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Phytosociological Investigation of Aquatic Halophytic Plant Communities of Azerbaijan

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ABSTRACT

This study was carried out to determine the plant associations distributed in the saltwater-swamp vegetation of Azerbaijan, between 2007 and 2018. A total of 95 plant associations belonging to five types were determined according to their habitat and phytosociological characteristics. Of these, pure in-water units constitute 33, coastal swamp associations amount to 24, wet grass associations account for 13, aquatic forest associations number eight, and hydrohalophytes add up to 16 plant associations. As a result of the investigation of the phytosociological characteristics of plant associations found in the halophytic aquatic habitats of Azerbaijan, the following associations have been introduced for the first time as new to region: *Halimione verrucifera-Juncetum littoralisae* ass. nova, *Limonieto meyeri-Juncetum littoralisae* ass.nova, *Junco marittimi-Tamaricietum ramosissimae* ass.nova**,** *Juncetum acutusae* Musayev & Atamov 2013, *Tamaricetum ramosissimae* Grosheim 2029, *Halocnemetum strobilacei* Oberd 1957, *Carici extenso-Salicornietea europaeae* Tx. in Tx. &Oberd, 1958) Julve, *Alopocuretum verticosae* Musayev & Atamov 2013, *Franketum hirsutae* Musayev & Atamov 2013, *Juncetum acutusae* Musayev & Atamov 2013, *Juncetum gerardieae* MM & VA 2013., *Juncetum littoralisae* Musayev & Atamov 2013, *Salicotnio europeo-Halocnemum strobiloceae* Musayev & Atamov 2013, *Spergulario-Halimionetum verruciferae* Musayev & Atamov 2013.

Keywords: halophytic habitat; plant associations; phytosociology; water-swamp vegetation; Azerbaijan;

1. INTRODUCTION

Azerbaijan differs noticeably from many surrounding countries with its temperate zone and plant diversity. The factors revealing the different vegetation types and rich flora of Azerbaijan are geographical location, geological structure, topographic diversity, different soil types, macro- and microclimate events and, most importantly, the Caucasus plant geography. Considering the fact that Azerbaijan is located between the Europe and Asia, two-way plant migrations between the two continents further increase diversity and endemism (Avcı 2005).

As a result of the floristic studies carried out in recent years, the number of taxa (species, subspecies and varieties) added to the Azerbaijani flora has reached 6000, and the number of endemic species is 460 which accounts for 7.7%. Of these taxa, a total of 449 taxa were included in the latest edition of the Red Book of Azerbaijan (Hebibbeyli, Huseynova, İbadullayeva et all. 2024).

The species diversity of habitats within the rich floristic structure of Azerbaijan is due to the different geographical structures of plants growth, microclimatic changes in the climate structure and various soil types (Avcı 2005).

Water-swamp vegetation has been studied in many regions of the world. In Turkey, some wetlands (Behçet 1994a, b; Seçmen & Leblebiçi

1996), saline wetlands (Aydoğdu & al. 2002; Hamzaoğlu & Aksoy 2006; Korkmaz & Mumcu 2014) have been explored. Some phytosociological studies have been carried out too.

It Turkey's wetlands, 23 in-water plant associations have been identified, 31 in coastal meadows, seven in wet meadows, one in wetland forest habitat, and 21 in saline habitat (Seçmen and Leblebici 1996).

Gecheva & al. (2013) investigated the aquatic macrophytes in the streams of Bulgaria and stated in their floristic study that they were composed of hydrophytes, halophytes and amphiphytes in the aquatic ecosystems of the region.

Some of these associations can be found in the water marsh plant communites of the high mountainous regions of Azerbaijan.

The water-swamp vegetation of Azerbaijan was investigated according to the Braun-Blanquet (1964) method and phytosociology of the common plant associations found in the terrestrial halophytic aquatic habitats was determined. Research and syntaxonomic classifications conducted in the present study have shown that the water-swamp vegetation of Azerbaijan totals 95 plant associations, including 12 classes, 16 orders, 26 alliances (Table 1).

Water-swamp plant associations have been found everywhere in Azerbaijan, starting from the sea level and up to the high-mountain areas (Grossheym 1946, 1948; Gulusashvili & al. 1975; Prilipko 1970; Prilipko & al. 1961; Prilipko, Agacanov, 1972; Hacıyev 1970, 1992; Aliyev & Halilov 1976; Hacıyev & al. 1979, 1990, 1991; Shaksuvarov,1994;; Sultanov 2000; Ibrahimov 2005; Talıbov & İbrahimov 2008; Mamedov 2011, Gurbanov, Huseynova, 2019).

In the research conducted by Korkmaz & al. (2012) in the Golardi Wildlife Protection Area in the Samsun Province, the authors evaluated syntaxonomically the dune, saline and forest type vegetation.

Atamov (2008) showed that hydrohalophytes were common in the coastal areas of the Caspian Sea. In the water-marsh vegetation, cryptophytes, hemicryptophytes and therophytes dominated in number and were characteristic for that vegetation. These plant types easily adapted to the water-swamp environment and could reproduce promptly in that environment. Some of the aquatic plants with rhizomes and perennial herbaceous stems grew readily in salty lakes and swamps, while others preferred freshwater lakes and swamps. The distinctive and dominant species of these plant types occasionally form pure and occasionally mixed associations.

Table 1. Comparison of water-swamp vegetation in the different regions of Azerbaijan.

Systematic categories and habitats	On the territory of Azerbaijan (Aliyev 1969)	On the territory of Azerbaijan (Aliyev 1969)	Absheron Peninsula (Efendiyeva 1989)	Kur-Araz Plain (Musayev 2010)	According to this study
	Number/%				
Type	1	1	1	1	1
Formation class/Class	2	2	2	2	12
Formation group/Ordo	12	8	9	8	16
Formation subgroup	-	8	2	4	-
Formation	46	33	18	13	26
Association	94	62	37	30	95
Coastal water-swamp	-	-	-	-	24
Wet grass	-	-	-	-	10

Systematic categories and habitats	On the territory of Azerbaijan (Aliyev 1969)	On the territory of Azerbaijan (Aliyev 1969)	Absheron Peninsula (Efendiyeva 1989)	Kur-Araz Plain (Musayev 2010)	According to this study
Water-swamp forest	-	-	-	-	9
Salt lake and marsh	-	-	-	-	17
İn water	20	22	11	12	33
In water and on land	31	73	30	20	68

In his study on the water-swamp vegetation of Azerbaijan, Aliyev (1969) found a total of 94 plant associations: 20 in water and 46 both in water and on land. Babayev (1974) identified 51 associations altogether in the water-swamp vegetation of the high-mountainous regions of the Minor Caucasus: 20 in water and 31 both in water and on land.

2. MATERIALS AND METHODS

In the investigation and classification of phytosociological properties of vegetation of aquatic halophytic habitats, classifications based on the dominance principle were used by Katanskaya (1956, 1981) and Aliyev (1966, 1967, 1969, 1971). In this research, for the first time, phytosociological properties of plant associations found in halophytic aquatic-marsh habitats were investigated within the borders of Azerbaijan based on the Braun-Blanquet (1964) method. In the classification of aquatic plant communities in the world (Rivaz-Martinez et al. (2001; Mucina et al. 2016), primary sources were also used to reveal the diversity of aquatic vegetation in Azerbaijan. Between 2007 and 2018, studies were conducted in lakes and marshes located in the plains of Azerbaijan, on the seashore, especially in the Lenkeran Plain (Great and Small Kizilagach Bay), Samur Devechi Plain (Devechi Port), Candar Lake and Batabat Lake of Nakhchivan, Araz Valley, Kur Araz Plain (Hajigabul, Sarisu) and Absheron Peninsula (Masazır salt lake, Lokbatan and Kanligol). Plant samples were collected at different vegetation periods. The identification of the samples was based on the Flora of Azerbaijan (Karyagin, 1950-1961). Samples were collected from the Institute of Botany of the National Academy of Sciences of Azerbaijan Presented to the herbarium, Baku. Life forms of plants were given according to Raunkier (1934) and vegetation tables were compiled according to the principle of “minimum area” according to Braun-Blanquet (1964). Syntaxonomic nomenclature of units followed Weber et al. (2000).

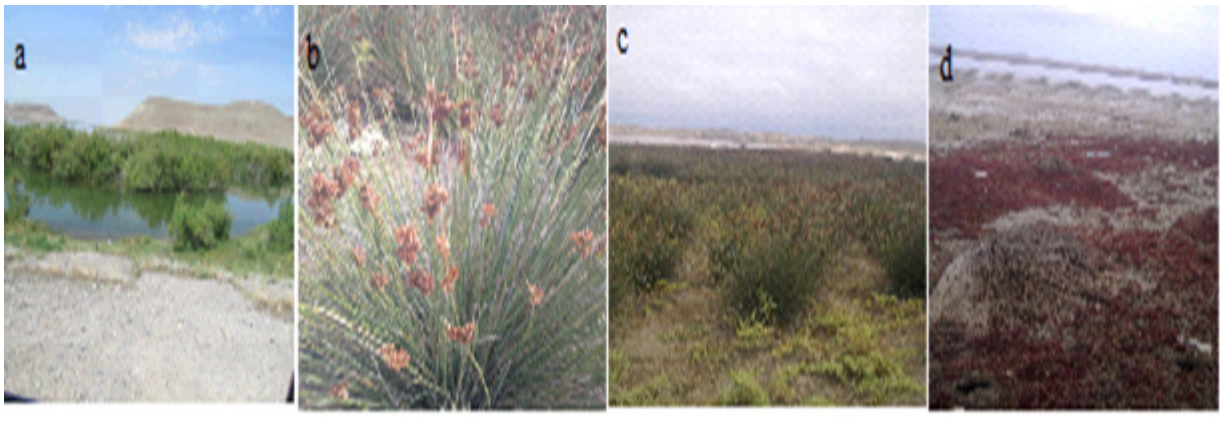

Figure 1. Some taxa distributed in halophytic aquatic habitats: a) *Tamarix ramosissima*, b) *Juncus maritimum*, c) *Juncus litoralis*, d) *Salicornia europaea*

3. RESULTS AND DISCUSSION

As a result of the present research, the water-swamp vegetation of Azerbaijan has been investigated according to the Braun-Blanquet (1964) method and the syntaxonomic evaluation results are given below.

In this study, the vegetation of the marsh ecosystems of Azerbaijan is investigated for the first time according to the Braun-Blanquet method, and the plant associations are identified and classified as follows:

Hydrohalophyte plant associations

These are associations formed by halophyte plants growing in swamps near salt lakes or the sea coast (Fig. 1).

1. *Halocnemetum strobilacei* Oberd. 1957

Halimione portulacoides and Hordeum marinum var. marinum, along with the distinctive taxa, were found on the plains near Lokbatan and in places close to the sea. Limonium angustifolium was identified in the flora and phytocenological structure of the association (Table 2).

Fig. 2a illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. The observations showed that in the phytocenological structure of that association, with the participations of therophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered in the sample areas, which is due to the chemical composition of the soil and water environment in which the association spreads.

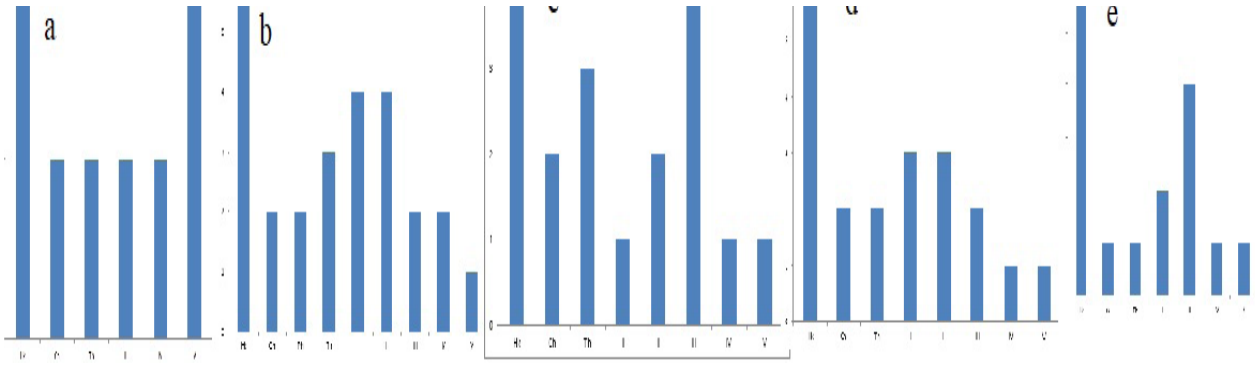

Figure 2. Ranking of the taxa participating in the glandular plant associations in the halophytic aquatic habitats according to life forms and occurrence: a, *Halocnemetum strobilacei*: b, *Junco-Tamarici ramassisimae*; c, *Spergulario-Halimionetum verruciferae*; d, *Halimione verrucifera-Juncetum littoralisae*; e, *Limonio meyeri-Juncetum littoralis*.

Table 2. Phytocenological characteristics of the plant associations* in the halophytic aquatic habitats of Azerbaijan.

Sample area No	762	763	764	765	766	767	768	769	770	771	Life form	Random income
Area size (m^2)	16	16	16	16	16	25	25	25	16	16		
Altitude (m)	45	45	45	60	70	70	60	60	120	130		
Inclination (%)	1	2	2	2	3	3	2	1	1	2		
Weed height (cm)	15	20	15	20	15	10	10	12	12	15		
Soil type	Ş*	Ş*	Ş*	Ş*	Ş*	Ş*	Ş*	Ş*	Ş*	Ş*		
Number of species	3	3	4	3	3	4	3	4	3	3		
Vegetation cover %	30	40	50	40	40	40	45	45	30	40		
Characteristic taxa of the association:												
Halocnemum strobilaceum	33	33	23	22	33	33	34	32	33	22	Ch	V
Sample area No	772	773	774	775	776	777	778	779	780	781		
Tamarix parviflora	22	11	+1	11	11	22	33	23	33	11	Ph	V

Tamarix ramosissima	+1	-	11	-	-	-	-	-	-	+1	Ph	II
Juncus littoralis	11	22	+1	11	+1	11	+1	+1	-	-	Ch	IV
Sample area No	782	783	784	785	786	787	788	789	790	791		
Limonium meyeri	-	-	-	+1	-	+1	+1	+1	+1	-	Hk	III
Petrosimonia brachiata	+	+	11	-	-	+1	+1	+1	-	+1	Th	IV
Sample area No	792	793	794	795	796	797	798	799	800	801		
Halimione verrucifera	33	22	11	23	23	32	34	33	23	22	Hk	V
Spergularia marina	+1	11	+	-	-	+1	-	-	-	+1	Hk	III
Sample area No	802	803	804	805	806	807	808	809	810	811		
Juncus littoralis	33	34	44	33	32	11	23	+1	33	22	Ch	V
Halimione verrucifera	11	+1	11	+1	+	22	+1	-	+1	-	Hk	IV
Sample area No	812	813	814	815	816	817	818	819	820	821		
Juncus littoralis	33	11	+1	-	33	23	33	34	22	+1	Ch	V
Limonium gmelinii	11	11	22	33	+1	-	-	+1	+1	22	Hk	IV
Sample area No	822	823	824	825	826	827	828	829	830	831		
Tamarix ramosissima	33	22	34	44	33	22	33	34	32	33	Ph	V
Aeluropus littoralis	11	+1	+	-	+1	11	+1	+1	-	+1	Ch	IV
Sample area No	832	833	834	835	836	837	838	839	840	841		
Carex extensa	22	33	+1	-	22	33	44	22	11	+1	Hk	V
Salicornia europaea	-	+1	11	22	+1	-	+	+1	12	22	Th	IV
Sample area No	842	843	844	845	846	847	848	849	850	851		
Juncus maritimus	33	34	23	33	34	34	22	11	23	33	Ch	V
Atropis gigantea	+1	+1	+1	+1	+1	-	-	-	+1	-	Hk	III
Sample area No	852	853	854	855	856	857	858	859	860	861		
Phragmites australis	44	34	33	33	44	34	33	33	22	33	Hk	V
Juncus maritimus	+1	+1	+1	+	-	+1	+1	+	11	11	Ch	V
Sample area No	862	863	864	865	866	867	868	869	870	871		
Carex extensa	+1	+1	11	33	33	22	11	23	22	+1	Hk	IV
Halocnemum strobilaceum	11	22	11	+1	+1	+1	+1	-	-	22	Ch	III
Sample area No	872	873	874	875	876	877	878	879	880	881		
Alopecurus ventricosus	33	44	34	33	34	23	+1	+1	34	44	Hk	V
Asrostis distans	+1	+1	-	+1	11	+1	+1	11	-	-	Hk	IV
Sample area No	882	883	884	885	886	887	888	889	890	891		
Juncus littoralis	33	+1	11	23	22	33	11	+1	+1	44	Ch	V
Aeluropus littoralis	+1	22	11	-	+1	-	11	11	11	+1	Hk	IV
Sample area No	892	893	894	895	896	897	898	899	900	901		
Juncus acutus	22	23	+1	11	23	11	34	22	23	33	Ch	V

Phragmites communis	+1	-	11	11	-	+1	-	+1	+1	-	Hk	III
Sample area No	902	903	904	905	906	907	908	909	910	911		
Juncus gerardi	11	+1	+1	33	33	22	22	34	11	23	Ch	V
Juncus acutus	11	22	23	-	-	11	-	-	+1	+1	Ch	III
Sample area No	912	913	914	915	916	917	918	919	920	921		
Frankenia hirsuta	33	33	33	32	33	33	+1	12	11	22	Hk	V
Salsola crassa	+	+	+1	-	+1	+	+	+	-	+	Th	IV
Salicornia europaea	-	+	-	+	-	-	-	+	+	+	Th	III
Hordeum hytrix	+	-	-	-	+	-	+	+	-	-	Th	II
Accompanying taxa												
Halimione portulacoides	11	11	+	22	+	11	11	+1	+	11	Hk	V
Hordeum hytrix	11	+1	22	-	11	11	+1	+	-	-	Th	IV
Limonium angusifolium	-	-	+1	+	-	+	-	+1	+	+	Hk	III
Crypsis aculeata				+					+		Th	I
Lycium ruthenicum	-	-	+	-	-	-	+	-	-	-	Ch	I
Salsola soda	-	-	-	-	-	+	-	-	+1	+	Th	I
Oenanthe fistulosa	-	-	-	+1	-	-	+1	-	-	+1	Hk	II
Inula viscosa	-	+1	+1	-	-	-	-	-	-	-	Hk	I
Polypogon monspeliensis	-	-	-	+	+1	-	11	-	+1	+	Hk	III
Artemisia santonicum	+1	-	+1	-	-	-	-	+1	-	-	Hk	II

**Phytocenological characteristics of the Halocnemetum strobilacei Oberd 1957 , Spergulario-Halimionetum verrucciferae Musayev & Atamov 2013, Junco marittimi-Tamaricietum ramosissimae Musayev & Atamov 2013, Halimione verrucifera-Juncetum littoralisae MM & VA 2024, Limonio meyeri -Juncetum littoralisae MM VA 2024, Tamaricetum ramosissimae Grossheim 1929, Carici extenso-Salicornietea europaeae (Tx. in Tx. & Oberd. 1958) Julve 1993, Juncetum maritimum (Rubel 1930) Pignatti 1953, Phragmito-Juncetum maritimi Korzh.et Kljukin 1990, Carici extenso-Halocnemetum strobilacei Vural, Duman & al. 1994, Alopecuretum ventricosa Musayev & Atamov 2013, Juncetum litoralisae Musayev & Atamov 2013, Juncetum acutusae Musayev & Atamov 2013, Juncetum gerardiae Musayev & Atamov 2013, Salicornio europeo-Halocnemetum strobilacei Musayev & Atamov 2013, Franketum hirsutae Musayev & Atamov 2013associations.*

2. *Junco marittimi-Tamaricietum ramosissimae* Musayev & Atamov 2024 ass.nova.

In the Shirvan Plain, Kur-Araz Plain and around the salty lakes in the Samur-Davachi Plain, the vegetation cover amoiunted to 40-90% and the vegetation cover varied between 20-150 cm. The accompanying species were: Tamarix ramosissima, Juncus littoralis, Limonium meyeri, Petrosimonia brachiata, Aster tripolium, Hordeum hystrix, Polypogon monspeliensis, Imperata cylindrica, Halocnemum strobilaceum, Halimione portulacoides, Juncus maritimus, and Elymus elongatus (Table 2).

Fig. 2b illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participations of phanerophytes, xamophytes, therophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered in the sample areas, which is due to the

chemical composition of the soil and water environment in which the association spreads.

3. *Spergulario-Halimionetum verruciferae* Musayev & Atamov 2013

In the moist, fertile forests and swamps of the Khazar Plain, Absheron Peninsula, Qobustan, Kur-Araz Plain, Bozdag, and Nakchivan, the vegetation cover of that association was 60-70%, while the varied between 5-30 cm. The accompanying species were: Halimione verrucifera, Spergularia marina, Halocnemum strobilaceum, Aeluropus littoralis, Salicornia europaea, Juncus maritimus, Limonium gmelini, Hordeum hystrix , and Crypsis aculeata (Table 2).

Fig. 2c illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participations of trophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is due to the chemical composition of the soil and water environment in which the association spreads.

4. *Halimione verrucifera-Juncetum littoralisae* Musayev & Atamov 2024 ass.nova

In the Absheron Peninsula and around Lake Masazır, in the swampy areas around Lake Hacıqabul and Acınohur, the vegetation cover was 60-90% and the varied between 60-100 cm. The following species participated in that association: Juncus littoralis, Halimione verrucifera, Limonium suffruticosum, L. caspium, L. meyeri, Petrosimonia brachiata, Aeluropus littoralis, Frankenia hirsuta, Lycium ruthenicum, Salsola soda (Table 2).

Fig. 2d illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of therophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is due to the chemical composition of the soil and water environment in which the association spreads.

5. *Limonio meyeri-Juncetum littoralisae* Musayev & Atamov 2024 ass.nova

In the Absheron Peninsula, Kur-Araz, Hazar and Samur-Devachi plains, lakeside salt marsh areas, the degree of plant cover varies between 60-90% and plant height varies between 80-100 cm. The flora of the union includes:, Limonium meyeri, Limonium gmelinii, Atriplex hastata, Aeluropus littoralis, Juncus littoralis Oenanthe fustulosa, Inula viscosa, Petrosimonia brachiata etc. taxa (Table 2).

Fig. 2e illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of therophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is due to the chemical composition of the soil and water environment in which the association spreads.

6. *Tamaricetum ramosissimae* Grossheim 1929

That association occurred in Samur- Davaci, Khazar Plain, Absheron Pninsula, Bozdağ Range, Kür-Araz Plain, Alazan- Ayriçay, Minor Caucasus, and Lankaran Plain, on humid and inundated coasts and around irrigation channels. The vegetation cover in the coastal sands was 40- 100%, the projection cover 100-200 (350) cm, and the most common taxa were: Tamarix ramosissima, Aeluropus littoralis, Polypogon monspeliensis, Atropis gigantea (Table 2, Fig. 3a).

Fig. 3a illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of phanerophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sampe areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

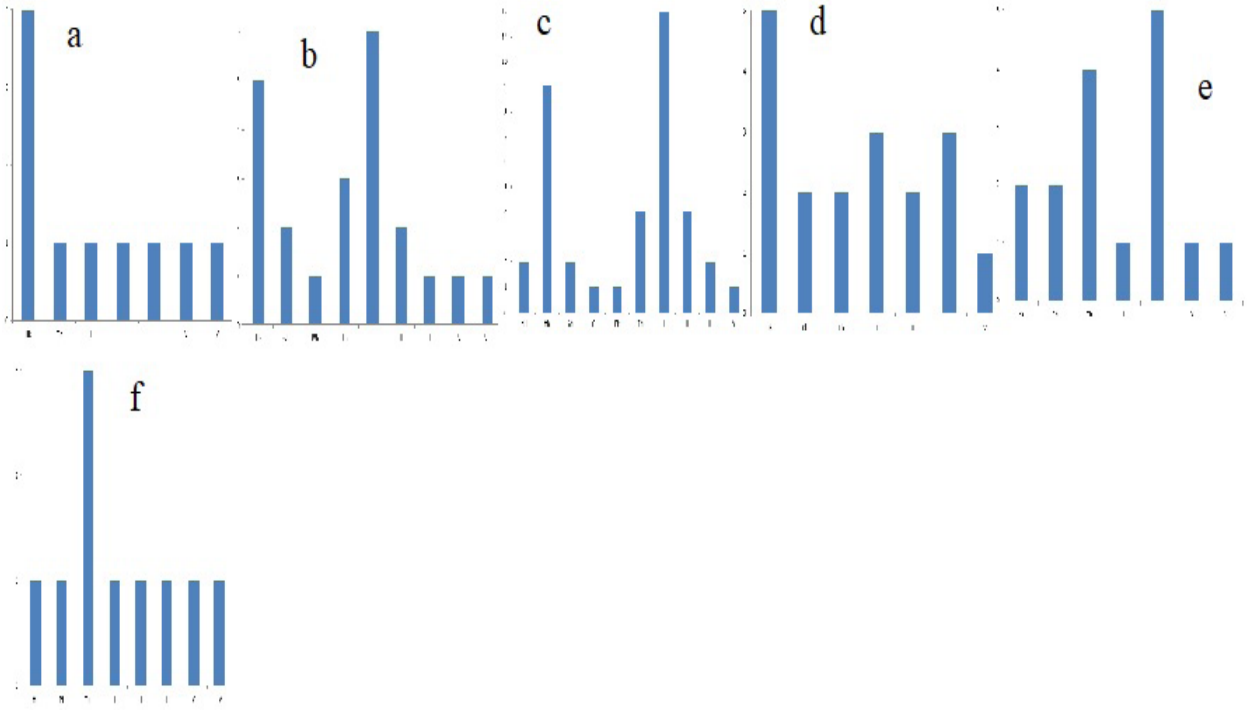

Figure 3. Ranking of the taxa participating in the glandular plant associations in the halophytic aquatic habitats according to life forms and occurrence: a, *Tamaricetum ramosissimae*; b, *Carici extenso-Salicornietum europae*; c, *Juncetum maritimum*; d, *Phragmito-Juncetum maritimi*; e, *Carici extenso-Halocnemetum strobilacei*.

7. *Carici extenso-Salicornietum europaea* (Tx. in Tx. & Oberd. 1958) Julve 1993

That association was found in the Absheron Peninsula, Qobustan, around Hacıkabul Lake, Kur-Araz Plain, and Acınohur Lake's salt marshes. It consisted of the following taxa: *Atropis gigantea*, *A. bulbosa*, *Hordeum hystrix*, *Suaeda altissima*, *Suaeda prostrata*, *Artemisia santonicum*, *Frankenia hirsuta, Halocnemum strobilaceum* (Table 2).

Fig. 3b illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participations of therophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

8. *Juncetum maritimi* (Rubel 1930) Pignatti 1953

It has been observed that it spreads in swampy areas on the shores of halophytic lakes, the vegetation cover is between 70-80%, the plant height is between 100-120 cm and the number of taxa varies between 2 and 9. It has been determined that *Juncus maritimus, Atropis gigantea, Carex divisa, Limonium meyeri, Aeluropus littoralis, Elymus repens, Paspalium paspaloides, Typha domingensis, Schoenoplectus lacustris* and other taxa participate in its flora(Table 2, Fig. 3b).

Fig. 3c illustrates the life forms of this union that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of hydrophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

***9. Phragmito-Juncetum maritimae* Korzh.et Kljukin 1990**

That association was widepread along the coast of the Caspian Sea of Birli, especially in the coastal swamps close to Shirvan, Masali and Lankaran districts. Vegetation cover was 100%. Along with *Phragmites australis* and *Juncus*

maritimus which dominated in the association, such taxa as *Carex extensa*, *Halimione verrucifera*, *Juncus littoralis* also participated in the phytoceneological structure of the association (Table 2).

Fig. 3d illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of chamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, wich is related to the chemical composition of the soil and water environment in which the association spreads.

10. *Carici extenso-Halocnemetum strobilacei* Vural, Duman & al. 1994

That association was found on the edges of salt lakes. The vegetation cover varied between 50-80% and the projection cover between 10-60 cm. the association included such taxa as *Halocnemum strobilaceum*, *Carex extensa*, *Halimione verrucifera*, *Limonium meyeri*, *Juncus maritimus*, *Aster tripolium*, *Phragmites australis*, and *Tamarix ramosissima* (Table 2).

Fig. 3e illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of therophytes, phanerophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

11. *Alopecuretum ventricosae* Musayev & Atamov 2013

The vegetation cover of that association was 60-90%, the vegetation cover was 60-80 cm, and the number of taxa encountered within the association varied between 2-5. That association spread in the Khazar Plain, Absheron Peninsula, Kür-Araz Plain, Qobustan, Bozdağ, Kür-Araz and Naxçıvan plains. It grew in moist and salty areas. Its composition included the following taxa: *Agsrostis distans*, *Hordeum hystrix*, *Eleocharis uniglumis*, *Bolboschoenus maritimus* (Table 2).

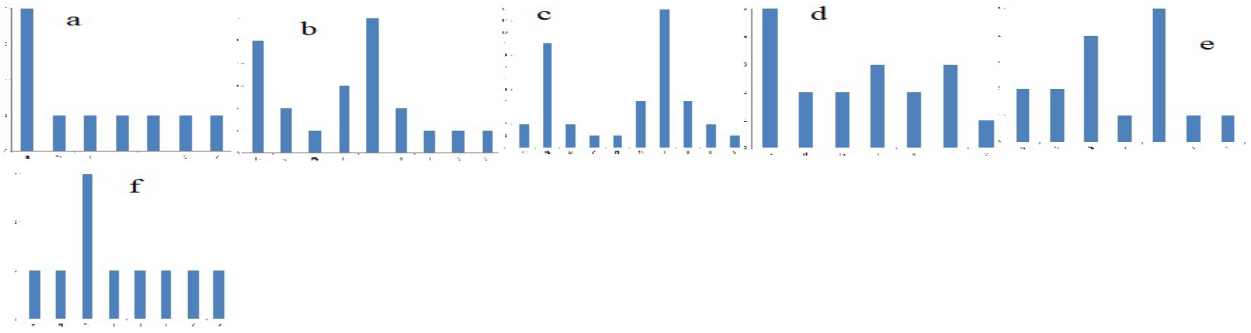

Figure. 4. Ranking of the taxa participating in the glandular plant associations in the halophytic aquatic habitats according to life forms and occurrence: a, *Alopecuretum ventricosa*; b, *Juncetum litoralisae*; c, *Juncetum acutusae*; d, *Juncetum gerardiae*; e, *Salicornio europeo-Halocnemetum strobilacei*; f, *Franketum hirsutae.*

Fig. 4a illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of therophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

12. *Juncetum littoralisae* Musayev & Atamov 2013

That association was mostly found in the substantial salty sands along the Khazar coast, seldom on the Bozqir Plateau and the Kur-Araz Plain. Its vegetation cover varied between 50-80% and the projection cover was between 60-100 cm. Along with the dominant species, the most common taxa were: *Aeluropus littoralis*, *Hordeum hystrix*, *Cyperus longus*, *Cirsium italicum*, *Spergularia media*, *Atropis gigantea*,

Artemisia santonicum, *Tamarix ramosissima*, *Bolboschoenus maritimus* var. *maritimus*, *Atriplex hastata* (Table 2).

Fig. 4.b illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of therophytes, phanerophytes, xamophytes, and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

13. *Juncetum acutusae* Musayev & Atamov 2013

In the Samur-Deveçi, Abşeron Peninsula, Kur-Araz and Lankaran plains, and especially along the Khazar coast, in humid flat sandy areas and water places 0-10 (20) cm deep, the vegetation cover of that association reached 40- 70(90) %, and its projection cover 100-120. *Phragmites communis*, *Tamarix ramosissima*, *Schoenoplectus lacustris*, *Iris pseudacorus*, *Veronica anagallis-aquatica*, *Sparganium erectum*, *Juncus gerardi*, *Triglochin palustre*, *Zannichellia palustris*, *Plantago maritima*, *Salicornia europaea*, *Carex distans*, *Eragrostis collina*, *Falcaria falcarioides*, *Ruppia maritima*, *Frankenia hirsuta*, *Suaeda altissima*, and *Scirpoides holoschoenus* were the participating taxa in that association (Table 2, Fig. 4b).

Fig. 4c illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of therophytes, xamophytes, hydrophytes, geophytes, and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

14. *Juncetum gerardiae* Musayev & Atamov 2013

Along the lakes, streams, canals and flat humid, sandy and swampy meadows of Azerbaijan, from the plains to the central mountain range, the vegetation cover of that association was between 40-70 (100) cm and the taxa *Juncus acutus*, *Plantago maritima*, *Phragmites australis*, *Cynodon dactylon*, *Bolboschoenus maritimus*, and *Schoenoplectus lacustris* participated in the phytocenological structure, along with the characteristic species of the association.

Juncetum associations are most typical and widely distributed in the swamps. They thrive there in the form of small islands in the Absheron Peninsula, the Kur-Araz and Khazar plains. *Juncus gerardi*, one of the characteristic species of the association, adds dark hues to the general appearance of the association when it start flowering from mid-July. When the species *Inula aspera* and *Taraxacum confusum* are in bloom, the association becomes more visible in the swamps and places with quickly drying water. *Cynodon dactylon* mostly predominates the association. Since these lands are used as grazing areas for various species of cattle and sheep, such as *Juncus maritimus*, in spring, forms small, green, coma-shaped patches (Table 2).

Fig. 4d illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of therophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

15. *Salicornio europaea-Halocnemetum strobilacei* Musayev & Atamov 2013

That association is found on the edges of swamps in the Absheron Peninsula, Samur-Davachi, Kur-Araz and Khazar plains, and within the swamps, where the amount of salt increases in spring.

Halocnemum strobilaceum and *Suaeda microphylla* are the characteristic species of the association. Most of these plants appear in places where they grow well on dry soil. In literary sources, these assocation have also been shown as spreading over wide areas, starting from the December. Sea to Central Asia (Yurdakulol 1974;

Yurdakulol & Ercoþkun 1990).

The vegetation cover of the association varies between 30-50%. As the amount of salt increases in the upper soil layers in spring, the areas between some plants, such as *Holocnemum strobilaceum* and *Suaeda mycrophylla*, which are the characteristic species of the association, become bare and the species spread. They thrive in places where the amount of salt is the highest. As the soil dries out, the salt left by the evaporating water coming from the lower to the upper soil layers hardens completely the upper soil layers and amounts to more than 3%. Typical examples of such patches could be seen around Böyük Şor, Masazır (Absheron Peninsula), Hacıkabul, and Acınohur Lake (Table 2, Fig.4c).

Fig. 4e illustrates the life form of the association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of therophytes, xamophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

16. *Franketum hirsutae* Musayev & Atamov 2013

That association could be found locally around the Absheron Peninsula, Kür-Araz, Samur-Deveci and the salty lakes of the Khazar Plain. It was encountered in swamps, between halophyte units and *Artemisietum* associations.

After drying up of the swamp, the association emerges where the water level is not very deep. Its vegetation cover varies between 30-50(60)%. In July, the characteristic forms of that associatin bloom and it looks more lively and attractive (Table 2).

Fig. 4f illustrates the life forms of that association and the frequency of occurrence of the species in the sample areas. Observations have shown that in the phytocenological structure of that association, with the participation of therophytes, phanerophytes and hemicryptophytes, species with very different frequency of occurrence have been encountered within the sample areas, which is related to the chemical composition of the soil and water environment in which the association spreads.

4. CONCLUSION

Five hundred and two taxa belonging to 62 families and 208 genus were found in the water-swamp flora of Azerbaijan. Taxa belonging to the families of *Poaceae*, *Cyperaceae*, *Ranunculaceae*, *Fabaceae*, *Potamogetonaceae*, *Juncaceae*, and *Salicaceae* were widestrepresented. The genus *Carex*, *Ranunculus*, *Juncus*, *Potamogeton*, *Schoenoplectus*, *Cyperus* and *Salix* contained the greatest number of taxa.

The *Poaceae* family manifested 47 genus, followed by *Cyperaceae* with 18, *Cenopodiaceae* and *Fabaceae* with nine each, *Lamiaceae* and *Asteraceae* with seven each, *Brassicaceae* and *Apiaceae* with five each, and *Potamogetonaceae* and *Scrophuloriaceae* families represented by four each. A total of 68 genus with three or fewer species were encountered.

Syntaxonomic classifications made by the authors of this study have shown that the aquatic communities of Azerbaijan total 95 plant associations: 12 classes, 16 orders, 26 alliances (Musayev, Atamov et al, 2015; Atamov, 2022). During the vegetation studies of the region, the water-swamp ecosystems seemed to have been investigated extensively, but the world-wide applied methods were not used in the classification of the vegetation, which was based only on the dominance principle, without taking into account the habitat types, phytosociological structure and ecological conditions. A further detailed research of the large lakes and aquatic communities within the borders of Azerbaijan will undoubtedly provide new floristic records and reveal new plant associations.

According to the obtained results, the water-swamp ecosystems have been extensively investigated in the earlier studies, but without using the world-wide applied methods in the classification of vegetation. The earlier studies have been only based on the principle of dominance, without taking into consideration the habitats, phytocenological structure of the vegetation and ecological conditions.

A further detailed investigation of the large lake and water-swamp ecosystems

within Azerbaijan would certainly reveal new plant associations to supplement the former flora records.

In the study area, the widest spread and most characteristic were: *Halocnemum strobilacei* Oberd 1957, *Junco marittimi-Tamaricietum ramosissimae* Musayev & Atamov 2024, *Spergulario-Halimionetum verruciferae* Musayev & Atamov 2013, *Halimione verrucifera-Juncetum littoralisae* Musayev & Atamov 2024, *Limonio meyeri-Juncetum littoralisae* Musayev & Atamov 2024, *Tamaricetum ramosissimae* Grosheimi 1929, *Juncetum acutusae* Musayev & Atamov 20133**,** *Carici extenso-Salicornietea europaeae* (Tx. in Tx. & Oberd. 1958) Julve 1993, *Juncetum maritimum* Pignatti 1953, *Phragmito-Juncetum maritime* Korzh.et Kljukin 1990, *Carici extenso-Halocnemum strobilacei* Vural, Duman & al. 1994, *Alopecuretum ventricosa* Musayev & Atamov 2013, *Juncetum littoralis* Musayev & Atamov 2013, *Juncetum acutusae* Musayev & Atamov 2013, *Juncetum gerardiae* Musayev & Atamov 2013, *Salicornio europea-Halocnemum strobilacei* Musayev & Atamov 2013, and *Franketum hirsutae* Musayev & Atamov 2013. In conclusion, the water-swamp communities were divided into five types according to habitat diversity: 1) in-water habitats (33); 2) coast marsh (31); 3) wet grass (13); 4) aquatic forest (8), 5) hydrohalophytes (16 plant associations).

As a result of the study of phytosociological properties of plant associations in halophytic wetlands of Azerbaijan, the phytosociological properties of the following associations of the region were identified:

Halimione verrucifera-Juncetum littoralisae Musayev & Atamov 2024 ass.nova, *Limonieto meyeri-Juncetum littoralisae* Musayev & Atamov 2024 ass.nova, *Tamaricetum ramosissimae* Grosheimi 1929, *Juncetum acutusae* Musayev & Atamov 2013, *Halocnemetum strobilacei* Oberd 1957, *Junco marittimi-Tamaricetum ramosissimae* Musayev & Atamov 2013, *Carici extenso-Salicornietum europaeae* (Tx. in Tx. & Oberd, 1958) Julve, *Alopocuretum verticosae* Musayev & Atamov 2013, *Franketum hirsutae* MM & VA 2013, *Juncetum acutusae* Musayev & Atamov 2013, *Juncetum gerardieae* Musayev & Atamov 2013, *Juncetum littoralisae* Musayev & Atamov 2013, *Salicotnio europeo-Halocnemetum strobilocei* Musayev & Atamov 2013, *Spergulario-Halimionetum verruciferae* Musayev & Atamov 2013.

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