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Population Dynamics and Multivariate Analysis of Vegetation in Lake Manzala, Egypt

Adel A. Ramadan
Botany Department, Faculty of Science, Suez Canal University, Ismailia, Egypt

Abstract: A distribution map of 17 prominent species in different habitats of lake Manzala is constructed after surveying 17 major stations distributed over the lake. The spatial population dynamics was tested through a comparison with a previous mapping, before 20 years ago. During that period six species showed reduced zonation, however, other species invaded the lake, sometimes with expanded zonation. Studying the temporal dynamics on the species-level in the lake over 8-years period, on 16 species showed that five species (31%) became extinct from the lake, while six species (27% of the present potential) are the new records. Our new records include *Azolla filiculoides* (fern), *Jussiaea repens, Lemna gibba and Ruppia maritima*, as hydrophytes and *Echinocloa stagnina* and *Panicum repens*, as lithophytes or amphibians. The cumulative temporal dynamics over 60-years period (1937-1996) was investigated on the cumulative number of species (36) and revealed that the ratio of the extinct species to the sustaining species is 17:19 species, respectively (i.e. 47% : 53%). The multivariate classification analysis of 30 stands resulted in six community types, namely *Eichhornia crassipes, Phragmites australis-Typha domingensis, Inula crithmoides, Halocnemum strobilaceum, Arthrocnemum macrostachyum* and *Sarcocornia fruticosa*. Seventeen species are organized in four clusters, representing habitats with different salinity levels, namely fresh-water, transitional water quality (ecotones), low saline soil and high saline soil. The multivariate ordination analysis on 17 species resulted in five distinct clusters between the first two axes. The first axis showed a positive correlation with moisture availability, while the second axis showed a negative correlation with salinity levels, suggesting that moisture and salinity are likely to be the major limiting factors for distribution of plant species in lake Manzala's environment.

Key words: Distribution maps, temporal and spatial dynamics, classification, ordination

Introduction

According to Forbes (1887), a lake is a small world composed of environmental features and living organisms bound and organized by inter-dependence and inter-relationships. The Mediterranean coast of Egypt extends for about 970 km, from Sallum (in the west) to Rafah (in the east) and is characterized by five big lakes, namely; Mariut (western coast), Idku, Burullus, Manzala (Deltaic coast) and Bardawil (Sinai coast). The formation of these lakes was associated with the presence of old seven branches of the Nile in its delta.

Due to the anthropogenic impact, quick environmental changes in LM were and still happening. Accordingly, such a lake needs monitoring studies and updated evaluation for productivity of its natural wealth. LM has gradually transformed, with time, from a brackish environment (Fouad, 1926; Bishai and Yossef, 1977) to eutrophic fresh water in response to increased fresh water inputs, nutrient loading associated with agricultural land reclamation processes and due to the urban waste disposal. The available studies on the plant life are scarce and fragmentary (Montasir 1937; Anonymous, 1982; Zahran *et al.*, 1989, Ishak and El-Halawany, 1989; Zahran *et al.*, 1990). The structural criteria of the dominant plant species in relation to their environment were recently assessed by Farag-Alla (2001). The studies on pollution in LM are Khalil (1985), Salib and Khalil (1986), Abdel Moati and Dowidar (1988) and Siegel *et al.* (1994). Also Ramadan and Mekki (1996) and Mekki (1996) inspected the toxicity effects by four heavy metal pollutants (Pb, Cd, Zn and Hg) in LM on the cyto-genetic components of selected crops.

According to Khalil (1990), the absence of thermal stratification is due to the shallowness of the lake's water (max 1.5 m). The maximum surface water temperature (29-30°C) was recorded in July-August and the minimum one (12-13°C) was in December-January.

Although lake Manzala is a brackish lake because of its connection with Mediterranean sea, it sustains the maximum of marine and fresh water (Bishai and Yossef, 1977). Based on previous records the temporal changes in average salinity showed a declining trend during a time period of 80 yrs (Fouad, 1926; El-Wakeel and Wahby, 1970; Shaheen and Yossef, 1978). This temporal declining pattern of salinity is attributed to several reasons such as: the increased inflow of agricultural drainage water, domestic sewage input and the restricted water inflow in El-Gamil lake-sea connection during 1960's and due to the partial blockage of the connection during 1970-1973.

The spatial changes in average salinity of lake Manzala show also a declining trend from the northern sector to the southern one, as detected from five stations and reported by Khalil (1990). Station I in the northern sector is the most saline part (>30,000 mg/l). However, station II, in the middle, is brackish (15,000-25,000 mg/l). Station III is transitional (3,000-15,000 mg/l). Station IV is slightly brackish (2,000-5,000 mg/l) and finally, station V in the southern sector is of the lowest salinity (<2,000 mg/l) in Bahr El-Baqar Drain (Khalil, 1990).

The mean pH-value of the lake is fluctuated around 8 with seasonal change in some areas. In the northern part it is relatively high, sometimes reaching 10. The pH-values of the southern part are lower perhaps due to fermentation of the organic matter which enriches this part and due to low oxygen content. Several investigators have recorded pH-values e.g. (Ibrahim, 1989; Khalil, 1985; Salib and Khalil, 1986). Zaki (1994) reported that the minimum pH-value (6.1) was found in the southern part, while the maximum value (8.4 or even 9.0) was found in the middle and northern parts, respectively.

The present study aims to construct an updated distribution map of the most prominent plant species in the lake and to evaluate their spatial and temporal dynamics and finally to describe the phytosociological structure of the lake's vegetation by applying multivariate analysis along the ecological gradients.

Materials and Methods

Lake Manzala has an original area of about 904,785 km^2 and is located in the north eastern quadrant of the delta between 31° 00' and 31°, 30' N latitudes and 31°45' and 32° 22' E longitudes (Fig. 1). The maximum length and width of the lake are 64.5 and 49.0 km, respectively and its total shoreline is 293 km.

The climatic data of LM were collected from five climatic stations (Ismailia, Port Said, Damietta, Sirw and Mansoura). Climatic details about radiation, sun shine, cloudiness, temperature, precipitation, surface winds, relative humidity and evaporation are given in Anonymous (1982) and Ramadan and Mekki (1996).

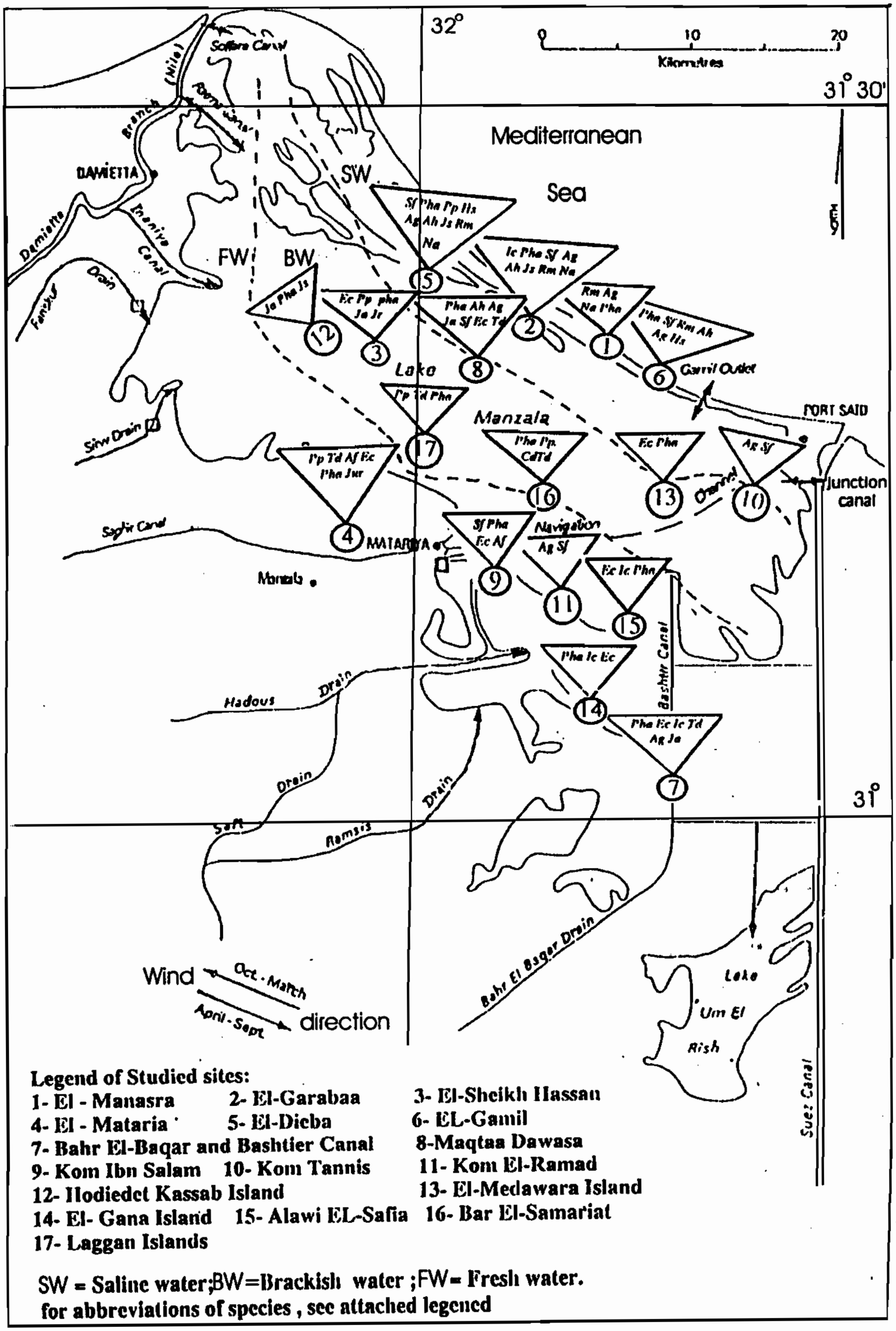

Fig. 1: Distribution map of 17 prominent plant species in lake Manzala

Af - Azolla filiculoides *Ag - Arthrocnemum macrostachyum (A. glaucum)* *Ah - Atriplex halimus (A. portulacoides)*
Cd - Ceratophyllum demersum *Ec - Eichhornia crassipes* *Hs - Halocnemum strobilaceum*
Ic - Inula crithmoides *Ja - Juncus acutus* *Jr - Juncus rigidus* *Js - Juncus subulatus*
Jur - Jussiaea repens *Na - Najas armata* *Pha - Phragmites australis* *Pp - Potamogeton pectinatus*
Rm - Ruppia maritima *Sf – Sarcocornia fruticosa* (syn. *Salicornia fruticosa*) *Td - Typha domingensis*

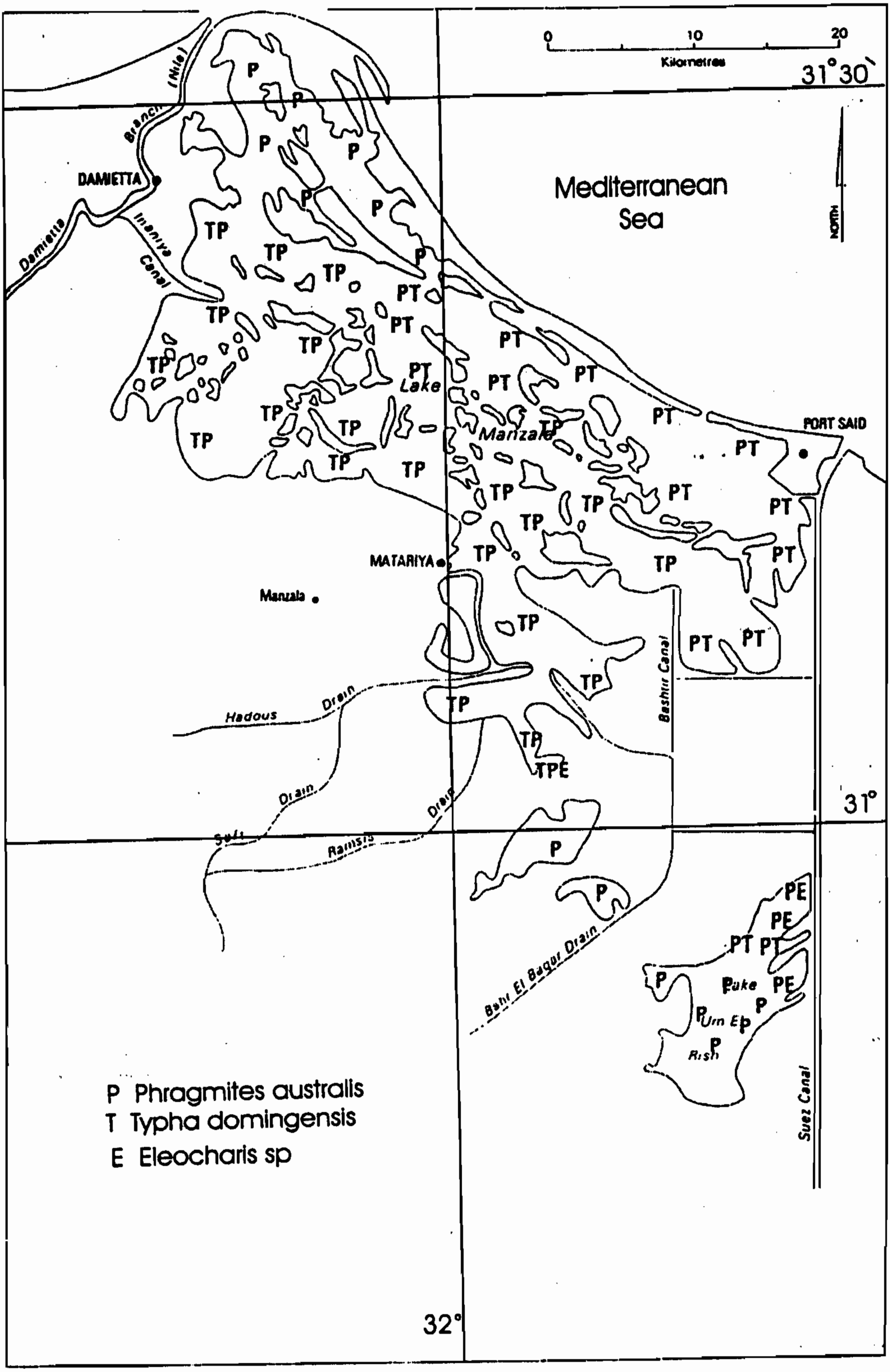

Fig. 2: Distribution of major emergent aquatic plants in lake Manzala (after Anonymous, 1982)

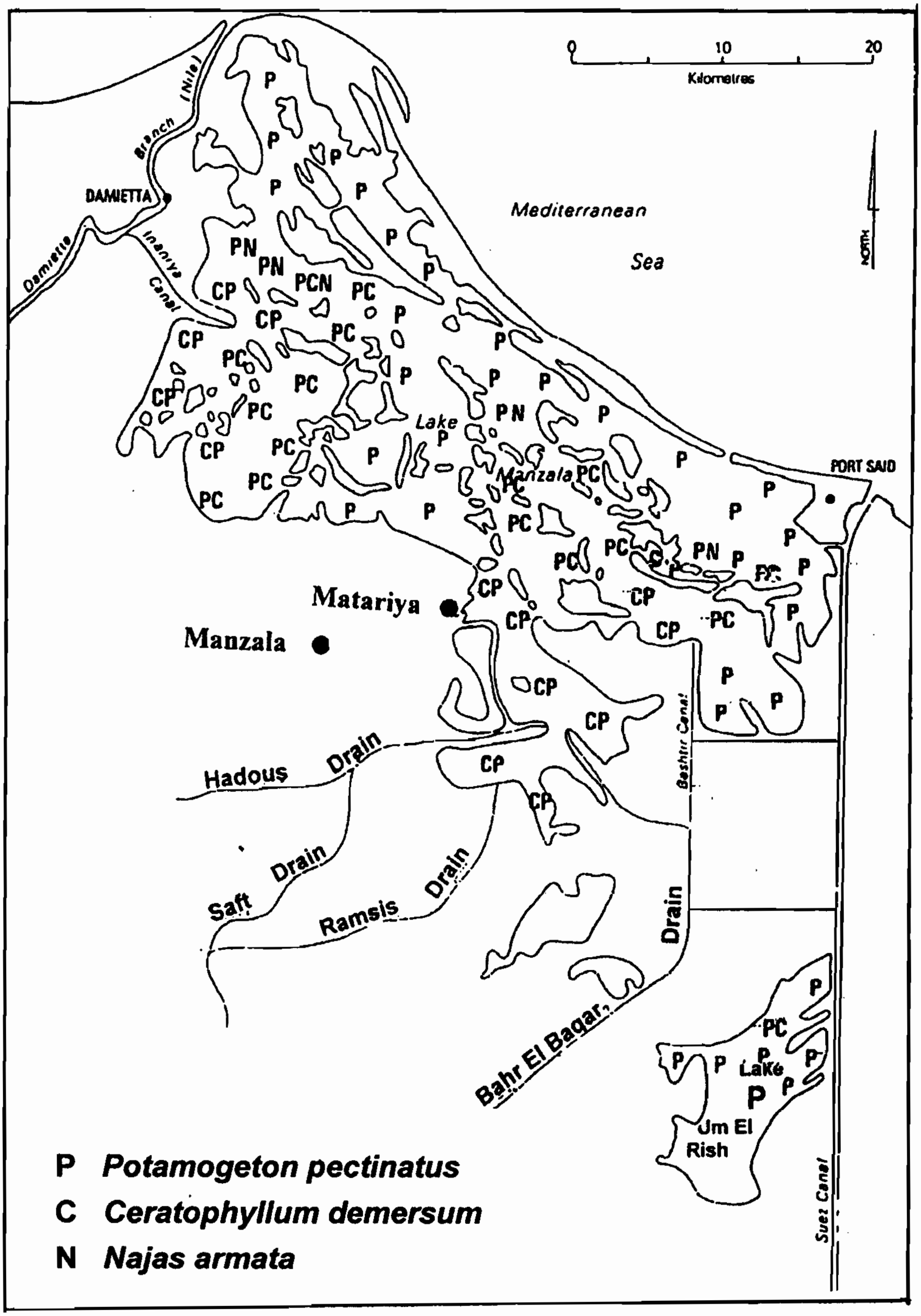

Fig. 3: Distribution of major submergent aquatic plants in lake Manzala (after Anonymous, 1982)

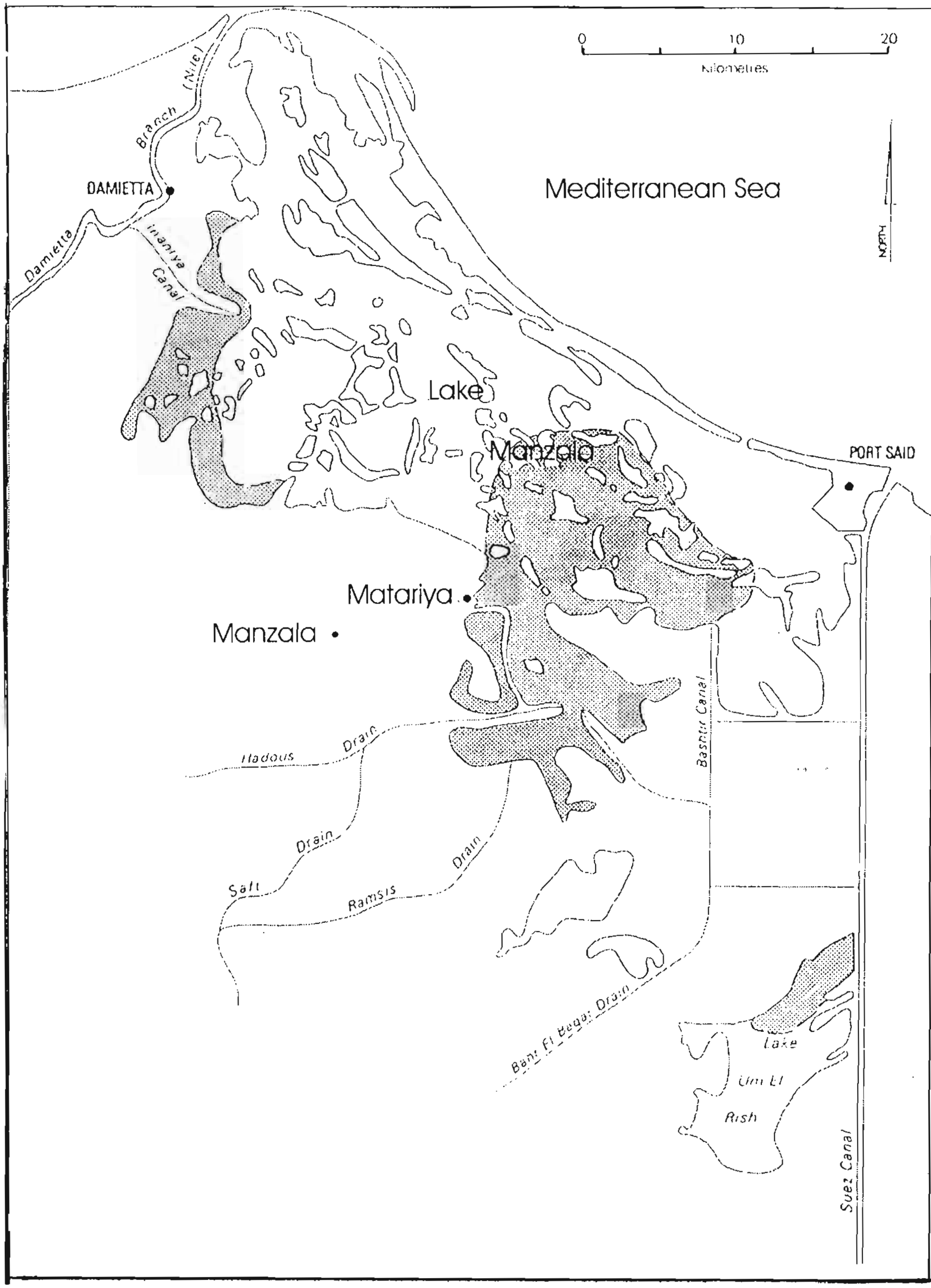

Fig. 4: Distribution of *Eichhornia crassipes* in lake Manzala (after Anonymous, 1982)

The plant identification followed Täckholm (1974) and was updated according to Boulos (1995). Sampling sites included aquatic habitats, wetlands and island habitats.

Distribution map of plant species: A distribution map of plant species in LM was constructed based on field observations and multiple visits to seventeen stations covering most of the lake's area. Accurate recording of plant species in each station was undertaken.

Spatial and temporal dynamics of plant species: The spatial dynamics of plant species in the lake were evaluated by comparing the components of our recent distribution map against the distribution maps, constructed for the lake, twenty years ago by Anonymous (1982). The growing and declining trends of selected plant species (expressed as net spatial trend, Pn%) were evaluated by comparing our recent presence values against previous presence values. We derived the approximate P % values for species from the maps of Anonymous (1982) by counting the total number of demarcations given for each species, relative to the total number of demarcations given for all species, in two maps (Figs. 2 and 3). In the third map (Fig. 4), the presence value was approximately derived from the area covered by *Eichhornia crassipes*, as a ratio relative to the total area of the lake.
The temporal dynamics, on the species-level, was evaluated by comparing our recently recorded species list against two lists from the previous studies of Montasir (1937) and Ishak and El-Halawany (1989) with a special reference to three categories of species, namely "new records (N)", "extinct species (E)" and "sustaining species (S)". Also the temporal dynamics, on the community-level, was evaluated by comparing our recent results against that of Zahran *et al.* (1989).

Vegetation analysis: This was carried out using the cover percentage for community structure. The community types were named after the dominant species. The classification and ordination of species and stands were carried out using the computer programs TWINSPAN (Hill, 1979a) and DECORANA (Hill, 1979b), respectively.

Water analysis: Electrical conductivity (EC, μ mohs/cm) was determined by a conductivity meter, model HI 8033 Hanna Inst., then salinity (g/l) was calculated according to Pipers (1947).

Soil analysis: Surficial soil samples were collected from sediments of ten stations representing different habitats e.g. wetlands, lake's bottom and dry islands. The samples were air-dried and passed through a 2 mm-sieve, then chemically analyzed for pH-value of the soil extract, using pH meter model HI 8014 Hanna Inst. The electric conductivity, (EC, μ mohs/cm) and total soluble salts (g/l) were determined as mentioned above. The total $CaCO_3$ % of the soil was determined by the back titration methods (Jackson 1974). The soil extract was prepared by saturated soil paste.

Results and Discussion

Distribution pattern of the prominent plant species in Lake Manzala: The distribution pattern of plant species in LM was studied in 17 stations covering most of the lake's area which is divided into three sectors of different levels of water salinity (Fig. 1). The northern sector has mostly saline water (SW), the medium sector has mostly brackish water (BW) and the southern sector has mostly fresh water (FW). Some stations are included in two sectors, due to being located on the hypothetical border-line between two sectors.

Northern sector: This sector was studied in seven sites, namely El-Gamil (6), El-Manasra (1), El-Garabaa (2), El-Dieba (5), Tannis Island (10), Dawasa section (8) and El-Medawara Island (13). The most common amphibian species are *Phragmites australis, Juncus subulatus* and *Inula crithmoides*. The common terrestrial species are *Arthrocnemum macrostachyum (A. glaucum), Sarcocornia fruticosa* (syn. *Salicornia fruticosa*), *Halocnemum strobilaceum* and

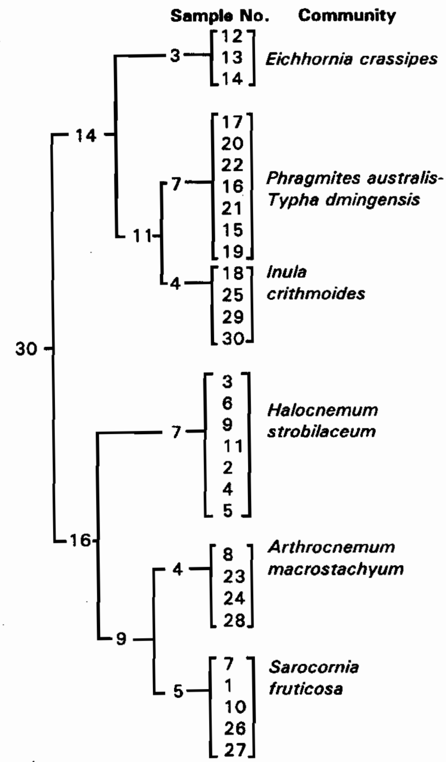

Fig. 5: Classification of 30 stands of vegetation in lake Manzala using TWINSPAN

Atriplex portulacoides. The submerged hydrophytes are *Ruppia maritime* and *Najas armata* (Fig. 1).

Medium sector: This sector was studied in seven sites, namely Tannis Island (10), El-Medawara Island (13), Lagan Island (17), Dawasa section (8), El-Sheikh Hassan Island (3), Kassab Island (12) and El-Samariat Island (16). The most common amphibian species are *Phragmites australis, Juncus acutus, J. subulatus* and *Typha damingensis*. The common terrestrial species are *Atriplex portulacoides* and *Sarcocornia fruticosa* and the floating hydrophyte is *Eichhornia crassipes.*

Southern sector: This sector was studied in seven sites, namely Bahr El-Baqar drain and Bashteer Canal area (7), El-Gana Island (14), Alawi El-Safia (15), El-Samariat Island (16), Ibn Salam Island (9 and 11) and El-Mataria (4). The most common amphibian species are *Phragmites australis, Typha domingensis, Juncus acutus* and *Inula crithmoides*. The common terrestrial species are *Arthrocnemum macrostachyum* and *Sarcocornia fruticosa*. The floating hydrophytes are *Azolla filiculoides* (a new record, recently introduced fern from China and we consider it as the most competitive invader to LM), *Eichhornia crassipes*, and *Jussiaea repens* (a new record also).
It is concluded that hydrophytes are the most sensitive species for salinity and they are the most characteristic species for the three sectors in LM. As a result, *Azolla filiculoides* and *Jussiaea repens* (two new records) are only confined to the southern sector in fresh water. The same zonation applies to *Eichhornia crassipes* (although it is sometimes found in brackish water in the medium sector). However, *Ruppia maritima* (a new record) and *Najas armata* are only confined to the northern sector of the lake, in saline water.
Montasir (1937) recorded twenty seven halophytic terrestrial amphibians, but not hydrophytic species in LM (Table 2).

Table 1: Spatial dynamics of seven hydrophytic species, after 15 years in lake Manzala

		Ramadan and Mekki (1996) Station No.																			Anonymous (1982)		Net spatial trend
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17					
		Water type																	Total No.	P2	Total	Approx.	
Growth form	Species	s	s	b	f	s	s	f	b	f	b	f	b	b	f	f	b	b	sites	%	no. sites	P1%	(Pn%)*
Emergent hydrophytes	*Phragmites australis*	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	15	88	44	55	33
	Typha domingensis	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	+	+	5	30	35	44	-14
	Eleocharis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	1	1	-1
Submerged hydrophytes	*Potamogeton pectinatus*	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	+	+	5	30	72	68	-38
	Ceratophyllum demersum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	1	6	29	28	-22
	Najas armata	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	3	18	5	5	13
Floating hydrophytes	*Eichhornia crassipes*	-	-	+	+	-	-	+	+	+	-	-	-	+	+	+	-	-	8	47	25	25	22

* (Pn%) = P2% - P1%, s= saline, b= brackish, f= fresh water, + = present, - = absent.

Table 2: Temporal dynamics in species structure during up to 60 years in Lake Manzala

No.	Species	Montasir (1937)	Ishak and El-Halawany (1989)	Ramadan and Mekki (1996)	Sustaining spp. (S)
	Terrestrial and amphibian species / No. years ago	60 years	8 years		
1	*Arthrocnemum macrostachyum* (Moric.) K. Koch. (*A. glaucum*)	*	*	*	(S)
2	*Arundo donax* L.	*			(S)
3	*Atriplex portulacoides* L.	*		*	(S)
4	*Atriplex. Farinosa* Forssk.	* (E)			
5	*Carex divisa* Huds.		* (E)		
6	*Cistanche tubulosa* (Schenk) Hook. (*C. lutea*)	* (E)			
7	*Cressa cretica* L.	*	* (E)		
8	*Cyperus laevigatus* L.	*		*	(S)
9	*Echinocloa stagnina* (Retz.) P. Beauv.			* (N)	
10	*Frankenia pulverulenta* L.		*	*	(S)
11	*Halocnemum strobilaceum* (Pall.) M. Bieb.	*		*	(S)
12	*Halopeplis perfoliata* (Forssk.) Asch in Schweinf.	* (E)			
13	*Inula crithmoides* L.	*		*	(S)
14	*Juncus acutus* L.			*	
15	*Juncus rigidus* Desf. (*J. arabicus, J. maritimus*)	*	*	*	(S)
16	*Juncus subulatus* Forssk.			*	
17	*Limoniastum monopetalum* (L.) Boiss.	* (E)			
18	*Nitraria retusa* Asch.		* (E)		
19	*Panicum repens* L.			* (N)	
20	*Phragmites australis* (Cav.)Tren. Ex Stend.	*	*	*	(S)
21	*Sarcocornia fruticosa* (L.) L. (*Salicornia fruticosa*)	*	*	*	(S)
22	*Salicornia europaea* L. (*S. herbacea*)	*	* (E)		
23	*Salsola kali* L.	* (E)			
24	*Salsola longifolia* Forssk.	* (E)			
25	*Scirpus litoralis* Schrad. Fl. Germ.		* (E)		
26	*Sporobolus spicatus* (Vahl) Kunth.	* (E)			
27	*Statice delicatula* De Gerard.	* (E)			
28	*Suaeda pruinosa* Lange. Vidensk. Meddel.	*			(S)
29	*Suaeda maritima* (L.) Dumort. (*S. salsa*)	* (E)			
30	*Suaeda splendens* (Pourr.) Gren. and Godr.	* (E)			
31	*Suaeda vera* Forssk. ex JF. Gmel.	* (E)			
32	*Suaeda vermiculata* ex JF. Gmel.	* (E)			
33	*Tamarix aphylla* (L.) H. B62Karst. Deutschl. (*T. articulata*)	*			(S)
34	*Tamarix nilotica* (Ehrenb.) Bunge. Tent.		*		(S)
35	*Typha domingensis* (Pers.) Poir. Ex Stend. (*T. angustata, T. australis*)	*	*	*	(S)
36	*Zygophyllum album* L.	*			(S)
	Aquatic species				
37	*Azolla filiculoides* Lam. (fern)			* (N)	
38	*Ceratophyllum demersum* L.		*	*	(S)
39	*Eichhornia crassipes* (C. Mart.) Solms in A.&C. Dc.		*	*	(S)
40	*Jussiaea repens* L.			* (N)	
41	*Lemna gibba* L.			* (N)	
42	*Najas marina* L. (*N. armata*)		*	*	(S)
43	*Potamogeton pectinatus* L.		*	*	(S)
44	*Ruppia maritima* L.			* (N)	
Total No. spp.		27	16	22	
Total No. (Extinct spp. New records and Sustaining spp.)		12 (E)	5 (E)	6 (N)	19 (S)
Percentage		44%	31%	27%	
Cumulative % of Extinct spp. (E) and Sustaining spp. (S)		47% (E)			53% (S)

(E) = Extinct species, Shaded row (N) = New record, (S) = Sustaining species.
* = present, NB. The cumulative % of extinct and sustaining spp. % are calculated relative to the cumulative no. (36) of different spp. recorded by Montasir (1937) and Ishak and El-Halawany (1989).

Table 3: Mean values of soil analysis of samples from Lake Manzala in 1994 - 1995

Sample No.	Locality	Sector	EC (μmohs/cm)	Salinity (g/l)	$CaCO_3$ %
1	El-Bashteer canal area	S	2.76	1.80	14.91
2	Dawasa section lland	N - M	16.60	10.60	14.88
3	Bahr El-Baqar bottom-1	S	28.00	17.90	14.55
4	Bahr El-Baqar bottom-2	S	27.80	17.80	13.95
5	Bahr El-Baqar	S	31.50	20.20	7.50
6	El-Gayara Island-1	M - S	2.55	1.60	14.91
7	El-Gayara Island-2	M - S	2.12	1.40	14.91
8	El-Ramad Island	S	7.14	4.60	14.85
9	Kom Tannis Island	N - M	1.40	1.00	7.20
10	El-Samariat Island	M - S	1.44	1.00	14.40

Sector : N= north, M= middle, S= south

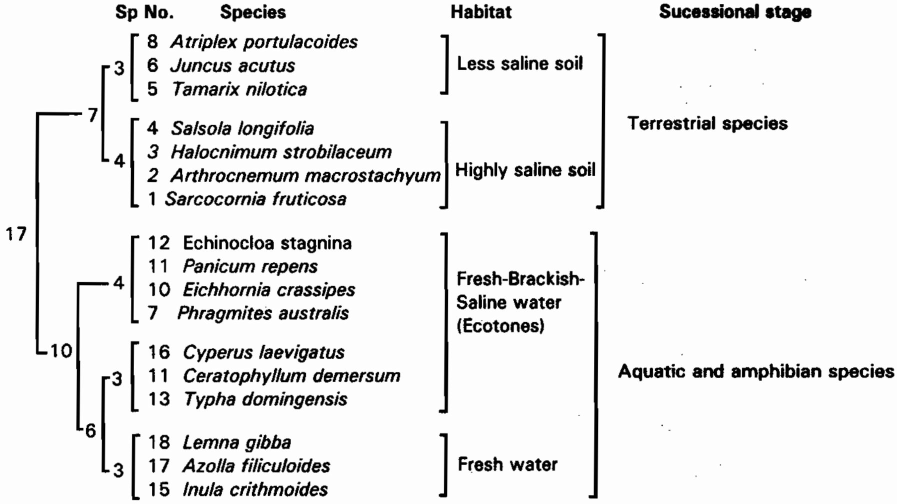

Fig. 6: Classification of species using TWINSPAN

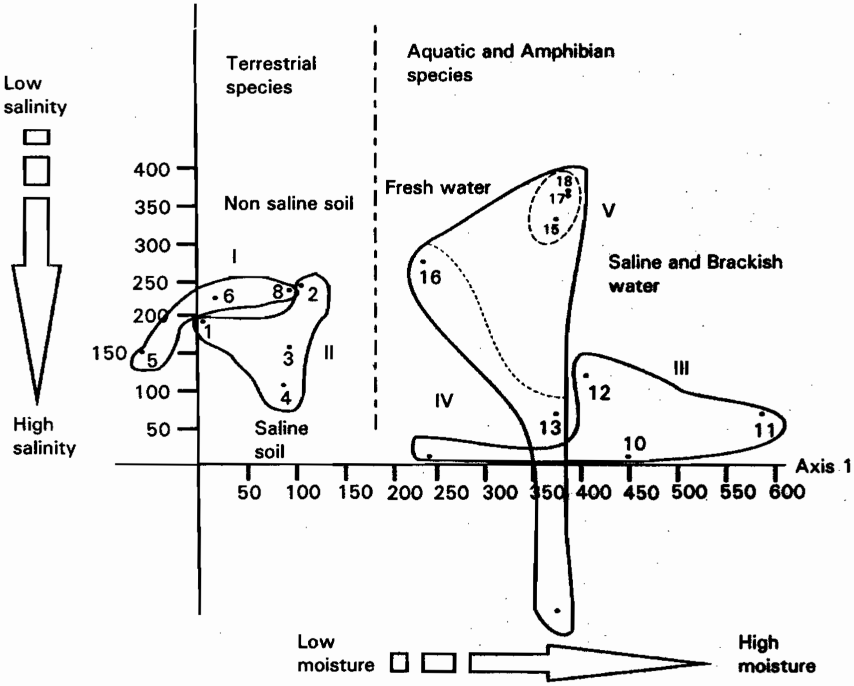

Fig. 7: Ordination of species using DECORANA

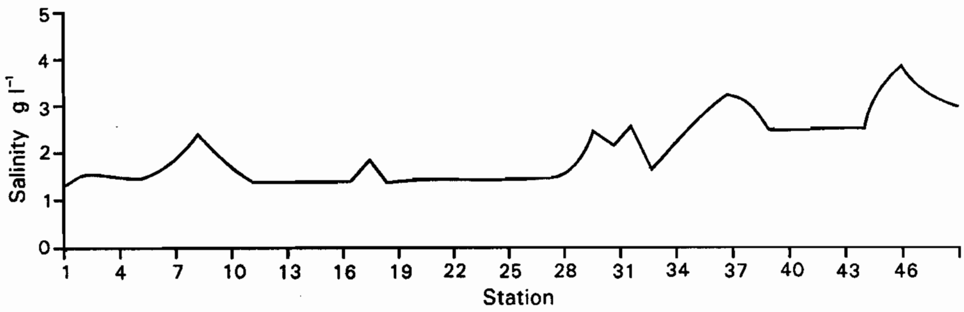

Fig. 8: Salinity of water at 48 stations in a south-north transect in lake Manzala

Anonymous (1982) recorded seven terrestrial and aquatic species, and Ishak and El-Halawany (1989) recorded sixteen terrestrial and aquatic species. Meanwhile, we have recorded a total of twenty two species (fourteen terrestrial/amphibian and eight aquatic species).

The spatial dynamics of seven (amphibian and aquatic) species in LM are here discussed by comparing their distribution in our map (Fig. 1 and Table 1) against the three former distribution maps (Figs. 2, 3, 4, after Anonymous, 1982). Looking to the most recent spatial distribution of the seven plant species (Table 1) and keeping in mind the progressive increment in the pollution rate and the human impact on the lake, we notice that the most common and widely distributed species ($P_2\%$ = 88) is *Phragmites australis,* while the most rare species ($P_2\%$ = 6%) is *Ceratophyllum demersum.* Inspecting the four maps (Figs. 1,2,3,4) and Table (1), it is obvious that after 20 yrs, a pronounced declining trend in the net presence ($P_n\%$) is encountered for three species as follows: *Typha domingensis,* declined from 44 to 30% ($P_n\%$ = -14%), *Potamogeton pectinatus,* from 68 to 30% ($P_n\%$ = -38%) and *Ceratophyllum demersum,* from 28 to 6% ($P_n\%$= -22%). An opposite growing trend was encountered for three other species as follows: *Phragmites australis* (the most common species) increased from 55 to 88% ($P_n\%$ = + 33%) and *Najas armata,* from 5 to 18 % ($P_n\%$ = + 13%) and *Eichhornia crassipes,* from 25 to 47 % ($P_n\%$ = 22%). The seventh species *Eliocharis sp,* which was formerly very rare, became almost extinct.

Our list of new records (Table 2 and Fig. 1) includes six species, namely *Echinocloa stagnina, Panicum repens, Azolla filiculoides, Jussiaea repens, Lemna gibba* and *Ruppia maritima.* It is thought that *Azolla* invaded the Egyptian aquatic habitats on the expense of *Lemna gibba* (Boulos, 1995).

The temporal dynamics of species in LM are recognized by comparing our species list (Ramadan and Mekki, 1996) against those recorded, 60 yrs ago, by Montasir (1937) and those recorded, 8 yrs ago, by Ishak and El-Halawany (1989) (Table 2). It is obvious that after sixty years, twelve species (44%) became extinct out of the twenty seven records of Montasir (1937). On the other hand, after 8 years, five species (31%) became extinct out of the sixteen records of Ishak and El-Halawany (1989). Considering the cumulative number of species (36), recorded by both of Montasir (1937) and Ishak and El-Halawany (1989), the total of 17 species (47%), became extinct, however, a total of 19 species (53%) are still sustaining up till now, in spite of different impacts on the lake (Table 2).

Synthetic characterization of plant communities by multivariate analyses: The results of two multivariate analyses (classification and ordination) using two computer programs TWINSPAN and DECORANA, respectively are summarized as follows:

Sample classification: Six clusters of samples are recognized which are inhabited by the following six major plant community types:

1- *Eichhornia crassipes* community type, dominated by a floating hydrophyte (stands 12, 13 and 14). The characteristic species are *Echinocloa stagnina, Panicum repens,* and *Phragmites australis.* The habitat features of this community type are mainly fresh- slightly brackish waters.
2- *Phragmites australis-Typha domingensis* community type, co-dominated by two amphibian reeds (stands 15, 16, 17, 19, 20, 21 and 22). The only characteristic species is *Ceratophyllum demersum.* The associate species are: *Echinocloa stagnina, Eichhornia crassipes* and *Panicum repens.* The habitat features are either fresh- brackish water, or wetlands with shallow surface water of moderate to fairly high salinity (Table 3).
3- *Inula crithmoidies* community type, dominated by an amphibian species (stands 18, 25, 29 and 30). The characteristic species are *Azolla filiculoides* and *Lemna gibba.* Associate species are *Phragmites australis, Cyperus laevigatus.* and *Typha domingensis.* They are all distributed mainly in the southern sector of the lake. The habitat features are mainly fresh-brackish-fairly saline water (i.e water ecotones). It should be mentioned that fresh water of bad quality prevail in the southern sector of the lake due to the high level of pollution from three different sources, namely agricultural, municipal and industrial effluents.
4- *Halocnemum strobilaceum* community type dominated by a terrestrial species (stands 2, 3, 4, 5, 6, 9 and 11). It is characterized by *Salsola longifolia* and associated with *Sarcocornia fruticosa* (syn. *Salicornia fruticosa*) and *Phragmites australis.* The habitat features are highly saline grounds (Table 3).
5- *Arthrocnemum macrostachyum (A. glaucum)* community type, dominated by a terrestrial species (stands 8, 23, 24 and 28). It is characterized by *Atriplex portulacoides* and associated with *Juncus acutus, Halocnmum strobilaceum, Sarcocornia fruticosa,* and *Phragmites australis.* The habitat features are also saline grounds.
6- *Sarcocornia fruticosa* community type, dominated by a terrestrial species (stands 7, 1, 10, 26 and 27). It is characterized by *Tamarix nilotica* and associated with *Juncus acutus, Salsola longifolia, Atriplex portulacoides, Halocnemum strobilaceum,* and *Phragmites australis.* The habitat features are highly saline grounds.

Generally, the vegetation structure as well as the species potentiality of LM indicates a very heterogeneous environment. The vegetation of islands has been dramatically affected by the changes in salinity and pollution levels (Abdel Moati and Dowidar 1988 and Ramadan and Mekki, 1996) in addition to the drying processes for cultivation and the cessation of the Nile river floods due to the construction of the High Dam on the Nile river in Aswan, south Egypt. The number of native species of LM has also been decreased, due to the above reasons, in addition to the extinction of considerable numbers of them (Table 2). Twelve (non-native) species were also recorded in the lake (Ishak and El-Halawany, 1989).

The temporal dynamics on the community-level in LM is encountered from a comparison between our recent findings and those of Zahran *et al.* (1989) as follows:

Community type	(Zahran *et al.*, 1989)		(Ramadan and Mekki, 1996)
Phragmitis australis.	+	---------	+
Juncus acutus.	+		-
Juncus rigidus.	+		-
Arthrocnemum macrostachyum	+	---------	+
Atriplex protulacoides.	+		-
Halocenmum strobilaceum.	+	---------	+
Zygophyllum album.	+		-
Eichhornia crassipes	-		+
Inula crithmoides	-		+
Sarcocornia fruticosa	-		+

Zahran *et al.* (1989) recorded seven major plant communities, while after eight years (in 1996) we recorded six communities, three of them only are similar to those of Zahran *et al.* (1989). Such temporal changes in the lake's potentiality of plant communities are likely to be due to the factors mentioned above, in addition to the establishment of aquaculture (Anonymous, 1982).

We may conclude that the vegetation of lake Manzala's islands is essentially of salt-marsh habitats (Table 3). It is usually present on the boundaries of islands and extends landward for short distances while the rest of the islands are practically barren lands (Montasir, 1937). *Phragmitis australis* predominates along the shore line of the islands, then *Juncus acutus* and *Juncus rigidus* followed by *Arthrocnemum glaucum, Atriplex portulacoides* and *Halocenmum strobilaceum* which predominate on the relatively elevated grounds with deep sand deposits. *Zygophyllum album* community occupies the most landward followed by the barren islands (Zahran *et al.*, 1989). Within the above communities, lists of associate species were recorded such as: *Inula crithmoides, Frankenia hirsuta, Suaeda peruinosa, Cressa cretica, Tramarix nilotica, Scirpus tuberosus, Cyperus laevigatus, Plantago crassifolia, Cynodon dactylon, Typha domingensis and Eichhornia crassipes.* The present status indicated that *Eichhornia crassipes* and *Salicornia fruticosa* became more abundant and amounted to the level of communities. The same applies to *Azolla filiculoides* and *Lemna gibba.*

Classification and ordination of species: The application of classification by TWINSPAN and ordination by DECORANA computer programs (Hill, 1979 a and b, respectively) on 17 species revealed five clusters of species, based on the gradient in ecological criteria. Salinity levels and moisture availability seem to be the most limiting factors, for distribution of the plant species in LM. Checking the dendrogram of classification of the five clusters (Fig. 6) and their ordination diagram between axes 1 and 2 (Fig. 7) we mention the following remarks.

Clusters (I): Includes terrestrial species inhabiting less saline soils e.g. *Atriplex portulacoides, Juncus acutus* and *Tamarix nilotica.*

Cluster (II): Includes species inhabiting highly saline soils e.g. *Salsola longifolia. Halocnemum strobilaceum, Arthrocnemum macrostachyum,* and *Sarcocornia fruticosa.*

Cluster (III): Includes floating hydrophytes and amphibian species, tolerant of moderate salinity e.g. *Eichhornia crassipes, Echinocloa stagnina, Phragmites australis,* and *Panicum repens.*

Cluster (IV): Includes submerged and emerged species inhabiting saline to brackish water habitats e.g. *Ceratophyllum demersum, Cyperus laevigatus* and *Typha domingensis.*

Cluster (V): Includes floating hydrophytes and amphibian species inhabiting fresh water habitats e.g. *Lemna gibba, Azolla filiculoides,* and *Inula crithmoides.*

The interpretation of the two ordination axes (1 and 2) of DECORANA suggests the following ecological gradients: The first axis is positively correlated with the gradient in moisture availability, while the second axis is negatively correlated with the gradient of salinity levels (Table 3 and Fig. 8). These findings agree with those of Zahran *et al.* (1989) who outlined that land relief, level of underground water, soil salinity and soil moisture are the major factors governing the pattern of the vegetation of lake Manzala and are the bases for the recognition of it's community types.

In conclusion, It is obvious that the rate of environmental changes in lake Manzala seems very high, mainly due to humans and their pollution impacts. This could be depicted from the items of comparison in the present study, such as spatial and temporal population/specific dynamics and the high changing rates for the extinct, newly recorded and sustaining species. Human and pollution impacts on LM will be our subjects in forthcoming papers.

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