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Floristic Composition of Lake Abha, Southwestern Saudi Arabia

دراسة الغطاء النباتي لبحيرة أبها في جنوب غرب المملكة العربية السعودية

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ABSTRACT: The study analyzes the vegetation along Lake Abha in Southwestern Saudi Arabia. A total of 42 plant species were recorded. The annuals decrease, and the biennials and perennials increase along the moisture gradient form the terraces to the free – water zone. Six vegetation clusters were identified. The most important are clusters which were identified by the presence of the following species: *Phragmites australis, Juncus punctorius, Typha domingensis, Cyperus rotundus, Datura innoxia, Cynodon dactylon, Cornulaca monacantha,* and *Potamogeton nodosus.* Each of these communities has been analyzed by classification and ordination techniques and its habitat described and discussed.
Key words: *flora, diversity, hydrophytes, water level, disturbance, Lake Abha, Saudi Arabia.*

المستخلص: تهتم هذه الدراسة بتحليل الغطاء النباتي لبحيرة أبها بجنوب غرب المملكة العربية السعودية. تم خلال هذه الدراسة تسجيل 42 نوعاً نباتياً. وقد لوحظ نقص نسبة النباتات الحولية وزيادة نسبة النباتات ثنائية الحول والمعمرة مع الاضطراد في زيادة الرطوبة من منطقة ضفة البحيرة إلى منطقة الماء الحر. وتم الحصول على 6 مجموعات نباتية أهمها وأكثرها انتشاراً تلك التي يسودها نباتات: *Phragmites australis* (البوص)، *Juncus punctorius* (السمار)، *Typha domingensis* (البردى - الدوس)، *Cyperus rotundus* (السعد)، *Datura innoxia* (سكران)، *Cynodon dactylon* (النجيل)، *Cornulaca monacantha* (الثلج) و *Potamogeton nodosus* (لسان الماء). ولقد تم إجراء التحليل الإحصائي لهذه المجتمعات النباتية ووصف ومناقشة العلاقة بينها وبين البيئات الموجودة بها.
كلمات مدخلية: *الغطاء النباتي، تنوع، سطح الماء، اضطراب، بحيرة أبها، المملكة العربية السعودية.*

INTRODUCTION

Lake Abha was established in 1974 west of Abha City, on latitude 18°13'N and longitude of 42°36'E, at an elevation of about 2200 meters above sea level. A large water body is contained behind the Abha Dam. The main source of water is rain, which falls on the surrounding mountains, especially those to the west of Abha. The climate is characterized by warm Summer temperatures (20°-30° C) and mild Winter temperatures (10°-20° C). The area has mean annual rainfall of 342 mm, mean relative humidity of 87%, mean annual radiation of 532 g.cal/cm^2/day, and mean annual wind speed of 11.3 km/hr, with mean maximum of 13.4 km/hr (Anonymous, 2000).

Lake Abha at its maximum capacity can hold about 2 million cubic meters of water and covers an area of about 286,000 square meters. The borders of the lake are surrounded by vegetation. A plan is underway to regulate the use of this water for drinking and agricultural purposes. The ecology of the lake was studied by Abulfatih and Al-Khalili (1979). Since then, no comprehensive

study on its plant life has been undertaken.

Multiple uses of this resource require the management of vegetation of wetlands in a way that all interests are fulfilled (Zone, 1982). The aim of the present work is to analyze the lake floristic features in terms of species composition, diversity, abundance and behavior of common species. It aims also at identifying the plant communities and the environmental factors that affect their distribution using the multivariate analysis.

METHODS

Eighty four sites were selected along the shores of the lake distributed in 7 locations within the study area (Figure. 1). Each site was divided into 4 main zones: terrace, slope, littoral and water. In each site, long rectangular stands, each representing one zone, were sampled. The length and width of each varied according to the width of the zone. In each stand, the species encountered were identified using the standard floras, (Täckholm, 1974, Migahid, 1978, Collenette, 1985 and Mandaville, 1990), and their life form and abundance (visual estimate of coverage as a percentage of the stand area) were recorded. Two statistical methods were employed for of multivariate analysis (Classification (agglomerative cluster analysis) and ordination (Principal Component Analysis), both with their merits in helping the understanding of the vegetation, the environment and their interaction.

The classification and ordination techniques, applied here were according to STAT-ITCF program (Foucart, 1982; Roux, 1985). Species richness (alpha–diversity) was calculated as the average number of species per stand, and species turnover (beta-diversity) as the ratio between the total number of species in a certain zone and its species richness (Whittaker, 1972). The species turnover gives an idea about the species replacement or biotic change along the environmental gradients (Wilson and Shmida, 1984). Soil profile samples (0 - 50cm) were collected from the terrace and slope stands, and water samples were collected from the water surface down to 50 cm at a distance of 1.5 m from the shore. Texture and organic matter of the soil samples were estimated using the hydrometer and loss-on- ignition methods, respectively. Electric conductivity (EC) and pH were estimated on 1:5 soil - water extracts and on the water samples, using conductivity and pH meters. The alkalinity and chlorides of the water samples were estimated by titration against H_2SO_4 and $AgNO_3$, respectively (Allen, *et. al.* 1974).

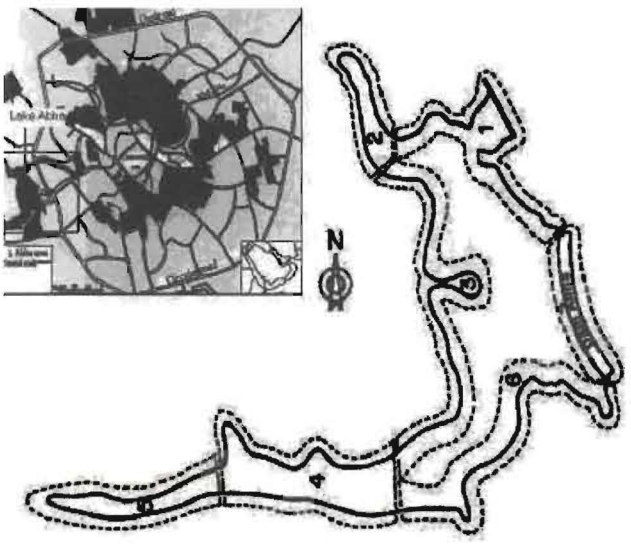

Fig. 1. Lake Abha. Dotted Lines Mark Boundary and Dashed Lines and Numbers Mark the 7 Locations (After Abulfatih and Al-Khalili, 1979).

RESULTS

The number of species recorded in 10% or more the sample stands along the Lake Abha was 42 (Table 1). Some species were recorded in one zone only (e.g *Cyperus rotundus, Tamarix aphylla, Plantago major, Datura innoxia* and *Rumex Conglomeratus* were recorded along the terraces whereas *Ceratophyllum demersum* and *Bacopa monnieri* were recorded in the free water zone). *Typha domingesis* and *Phragmites australis* are the ubiquitous species that extend from the terraces to the free water zone.

The classification and ordination techniques resulted in 24 clusters, which were grouped into six vegetation types. The segregation of the sampled stands along the first four axes PCA is not clear, while the 6 vegetation clusters are well segregated along Axes 1 and 2 (Figure 2).

Table 1. Percent Presence of the Species that have >10% in at Least One Zone along Lake Abha. (Ph = Phanerophytes, Ch = Chamaephytes, Gh = Geophytes-Helophytes, Hc = Hemicryptophytes, Hh = Hydrophytes And Th = Therophytes).

Species	Life form	Terrace	Slope	Littoral	Water
Acacia tortilis	Ph	8.6	3.1		
Aeluropus lagopoides	Ch	25.1	18.3	4.3	
Alhagi maurorum	Hc	11.3	25.3		
Amaranthus hybridus	Th	26.4	3.4	9.2	
Ammi major	Th	9.5			
Arundo donax	Gh		3.1	2.1	
Avena fatua	Th	6.2			
Bacopa monnieri	Hh				18.5
Bromus rubers	Th	18.5	15.2		
Ceratophyllum demersum	Hh				80.4
Chenopodium album.	Th	7.9	50.5	3.3	
Chenopodium murale	Th	17.1	60.7	4.1	
Convolvulus arvensis	Hc	23.4	4.7		
Conyza linifolia	Th	5.1			
Cornulaca monacantha	Th	15.5	22.3	3.3	
Cynodon dactylon	Gh	12.3	32.3		
Cyperus rotundus	Gh	15.3			
Datura innoxia	Th	14.3			
Digitaria abyssinica	Th	9.5	45.5	4.5	
Echinocloa stagnina	Gh	3.4	55.3	7.6	
Imperata cylindrica	Gh	17.5	3.1		
Juncus punctorius	Gh	4.6		4.5	
Juncus rigidus	Gh	14.1	25.3	7.8	
Launaea nudicauls	Hc	13.1	9.2		
Lemna minor	Hh				7.9
Ludwigia stolonifera	Hh	12.7	2.1	5.9	
Lycium shawii	Ch	14.3	9.1	7.4	
Panicum turgidum	Gh	17.3	45.5		
Pennisetum villosum	Th	6.7	9.9		
Phragmites australis	Gh	24.7	83.4	65.7	10.7
Phyla nodiflora	Hc				18.2
Plantago major	Hc	15.7			
Potamogeton nodosus	Hh				45.3
Ranunculus forskoehlli	Gh	12.3	15.3		
Ricinus communis	Ph	5.7	4.7		
Rumex cenglomeratus	Th	28.2			
Rumex vesicarius	Th	10.4	15.3		
Ruppia maritima	Hh				14.7
Suaeda monoica	Ch	20.1		12.3	
Tamarix aphylla	Ph	17.2			
Typha domingensis	Gh	22.5	69.5	49.5	11.8
Ziziphus spina-christi	Ph	4.2	4.7		

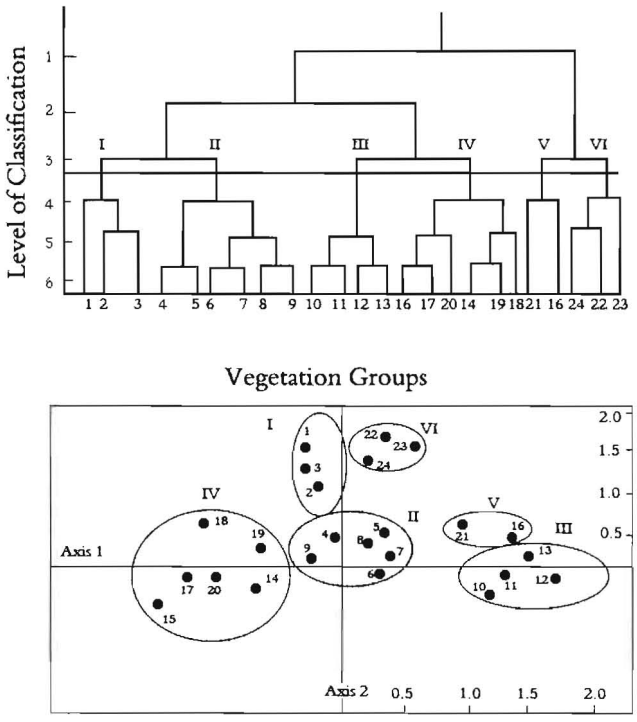

Fig. 2. Relationship Between 24 Vegetation Dendrogram Resulting from the Cluster Analysis and PCA (Principal Component Analysis), Axes 1 and 2, and Position of 6 Vegetation Types.

Group I consists of 2 stands codominated by *Typha domingensis* and *Phragmites australis*. Group II consists of 22 stands codominated by *Datura innoxia, Phragmites australis* and *Aeluropus lagopoides*. Group III consists of 6 stands codominated by *Typha domingensis*, *Phragmites australis* and *Cornulaca monacantha*. Group IV consists of 33 stands codominated by *Juncus punctorius, Cynodon dactylon* and *Phragmites australis*. Group V consists of 6 stands codominated by *Cyperus rotundus* and *Typha domingensis*. Group VI consists of 15 stands codominated by *Typha domingensis*, *Phragmites australis*, *Digitaria abyssinica* and *Potomogeton nodosus*.

The vegetation clusters characterized by *Juncus punctoruis, Cynodon dactylon* and *Phragmities asutralis* (No. 4) had the widest distribution range since they were encountered in 33 stands out of the 84 sampled stands. (i.e. 39.3%). The cluster dominated by *Phragmites australis* (No. 2) comes second in order after cluster No. 4. (in 22 stands (26.2%)). On the other hand, some clusters have a very limited

Table 2. Mean Characteristics of 6 Vegetation Clusters Derived by STAT- ITCF Program (T: terrace zone, S: slope zone, L: littoral zone and W: free water zone).

Cluster	Stand distribution Total	T	S	L	W	Total species	Species richness	Cover %	Characteristic species
1	2	-	-	2	-	5	4.1	36 8	*Typha domingensis* *Phragmites australis*
2	22	10	10	2	-	18	6.2	25 55 11	*Datura innoxia* *Phragmites australis* *Aeluropus lagopoides*
3	6	-	1	4	1	3	1.9	15 15 20	*Phragmites australis* *Typha domingensis* *Cornulaca monacantha*
4	33	19	10	4	-	34	5.0	46 40 38	*Juncus punctorius* *Cynodon dactylon* *Phragmites australis*
5	6	-	-	-	6	6	4.4	15 11	*Cyperus rotundus* *Typha domingensis*
6	15	8	3	1	3	24	5.8	26 35 30 25	*Digitaria abyssinica* *Typha domingensis* *Phragmites australis* *Potomogeton nodosus*
Total	**84**	**37**	**24**	**13**	**10**				

range of distribution. No. 1 and No. 6, dominated by *Typha domingensis* and *Phragmities australis*) and were found near the water edge of the evaporation ponds (Table 2).

The number of annual species decreases from the terrace zone towards the free water zone (Table 3). The free water zone is sheltered by grasses and herbs only. The total number of species, species richness and to some extent, the species turnover decreased along the moisture gradient. In general, soil salinity decrease from the terraces to the water edge. The salinity, alkalinity and chlorides of the water were much higher than those of the moisture gradient of the lake. (Table 4).

Table 3. Life form Spectrum, Species Richness and Species Turnover of Lake Abha.

Life form	Zones			
	Terrace	Slope	littoral	Water
	Annuals			
Grasses	4.3	3.9	5.3	
Herbs	31.7	22.7	17.2	
Total	**35.0**	**26.6**	**22.5**	
	Biennials			
Total	**2.5**	**5.4**	**4.4**	
	Perennials			
Grasses	10.8	8.8	10.3	19.4
Herbs	12.3	11.4	10.5	79.1
Shrub lets	6.4	7.5	5.8	
Shrubs	10.8	14.8	13.8	
Trees	2.3	3.8		
Total	**42.6**	**46.3**	**40.4**	**98.5**
Parasites	1.2	1.5		
Total species	52	49	19	4
Species richness	4.7	4.3	2.8	1.2
Species turnover	11.1	11.4	6.8	3.3
Plant cover (%)	44.8	59.1	88.3	40.1

Table 4. Mean and Standard Error of some Soil and Water Characteristics along Lake Abha.

Zone type	EC (ms)	pH	OM (%)	Sand (%)	Silt (%)	Clay (%)	Alkalinity (ppm)	Cl^- (ppm)
Soil characteristics								
Terraces	5.8±3.2	7.3±0.1	1.3±0.2	73.3±2.8	19.5±3.6	7.2±0.8	-	-
Slope	4.5±1.4	7.4±0.1	2.5±0.3	67.5±4.7	21.8±4.1	10.7±2.1	-	-
Littoral	1.7±1.4	7.4±0.1	1.8±0.1	68.9±3.2	20.8±4.2	10.3±1.6	-	-
Total mean	4.1±2.6	7.4±0.1	1.9±0.2	69.9±3.0	20.7±4.4	9.4±1.4	-	-
Water characteristics								
Mean	1.8±0.7	7.9±0.1	-	-	-	-	239.5±24.2	515.7±121.1

DISCUSSION

Abulfatih and Al-Khalili (1979) have enumerated several plant associations of shorelines, terraces, slopes and water edges, many of which are comparable to those of the present study. On the other hand, there is a low floristic similarity between these zones. This indicates gradual species compositional changes throughout the shorelines, terraces, slopes and water edges. Similar conclusions have been made by El-Sheikh (1989), Shaltout and El-Halawany (1993) and Al-Sodany (1998). Moreover, the two-dimensional polar ordination (Bray and Curtis, 1957) based on the similarity degree between the species composition of the different zones indicates clear segregation between the cluster that represents the lake shoreline, terraces and slopes on one side, and the other clusters on the other sides. This may be attributed to the difference in the moisture status of these zones as compared with the other ones. Similar conclusion were made by Al-Sodany (1998) and Shaltout, *et al.* (2005).

The biodiversity of fresh water bodies is among the most poorly known on the earth (WRI, *et al.* 1992) that is seriously threatened today. Diversity in fresh water ecosystems is distributed in a fundamentally different pattern from those of marine or terrestrial systems. Although the riparian vegetation along rivers has a fundamental importance in stream ecology (Cummins. *et al.* 1984), and has attracted the interest of botanists for many years, the factors that control its species richness are still poorly understood (Nilsson, *et al.* 1989). The trend of variation in some diversity indices is related to the estimated importance value. Use of plant cover as an importance value index has an advantage over other estimates such as density and frequency (Shaltout, 1985). Plant cover is an attribute of greater ecological significance, because it gives a better measure of plant biomass and enables the evaluation of all plant life forms. Therefore, in the present study, the relative plant cover was used as an estimate of the importance value of species, and an estimate of the diversity indices.

At Lake Abha, the terrace zones have the highest value of species richness, while the lake free water had the lowest. Moreover, the low diversity of water zones may be due to the fact that though most of its species are highly specific to the aquatic habitat, the same species occur through at nearly all sites. The high disturbance of these zones (cleaning practices, aquatic weed control, water pollution and excessive waste discharge) may also explain their low diversity (Grime, 1973). Similar conclusions were made by Shaltout and El-Halawany (1993) and Shaltout, *et. al.* (1994). In general, the aquatic weed are aggressively colonizing ruderals which tend to form dense monodominant stands (Holzner, 1978). This increases their competitive ability resulting in lower species richness, which means that the species replacement or biotic change is low at this zone (Wilson and Shmida, 1984).

Among the plant associations reported in Springuel (1985) only one was a hydrophyte (*Ceratophtyllum demersum*). In the present study, 42 species were recorded along Lake Abha. Ten species were recorded in the study of Abulfatih and Al-Khalili (1979) in the same lake. Some of them are of common occurrence (e.g. *Typha domingensis* and *Phragmites australis*), while many others are rare. The floristic composition of the plant community near the edges of the lake is more similar to those of the slope than to those of the two other zones. This may be related to their comparable moisture status.

The decrease of annuals and increase of biennials and perennials along the moisture gradient may indicate that wetlands favours the annuals. The increase of perennials (many of which are rhizomatous) may be due to the inhibition of establishment from seed and promotion of colonization by creeping growth, as a result of the unstable substratum along the lake. Similar conclusions were made by Zahran, *et al.* (1989).

Phragmites australis in one of the characteristic species of 4 of the 6 vegetation clusters identified in the present study. This may indicate that the vegetation of the lake in the study area belongs to the synthaxos phragmitetea that was described for the wetlands in the Middle East (Zohary, 1973).

According to Abulfatih and Al-Khalili (1979) the vegetation on Lake Abha could be divided into three major groups of aquatic plants, which were dominated by: 1. Emergent plants

(*Cyperus routundus, Juncus subulatus, Scripus holoschoenus*, and *Typha domingensis*); 2. Floating plants (*Potamogeton nodosus, Ranunuculs forskoehlli* and *Lemna minor*); and 3. Submerged plants (*Chara* species.). This conclusion is supported by the presence of vegetation types: (a) dominated by *Typha domingensis*, (b) dominated by *Datura innoxia* and *Phragmites austrais*, and (c) dominated by *Juncus punctorius* and *Cynodon dactylon* (*Chara* species were not recorded in the present study).

Similar conclusions were reached by Zahran, *et al.* (1989) in their study on the vegetation on islands in Lake Manzala, Egypt, of which seven community type were described, dominated by: *Phragmites australis, Juncus acutus, Juncus rigidus, Arthocnemum macrostachyum, Atriplex portulacoides, Halocnemum strobilaceum* and *Zygophyllum aegyptium.*

Phytosociologists have classified the various types of macrophyte communities using ordination techniques to simplify distribution patterns along the gradients of environmental variables (Gauch, 1982; Springuel and Murphy, 1991; Grillas, 1990; Spink, 1992). The classification of Lake Abha vegetation identified 6 vegetation groups. These groups were separated along the DCA ordination axes reflecting moisture gradient contents from the communities of the free water habitats to those of the shoreline habitats. The moisture gradient starts with communities representing the free water (*Potamogeton nodosus, Lemna minor, Ruppia maritima, Bacopa monnieri* and *Ceratophyllum demersum*), water edge (*Cyperus rotundus, Typha domingensis,* and *Phragmites australlis)*, shoreline (*Rumex conglomeratus, Cornulaca monacantha, Chenopodium murale* and *Cynodon dactylon*).

Table 5. Comparison of Characters of Water in Lake Al-Kharji, Nile Delta, Al-Gasis, Edku and Lake Abha.

Present and Earlier Studies	EC mS/cm	pH	Alkalinity (ppm)	Chlorides (ppm)
Youssef & El-Shiekh (1981) (Al-Kharji)	2.9	7.5	--	--
El- Sheikh (1989) (Nile Delta)	0.4	7.7	183	62
Shaltout & El-Halawany (1993) (Al-Gasis)	2.6	8.5	210	597
Shaltout *et al* (2005) (Lake Edku)	2.8	7.8	--	--
Present Study (2007)	1.8	7.9	239	515

Comparing the characters of water in Lake Abha and that of the other regions, we note that (see, Table. 5).

The water of Lake Abha, Al-Hassa Oasis and Al-Kharj in Saudi Arabia are not more saline than the Nile Delta. This leads to differences among their floristic and vegetation structure.

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