Chapter 7

VEGETATION AND HABITAT ECOLOGY OF LAGOONS IN NORTH EGYPT: ROLE OF EDAPHIC AND ANTHROPOGENIC FACTORS

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ABSTRACT

The main habitats of lagoons in the Nile Delta of Egypt include the Mediterranean Deltaic coast, the sand bar between the northern shore and Mediterranean Sea, the water courses that drain into the lakes and the wetland around it. These lagoon habitats represent highly dynamic ecosystems in Egypt that have been undergoing continuous changes until the present time due to increasing human impact. Increasing threats to plant diversity of lagoons in Egypt include loss of natural habitats through increased inhabitants which require more land for housing, roads, cultivation, industry, and waste disposal. In order to identify the plant communities, species diversity, vulnerable habitats, threatened species and environmental factors that affect their distribution, a multivariate (TWINSPAN, DCA and CCA) and statistical analysis of the vegetation data were applied. The vegetation was classified into different groups (i.e. plant communities). Many groups were dominated by halo-tolerant plants (e.g. *Arthrocnemum macrostachyum*, *Sarcocornia fruticosa*, *Halocnemum strobilaceum*, *Salsola kali*, *Senecio glaucus*, *Cakile maritima*, *Zygophyllum album*, *Bassia indica*, *Mesembryanthemum nodiflorum*, *Limbarda crithmoides*, etc) and common reed (*Phragmites australis*). The other few groups dominated by the emergent (e.g. *Typha domingensis*, *Juncus acutus*, *Cyperus alopecroides*, etc.) and hydrophytes plants (e.g. *Potamogeton pectinatus*, *Ceratophyllum demersum*, *Echhornia crassipes*, etc). Moisture, salinity, sedimentation and anthropogenic factors were the main factors that governed the plant succession in these lagoons.

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ECOLOGY CHARACTERISTICS OF LAGOONS HABITAT IN NILE DELTA

Coastal Lagoons

Phleger (1969), defined coastal lagoons as shallow inland marine waters, usually oriented parallel to the coast, separated from the ocean or sea by a barrier, and connected to the ocean by one or more restricted inlets. To this should be added that the ocean or sea entrance (s) can at times be closed off by sediment deposition as a result of wave action and littoral drift. A workable definition of a coastal lagoon is thus ***a shallow coastal water body separated from the ocean or sea by a barrier, connected at least intermittently to the ocean or sea by one or more restricted inlets, and usually oriented shore-parallel.*** Therefore, “Lagoon” a shallow, coastal body of water separated from the ocean or sea by a sand bar, which may periodically breach, opening the lagoon to the sea for a time. Lagoons can form where a river meets the sea or ocean (an estuarine lagoon), or without the influence of a river. Coastal lagoons do not usually have a free connection with the open sea and may only be inundated with sea water at irregular intervals (Mc Lusky 1990). Lagoon also is a small world composed of environmental features and living organisms, bound and organized by interdependence and interrelationships (Forbes 1987). Coastal lagoons occupy 13% of coastal areas worldwide, and are often impacted by both natural and anthropogenic influences (Mee, 1978; Sikora & Kjefie, 1985). Depending on local climatic conditions, lagoons exhibit salinities which range from completely fresh to hypersaline (Moore & Slinn, 1984; Kjefie, 1986; Kjerfve & Magill, 1989; Knoppers et al., 1991). Coastal lagoons experience forcing from river input, wind stress, tides, precipitation to evaporation balance, and surface heat balance, and respond differently to these forcing functions. Water and salt balances, lagoon water quality, and eutrophication depend critically on lagoon circulation, salt and material dispersion, water exchange through the ocean or sea canal (s), and turnover, residence, or flushing times. The understanding of physical, chemical, geological, and ecological dynamics of lagoons is important for planning and implementation of coastal management strategies in coastal lagoons. Kjerfve (1986) sub-divided coastal lagoons into three geomorphic types according to water exchange with the coastal ocean: Choked, Restricted and Leaky Lagoons (Figure 1).

ECOLOGICAL CHARACTERISTICS OF LAGOONS

Coastal lagoons are highly productive ecosystems. They contribute to the overall productivity of coastal waters by supporting a variety of habitats including salt marshes, seagrasses, and mangroves (Anthony, et al., 2009). They also provide essential habitat for many fish and shellfish species (Bertness, 2007). Such beds play an important role in influencing the shape and stability of the shoreline, regulating dissolved oxygen (Nixon & Oviatt 1972) and filtering suspended matter (Bertness, 2007). They can enhance the biodiversity of a lagoon by providing a physical refuge from predation and also serve as nursery and feeding habitat to a variety of organisms (Heck & Thoman 1984, Harris et al., 2004). On the Egypt coast, salt marshes are one of the most prevalent habitats in lagoons and are one of the most productive natural vascular plant communities in the world (Whittaker 1975; Bertness 2007; El-Sheikh et al. 2012). Because of their relatively low flushing rates, coastal lagoons are favorable habitats for primary producers (phytoplankton and aquatic plants). Nutrients are transported to lagoons from surface and ground water flows, and through exchange with the sea. Because nutrient availability often limits primary productivity, coastal lagoons can foster high rates of primary production, thereby supporting high rates of secondary production as compared to other aquatic ecosystems (Nixon 1982, Nixon 1995). However, primary production that exceeds the demands of consumers can lead to eutrophication (Valiela et al. 1992). Eutrophication is characterized by excessive phytoplankton and macroalgae blooms and subsequent hypoxia, reduced light penetration (McGlathery 2001; Anderson et al. 2002), stress and die-offs of marine organisms, loss of seagrass beds, changes in food web interactions and community structure, and loss of biodiversity (National Research Council 2000). Lagoons and their associated ecosystems are highly valued by society. These values reflect the commercial, recreational, and tourism uses of lagoons as pleasant swimming beaches. Pragmatic values also include ecosystem services that indirectly support human uses. For example, salt marshes provide nursery habitat for juvenile fish that support commercial fisheries and protect developed shorelines by reducing the impact of severe storms (Anthony et al. 2009).

The lakes and lagoons are a major estuarine water body located in Egypt whose remaining natural resources need to be protected. The lagoonal ecosystem has been stressed through the past many years due to many anthropogenic influences. Altered hydrology of the system allows massive freshwater discharges into the lagoon. These discharges carry large influxes of nutrients, suspended and dissolved organic matter, contaminants, and toxins into the lagoon, affecting the flora and fauna. Additional pressures in this urbanized coastal area include boating and fishing pressures, as well as loss of natural habitat through physical alterations to the system (Galal, et al. 2012).

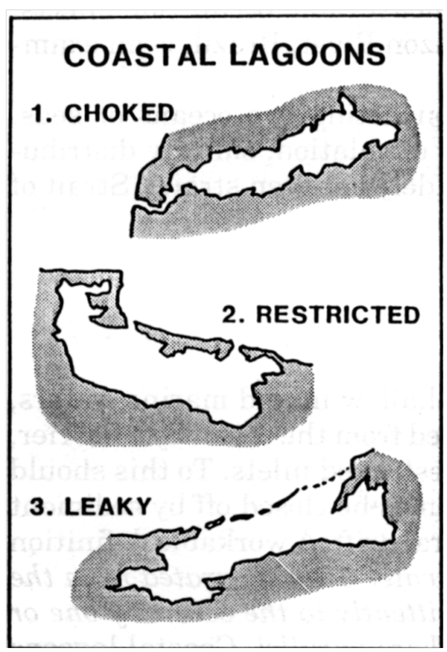


Figure 1. Coastal lagoons can conveniently be sub-divided into choked, restricted, and leaky systems based on the degree of water exchange with the adjacent coastal ocean (after Kjerfve, 1986).

LAGOON ECOLOGY OF CENTRAL COASTAL FISHES

The lagoons at the mouths of Nile Delta have been highly modified by adjacent agricultural and urban development. In addition, they receive the accumulated impacts of water diversion, sedimentation and pollution discharges within the watersheds. Despite historical impacts, these estuaries can provide potentially valuable habitat for aquatic invertebrates, fishes and the wildlife dependent upon them. The relative value of individual estuaries varies with size, tidal action, depth, salinity and water quality. These features not only vary between estuaries, but also vary within estuaries on a seasonal and year-to-year basis. Based upon studies of many estuaries in Nile Delta, this chapter outlines some of the important factors in the functioning of lagoons. It also describes the vegetation structure and habitat ecology of lagoons in Egypt.

HABITAT TYPES OF LAGOONS IN EGYPT

The Mediterranean coastal region of Egypt extends for about 970 km from Sallum in the west (31° 34` N, 25° 09`E) to Rafah in the east (34° 20`N, 31° 25`E) (Table 1) (Galal et al. 2012). Many smaller lagoons and lakes extend along this coast: Mariut (Western Coast), Edku, Burullus and Manzala (Deltaic Coast) and Bardawil (Sinai Coast). All lakes have a brackish water nature except Bardawil has saline water (Figure 2). These lagoon possibly represented as interdistributary bays, were closed-in by the long shore growth of spit from the various cuspate subdeltas. They are separated from the Mediterranean Sea by strips of sand bars. They also may have developed out of flood basins, especially during stages of large Nile floods. The lagoon expansion during the last 2000 years has been irregular, mainly due to subsidence behind a stable beach barrier. There is a record of rapid spread of swamps and lagoons since the 5-10th centuries, in coincidence with the major earthquakes (Abu Al-Izz 1971; Ben Menchem 1979). Shaltout & Al-Sodany (2008) described six main types of habitat in the Nile Delta coast and 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.

SOILS

The soil of the Nile Delta coastal belt are genetically related to the major morphological units of alluvial plain deposition: sand dunes and coastal sandy plains, Nile levees and channels (silt to fine sand), Nile flood basins composed of silt and areas of marshes. Modifications have been introduced by continued agricultural activity (Balba 1981). Deposited in the brackish water of lagoon, lakes and swamps, the clay soils of the fluvio-marine marshlands contain some lime but much salt and gypsum (Galal, et al. 2012). The soils are saline sodic with a high concentration of salts on the surface.

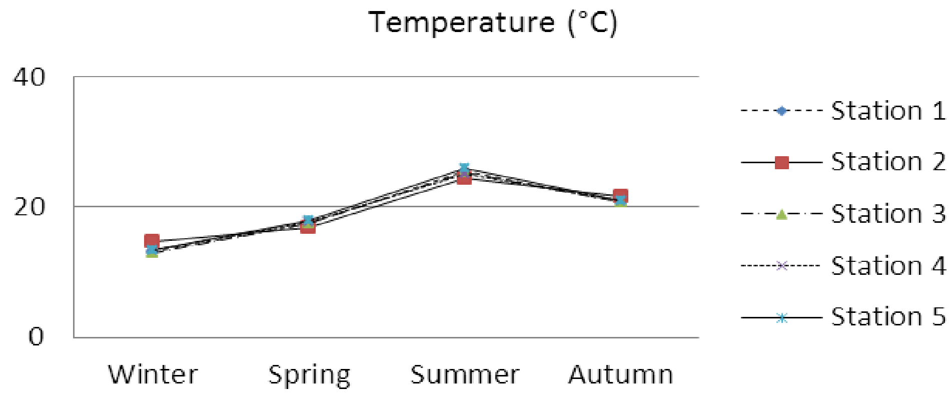


Figure 2. Seasonal variations of temperature water in five stations.

Table 1. Morphometry of the five northern lakes under study after (Galal, et al. 2012)

Lake	**Coordinates**		**Dimensions**			**Area (km^2)**	**Fish Production (Ton / ha)**
	Latitude (N)	**Longitude (E)**	**Mean depth (m)**	**Maximum length (km)**	**Maximum width (km)**		
Mariut	31°2´ - 31°12´	29°51´- 29°59´	*1.2*	*8.8*	7.7	*63*	0.50
Edku	31°13´ - 31°16´	30°07´ - 30°14´	*1.0*	21.0	*6.0*	126	1.10
Burullus	31°25´ - 31°35´	30°30´ - 31°10´	1.0	64.0	16.0	410	*1.20*
Manzala	31°00´ - 31°30´	31°16´ - 32°20´	1.1	64.5	*49.0*	*1200*	0.70
Bardawil	31°03´ - 31°14´	32°40´ - 33°30´	*1.0*	*75.0*	22.0	650	*0.03*

CLIMATE

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 to 30 °C) and mild winters (10 to 20 °C). The aridity index (P/PET: where P is the annual precipitation and 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 hyper-arid region (Shaltout & Al-Sodany 2008).

STUDY DESIGN OF NORTH EGYPT LAGOONS

Many lagoons were surveyed in the last few years by many authors such as: Shaltout & Al-Sodany (2008) selected 227 stands which represented the different habitats at Burullus coastal lagoon; El-Sheikh et al. (2012) selected 22 stands to represent the different successional stages through 10 years of the land fill of lagoon at Burullus lake and Galal, et al. (2012) selected 148 stands in Mariut and 150 stands in Edku lake. The sampled stands about 20 m^2 was observed seasonally. The species present life forms and chorotypes were recorded. Soil and water samples were collected and their physical and chemical characteristics were analyzed. The total cover of each species (%) was estimate according (Canfield 1941). Two-way indicator species analysis (TWINSPAN), detrended correspondence analysis (DECORANA) and (CANOCO) were applied to stand, the plant cover and environmental variable matrices (species x stands x environment) (Hill, 1979 a, b; Ter Braak & Smilauer, 2002).

Species richness (α-diversity) of the vegetation cluster was calculated as the average number of species $stand^{-1}$. Equitability or evenness of the relative importance values of species was expressed according to the Shannon-Wiener index ($\hat{H} = -\Sigma$ pi log pi). A relative concentration of dominance was expressed by the Simpson index ($C = \Sigma pi^2$): where (pi) is the relative importance value (i.e., relative cover) of the ith species (Whittaker, 1972; Pielou, 1975; Magurran, 1988). The simple linear correlation (r) and analysis of variance ANOVA one were calculated for soil and vegetation variables according to SAS software (1989-196).

Table 2. Endemic species recorded in the five lagoons according to the IUCN (1994) Red list categories (after El-Hadidi and Hosny 2000 and Galal, et al., 2012)

Species	Life form	Nortern lakes				
		Mariut	Edku	Burullus	Manzala	Bardawil
Endemics						
Sinapis allionii Jacq.	Therophyte	+		+		
Bromus aegyptiacus Tausch	Therophyte	+			+	
Sonchus macrocarpus Boulos & C. Jeffrey	Chamaephyte			+		
Astragalus camelorum Barbey	Chamaephyte					+
Bellevalia salah-eidii Taekh. & Boulos	Geophyte-Helophyte					+
Near endemics						
Carduncellus mareoticus (Delile) Hanelt	Chamaephyte	+				
Biarum olivieri Blume	Geophyte-Helophyte					+
Iris mariae Barbey	Geophyte-Helophyte					+

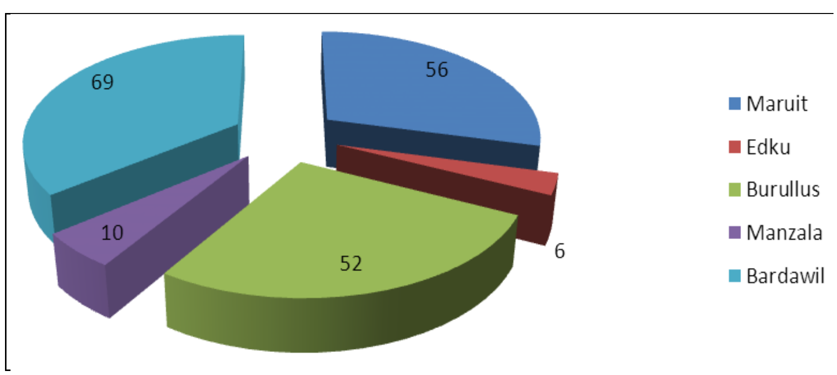


Figure 3. Number of species unique to each lake.

FLORISTIC DIVERSITY

A total of about 402 species belonging to 248 genera and 68 families were recorded in these lakes (Galal, et al., 2012). The grasses (66 spp.) have the highest contribution to the total flora, followed by composites (44 spp.) and chenopods (38 spp.). Floristically, the richest lake was Burullus. Burullus had the highest species number (224 spp. = 56%), followed by Mariut (148 spp.= 49%), Manzala (144 spp. = 36%), Edku (120 spp. = 30%) and Bardawil (136 spp. = 34%). A total of 189 species (48% of the total species) were recorded in only one lagoon "a unique species", 95 of them are annual and 94 perennials. Also, 56 species of them were recorded in Mariut only (as: *Anchusa hispida*, *Carrichtera annua*, *Mellilotus messanensis*, *Arisarum vulgar* and *Fagonia cretica*), 6 in Edku, 52 in Burullus, 10 in Manzala and 69 in Bardawil lagoon (Figure 3). The life forms of the recorded species indicated the predominance of therophytes (203 spp. = 51%) followed by geophytes–helophytes (61 spp. =15 %), chamaephytes (56 spp. =14 %), hydrophytes (48 spp. =12%) and hemicryptophytes (42 spp. =10%) (Figure 4). The global distribution of the recorded species indicated that seven species are endemic (Table 2) as: *Zygophyllum aegyptium*, *Sinapis allionii*, *Sonchus macrocarpus*, *Astragalus camelorum*, *Allium papillare*, *Bellevalia salah-eidii* and *Iris mariae* and most of the recorded species are Saharo-Arabian (57 spp.) of monoregionals. Fourteen species are threatened according to IUCN (1994) Red list categories (after El-Hadidi and Hosny 2000): *Astragalus camelorum*, *Bellevalia salah-eidii*, *Biarum olivieri*, *Chlamydophora tridenata*, *Clerodendrum acerbianum*, *Cynomorium coccineum*, *Iris mariae*, *Juncus bufonius*, *Lobularia arabica*, *Nymphaea caerulea*, *Nymphaea lotus*, *Salsola tetragona*, *Sinapis allionii* and *Sonchus macrocarpus* (Shaltout & Khalili 2005; Shaltout & Al-Sodany 2008;Galal, et al., 2012; El-Sheikh et al., 2012).

VEGETATION AND HABITAT COMPOSITION ANALYSIS

Burullus Lagoon: As a Case Study

Habitat analysis

The application of multivariate analysis techniques on the plant spp. 197 spp. x 10 habitats (after Shaltout and Al-Sodany 2008) (Figure 5) and the similarity DCA ordination (Figure 6) indicate a distinction of four clusters. These clusters were separated along the prevailing edaphic gradient from the shoreline to the open water. Cluster A: comprises the sand formation, cluster B: include the salt marshes, cluster C: include the shorelines and cluster D comprises lagoon open water habitats. The application of DCA and CCA confirmed the separation between these clusters and indicated relationships between environmental gradients and topographic aspects of lagoons (Figure 6 and 7a,b). CCA ordination was used to verify the correlation analysis between the dominant environmental factors and CCA axes (Figure 7a and b and Table 3). Correlation analysis indicated that the separation of the species along the first axis is strongly affected positively by pH, silt, organic matter, nitrogen, Na and K content and negatively by clay, P and Ca contents. On the other hand, Mg and silt content are correlated positively with the second axis and negatively with sand. Therefore, the cluster A that occupies the sand formation and B that occupies the salt marshes were separated on the left hand of axis 1 from the cluster C and D which inhabited the shoreline and open water zones on the right hand of axis 2 (Figure 7a). Halophytes and geophytes species occupied the sand formation and salt marshe habitats of communities (e.g. *Salsola kali*, *Senecio glaucus*, *Mesem.nodiflorum*, *Mesem. Crystallinum*, *Phragmites australis*, *Arthrocnemum macrostachyum*, *Sarcocornia fruticosa*, *Suaeda vera*, *Tamarix nilotica*, *Halocnemum strobilaceum*,*Cynodon dactylon*,*Zygophyllum album* var. *album*, *Inula crithmoides*, *Juncus acutus*) on the negative part of axis 1 are correlated with sand, clay, P, Ca and EC content. On the other hand, the hydrophytes species occupied open water habitat of communities (e.g. *Potamogeton pectinatus*, *Eichhornia crassipes*, *Ceratophyllum demersum*, *Lemna perpusilla*,*Ludwigia stolonifera*, *Lemna gibba*, *Potamogeton crispus*, *Azolla filiculoides*, *Wolffia hyaline*, *Ceratophyllum submersum*, *Najas marina v. armata* and *Najas minor*) on the positive part of axis 1 are correlated with pH, silt, organic matter, nitrogen, Na and K content (Figure 7b).

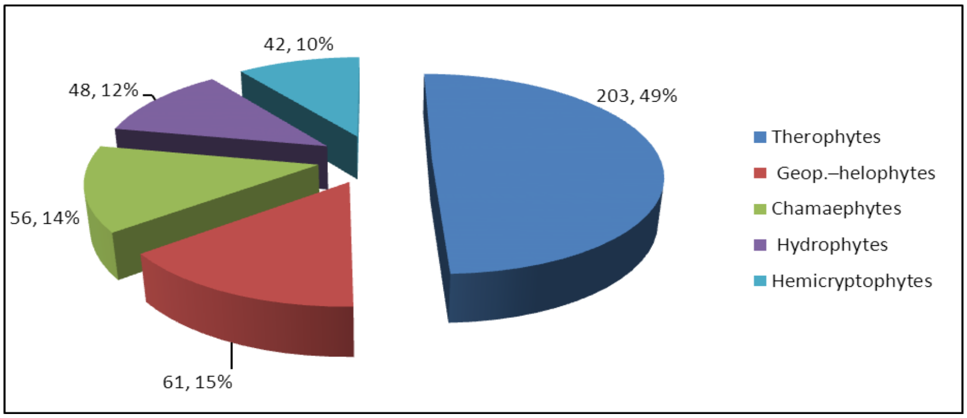


Figure 4. Life form spectra of the recorded species in the five lagoons North Egypt, after Galal, et al., (2012).

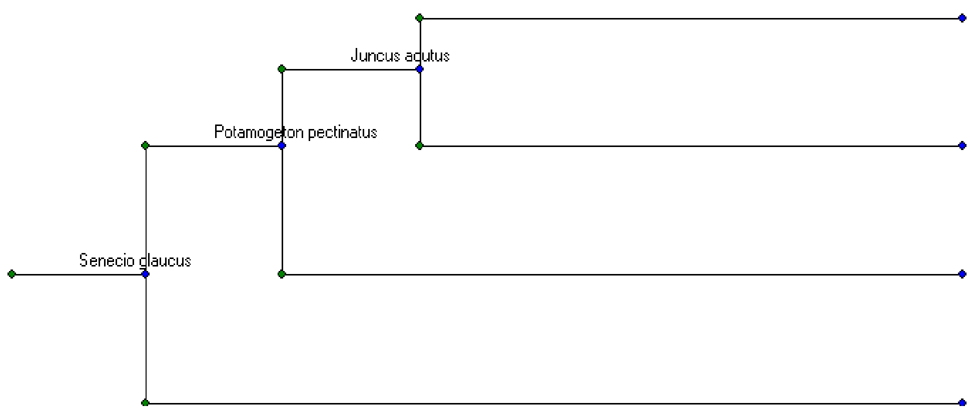


Figure 5. TWINSPAN classification of 10 habitats led to 4 habitat groups. 1=SM: salt marshes, 2=SS: sand formations, 3=LG: lake cuts, 4=TD: terraces, 5=SD: slopes, 6=ED: water edges and 7=OD: open water zones of the drains, 8=LS: lake shores. 9=LO: open water of the lake and 10= IS: lake islets.

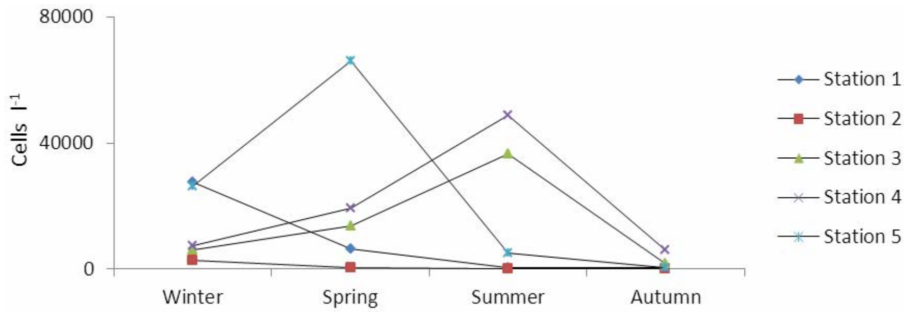


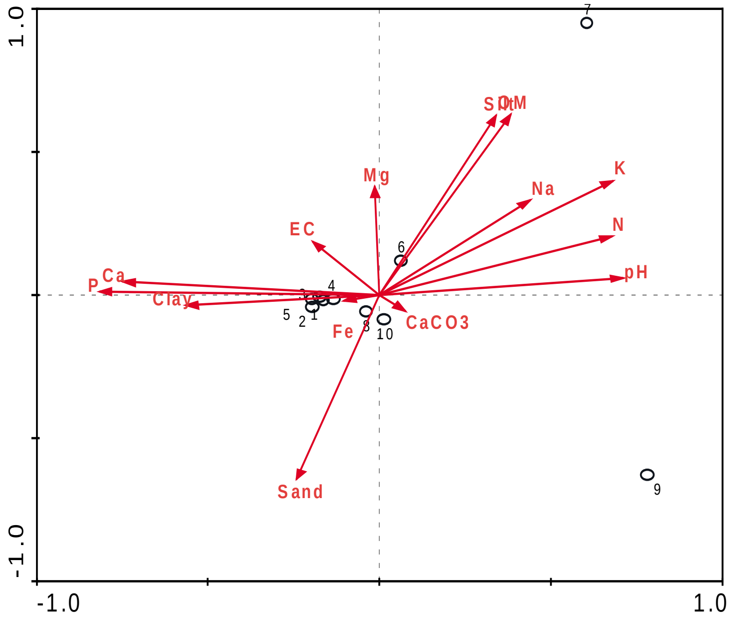
Figure 6. Seasonal changes of dinoflagellate community in five stations of Ghar El Melh lagoon.

LAKE BURULLUS: VEGETATION COMPOSITION

After the study of Shaltout and Al-Sodany (2008), 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 6^{th} level of classification. The application of DCA on the same set of data indicated a reasonable segregation between many of these groups along the ordination plane of axes 1 and 2 (Figure 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 australis*-*Suaeda pruinosa*, *Phragmites australis* - *Arthrocnemum macrostachyum*, *Suaeda vera*-*Inula crithmoides*, *Halocnemum strobilaceum* and *Salsola kali*).

Table 3. Inter-set correlations of environmental variables with axes CCA of the 10 Burullus habitats. Significant values at * ≤0.05, ** ≤0.01 and* ≤0.001**

Variable	AX1	AX2
pH	0.71***	0.06
EC	-0.19	0.19
Clay	-0.56**	-0.04
Silt	0.34*	0.63**
Sand	-0.24	-0.64**
OM	0.38*	0.63**
$CaCO_3$	-0.05	0.13
N	0.68**	0.21
P	-0.82***	0.01
Na	0.44*	0.33*
K	0.68**	0.40*
Ca	-0.75***	0.05
Mg	-0.01	0.38*
Fe	-0.10	-0.02



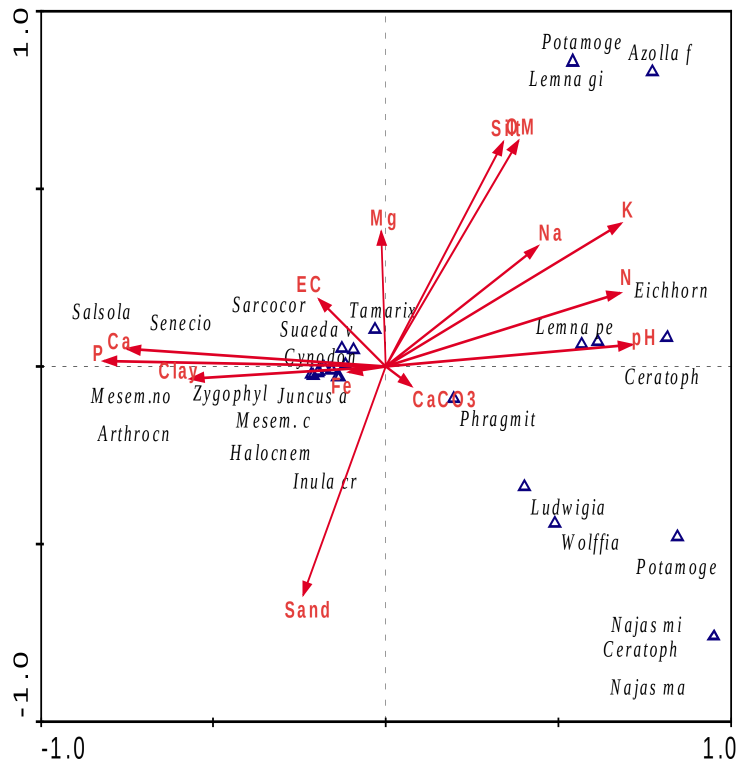
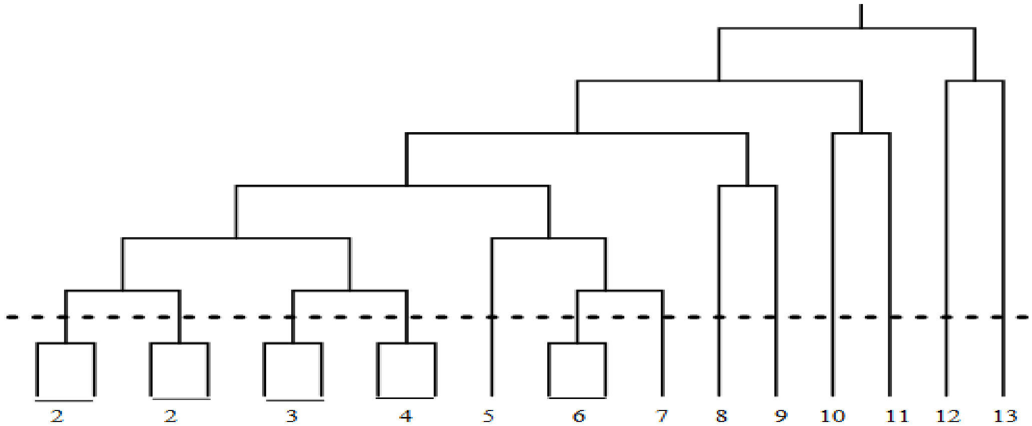
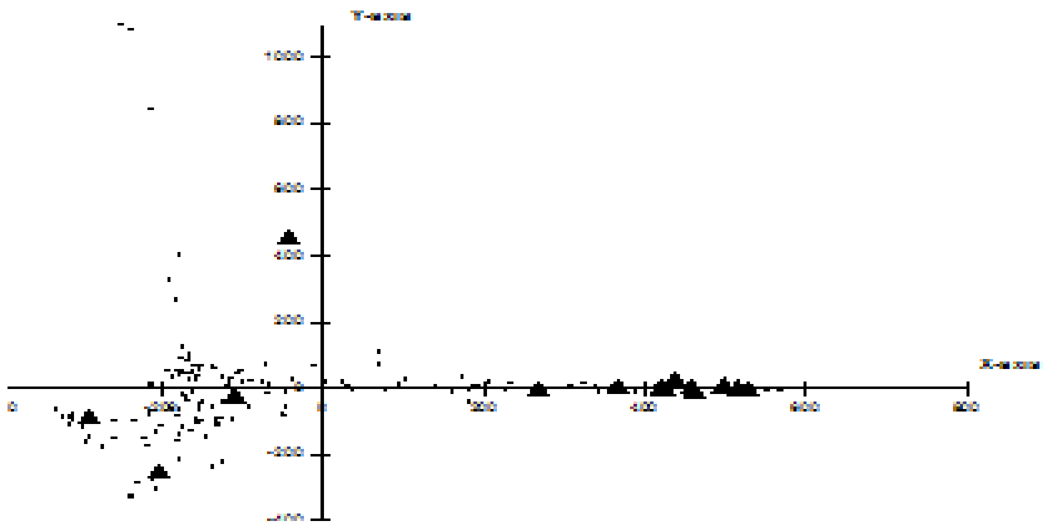


Figure 7a,b. CCA ordination of common dominant species in 10 habitats 1=SM: salt marshes, 2=SS: sand formations, 3=LG: lake cuts, 4=TD: terraces, 5=SD: slopes, 6=ED: water edges and 7=OD: open water zones of the drains, 8=LS: lake shores. 9=LO: open water of the lake and 10=IS: lake islets.



a: TWINSPAN



b: DECORANA

Figure 8 a&b. 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* (After, Shaltout & Al-sodany 2008).

Phragmites australis is common in aquatic and moist places throughout north lagoons except Bardawil lagoon (Täckholm, 1974, Zahran & Willis 1992, Boulos 2005, Shaltout & Al-sodany 2008; El-sheikh 2012). Its growth in Burullus lagoon represents one of the most important reed bed in the Mediterranean basin, where this type of habitat is becoming rare and threatened, due to many human impacts in these north lagoon of Egypt as: discharge of polluted liquid, soil and organic refuses, grazing, cutting, burning and drying for cultivation.

Wintering and migrant birds are strongly dependent on the reed beds for forage, refuge and breeding (Shaltout et al. 2004; Shaltout et al. 2005a; Shaltout & Khalil 2005; Shaltout & Al-Sodany 2008 and El-Sheikh et al. 2012). *Potamegaton pectinatus* is submerged macrophytes of nearly cosmopolitan distribution. It is the most dominant submerged plant in Burullus lagoon. It can also tolerant high salinity, pH, alkalinity and eutrophic waters, and may be grows in these polluted water and accumulate them in its leaves and stem (Demirezen & Aksoy 2004; Shaltout & Khalil, 2005).

VEGETATION COMPOSITION IN 5 LAGOONS OF NORTHERN EGYPT

After Galal, et al. (2012) multivariate analysis is used to analyze the vegetation and environmental variables of 298 sampled stands in 5 lagoons. 17 vegetation groups in Lake Mariut (188 spp. x148 samples), 15 in lagoon Edku (112 spp. x 150 samples), 13 in lagoon Burullus (197 spp. x 227 samples), 8 in Manzala (37 spp. x 100 samples) and 9 in Bardawil (45 spp. x 150 samples) were identified. These groups were separated along the prevailing moisture and salinity gradient from the shoreline to the open water.

The plant communities were listed with their species diversity and some common edaphic factors in (Table 4). The diversity of plant communities generated from multivariate analysis in Maruit lagoon characterize by different habitats (habitat diversity). Communities that inhabit open water habitat are less divers than other communities. The high specificity of the species of these communities to their habitats may be support this finding. On the other hand, the communities that extend their occurrence along more than one habitat have the highest diversity. These results are coinciding with that of (Al-Sodany 1998; Shaltout & Khalil, 2005).

DISTRIBUTION OF COMMON PLANT COMMUNITIES IN DIFFERENT LAGOONS OF NORTHERN EGYPT

The characteristic species of plant communities identified in the five lagoons of North Egypt are indicated in (Table 5) (After Galal, et al., 2012). *Ceratophyllum demersium-Phragmites australis*, *Potamegaton pectinatus* and *Typha domingensis* are common in all the lagoons except Bardawil. On the other hand communities dominated by *Halocnemum strobilaceum* and *Sarcocornia fruticosa* are common in all lagoons except Manzala. Two communities were recorded in 3 lagoons: *Echinochloa stagnina* and *Eichhornia crassipes*. Five communities were recorded in 2 lagoons: *Arthrocnemum macrostachyum*, *Juncus acutus*, *Najas marina* var. *armata*, *Limbarada crithmoides*, *Saueda vera* and *Zygophyllum album*. A total of 32 communities were recorded only in one lagoon, 8 of these communities were recorded in Mariut only and 7 in Edku. *Salsola kali* and *Suaeda vera* were restricted in Burullus, 4 were recorded in Manzala and 11 has a unique occurrence in Bardawil lagoon (Table 5).

Table 4. The vegetation groups and associated species recorded in the five lagoon in North of Egypt with their species diversity and some edaphic variables after (, Shaltout & Khalil 2005; Galal, et al. 2012; Shaltout & Al-Sodany 2008; El-Sheikh et al. 2012)

Community name	Associated species	Species diversity indices			Edaphic variables		
		Total cover of 1st dominant sp %	Sp. richness	Shannon H	Simpson C	pH	EC $mScm^{-1}$
Lake Maruit							
1. *Arthocnemum macrostachym-Juncus rigidus*	*Sarcocornia fruticosa-Sonchus oleraceus*	50	4	0.5	1.3	7.9	27
2. *Sarcocornia fruticosa-Halocnemum strobilaceum*	*Atriplex semibaccata-Phragmites australis*	50	10	2.5	5.5	7.7	15
3. *Atriplex halimus-Tamarix nilotica*	*Phragmites australis- Sarcocornia fruticosa*	29	11	3.3	12.9	7.9	6
4. *Bromus rubens-Launaea nudicaulis*	*Cynanchum acutum-Atriplex semibaccata*	13	23	3.2	21.0	7.8	5
5. *Phragmites australis*	*Cynanchum acutum-Plucheadiscorides*	73	12	2.5	3.8	7.9	4
6. *Atriplex semibaccata-Phragmites australis*	*Hordium murinum* subsp. *Leporinum-Suaeda vera*	6	24	3.9	27.3	7.8	4
7. *Cynanchum acutum-Phragmites australis*	*Cynodon dactylon-Bassia indica*	8	25	4.2	20.8	7.8	4
8. *Voltaria tubiflorae*	*Bassia indica-Malva parviflora*	3	19	3.1	10.0	7.9	7
9. *Najas marina* var *armata*	*Phragmites australis-Ceratophyllum demersum*	92	5	0.5	1.2	6.8	2
10. *Phragmites australis-Typha domingensis*	*Myriophyllum spicatum-Ceratophyllum demersum*	47	6	1.7	3.4	7.9	8
11. *Phragmites australis*	*Eichhornia crassipes-Echinochloa stagnina*	82	5	1.7	2.3	7.4	6
12. *Eichhornia crassipes*	*Phragmites australis-Ludwigia stolonifera*	86	6	1.0	1.6	7.3	5
13. *Echinochloa stagnina-Phragmites australis*	*Ceratophyllum demersum-Typha domingensis*	24	10	2.3	7.2	8.0	6
14. *Ceratophyllum demersum*	*Eichhornia crassipes-Azolla filiculoides*	24	7	1.9	5.3	7.2	5

Table 4. (Continued)

Community name	Associated species	Species diversity indices			Edaphic variables		
		Total cover of 1st dominant sp %	Sp. richness	Shannon H	Simpson C	pH	EC mScm^{-1}
15. *Potamogeton pectinatus-Eichhornia crassipes*	*Myriophyllum spicatum-Ceratophyllum demersum*	60	5	1.4	2.7	7.2	6
16. *Potamogeton pectinatus- Phragmites australis*	*Echinochloa stagnina*	75	3	0.7	1.7	7.1	11
17. *Potamogeton pectinatus*	*Phragmites australis*	99	1.2	0.1	1.0	7.1	15
Lake Edku							
1. *Eichhornia crassipes*	*Echinochloa stagnina-Rununclus scleratus*	63	7.3	1.4	2.5	7.9	1.4
2. *Echinochloa stagnina- Eichhornia crassipes*	*Ludwigia stolonifera-Rununclus scleratus*	31	6.6	1.3	2.7	7.8	1.5
3. *Ceratophyllum demersum-Eichhornia crassipes*	*Echinochloa stagnina-Potamogeton pectinatus*	21	8.0	2.0	7.0	7.7	2.8
4. *Potamogeton pectinatus*	*Phragmites australis-Eichhornia crassipes*	41	6.0	1.5	3.6	7.7	2.9
5. *Cyperus articulates*	*Panicum coloratum- Typha domingensis*	73	3.0	0.8	1.7	7.8	9.4
6. *Typha domingensis*	*Phragmites australis-Eichhornia crassipes*	65	4.0	0.7	1.9	7.7	11.0
7. *Phragmites australis*	*Typha domingensis-Echinochloa stagnina*	91	4.0	0.5	1.2	7.7	2.4
8. *Arundo donax*	*Cynanchum acutum-Plucheadiscorides*	96	4.0	0.2	1.1	7.8	1.5
9. *Juncus acutus-Typha domingensis*	*Atriplex protulacoides-Limbarda crithmoides*	18	9	1.7	4.2	7.8	10
10. *Phragmites australis-Typha domingensis*	*Limbarda crithmoides-Sarconcornia fruticosa*	38	13	1.6	3.9	7.8	3.1
11.*Halocnemum strobilaceum-Sarconcornia fruticosa*	*Phragmites australis-Scirpus litoralis*	80	5	0.6	1.5	7.5	14.2
12. *Sauaeda verra-Rumex dentatus*	*Sarconcornia fruticosa-Chenopodium murale*	46	14	2.1	4.0	7.8	3.7
13. *Bassia indica-Limbarda crithmoides*	*Atriplex halimus-Suaeda vera*	17	24	2.8	15	7.9	3.1

Community name	Associated species	Species diversity indices			Edaphic variables		
		Total cover of 1st dominant sp %	Sp. richness	Shannon H	Simpson C	pH	EC $mScm^{-1}$
14. *Centauria calcitrapa*	*Limbarda crithmoides-Cynodon dactylon*	42	15	1.7	3.8	7.9	12.4
15. *Cynodon dactylon-Medicago polymorpha*	*Pluchea discorides-Cyperus rotundus*	28	33	2.8	10	7.9	0.3
Lake Burullus							
1.*Arthrocnemum macrostachyum-Juncus acutus*	*Atriplex protulacoides-Limbarda crithmoides*	41	8.1	1.5	0.04	7.7	4.6
2. *Phragmites australis-Sauaeda pruinosa*	*Arthrocnemum macrostachyum-Malva parvifora*	59	134	1.5	0.05	7.5	2.8
3.*Phragmites australis-Arthrocnemum macrostachyum*	*Salsola kali-Limbarda crithmoides*	17	7.7	1.3	0.06	7.7	2.7
4. *Suaeda vera-Limbarda crithmoides*	*Atriplex protulacoides-Arthrocnemum macrostachyum*	28	7.8	1.7	0.03	7.9	2.9
5. *Juncus acutus*	*Phragmites australis-Scirpus litoralis*	17	3.2	1.7	0.03	7.9	5.9
6. *Sarcocornia fruticosa*	*Arthrocnemum macrostachyum-Spergularia marina*	53	11.0	1.6	0.03	7.8	11
7. *Potamogeton pectinatus*	*Eichhornia crassipes-Ceratophyllum demersum*	87	3.3	1.1	0.11	8.1	2.9
8. *Halocnemum strobilaceum*	*Arthrocnemum macrostachyum-Spergularia marina*	21	9.4	1.7	0.03	8.0	3.5
9. *Salsola kali*	*Limbarda crithmoides-Secio galucus*	31	2.5	1.0	0.12	8.1	1.5
10. *Phragmites australis*	*Typha domingensis-Limbarda crithmoides*	18	2.3	1.7	0.03	8.0	9.0
11. *Phragmites australis-Potamogeton pectinatus*	*Eichhornia crassipes-Ceratophyllum demersum*	51	3.2	1.0	0.02	8.7	8.1
12. *Typha domingensis-Ceratophyllum demersum*	*Atriplex protulacoides- Limbarda crithmoides*	51	4.1	1.2	0.17	8.8	5.7
13. *Phragmites australis-Potamogeton pectinatus*	*Eichhornia crassipes-Ceratophyllum demersum*	15	2.3	0.9	0.10	8.9	6.6

Table 4. (Continued)

Community name	Associated species	Species diversity indices			Edaphic variables		
		Total cover of 1st dominant sp %	Sp. richness	Shannon H	Simpson C	pH	EC $mScm^{-1}$
Lake Manzala							
1. *Azolla filiculoides*	*Ludwigia stolonifera*	0.0	0.0	0.0	0.0	0.0	0.0
2. *Eichhornia crassipes*	*Azolla filiculoides-Echinochloa stagnina*	0.0	0.0	0.0	0.0	0.0	0.0
3. *Potamiogeton pectinatus*	--	0.0	0.0	0.0	0.0	0.0	0.0
4. *Ceratophyllum demersum*	*Najas marina* var *armata*	0.0	0.0	0.0	0.0	0.0	0.0
5. *Typha domingensis*	--	0.0	0.0	0.0	0.0	0.0	0.0
6. *Scirpus maritimus*	--	0.0	0.0	0.0	0.0	0.0	0.0
7. *Phragmites australis*	--	0.0	0.0	0.0	0.0	0.0	0.0
8. *Ruppia maritime*	--	0.0	0.0	0.0	0.0	0.0	0.0
Lake Bardawil							
1.*Ruppia cirrhosa-Cymodocea nodosa*	*Halodule uninervis*	17	0.3	0.4	0.40	0.0	0.0
2. *Halocnemum strobilaceum*	*Sarcocornia fruticosa-Zygophyllum album*	47	0.5	0.2	0.14	0.0	0.0
3. *Zygophyllum album*	*Arthrocnemum macrostachyum-Suaeda vera*	61	0.6	0.1	0.10	0.0	0.0
4. *Nitraria retusa*	*Juncus rigidus-Tamarix nilotica*	55	0.7	0.9	0.12	0.0	0.0
5. *Stipagrostis plumose-Retama raetum*	*Pancratium maritimum-Ononis serrata*	90	1.4	1.3	0.06	0.0	0.0
6. *Panicum turgidum-Thymelaea hirsute*	--	91	0.9	1.3	0.06	0.0	0.0
7. *Artemisia monosperma*	*Thymelaea hirsute-Moltkiopsis ciliata*	95	1.6	1.4	0.05	0.0	0.0
8. *Asparagus stipularis*	*Devera tortusa-Lycium shawii*	90	1.2	1.3	0.05	0.0	0.0
9. *Stipagrostis scoparia-Calligonum plygonoides*	*Astragalus fruticosus-Cyperus conglomeratus*	47	0.4	0.9	0.14	0.0	0.0

Table 5. The common plant communities inhabit the most habitats recorded in the five lakes (after Galal, et al., 2012)

Characteristic species	Life form	Mariut	Edku	Burullus	Manzala	Bardawil	Total
Communities of open water							
Azolla filiculoides Lam.	HH				+		1
Ceratophyllum demersum L.	HH	+	+	+	+		4
Cymodocea nodosa (Ucria) Asch.	Th					+	1
Eichhornia crassipes (C.Mast.) Solms	HH	+	+		+		3
Ludwigia stolonifera (Guill & Perr.) P. H. Raven	HH				+		1
Najas marina var. armata (H. Lindb.) Horn	HH	+			+		2
Potamogeton pectinatus L.	HH	+	+	+	+		4
Ruppia cirrhosa (Petagna) Grande	HH					+	1
Ruppia maritima L.	HH				+		1
Communities of swamps							
Arundo donax L.	GH		+				1
Cyperus articulatus L.	GH		+				1
Echinocloa stagnina (Retz.) P.Beauv.	GH	+	+		+		3
Juncus acutus L.	GH		+	+			2
Juncus rigidus Desf.	GH	+					1
Phragmites australis (Cav.) Trin.ex Steud	GH	+	+	+	+		4
Scirpus maritimus L.	GH				+		1
Typha domingensis (Pers.) Poir.ex Steud	GH	+	+	+	+		4
Communities of shoreline							
Cynanchum acutum L.	GH	+					1
Centauria calcitrapa L.	Ch		+				1
Launaea nudicaulis (L.) Hook. F.	H	+					1
Cynodon dactylon (L.) Pers.	GH		+				1
Bromus rubens L.	Th	+					1
Medicago polymorpha L.	Th		+				1
Rumex dentatus L.	Th		+				1
Volutaria tubuliflora (Murb.)Sennen.	Th	+					1
Bassia indica (Wieght) A. J. Scott	Th		+				1
Salsola kali L.	Th			+			1
Communities of saline sand formations							
Atriplex halimus L.	Ph	+					1
Nitraria retusa (Forssk.) Asch.	Ph					+	1
Tamarix amplexicaulis Ehrenb.	Ph	+					1
Arthrocnemum macrostachyum (Moric.) K. Koch	Ch	+		+			2
Halocnemum strobilaceum (Pall.) M. Bieb.	Ch	+	+	+		+	4
Limbarda crithmoides (L.) Dumort.	Ch		+	+			2
Sarcocornia fruticosa (L.) A. J. Scott.	Ch	+	+	+		+	4

Table 5. (Continued)

Characteristic species	**Life form**	**Mariut**	**Edku**	**Burullus**	**Manzala**	**Bardawil**	**Total**
Suaeda pruinosa Lange	Ch			+			1
Suaeda vera Forssk. Ex. J. F. Gmel.	Ch		+	+			2
Zygophyllum album L.f.	Ch					+	1
Atriplex semibaccata R.Br.	Th	+					1
Communities of non-saline sand formations							
Asparagus stipularis Forssk.	GH					+	1
Calligonum polygonoides L.	Ph					+	1
Artemisia monosperma Delile	Ch					+	1
Moltkiopsis ciliata (Forssk.) I. M. Johnst.	Ch					+	1
Thymelaea hirsuta (L.) Endl.	Ch					+	1
Stipagrostis scoparia (Trin. & Rupr.) de Winter	H					+	1
Panicum turgidum Forssk.	GH					+	1
Total		**18**	**18**	**12**	**12**	**13**	**45**

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