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HABITAT AND VEGETATION TYPES OF LAKE BOROLLUS PROTECTED AREA, EGYPT

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ABSTRACT

Lake Borollus is one of the Ramsar wetland sites. The present study aims to recognize the habitats and describe the vegetation – environmental relationships in Lake Borollus protected area. Such study helps to determine the most important environmental factors affecting the identified vegetation types in this lake.

The plant communities of Lake Borollus protectorate were analyzed using 102 stands representing the apparent variation in habitats and vegetation. Multivariate analysis of the vegetation and environmental variables of the 102 stands led to the recognition of 6 vegetation groups. These groups are named after their diagnostic perennial species as follows: A) *Suaeda vera-Sporobolus pungens,* B) *Arthrocnemum macrostachyum,* C) *Limbarda crithmoides,* D) *Arthrocnemum macrostachyum,* E) *Alhagi graecorum* and F) *Polygonum equisetiforme-Launaea resedifolia – Echinops spinosus.* The vegetation groups yielded by TWINSPAN-classification were more or less distinguishable and having a clear pattern of segregation on the Detrended Correspondence Analysis ordination planes.

The Canonical Correspondence Analysis of the sampled stands indicated that, the most effective soil variables controlling distribution and abundance of the identified vegetation groups, and which showed a highly significant correlations with the first and second ordination axes were: soil texture (clay & sand), moisture content, porosity, potassium, sodium and calcium cations, organic matter, calcium carbonate, electrical conductivity, sulphate and bicarbonate.

Key words: Lake Borollus Mediterranean Coast — Multivariate Analysis – Soil Variables -Vegetation.

INTRODUCTION

Wetlands occur in many geomorphological settings including river deltas, coastal and inland lagoons (lakes), intertidal zones, river flood plains, inland depressions and flats **[Britton & Crivelli, 1993]**. On a global scale wetlands are widely distributed, found in all climates and in all continents except Antarctica. More than half of the world's total wetland area is found in tropical and subtropical regions, while a large proportion of the rest is in boreal peatlands **[Mitsch & Gosslink 2000]**. The term wetland envelops a wide variety of habitats, from mangroves along tropical shorelines to peatlands in territories that lie just south of the Arctic.

Cronk and Fennessy (2001) divided the wetland habitats according to hydrology, salinity and pH value into the following three categories:

1. Marshes are generally dominating by herbaceous species. These include coastal and inland marshes. Coastal marshes comprise salt marshes and tidal freshwater marshes. Inland marshes may be found at the edge of lakes (lacustrine) or rivers (riverine) or they may be depressional wetlands.
2. Forested wetlands are commonly dominated by woody vegetation of diverse sizes. These can include trees over 50 m tall, dwarf trees (1m height) in areas of environmental stress, or shrubs. Their geographical range extends from boreal regions to the tropics, along coastlines, and in alpine regions **[Lugo *et al.*, 1988]**. These comprise coastal forested wetlands (mangrove swamps) and inland forested wetlands.
3. Peatlands are wetlands in which plant matter (peat) accumulates due to anaerobic conditions and slow decomposition. They are distinguished into two main types: fens and bogs. Fens are fed by water that carries minerals from the surrounding mineral- rich formations, and are sometimes called minerotrophic. The calcium concentration and the pH values of fens tend to be relatively high. While, bogs (ombotrophic) receive mostly water that is much poorer in minerals and have a lower pH **[Moore & Bellamy, (1974) and Wassen *et al.*, 1990]**. Both woody and herbaceous plants are found in peatlands.

The wetlands in Egypt are considered as one of the most principal ecosystems, which are widely distributed all over the country. These habitat types are numerous including lakes, River Nile system, depressions, Mediterranean Sea and Red Sea. Lakes are the most conspicuous wetland habitat type comprising six natural shallow brackish lakes and one artificial lake. The natural lakes include five Mediterranean northern lakes located from east to west as follows: Bardawil, Manzala, Borollus, Idku and Mariut, and one inland Lake Qarun which is situated in the Fayium Depression. The man made Lake Nasser is formed behind the Aswan High Dam (South of Egypt).

Lakes are ecologically important wetland habitats or aquatic ecosystems in Egypt as well as in the world. Lake Borollus was designated as a wetland nature reserve under the International Ramsar Convention since 1998. Lake Borollus protected area lies in Kafr El-Sheikh Governorate (Egypt) and it covers an area of about 460 km^2.

There are extensive studies carried out on the Egyptian lakes, especially in the fields of geography, hydrology, zoology, hydrobiology, etc. A pioneer ecological study of Lake Manzala was carried out by Montasir (1937), and followed by the study of Khedr (1989). Haroun (1989) studied the seasonal changes and phytochemical evaluation of some plant species inhabiting Lake Borollus. Ecological and phytochemical studies on Lake Idku were carried out by Abu-Zied (1990). Khedr (1997) studied the distribution of aquatic macrophytes in Lake Manzala. Khedr and Zahran (1999) reported a comparison between the floristic composition of two Mediterranean coastal lakes, Manzala and Borollus. Khedr (1999) described floristic composition and phytogeography in Lake Borollus. Also, Khedr and Lovett-Doust (2000) determined floristic diversity and vegetation composition on the islands of Lake Borollus. El-Bana *et al.* (2002) studied vegetation composition of a threated hypersaline Lake Bardawil (North Sinai). Shaltout *et al.* (2004) studied the status of *Phragmites australis* in Lake Borollus. Shaltout *et al.* (2005 a&b) also described the habitat and vegetation of Lake Idku and Lake Mariut respectively.

The present investigation is a quantitative phytosociological study in Lake Borollus protected area. It aims at:

1) Determination of the vegetational structure in terms of the spatial variations in abundance by using multivariate analysis (classification and ordination).

2) Analysis of the spatial and temporal variations in environmental factors and to ascertain the degree of correlations between environmental variations in an attempt to determine factor or factors controlling the distribution and abundance of vegetation in the different habitats of the study area.

THE STUDY AREA

Lake Borollus was designated as a wetland nature reserve under the International Ramsar Convention since 1998. Lake Borollus protected area lies in Kafr El-Sheikh Governorate and it covers an area of about 460 km^2. The study area includes Lake Borollus and its Deltaic Mediterranean coastal land in Kafr El-Sheikh Governorate. The Deltaic coastal belt in Kafr El-Sheikh Governorate extends about 100 km along the Mediterranean Sea and embraces the shallow brackish Lake Borollus which is situated on the eastern side of the Rosetta branch of the River Nile. It occupies a central position along the Mediterranean coast of the Nile Delta. It is the second largest natural lake in Egypt after Lake Manzala. In width it extends from Baltim at the Mediterranean Sea to El-Hamool, El-Riad and Sidi Salim districts in the south and Motobas district from the west (Figure 1).

Lake Borollus is connected with the Mediterranean Sea by a narrow (c. 50 m wide) outlet called Boughaz El-Borollus, and with the Rosetta branch of the River Nile by the Brimbal canal. Some 25 islets of different sizes are distributed within the lake, (Fig. 1) where they form the physical isolations between the different sections of the lake **[El-Bayomi 1999]**. The depth of this lake varies between 20 cm close to the shoreline and 200 cm at the middle part and near the sea outlet. Toubar (1991) distinguished four types of characteristic landforms in Lake Borollus: 1) shore landforms (backshore flats, foreshore and barrier beach), 2) lake landforms (Lake Borollus, El-Boughaz inlet, shoreline and islands), 3) landforms (sand sheets, sand aeolian hummocks and sand dunes) and 4) riverine landforms (palaeochannels, marshes, natural levee and accretion ridges).

According to the system applied in UNESCO's map of the world distribution **[UNESCO, 1977 and Ayyad *et al.*, 1983]**, the Mediterranean coastal region lies in the attenuated arid province characterized by a long dry period and annual winter rainfall from 100-160 mm, warm summer (27-31°C), mild winter (8.2-24°C), and aridity index (P/ETP) less than 0.03. Accordingly, Lake Borollus belongs to the arid and/or semi-arid climatic belts of the northern coastal region of Egypt. The soils of the extreme northern part of the Nile Delta are

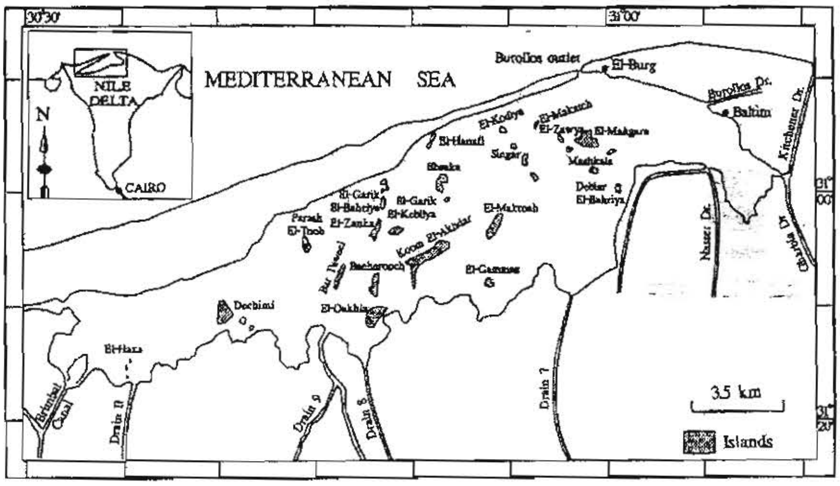

Figure (1) . Location map showing the study area .

characterized by coastal sand drift mixed with Nile deposits forming the marine-alluvial soils. These soils are sandy in nature, poorly drained, very saline and mostly barren or under reclamation **[Soliman, 1966]**. El-Gazayerly (1986) reported that the soils of Lake Borollus are Marino-Alluvial soil classified under order Entisols (Fluvents and Psamments). Fluvents include lacustrine and alluvial soils, while Psamments comprise sand dunes and marine soils. Lake Borollus receives water from four sources: a) brackish water, discharged from agriculture drainage areas through numerous drains, mainly situated along its southern shoreline, b) sea water, through a narrow inlet putting the lake and nearby sea into direct communication, c) brackish water through Brimbal canal on its west coast and d) rain water during winter season.

MATERIALS AND METHODS

a- Vegetation analysis

One hundred and two stands were selected for sampling the vegetation types in the different habitats of the study area. The chosen stands were distributed to cover all local physiographic variations within the habitat types and to ensure sampling of a wide range of vegetational variations. The stand size was 13x13 m, and the sampling process was carried out during March-September 2005. In each stand, relative density and relative frequency were estimated by using point-centered quarter method **[Cottam & Curtis (1956) and Ayyad (1970)]**, while relative cover was estimated by applying the line intercept method **[Canfield (1941)]**. The abundance of species as expressed by the relative values of density, frequency and cover were calculated for each perennial species and summed up to give an estimate of its importance value (out of 300). The annual species were only recorded. Identification and nomenclature were according to **[Täckholm (1974); Davis (1965-1985); Zohary (1966 & 1972); Feinbrun-Dothan (1978 & 1986) and upto date by Boulos (1999-2005)]**.

b- Soil analysis

Five soil samples were collected from a profile (0-50 cm) of each stand, and then mixed well to form a composite soil sample. Soil texture was determined by Bouyoucos hydrometer method. Moisture content was determined by using sealed tins for collecting soil samples in the field, and then dried at 105°C in oven in the laboratory. Soil porosity was determined as described by **[Zahran (1987)]**. Calcium carbonate was estimated gravimetrically according to **[Jackson (1962)]**, while oxidizable organic carbon (as indication of the total organic matter, where % organic matter = % organic carbon x 1.724) was determined using Walkely and Black rapid titration method as described by Piper (1947). Soil water extracts of 1:5 were prepared for determinations of soil reaction using pH meter Model HI 8519, and soil salinity (EC) using CMD 830 WPA conductivity meter. Soluble chlorides were determined by direct titration against silver nitrate solution (N/35.5) using 5% potassium chromate indicator **[Jackson (1962)]**. Sulphates were obtained by the difference between cations and anions of soil extract according to **[Jackson (1962)]**. Soluble carbonates and bicarbonates were determined by titration method using H_2SO_4 (0.1N), phenol phthalein and methyl orange as indicators for carbonate and bicarbonate, respectively (Richard, 1954). The extractable sodium and potassium cations were estimated using flame photometer **[Allen *et al.*, (1986)]**. Extractable calcium and magnesium cations were determined using EDTA (0.01N) as described by **[Jackson (1962)]**. The sodium and potassium adsorption ratios were calculated to use as indices expressing the combined effects of the different ions in the soil **[Mckell & Goodin (1984)]**.

c- Data analysis

Two trends of multivariate analysis were applied in the present study, namely classification and ordination. The classification technique applied here was Two-Way Indicator Species Analysis (TWINSPAN) **[Hill (1979)]**. The matrix of importance values of 41 perennial species was used in the TWINSPAN-classification of the sampled 102 stands. On the other hand, the ordination techniques applied here were Detrended Correspondence Analysis (**DCA**) and Canonical Correspondence Analysis (**CCA**) **[ter-Braak (1988)]**. The simple linear correlation coefficient (**r**) was calculated for assessing the relationship between the estimated different soil variables. While, the relationship between vegetation groups on one hand, and edaphic variables on the other hand was indicated on the ordination diagram produced by **CCA-biplot**. All statistical treatments applied in the present investigation were according to **[Snedecor & Cochran (1968) and Anonymous (1993)]**.

RESULTS

A- Classification of stands

The dendrogram resulting from the application of TWINSPAN classification based on the importance values of 41 perennial species recorded in 102 stands in the study area indicated the distinction of six vegetation groups (Figure 2) and the vegetation composition of these groups is presented in Table 1.

Group A comprises 4 stands codominated by *Suaeda vera* (IV = 96.01) and *Sporobolus pungens* (IV = 84.26). Important and indicator species in this group is *Lycium schwienfurthii* (IV = 72.82). *Atriplex halimus* (IV = 18.04) is one of the common species in this group.

Group B includes 5 stands dominated by the indicator species *Arthrocnemum macrostachyum* (IV = 92.06). The most important species in this group comprise *Juncus acutus* (IV = 52.80), *Suaeda vera* (IV = 52.56), *Atriplex portulacoides* (IV = 31.26) and *Halocnemum strobilaceum* (IV = 28.59).

Group C consists of 33 stands dominated by *Limbarda crithmoides* (IV = 95.54). Important and indicator species in this group include *Alhagi graecorum* (IV = 32.63), *Arthrocnemum macrostachyum*

(IV = 31.93), *Juncus acutus* (IV = 28.89) and *Atriplex portulacoides* (IV = 22.57). The grasses *Phragmites australis* (IV = 16.90), *Cynodon dactylon* (IV = 16.39) and rush *Juncus rigidus* (IV = 14.52) are also common associates in this group.

Group D comprises 36 stands dominated by the indicator species *Arthrocnemum macrostachyum* (IV = 131.90). Important and indicator species in this group include halophytes: *Zygophyllum aegyptium* (IV = 34.99), *Halocnemum strobilaceum* (IV = 27.99), *Phragmites australis* (IV = 25.59) and *Juncus acutus* (IV = 20.71).

Group E include 19 stands dominated by *Alhagi graceorum* (IV = 138.20). Important and indicator species comprise *Cynodon dactylon* (IV = 33.15), *Arthrocnemum macrostachyum* (IV = 29.86), *Cyperus capitatus* (IV = 24.58) and *Zygophyllum aegyptium* (IV = 19.44).

Group F consists of 5 stands codominated by *Polygonum equisetiforme* (IV = 56.29), *Launaea resedifolia* (IV = 55.46) and *Echinops spinosus* (IV = 45.62). Important indicator species in this group comprise *Arthrocnemum macrostachyum* (IV = 43.30), and *Calligonum polygnoides* subsp. *comosum* (IV = 30.40).

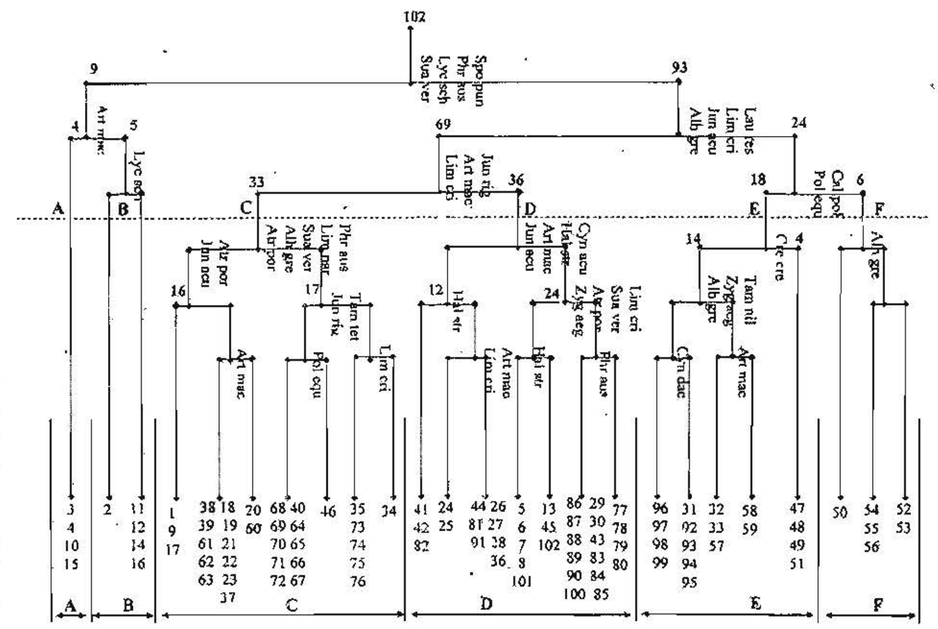

Figure (2) . Two Way Indicator Species Analysis dendrograme of the 102 sampled stands based on the importance value of the 41 perennial species with the names abbreviated into the first three letters of each of the genus and species .

Table (1): Mean and coefficient of variation (value between brackets) of the importance values (out of 300) of indicator and preferential species in the different vegetation groups resulting from TWINSPAN classification.

Species	Vegetation groups					
	A	B	C	D	E	F
Aeluropus lagopoides	—	—	2.84 (2.16)	—	7.14 (3.01)	7.93 (1.69)
Alhagi graecorum	—	—	32.63 (1.48)	1.93 (6.00)	138.20 (0.32)	—
Arthrocnemum macrostachyum	4.14 (0.71)	92.06(0.34)	31.93 (1.02)	131.90 (0.39)	29.86 (1.0)	43.30 (0.86)
Asparagus stipularis	8.20(0.79)	5.42 (1.89)	—	—	—	—
Atriplex halimus	18.04 (1.17)	1.62(2.23)	2.32 (3.33)	1.52 (6.00)	—	—
Atriplex portulacoides	1.37 (1.22)	31.26(0.64)	22.57(1.75)	3.88 (3.05)	—	—
Calligonum polygonoides subsp. *comosum*	—	—	—	—	1.32 (2.50	30.40 (0.59)
Carex extensa	—	—	0.59 (5.35)	—	—	—
Cistanche phelypaea	—	—	—	1.39 (2.16)	0.33 (4.36	0.15 (2.24)
Cressa cretica	5.11 (2.00)	—	4.33 (3.41)	—	6.40 (2.11)	—
Cynanchum acutum	—	—	1.48 (2.54)	3.81 (3.51)	2.37 (4.20)	4.91 (2.24)
Cynodon dactylon	—	—	16.39 (1.51)	2.82 (3.94)	33.15 (1.45)	—
Cyperus capitatus	—	—	—	3.32 (6.00)	24.58 (1.29)	8.03 (2.24)
Cyperus laevigatus	—	—	0.07 (5.32)	—	—	—
Echinops spinosus	—	—	—	—	3.03 (3.08)	45.62 (0.40)
Elymus farctus	—	—	—	3.36 (3.55)	—	—
Halocnemumstrobilaceum	—	28.59 (0.98)	2.96 (3.53)	27.99 (1.38)	5.12 (1.74)	4.38 (1.46)
Imperata cylindrica	—	—	0.17 (5.74)	—	—	—
Juncus acutus	8.16 (1.81)	52.80 (0.52)	28.89 (1.51)	20.71 (1.62)	0.14 (3.28)	0.23 (2.24)
Juncus rigidus	—	0.29 (2.21)	14.52 (1.49)	2.97 (3.18)	—	—
Launaea resedifolia	—	—	—	1.20 (3.43)	5.83 (1.70)	55.46 (0.65)
Limbarda crithmoides	0.10 (2.10)	15.20 (0.94)	95.54 (0.50)	12.43 (1.72)	—	—
Limonium narbonense	—	—	3.77 (2.62)	—	—	—
Lycium schwienfurthii	72.82 (0.48)	7.71 (1.12)	—	—	0.79 (4.36)	5.83 (2.24)
Nicotiana glauca	—	—	1.57 (2.96)	—	—	—
Pancratium maritimum	—	—	—	2.63 (1.82)	—	—
Punicum turgidum	—	—	—	—	2.63 (1.82)	—
Phoenix dactylifera	—	—	—	1.08 (6.00)	—	—
Phragmites australis	—	0.03 (2.00)	0.02 (5.74)	—	—	—
Pluchea dioscoridis	—	—	16.90 (1.81)	25.59 (1.22)	7.20 (1.83)	9.07 (0.77)
Polygonum equisetiforme	—	—	0.39 (4.81)	0.45 (6.00)	—	—
Scirpus litoralis	—	—	4.99 (3.23)	2.28 (2.62)	0.96 (2.39)	56.29 (0.45)
Scirpus maritimus	—	—	0.12 (4.09)	—	—	—
Sporobolus pungens	84.26 (0.75)	12.20 (1.45)	—	—	—	—
Sporobolus spicatus	—	—	—	—	—	4.43 (2.24)
Suaeda vera	96.01 (0.28)	52.56 (0.48)	2.14 (2.98)	6.44 (2.67)	0.38 (3.68)	—
Tamarix nilotica	—	—	1.63 (3.09)	4.60 (2.15)	5.92 (1.52)	16.55 (0.84)
Tamarix tetragyna	—	—	3.35 (2.82)	5.18 (2.55)	5.44 (2.80)	—
Typha domingensis	—	0.26 (2.23)	0.73 (3.32)	—	—	—
Urginea undulata	1.79 (2.00)	—	—	—	—	—
Zygophyllum aegyptium	—	—	5.11 (3.25)	34.99 (1.01)	19.44 (1.74)	7.28 (1.05)

B- Sciological range (sr) of plant species in the identified vegetation groups

The presence and distribution of perennial, biennial and annual species in the vegetation groups identified by TWINSPAN classification are shown in Table 2. *Arthrocnemum macrostachyum* and *Juncus acutus* are recorded in all six groups and attained the highest presence percentage (P = 100%) but with different importance values. The first species dominated two groups (B & D) while, the second species was not dominant in any of the identified vegetation groups. Three perennials are recorded in five groups (P = 83.33%). These include *Halocnemum strobilaceum, Phragmites australis* and *Suaeda vera.* The first and second species were recorded in all groups except group A, while the third species codominated group A and was recorded in all groups except group F.

Eight perennials are recorded in four groups (P = 66.67%). Out of them, four taxa namely, *Cynanchum acutum, Polygonum equisetiforme, Tamarix nilotica* and *Zygophyllum aegyptium* are missed in two groups (A & B). *Atriplex halimus, Atriplex portulacoides* and *Limbarda crithmoides* are missed in another two groups (E & F). *Lycium schwienfurthii* is missed in two groups (C & D). Nine perennial species are recorded in three groups (P = 50.00%). These comprise *Alhagi graecorum, Cynodon dactylon, Tamarix tetragyna, Cistanche phelypaea, Cyperus capitatus, Launaea resedifolia, Aeluropus lagopoides, Cressa cretica* and *Juncus rigidus*. Seven perennials are recorded in two groups (P = 33.33%), these include *Asparagus stipularis, Sporobolus pungens, Calligonum polygonoides* subsp. *comosum, Echinops spinosus, Pluchea dioscoridis, Scirpus maritimus* and *Typha domingensis*. Twelve perennials are recorded in only one group (P = 16.67%), these comprise *Urginea undulata, Carex extensa, Cyperus laevigatus, Imperata cylindrica, Limonium narbonense, Nicotiana glauca, Phoenix dactylifera, Scirpus litoralis, Elymus farctus, Panicum turgidum, Pancratium maritimum* and *Sporobolus spicatus*.

One biennial species namely, *Spergularia marina* is recorded in all six groups. Forty-seven annuals are recorded in the present study. These annuals can be grouped according to their seasonality into three categories:

Table (2): Sociological range (sr) of plant species in the vegetation groups identified by TWINSPAN classification of the study area.

No.	Species	Vegetation group						Sr %
		A	B	C	D	E	F	
	A- Perennials:							
1	Arthrocnemum macrostachyum	+	+	+	+	+	+	100.00
2	*Juncus acuts*	+	+	+	+	+	+	100.00
3	*Halocnemum strobilaceum*		+	+	+	+	+	83.33
4	*Phragmites australis*		+	+	+	+	+	83.33
5	*Suaeda vera*	+	+	+	+	+		83.33
6	*Atriplex halimus*	+	+	+	+			66.67
7	*Atriplex portulacoides*	+	+	+	+			66.67
8	*Cynanchum acutum*			+	+	+	+	66.67
9	*Inula crithmoides*	+	+	+	+			66.67
10	*Lycium schwienfurthii*	+	+			+	+	66.67
11	*Polygonum equisetiforme*			+	+	+	+	66.67
12	*Tamarix nilotica*			+	+	+	+	66.67
13	*Zygophyllum aegyptium*			+	+	+	+	66.67
14	*Aeluropus lagopoides*			+		+	+	50.00
15	*Alhagi graecorum*			+	+	+		50.00
16	*Cistanche phelypaea*				+	+	+	50.00
17	*Cressa cretica*	+		+		+		50.00
18	*Cynodon dactylon*			+	+	+		50.00
19	*Cyperus capitatus*				+	+	+	50.00
20	*Juncus rigidus*		+	+	+			50.00
21	*Launaea resedifolia*				+	+	+	50.00
22	*Tamarix tetragyna*			+	+	+		50.00
23	*Asparagus stipularis*	+	+					33.33
24	*Calligonum polygonoides* subsp. *comosum*					+	+	33.33
25	Echinops spinosissimus					+	+	33.33

Table (2). Continued.

No.	Species	Vegetation group						Sr %
		A	B	C	D	E	F	
26	Pluchea dioscoridis			+	+			33.33
27	*Scirpus maritimus*			+	+			33.33
28	*Sporobolus pungens*	+	+					33.33
29	*Typha domingensis*		+	+				33.33
30	*Carex extensa*			+				16.67
31	*Cyperus laevigatus*			+				16.67
32	*Elymus farctus*				+			16.67
33	*Imperata cylindrica*			+				16.67
34	*Limonium narbonense*			+				16.67
35	*Nicotiana glauca*			+				16.67
36	*Pancratium maritimum*					+		16.67
37	Panicum turgidum				+			16.67
38	*Phoenix dactylifera*			+				16.67
39	*Scirpus litoralis*			+				16.67
40	*Sporobolus spicatus*						+	16.67
41	*Urginea undulata*	+						16.67
	B- Biennials:							
1	Spergularia marina	+	+	+	+	+	+	100.00
	C- Annuals:							
	(a) All-year annuals:							
1	*Senecio glaucus* subsp. *coronopifolius*	+	+	+	+	+	+	100.00
2	*Cakile maritima* subsp. *maritima*	+	+	+	+	+		83.33
3	Sonchus oleraceus	+				+	+	50.00
4	*Bassia indica*			+	+			33.33
5	*Chenopodium murale*	+				+		33.33
6	*Conyza bonariensis*					+	+	33.33
7	*Suaeda maritima*			+	+			33.33
8	*Solanum nigrum*			+				16.67

Table (2). Continued.

No.	Species	Vegetation group						Sr %
		A	B	C	D	E	F	
	(b) Winter- spring annuals:							
1	Frankenia pulverulenta	+	+	+	+	+	+	100.00
2	*Lotus halophilus*		+	+	+	+	+	83.33
3	*Mesembryanthemum crystallinum*	+	+	+	+	+		83.33
4	*Mesembryanthemum nodiflorum*	+	+	+	+	+		83.33
5	*Juncus bufonius*			+	+	+		50.00
6	*Malva parviflora*	+	+	+				50.00
7	*Parapholis incurva*		+	+	+			50.00
8	*Schismus barbatus*	+				+	+	50.00
9	*Sphenopus divaricatus*			+	+	+		50.00
10	*Brassica tournefortii*	+				+		33.33
11	*Bromus catharticus*					+	+	33.33
12	*Bromus diandrus*					+	+	33.33
13	*Carduus getulus*	+				+		33.33
14	*Carthamus tenuis*	+				+		33.33
15	*Centaurea glomerata*	+				+		33.33
16	*Emex spinosa*	+				+		33.33
17	*Hordeum marinum*	+				+		33.33
18	*Ifloga spicata*					+	+	33.33
19	*Medicago polymorpha*	+					+	33.33
20	*Plantago squarrosa*					+	+	33.33
21	*Polypogon monspeliensis*					+	+	33.33
22	*Riechardia tingitana*	+				+		33.33
23	*Urtica urens*			+		+		33.33
24	*Adonis dentata*	+						16.67
25	*Aegilops bicornis*					+		16.67
26	*Anchusa humilis*					+		16.67

Table (2). Continued.

No.	Species	Vegetation group						Sr %
		A	B	C	D	E	F	
27	Astragalus peregrinus	+						16.67
28	*Bupleurum semicompositum*	+						16.67
29	*Calendula arvensis*	+						16.67
30	*Cutandia memphitica*						+	16.67
31	*Erodium laciniatum*						+	16.67
32	*Ononis serrata*	+						16.67
33	*Rumex pictus*						+	16.67
	(c) Summer- autumn annuals:							
1	Salsola kali	+	+	+	+	+		83.33
2	*Centaurium pulchellum*				+	+		33.33
3	*Halopeplis amplexicaulis*			+	+			33.33
4	*Bassia muricata*					+		16.67
5	*Corchorus olitorius*			+				16.67
6	*Euphorbia prostrata*					+		16.67

a) All-year annuals (8 species) e.g. *Senecio glaucus, Cakile maritima, Sonchus oleraceus, Chenopodium murale,* etc.

b) Winter-spring annuals (33 species) e.g.*Frankenia pulverulenta, Lotus halophilus, Mesembryanthemum crystallinum, Malva parviflora, Juncus bufonius, Richardia tingitana,* etc.

c) Summer-autumn annuals (6 species) e.g. *Salsola kali, Corchorus olitorius, Bassia muricata,* etc.

C- Ordination of stands

The ordination of sampled stands in different habitats of the study area was applied using Detrended Correspondence Analysis (DCA, Figures 3 & 4). It is obvious that groups A and F are clearly separated from other groups (B, C, D & E) which are randomly scattered in the middle part of the diagram. Group A is segregated at the outermost middle right side of DCA diagram while, group F is separated at the upper left side of the ordination diagram. Group B is segregated at the middle right side of the diagram, whereas group D is separated at the middle left side. Group C is segregated at the lower side of DCA diagram and at the opposite position of group D. However, group E is segregated at the innermost middle left side of the diagram and at the opposite direction of group B.

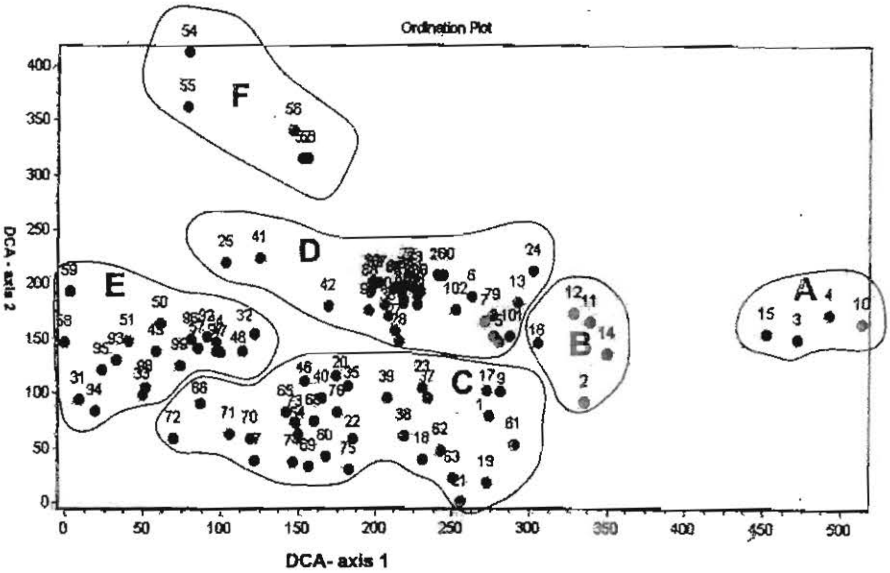

Figure (3) . Detrended Correspondence Analysis (DCA) ordination diagram of the 102 sampled stands with TWINSPAN groups sperimposed .

D- Vegetation – soil relationships

a) Soil variables of the vegetation groups

The soil variables of the six vegetation groups derived from TWINSPAN classification are presented in Table 3. The soil texture in all groups indicate mainly coarse fraction (sand) and partly fine fractions (silt & clay). The highest mean percentages of moisture content and porosity are recorded in group C, while the lowest mean values are recorded in group F, which also shows the lowest mean values of calcium carbonate (6.00%), organic carbon (0.27%), pH value (8.06%), electrical conductivity (0.59 ds/m), chloride (1.14 meq./L), sulphate (2.66

meq./L), carbonate (0.13 meq./L), bicarbonate (1.29 meq./L), sodium (1.05 meq./L), potassium (0.31 meq./L), sodium adsorption ratio (0.85) and potassium adsorption ratio (0.23). Group A attained the lowest mean values of calcium (1.80 meq./L) and magnesium (0.90 meq./L).

On the other hand, the highest mean values of calcium carbonate (13.67%) is attained in group D, pH value (8.3) in both of groups B & D and potassium adsorption ratio (0.94) in group A. However, group C attained the highest mean values of carbonate (0.32 meq./L), bicarbonate (2.32 meq./L) and calcium (12.35 meq./L). Group B attained the highest mean values of organic carbon (1.32%), electrical conductivity (8.00 ds/m), chloride (34.36 meq./L), sulphate (18.38 meq./L), sodium (40.35 meq./L), potassium (1.51 meq./L), magnesium (6.20 meq./L) and sodium adsorption ratio (20.14).

b) Correlation coefficient (r) between different soil variables in the sampled stands

As shown in Table 4, the following correlations may be noted:

1. Clay fraction has positive significant correlations with all soil variables except soluble carbonate content.
2. Carbonate content has no significant correlations with all soil variables except pH value.
3. Sand fraction has negative significant correlations with all soil variables except calcium cation.
4. Moisture content, chloride and sodium adsorption ratio showed positive significant correlations with all soil variables except calcium cation.
5. Potassium cation and electrical conductivity exhibited positive significant correlations with all soil variables except pH value.
6. Calcium carbonate, organic carbon and sodium cation have positive significant correlations with all soil variables except pH and calcium cation.
7. Silt fraction showed positive significant correlations with all soil variables except soil porosity and calcium.
8. Soil porosity, sulphate and magnesium have positive significant correlations with all soil variables except pH value and potassium adsorption ratio.

Table (3): Mean and standard error of the different soil variables at 0 – 50 cm depth in the sampling stands of groups obtained by TWINSPAN classification.

Soil variables	Vegetation groups					
	A	B	C	D	E	F
Sand (%)	89.42 ± 1.21	84.76 ± 3.46	84.05 ± 1.67	83.70 ± 3.31	93.64 ± 0.70	91.80 ± 0.30
Silt (%)	3.85 ± 0.92	4.70 ± 0.48	3.82 ± 0.88	7.89 ± 2.13	1.33 ± 0.18	3.00 ± 0.43
Clay (%)	6.73 ± 0.84	10.54 ± 3.16	12.08 ± 1.14	8.41 ± 1.39	5.03 ± 0.65	5.20 ± 0.37
Moisture content (%)	1.40 ± 0.19	7.64 ± 2.45	9.81 ± 1.23	9.08 ± 2.01	1.52 ± 0.38	0.33 ± 0.03
Porosity (%)	37.13 ± 0.56	38.31 ± 1.37	39.72 ± 0.44	39.03 ± 0.75	36.87 ± 0.76	36.75 ± 0.63
Ca CO_3 (%)	9.63 + 2.97	7.75 ± 2.04	12.42 ± 2.03	13.67 ± 2.50	6.24 ± 1.58	6.00 ± 0.39
Organic carbon (%)	0.92 + 0.12	1.32 ± 0.21	0.89 ± 0.12	0.72 ± 0.14	0.29 ± 0.03	0.27 ± 0.03
Organic matter (%)	1.58 + 0.21	2.27 ± 0.37	1.53 ± 0.21	1.14 ± 0.23	0.50 ± 0.05	0.46 ± 0.06
pH	8.29 ± 0.09	8.34 ± 0.06	8.25 ± 0.03	8.34 ± 0.04	8.09 ± 0.07	8.06 ± 0.17
EC (ds/m)	1.82 ± 0.61	8.00 ± 3.02	4.67 ± 0.54	4.73 ± 0.77	1.86 ± 0.39	0.59 ± 0.15
Cl- (meq. /L)	7.33 ± 2.50	34.36 ± 12.45	12.32 ± 2.34	22.09 ± 4.75	5.61 ± 1.62	1.14 ± 0.16
SO4-- (meq. /L)	4.39 ± 1.97	18.38 ± 10.28	17.80 ± 2.09	10.78 ± 1.58	5.72 ± 1.34	2.66 ± 0.55
CO3-- (meq. /L)	0.29 ± 0.12	0.28 ± 0.05	0.32 ± 0.04	0.17 ± 0.04	0.30 ± 0.04	0.13 ± 0.05
HCO3- (meq. /L)	1.88 ± 0.23	1.88 ± 0.15	2.32 ± 0.13	1.44 ± 0.08	1.97 ± 0.10	1.29 ± 0.21
Na^+ (meq. /L)	10.10 ± 3.75	40.35 ± 11.53	16.27 ± 3.34	7.06 ± 2.20	26.69 ± 5.39	1.05 ± 0.23
K^+ (meq. /L)	1.08 ± 0.20	1.51 ± 0.18	1.03 ± 0.07	0.45 ± 0.06	0.76 ± 0.09	0.31 ± 0.04
Ca^{++} (meq. /L)	1.80 ± 0.35	6.84 ± 4.56	12.35 ± 1.45	3.79 ± 0.63	4.33 ± 0.56	2.12 ± 0.46
Mg^{++} (meq. /L)	0.90 ± 0.27	6.20 ± 4.06	3.10 ± 0.38	1.64 ± 0.39	3.36 ± 0.45	1.74 ± 0.54
SAR	8.30 ± 2.62	20.14 ± 3.17	6.71 ± 1.43	4.05 ± 0.96	13.79 ± 2.86	0.85 ± 0.25
PAR	0.94 ± 0.12	0.91 ± 0.18	0.41 ± 0.03	0.29 ± 0.03	0.41 ± 0.04	0.23 ± 0.03

Table (4). Pearson-moment correlation (r) between the soil variables in the stands surveyed in different habitats of the study area.

Sand	1.000																		
Silt	-0.913	1.000																	
Clay	-0.867	0.588	1.000																
M.c	-0.683	0.577	0.678	1.000															
Por.	-0.328	0.191	0.418	0.472	1.000														
Ca CO3	-0.718	0.735	0.518	0.486	0.288	1.000													
O.c	-0.668	0.685	0.481	0.583	0.273	0.744	1.000												
PH	-0.268	0.253	0.228	0.291	0.134	0.146	0.099	1.000											
EC	-0.646	0.565	0.588	0.685	0.496	0.497	0.730	0.101	1.000										
Cl-	-0.690	0.669	0.554	0.735	0.394	0.463	0.678	0.210	0.909	1.000									
SO4--	-0.481	0.338	0.536	0.499	0.506	0.379	0.530	-0.041	0.751	0.474	1.000								
CO3--	0.071	-0.103	-0.018	0.101	-0.060	0.092	0.010	0.207	-0.016	-0.080	0.056	1.000							
HCO3-	-0.329	0.290	0.294	0.327	0.306	0.378	0.360	0.324	0.269	0.201	0.231	0.070	1.000						
Na+	-0.729	0.711	0.580	0.753	0.395	0.538	0.743	0.192	0.927	0.972	0.579	-0.049	0.211	1.000					
K+	-0.643	0.503	0.661	0.646	0.491	0.400	0.632	0.179	0.790	0.692	0.706	-0.010	0.334	0.721	1.000				
Ca++	-0.104	-0.082	0.301	0.164	0.388	0.031	0.111	-0.142	0.338	0.045	0.710	0.130	0.254	0.040	0.420	1.000			
Mg++	-0.395	0.292	0.427	0.462	0.538	0.218	0.386	0.119	0.766	0.649	0.686	-0.154	0.151	0.629	0.568	0.403	1.000		
SAR	-0.703	0.749	0.481	0.699	0.202	0.596	0.754	0.256	0.754	0.861	0.370	0.085	0.220	0.909	0.601	-0.173	0.326	1.000	
PAR	-0.481	0.478	0.371	0.399	0.084	0.334	0.517	0.291	0.389	0.471	0.157	0.086	0.183	0.516	0.682	-0.196	0.037	0.662	1.000
	Sand	Silt	Clay	M.c	Por.	CaCO3	O.c	pH	EC	Cl^-	$SO4^{--}$	$CO3^{--}$	$HCO3^-$	Na^+	K^+	Ca^{++}	Mg^{++}	SAR	PAR

Abbreviations:

M.c = Moisture content

Por. = Porosity

O.c = Organic carbon

EC = Electrical conductivity

PAR = Potassium adsorption ratio

SAR = Sodium adsorption ratio

Significant at $p < 0.05$ = 0.195

Significant at $p < 0.01$ = 0.254

Significant at $p < 0.001$ = 0.321

c) Correlation between soil variables and vegetation gradients

The correlation between vegetation groups and soil variables is indicated on the ordination diagram produced by Canonical Correspondence Analysis (CCA) of the biplot of species – soil variables (Figure 5). It is clear that the dominant indicator and preferential perennial species of the halophytic vegetation groups (B, C & D) are separated at the upper side of CCA-biplot diagram and show a close relationships with many effective soil variables such as potassium, organic matter, potassium and sodium adsorption ratios, sulphate, moisture content, clay fraction, electrical conductivity, sodium, calcium carbonate, bicarbonate, soil porosity and calcium cation. On the other hand, the dominant, codominant, indicator and preferential perennial species of the psammophytic vegetation groups (A, E & F) are segregated at the lower side of the CCA diagram and exhibit a clear relationship with sand fraction only.

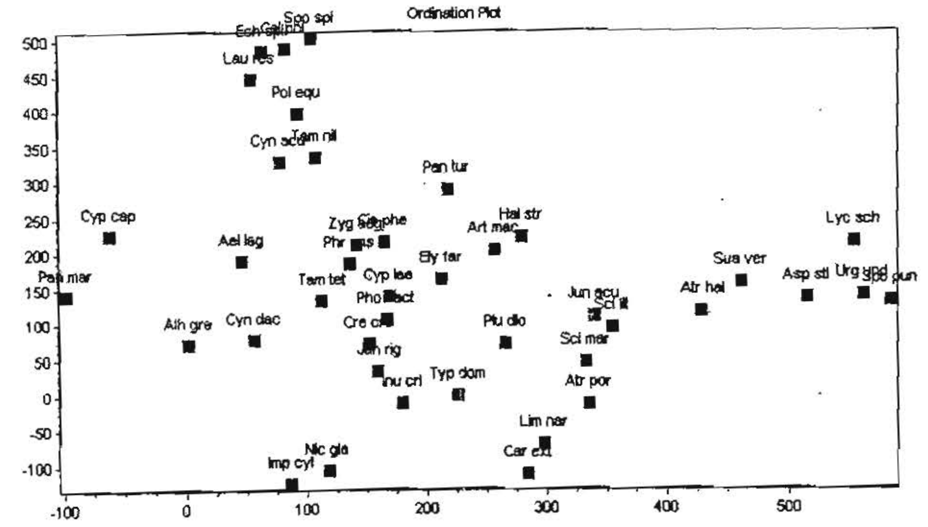

Figure (4) . Detrended Correspondence Analysis (DCA) ordination diagram of the species with the names abbreviated into the first three letters of each of the genus and species(see Table 1) .

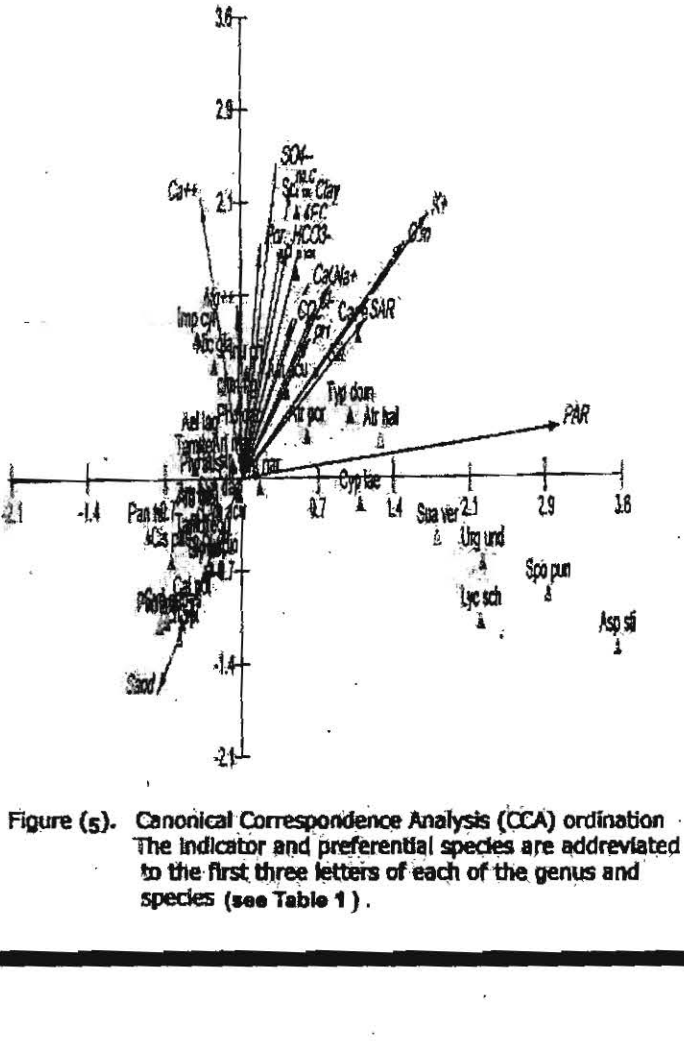

Figure (5). Canonical Correspondence Analysis (CCA) ordination The indicator and preferential species are addreviated to the first three letters of each of the genus and species (see Table 1).

DISCUSSION

The wetlands develop a wide variety of habitats, from mangroves along tropical shorelines to peatlands that lie south of the Arctic. It is estimated that 6.4% of the world's land area, or nearly 9 millions km^2, is wetland. Wetlands play a vital role in global nutrient and element cycles and provide key ecosystem services such as flood attenuation, shoreline stabilization, erosion control, ground water recharge and discharge, and water purification [**Mitsch & Gosselink (2000)**]. Also, they provide economic benefits by supporting fisheries, agriculture, timber, recreation, ecotourism, transport, water supply and energy resources [**Davis (1993)**].

Lake Borollus is one of the most important wetlands along the Mediterranean coast of Egypt. Lake Borollus protectorate aims at conserving the biological diversity and species that endangered as a result of human activities, monitoring environmental change in the lake and protecting special areas. It also aims at encouraging the environmental tourism, conducting scientific and applied research, maintaining natural resources, receiving the migration wild birds, and it is an important spawning and nursery area for fishes.

The phytosociological study dealt with in the present work revealed that, the vegetation in Lake Borollus protected area is classified into six vegetation groups derived by TWINSPAN classification. Group A is codominated by *Suaeda vera* and *Sporobolus pungens*, group B is dominated by *Arthrocnemum macrostachyum,* group C is dominated by *Limbarda crithmoides,* group D is dominated by *Arthrocnemum macrostachyum,* group E is dominated by *Alhagi graceorum* and group F is codominated by *Polygonum equisetiforme, Launaea resedifolia* and *Echinopus spinosus*.

It is of interest to notice that, the vegetation groups A, E and F may represent the sand formation habitat type, while groups B, C and D may represent the salt marsh habitat types in the study area. In the salt marshes, the dominant perennial species are *Arthrocnemum macrostachyum* and *Limbarda crithmoides*. The other indicator and/or common associated species in this habitat include *Suaeda vera, Halocnemum strobilaceum, Juncus acutus, Atriplex portulacoides, Phragmites australis, Juncus rigidus, Zygophyllum aegyptium, Tamarix nilotica,* etc. All of these halophytes constitute the major part of the vegetation composition of both littoral and inland salt marshes in Egypt [**Zahran (1982)**]. On the other hand, the vegetation groups which may represent sand formations can be subdivided into three groups according to their different subhabitats: group A (*Suaeda, vera – Sporobolus pungens*) may represent saline sand flats, group E (*Alhagi graecorum*) may represent sand bars and sand dunes and group F (*Polygonum* *equisetiforme – Launaea resedifolia – Echinops spinosus*) may represent raised non-saline sand flats and sand dunes. The indicator and most common associated species of the sand formations comprise *Lycium schwienfurthii, Cyperus capitatus, Moltkiopsis ciliate, Calligonum polygonides* subsp. *comosum, Asparagus stipularis, Elymus farctus,* etc.

The vegetation groups identified in the salt marshes (B, C & D) in the present study may be related to class *Salicornietea europaeae* described by Zohary (1973) which comprises all plant communities of the salt marshes in the Mediterranean coastal belt. The recognized groups (*Arthrocnemum macrostachyum* and *Limbarda crithmoides*) which dominate the salt marshes in the present work may be related to *Salicornion alliance* described by Tadros and Atta (1958). On the other hand, the vegetation groups of the sand formations in the present investigation may be related to different classes, orders, alliances and associations. The community type codominated by *Suaeda vera* and *Sporobolus pungens* (group A) may be related to alliance of *Plantaginion crassifoliae* with two associations of *Junceto-Schoenetum* and *Schoenetum nigricantis* described by Tadros (1953). While, *Alhagi, graecorum* community type (group E) may be related to alliance of *Atriplico-Suaedion palaestinae* described by Eig (1946). However, the community type codominated by *Polygonum equisetiforme, Launaea resedifolia* and *Echinops spinosus* (group F) may be related to the associations of *Scolymetum hispanica* **[Oberdorfer (1957)]**, *Panicetum turgidi* **[Kassas (1952)]** and *Lasiuretum hirsuti* **[Kassas & El-Abyad (1962)]** respectively.

The application of DCA ordination in the sampled stands of the study area indicated that groups A and F are clearly separated from the other groups (B, C, D & F). This may be due to the dissimilarity between the floristic composition of the sampled stands in groups A & F and due to the similarities between the other four groups.

Serag (1986) found that the most effective soil factors controlling the distribution of salt marsh vegetation in Damietta coastal land were calcium carbonate, organic carbon, sulphate, bicarbonate and potassium cation, while in the sand formations, the most important soil variables were water-holding capacity, soil salinity, chloride and magnesium cation. Mashaly (1987) reported that the most decisive edaphic factors controlling the distribution of the halophytic vegetation in the salt affected lands in Dakahlia – Damietta coastal region were moisture availability and calcareous deposits, while in the sand formations, the most effective soil variables were moisture content, porosity, water-holding capacity, organic carbon, calcium carbonate, pH value, electrical conductivity, chloride, sulphate and calcium cation. In the northern lakes, Khedr (1989) reported that the most important edaphic factors controlling the distribution of plant species in Lake Manzala islands were soil texture, moisture content, calcium carbonate and salinity. Khedr and Lovett-Doust (2000) mentioned that the zonation pattern of vegetation in Lake Borollus showed an interesting gradient of edaphic factors such as soil salinity, clay, organic carbon, total nitrogen and potassium cation. El-Bana *et al.* (2002) reported that the vegetation pattern in Lake Bardawil followed soil variables such as electrical conductivity, pH value, sodium and potassium cations. Shaltout *et al.* (2005 a&b) mentioned that soil moisture, salinity and sedimentation were the main operative factors in the successional process of the vegetation in Lake Idku and Lake Mariut.

In the present study, the application of Canonical Correspondence Analysis (CCA-biplot) between the position of vegetation groups on the ordination planes and soil variables of their stands indicated that, potassium, organic matter, sulphate, moisture content, clay fraction, electrical conductivity, sand fraction, calcium, sodium, calcium carbonate, bicarbonate and soil porosity were the most critical edaphic factors controlling the distribution and abundance of vegetation types in the salt marshes and sand formations of Lake Borollus protected area.

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الموئل وأنواع الكساء النباتي في محمية بحيرة البرلس – مصر

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بحيرة البرلس واحدة من محميات المناطق الرطبة ، حيث تهدف هذه الدراسة إلى التعرف على الموائل المختلفة ووصف الغطاء النباتي بها وعلاقة ذلك بالعوامل البيئية المؤثرة والسائدة في محمية بحيرة البرلس .

تم التعرف على المجتمعات النباتية (العشائر) في محمية بحيرة البرلس وذلك بتحليل ١٠٢ موقعا تمثل جميع الإختلافات سواء بالموائل أو الغطاء النباتي ، حيث أدى هذا التحليل وبعد إستخدام البرامج الإحصائية (**TWINSPAN**) إلى التعرف على ست مجموعات نباتية كالتالي:

١- مجموعة (**A**) بها سيادة مشتركة بين عشيرتي :
Suaeda vera – Sporobolus pungens

٢- مجموعتين (**B & D**) تسودهما عشيرة:
Arthrocnemum macrostachyum

٣- مجموعة (**C**) تسودها عشيرة : *Limbarda crithmoides*

٤- مجموعة (**E**) تسودها عشيرة : *Alhagi graecorum*

٥- مجموعة (**F**) بها سيادة مشتركة بين عشائر :
Polygonum equisetiforme – Launaea resedifolia – Echinops spinosus

وبإستخدام برنامج تحليل التطابق الكنسي (CCA) إتضح أن أكثر عوامل التربة إرتباطا بتوزيع ووفرة المجموعات النباتية الستة التي تم التعرف عليها بمحمية بحيرة البرلس هي : قوام التربة – رطوبة التربة – نفاذية التربة – البوتاسيوم – الصوديوم – الكالسيوم – المادة العضوية – كربونات الكالسيوم – الملوحة (التوصيل الكهربي) – الكبريتات – البيكربونات .