

Symposium on Natural and Applied Sciences
Hosted Online from London, United Kingdom
Date: 5th October, 2026
Website: https://econferencia.com

LONG-TERM VEGETATION SUCCESSION ON THE DESICCATED FLOOR OF THE ARAL SEA (1981–2024): DIVERSITY DYNAMICS AND SENSITIVITY TO CLIMATE VARIABILITY

J. A. To'layev [1],
B. A. Pulatov [2]
[1] Research Institute of Environment and Nature Conservation Technologies, Tashkent, Uzbekistan
[2] Rector, Central Asian University for Environmental Studies and Climate Change (Green University), Tashkent, Uzbekistan

Abstract
The desiccation of the Aral Sea has exposed the Aralkum, a new desert in which vegetation develops through primary succession under salinization, aeolian processes and a warming, increasingly continental climate. We analysed a 38-year record from a permanent plot in the eastern dried seabed of Uzbekistan, combining 14 observation years between 1981 and 2001 with a resurvey in 2024 and a transect of observation points running from the former shoreline towards younger surfaces. Between 1981 and 2001, total projective cover rose from 24% to 44%, the Shannon index from 0.715 to 1.568 and Pielou's evenness from 0.311 to 0.806, while Jaccard similarity to the initial community fell to 0.417. By 2024 the species composition had been almost completely replaced (Jaccard 0.129 relative to 1981), and saxaul and mixed shrub communities with up to 55% cover had formed. A sharp cover decline in 1998–1999 and a rapid recovery in 2001 show that young desert communities are highly sensitive to interannual climatic variability.

Keywords: Aral Sea, Aralkum, primary succession, vegetation dynamics, diversity indices, climate change, Haloxylon, permanent plot.



Symposium on Natural and Applied Sciences
Hosted Online from London, United Kingdom
Date: 5th October, 2026
Website: https://econferencia.com

Introduction

Drying of the Aral Sea has created a desert of more than 5 million ha, of which 2.5–3.0 million ha lie in Uzbekistan [1]. As the shoreline retreated, a gradient of surface age was formed: the oldest surfaces, exposed for 50–60 years, lie along the historical coast, while the youngest surround the residual water bodies. This age gradient controls the stages of plant succession, the degree of soil development and the salinity regime across the dried seabed [1, 4].

The physical setting of this succession is changing. Central Asia warmed by about 0.36–0.42 °C per decade in 1979–2011, faster than the global mean [2], and the loss of the sea has made the local climate more continental, with hotter summers, colder winters and a larger diurnal temperature range near the former shoreline [3]. Since 2018, protective plantations have also been established on about 1.94 million ha of the dried seabed, adding a strong anthropogenic driver. Long-term plot records that can link vegetation change to these drivers are rare.

The aim of this study was to quantify how plant community structure on the oldest part of the dried seabed has changed over nearly four decades of succession. The objectives were: (i) to describe changes in species richness, cover, diversity and composition in 1981–2001; (ii) to assess the composition of the community in 2024; and (iii) to evaluate the sensitivity of the community to interannual variability.

Study area

The study area is located in the Mo'ynoq district of the Republic of Karakalpakstan, in the eastern part of the dried seabed (about 43.42–43.83° N, 60.16–60.20° E). The climate is a sharply continental cold desert climate (Köppen BWk). According to the Mo'ynoq weather station (1961–1990), mean annual air temperature is 10.4 °C, with −5.6 °C in January and 27.3 °C in July, giving an

annual amplitude of more than 33 °C. Annual precipitation is only 129 mm, with a spring maximum (March–April, 29.5% of the annual total) and an autumn–winter maximum (October–December, 33.0%); June–September receive only 21.2 mm. The arid period lasts seven months, from April to October. The area has about 50 storm days per year, with wind speeds reaching 20–25 m/s, which drives sand burial and root exposure of plants.

Groundwater lies at 0.5–1 m near the residual water bodies and deepens to 3–5 m or more towards the former coast, and it is highly mineralized. Combinations of groundwater depth, substrate texture (from sand to heavy clay) and salinity create a mosaic of habitats on the dried seabed.

Materials and methods

The permanent plot was established in 1981 on sandy substrate that had been exposed for 17 years. Species composition, number of species, total projective cover and per-species projective cover were recorded in 1981–1987, 1989, 1990, 1992, 1994, 1998, 1999 and 2001. The site was resurveyed during a field expedition on 15–30 August 2024. During the same expedition, plant communities were described at observation points along a south–north transect from the former shoreline towards younger, more saline surfaces, including sites with and without afforestation. Coordinates were recorded by GPS, and species names were checked against Plants of the World Online and World Flora Online, taking into account recent changes in Chenopodiaceae nomenclature (e.g. Xylosalsola richteri instead of Salsola richteri).

Community diversity was assessed with the Shannon index, $H' = -\Sigma\, p_i \ln p_i$, where p_i is the share of species i in the summed projective cover of all species, and with Pielou's evenness, $E = H'/\ln S$, where S is the number of species. Compositional turnover was measured with the Jaccard coefficient, $J = c/(a + b - c)$, where a and

b are the numbers of species in the two compared years and c is the number of species shared by both.

Results

Community structure indicators for the observation years are given in Table 1.

Table 1. Dynamics of community structure on the permanent plot, 1981–2001

Year	Years since exposure	Species	Total cover, %	H'	E	Jaccard vs 1981
1981	17	10	24	0.715	0.311	1.000
1982	18	10	24	0.715	0.311	0.667
1983	19	12	26	0.868	0.350	0.692
1984	20	10	26	0.881	0.383	0.818
1985	21	12	26	0.924	0.372	0.692
1986	22	11	27	0.957	0.399	0.615
1987	23	12	33	1.071	0.431	0.571
1989	25	10	33	1.036	0.450	0.667
1990	26	10	32	0.942	0.409	0.667
1992	28	11	32	0.913	0.381	0.615
1994	30	13	35	1.221	0.476	0.533
1998	34	10	21	1.419	0.646	0.727
1999	35	7	21	1.486	0.763	0.545
2001	37	7	44	1.568	0.806	0.417

Note: indices were calculated from per-species projective cover. For 1998, cover values were available for 9 of the 10 recorded species; indices were calculated for these 9 species.

Three successional stages were identified.

1. 1981–1990 (years 17–26 after exposure): a relatively stable community with 10–12 species; cover increased from 24% to 32–33%. The psammophytic grass Stipagrostis pennata held a constant 20% cover, i.e. 60–83% of the total, while the psammophytic shrub Eremosparton aphyllum grew from 2% to 10%. Annual chenopods (Salsola paulsenii, Corispermum aralo-caspicum, C. hyssopifolium) occurred with only 0.1–0.5% cover. Owing to strong single-species dominance, H' remained low (0.72–1.07) and E was 0.31–0.45.

2. 1992–1994 (years 28–30): dominance shifted to E. aphyllum (20%) as S. pennata halved to 10%; Calligonum crispatum increased from 0.5% to 2% and the perennial herb Chondrilla brevirostris became established. Species number (13) and cover (35%) peaked in 1994, marking the transition from a grass stage to a shrub stage.

3. 1998–2001 (years 34–37): cover fell from 35% to 21% in 1998–1999, S. pennata dropped to 4% and 1%, E. aphyllum to 10%, and species number fell to 7. By 2001 cover recovered to 44%: S. pennata returned to 20%, while C. crispatum (12%), Lycium ruthenicum (7%) and C. brevirostris (6%) reached their highest values of the whole record.

Over 1981–2001 the Shannon index increased 2.2-fold and evenness 2.6-fold, although species number declined from 10 to 7. This reflects a move from absolute dominance of one grass towards a more balanced community of grasses and psammophytic and haloglycophytic shrubs. Similarity between consecutive observation years remained high (Jaccard 0.57–1.00), indicating gradual year-to-year change, but cumulative similarity to 1981 fell steadily to 0.417 by 2001: about half of the initial species composition was renewed within 20 years.

The 2024 resurvey showed a qualitatively new community. Only 4 of the 21 species recorded in 1981–2001 persisted (S. pennata, L. ruthenicum, S. paulsenii, C. aralo-caspicum); the former dominant E. aphyllum, as well as C. crispatum, Leymus racemosus, C. brevirostris and Astragalus brachypus, were not found. Jaccard similarity fell to 0.103 relative to 2001 and to 0.129 relative to 1981. The leading species of 2024 are listed in Table 2.

Table 2. Leading plant species in the eastern dried seabed in 2024

Species	Family	Life form	Max. cover, %
Haloxylon persicum	Chenopodiaceae	shrub	55
Calligonum acanthopterum	Polygonaceae	shrub	25
Stipagrostis pennata	Poaceae	perennial herb	20
Haloxylon ammodendron	Chenopodiaceae	tree	15
Alhagi pseudalhagi	Fabaceae	perennial herb	15
Stipagrostis karelinii	Poaceae	perennial herb	15
Tamarix hispida	Tamaricaceae	shrub	10
Ephedra strobilacea	Ephedraceae	shrub	10
Xylosalsola richteri	Chenopodiaceae	shrub	10
Halostachys caspica	Chenopodiaceae	shrub	8

Note: cover values are the maximum recorded for each species at the observation points of the study area.

Along the transect, community structure followed the surface age gradient. On the oldest sandy surface near the former shoreline, a mixed saxaul community with Alhagi pseudalhagi had 36% cover. Northwards, on younger and more saline surfaces, it was replaced by Halostachys caspica–Halocnemum strobilaceum communities with halophytic annuals (16%), then by Halocnemum communities

(10%), and at the northernmost point by a sparse community of annual chenopods (10%). The only exception was a site where saxaul had been planted in 2000–2002: there a mixed community of saxaul, Tamarix, Halostachys and Halocnemum had formed, with 35% cover, 2–3.5 times higher than in the neighbouring natural communities.

Discussion

The overall trajectory — psammophytic grassland (S. pennata) → psammophytic shrubs (E. aphyllum, C. crispatum) → saxaul and mixed shrub communities (H. persicum, H. ammodendron, C. acanthopterum, X. richteri) — agrees with the succession scheme described for sandy substrates of the Aralkum [4]. The increase of total cover from 24% (1981) to 44% (2001) and up to 55% in 2024 indicates that vegetation on the old sandy surfaces is stabilizing, i.e. ecological recovery is under way. Part of the 2024 shrub layer, however, consists of species widely used in afforestation (saxaul, Calligonum, X. richteri, Tamarix, Halostachys), which entered the community by planting or by dispersal from nearby plantations. Natural and assisted succession therefore cannot be fully separated for the 2001–2024 interval.

The 1998–1999 collapse and rapid recovery suggest that perennial grasses survive dry years by reducing aboveground biomass and persisting through their root systems. Under climate change, more frequent dry years may amplify such fluctuations and increase mortality of perennial grasses and young shrubs. On younger surfaces, increasing salinity is expected to slow the transition from halophyte stages to later stages. The main limitations of this study are the 23-year gap between 2001 and 2024 and the late-summer timing of the resurvey, which underrepresents spring ephemerals.





Conclusions

1. Over 38 years of succession, vegetation on the oldest sandy surfaces of the Aralkum has become denser (24% → 44–55% cover), more even (E 0.311 → 0.806) and structurally more complex, indicating ongoing ecological recovery.
2. The community passed through three stages and, by 2024, its composition had been almost completely replaced (Jaccard 0.129), with saxaul and Calligonum shrublands now dominant.
3. Strong interannual fluctuations show high sensitivity to climatic variability. Annual monitoring that combines permanent plots with UAV and satellite data, and correlation of plot data with long-term weather records, is recommended.

References

1. Breckle S.-W., Wucherer W., Dimeyeva L.A., Ogar N.P. (eds.) Aralkum – a Man-Made Desert: The Desiccated Floor of the Aral Sea (Central Asia). Ecological Studies, Vol. 218. Berlin, Heidelberg: Springer, 2012.
2. Hu Z., Zhang C., Hu Q., Tian H. Temperature changes in Central Asia from 1979 to 2011 based on multiple datasets // Journal of Climate. 2014. Vol. 27. P. 1143–1167.
3. Small E.E., Sloan L.C., Nychka D. Changes in surface air temperature caused by desiccation of the Aral Sea // Journal of Climate. 2001. Vol. 14. P. 284–299.
4. Wucherer W., Breckle S.-W. Vegetation dynamics on the dry sea floor of the Aral Sea // Sustainable Land Use in Deserts. Berlin, Heidelberg: Springer, 2001. P. 52–68.