 265.6 mm (1991) and the minimum precipitation was 19.7 mm (2000) (Fig. 1e). Winter and spring precipitation trends are consistent with the annual variable trend. Annual precipitation was 16.30 mm and gradually increased by 0.19 mm/year during the study period. The average annual precipitation in summer is 1.14 mm.

In contrast to the continuous increase in temperature and precipitation, humidity showed a slight decrease during the study period, with a rate of -0.03%/year (Fig. 1f). The humidity change trend can be divided into two phases: 1930 -1969 and 1969 -2020. In the previous period, the average annual humidity increased at a rate of 0.09%/year. The growth rates were 0.03%/year, 0.18%/year and 0.25%/year in spring, summer and autumn respectively. In winter, humidity gradually decreased at a rate of -0.19%/year. Only the increase in humidity in summer and autumn was significant. In the last phase, the average annual humidity significantly decreased at a rate of - 0.16%/year. The rates of

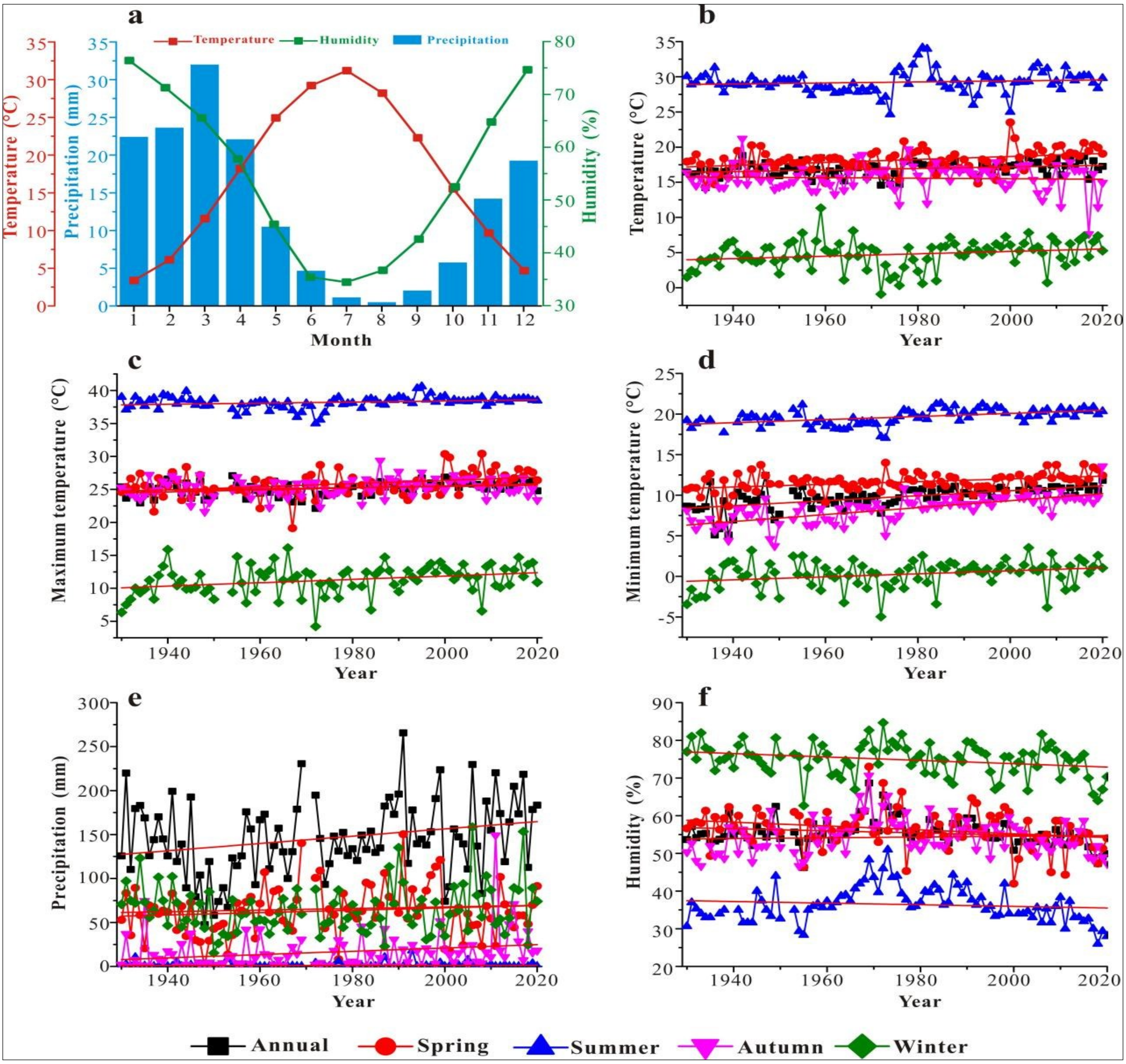


**Fig. 1**. Meteorological data (Source: Department of Meteorology of Uzbekistan, meteorological stations: Termiz and Tuyamuyin) on the Amu Darya River for 1930-2020: a - fluctuations in precipitation, temperature and humidity on a monthly scale; b - average annual temperature; c - maximum temperature; d - minimum temperature; e - precipitation; f - humidity. Source: Department of Meteorology of Uzbekistan, meteorological stations: Termiz and Tuyamuyin.

decrease in spring, summer, autumn and winter were - 0.16%/year, -0.27%/year, - 0.16%/year and - 0.19%/year, respectively. The trend of humidity decrease in 4 seasons has withstood a serious test.

### Phytocenotic characteristics of the coenopopulation

Six *Glycyrrhiza glabra* community populations were studied during field studies conducted in 2022 - 2023. The natural complexes of the valleys of the largest rivers in Central Asia are under threat of degradation in the conditions of intensive desertification related to climate aridization and an increasing anthropogenic load on ecosystems. The area of natural tugai vegetation of the Amu Darya dramatically decreased during the past century and this process continues. The control of these changes requires the creation of a monitoring system of tugai ecosystems, using a regular survey of populations of indicative plant species (43).

The first coenopopulation (CP 1) grows as part of the *Tamaricetum ramosissimae-Euphratica populosum* plant community. The geographic coordinates of this coenopopulation are N 41.038962, E 61.96956 (near the village of Sarimai) and the soil of the described area is loamy (Fig. 2). The total projective cover of the grass stand is 68%. The plant community consists of 10 species of flowering plants. *Tamarix ramosissima* and *Populus euphratica* dominate. The second coenopopulation (2 CP) grows in the Beruni district in forestry (N 41.679949 E 60.68883) (Fig. 2). The plant community is *Populeta spinosae-ramosissimae tamaricosum*, where this coenopopulation was recorded. There are 16 species of plants belonging to different life forms noted here. The total projective cover of the grass stand reaches up to 98%. The plant community is dominated by *Populus spinosa*, *Populus euphratica*. The soil of the described area is loamy and saline. The third coenopopulation (3 CP) was studied in the *Populeta*

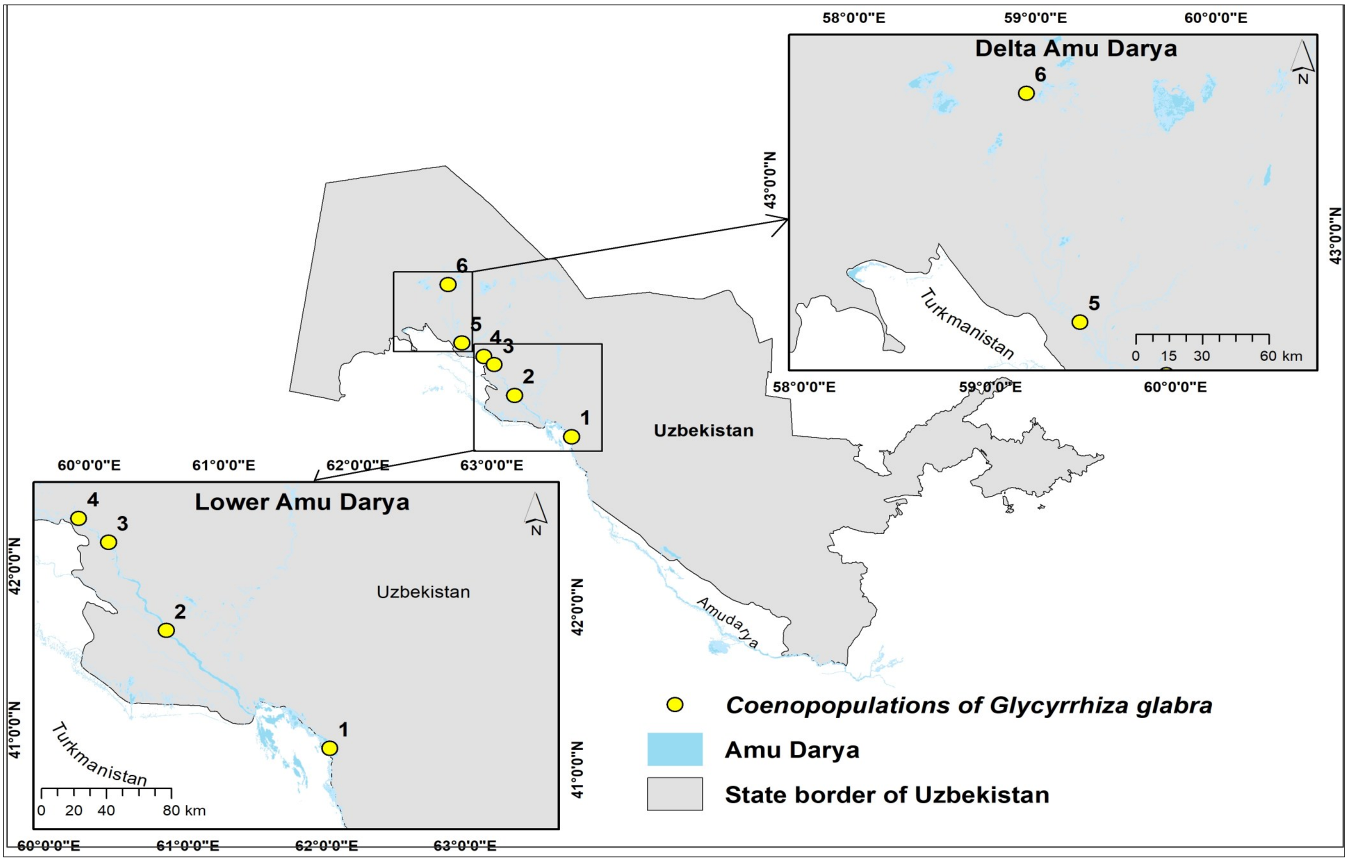


**Fig. 2.** Distribution map of *G. glabra* coenopopulation.

*euphraticae - glycyrrhioso -ramosissimae tamaricosum* community (N 42.18752 E 60.191444). The soil of the studied area is loamy and saline. The floristic composition of the community consists of 7 species. The plant community is dominated by *Populus euphratica*, co-dominated by *Glycyrrhiza glabra* and *Tamarix ramosissima*. The aggregate projective cover of the grass stand measures approximately 84%. The share of the studied species is 20%. The fourth coenopopulation (CP 4) was identified in the area of the Berdak settlement (N 42.315737 E 59.953254) as part of the *Populeta pruinosae - belangerianae halostachydosum* community (Fig. 2). There are 10 species recorded in the plant community. Here, the dominants of the community are *Populus pruinosa* and *Glycyrrhiza glabra*. The combined projective cover of the grass stand stands at 93%, with dominant species contributing 80% of this total. The projective cover of the species under study in this community does not exceed 5%. The fifth coenopopulation (CP 5) was registered in the Khuzhaili forestry (Fig. 2) in the *Populeta euphraticae - glabrae glycyrrhiosum* community (N 42.512639 E 59.449658). The soil of the described territory is a sandy loam plain. The floristic composition is 5 species, dominated by *Glycyrrhiza glabra*, *Populus euphratica*, the share of the studied species is a maximum - of 88%. The total projective cover of the grass stand is about 93%. The sixth coenopopulation (CP 6) is described in the *Populeta euphraticae-angustifolia elaeagnosum* plant community (N 43.508151 E 58.994047). The soil of the study area is sandy loam and saline. The plant community contains 8 flowering plants. *Populus euphratica* and *Elaeagnus angustifolia* dominate. The total projective cover is 55 -56%. Massive deforestation has been noted (Table 1).

**Table 1.** Characteristics of plant communities involving *Glycyrrhiza glabra*

| No | Species | Life forms | Projective covering, % | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 CP | 2 CP | 3 CP | 4 CP | 5 CP | 6 CP |
| 1 | *Populus euphratica* | Tree | 20 | 20 | 60 | + | 28 | |
| 2 | *P. pruinosa* | Tree | - | 60 | + | 50 | 2 | - |
| 3 | *Elaeagnus angustifolia* | Tree | - | - | - | - | - | 25 |
| 4 | *Salix songarica* | Tree | - | + | - | - | - | - |
| 5 | *Halimodendron halodendron* | Shrub | - | + | + | 30 | - | - |
| 6 | *Halostachys belangeriana* | Shrub | - | + | + | + | - | - |
| 7 | *Tamarix hispida* | Shrub | - | + | - | - | - | + |
| 8 | *Tamarix ramosissima* | Shrub | 40 | 5 | - | + | + | - |
| 9 | *Alhagi persatum (pseudalhagi)* | Perennial | + | + | - | - | - | - |
| 10 | *Aeluropus littoralis* | Perennial | + | + | + | + | - | - |
| 11 | *Phragmites australis* | Perennial | + | + | - | - | + | + |
| 12 | *Glycyrrhiza glabra* | Perennial | + | + | 19 | 5 | 60 | + |
| 13 | *Calamagrostis dubia* | Perennial | - | - | - | - | - | + |
| 14 | *Karelinia caspia* | Perennial | + | + | + | - | - | - |
| 15 | *Leymus multicaulis* | Perennial | - | + | - | + | - | - |
| 16 | *Limonium otolepis* | Perennial | + | - | - | - | - | - |
| 17 | *Salsola sclerantha* | Perennial | - | - | - | + | - | + |
| 18 | *Trachomitum scabrum* | Perennial | + | + | - | - | - | - |
| 19 | *Zygophyllum oxianum* | Perennial | - | - | - | + | - | - |
| 20 | *Atriplex thunbergiifolia* | Annual | - | - | - | - | - | + |
| 21 | *Suaeda paradoxa* | Annual | - | + | - | + | - | - |
| 22 | *Cynanchym sibiricum* | Liana | + | + | - | - | + | - |

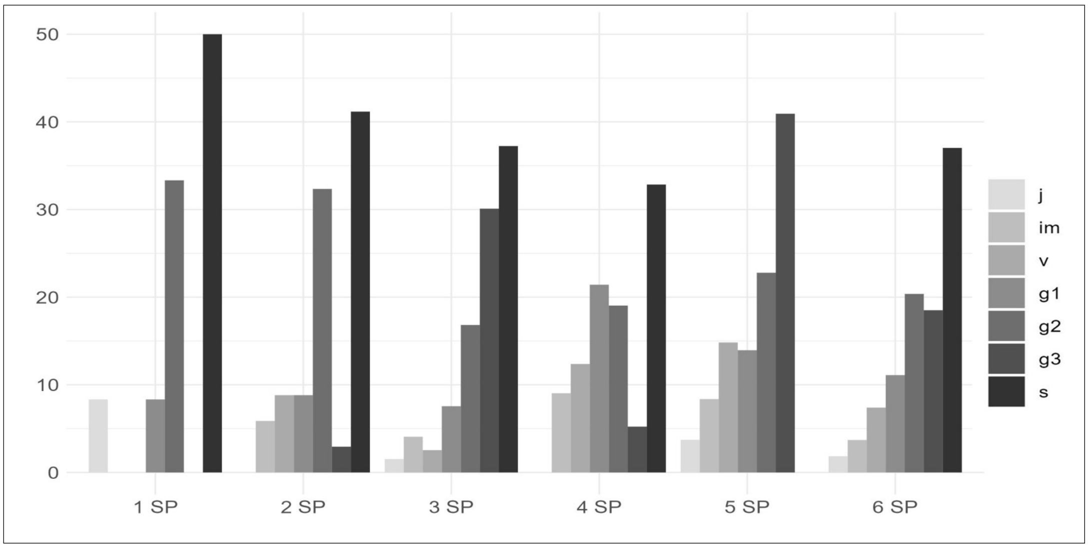


**Fig. 3.** Ontogenetic structure of *G. glabra* coenopopulations.

j- Juvenile; im-Immature; v-Virginile; g1-Young generative; g2-Mature generative; g3-Old generative; s-Senile.

### Ontogenetic structure and types of coenopopulations of *Glycyrrhiza glabra*

No one has previously studied in detail the ontogenetic structure of coenopopulations in the conditions of Tugai vegetation of the Amu Darya *Glycyrrhiza glabra*. Our studies revealed that the studied coenopopulations are normal, but incomplete (Fig. 3). Self-maintenance of coenopopulations occurs by seeds and vegetative means. Based on the peculiarities of the biology of the species - high seed productivity and reproduction by both generative and vegetative means, the characteristic ontogenetic spectrum of coenopopulations of this species will be a left-sided type with a peak in pre-reproductive individuals.

The ontogenetic spectrum of the coenopopulation of *Glycyrrhiza glabra* of the 2-vertex right-sided type. The proportion of old generative individuals in coenopopulations varies from 2.94 (CP 1) to 40.93 (CP 5). There were no juveniles in coenopopulations 2 and 4 at the time of the study. In the studied coenopopulations, the number of senile individuals varies from 28.78 (CP 3) to 50.0% (CP 1). The absence of the senile state fraction in coenopopulations 7 is probably due to the fairly rapid death of old generative individuals. The only thing is that a small proportion (8.33%) of individuals of the juvenile age state was noted here. The absence of the young fraction in CP 1 is associated with the irregular growth of young individuals from underground buds and a strong anthropogenic load. In it, the number of individuals of the species under study is about 12 specimens and all of these individuals are in the generative and senile age state. This coenopopulation, as mentioned above, was studied near the village of Sarimai.

In coenopopulations 1 and 2, the first peak is observed in middle - aged generative states. The notable prevalence of medium-generative individuals correlates with a steady rise in the life expectancy of individuals during the generative phase. Within these coenopopulations, a peak in the senile state is observed among individuals. The high % of old generative individuals and the absence of the senile fraction (CP 5) are undoubtedly the result of a fairly rapid death of individuals.

The high % of senile individuals (except for CP 5) in the surveyed coenopopulations is, on the one hand, associated with a change in the water regime of the surveyed tugai (decrease in groundwater level, lack of flooding) and on the other hand, with a gradual increase in anthropogenic pressure due to the irregular collection of rhizomes as medicinal raw material.

The density of individuals in the studied coenopopulations varied from 0.6 to 7.17 individuals/m$^2$ and the ecological density - 0.85-8.1 individuals/m$^2$ (Table 2).

A comparison of recovery and aging indices reflecting the dynamic state of *Glycyrrhiza glabra* coenopopulations was carried out.

Compared to other coenopopulations, the highest recovery index (0.46) was determined in CP 4, *Populeta pruinosae-belangerianae halostachydosum* plant communities (Table 2). The number of pregenerative individuals is 21.42 %. A low recovery index was determined in CP 1 in the *Tamaricetum ramosissimae-euphratica populosum* association. This is due to the absence of immature and virginal individuals in coenopopulations. The aging index in coenopopulations varies from 0 to 0.92. A high index of replacement index (0.27%) was noted in the coenopopulation studied in the Khuzhaili forestry (CP 5), its low index (0.1) was observed in CP 1, CP 3. According to the “delta-omega” classification (Zhivotovsky 2001), CPU 5 - mature, CPU 4 - transitional, CPU 1, 2, 3, 6 - old. The index values fluctuate significantly: w - from 0.49 to 0.70; Δ - from 0.24 to 0.66 (Table 2).

## Conclusion

The studied coenopopulations of *Glycyrrhiza glabra L.* in various ecological and phytocenotic conditions are normal and incomplete. Under favorable living conditions, characterized by adequate soil moisture, individuals undergo complete ontogeny. The ontogenetic spectra of specific coenopopulations are double-peaked and right-sided, with a peak in the mid-generation and senile fractions. The

**Table 2**. Demographic indicators of *G. glabra* coenopopulations.

| No CP | Demographics | | | | | | | | CP types |
|---|---|---|---|---|---|---|---|---|---|
| | $I_{res}$ | $I_{ag}$ | $I_{rep}$ | Average density of individuals, pcs (1m²) | $P_{ecol}$ (1м²) | Number of individuals | Δ | w | |
| 1 | 0.2 | 0.5 | 0.1 | 0.6 | 0.85 | 12 | 0.66 | 0.49 | old |
| 2 | 0.33 | 0.41 | 0.15 | 1.13 | 1.61 | 34 | 0.61 | 0.53 | old |
| 3 | 0.15 | 0.37 | 0.1 | 6.53 | 7.53 | 196 | 0.58 | 0.55 | old |
| 4 | 0.46 | 0.32 | 0.21 | 7.0 | 8.1 | 210 | 0.52 | 0.53 | transitional |
| 5 | 0.34 | 0 | 0.27 | 7.17 | 7.96 | 215 | 0.45 | 0.70 | mature |
| 6 | 0.25 | 0.92 | 0.13 | 1.8 | 2.0 | 54 | 0.24 | 0.58 | old |

**Note:** $I_{res}$ - restoration index, $I_{rep}$ - replacement index, $I_{ag}$ - aging index, $P_{ecol}$ - ecological density, Δ - delta, w- omega

characteristic and studied spectra of *Glycyrrhiza glabra* do not coincide. Four of the 6 coenopopulations of *G. glabra* turned out to be old, one coenopopulation was transitional. In coenopopulations, recovery is very low, which requires urgent measures for their protection and restoration. According to long-term meteorological data, the appearance of drought in the winter seasons in the territories of the Amu Darya River is an alarming signal. This leads to the appearance of minimal water content, seasonality and episodicity of water supply to tugai massifs, as a result of which "drought areas" arise.

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## Authors' contributions

SUS investigated the ontogenetic structure of *Glycyrrhiza glabra* and coenopopulation types. KFS characterized the phytocenotic features of the coenopopulation. BAA analyzed long-term climatic characteristics. BSK and JSS conducted fieldwork and investigated general methodologies. All authors reviewed and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** The authors declare no conflicts of interest.

**Ethical issues:** None

## References

1. Malcolm JR, Liu C, Neilson RO, Hansen A, Hannah L. Global warming and extinctions of endemic species from biodiversity hotspots. Conserv Biol. 2006;20(2):538–48. 10.1111/j.1523-1739.2006.00364.x
2. Colwell RK, Brehm G, Cardelús CL, Gilman AC, Longino JT. Global warming, elevational range shifts and lowland biotic attrition in the wet tropics. Science. 2008;322(5899):258–61. https://doi.org:10.1126/science.1162547
3. Khabibullaev BSh, Shomurodov KhF, Adilov BA. Impact of long-term climate change on *Moluccella bucharica* population decline in Uzbekistan. Plant Sci Today. 2022;9(2):357–63. https://doi.org/10.14719/pst.1464
4. Shomurodov KhF, Khabibullaev BSh. Investigation of changes in the species composition of the plant community containing relict species of *Moluccella bucharica* for half a century. Malayan Nat J. 2022;74(1):19–29.
5. Sapanov MK. Peculiarities and ecological consequences of climate warming in the Northern Caspian semi-desert. Povolzhskiy J Ecol. 2021;1:64–78. https://doi.org/10.35885/1684-7318-2021-1-64-78
6. Fenu G, Al-Rammahi HM, Cambria S, Cristaudo AE, Khabibullaev BS, Mohammad MK, et al. Global and Regional IUCN Red List Assessments: 14. Ital Bot. 2022;14: 81–94. https://doi.org/10.3897/italianbotanist.14.97176
7. Fenu G, Cambria S, Giacò A, Khabibullaev BS, Shomurodov KhF, et al. Global and Regional IUCN Red List Assessments: 16. Ital Bot. 2023;16:121-33. https://doi.org/10.3897/italianbotanist.16.115947.
8. Orsenigo S, Cambria S, Khabibullaev BSh, Shomurodov KhF, Tavilla G, Troia A, et al. Global and Regional IUCN Red List Assessments: 13. Ital Bot. 2022;13:85–94. https://doi.org/10.3897/italianbotanist.13.86714
9. Xu B, Hugjiltu M, Baoyin T, Zhong Y, Bao Q, Zhou Y, et al. Rapid loss of leguminous species in the semi-arid grasslands of Northern China under climate change and mowing from 1982 to 2011. J Arid Land. 2020;12(5):752–65. https://doi.org/10.1007/s40333-020-0022-9
10. Korolyuk AY, Shomurodov KhF, Khabibullaev BSh, Sadinov JS. Composition and structure of tugai communities in indication of ecological conditions in Lower Amu Darya. Sibirskiy Ekologicheskiy Zhurnal. 2024;1:131–38. https://doi.org:10.15372/SEJ20240111
11. Mailun, ZA. Tugai vegetation. In: Vegetation cover of Uzbekistan. Tashkent: Science: 1973; p. 303–75.
12. Makulbekova GB, Kurochkina LYa, Vukhrer VV, Dimeeva LA. Distribution, structure and mapping. Complex characteristics of pastures in the desert zone of Kazakhstan. Alma-ata: Science, 1990; p. 139–52.
13. Isambaev AI. Reed thickets in the middle reaches of the Syrdarya River. Proc Inst Bot Acad Sci KazSSR. 1962;18:23–72.
14. Rakhimova NK, Shomurodov KhF, Sharipova VK, Saitjanova USh, Sadinov JS. Using biodiversity indices to assess the current state of tugai vegetation of the Amu Darya River, Uzbekistan. Biodiversitas. 2023;24(1):467–72. https://doi.org:10.13057/biodiv/d240153
15. Saribaeva ShU, Shomurodov KhF. Actual State of Coenopopulations of *Astragalus cenralis* Sheld. under Conditions of Kuldzhuktau Ridge (Kyzylkum Desert). Arid Ecosyst. 2017;7(4):

265-70. https://doi.org:10.1134/S2079096117040096

16. Rakhimova T., Rakhimova NK. Ontogenesis and ontogenetic structure of cenotic populations of *Eremurus anisopterus* (Asphodelaceae) in the Kyzylkum desert (Uzbekistan). Botanica Pacifica. Bot Pac J Plant Sci Conserv. 2022;11(2):39–44. https://doi.org:10.17581/bp.2022.11218
17. Saribaeva ShU., Shomurodov KhF., Abduraimov OA. Ontogenesis and Ontogenetic structure of local populations of the *Astragalus holargyreus* Bunge (Fabaceae) of the Narrow-Local Endemic of Kyzylkum. Arid Ecosyst. 2021;12(1):78–84. https://doi.org:10.1134/S2079096122010103
18. Rakhimova NK, Rakhimova T, Shomurodov KhF, Sharipova VK. The status of coenopopulations of *Xylosalsola chiwensis* (Popov) Akhani & Roalson and *Scorzonera Bungei* Krasch. & Lipsch. on the Ustyurt Plateau (Uzbekistan). Arid Ecosyst. 2023;13(2):189–95. https://doi.org:10.1134/S2079096123020117
19. Akhmedov A, Beshko N, Keldiyorov X, Umurzakova Z, Hasanov M, Atayeva S, et al. Ontogenetic structure of populations of *Phlomis nubilans* (Lamiaceae) in Uzbekistan under drought climate. Ekológia (Bratislava). 2023;42(4):349–53. https://doi.org:10.2478/eko-2023-0039
20. Khabibullaev BSh. Current state of populations of rare species of the genus *Moluccella* L. (Lamiaceae) in Uzbekistan. [PhD dissertation], Toshkent. 2023;5–18.
21. Abduraimov OS, Kovalenko IN, Makhmudov AV, Allamurotov AL, Mavlanov BJ. Ontogenetic structure of coenopopulations of *Allium pskemense* (Amaryllidaceae) in Uzbekistan. Biosyst Divers. 2022;30(1): 88–94. https://doi:10.15421/012209
22. Saribaeva ShU, Allamuratov A, Mavlanov B, Mamatkosimov O. Assessment of the state of the *Allium praemixtum* Vved. coenopopulation (*Amaryllidaceae*) on the ridges of Uzbekistan. Arid Ecosyst. 2023;13(4):419–24. https://doi.org:10.1134/S2079096123040133
23. Abduraimov OS, Maxmudov AV, Kovalenko I, Allamurotov AL, Mavlanov BJ, Saribaeva ShU, et al. Floristic diversity and economic importance of wild relatives of cultivated plants in Uzbekistan (Central Asia). Biodiversitas. 2023;24(3):1668–75. doi:10.13057/biodiv/d240340
24. Abdiniyazova, GZh., Khozhimatov OK. Current state of natural thickets of *Glycyrrhiza glabra* L. in Karakalpakstan. Bull Karakalpak Branch Acad Sci Repub Uzbekistan. 2013;3/2 (59):455-56.
25. Kuznetsova MA. Tales about medicinal plants (Moscow): Higher School. 1992; 228–29.
26. Akopov IE. The most important domestic medicinal plants and their use (Tashkent): Medicine;1990.
27. Tolstikov GA, Baltina LA, Grankina VP, Kondratenko RM, Tolstikova TG. Licorice: biodiversity, chemistry, medicinal uses. Monograph. Novosibirsk: Geo; 2007.
28. Khojimatov OK, Khamrayeva D, Malsev I, Khujanov A, Kasimov Z, Saitjanova U, et al. Atlas of wild medicinal plants of Uzbekistan. Retrieved February 17, 2021, from https://planta-medica.uz/glycyrrhiza-glabra-l-solodka-golaya-lakrichnyj-koren/
29. Kendall MG. Rank Correlation Methods. London; 1975.
30. Aizen E, Aizen V, Melack J, Nakamura T, Ohta T. Precipitation and atmospheric circulation patterns at mid-latitudes of Asia. Int J Climatol. - United Kingdom. 2001;21(5):535–56. https://doi.org/10.1002/joc.626
31. Yao J, Yang Q, Mao W, Zhao Y, Xu X. Precipitation trend-elevation relationship in arid regions of the China. Glob Planet Change. Netherlands. 2016;143:1-9. https://doi.org:10.1016/j.gloplacha.2016.05.007
32. Ponyatovskaya VM. Lavrenko EM, Korchagina AA. Field geobotany. Moscow-Leningrad: Science; 1964. p. 209–89.
33. Royal Botanic Gardens. Plants of the World Online. https://powo.science.kew.org
34. Uranov AA. Age diversity of phytocoenopopulations as the function of time and energetic wave processes. Biol Sci; 1975;2:7–34.
35. Zhivotovsky LA. Ontogenetic states, effective density and classification of plant populations. Russ J Ecol. 2001;32:1–5. https://doi.org:10.1023/A:1009536128912
36. Plant coenopopulations (basic concepts and structure. in Russian). Moskow; 1976.
37. Zaugolnova LB. The structure of populations of seed plants and problems of their monitoring: Biological sciences. [Thesis] St. Petersburg; 1994.
38. Uranov AA, Smirnova OV. Classification and main features of the development of populations of perennial plants. Bull MOIP. 1969; 74(2): 119–34.
39. Coenopopulations of Plants (Essays on Population Biology). Moskow. 1988.
40. Odum Yu. Ecology. Moscow: 1986.
41. Glotov NV. On assessing the parameters of the age structure of plant populations. In: Life of Populations in a Heterogeneous Environment. 1998.
42. Komin GE. Application of dendrochronological methods in environmental monitoring of forests. Forestry. 1990;2: 3–11.
43. Korolyuk AY, Shomurodov HF, Khabibullaev BS, Sadinov ZS. Composition and structure of Tugai communities in the indication of ecological conditions in the Lower Amu Darya Contemp Probl Ecol. 2024;17(1):106–11. https://doi.org:10.1134/S1995425524010074

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