Hydrophytes of the Nile in Egypt

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Abstract The vascular freshwater weeds of the River Nile in Egypt comprises 87 species of flowering plants, belonging to 45 genera and 25 families. Out of these, 12 are dicots and 13 are monocots. In addition there are 3 pteridophytes, viz. *Azolla filiculoides*, *Marsilea aegyptiaca* and *M. capensis*. Cyperaceae is represented by 19 species followed by Gramineae (15 species), Lemnaceae and Potamogetonaceae (6 species each), Najadaceae (4 species), 3 species belong to each of 6 families and 2 species belonging to each of 3 families. The other families are represented by only one species.

Habitat wise, submerged hydrophytes are represented by 21 species (11 genera and 9 families), free floating hydrophytes by 9 species (6 genera and 4 families), fixed floating by 5 species (4 genera and 4 families) whereas emergent hydrophytes are represented by the highest number of species (54), in 28 genera and 13 families.

The aquatic vegetation of the Nile in Egypt is classified under 36 communities dominated by 8 submerged, 9 floating and 19 emergent species. The distribution of these communities and their floristic composition as well as the impact of the establishment of Aswan High Dam (1965) is discussed.

1 Introduction

The present article is a discussion of the aquatic plants (hydrophytes, macrophytes) growing in the Egyptian Nile, whether submerged, floating or emergent. Of the River Nile, the terminal 1,530 km lie within Egypt (see map in Dumont, 2009). Its basin includes the Fayum Province, a depression in the Western Desert connected with the river by a semi-natural irrigation canal (Bahr Yusuf) and occupied by saline Lake (=Birket) Qarun (see El-Shabrawy & Dumont, 2009).

Recently (1997), the Egyptian Government established two new canals to expand the amount of cultivable land irrigated by the Nile: Sheikh Zaied canal

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and El-Salam canal. The first takes water from Aswan High Dam Lake to the Toshka Depression of the Western Desert (El-Shabrawy & Dumont, 2009). El-Salam Canal, on the other hand, takes water from the Damietta Branch of the Nile to irrigate land in the north of the Sinai Peninsula. This means that two man-made sub-regions can be added to the present sub-regions: the Nile Valley, the Nile Delta, the Nile Fayum (three natural sub-regions), and Toshka and Sinai (two man-made sub-regions) (Zahran et al., 2003).

The Nile water in Egypt flows through a network of irrigation and drainage canals over the broad alluvial expanses of the valley, delta and Fayum. Khattab (1992) estimated the total length of the irrigation and drainage system at about 48,000 km, distributed according to the width of the bases of irrigation and drainage canals respectively as follows: 3,260 and 850 km for >10 m base width; 2,880 and 1,440 km for 5–10 m base width and 25,500 and 14,100 km for <5 m base width.

The description given hereafter deals with the Nile basin as it appears today. However, deep changes occurred over time, and those that took shape during the last four or five millennia were almost entirely due to man. The Nile valley during the Neolithic must indeed have looked quite different from today; in particular, the expanses of temporary and permanent marshlands were far more extensive than at present and large areas of Lower Egypt may have looked like miniature Sudd – swamps (Rzóska, 1976).

2 Diversity of the Hydrophytes in the River Nile in Egypt

According to Hassib (1951), the flora of the Nile in Egypt contains ca 534 species (algae excluded), ca 25% of the flora of the country. During the last 30 years, studies of the flora of the Nile, particularly after the establishment of Aswan High Dam (1965), have been carried out by Tackholm (1974), El-Hadidi (1971), Moursi (1976), Batanouny & El-Fiky (1983), Springuel & Murphy (1990, 1991), El-Kholi (1989), Khedr (1989), Murphy et al. (1989), Serag (1991, 1996, 2000), Shaltout et al. (1994), Zahran et al. (1998, 2003), Khedr (1998), Khedr & Zahran (1999), Hussein (2000) El-Bana et al. (2000), Bishai et al. (2000), Zahran (2003), Shaltout & Khalil (2005) & Khalil & Shaltout (2006). These studies reveal that the vascular freshwater weed flora of Egypt includes 87 species of flowering plants, in 45 genera representing 25 families (Table 1). Twelve are Dicotyledoneae, and 13 are Monocotyledoneae. In addition, the flora includes 3 Pteridophytes, namely: *Azolla filiculoides* of Azollaceae and 2 species (*Marsilea aegyptiaca* and *M. capensis*) of the Marsileaceae (Table 2). Nineteen families are represented by one genus; two (Alismataceae and Onagraceae) by two genera and two (Hydrocharitaceae and Lemnaceae) by three genera. Cyperaceae is represented by six and Gramineae by ten genera. The highest number of species (19) belong to Cyperaceae, followed by Gramineae (15 species). Lemnaceae is represented by six species, Potamogetonaceae by six, four Najadaceae, three species in each of Alismataceae, Ceratophyllaceae, Hydrocharitaceae, Juncaceae, Onagraceae, Polygonaceae and Ranunculaceae, and two species in Nymphaeaceae, Amaranthaceae and Marsileaceae. The other

Table 1 List of the macroaquatic flora of the River Nile system, Egypt (Täckholm, 1974; Boulos, 1995; Zahran et al., 2003)

Family	Species	Distribution			H	AB
		Nd	Nv	Nf		
I. Submerged						
Ceratophyllaceae	*Ceratophyllum demersum*	+	+	+	p	dN
	C. muricatum	+	–	–	p	rr
	C. submersum	+	–	–	p	rr
Haloragaceae	*Myriophyllum spicatum*	+	+	+	p	dN
Hydrocharitaceae	*Elodea canadensis*	+	–	–	p	dNd
	Otellia alismoides	+	+	+	p	c
	Vallisneria spiralis	–	+	–	p	rr
Lentibulariaceae	*Utricularia inflexa*	+	–	–	p	r
Najadaceae	*Najas graminea*	+	+	–	a	r
	N. horrida	+	+	–	a	dNv
	N. marina subsp. *Armata*	+	+	–	a	dN
	N. minor	+	–	–	a	r
Podostemaceae (incl. Tristicheae)	*Tristicha trifaria*	+	–	–	p	rr (Aswan cataract)
Potamogetonaceae	*Potamogeton crispus*	+	+	+	p	dN
	P. pectinatus	+	+	+	p	dNd
	P. perfoliatus	–	+	–	p	rr
	P. trichoides	–	+	–	p	rr
	P. lucens	+	–	–	p	r
	P. panormitanus	–	+	–	p	c
Ruppiaceae	*Ruppia maritima var. rostrata*	+	+	+	p	dN
Zannichelliaceae	*Zannichellia palustris*	+	+	+	p	cc
II. Floating						
(a) Free floating						
Araceae	*Pistia stratiotes*	+	–	–	p	dNd
Azollaceae (Pteridophyta)	*Azolla filiculoides*	+	+	+	p	dNd
Lemnaceae	*Lemna gibba*	+	+	+	p	dNd
	L. minor	+	–	–	p	rr
	L. perpusilla	+	–	–	p	rr
	Spirodela polyrhiza	+	+	+	p	cc
	S. punctata	+	–	–	p	r
	Pseudowolffia hyalina	+	+	+	p	c
Pontederiaceae	*Eichhornia crassipes*	+	+	+	p	dN

(continued)

Table 1 (continued)

Family	Species	Distribution			H	AB
		Nd	Nv	Nf		
(b) Fixed floating						
Nymphaeaceae	*Nymphaea caerulea*	+	–	+	p	dNd
	N. lotus	+	–	+	p	dNd
Onagraceae	*Ludwigia stolonifera*	+	+	+	p	dNd
Potamogetonaceae	*Potamogeton nodosus*	+	+	+	p	dN
Gramineae (Poaceae)	*Vossia cuspidata**	+	+	+	p	dNd + near Cairo
III. Emergent						
Alismataceae	*Alisma plantago–aquatica*	+	–	–	p	r
	A. gramineum	+	+	–	p	r
	Damasonium alisma	+	+	+	p	r
Amaranthaceae	*Alternanthera nodiflora*	+	+	–	a,p	c
	A. sessiles	+	+	–	a,p	c
Cruciferae (Brassicaceae)	*Rorippa palustris*	+	+	–	Bi	c
Cyperaceae	*Carex divisa*	+	+	+	p	c
	Cyperus alopecuroides	+	+	+	p	dNd
	C. articulatus	+	–	–	p	dNd
	C. difformis	+	+	+	p	dNd
	C. digitatus subsp. *Auricomus*	+	–	–	p	rr
	C. fuscus	+	–	–	a	rr
	C. papyrus	+	–	–	p	dNd + dNv (cultivated)
	C. schimperianus	+	–	–	p	Nd
	Eleocharis capitata	+	–	–	a,p	rr
	E. granulata	+	–	–	a,p	r
	E. palustris	+	+	+	p	cc
	E. parvula	+	–	–	p	rr
	Fuirena ciliaris	+	–	–	p	rr
	Pycreus mundtii	+	–	+	p	dNf
	P. polystachyos	+	–	–	p	r
	Scirpus articulatus	+	–	+	p	rr
	S. litoralis	+	+	+	p	dNd
	S. maritimus	+	–	–	p	dNd
	S. triqueter	+	+	+	p	dNd
Elatinaceae	*Bergia capensis*	+	–	–	p	c

(continued)

Table 1 (continued)

Family	Species	Distribution			H	AB
		Nd	Nv	Nf		
Gramineae (Poaceae)	Echinochloa colona	+	+	+	a	cc
	E. crusgalli	+	+	–	a	cc
	E. pyramidalis	Unknown	locality			rr
	E. stagnina	+	+	+	p	dNd
	Hermarthria altissima	+	–	–	p	r
	Leersia hexandra	+	–	–	p	dNd
	Leptochloa fusca	+	+	+	p	dNd
	Panicum repens	+	+	+	p	cc
	Paspalidium geminatum	+	+	+	p	c
	P. obtusifolium	+	–	–	p	rr
	Paspalum distichum	+	–	–	p	dNd
	Phragmites australis	+	+	+	p	dN
	P. mauritanus	+	–	–	p	rr
	Saccharum spontaneum subsp. *Aegyptiacum*	+	+	+	p	dNd
Juncaceae	*Juncus bufonius*	+	+	+	a	c
	J. fontanesii subsp. *Pyramidatus*	+	–	–	p	r
	J. subulatus	+	+	+	p	dNd
	Marsilea capensis	+	–	–	p	rr
Marsileaceae (Pteridophyta)	*M. strigosa*	Unknown	locality		p	rr
Onagraceae	*Epilobium hirsutum*	+	+	+	p	c
	Ludwigia erecta	–	+	–	a	rr
Polygonaceae	*Persicaria lanigera*	+	–	–	p	rr
	P. salicifolia	+	+	+	p	dNd
	P. senegalensis	+	+	+	p	dN
Ranunculaceae	*Ranunculus rionii*	+	–	–	a	r
	R. sceleratus	+	+	+	a	rr
	R. trichophyllum	+	–	–	a,p	rr
Scrophulariaceae	*Veronica anagallis – aquatica*	+	+	+	p	cc
Typhaceae	*Typha domingensis*	+	+	+	p	dN

Nd = Nile Delta (including the northern lakes), Nv = Nile Valley (including the southern reservoirs), Nf = Nile Fayum, N = Nile system, H = habit of plant (a = annual, bi = biennial, p = perennial), AB = abundance (rr = very rare, r = rare, c = common, cc = very common, d = dominant), + = present, – = absent.

Table 2 Dominant aquatic macrophytes in the River Nile system of Egypt (after Zahran et al., 2005)

Dominant species	A	B
I. Submerged species		
1. *Ceratophyllum demersum*	+	+
2. *Elodea Canadensis*	−	+
3. *Myriophyllum spicatum*	+	+
4. *Najas horrida*	+	−
5. *N. marina* subsp. *Armata*	+	−
6. *Potamogeton crispus*	+	+
7. *P. pectinatus*	−	+
8. *Ruppia maritima*	−	+
II. Floating species		
1. *Azolla filiculoides*	−	+
2. *Eichhornia crassipes*	+	+
3. *Lemna gibba*	−	+
4. *Ludwigia stolonifera*	−	+
5. *Nymphaea caerulea*	−	+
6. *N. lotus*	−	+
7. *Pistia stratiotes*	−	+
8. *Potamogeton nodosus*	+	+
9. *Vossia cuspidata*	−	+
III. Emergent species		
1. *Cyperus alopecuroides*	−	+
2. *C. articulatus*	−	+
3. *C. difformis*	−	+
4. *C. papyrus*	−	+
5. *C. schimperianus*	−	+
6. *Echinochloa stagnina*	−	+
7. *Juncus subulatus*	−	+
8. *Leersia hexandra*	−	+
9. *Leptochloa fusca*	−	+
10. *Paspalum distichum*	−	+
11. *Persicaria salicifolia*	−	+
12. *P. senagalensis*	+	+
13. *Phragmites australis*	+	+
14. *Pycreus mundtii*	−	+
15. *Saccharum spontaneum* subsp. *aegyptiacum*	−	+
16. *Scirpus litoralis*	−	+
17. *S. maritimus*	−	+
18. *S. triqueter*	−	+
19. *Typha domingensis*	+	+

A = recorded in the Aswan area only (River Nile section at Aswan + Aswan Reservoirs), B = recorded in the other parts of the River Nile system northwards including northern lakes, + = occurs as dominant, − = does not occur as dominant but may occur otherwise.

families are represented by a single species. According to habitat, submerged, floating or emergent, the distribution is as follows: submerged hydrophytes are represented by 9 families, 11 genera and 21 species, free floating hydrophytes by four families, six genera and nine species, fixed-floating hydrophytes by four families (Potamogetonaceae is represented also by submerged plants and Onagraceae also by emergent plants), four genera and five species and emergent hydrophytes are represented by 13 families, 28 genera (*Ludwigia* occurs also in the fixed floating group) and 54 species. Potamogetonaceae is represented by six submerged and one floating species whereas Onagraceae is represented by one floating and two emergent species.

The diversity of the aquatic plants of Egypt attracted the attention of Kassas (1971), who stated that the building of dams and barrages across the Nile and its tributaries, particularly Aswan High Dam, had segmented the natural hydrobiological system, with undoubted impact on water quality and biota. The low species diversity of the aquatic vegetation types of the irrigation and drainage canals in the Nile Delta is considered by Shaltout et al. (1995) to be related to the high disturbance of these habitats caused by the repeated removal of the silt and weeds during maintenance.

The emergent and floating macrophyte groups were reported by Khedr and El-Demerdash (1997) to have high species richness. The highest mean value was recorded in the group dominated by *Azolla filiculoides* (6.1 species per stand); the lowest (4.5 species per stand) in the group dominated by *Ceratophyllum demersum*.

Khedr (1999c) reported that the Shannon Diversity Index (H′) was highest in emergent macrophytes (H′ = 1.26), followed by free-floating species (H′ = 1.07) and fixed-floating species (H′ = 0.87). He noted that the Shannon Diversity Index positively correlated with species richness (r = 0616, P < 0.0001) and evenness (r = 0.433, P < 0.0001). The vegetation group with the dominant species *Potamogeton crispus* and *P. nodosus* in the irrigation canals showed the highest Shannon mean evenness value (E_s = 0.77). The lowest mean evenness value (E_s = 0.53) was recorded in the vegetation group dominated by *Eichhornia crassipes* and *Echinochloa stagnina*. The Simpson Index was highest (S = 0.55) in this vegetation group, and lowest (S = 0.31) for submerged species.

3 Hydrophyte Communities

The aquatic vegetation may be classified into 36 communities dominated by 8 submerged, 9 floating and 19 emergent species, as shown in Table 2. The submerged communities are dominated by: *Ceratophyllum demersum*, *Elodea Canadensis*, *Myriophyllum spicatum*, *Najas horrida*, *N.marina armata*, *Potamogeton crispus*, *P. pectinatus and Ruppia maritima*. The free-floating dominants are *Azolla filiculoides*, *Eichhornia crassipes*, *Lemna gibba and Pistia stratiotes* whereas *Ludwigia stolonifera*, *Nymphaea caerulea*, *N. lotus*, *Potamogeton nodosus* and *Vossia cuspidata* are the dominant fixed-floating species. Boulos (1995) reported that *V. cuspidata* may also grow as a submerged hydrophyte. The emergent communities are dominated by: *Cyperus alopecuroides*,

Table 3 Distribution of the communities of the hydrophyte vegetation of the River Nile system in Egypt

Group	Communities in A + B	Communities in A only	Communities in B only	Total
I. Submerged	3	2	3	8
II. Floating	2	0	7	9
III. Emergents	3	0	16	19
Total	8	2	26	36

A = recorded in the Aswan Area only, including Aswan Reservoirs, B = recorded in the Nile system northwards, A + B = recorded in the whole Nile system of Egypt.

Table 4 Occurrence (%) of the freshwater dominant macrophytes in the three subregions of the River Nile system in Egypt

Subregion	Nd (%)	Nv (%)	Nf (%)
I. Submerged (22%)	45	36	19
II. Floating (25%)	46	23	31
III. Emergents (53%)	50	26	24

Nd = Nile Delta, Nv = Nile Valley, Nf = Nile Fayum.

C. articulatus, *C. difformis*, *C. schimperianus*, *Echinochloa stagnina*, *Eleocharis capitata*, *Juncus subulatus*, *Leersia hexandra*, *Leptochloa fusca*, *Paspalum distichum*, *Persicaria salicifolia*, *P. senegalensis*, *Phragmites australis*, *Pycreus mundtii*, *Saccharum spontaneum* subsp. *aegyptiacum*, *Scirpus litoralis*, *S. maritimus S. triqueter* and *Typha domingensis*. The distribution of the 36 communities in the three subregions, Nile Valley, Delta and Fayum (Table 3), reveals that *Najas horrida* and *N. marina* subsp. *armata* are dominants in the Aswan area only. Both may occur as associate species northwards. On the other hand, there are 26 communities, dominated by 3 submerged, 7 floating and 16 emergent species characteristic of the main river north of Aswan area. These dominant hydrophytes may occur as associate species in the Aswan area. Eight species (three submerged, two floating and three emergent) are dominants in all parts of the River Nile.

Table 4 shows the occurrence (%) of the freshwater dominant macrophytes, in the three subregions of the Nile in Egypt: 53% of the dominant hydrophytes are emergent, 25% are floating and 22% are submerged dominant species. The Nile Delta subregion contains the highest number: 45% of the submerged, 46% of the floating and 50% of the emergent species. The Nile Valley subregion contains the lowest number (23%) whereas the Fayum subregion contains 31% of dominant floating hydrophytes.

4 Two Important Plants: Papyrus and Water Hyacinth

4.1 Cyperus papyrus (Fig. 1)

C. papyrus is a tall, robust, leafless sedge that can grow 4–5 m high. It features a grass-like clump of triangular green stems that rise up from thick, woody rhizomes. Each stem is topped by a dense clusters of thin, bright green, thread-like rays

Fig. 1 Dense growth of *Cyperus papyrus* on the bank of Damietta Branch, River Nile, Egypt (*see Color Plates*)

around 10–30 cm in length. Greenish-brown flower clusters appear at the end of the rays. The flowers give way to brown, nut-like fruits.

Papyrus forms vast stands in swamps and along stream banks throughout eastern Africa. In Egypt, where papyrus is entwined with cultural history, Tackholm and Drar (1950) thought it had became extinct 150 years earlier. In July 1968, however, discovered a stand of about 20 plants among other reeds in a freshwater swamp of the Wadi El-Natrun Depression. Also, Hussein (2000) recorded papyrus in some islands of the River Nile in the area of Cairo, and Serag (2000) found it in the wetlands associated with the downstream section of the Damietta Branch of the River Nile. In ancient Egypt, as far back as 4,400 BP, it was used for food, fiber, shelter, formal bouquets, funeral garlands, boats, fans, sandals, matting corkage, boxes and paper. Its pith was recommended for food, while the starchy rhizomes and lowermost parts of them were cutoff and consumed raw, boiled, or roasted papyrus was also a favorite ornament in ancient art and craft (N.A.S., 1976). Papyrus swamps provide hypoxic and structural refugia for cichlids from predatory fish Nile Perch and are an important habitat for endangered bird species. Galen, Dioscoroides and later Islamic pharmacologists, e.g. Ibn Gulgul and El-Ghafigi, included papyrus among medicinal plants. The pith was recommended for widening and drying a fistula. The main use, anyhow, seems to have been confined to burnt papyrus sheets, the ash of which was reputed to have the action of pulverized charcoal and used for certain diseases.

Also, the little boat (or box) in which the mother of the Prophet Moses or Musa (1350–1340 BC) released her son to the Nile was made of papyrus.

Embarking upon his Ph. D. thesis on papyrus, Ragab (1980) faced the difficulty that this plant had become extremely rare in Egypt. In 1960, he travelled to the Sudan where *C. papyrus* grows abundantly in the Sudd, brought back a few rhizomes, and planted them on the bank of the Nile at Giza. One year later, he had enough shoots to establish a plantation and start experiments on papyrus sheet making. He succeeded in producing paper from the culms of papyrus using drawings of ancient pharaonic paintings and created a new touristic industry in Egypt. During the 30 subsequent years, Ragab produced and exported more than 10 million papyrus paper sheets to different parts of the world.

4.2 Water Hyacinth

E. crassipes (water hyacinth), is a perennial, surface free-floating, mat-forming aquatic plant of wide distribution in South America. In Egypt, *E. crassipes* was introduced as an ornamental plant during the rule of Khedive Tawfiq (1879–1892) and has, for many years, been grown in gardens of Cairo and Alexandria (Zahran, 1976). Percheron (1903) warned about the dangers of its spread in the Egyptian canals and drew attention to the problems that would occur if it would grow freely. Indeed, few decades later, Simpson (1932) reported *E. crassipes* to be widely distributed in freshwater channels of the Nile Delta and near Cairo and Alexandria. In the brackish water of the delta lakes, it is limited by its lack of tolerance to saline water. Zahran (1976) stated that it is difficult to find a canal, stream or drain not infested by water hyacinth particularly in the Fayum and Nile Delta.

E. crassipes has many uses, e.g. as soil fertilizer, raw material for paper making, biogas production and fodder for livestock and fish as well as cleaner for chemical pollutants of the water (Baruah, 1984). In Egypt, mechanical, manual, chemical and biological (herbivorous fish) control measures have been tried. Biological control by a fungal pathogen using pure powder of the fungal pathogen has been attempted, but large-scale application needs further tests.

5 Impact of the Aswan High Dam

Rorslett (1988) stated that building a dam across a river, and impounding water behind it, causes profound changes in limnological regime. These include chemical and physical changes, in turn affecting flora and fauna. The establishment of the Aswan High Dam (1964) brought the River Nile under full control, with great effects on the plant life associated with the river (Nd, Nv, Nf), and its artificial reservoirs, natural lakes, and irrigation and drainage systems. Two examples are presented to show the impact of the High Dam; the first describes the status of the aquatic weeds in the extreme south (Aswan area), the second in Lake Manzala (Delta).

5.1 Aswan Area

The extreme south of the Nile in Egypt is occupied by three water bodies: Lake Nasser (High Dam Reservoir), Aswan Reservoir, and the River Nile north of Aswan Reservoir. Ali et al. (1995) noted that Lake Nasser water level is strongly dependent on the flood pattern. A high range of water level fluctuation was recorded in 1988 after a series of low-flood years. First, a continuous low water level exposed littoral shallow water habitats, and submerged macrophytes became exposed and desiccated. Following this, a period of continuous high water level caused low-light conditions.

These two events caused substantial loss of submerged aquatic plants in Lake Nasser during 1988. The initial community had *Najas horrida*, not recorded by Tackholm (1974) or by Boulos (1995), as the dominant species with six others. Following the destruction of this community, *Najas marina armata* became dominant, with four other taxa present (*Najas horrida*, *Potamogeton schweinfurthii*, *Vallisneria spiralis* and *Zannichellia palustris*). In Aswan Reservoir, however, the water level regime follows a fixed pattern in which each day a certain amount of water is released. Usually, water is stored overnight and released during the day. A severe physical disturbance results from this daily range of ca 3 m level fluctuation (Ali, 1987). In this reservoir *Ceratophyllum demersum* was the dominant macrophyte, with *Najas horrida*, *Potamogeton crispus* and *Zannichellia palustris*. In the river, the water level is regulated to meet Egypt's demands for cultivation. This results in a gradual increase in water level, followed by a gradual decrease and creates a favourable habitat in which more species became established than before regulation. Submerged species that thus became established include *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Najas horrida*, *Potamogeton pectinatus* and *Vallisneria spiralis*, in addition to the alga *Chara globularis* var. *globularis* (Ali, 1987).

According to Springuel and Murphy (1990) and Ali et al. (1995), data collected prior to 1988, on the frequency and standing crop of macrophytes of the littoral zone (0–3 m depth) of Lake Nasser, Aswan Reservoir and River Nile at Aswan show that aquatic plant growth differs significantly ($P < 0.05$), with a downstream trend of increasing production from Lake Nasser through Aswan Reservoir to the river channel below the dam. There were major differences in community dominance in the three systems during 1988–1989. *Najas marina armata* dominated the disturbed zone of Lake Nasser, making up nearly 40% of total standing crop. Other species present were *Chara globularis* var. *globularis*, *Najas horrida* and *Vallisneria spiralis*. In contrast, in both the Aswan Reservoir and River Nile, the dominant species were *Ceratophyllum demersum* (comprising 59–78% of total standing crop) and *Potamogeton crispus* (comprising 15–20% of total standing crop). In the River approximately 25% of total submerged standing crop was of other species, notably *Myriophyllum spicatum* and *Potamogeton perfoliatus*. Ali and Soltan (2006) stated that *M. spicatum* replaced the originally dominant *Najas marina armata* in Lake Nasser.

In the River Nile, there was a seasonal shift in dominance of the submerged community from *Ceratophyllum demersum* during autumn and winter, through *Potamogeton crispus* in early summer, to *P. perfoliatus* in late summer and early autumn. In Aswan Reservoir *Ceratophyllum demersum* showed continuous dominance, reaching its peak standing crop during winter when water levels are lowest. In Lake Nasser, a different community was present, co-dominated by *Najas horrida* and *N. marina armata* (Ali et al., 1995). The altered water regime of the Nile also favours the upstream spread of *Eichhornia crassipes*. In January 1986, two plants found in the River just north of Aswan were removed. No subsequent occurrences have been recorded since (Springuel & Murphy, 1990).

5.2 Lake Manzala

Lake Manzala (31°–31° 30′ N, 31° 50′–32° 15′ E), the largest of the delta lakes of Egypt (Khedr, 1989) opens to the Mediterranean Sea. Its northern section is consequently characterized by saline water. The south has many inlets through which water drains from the surrounding provinces (Port Said, Ismailia, Damietta, Sharkiya and Dakahliya). Also, sewage from Cairo reaches Lake Manzala through Bahr El-Baqar Drain, while freshwater reaches the lake from Damietta branch. Thus, Manzala Lake receives three types of water: freshwater, sea water and drainage water. Abu Al-Izz (1971) states that the flow of drainage water rate to the lake diminishes its salinity to 0.8–1.0%. Manzala Lake was even used for drinking during times of flood. However, since the establishment of the Aswan High Dam (1965) no more floods occur and the regime of the four lakes has changed. In general, they have become fresher, but with a horizontal saline gradient. However, huge amounts of drainage and sewage waters reach the lakes daily, in addition to a small amount of Nile water, with considerable effects on their chemical, physical and biological characteristics.

The vegetation of Lake Manzala has been discussed by Montasir (1937) who recognizes three vegetation types: hydrophytic, halophytic and helophytic. The dominant helophytes were *Cyperus* spp., *Juncus* spp., *Phragmites australis* and *Typha domingensis* and the dominant hydrophytes were *Ceratophyllum demersum*, *Eichhornia crassipes*, *Lemna* spp. and *Potamogeton crispus*. Khedr (1989) reported that, apart from the dominant reeds (*Phragmites australis* and *Typha domingensis*), Lake Manzala is characterized by five dominant hydrophytes: *Eichhornia crassipes*, *Ludwigia stolonifera*, *Najas marina armata*, *Potamogeton pectinatus* and *Ruppia maritima*. Other species include *Alternanthera sessilis*, *Ceratophyllum demersum*, *Cyperus articulatus*, *Echinochloa stagnina*, *Epilobium hirsutum*, *Juncus subulatus*, *Leersia hexandra*, *Lemna gibba*, *L. minor*, *Leptochloa fusca*, *Nymphaea caerulea*, *Panicum repens*, *Paspalidium geminatum*, *Paspalum distichum*, *Persicaria salicifolia*, *P. senegalensis*, *Pistia stratiotes*, *Scirpus litoralis* and *S. maritimus*. Khedr (1997) recognized eleven aquatic communities in Lake Manzala dominated by *Ceratophyllum demersum*, *Najas marina armata*,

Potamogeton crispus and *Ruppia maritima* (submerged), *Eichhornia crassipes*, *Ludwigia stolonifera*, the fern *Azolla filiculoides* (floating), *Echinochloa stagnina*, *Phragmites australis*, *Scirpus maritimus*, and *Typha domingensis* (emergent).

The associate species, in addition to those recorded by Khedr (1989), include *Nymphaea lotus* and *Spirodela polyrhiza* (floating) and *Marsilea aegyptiaca*, *Rorippa palustris* and *Veronica anagallis-aquatica* (emergent). At that time, *Myriophyllum spicatum* had not yet reached Lake Manzala. Nowadays, this submerged plant occasionally grows in the lake (Khedr & Zahran, 1999; Zahran, 2003).

Khedr (1997) obtained a TWINSPAN dendrogram from 100 stands studied, which he split into eight ecologically meaningful groups. In terms of their indicator species, these are:

Group A. Indicated by *Ludwigia stolonifera* and *Azolla filiculoides* characteristic of stagnant freshwater in the western and southern parts of the lake.

Group B. Indicated by *Eichhornia crassipes*, *Echinochloa stagnina* and *Azolla filiculoides*, characteristic of the polluted parts of the lake at the mouth of the drains in the south-west.

Group C. With *Potamogeton pectinatus* as indicator species, more abundant than floating emergent species in all parts of the lake.

Group D. With *Najas marina armata* and *Ceratophyllum demersum* as indicator species. Both are dominant in the west and middle parts of the lake, forming dense monospecific stands that hinder navigation.

Group E. Indicated by *Typha domingensis*, variably distributed but with low abundance close to the sea because, unlike *Phragmites australis*, this species is not highly salt-tolerant.

Group F. With *Scirpus maritimus* as indicator species. In swamps and around islands, particularly in shallow parts.

Group G. Indicated by *Phragmites australis*, the most frequent species in the lake; it occurs in all parts, even if saline and polluted.

Group H. Indicated by *Ruppia maritima*, dominant in the shallow parts and lagoons of the section near the Mediterranean Sea, where salinity is relatively high.

Variations in characteristics within each group are often large. Groups A and B, dominated by floating hydrophytes, occur in areas having the lowest EC values (1.77 and 1.37 mS cm^{-1}, respectively). Groups C and D, dominated by submerged species, are significantly different from most others with respect to depth and dissolved oxygen. Group H, indicated by *Ruppia maritima*, differs from others with respect to EC, CI, pH and PO4-P. It has the highest mean values of these variables: 21.05 mS cm^{-1}, 13.4 g l^{-1}, 9.05 and 3.25 µg l^{-1}, respectively. Group F, indicated by *Scirpus maritimus*, differs from all except Group A with respect to nitrate concentration.

Of all environmental factors, EC seems to control the distribution of aquatic plant communities best. *Ruppia maritima* is restricted to the saline section, whereas

Eichhornia crassipes, *Ludwigia stolonifera*, *Azolla filiculoides* and *Echinochloa stagnina* are dominant in fresh or slightly saline waters. *Phragmites australis*, *Potamogeton pectinatus* and *Scirpus maritimus* are of wide ecological amplitude; they occur in all parts of the lake.

There is evidence for change in the macrophyte communities in recent times. During a 1989 survey, *Ceratophyllum demersum*, *Echinochloa stagnina* and *Scirpus maritimus* were considered as associate species but now they are dominants. *Azolla filiculoides*, formerly absent from the lake (Khedr, 1989), now dominates a well-established community (Khedr, 1997). This fern, introduced to Egypt as a biofertilizer in rice fields, successfully invaded the Nile Delta drainage and irrigation canals (Khedr & EI-Demerdash, 1995). Other recently recorded species are *Marsilea aegyptiaca*, *Rorippa palustris* and *Veronica anagallis-aquatica*.

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