Wetlands Ecol Manage (2008) 16:421–439
DOI 10.1007/s11273-008-9079-5

ORIGINAL PAPER

Vegetation analysis of Burullus Wetland: a RAMSAR site in Egypt

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Received: 26 January 2007 / Accepted: 3 January 2008 / Published online: 15 March 2008

Abstract We analyzed the vegetation of Lake Burullus at the deltaic Mediterranean coast of Egypt, the sand bar between its northern shore and Mediterranean Sea, the water courses that drain into the lake and the wetland around it. Our ultimate aim was to identify threatened species and communities and the environmental factors that affect their distribution in order to formulate a plan for their conservation. The total number of the recorded species was 197 (100 annuals and 97 perennials), including 12 floating and submerged hydrophytes. Three species are endemic to Egypt: two annuals (*Sinapis arvensis* subsp. *allionii* and *Sonchus macrocarpus*) and one perennial (*Zygophyllum album* var. *album*). Thirty-four species are rare allover Egypt (15 annuals and 19 perennials). The lake area included 10 types of habitat (sand formations, salt marshes, lake cuts, terraces, slopes, water edges and open water of the drains, islets, shores and lake). The vegetation was classified into 13 groups (i.e., plant communities). Six groups were dominated or co-dominated by the common reed (*Phragmites australis*); these groups occupied a wide environmental gradient from xeric to hydric habitats. Five other groups were dominated by halophytic species (*Arthrocnemum macrostachyum*, *Suaeda vera*, *Sarcocornia fruticosa*, *Halocnemum strobilaceum* and *Salsola Kali*). The remaining two groups were dominated by the emergent Typha domingensis and the submerged *Potamogeton pectinatus*. Moisture, salinity and sedimentation were the main factors that governed the plant succession in this wetland.

Key words Biodiversity · Classification · Conservation · Endemic species · Hydrophytes · Nile Delta · Ordination · Vegetation

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Introduction

Wetlands are of ecological importance due to their hydrologic attributes and their role as ecotones between terrestrial and aquatic ecosystems. They function as downstream recipients of water and waste from both natural and human sources, and have been often transformed to dry lands for agriculture and human settlements, among others. Also, river control schemes have often caused the loss of wetlands. The attributes of wetlands include high productivity; sources, sinks and transformers of numerous chemical, biological and genetic materials; and valuable habitats for fisheries, wildlife and birds. Conservation associations worldwide have noted and described the alarming changes in these important habitats. This led to the Convention on Wetlands known as RAMSAR Convention in 1971. Burullus Wetland along the deltaic Mediterranean coast of Egypt is one of the RAMSAR sites and was declared as a natural protectorate in 1998.

Distribution of the hydrophytes in Lake Burullus was studied by Samaan et al. (1988). They reported that the lake is characterized by extensive growth of hydrophytes, particularly along its eastern and southern shores beside the outlets of the drains. The dominant submerged plant was *Potamogeton pectinatus*, while *Potamogeton crispus* and *Ceratophyllum demersum* were less frequent, and *Najas armata* was of very limited distribution. The dominant emerged plant was *Phragmites australis* and, to some extent, *Typha domingensis* which grows well around the margins of the lake and islets. Floating plants *Eichhornia crassipes*, *Lemna gibba* and *Spirodella polyrrhiza* appeared also near the outlets of the drains where their growth was enhanced by the flowing of fresh water.

Environment, fauna and vegetation of Lake Burullus were studied, as a part of the north Nile Delta by Al-Sodany (1992), Shaltout et al. (1995) and El-Kady et al. (2000). These studies indicated the presence of 12 types of habitat, 171 flowering plants and 8 vegetation types. The behavior of the common species and vegetative types was affected by soil moisture, salinity, fertility and anthropogenic gradients. The study of Al-Sodany (1998) on the water bodies in north Nile Delta, including Lake Burullus, indicated the presence of 227 species and 32 vegetation groups affected by a complex gradient of the same factors mentioned in the previous studies.

In a comparative study on the plant life of Burullus and Manzala lakes, Khedr and Zahran (1999) concluded that, despite the two times larger area of Lake Manzala compared with Lake Burullus, and the environmental similarities between both lakes, Lake Burullus was floristically richer (135 species belong to 41 families) than Lake Manzala (102 species belong to 36 families). They mentioned also that the islets of Lake Burullus seemed to be a suitable habitat for some plants absent from the islets of Lake Manzala (e.g., *Lycium schweinfurthii*, *Pancratium maritimum, Allium roseum*, *Silene succulenta*, *Asparagus stipularis* and several annuals). Some plant species recorded in Lake Burullus, such as *Ipomoea imperati and Limonium narbonense*, were rare, perhaps, threatened and a priority for conservation (Khedr 1999; Khedr and Lovett-Doust 2000).

The present study aimed to determine and analyze the floristic composition of Lake Burullus, its sand bar between the northern shore of the lake and the Mediterranean Sea, and the water courses that drain into the lake from its southern shore (i.e., Burullus Wetland). The ultimate aim of this study was to identify the threatened species and communities and to assess the environmental factors that affect their distribution in order to develop a plan for their conservation.

Study area

Lake Burullus is a shallow brackish lake extending for 47 km along the deltaic Mediterranean coast of Egypt (Fig. 1). Its main basin has an oblong shape and could be classified into three sectors (eastern, middle and western), each with some homogeneity in geomorphology, hydrology and biology. The islets scattered in the lake form physical separations between these sectors. The western sector is the least wide (<5 km); the middle sector has an average width of 11 km (El-Bayomi 1999). The lake's area decreased from 502.7 km^2 in 1984 to 410 km^2 in 1997 (its length decreased from 56 to 47 km, while the width decreased from 15 to 14 km). The water depth reaches 200 cm in the middle and near the sea outlet (Bughaz El-Burullus).

Al-Sodany (1998) described six main types of habitat in the Burullus wetland: (1) coastal salt marshes covered with water, (2) sand formations that cover the surface of the marine bar (sheets, hillocks and dunes), (3) lake cuts that represent the recent lands resulting from the drying process of the outermost western and eastern fringes of the lake during 1984–1997, (4) drains that discharge at the southern shore, (5) the lake proper which is classified into lake shore and open water, and (6) the islets scattered within the water body.

According to the map of the world distribution of arid regions (UNESCO 1977), the northern Mediterranean part of the Nile Delta belongs to the arid region. The climatic conditions are warm summers (20–30°C) and mild winters (10–20°C). The aridity index (P/PET: where P is the annual precipitation and

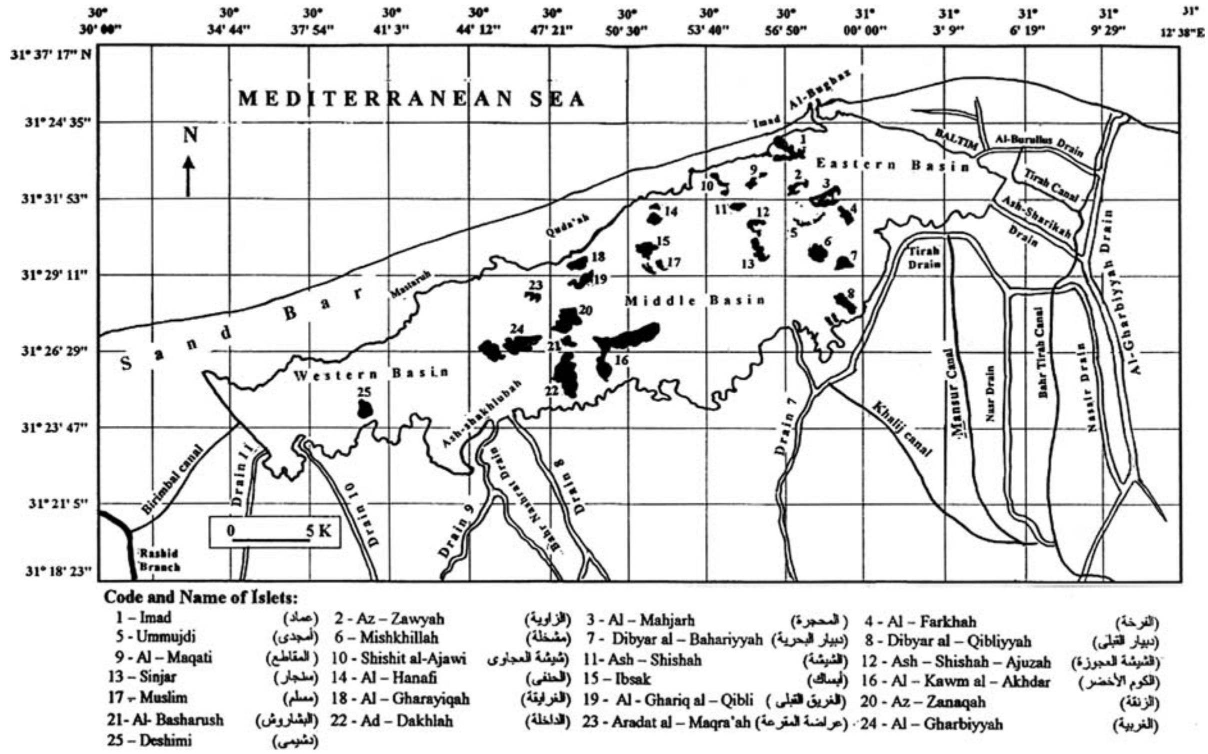

Fig. 1 Map showing the study area

Table 1 Long-term averages (≥20 years) of the climatic records at two stations in the Burullus Wetland (Anonymous 1980)

Meteorological variable	Rosetta		Baltim	
	31°24′ N, 30°25′ E		31°33′ N, 31°05′ E	
	Range	Mean	Range	Mean
Maximum air temperature (°C)	18.1–30.4	24.6	17.4–29.7	24.0
Minimum air temperature (°C)	10.8–23.4	17.0	11.2–23.6	17.3
Mean air temperature (°C)	13.0–26.3	19.8	14.4–26.5	20.5
Relative humidity (%)	65.0–72.0	69.0	65.0–73.0	69.0
Evaporation (mm/day)	3.3–4.8	4.2	3.3–5.6	4.6
Rainfall (mm/month)	0.0–50.3	–	0.0–46.6	–

PET is the potential evapo-transpiration) ranges between 0.03 and 0.2 in the north Delta (arid region), and less than 0.03 in the south hyperarid region. Long-term climatic averages recorded at two meteorological stations distributed within the study area are presented in Table 1 (after Anonymous 1980).

Materials and methods

Two hundred and twenty-seven stands were selected to represent the main habitats in the study area. The stand size was about 20 × 20 m in all habitats (approximately the minimal area of the plant communities), except for the drains and the lake where the length and width of the stands varied according to the extension of plant cover along them. In each stand, the annual and perennial species were listed. Nomenclature was according to Täckholm (1974) and Boulos (1999, 2000, 2002, 2005). Life forms were identified according to the scheme of Raunkiaer (1937), rarity forms after Rabinowitz (1981) and floristic categories following many authors as quoted by Ahmed (2003).

Plant cover was estimated using the line intercept method (Canfield 1941): 5 parallel lines, each of 20 m long, were laid down in each stand (2–3 lines for the stands of the drains and lake). The lengths of interceptions by each species in each stand were measured in cm, summed up and related to the total length of lines stretched in that stand. The cover was expressed as m/100 m. Such estimates were used to calculate the relative cover or importance values (P*i*) of each species. Two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DECORANA) were applied to the cover estimates of 197 species in 227 stands (Hill 1979a, b).

Species richness (alpha diversity) was calculated for each vegetation group as the average number of species per stand. Species turnover (beta diversity) was calculated as a ratio between the total number of species in a certain vegetation group and its alpha diversity. Relative evenness (H′: Shannon–Weiner index) and relative concentration of dominance (C: Simpson's index) were expressed according to the following equations: $H' = -\sum^{s} Pi\ (\text{Log } Pi)$ and $C = \sum^{s} (Pi)^2$, where "s" is the total number of species and "P*i*" is the relative importance value (relative cover) of the *i*th species (Whittaker 1972; Pielou 1975; Magurran 1988).

Three soil samples were collected from each stand; each sample represented a profile from the top down to 50 cm below the soil surface (composite sample). Soil texture was determined by Bouyoucos hydrometer (Piper 1966), and the results were used to calculate the percentages of sand, silt and clay. Total organic matter was estimated based on loss-on-ignition at 450°C and total $CaCO_3$ was estimated by Collin's calcimeter. Soil-water extracts (1:5) were prepared for the estimation of electrical conductivity (EC in mS/cm) and pH. Extracts of 5 g soil samples were prepared using 2.5% v/v glacial acetic acid for estimating P, K, Ca, Na, Mg and Fe. N was estimated by the micro-Kjeldahl method. K, Ca and Na were estimated by flame photometry, while Mg and Fe were measured with atomic absorption spectrophotometry. Molybdenum blue and indophenol methods were used for estimation of P and N, respectively, using colorimetric spectrophotometer. All these procedures were according to Jackson (1962) Allen et al. (1974) and Greenberg et al. (1992).

Water sampling was carried out in the three sectors of Lake Burullus (eastern, middle and western). In each sector, two to three water samples were collected to represent the north, middle and south of the lake. Each sample was taken as integrated composite sample from the top down to 50 cm below the water surface. Water depth and water transparency were measured using a white Seechi disc with a diameter of 30 cm. The disc was lowered slowly from the shaded side of the boat until it disappeared, and lowered again until reaching the bottom for the water depth measurement. The salinity (as electric conductivity) and pH of the water were estimated, in situ, using a conductivity and pH meter, respectively. Three water samples were collected, from each site, in polyethylene bottles. Alkalinity and chlorosity (Cl) were determined using the titration against HCl and $AgNO_3$ (Mohr's method), respectively. Sulfates were estimated using a gravimetric method with ignition of the residue.

Results

The total number of the species recorded in the Burullus Wetland was 197. Seven perennials (*Phragmites australis*, *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum*, *Sarcocornia fruticosa*, *Suaeda vera*, *Cynodon dactylon* and *Tamarix nilotica*); and five annuals (*Salsola kali*, *Senecio glaucus* subsp. *coronopifolius*, *Mesembryanthemum nodiflorum*, *Polypogon monspeliensis* and *Spergularia marina*) were recorded in 8 out of 10 habitats (≥75%). Considering the global phytogeographical distribution, most of the species belonged to the Mediterranean region (13 mono-regional + 41 bi-regionals + 62 pluri-regionals), while the Irano-Turanian species were in the second order (25 bi-regionals + 59 pluri-regionals), followed by Saharo-Arabian (9 mono-regional + 26 bi-regionals + 25 pluri-regionals). In general, the pluri-regional species were the highest (65 species = 33.0%), followed by the bi-regional ones (57 species = 28.9%). The mono-regionals (40 species = 20.3%) and cosmopolitans (31 species = 15.7%) were the lowest (Appendix 1). In addition, three species were endemic to Egypt: one perennial (*Zygophyllum album* subsp. *album*) and 2 annuals (*Sinapis arvensis* subsp. *allionii* and *Sonchus macrocarpus*). Regarding the rarity forms, most species (44 perennials and 40 annuals) had a small geographical distribution, narrow habitat specificity and low abundance. No species had small geographical distribution, wide habitat specificity and high abundance (Fig. 2).

The islets of the lake had the highest number of species (89 = 45.2% of the total species), 26 of them were recorded only in this habitat (including *Sinapis arvensis* subsp. *allionii*, *Adonis dentata*, *Calendula arvensis*, *Erodium laciniatum*, *Filago desertorum*, *Paronychia arabica*, *Asparagus stipularis*, *Lycium schweinfurthii, Pancatium maritimum* and *Urginea undulata*). The drain terraces had the second highest number of species (87 = 44.2% of the total species), while the open water of the lake and drains had the lowest (16 and 14 species). On the other hand, the drain slopes and lake islets had the highest species richness (13.4 and 11.3 species/stand), while the open water of the lake had the lowest richness (2.5 species/stand) and relative evenness (H′ = 1.02), but the highest relative concentration of dominance (C = 0.12). Also, the open water of the drains had low relative evenness (1.05) and high relative concentration of dominance (C = 0.11) (Table 2).

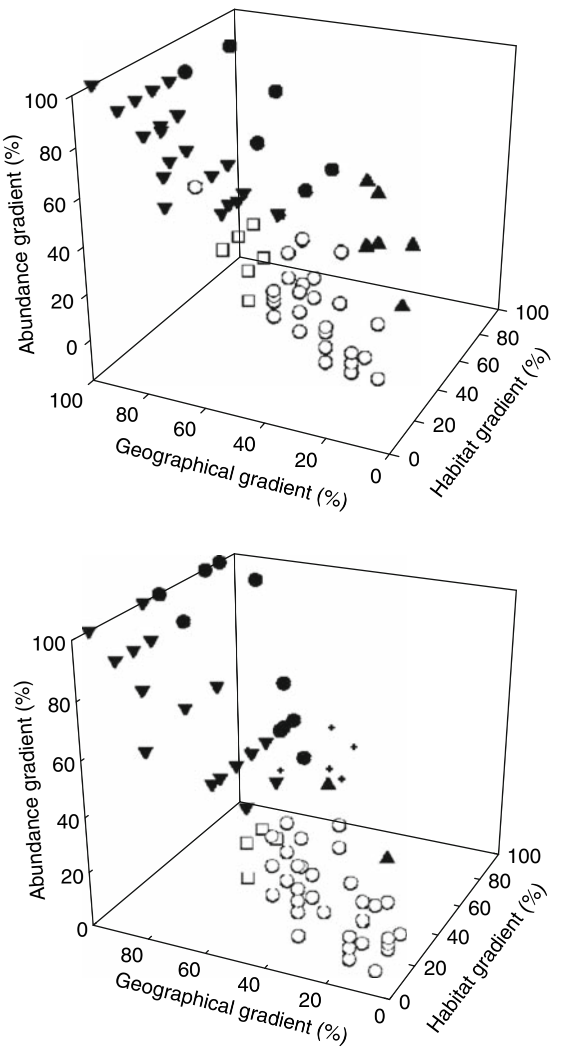

Fig. 2 Ordination of the recorded species in Burullus Wetland along the geographical, habitat and abundance gradients. The rarity forms of Rabinowitz (1981) are as follows: ●: locally abundant over a large range in several habitats, +: Constantly sparse over a large range in several habitats, ▽: locally abundant over a large range in a specific habitat, △: constantly sparse in a specific but over a large range, □: constantly sparse and geographically restricted in several habitats and ◯: constantly sparse and geographically restricted in specific habitats

Soil of the sand sheets had the highest value of phosphorus (43.0 mg/100 g), but the lowest of silt (0.5%), organic matter (0.3%), calcium carbonate (2.1%), pH (7.5), nitrogen (16.4 mg/100 g), sodium (141.7 mg/100 g), potassium (22.8 mg/100 g) and magnesium (157.1 mg/100 g) (Table 3). Soil of the drain slopes had the highest clay (16.2%) and calcium carbonate content (10.9%), but the lowest iron (6.8 mg/100 g); while that of the drain water edges had the highest electric conductivity (11.0 mS/cm), nitrogen, sodium and calcium (93.9, 793.7 and 1618.3 mg/100 g, respectively), but the lowest sand content (60.9%). Soil of the lake shore had the highest content of sand (87.6%), magnesium and iron (338.4 and 20.6 mg/100 g), while that of the salt marshes had the highest content of phosphorus (43.1 mg/100 g). On the other hand, the sediments of the drains open water had the highest content of silt (29.8%), organic matter (5.4%), pH (8.1) and potassium (308.6 mg/100 g), but the lowest of phosphorus (13.1 mg/100 g); while those of the lake open water had the highest of pH (8.1) and the lowest of electrical conductivity (1.5 mS/cm), phosphorus (4.9 mg/100 g) and calcium (355 mg/100 g).

In most cases, salinity, N, Na, K, Cl, SO_4 and alkalinity in lake water decreased from east to west and/or from south to north direction (Table 4). The eastern sites had the highest values of electrical conductivity (11.7 mS/cm), N (331.3 mg/l), Mg (213.8 mg/l), Na (1490.7 mg/l), K (37.4 mg/l), Cl (2394.9 mg/l), SO_4 (1516.8 mg/l) and alkalinity (411.6 mg/l); while the western sites had the highest water depth (78.3 cm) and transparency (65.6 cm). On the other hand, the southern sites had the highest of N (286.1 mg/l), Ca (513.1 mg/l), Na (1151.4 mg/l), K (26.3 mg/l), Cl (2230.5 mg/l) and alkalinity (399.2 mg/l); while the northern sites had the highest water depth (86.2 cm), transparency (63.0 cm) and electrical conductivity (8.5 mS/cm).

Table 2 Variation in some diversity indices calculated for the main habitats of the Burullus Wetland

Habitat	SM	SS	LG	TD	SD	ED	OD	LS	LO	IS	Mean
Total species	51	45	29	87	69	59	14	65	16	88	52.3
Species richness	8.1	3.2	7.7	11.0	13.4	7.8	3.3	9.4	2.5	11.3	7.8
Species turnover	6.3	14.1	3.8	7.9	5.2	7.6	4.2	6.9	6.4	7.8	7.0
Relative conc. of dominance	0.04	0.05	0.06	0.03	0.03	0.03	0.11	0.03	0.12	0.03	0.05
Relative evenness	1.52	1.47	1.33	1.73	1.66	1.63	1.05	1.65	1.02	1.68	1.47

SM: salt marshes, SS: sand formations, LG: lake cuts, TD: terraces, SD: slopes, ED: water edges and OD: open water zones of the drains, LS: lake shores. LO: open water of the lake and IS: lake islets

Table 3 Means (1st line) standard deviation (2nd line) of some soil characteristics collected from represented stands of the main habitats of Lake Burullus area

Variable	SM	SS	LG	TD	SD	ED	OD	LS	LO	Total mean	*F*
pH	7.7	7.5	7.7	7.9	7.9	7.8	8.1	8.0	8.1	7.8	5.46**
	0.3	0.2	0.2	0.3	0.2	0.3	0.4	0.3	0.4	0.3	
EC (mS/cm)	4.6	2.8	2.7	2.9	5.9	11.0	2.9	3.5	1.5	5.0	5.39**
	2.6	0.9	1.9	2.0	5.6	10.5	2.7	1.7	0.6	5.8	
Bulk parameters (%)											
Clay	13.0	12.2	13.4	10.4	16.2	13.0	9.1	9.2	9.3	12.2	0.76^{ns}
	2.7	2.5	4.1	4.8	24.5	7.2	7.2	3.8	3.3	10.6	
Silt	5.2	0.5	1.0	15.3	17.1	26.1	29.8	2.7	4.6	13.6	10.68**
	9.7	0.6	1.4	15.6	14.3	15.5	16.0	3.8	5.6	15.7	
Sand	82.0	87.4	85.5	74.3	71.7	60.9	61.1	87.6	86.1	74.9	10.01**
	10.1	2.4	4.5	13.8	14.5	16.0	17.7	7.3	8.1	15.8	
OM	1.1	0.3	0.9	3.1	3.1	4.3	5.4	1.1	1.4	2.4	4.96**
	1.3	0.1	0.6	3.4	2.8	2.5	5.1	0.7	0.4	3.1	
$CaCO_3$	2.3	2.1	2.5	3.1	10.9	2.5	3.7	4.1	4.3	4.0	0.52^{ns}
	0.3	0.3	0.5	4.8	4.8	1.4	2.1	4.6	2.0	5.7	
Elements (mg/100 g)											
N	25.2	16.4	27.4	56.0	34.9	93.9	75.8	39.7	67.9	51.0	4.31**
	21.1	9.2	18.5	64.9	34.4	67.5	72.4	24.8	32.0	55.4	
P	43.1	43.0	25.7	38.3	30.9	27.6	13.1	42.6	4.9	33.3	9.08**
	16.7	15.1	9.2	16.7	13.2	16.8	7.2	4.6	2.6	18.1	
Na	383.1	141.7	212.8	677.9	438.1	793.7	718.1	468.7	480.2	531.0	4.41**
	479.0	91.9	124.0	619.5	199.0	308.0	278.0	253.0	182.0	434.0	
K	58.1	22.8	28.3	182.9	160.9	196.5	308.6	98.3	184.0	143.4	8.96**
	86.1	7.7	6.8	181.2	128.8	105.0	80.8	67.3	65.4	136.0	
Ca	1396.3	750.0	1497.5	1401.9	1536.4	1618.3	516.7	1080.8	355.0	1276.6	2.72*
	905.0	115.0	691.0	1271	919	1156	384.6	698.9	105.0	981.0	
Mg	236.1	157.1	182.4	250.9	273.5	283.9	284.8	338.4	166.0	254.2	2.61*
	155.0	43.3	55.0	97.4	58.0	154.7	94.2	167.0	63.9	124.0	
Fe	12.9	10.9	14.8	7.8	6.8	14.8	10.9	20.6	10.4	11.9	0.12^{ns}
	11.1	3.3	8.4	5.1	5.0	7.4	10.3	20.2	1.5	13.1	

SM: salt marshes, SS: sand formations, LG: lake cuts, TD: terraces, SD: slopes, ED: water edges and OD: open water zones of the drains, LS: lake shores and LO: open water of the lake. * $P \leq 0.01$, ** $P \leq 0.0001$, ns: not significant

Table 4 Site variation in the total mean (1st line) and standard deviation (2nd line) of the water characteristics of Lake Burullus

Variable	Site						Mean	*F*-value	
	East–West axis			North–South axis				E–W axis	N–S axis
	East	Middle	West	North	Middle	South			
Physical properties									
Air temperature (°C)	22.7	23.9	24.4	24.1	23.2	23.4	23.6	1.2^{ns}	0.3^{ns}
	3.4	4.1	4.5	4.1	4.2	3.8	4.0		
Water temperature (°C)	23.4	24.0	23.1	23.6	23.7	23.4	23.6	0.2^{ns}	0.0^{ns}
	4.4	4.3	4.3	4.4	4.5	4.2	4.3		
Water depth (cm)	62.9	74.0	78.3	86.2	65.3	59.4	70.9	3.0^{ns}	13.7***
	18.1	22.9	26.2	20.8	17.1	19.8	22.8		
Transparency (cm)	54.4	45.0	65.6	63.0	36.4	55.9	53.7	3.5*	6.3**
	29.8	19.5	27.8	24.7	12.5	30.6	26.7		
pH	8.66	8.81	8.65	8.64	8.85	8.70	8.72	2.6^{ns}	3.3*
	0.30	0.17	0.36	0.28	0.18	0.32	0.29		
EC (mS/cm)	11.7	6.6	5.7	8.5	8.1	8.3	8.3	12.1***	0.0^{ns}
	5.3	3.7	4.8	6.4	4.0	5.0	5.3		
Elements (mg/l)									
N	331.3	239.3	160.5	207.3	276.3	286.1	254.1	8.2***	2.1^{ns}
	166.4	144.9	78.4	108.3	178.9	169.8	154.5		
P	30.3	135.5	69.3	30.3	112.9	106.4	79.5	5.6**	3.7*
	50.5	162.8	104.7	45.2	165.2	134.7	124.1		
Ca	478.9	488.1	434.1	434.5	463.2	513.1	471.2	1.0^{ns}	2.7^{ns}
	100.3	170.3	80.9	100.8	160.9	119.6	127.9		
Mg	213.8	134.5	110.7	157.3	199.5	131.8	158.3	7.9***	2.5^{ns}
	98.4	94.7	84.2	99.0	115.8	90.4	102.4		
Na	1490.7	935.0	620.1	989.3	1047.7	1151.4	1064.6	20.6***	0.5^{ns}
	601.6	428.4	208.8	526.7	658.5	584.7	579.4		
K	37.4	18.8	9.8	22.0	21.7	26.3	23.5	19.4***	0.5^{ns}
	20.4	13.4	6.7	17.9	22.1	18.0	18.9		
Cl	2394.9	1832.6	1374.6	1730.0	1775.2	2230.5	1929.0	13.0***	3.5*
	690.0	786.8	382.6	595.1	437.2	1003.8	774.6		
SO_4	1516.8	821.9	615.3	1078.6	1326.7	785.8	1030.8	3.9*	1.1^{ns}
	1853.5	367.0	370.5	1411.6	1653.9	404.5	1220.8		
Alkalinity	411.6	388.1	312.8	345.7	395.1	399.2	378.1	12.0***	4.2*
	65.6	84.6	32.1	47.9	78.5	91.0	77.4		

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, ns: not significant

The application of TWINSPAN on the cover estimates of 197 species recorded in 227 stands led to the recognition of 13 vegetation groups at the 6th level of classification. The application of DECORANA on the same set of data indicated a reasonable segregation between many of these groups along the ordination plane of axes 1 and 2 (Fig. 3). Two groups mainly occupied the lake islets (*Arthrocnemum macrostachyum–Juncus acutus* and *Typha domingensis–Ceratophyllum demersum*), three inhabited the lake open water (*Potamogeton pectinatus–Phragmites australis* and *Phragmites australis–Potamogeton pectinatus*) and three inhabited the lake shores (*Juncus acutus*, *Sarcocornia fruticosa* and *Phragmites australis–Typha domingensis*). On the other hand, five groups occupied a wide habitat gradient (*Phragmites*

Table 5 Characteristics of the 13 vegetation groups derived after the application of TWINSPAN

VG.	*N*	Total spp.	G/P (%)	Habitats										First dominant	P (%)	C (%)	Second dominant	P (%)	C (%)
				SM	SS	LG	TD	SD	ED	OD	LS	LO	IS						
1	9	37	4.0	11		11							78	*Arthrocnemum macrostachyum*	100	41	*Juncus acutus*	44	31
2	10	55	4.4	20	10		40	10				20		*Phragmites australis*	60	59	*Suaeda pruinosa*	50	12
3	150	170	66.1	16	8	6	7	13	11	7	4	5	21	*Phragmites australis*	48	17	*Arthrocnemum macrostachyum*	44	22
4	8	53	3.5				13	13	25	13		13	25	*Suaeda vera*	63	28	*Inula crithmoides*	50	27
5	3	27	1.3						33		67			*Juncus acutus*	100	17	*Phragmites australis*	100	6
6	11	50	4.9				18		18		55		9	*Sarcocornia fruticosa*	73	53	*Arthrocnemum macrostachyum*	64	5
7	10	11	4.4							10		90		*Potamogeton pectinatus*	100	87	*Eichhornia crassipes*	90	10
8	3	16	1.3				33			33			33	*Halocnemum strobilaceum*	67	21	*Polypogon monspeliensis*	67	9
9	2	10	0.9				50	50						*Salsola kali*	100	31	*Senecio glaucus subsp. coronopifolius*	100	8
10	5	39	2.2				20				80			*Phragmites australis*	80	18	*Typha domingensis*	80	6
11	6	18	2.6				17			17		67		*Phragmites australis*	100	51	*Potamogeton pectinatus*	50	23
12	3	16	1.3									33	67	*Typha domingensis*	67	51	*Ceratophyllum demersum*	67	22
13	7	36	3.1				29	14				57		*Phragmites australis*	71	15	*Potamogeton pectinatus*	43	9

N: number of stands, G/P: the percentage of the stands representing each vegetation group in relation to the total sampled stands, P: presence of species (%), C: relative cover of species (%). The habitats are: SM: salt marshes, SS: sand formations, LG: lake cuts, TD: terraces, SD: slopes, ED: water edges and OD: open water zones of the drains, LS: lake shores, LO: open water of the lake and IS: lake islets

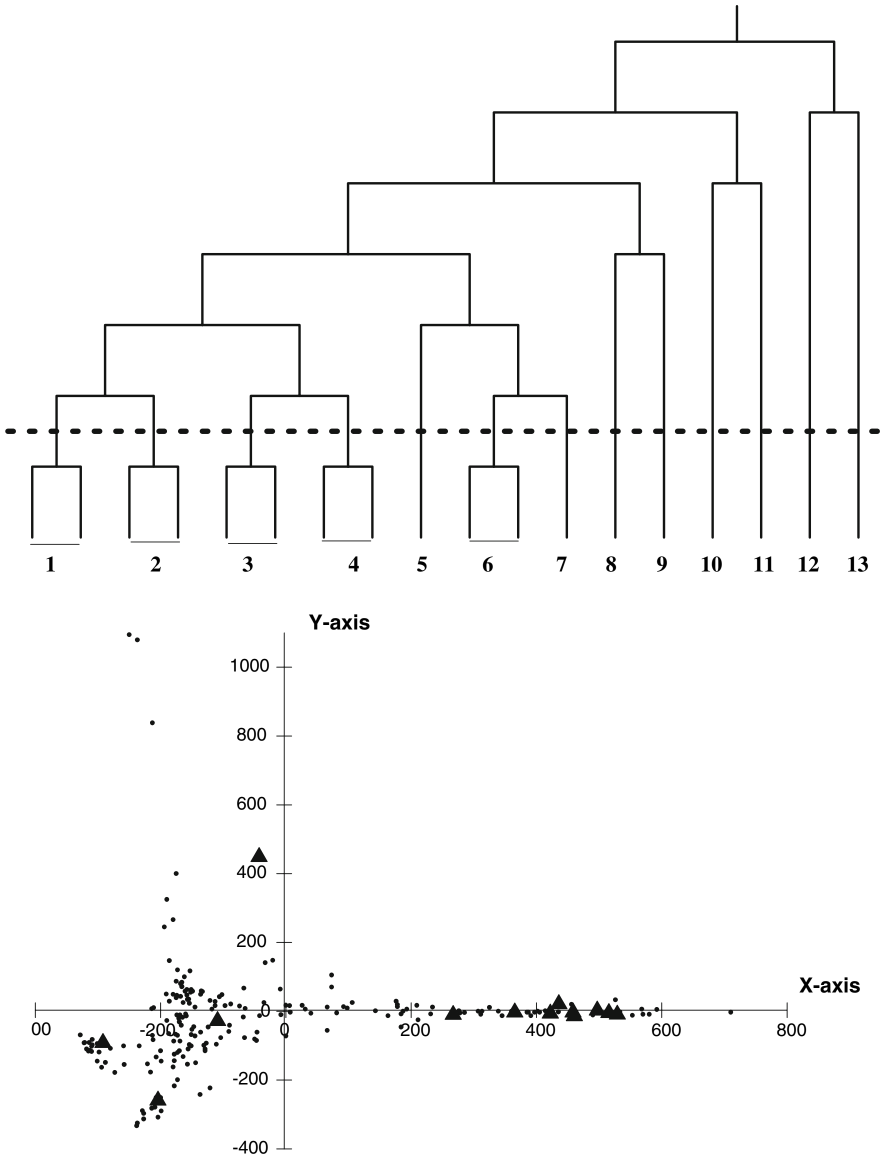

Fig. 3 The relationship between the 13 vegetation groups generated after the application of TWINSPAN classification technique and their ordination along the axes 1 and 2 of DECORANA. The names of these groups are: 1 = *Arthrocnemum macrostachyum–Juncus acutus*, 2 = *Phragmites australis–Suaeda pruinosa*, 3 = *Phragmites australis–Arthrocnemum macrostachyum*, 4 = *Suaeda pruinosa–Inula crithmoides*, 5 = *Juncus acutus*, 6 = *Sarcocornia fruticosa*, 7 = *Potamogeton pectinatus*, 8 = *Halocnemum strobilaceum*, 9 = *Salsola kali*, 10 = *Phragmites australis*, 11 = *Phragmites australis–Potamogeton pectinatus*, 12 = *Typha domingensis–Ceratophyllum demersum*, and 13 = *Phragmites australis–Potamogeton pectinatus*

australis–Suaeda pruinosa, *Phragmites australis–Arthrocnemum macrostachyum*, *Suaeda vera–Inula crithmoides*, *Halocnemum strobilaceum* and *Salsola kali*) (Table 5).

Discussion

From the plant diversity viewpoint, Lake Burullus is considered one of the richest sites in Egypt, taking into account its relatively small area (410 km^2). For example, its flora approximates half of the flora of Nile Delta that has an area of about 22,000 km^2, and exceeds those of many of the Egyptian natural reserves such as Omayed Biosphere Reserve (700 km^2: 251 species), Nabq (600 km^2: 134 species) and Wadi Al-Allaqui (30,000 km^2: 92 species) (Shaltout and Al-Sodany 2000, 2002). On the other hand, the lake islets have the highest number of species; most of them grow typically on sandy habitat. Local variation in topography, water level and soil depth in the large islets (e.g., Al-Kawm Al-Akhdar and

Dishimi) often create heterogeneity within communities, which probably accounts for increased species richness (Khedr and Lovett-Doust 2000). These large islets include many rare and confined species that do not occur elsewhere in the region. So, we are suggesting the declaration of Al-Kawm, Al-Akhdar and Dishimi islets as core zones for the conservation of the rare and confined species. Compared with a previous study on the islets of Lake Burullus, Khedr and Lovett-Doust (2000) recorded 58 species, while 89 species were recorded in the present study. This may be due to a difference in rainfall and/or protection against severe human impacts after the declaration of Lake Burullus as a Natural Protectorate.

Neophytes are noteworthy species that differ from each other not only in time and way of their introduction but also in the degree of their establishment in various local artificial, seminatural or natural coenoses. Seven of these species invaded the Nile Delta including the Burullus Wetland: *Paspalum distichum* (Hejny and Kosinova 1977), *Ipomoea carnea* (Al-Sodany 1998), *Bassia indica* (Drar 1952), *Aster squamatus* (Boulos and El-Hadidi 1994), *Eichhornia crassipes* (Täckholm and Drar 1950), *Azolla filiculoides* (Yanni 1992) and *Vossia cuspidata* (Shehata, 1996). In addition, three species are considered new records to Nile Delta (*Convolvulus lanatus*, *Cornulaca monocantha* and *Fagonia arabica*). The seeds of these species may be transported to this region with the sand and gravels used in the construction of the International Road that crosses the Burullus Wetland.

Therophytes are the most frequent life form in the study area, followed by cryptophytes (geophytes-helophytes and hydrophytes). This trend is similar to that of the whole Egyptian flora (Hassib 1951), the flora of the Nile Delta (Ahmed 2003), and the whole flora of the five Egyptian northern lakes (Shaltout and Galal 2006). The dominance of therophytes seems to be in response to the adverse climatic conditions, moisture deficiency, substrate instability and biotic influence.

From a phytogeographical viewpoint, Mediterranean elements are the most represented chorotype in the present study taking the following sequence: pluri-regionals > bi-regionals > mono-regionals. Irano-Turanian elements come in second followed by Saharo-Arabian, while the other elements have a minor representation. There is no doubt about the existence of biogeographical links between Mediterranean, Irano-Turanian and Saharo-Arabian elements. An important part of the recent synanthropic flora of Egypt has a Mediterranean origin or distribution. It might be expected that the Mediterranean species would occur mainly close to the Mediterranean coast including the coast of the Nile Delta. The plenty of the Mediterranean elements in the flora of the Nile Delta, particularly its Mediterranean coast, pushed Mashaly (1987) to favor the occurrence of Mediterranean territory in the deltaic coast. However, a relatively large percentage of the Mediterranean plants, particularly the annuals in the flora of Egypt in general and Nile Delta in particular, is embodied in the ruderal and segetal vegetation of the country. In addition, three endemic species (out of 14 occurring in Nile region: Boulos 1999, 2000, 2002, 2005) were recorded in the study area (*Zygophyllum album* subsp. *album*, *Sinapis arvensis* subsp. *allionii* and *Sonchus macrocarpus*).

In Lake Burullus, the islets and drain terraces have the highest species richness associated with the increase in annuals during spring (El-Kady et al. 2000). In addition, habitat heterogeneity and human manipulation of land seem to be acceptable reasons for the higher diversity of these habitats. Moderate disturbance of the existing vegetation by grazing animals and fishermen through cutting or burning of vegetation may also lead to increase the species richness. This disturbance often leads to distinct local variation in soil properties which meet the edaphic requirements of many species within communities (Khedr and Lovett-Doust 2000). On the other hand, low species diversity of open water zones may be related to homogeneity of the aquatic habitats compared with the terrestrial ones. Moreover, the low diversity of the open water zone may be because most of its species are highly specific to that aquatic habitat, thus the same species occurs at nearly all sites. High disturbance of this zone (e.g., cleaning practices, aquatic weed control, water pollution and excessive waste discharge) may also explain its low diversity (Grime 1973). Similar conclusions were made by Shaltout and El-Halawany (1993) and Shaltout et al. (1994, 2005a).

Transparency of the lake water is affected by water inflow from the sea outlet (Boughaz El-Burullus) and drains, wind action, and suspended matters (Beltagy 1985). In general, north and west sectors of Lake Burullus have the highest transparency and this may explain the high density of *Potamogeton pectinatus* in this sector (its tuber production may be limited under turbid conditions: Van Dijk and Van Vierssen 1991). On the other hand, the middle sector has the lowest transparency. This may be due to the high load of drainage water loaded with suspended materials (Radwan et al. 1997) and the active movement of fishing boats in this sector. Salinity distribution in the lake water reflect a decreased gradient from the east to west. This gradient depends on the amount of drainage water that comes from the south, fresh water from Berembal Canal at the west, and sea water from the sea outlet at the east.

Comparing the water characteristics of the northern lakes in Egypt (Mariut: Abdel Malik and Khalil 1994, Edku: Fathy et al. 2000, Burullus: present study, Manzala: Shakweer 2005 and Bardawil: Abdel Malik and Khalil 1994), indicates that Lake Bardawil is hypersaline (EC = 67.5 mS/cm), while the other lakes are brackish (EC ranges from 5.3 mS/cm in Lake Mariut to 11.5 mS/cm in Lake Edku). In addition, Lake Bardawil is the least polluted (N in subsurface water = 21 mg/l, phosphorus = 15 mg/l), while Lake Mariut is severely polluted due to excessive agricultural and industrial drainage (N = 926 mg/l, phosphorus = 135 mg/l). So, along these salinity and pollution gradients, Lake Burullus is considered a brackish, moderately polluted lake (N = 254.1 mg/l, phosphorus = 79.5 mg/l).

The vegetation of the Burullus Wetland was classified into 13 vegetation groups (i.e., plant communities). Comparable groups were identified in the northern Egyptian lakes such as *Typha domingensis–Ceratophyllum demersum*, *Potamogeton pectinatus*, *Phragmites australis*, *Sarcocornia fruticosa* and *Phragmites australis–Typha domingensis* groups in lakes Maruit and Edku (Shaltout et al. 2005a, b); *Halocnemum strobilaceum* group in Lake Bardawil (El-Bana et al. 2002) and *Typha domingensis–Ceratophyllum demersum* and *Phragmites australis* in Lake Manzala (Zahran and Willis 2003). Two groups were identified only in Lake Burullus (*Juncus acutus* and *Salsola kali* groups). On the other hand, six groups were overwhelmingly dominated or codominated with common reed (*Phragmites australis*) and occupied a wide gradient from xeric to hydric habitats. This indicated the need for controlling the growth of common reed, particularly near the mouths of the drains and lake shores. This control is also urgently needed to maintain the connection between the water bodies of the lake to prevent its fragmentation into sub-basins (Shaltout et al. 2004).

Depending on topographic and landform conditions, moisture, salinity and sedimentation are the main operative factors that govern the plant succession in the Burullus Wetland. Built-up of soil as well as continuous discharge of fertile drainage water into lake (Radwan 2001) increases organic matter content which favors the growth of swampy communities in rooted submerged (*Ceratophyllum demersum* and *Potamogeton pectinatus*) and floating ones (*Eichhornia crassipes* and *Azolla filiculoides*). Retrogression may occur as a result of mechanical dredging of the lakebed (Fig. 4). Decrease of salinity may lead to the formation of emergent communities such as *Phragmites australis*, while the increase of salinity enhances the growth of halophytic ones such as *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum* and *Sarcocorinia fruticosa*. Urban stages characterized by ruderal communities (e.g., *Bassia indica*, *Salsola kali* and *Tamarix nilotica*), may develop as a result of urban construction such as roads and canals (Shaltout and El-Sheikh 2003). On the other hand, the segetal stage characterized by segetal weeds (e.g., *Malva parviflora*, *Polypogon monspliensis* and *Sonchus oleraceus*) may be produced as a result of land reclamation. Furthermore, increased aridity and decreased human disturbance enhance the formation of the desert stage characterized by xerophytes such as *Lycium schweinfurthii*, *Cornulaca monocantha* and *Urginea undulata*.

Conclusions

1. Ten species in the study area are considered noteworthy because they offer many goods and services to the local inhabitants (*Phoenix dactylifera*, *Tamarix nilotica*, *Tamarix tetragyna*, *Phragmites australis*, *Alhagi graecorum*, *Atriplex halimus*, *Panicum turgidum*, *Ricinus communis*, *Tamarix aphylla*, *Typha domingensis*). Thus, plant diversity in this region needs sustainable management to reduce severe human impact which includes continued land reclamation impacting natural habitats, particularly the salt marshes and sand formations (i.e., sand sheets, hillocks and dunes) that occur on the sand bars and some islets (e.g., Al-Kawm Al-Akhdar). These habitats support many confined species that do not occur elsewhere in this region.

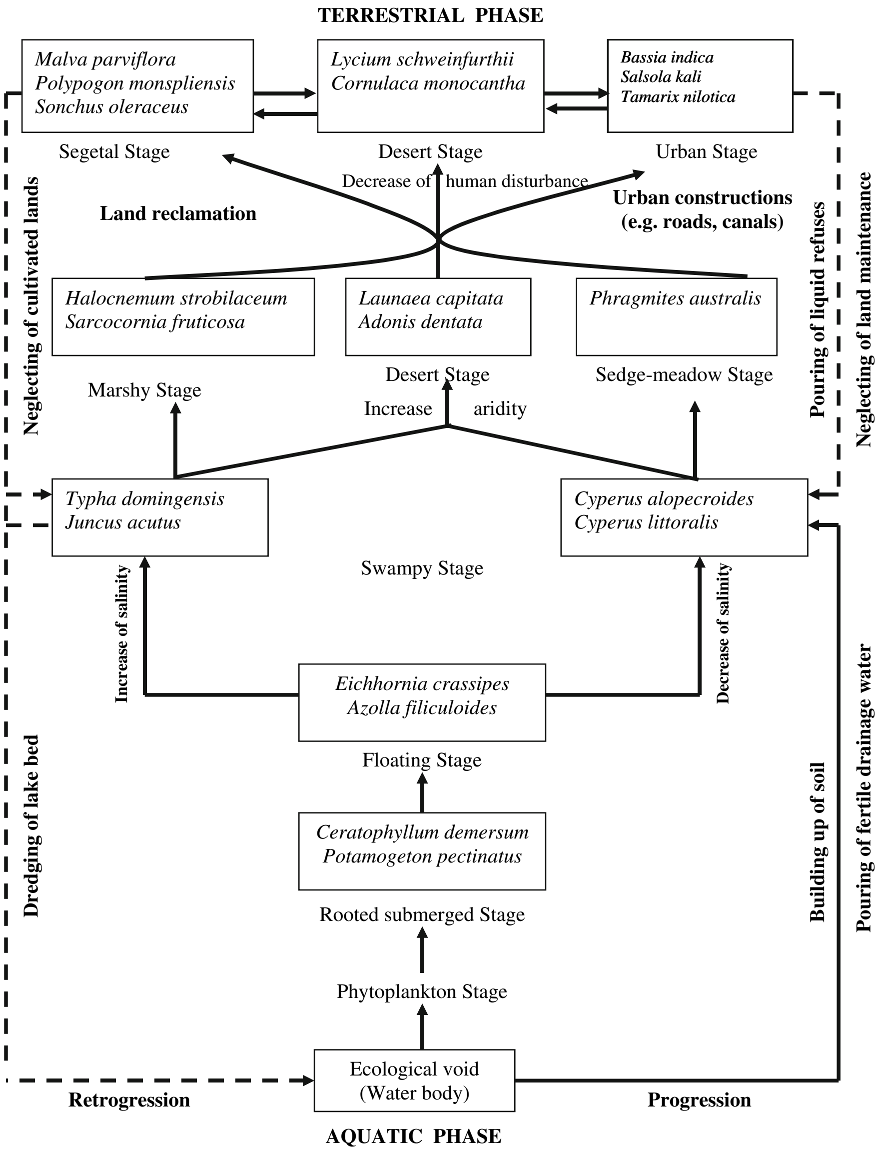

Fig. 4 Schematic representation of the presumed successional relationship between the communities dominating the different habitats in Burullus Wetland

2. Al-Kawm, Al-Akhdar and Dishimi islets contain many rare and confined species. It is suggested to declare these islets as core zones for the conservation of these rare and confined species.
3. It is important to carry out a long term monitoring program for the endemic, rare and noteworthy species in the Burullus Wetland. This will help in any management plan for conserving the threatened species and controlling the growth of the invasive ones. Compared with the five lakes in northern Egypt, Lake Burullus is a brackish, moderately polluted lake. Two aquatic species are overabundant in its waters and need to be controlled (*Phragmites australis* and *Potamogeton pectinatus*).
4. *Phragmites australis* is common in aquatic and moist places throughout Egypt (Tackholm 1974; Zahran and Willis 1992; Boulos 2005). It is a dominant species in all the northern lakes except Lake Bardawil (El-Bana 2003; Khedr 1989; Abdel-Malek and Khalil 1994). Its growth in Lake Burullus represents one of the most important reed beds in the Mediterranean basin, where this type of habitat is becoming rare and threatened (Shaltout and Al-Sodany 2000). Wintering and migrant birds are strongly dependent

on the reed beds for foraging, refuge and breeding (Shaltout et al. 2004). Also, this plant creates a suitable shelter for fishes particularly the fry and juveniles (Khalil and El-Dawy 2002). It may also be a suitable monitor for water pollution because it is easily collected and analyzed throughout the year (Baldantoni et al. 2005). Thus, we need to manage this reed, not eradicate it, in order to minimize its negative effects and maximize its benefits.

5. *Potamogeton pectinatus* is a submerged macrophyte of nearly cosmopolitan distribution. It is of worldwide importance as a waterfowl food, but also can be a nuisance in irrigation canals and recreational areas. It is the most dominant submerged plant in Lake Burullus, seems to prefer stable water levels, but can tolerate significant water level fluctuations. It also tolerates high salinity, pH, and alkalinity, but it fares poorly among specialist taxa in acidic or nutrient-poor waters (Kantrud 1990). This plant is highly tolerant to eutrophic waters, and may be the only submerged macrophyte that grows well in these polluted waters. On the other hand, *Potamogeton pectinatus* can absorb and translocate metals from the contaminated aquatic system and may accumulate them in its leaves and stems (Demirezen and Aksoy 2004).

Appendix 1

Presence percentage of the recorded species in the main habitats of Burullus Wetland

Species	Life form	Floristic category	SM	SS	LG	TD	SD	ED	OD	LS	LO	IS	P (%)
Annuals													
Salsola kali	Th	COSM	82	100	100	49	44	16	6	31			80
Senecio glaucus subsp. *coronopifolius*	Th	ME + SA + IT	22	27	70	67	48	4		13		2	80
Mesembryanthemum nodiflorum	Th	ME + ES + SA	26	8	20	39	8	12		25		11	80
Polypogon monspeliensis	Th	COSM	4	8	20	21	28	4		44		18	80
Spergularia marina	Th	ME + ES + IT	22	15	50	12	24	16		63		30	80
Chenopodium album	Th	COSM		15	10	6	4	8		6		4	70
Mesembryanthemum crystallinum	Th	ME + ES	19	18	20	15	8					2	60
Sphenopus divaricatus	Th	ME + SA + IT	7	8		9	12			13		4	60
Rumex dentatus	Th	ME + ES + IT				15	36	36		31	13	13	60
Chenopodium murale	Th	COSM	4			27	24			6		7	50
Malva parviflora	Th	ME + IT	19			27	24			13		11	50
Conyza bonariensis	Th	ME + MA		15		6	4	4		6			50
Chenopodium ambrosioides	Th	COSM				6	20	16		38		2	50
Chenopodium opulifolium	Th	ME + ES + IT				3	4	4		6		7	50
Ranunculus sceleratus	Th	ME + ES + IT				6	4	16			7	11	50
Trigonella stellata	Th	SA + IT	11	8	10					6			40
Sonchus oleraceus	Th	COSM				33	44	4				2	40
Anethum graveolens	Th	SU	4			3	4						30
Cichorium endivia subsp. *pumilum*	Th	ME + IT	4			9	4						30
Cutandia memphitica	Th	ME + SA + IT	11	8								2	30
Hordeum vulgare	Th	ME + IT	4			6	4						30
Echinochloa crusgalli	Th	ME + ES + IT				6		4		13			30
Reichardia tingitana	Th	SA + IT		27	10							4	30
Ifloga spicata	Th	ME + SA		18		3						9	30
Hordeum marinum	Th	ME + ES + IT				6	4					7	30

continued

Species	Life form	Floristic category	SM	SS	LG	TD	SD	ED	OD	LS	LO	IS	P (%)
Hordeum murinum subsp. *leporinum*	Th	ME + IT				21	16					2	30
Medicago polymorpha	Th	COSM				3	4					15	30
Urospermum picroides	Th	ME + IT				3	4					2	30
Melilotus indicus	Th	ME + SA + IT				9	12			6			30
Sonchus asper	Th	ME + IT				3	4			13			30
Chenopodium glaucum	Th	ME + ES + IT	15		10								20
Eruca sativa	Th	ME + SA + IT + ES	4			3							20
Lotus halophilus	Th	ME + SA		8								7	20
Schismus barbatus	Th	ME + SA + IT		8								15	20
Amaranthus viridis	Th	COSM			10	33							20
Avena fatua	Th	COSM				6	4						20
Bassia indica	Th	IT + SU				6	4						20
Beta vulgaris	Th	ME + ES + IT				24	20						20
Carduus pynocephalus	Th	ME + IT				6	4						20
Cyperus difformis	Th	COSM				3	4						20
Lolium perenne	Th	ME + ES + IT				6	12						20
Lolium temulentum	Th	ME + ES + IT				6	8						20
Lotus arabicus	Th	TR				6	8						20
Parapholis marginata	Th	ME				6	4						20
Senecio vulgaris	Th	ME + ES + IT				6	8						20
Trigonella laciniata	Th	SA + SU				12	16						20
Emex spinosa	Th	ME + SA				3						7	20
Ammi visnaga	Th	ME + IT				3		4					20
Lolium multiflorum	Th	ME + IT + EU				3				6			20
Phalaris minor	Th	ME + IT				6				6			20
Anagallis arvensis	Th	ME + ES + IT					4					2	20
Eclipta alba	Th	TR + MA						4		6			20
Carex divisa	Th	ME + ES + IT	4										10
Amaranthus lividus	Th	TR	11										10
Astragalus peregrinus	Th	SA	4										10
Frankenia pulverulenta	Th	ME + ES + IT	4										10
Rapistrum rugosum	Th	ME + ES + IT	4										10
Bromus catharicus	Th	ME + ES + IT + MA		8									10
Cakile maritima	Th	ME + IT		8									10
Orobanche crenata	Th	ME + IT		15									10
Rumex pictus	Th	ME + SA			40								10
Brassica rapa	Th	COSM				3							10
Coronopus didymus	Th	COSM				3							10
Coronopus squamatus	Th	ME + ES + IT				3							10
Juncus bufonius	Th	COSM				6							10
Raphanus raphanistrum	Th	ME + ES				9							10
Trifolium alexandrinum	Th	ME				3							10
Amaranthus hybridus	Th	TR					4						10

continued

Species	Life form	Floristic category	SM	SS	LG	TD	SD	ED	OD	LS	LO	IS	P (%)
Coriandrum sativum	Th	ME + IT					4						10
Gnaphalium luteo-album	Th	TR					4						10
Lathyrus marmoratus	Th	ME					4						10
Phalaris paradoxa	Th	ME + IT + EU					4						10
Sisymbrium irio	Th	COSM					4						10
Sonchus macrocarpus	Th	Endemic					4						10
Trifolium resupinatum	Th	ME + ES + IT					8						10
Medicago intertexa v. *ciliaris*	Th	ME + ES						4					10
Rorippa palustris	Th	ME + ES						4					10
Setaria verticillata	Th	COSM						8					10
Setaria viridis	Th	ME + ES + IT						4					10
Chrysanthemum coronarium	Th	ME								6			10
Poa annua	Th	ME + ES + IT								6			10
Adonis dentata	Th	ME + SA + IT										4	10
Astragalus boeticus	Th	ME										2	10
Brassica tournefortii	Th	ME + SA + IT										2	10
Calendula arvensis	Th	ME + ES + IT + SA										2	10
Cutandia dichtoma	Th	SA + IT										2	10
Echinochloa colona	Th	ME + IT + TR										2	10
Erodium laciniatum	Th	ME										2	10
Euphorbia peplis	Th	ME + ES + IT										11	10
Filago desertorum	Th	SA + IT										4	10
Launaea capitata	Th	SA + SU										11	10
Lobularia arabica	Th	SA										9	10
Paronychia arabica	Th	ME + SA + SU										7	10
Parapholis incurva	Th	ME + ES + IT										2	10
Portulaca oleracea	Th	COSM										2	10
Ranunculus marginatus	Th	SA + IT										2	10
Silene villosa	Th	SA										7	10
Sinapis arvensis subsp. *allionii*	Th	SA										7	10
Spergula fallax	Th	ME + SA + SU										2	10
Sporopolus pungens	Th	ME + ES										7	10
Perennials													
Phragmites australis	GH	COSM	41	27	20	24	52	44	31	69	93	74	100
Arthrocnemum macrostachyum	Ch	ME + SA	85	91	100	46	56	24	6	88		72	90
Sarcocornia fruticosa	Ch	SA	30	8	60	33	52	40	13	63		46	90
Suaeda vera	Ch	ME + ES + SA	30	8	60	52	52	16	13	19		32	90
Tamarix nilotica	Ph	SA + SU	41	15	10	9	8	8	19	56		19	90
Halocnemum strobilaceum	Ch	ME + SA + IT	56	91	90	15	24	4		13		22	80
Cynodon dactylon	GH	COSM	11	8	10	15	16	20		19		11	80
Zygophyllum album var. *album*	Ch	ME + SA	26	46	50	15	12	12		6			70
Inula crithmoides	Ch	SA	22	8		9	4	4		25		59	70
Juncus acutus	GH	ME + ES + IT	44	8	40	6		8		63		57	70

continued

Species	Life form	Floristic category	SM	SS	LG	TD	SD	ED	OD	LS	LO	IS	P (%)
Polygonum equisetiforme	GH	ME + IT	7		20	33	20	28		31			60
Suaeda pruinosa	Ch	ME + SA	15		10	15	8			31		2	60
Aster squamatus	Ch	TR		15		6	20	24		19		2	60
Cressa cretica	H	ME + IT + TR	22	15	50	6						2	50
Juncus rigidus	GH	ME + SA + IT	15	8	10					6		39	50
Cyperus rotundus	GH	ME + IT + TR	4		20	3		8		6			50
Persicaria salicifolia	GH	COSM				6	8	12		6		4	50
Typha domingensis	GH	ME + IT				3		4		31	60	33	50
Paspalidium geminatum	GH	TR				3	4	4		13		2	50
Echinochloa stagnina	GH	TR						8	13	13	7	4	50
Atriplex canescens	Ch	MA	4			12	20	8					40
Launaea nudicaulis	H	SA + IT + SU		18	60	9				6			40
Phyla nodiflora	H	ME + IT + TR				3	12	16		6			40
Atriplex nummularia	Ch	TR				6	12	4		25			40
Saccharum spontaneum	GH	ME + SA + IT + TR				3		4		13		2	40
Suaeda maritima	Ch	COSM				3		8		6		13	40
Cynanchum acutum	Ph	ME + IT		8				4				4	30
Alhagi graecorum	Ch	ME + SA + IT + SU	7	8	10								30
Cyperus alopecuroides	GH	TR	4							13	27		30
Convolvulus arvensis	H	TR		8		3	8						30
Atriplex halimus	Ph	ME + SA				3	4					6	30
Scirpus maritimus	GH	COSM						8		25		17	30
Centaurea calcitrapa	Ch	ME + ES				6	8	4					30
Paspalum distichum	GH	COSM				3		4		13			30
Atriplex portulacoides	Ch	ME + ES + IT				3				6		61	30
Cyperus articulatus	GH	TR						4		6		2	30
Scirpus litoralis	GH	ME + IT + TR				3				6		19	30
Vossia cuspidata	GH	TR						4		6		2	30
Limonium pruinosum	GH	ME	7							13			20
Aeluropus lagopoides	GH	ME + SA + IT	19									26	20
Aeluropus littoralis	GH	ME + IT	4									2	20
Limoniastrum monpetalum	Ch	ME	7									2	20
Cynomorium coccineum	GH	ME + SA + IT	4									17	20
Atriplex leucoclada	Ch	SA + IT			10	3							20
Agathophora alopecuroides	Ch	SA				3				19			20
Pluchea dioscoridis	Ph	SA + SU				3		4					20
Centaurea pumilio	Ch	ME				6						13	20
Sphaeranthus suaveolens	H	TR					8	4					20
Mentha longifolia	GH	COSM					4	8					20
Juncus subulatus	GH	ME + SA + IT								31		11	20
Ipomoea carnea	H	ME + IT					4	4					20
Tamarix tetragyna	Ph	ME + SA								6		2	20
Alternanthera sessilis	GH	ME + IT + TR	4										10

continued

Species	Life form	Floristic category	SM	SS	LG	TD	SD	ED	OD	LS	LO	IS	P (%)
Echinops spinosissimus	H	ME + SA	4										10
Frankenia revoluta	H	ME + IT + EU	7										10
Imperata cylindrica	GH	ME + SA + IT	4										10
Ricinus communis	Ph	TR	7										10
Scirpus holoschoenus	GH	ME + ES + IT	7										10
Tamarix aphylla	Ph	SA + SU	15										10
Cistanche phelypaea	p	ME + SA		8									10
Convolvulus lanatus	Ph	SA		8									10
Cornulaca monacantha	Ch	SA + SU + IN		8									10
Cyperus capitatus	GH	ME + GC		8									10
Elymus farctus	GH	ME		8									10
Fagonia arabica	Ch	ES		8									10
Heliotropium curassavicum	Ch	TR		8									10
Orobanche cernua	P	ME + SA + IT		8									10
Panicum turgidum	GH	SA + SU		8									10
Silene succulenta	H	ME		8									10
Polypogon viridis	H	ME + IT + EU				6							10
Salix tetrasperma	Ph	ME + ES + IT				3							10
Silybum marianum	H	ME + ES + IT				3							10
Plantago major	H	COSM					4						10
Clerodendrum acerbianum	Ch	TR						4					10
Sida alba	H	SU						8					10
Orobanche ramosa var. *schweinfurthii*	P	ME + IT								6			10
Persicaria senegalensis	GH	ME + TR								6			10
Vigna luteola	Ch	SU + TR								6			10
Allium roseum	GH	SA										4	10
Asparagus stipularis	GH	ME + SA										15	10
Cyperus laevigatus	GH	ME + SA + IT										2	10
Lycium schweinfurthii	Ph	ME										17	10
Pancratium maritimum	GH	ME										7	10
Phoenix dactylifera	Ph	SA + SU										2	10
Urginea undulata	GH	ME + SA										2	10
Hydrophytes													
Potamogeton pectinatus	HH	COSM						4	13	6	93	15	50
Eichhornia crassipes	HH	TR						16	31	13	40	9	50
Ceratophyllum demersum	HH	COSM						4	31		40	17	40
Lemna perpusilla	HH	COSM							6	6	7	2	40
Ludwigia stolonifera	HH	ME + TR						4		13	13	4	40
Lemna gibba	HH	COSM						8	19				20
Potamogeton crispus	HH	COSM						8	19				20
Azolla filiculoides	HH	TR							63		13		20
Wolffia hyalina	HH	COSM								6	7		20

continued

Species	Life form	Floristic category	SM	SS	LG	TD	SD	ED	OD	LS	LO	IS	P (%)
Ceratophyllum submersum	HH	ME + ES + IT									7		10
Najas marina v. *armata*	HH	COSM									20		10
Najas minor	HH	ME + ES + IT									7		10
Total species			51	45	29	87	69	59	14	65	16	89	197

The habitats are SM: salt marshes, SS: sand formations, LG: lake cuts, TD: terraces, SD: slopes, ED: water edges and OD: open water zones of the drains, LS: lake shores, LO: open water of the lake and IS: lake islets. The life forms are: PH: phanerophytes, CH: chamaephytes, HC: hemicryptophytes, GH: geophytes-helophytes, HH: hydrophytes, TH: therphytes and PA: parasites. The floristic regions are: COSM: cosmopolitan, ES: Euro-Sibarian, IT: Irano-Turanian, ME: Mediterranean, PA: Pantropical, SA: Saharo-Arabian, SI: Sindian, SU: Sudanian, and TR: Tropical

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