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Floristic Composition of Lake Al-Asfar, Alahsa, Saudi Arabia

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Abstract: The vegetation communities of the shores of Lake Al-Asfar; a large salt lake in Al-Hofouf, Al-Hassa, Saudi Arabia; were studied. The aim of the research was to study the relationship between the distribution of vegetation along salt lake shores in relation to soil and climatic conditions. Four distinct lake shore habitats were examined. A total of 72 stands along the study area of the lake were investigated. It was concluded that soil texture, pH, soil moisture content, mineralization as well as the climatic factors were likely to be key factor in determining the distribution of vegetation communities along the shores and habitats of the lake. The study included: list of species and their families, growth forms, frequencies, densities, abundances, recurrence, diversity richness, heterogeneity and evenness in each of the four habitats along the lake. A total of 39 plant species belonging to 20 families were identified from the four studied habitats. More than 61% of the species recorded were perennial shrubs (PSH). Diversity richness indices were 2.02, 2.22, 3.05 and 4.91 in the inundated wet zone (Site I), moist zone (Site II), semi-dry zone (Site III) and arid zone (Site IV), respectively. Heterogeneity was from 2.01-3.10 (Shannon-H') and evenness was 0.89 to 0.98. The heterogeneity in species composition among the sites was moderate indicating that each site has its own unique flora. Those dominant communities occurring on highly and moderate saline soils of the four habitats (I, II, III and IV) along the lake included *Phragmites australis*, *Halocnemum strobilaceum*, *Zygophyllum mandavillei* and *Haloxylon salicornicum*, respectively.

Key words: Species composition, diversity, richness, frequency, importance value, heterogeneity, cover

INTRODUCTION

Environmental gradients and the distribution of vegetation along the shores of lakes have been related and directly associated with human activity. Among the environments that exhibit very distinct environmental gradients are the coastal and the inland salt marshes, coastlines and area of succession following the major disturbance (Fernandez-Gimenez and Allen-Diaz, 2001). The shores of lakes can support a diverse range of flowering plants. Some are tolerant of highly saline soil and ground-water and inundation to various degrees, while others inhabit low salinity soil lenses overlying saline sediments and ground-water. Consequently, vegetation often occurs in distinct zones related to environmental factors (Krüger and Peinemann, 1996) and to the biological characteristics of individual species (Joshi and Iyengar, 1982). Some species can occur across gradients, but their relative dominance may vary. They are, however, subject to physical disturbance through fisheries, birds and animals hunting, mining-related activities; they may be grazed by stock and feral animals; and, they may suffer intermittent perturbations through inundation resulting from episodic rainfall events (Roshier *et al*., 2001).

Disturbances along the shorelines of lakes have also a profound effect on species distribution emergent and woody plants and subsequent low water periods allow many plant species and vegetation types to regenerate from buried seeds (Keddy and Reznicek, 1986). Thus, fluctuating water levels increase the area of shoreline vegetation and create very diverse conditions, which enhanced the diversity of vegetation types and plant species (Hill *et al*., 1998).

In arid and semiarid regions at least, flooding and run off waters create a gradient of improved soil fertility from the dry to wet sites (Barnes *et al*.,1998). Therefore, water may cause a gradient of productivity and thereby a zonation of vegetation in two ways: directly through its availability in the soil water and indirectly by creating a soil fertility gradient (Lenscen *et al*., 1999). Arid environments often support a low vegetation cover. This is thought to be responsible for their fragility and predispose them to decertification under human influences. The vegetation cover is patchily distributed throughout the landscape. Both biotic and abiotic factors are thought to influence the distributive patterns of plant communities (Zhang *et al*., 2005). Inter-relationships between plant communities and environmental factors are complex, reflecting simultaneous changes in factors such

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as ground-water depth, soil moisture, salt content and soil stability. Liu and Zhou (1996) revealed that soil moisture and salt content controlled the distribution pattern of plant communities around Qinghai Province in China. Climate change also has the potential to have major impacts on the lakes including shoreline vegetation (Roshier *et al*., 2001). The difference in the environmental conditions, resources and disturbance are a few of many other factors that influence diversity and dynamics of the vegetation communities (Jafari *et al*., 2003).

Crisman *et al.* (2005) in his study on lakes, concluded that shallow and deep lakes should be considered as a minor function in regulating and determining the structure and composition of the adjacent littoral zones. Responses are complex and critical for the transformation of the different associated vegetation zone along shores of the lakes.

The study was aimed to survey and characterize the plant communities and their vegetation pattern along Lake Al-Asfar, Alahsa, Saudi Arabia in respect to variations of climate and soil parameters.

MATERIALS AND METHODS

The field trips of the study were carried out every month during the period January-December 2007, while the practical analysis of the study was conducted in the Department of Biology, King Faisal University, Saudi Arabia.

Study area

Physiography, geology and description: Geologically, Saudi Arabia is located in the Arabian Shelf which extends to the East of the Arabian Shield. It is made of a sequence of continental and shallow water marine sedimentary rocks that range in age from Cambrian to Pliocene. The municipality of Al-Hassa (Alahsa) constitutes the largest administrative area in the Kingdom of Saudi Arabia. Covering an area of 2500 km in the Southern part of the Eastern Province. The oases of Al-Hofouf and Al-Qatif cover the greater part of the district Al-Hassa. It contains a lot of scattered villages and small towns. Natural water springs are widespread along the Western edge of the oasis from South of Alahsa (Fig. 1).

The area under investigation, Lake Al-Asfar, is situated in Al-Hassa (Alahsa) oasis, which is the largest oasis in the Eastern Province of Saudi Arabia and is located 60 km to the West of the Arabian Gulf (Fig. 1). Lake Al-Asfar is a largest, narrow, man-made freshwater habitat (Al-Nafie, 2008), which running Eastnorth from Al-Hofouf towards Al-Uqair in Saudi Arabia (Al-Hofouf is the largest major city in Al-Hassa).The geographical location of the study area is between 49°10' and 49°55' Eastern longitude and 25°05' and 25°40' Northern latitude (Al-Taher,1999) and is around 110-160 m above sea level (Al-Barrak, 1993). It is formed by run-off from Al-Hassa Oasis and sewage effluent from Al-Hofouf, Abqaiq and numerous small towns and frequently forms the water in the reservoir (Al-Nafie, 2008). Undulating sandy areas are formed as a transitional zone of sand followed by distant forms of sand dunes which are spreading around the shores of the Lake for few kilometers. The Western and Northern shores of the lake are dominated by gravels and rocks, interspersed by deltas where streams disperse into the lake. The Southern and Eastern lake shores, however, are dominated by depositional and fine sand processes. The streams that enter the shores, deposit their sediments in small deltas. These sediments are then reworked to form small dunes on the distant areas on the lake or my blown across the lake to the opposite side (Dreaver *et al*., 1981; Al-Naeem, 2008).

Climate: Climatic data for the study area within the period January to December 2007 was obtained from the weather station of the Department of Meteorology and Civil Aviation, Al-Hofouf Weather Station, Saudi Arabia. Altitude was determined using a Global Positioning System (GPS).

Soil characteristics: Soil samples were taken at three random points from each site as a profile (composite samples) at a depth of 0-25 cm, mixed air-dried and passed through a 2 mm mesh prior to the analysis. Soil texture (%) of the different samples was determined according to Jackson (1967). Percentages of Soil Water Content (SWC) were determined by evaluating weight loss after drying at 105°C for 24 h (Wilde *et al*., 1979). Electrical conductivity; dS m^{-1} (EC) and pH for each sample were determined as a 1:5 dilution in deionized water (Wilde *et al*., 1979). Soil analyses including total dissolved salts; TDS (g L^{-1}), Organic Carbon; OC (%); Total Carbonates; TC (%), Chlorides (g/100 g dry wt.) was analyzed by precipitation as AgCl and titration according to Johnson and Ulrich (1959), sulfates (g/100 g dry wt.) were precipitated gravimetrically and estimated according to Wilde *et al.* (1979), sodium, potassium and calcium (g/100 g dry wt.) were determined in the 1:5 soil extract by flame photometer method (Jenway, PFP-7) according to Williams and Twine (1960).

Field work and vegetation analysis: Following a review of data from a preliminary survey of 14 sites along the lake area, four gradient sites were selected for detailed study (Fig. 1). The sites selected for study reflected the range of

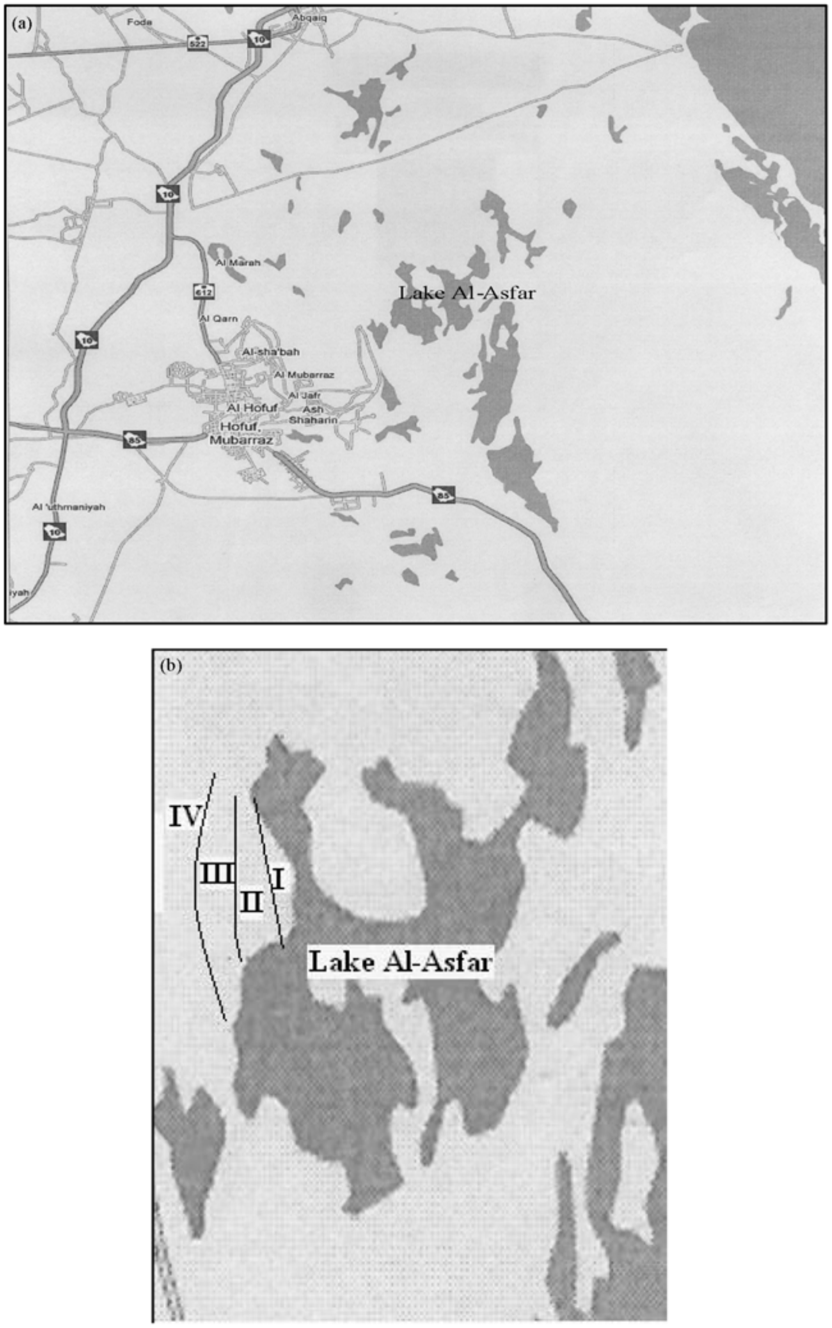

Fig. 1: Location map showing (a) general view of Lake Al-Asfar in Alahsa, Saudi Arabia and (b) different sites along the lake (I: Site I, II: Site II, III: Site III, IV: Site IV)

shore types identified and included inundated wet zone (site I), moist zone (site II), exposed semi-dry zone (site III) and arid zone (site IV). Detailed field surveys were conducted during summer and winter periods of the year 2007. At each site, parallel transects were established 5 m apart and perpendicular to the lake shore. Two transects were used at each site. Each transect commenced at a point immediately below which the lake surface was completely nonvegetated. The lengths of transects, therefore, varied with the slope of the lake shores and ranged from 10 m at site I to 100 m at sites III and IV. Starting from the lake edge, a stand of five

2×2 m^{-2} quadrats was placed along each transect at each successive point. A total of 72 stands were surveyed. Floristic data together with the recurrence (occurrence of the species in the studied quadrats of one site, % and = R) and recurrence index (recurrence in quadrats of all four sites, as a percentage of occurrence = RI) were calculated for each species as described by Kershaw (1974). In each stand, all plant species were listed and the vegetation parameters which included Absolute Density (AD), Relative Density (RD), Absolute Frequency (AF), Relative Frequency (RF), Absolute Abundance (AA) and Relative Abundance (RA) were measured. The sum of the relative values gave the Importance Value Index (IVI) for the different plant species (Braun-Blanquet, 1965). The diversity indices of plant species were determined including species richness according to:

$$\text{Margalef's richness index} = (S-1)/\text{In } N$$

where, S is total number of species in all sampling units and N is total number of individuals, diversity index by using Shannon Wiener diversity index (H') and evenness or equitability index (E) according to:

$$\text{Sheldon's evenness index} = \text{log base } H'/s$$

where, H' is Shannon-Wiener index and s is total number of species (Shaltout and El-Ghareeb, 1992; Barnes *et al*., 1998). The plant species were identified using the references of Mandaville (1965, 1984, 1986, 1990); Täckholm (1974), Batanouny (1979), Chaudhary and Cope (1983) and Collenette (1999).

RESULTS

Climate: Climatic records of the studied area for the period January to December 2007 were shown in Fig. 2. Scanty and variable rainfall is a common feature. The highest rainfall records of Alahsa Region were 13.7 and 15.1 mm during January and February 2007. The period from June to end of September was completely rainless. The area of Alahsa is characterized by an arid and high temperature. Temperature records in Fig. 2 show that the period May to September varied from 30.6 to 35.2°C, however, the lowest records of temperature were noticed during January and February 2007 (15.5, 16.7°C). Relative humidity is relatively high, especially during the period May to September and frequently reaches 63% in August. The lowest record of relative humidity (28%) was showed in December 2007.

Soil characteristics: Soil characteristics of each of the four studied habitats are shown in Table 1 and 2. Soil texture of the different habitats was of fine sand except in the soil of the inundated wet zone (site I) which tended to have much higher soil silt content than all other sites

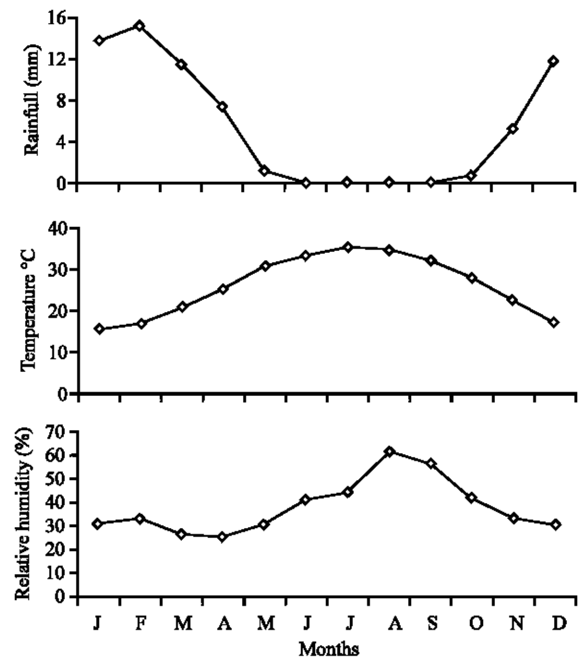

Fig. 2: Climatic records of rainfall (mm $month^{-1}$), temperature (°C) and relative humidity (%) of Al-Hofouf, Saudi Arabia during January-December 2007

Table 1: Regional positioning habitat types and their soil properties along Lake Al-Asfar, Al-Hofouf, Saudi Arabia

				Granulometric analysis (%)							
Site No.	Coordinates	Habitat type	Altitude (a.s.l.) m	Gravel	Coarse sand	Fine sand	Silt	Soil texture	SWC (%)	pH	EC dS m^{-1}
I	25°30'938"N 49°49'835"E	Inundated wet zone	111	0.2	11.3	43.1	45.4	Silt	10.6	7.6	9.9
II	25°32'132"N 49°48'316"E	Moist zone	110	0.5	17.5	43.8	38.2	Fine sand	7.5	7.5	9.7
III	25°33'157"N 49°49'147"E	Semi-dry zone	116	1.6	29.8	46.7	21.9	Fine sand	6.9	7.4	8.3
IV	25°34'795"N 49°47'606"E	Arid zone	114	1.9	34.7	52.7	10.7	Fine sand	4.7	7.7	10.8

a.s.l.: Above sea level, SWC: Soil water content, EC: Electrical conductivity, TDS: Total dissolved salts, OC: Organic carbon, TC: Total carbonates

(45.4%). Of the measured soil parameters, soil pH, EC and TDS were highly variable between the studied four sites, ranging between 7.4-7.8, 8.3-10.8 dS m^{-1} and 81.2-106.3 g L^{-1}, respectively (Table 1). The higher values of soil water contents among the different sites were correlated with the soil silty nature which is associated to the inundated wet zone habitat (site I). Soil organic carbon content was relatively low at all sites but slightly higher at site I and IV. Data of Table 2 showed that different soil samples recorded relatively higher values of Cl^{-}, $SO4^{-2}$ and Ca^{+2} (0.93, 0.79, 0.06 g/100 g dry wt., respectively). It was noted that soils at Site I tended to have much higher soil silt content than those recorded in all other sites (45.4%).

Vegetation floristic features: A total of 39 plant species belonging to 20 families were identified from the different studied habitats of Lake Al-Asfar (Table 3). Chenopodiaceae included 30.77% of the total species with modest RI ranged between 5-15% and

Table 2: Regional positioning habitat types and their soil properties along Lake Al-Asfar, Al-Hofouf, Saudi Arabia

Site No.	Coordinate	Habitat type	Altitude (a.s.l.) m	TDS (g L^{-1})	OC (%)	TC (%)	Cl^{-}	$SO4^{-2}$	Na^{+}	K^{+}	Ca^{+2}
							(g/100 g dry wt.)				
I	25°30'938"N 49°49'835"E	Inundated wet zone	111	89.7	0.36	1.25	0.72	0.71	0.88	0.24	0.05
II	25°32'132"N 49°48'316"E	Moist zone	110	85.5	0.28	0.83	0.79	0.65	0.68	0.19	0.02
III	25°33'157"N 49°49'147"E	Semi-dry zone	116	81.2	0.21	0.91	0.61	0.51	0.52	0.16	0.01
IV	25°34'795"N 49°47'606"E	Arid zone	114	106.3	0.33	1.03	0.93	0.79	0.71	0.21	0.06

a.s.l.: Above sea level, SWC: Soil water content, EC: Electrical conductivity, TDS: Total dissolved salts, OC: Organic carbon, TC: Total carbonates

Table 3: List of families and their species, life forms, Recurrence (R) and Recurrence Index (RI) based on the record in 5 studied quadrats 2×2 m^2 in each site

			Site					
Family	Plant species	Life form	I	II	III	IV	R	RI
Amaranthaceae	*Aerva javanica* (Burm.f.) Juss. Ex Schult	PSH	-	-	-	1	1	5
Asclepiadaceae	*Leptadenia pyrotechnica* (Forssk.) Decne	PSH	-	-	-	1	1	5
Asteraceae	*Launaea mucronata* (Forssk.) Muschl.	PH	-	-	-	1	1	5
Boraginaceae	*Heliotropium bacciferum* (Forssk.)	PSH	-	-	-	1	1	5
Boraginaceae	*Heliotropium europaeum* L.	AH	-	-	-	1	1	5
Brassicaceae	*Farsetia stylosa* R.Br.	PSH	-	-	-	1	1	5
Capparaceae	*Cleome droserifolia* (Forssk.)	PSH	-	-	-	1	1	5
Chenopodiaceae	*Anabasis setifera* Moq.	PSH	-	-	1	-	1	5
Chenopodiaceae	*Atriplex leucoclada* Boiss.	PSH	-	-	-	1	1	5
Chenopodiaceae	*Chenopodium album* L.	AH	-	1	-	-	1	5
Chenopodiaceae	*Cornulaca monacantha* Del.	PSH	-	1	-	1	2	10
Chenopodiaceae	*Halocnemum strbilaceum* (Pall.) M.Bieb.	PSH	1	-	-	-	1	5
Chenopodiaceae	*Halopeplis perfoliata* (Forssk.)Bunge Ex Asch.	PR	2	-	-	-	2	10
Chenopodiaceae	*Haloxylon salicornicum* (Moq.) Bunge ex Boiss.	PSH	-	-	-	2	2	10
Chenopodiaceae	*Salsola arabica* Botsch	PSH	-	-	1	-	1	5
Chenopodiaceae	*Salsola impricata* Forssk.	PSH	-	-	1	-	1	5
Chenopodiaceae	*Seidlitzia rosmarinus* Ehrenb. Ex Bunge	PSH	1	1	-	-	2	10
Chenopodiaceae	*Suaeda maritima* (L.)	AH	1	-	1	-	2	10
Chenopodiaceae	*Suaeda vermiculata* Forssk. ex J.F. Gmel.	PSH	1	1	1	-	3	15
Cyperaceae	*Cyperus conglomeratus* Rottb.	PS	1	1	-	-	2	10
Euphorbiaceae	*Euphorbia larica* Boiss	PSH	-	-	1	1	2	10
Gramineae	*Phragmites australis* (Cav.) Trim. Ex Steud	PG	2	-	-	-	2	10
Juncaceae	*Juncus rigidus* Desf.	PR	1	-	-	-	1	5
Leguminosae	*Acacia tortilis* (Forssk.) Hayne	PSH	-	-	-	1	1	5
Orobanchaceae	*Orobanche cernua* Loefl.	Pa	-	-	1	-	1	5
Plumbaginaceae	*Limonium axillare* (Forssk.) Kuntze	PSH	-	1	-	-	1	5
Poaceae	*Lasiurus scindicus* Henrard	PSH	-	-	-	1	1	5
Poaceae	*Lolium rigidum* Gaudin	AH	-	-	-	1	1	5
Poaceae	*Panicum turgidum* Forssk.	PG	-	-	-	1	1	5
Poaceae	*Pennisetum divisum* (J.F.Gmel.) Henrard	PG	-	-	-	1	1	5
Poaceae	*Sporobolus spicatus* (vahl.) Kunth	PH	-	-	-	1	1	5
Polygonaceae	*Rumex vesicarius* L.	AH	-	-	-	1	1	5
Resedaceae	*Ochradenus baccatus* Del.	PSH	-	-	-	1	1	5
Solanaceae	*Lycium shawii* Roem. and Schutt	PSH	-	-	-	1	1	5
Tamaricaceae	*Tamarix aphylla* (L.) Karst.	PSH	-	1	1	-	2	10
Zygophyllaceae	*Fagonia indica* Burm	PSH	-	-	1	1	2	10
Zygophyllaceae	*Zygophyllum mandavillei* Hadidi	PSH	-	1	1	1	3	15
Zygophyllaceae	*Zygophyllum qatarense* Hadidi	PSH	-	-	1	-	1	5
Zygophyllaceae	*Zygophyllum simplex* L.	AH	-	1	1	1	3	15

I: Inundated wet zone, II: Moist zone, III: Semi-dry zone and IV: Arid zone. The life forms are: PSH: Perennial shrub, AH: Annual herb, PG: Perennial grass, PR: perennial rush, PS: Perennial sedge, PH: Perennial herb, Pa: Parasite

Suaeda vermiculata attained the highest RI value among the family. Poaceae was represented as the second major family (12.82%) with relatively low RI (5%). Zygophyllaceae ranked the third and its species were about 10.26%. *Zygophyllum mandavillei* and *Z. simplex* were the dominant species with high RI of 15%. Boraginaceae was represented by two species, whereas there were sixteen families represented by a single species each (Table 3). The growth forms of the studied plant species exhibit a wide variation. Perennial shrubs (PSH) were the predominant growth forms (61.5%)followed by annual herbs AH (15.4%), perennial grasses PG, perennial rushes PR, perennial herbs PH and parasites Pa (Fig. 3).

The studied area along the lake Al-Asfar may be distinguished into four main gradient habitats: (1) inundated wet zone (site I) which is characterized by high abundance AA, frequency AF and importance value index IVI values of species *Phragmites australis* with AA 55%, AF 100%, IVI 108 followed by *Halopeplis perfoliata* with AA 30%, AF 60%, IVI 43.3%; *Juncus rigidus* with AA 35%, AF 20% and IVI 41.6 and *Halocnemum strobilaceum* with AA 25%, AF 40%, IVI 38.5 (Table 4). The other

Table 4: Floristic composition of plant species recorded in investigated sites of Lake Al-Asfar

Site	Plant species	AD (%)	AF (%)	AA (%)	RD (%)	RF (%)	RA (%)	IVI
I	*Halocnemum strbilaceum* (Pall.) M.Bieb.	10	40	25	10.5	14.8	13.2	38.5
	Halopeplis perfoliata (Forssk.)Bunge Ex Asch.	5	60	30	5.3	22.2	15.8	43.3
	Seidlitzia rosmarinus Ehrenb. Ex Bunge	10	20	20	10.5	7.4	10.5	28.4
	Suaeda maritima (L.)	5	10	10	5.3	3.7	5.2	14.2
	Suaeda vermiculata Forssk. ex J.F. Gmel.	5	10	5	5.3	3.7	2.6	11.6
	Cyperus conglomeratus Rottb.	5	10	10	5.3	3.7	5.2	14.2
	Phragmites australis (Cav.) Trim. Ex Steud	40	100	55	42.1	37.0	28.9	108.0
	Juncus rigidus Desf	15	20	35	15.8	7.4	18.4	41.6
II	*Chenopodium album* L.	5	20	10	7.1	5.1	9.5	21.7
	Cornulaca monacantha Del.	10	60	20	14.3	15.4	19.0	48.7
	Cyperus conglomeratus Rottb.	10	60	10	14.3	15.4	9.5	39.2
	Halocnemum strbilaceum (Pall.) M.Bieb.	15	100	25	21.4	25.6	23.8	70.8
	Limonium axillare (Forssk.) Kuntze	5	20	10	7.1	5.1	9.5	21.7
	Seidlitzia rosmarinus Ehrenb. Ex Bunge	5	10	5	7.1	2.6	4.8	14.5
	Suaeda vermiculata Forssk. ex J.F. Gmel.	10	80	15	14.3	20.5	14.3	49.1
	Tamarix aphylla (L.) Karst.	5	20	5	77.1	5.1	4.8	17.0
	Zygophyllum mandavillei Hadidi	5	20	5	7.1	5.1	4.8	17.0
	Zygophyllum simplex L.	5	10	5	7.1	2.6	4.8	14.5
III	*Anabasis setifera* Moq.	15	40	15	13.0	12.9	11.5	37.4
	Euphorbia larica Boiss	5	10	5	4.3	3.2	3.8	11.3
	Fagonia indica Burm	10	10	10	8.7	3.2	7.7	19.6
	Ochradenus baccatus Del.	5	10	5	4.3	3.2	3.8	11.3
	Salsola arabica Botsch	10	20	10	8.7	6.5	7.7	22.9
	Salsola impricata Forssk.	5	10	10	4.3	3.2	7.7	15.2
	Suaeda maritima (L.)	5	10	10	4.3	3.2	7.7	15.2
	Suaeda vermiculata Forssk. ex J.F. Gmel.	5	10	10	4.3	3.2	7.7	15.2
	Tamarix aphylla (L.) Karst.	10	10	5	8.7	3.2	3.8	15.7
	Zygophyllum mandavillei Hadidi	20	100	25	17.4	32.3	19.2	68.8
	Zygophyllum qatarense Hadidi	15	60	15	13.0	19.4	11.5	43.9
	Zygophyllum simplex L.	10	20	10	8.7	6.5	7.7	22.9
IV	*Acacia tortilis* (Forssk.) Hayne	5	10	5	2.1	1.9	2.4	6.4
	Aerva javanica (Burm.f.) Juss. Ex Schult	5	10	10	4.3	1.9	4.9	8.9
	Atriplex leucoclada Boiss.	10	20	10	4.3	3.9	4.9	13.1
	Cleome droserifolia (Forssk.)	5	10	5	2.1	1.9	2.4	6.4
	Cornulaca monacantha Del.	10	10	5	4.3	1.9	2.4	8.6
	Euphorbia larica Boiss	5	10	5	2.1	1.9	2.4	6.4
	Fagonia indica Burm	10	10	5	4.3	1.9	2.4	8.6
	Farsetia stylosa R.Br.	15	20	10	6.4	3.9	4.9	15.2
	Haloxylon salicornicum (Moq.) Bunge ex Boiss.	25	100	30	10.6	19.6	14.6	44.8
	Heliotropium bacciferum (Forssk.)	15	20	10	6.4	3.9	4.9	15.2
	Heliotropium europaeum L.	10	10	5	4.3	1.9	2.4	8.6
	Lasiurus scindicus Henrard	5	20	5	2.1	3.9	2.4	8.4
	Launaea mucronata (Forssk.) Muschl.	10	10	10	4.3	1.9	4.9	11.1
	Leptadenia pyrotechnica (Forssk.) Decne	10	20	10	4.3	3.9	4.9	13.1
	Lolium rigidum Gaudin	5	10	5	2.1	1.9	2.4	6.4
	Lycium shawii Roem. and Schutt	5	20	10	2.1	3.9	4.9	10.9
	Ochradenus baccatus Del.	5	10	5	2.1	1.9	2.4	6.4
	Panicum turgidum Forssk.	20	60	20	8.5	11.8	9.8	30.1
	Pennisetum divisum (J.F.Gmel.) Henrard	15	40	15	6.4	7.8	7.3	21.5
	Rumex vesicarius L.	5	20	5	2.1	3.9	2.4	8.4
	Sporobolus spicatus (vahl.) Kunth	5	10	5	2.1	1.9	2.4	6.4
	Zygophyllum mandavillei Hadidi	20	40	10	8.5	7.8	4.9	21.2
	Zygophyllum simplex L.	15	20	5	6.4	3.9	2.4	12.7

AD: Absolute density, AF: Absolute frequency, AA: Absolute abundance, RD: Relative density, RF: Relative frequency, RA: Relative abundance, IVI: Importance value index

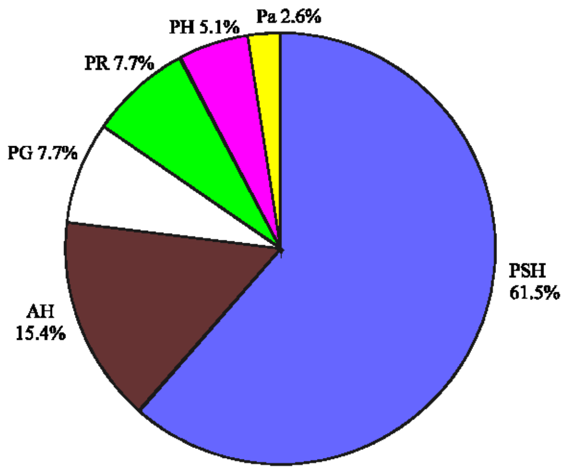

Fig. 3: Percentages of growth forms for the vegetation types recorded in the study area (PSH: Perennial shrub, AH: Annual herb, PG: Perennial grass, PR: Perennial rush, PH: Perennial herb, Pa: Parasite)

associated species (*Seidlitzia rosmarinus*, *Cyperus conglomeratus*, *Suaeda maritima* and *Suaeda vermiculata*) have ecologically a lower significant representation in the same Site I with IVI of 28.4, 14.2, 14.2, 11.6, respectively. (2) The dominant species in the moist zone (Site II) of the Lake are *Halocnemum strobilaceum* and *Suaeda vermiculata* which have AF of 100 and 80%, AA of 25 and 15% and IVI of 70.8 and 49.1 among all the observed species in Site II (Table 4). The co-associated characteristic species in the same site are *Cornulaca monacantha* and *Cyperus conglomeratus* with AF 60%, AA 20 and 10% and IVI 48.7, 39.2, respectively. *Tamarix aphylla*, *Zygophyllum mandavillei* and *Zygophyllum simplex* recorded the lowest values of AF (20, 10%), AA 5% and IVI (17, 14.5%), respectively. (3) The semi-dry zone (Site III) of the Lake Al-Asfar extends west into the inland sandy part of the studied area. *Zygophyllum mandavillei* and *Z. qatarense* are the dominant species of Site III (Table 4). They attained the highest values of AF (100, 60%), AA (25, 15%) and IVI (68.8, 43.9) among the recorded species in Site III. The co-dominant characteristic species is *Anabasis setifera* with AF of 40%, AA of 15% and IVI of 37.4%. Many other species are associated within the site such as *Salsola arabica*, *Zygophyllum simplex*, *Fagonia indica*, *Tamarix aphylla*, *Salsola impricata*, *Suaeda maritima*, *Suaeda vermiculata*, *Euphorbia larica* and *Orobanche cernua* with IVI of 22.9, 19.6, 15.7, 15.2, 11.3, respectively. (4) Arid zone (Site IV) which extends North beyond the semi-dry zone (Site III) where gravel depressions are almost mixed with the sand formations. The site is floristically

Table 5: Species richness, diversity (H') and evenness (E) for the studied habitats of Lake Al-Asfar, Al-Hofouf, Saudi Arabia

	Sites			
Index	I	II	III	IV
No. of species	8.00	9.00	12.00	23.00
Species richness	2.02	2.22	3.05	4.91
(H')	2.01	2.18	2.37	3.10
(E)	0.93	0.98	0.89	0.96

dominated with *Haloxylon salicornicum* species of AF 100, AA 30% and IVI 44.8 (Table 4). The characteristic co-dominant species *Panicum turgidum*, *Pennisetum divisum* and *Zygophyllum mandavillei* recorded relatively higher values of AF and IVI (AF 60%, IVI 30.1; AF 40%, IVI 21.5, AF 40%, IVI 21.2, respectively). *Zygophyllum mandavillei* was mainly present in the western section of the lake from along the two sites III and IV in relatively higher occurrence. The plant abundance of the other associated recorded species in Site IV ranged between 5 to 20% and the IVI ranged between 6.4 to 15.2% during the period of study (Table 4). The difference in species diversity between sites or communities is indicated in Table 5. The richness was calculated based on Margalef's index. Highest record (4.91) was observed in Site IV followed by Site III (3.05), while the least recorded was in Site I (2.02). Heterogeneity indices by using Shannon's index showed high species richness in Sites IV and III and relatively poor in Site I (2.01). Diversity evenness indices were used in this study because of their sensitivity towards species evenness distribution, especially in Sites II and IV (Table 5).

DISCUSSION

Based on the very limited studies and observations on the lake under investigation, the physiognomic features of the lake were not fully clear. The Lake Al-Asfar which is located NE of Alahsa, typically fills to a depth of about 1-2 m. Al-Nafie (2008) demonstrated that Lake Al-Asfar is the largest man-made lake which is situated 28 km NE of Alahsa city in the Eastern Province of Saudi Arabia. However, Al-Barrak, (1993) showed that the depth in the lake fills to a depth of about 0.6 m during summer, but depths of 2-4 m can occur after flooding which is associated with the rainfall during the winter season.

According to Zohary (1973), the area under investigation belongs to the East Saharo-Arabian Region which extends from the Atlantic Ocean to the Sind Desert. The climate of this Arabian regional subzone is characterized by a dry, tropical climate, with very hot summer and a mild winter (Alfarhan, 1999, 2001; Youssef and Al-Fredan, 2008). Meanwhile, Al-Kuwaiti and Ahmed (2003) stated that Alahsa has a mean average annual rainfall of 70.3 mm and an extreme maximum air temperature of 51.3°C at Al-Hofouf in June. They also added that Al-Hofouf (Alahsa) is characterized by long dry summer from May to September and short-term, highly variable small rains from December to February. In this concern, Zahran and Younes (1990), Shaltout *et al.* (1996) and Mossalam (2007) as well as Youssef and Al-Fredan (2008), studied the climate of different regions in Saudi Arabia and revealed that the climate of Saudi areas is of arid and tropical environment. Dreaver *et al.* (1981) stated that Alahsa, as a part of the Eastern Province in Saudi Arabia, receives the highest solar energy load 1200 Wm^{-2} in the world, thus providing favorable arid ecosystem for wild species to grow. On the other hand, Saudi Arabia is divided into two geological structural provinces Al-Naeem (2008): (1) The Arabian Shield, (2) and the Arabian Shelf. Saudi Arabia is situated in the Arabian Shelf. The most prominent geological feature is the dominating of shallow water marine sedimentary rocks that range in age from Cambrian to Pliocene.

Species recorded in the wet and the moist zones along the studied sites, are mainly disturbance-tolerant with little stress-tolerant. It is clear from present results that the silt nature of the first site was associated with attaining higher values of soil water content, pH and total carbonates. In this concern, Batanouny (1979) and Zahran (1983), illustrated that the soil composition, water availability and pH are good criteria in determining the type of habitat and the structure of inhabited vegetation.

However, Alfarhan (2001) concluded that the higher records of electrical conductivity, total dissolved salts and the mineralization contents are occurred between habitats of the fine sandy nature due to the dry and tropical climate which in turn, increase the evaporation of the water in the lake. Consequently, the amounts of cations and anions become very high, which will affect on increasing the ratio of dissolved salts. Several studies on the correlation between the soil characteristics and the vegetation composition had discussed the significant relationship between the soil physicochemical characteristics and the species composition. Tzialla *et al.* (2006) found that the number of species of quite salt lands was influenced by variation in soil water availability. This is in agreement with results of Zhang *et al.* (2005), Al-Kahtani *et al.* (2007) and Youssef and Al-Fredan (2008) who found that the number of species of the studied areas in Saudi Arabia could be affected and probably decreased by the reduction of water among the different layers of soils.

However, some species that are well suited to a wet environment in the present study, i.e. *Phragmites australis*, *Juncus rigidus* and *Halocnemum strobilaceum*, were not recorded in any of the vegetation samples collected from the drier zones. In this concern, Crisman *et al.* (2005), stated that the vigor of development and variation of plant species is correlated to water availability.

Plant species cover and IVI values of the present work, decreased along the different zones of the lake, starting from the shoreline and inwards, which is likely to be caused by lower levels of light, water and soil nutrients. The IVI is higher for the plant species growing along the shorelines which is seemingly associated with high soil water content. In this respect, Al-Kahtani *et al.* (2007) demonstrated that the gradual zonation of plant community composition of the gradient zones along lakes and channels are concurs with vegetation of species from different families.

The higher cover of species belonging to the perennial shrubs PSH followed by annual herbs AH, perennial grasses PG, perennial rushes PR, perennial herbs PH and parasites Pa. There was a big differences between the demographic factors (including density, cover and frequency) in the studied species along the different studied sites. Meanwhile, Lenssen *et al.* (1999) and Zhang *et al.* (2005) suggested that many of the observed differences in plant community composition and structure are attributed to inundation, competition or/and the environmental factors that most directly govern vegetation communities on the lake shores. The variation in density, frequency and abundance between the species may be attributed to habitat differences (Barnes *et al.*, 1998), habitat and species characteristics for adaptation (Youssef and Al-Fredan, 2008), degree of exploitation and conditions for regeneration (Crisman *et al.*, 2005). However, frequency may reflect the pattern of distribution Ayyad *et al.* (2000) and gives an approximate indication of the heterogeneity of a stand (Shibru, 2002).

It is evident from results of plant species richness and vegetation parameters, that there is a clear separation between vegetation groups in the wet sites. Site I is characterized by the occurrence of *Phragmites australis* and Site II by *Halocnemum strobilaceum*. On the other hand, groups in Sites III and IV are less well separated, because they are characterized by mixed communities mainly of shrubs and grasses. This may be attributed to water salinity (Halwagy and Halwagy,1977), light and soil nutrients (Abbadi and El-Sheikh, 2002). Zahran (1983, 1997) and Batanouny (1981) studied and identified the vegetation in Saudi Arabia, United Arab Emirates and Qatar. Halwagy and Halwagy (1977) as well as Abbadi and El-Sheikh (2002) recognized the plant association of the coastal areas and the low sand dunes vegetation along the Arabian Gulf in Kuwait. Their findings were in agreement with results of the vegetation groups in the present study.

In the present study four sites were surveyed along Lake Al-Asfar shores. There was a big differences between the demographic factors (including density, cover and frequency) in the studied species along the different studied sites. Perennial shrubs (PSH) attaining the highest cover, while perennial herbs PH and parasites Pa recorded the lowest cover percentages. Different stages of vegetation composition could be identified along the lake shoreline which included: a) amphibious crynohalophytes in the wet zone I, halophytes stage in the moist zone II and woody stage in zone III and IV. Because sites III and IV are not affected by the water level fluctuations, it comprised the desert plants (*Panicum turgidum*, *Pennisetum divisum* and *Zygophyllum mandavillei*). Soil salinity and water availability may likely to be a strong limiting factors for plant growth. Results indicate that each site along Al-Asfar lake has its own unique flora. However, the species residing shoreline areas were exhibited some variations. The heterogeneity in species composition was observed between the plants communities of the coastal sites along the lake. This may be due to these plant communities of the lake shore largely undergoing from the environmental factor variations, beside their continuous exposure to inundation and competition.

The work will be followed by a future study on mapping the plant communities along the same lake to make a full description for their structure, distribution and location of each plant community.

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