

# FLORISTIC COMPOSITION AND VEGETATION ANALYSIS OF A DELTAIC STRIP ON THE EGYPTIAN MEDITERRANEAN COAST

GALAL, T. M.<sup>1\*</sup> – ALI, E. F.<sup>1</sup> – AL-YASI, H. M.<sup>1</sup> – SAIF, T.<sup>1</sup> – HASSAN, L. M.<sup>2</sup>

<sup>1</sup>*Biology Department, Faculty of Science, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia*

<sup>2</sup>*Botany and Microbiology Department, Faculty of Science, Helwan University, Cairo 11790, Egypt*

*\*Corresponding author*

*e-mail: tarekhelwan@yahoo.com; phone: +966-57-015-9791*

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**Abstract.** Floristic features and vegetation of an Egyptian Deltaic Mediterranean coastal strip were assessed in terms of species composition, habitat characterization, vegetation analysis, and the economic and ecological importance of the recorded species. Four different habitats (salt marshes, sand formations, sand bars, and tidal flats) were surveyed during spring season 2018 through 25 stands (10 x 10 m) representing the different vegetation physiognomy and habitat types of the study area. Thirty-two species including 21 perennials and 11 annuals belonging to 14 families were recorded with a dominance of Asteraceae. Therophytes predominated the other life forms and biregional taxa dominated over the other phytogeographical elements. Five common plant communities were identified after the application of TWINSPAN: *Arthrocnemum macrostachyum-Sarcocornia fruticosa*, *Halocnemum strobilaceum*, *Zygophyllum aegyptium-Ephedra alata*, *Phragmites australis*, and *Sarcocornia fruticosa-Tamarix nilotica* group. Twenty-seven species have medicinal, 26 grazing, 9 fuel and 8 human food uses. On the other hand, 16 species are sand controller and 11 are ruderals. The salt marshes had the highest species diversity, while the tidal flats had the lowest. The present work documented the plant diversity in the study area, which is proposed for urbanization and consequently habitat destruction and biodiversity loss.

**Keywords:** *habitats, sand formations, salt marshes, Nile Delta, flora, multivariate analysis*

## Introduction

The Mediterranean coastal ecosystems are affected by various climates such as hyper-arid, arid, semi-humid and humid (Galal, 2005). They are subjected to extreme conditions and increasing stress due to human impacts such as land use, desertification, and climatic changes (Naveh and Dan, 1973). The Egyptian Mediterranean coastal area provides an evidence of anthropogenic disturbances, which led to habitat loss and habitat fragmentation resulting in diminishing the germplasm reservoir (El-Sadek and Ayyad, 2000). The Mediterranean coast of the Nile Delta is a narrow belt that was greatly affected by the sea and is characterized by villages and summer resorts (Zahran and Willis, 2009). Along the deltaic shoreline, there are sand dunes associated with the eastern banks of the past and present Nile branches (Galal and Fawzy, 2007).

Plant community plays a crucial role in maintaining biodiversity and conserving the environment and consequently sustainable management (Kandi et al., 2011; Shehata and Galal, 2015). Vegetation has been widely used to assess water quality and habitat characterization, in addition to predicting the properties of the neighboring communities (Appelgren and Mattila, 2005). Variation in the natural ecosystem components such as plant communities has led to a gradual variation in the structure, and composition of these communities. Therefore, studying the impact of environmental variables on the

classification and structure of plant communities is of great importance (Jafari et al., 2003). Zegeye et al. (2006) reported that the inter-relationships between community type and soil characteristics resulted in variations of species composition, vegetation, and plant community distribution (Galal et al., 2012). The floristic and plant ecological studies of the Mediterranean deltaic Coast were the main important research topic for several years (e.g., Mashaly, 1987; Khedr, 1989, 1997; Serag, 1991; Shaltout et al., 1995; Khedr and El-Demerdash, 1997; Galal et al., 2012).

The vegetation along the delta coast is characterized by several mechanically distinct and dynamic habitats, which are subjected to destruction by catastrophic changes of storms and floods, which can hamper habitat restoration due to the destruction of parent plants and their seed banks (Khedr and El-Demerdash, 1997). Multivariate analysis of vegetation including classification and ordination techniques was used to assess the ecological relationships between plant communities and their environment (Zhang and Zhang, 2000). In addition, the floristic studies are not only important in order to identify plant species in a certain area, but because plant species are socio-economically significant, where they are utilized as food, shelter, medicine and are extremely important for all living organisms in that area (Shehata and Galal, 2015).

The Egyptian Mediterranean coast contains the most valuable rangeland in the country; however, the uncontrolled cutting, grazing, and farming have induced serious destruction of its natural ecosystems (Shaltout et al., 1995). Due to increasing the Egyptian population, the Deltaic coast is subjected to increased anthropogenic disturbances (Imam and Kosinova, 1972). Moreover, the study area includes characteristic habitats such as salt marshes, tidal flats, sand bars and sand formations (sand hillocks, sand sheets, and baby sand dunes). The study was carried on a proposed area for urban projects, and thus the habitats in this area is subjected to destruction and loss of their biodiversity. Therefore, the main objectives of the present work are the description and analysis of the floristic features and vegetation types of this strip on the deltaic Mediterranean coast in terms of species composition, habitat characterization and plant diversity. In addition, it aims at identifying the goods and services provided by the recorded species. This study will document the plant diversity in such important area, which may be subjected to habitat destruction and biodiversity loss.

## Materials and methods

### *Study area and data collection*

The area of the Nile Delta approximates 22,000 km<sup>2</sup> comprising about 63% of the Egyptian fertile lands (Abu Al-Izz, 1971). Due to the agricultural activities along southlands of years, all soils except those of the northern coast, are man-made and are considered as anthropic variants of the Fluvisols and Gleysols (El-Bayomi, 1999; Galal et al., 2012). The study area (31° 26' - 31° 27' N and 30° 28' - 30° 29' E) was located at the coastal area of the Nile Delta (*Fig. 1*), which lies in the arid zone (Shehata and Galal, 2015). According to the map of UNESCO (1977) for arid regions, the northern Deltaic part belongs to the Mediterranean arid region. Climate is characterized by warm summer (20 to 30 °C) and mild winter (10 to 20 °C). The aridity index, calculated as P/PET, where P and PET are the annual precipitation and potential evapo-transpiration, respectively, ranges between 0.03 and 0.20 (Galal and Fawzy, 2007).

Four different habitats (salt marshes, sand formations, sand bars, and tidal flats; see *Fig. 2*) were surveyed during spring season (March–May) 2018 through 25 stands (10 ×

10 m) representing the apparent variation in the vegetation physiognomy in about 1 km<sup>2</sup> estimated area. Stands were distributed as six in each of the four habitats except sand formations (7 stands). At each stand, a list of species, the dominant species and visual estimate of the total cover and the cover of each species (%) were recorded. Identification and nomenclature of the recorded species were carried out according to Täckholm (1974) and Boulos (1999, 2000, 2002, 2005, 2009). The life form spectra of the recorded species were determined according to Raunkiaer scheme (Raunkiaer, 1937), while the global phytogeographical distribution was identified from Täckholm (1974), Zohary (1973) and Boulos (1999, 2000, 2002, 2005, 2009).

The environmental goods and economic services of the recorded species were determined based on-site observations, collected information from inhabitants and from the literature (e.g., Täckholm, 1974; El-Kady, 1980; Zohary, 1966, 1972; Feinbrun-Dothan, 1978, 1986; Danin, 1983; Boulos, 1983, 1989; Belal and Springuel, 1996; Shaltout, 1997). Economic services were classified into five categories: grazing, fuel, medicinal, edible, and other uses including furniture, making mats, chairs, and ornamental). The aspects of environmental importance include segetals, ruderals, sand controllers (i.e., sand binder, hummock, and wind breaks), bank retainers, shaders, parasites, poisoners, invaders, weed controllers, nitrogen fixers and water purificators.

### Data analysis

Multivariate analysis of the vegetation using Two-way indicator species analysis (TWINSPAN) and Detrended Correspondence Analysis (DCA) as classification and ordination techniques, respectively were applied to the matrix of 32 species in 25 stands in the Deltaic coast (Hill, 1979a, b). Plant diversity was assessed by determining species richness for each vegetation group resulted from the multivariate analysis, which was calculated as the average number of species per sampling plot. Shannon-Weaver index denoting the equitability or relative evenness was expressed as:

$$\hat{H} = -\sum_{i=1}^S P_i (\log P_i) \quad (\text{Eq.1})$$

where S is the total number of species and P<sub>i</sub> is the relative cover of the i<sup>th</sup> species. In addition, Simpson index was used to estimate the relative concentration of dominance, which is calculated as:

$$D = 1/C \text{ and } C = \sum_{i=1}^S P_i^2 \quad (\text{Eq.2})$$

where S is the total number of species and P<sub>i</sub> is the relative importance value (relative cover) of species (Magurran, 1988).

### Results

Thirty-two species including 21 perennials and 11 annuals related to 14 families were recorded in the different habitats in the area under investigation (Table 1). Asteraceae family was the dominant (8 species), followed by Chenopodiaceae (6 species) and Poaceae (5 species). Eighteen species were recorded as natural plants (e.g., *Ephedra alata*, *Zygophyllum aegyptium* and *Echinops spinosus*), while 13 species were terrestrial weeds (e.g., *Lotus glaber*, *Senecio vulgaris* and *Soncuhs oleraceous*), and one wetland weed (*Phragmites australis*). The life forms of the recorded species showed the

predominance of therophytes (34% of the total species) over chamaephytes (22%), geophytes-helophytes (19%), hemicryptophytes (13%), phanerophytes (9%) and parasites (3%) (Fig. 3). The chorological analysis of the recorded species showed that the biregional taxa (41%) dominated over the pluriregional (31%) and monoregional (16%), while cosmopolitan elements were represented by 12% (Fig. 4).

### **Habitat characterization**

The main recognized habitats in the study area are salt marshes, tidal flats, sand bars, and sand formations (Table 1). The characteristics of these habitats are described as follows:

#### *Salt marshes (6 stands)*

The coastal salt marshes are lowlands covered with water during the tide of the Mediterranean Sea with high salinity associated with high evaporation rate. They were covered with halophytes, which are salt tolerant plants of high potential for collecting and fixing soil deposits. Their clay deposits vary between 60 and 80%. Sixteen species were recorded along this habitat, the dominant of which are: *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum*, *Sarcocornia fruticosa* and *Zygophyllum aegyptium*, while the common associated species are: *Ephedra alata*, *Senecio glaucus* subsp. *coronopifolius* and *Reichardia tingitana*. The species diversity in this habitat (species richness) was 5.3 species/stand.

#### *Tidal flats (6 stands)*

These flats extend along the shores, and mainly they are submerged by the sea water during the tide, but during the ebb-tide water retreats again. They were devoid of plants as their surface was composed of homogeneous soil granules. Tidal flats are consisted of friable sands produced due to the erosion of the shore through the effect of waves. Thirteen species were recorded in these sand formations, the dominant of which: *A. macrostachyum*, *S. glaucus* subsp. *coronopifolius* and *Z. aegyptium*. *Cistanche phelypaea*, *Rumex pictus* and *Cakile maritima* are common associated species. The species diversity in this habitat (species richness) was 3.4 species/stand.

#### *Sand bars (6 stands)*

The study site contains a small sand bar (dunes) 2-3 m high. The merging of hillocks led to the formation of large dunes covered with dense vegetation. These dunes of the marine bar were affected by sand deposition. Nine species were recorded along this habitat, of them: *Ephedra alata*, *Salsola kali*, *Z. aegyptium* and *A. macrostachyum*. The species diversity in this habitat was 3.9 species/stand.

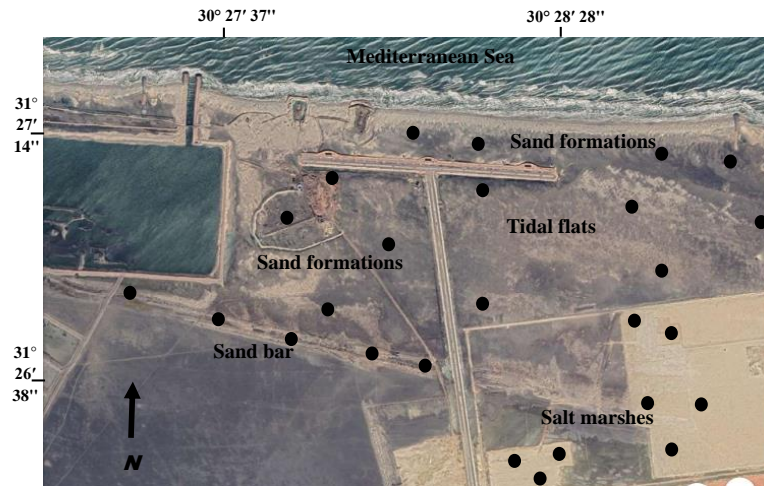
#### *Sand formations (7 stands)*

The marine bar of the study area was covered with three types of sand formations: sand sheets (or flats), baby sand dunes and hillocks, which were covered by some herbs and shrubs like *Tamarix nilotica*, which help in fixing these hillocks. Twenty-four species were recorded in the different sand formations of the study area, which includes: *Z. aegyptium*, *T. nilotica* and *Imperata cylindrica*. The species diversity in this habitat was 3.4 species/stand.

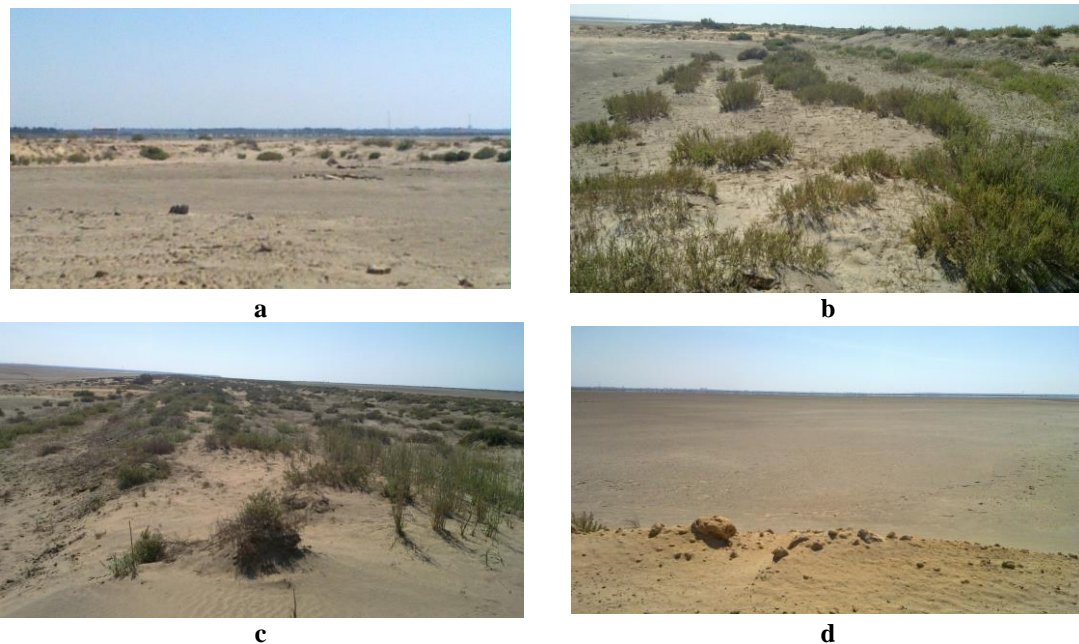
**Table 1.** Floristic categories and life forms of the species recorded in the study area

Species	State	Habit	Life form	Floristic category	Habitat			
					SM	SB	TF	SF
<b>Ephedraceae</b>								
<i>Ephedra alata</i> Decne.	NP	Perennial	Ch	SA-AR	1	1	1	1
<b>Polygonaceae</b>								
<i>Rumex pictus</i> Forssk.	NP	Annual	Th	ME+SA-AR			1	
<b>Chenopodiaceae</b>								
<i>Anabasis articulata</i> (Forssk.) Moq.	NP	Perennial	Ch	SA-AR	1			
<i>Arthrocnemum macrostachyum</i> (Moris.) K. Koch	NP	Perennial	Ch	ME+SA-AR	1	1	1	1
<i>Bassia indica</i> (Wiegth) A. J. Scott	TW	Annual	Th	IR-TR+S-Z				1
<i>Halocnemum strobilaceum</i> (Pall.) M. Bieb.	NP	Perennial	Ch	ME+SA-AR+IR-TR	1		1	
<i>Salsola kali</i> L.	NP	Annual	Th	COSM	1	1		
<i>Sarcocornia fruticosa</i> (L.) A. J. Scott.	NP	Perennial	Ch	SA-AR	1	1	1	1
<b>Brassicaceae</b>								
<i>Cakile maritima</i> Scop.	NP	Annual	Th	ME+IR-TR			1	
<b>Fabaceae</b>								
<i>Lotus glaber</i> Mill.	TW	Perennial	H	ME+ER-SR+IR-TR	1			1
<b>Zygophyllaceae</b>								
<i>Zygophyllum aegyptium</i> L.f.	NP	Perennial	Ch	ME+SA-AR	1	1	1	1
<b>Tamaricaceae</b>								
<i>Tamarix nilotica</i> (Ehrenb.) Bunge	NP	Perennial	Ph	SA-AR+S-Z	1		1	1
<b>Asclepiadaceae</b>								
<i>Cynanchum acutum</i> L.	TW	Perennial	Ph	ME+IR-TR				1
<b>Orobanchaceae</b>								
<i>Cistanche phelypaea</i> (L.) Cout.	NP	Perennial	P	ME+SA-AR			1	1
<b>Asteraceae</b>								
<i>Atractylis carduus</i> (Forssk.) C. Chr.	NP	Perennial	Ch	SA-AR	1			1
<i>Echinops spinosus</i> L.	NP	Perennial	H	ME+SA-AR				1
<i>Iflago spicata</i> (Forssk.) Sch.Bip.	NP	Annual	Th	ME+SA-AR		1		
<i>Launaea fragilis</i> (Asso) Pau	NP	Perennial	H	SA-AR	1			
<i>Reichardia tingitana</i> (L.) Roth	NP	Annual	Th	IR-TR+SA-AR	1			1
<i>Senecio glaucus</i> subsp. <i>coronopifolius</i> (Maire) C. Alexander	TW	Annual	Th	ME+SA-AR+IR-TR	1	1	1	1
<i>Senecio vulgaris</i> L.	TW	Annual	Th	ME+ER-SR+IR-TR		1		
<i>Silybum marianum</i> (L.) Gaertn.	TW	Perennial	H	ME+ER-SR+IR-TR				1
<i>Sonchu oleraceus</i> L.	TW	Annual	Th	COSM	1			1
<b>Juncaceae</b>								
<i>Juncus acutus</i> L.	TW	Perennial	GH	ME+ER-SR+IR-TR				1
<i>Juncus rigidus</i> Desf.	TW	Perennial	GH	ME+SA-AR+IR-TR				1
<b>Poaceae</b>								
<i>Cutandia memphitica</i> (Spreng.) K. Richt.	TW	Annual	Th	ME+SA-AR+IR-TR	1		1	1
<i>Cynodon dactylon</i> (L.) Pers.	TW	Perennial	GH	COSM				1
<i>Imperata cylindrica</i> (L.) Raeusch.	TW	Perennial	GH	ME+SA-AR+IR-TR				1
<i>Phragmites australis</i> (Cav.) Trin. ex Steud	AW	Perennial	GH	COSM	1	1	1	1
<i>Schismus barbatus</i> (L.) Thell.	NP	Annual	Th	ME+SA-AR+IR-TR			1	1
<b>Palmae</b>								
<i>Phoenix dactylifera</i> L.	NP	Perennial	Ph	SA-AR+S-Z				1
<b>Cyperaceae</b>								
<i>Cyperus capitatus</i> Vand.	TW	Perennial	GH	ME+GC				1

Ph: phanerophytes, Ch: chamaephytes, H: hemicryptophytes, GH: geophytes-helophytes, Th: therophytes and P: parasites. The floristic categories are ME: Mediterranean, COSM: Cosmopolitan, SA-AR: Saharo-Arabian, SU-ZA: Sudano-Zambezian, ER-SR: Euro-Sibarian, IR-TR: Irano-Turanian, SM: salt marshes, SB: sand bar, TF: tidal flats, SF: sand formation, NP: natural plants, TW: terrestrial weeds and AW: wetland weed



**Figure 1.** Location map of the study area showing the sampled sites (31° 26' - 31° 27' N and 30° 28' - 30° 29' E). Source: Google earth on 19 April 2018



**Figure 2.** (a) Vegetated sand bar, (b) salt marshes with halophytes, (c) sand formations with dense vegetation, (d) tidal flats with very sparse vegetation

### **Environmental and economic importance**

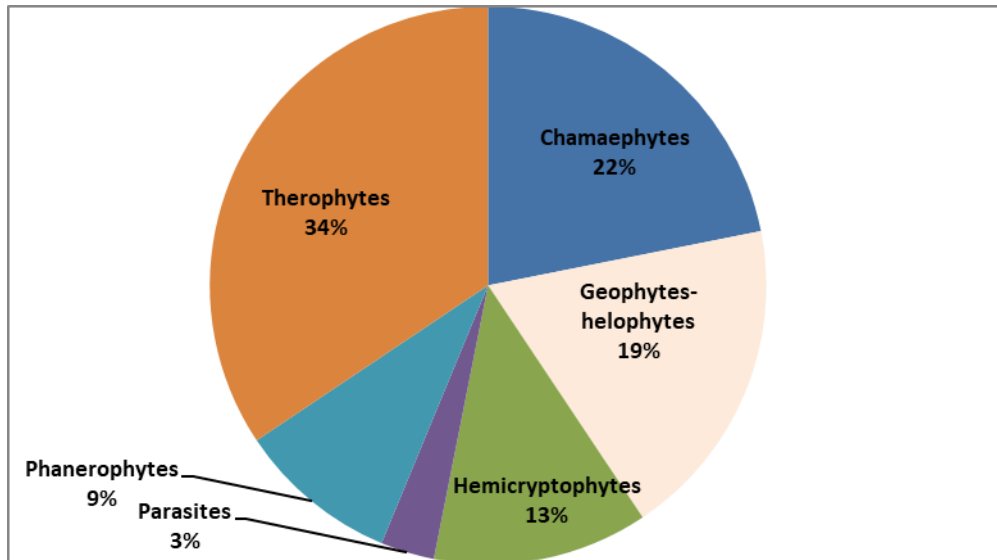
Twenty-nine species in the study area have at least one aspect of the environmental importance (Table 2). Six species have three environmental importance, of which: *T. nilotica* (shaders, ruderals, and sand controllers), *A. macrostachyum* (bank retainer, weed controller and sand controller) and *P. australis* (ruderal, invader and water purificator). A total of 11 species have two environmental importance such as *Anabasis articulata* (shader and sand controller) and *C. phelypaea* (sand controller and parasite). A total of 12 species have only one importance such as *Juncus rigidus* (ruderal) and *Z. aegyptium* (sand controller).

**Table 2.** Environmental and economic values of the recorded species in the Deltaic strip of the study area

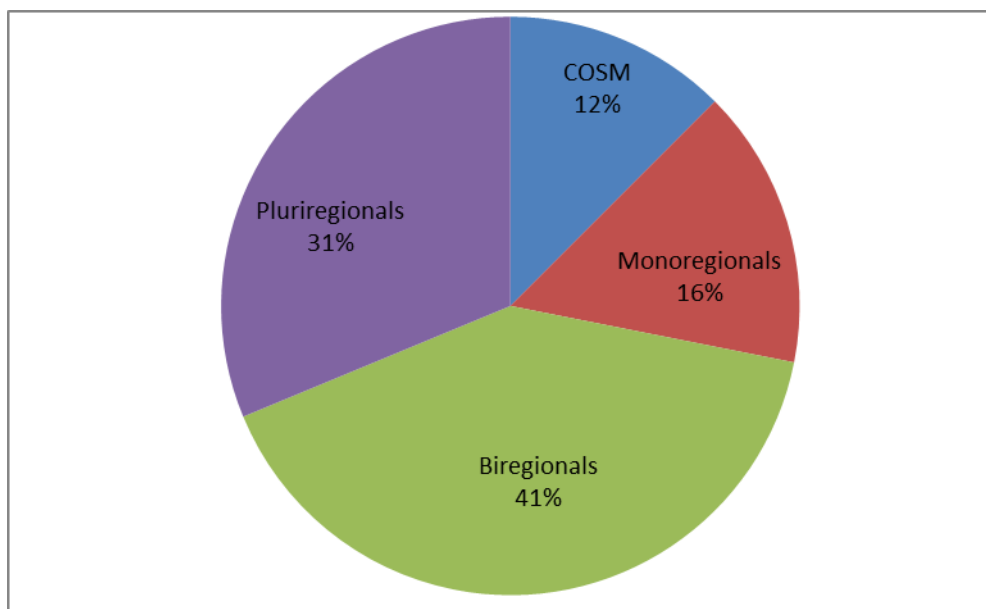
Species	Environmental importance											Economic importance						
	Br	Sh	Ru	Sw	In	Wc	Sc	Wp	Pa	OT	Total	GR	FU	ME	HF	TI	OT	EI
<i>Anabasis articulata</i>		+					+				2	+	+	+				3
<i>Arthrocnemum macrostachyum</i>	+					+	+				3	+	+	+				3
<i>Atractylis carduus</i>							+			+	2	+		+				2
<i>Bassia indica</i>			+								1	+	+	+				3
<i>Cakile maritima</i>		+					+			+	3	+		+			+	3
<i>Cistanche phelypaea</i>							+		+		2			+				1
<i>Cutandia memphitica</i>							+				1	+						1
<i>Cynanchum acutum</i>			+								1							
<i>Cynodon dactylon</i>				+			+				2	+	+	+				3
<i>Echinops spinosus</i>							+			+	2	+	+	+	+			4
<i>Ephedra alata</i>		+					+			+	3			+				1
<i>Halocnemum strobilaceum</i>	+						+				2	+		+				2
<i>Iflago spicata</i>										+	1	+		+				2
<i>Imperata cylindrica</i>	+		+			+					3	+		+			+	3
<i>Juncus acutus</i>			+				+				2	+		+			+	3
<i>Juncus rigidus</i>			+								1	+		+			+	3
<i>Launaea fragilis</i>												+		+				2
<i>Lotus glaber</i>			+								1	+		+				2
<i>Phoenix dactylifera</i>												+	+	+	+	+	+	6
<i>Phragmites australis</i>			+		+			+			3	+	+	+	+		+	5
<i>Reichardia tingitana</i>							+			+	2	+		+				2
<i>Rumex pictus</i>			+								1	+		+	+			3
<i>Salsola kali</i>			+								1			+	+		+	3
<i>Sarcocornia fruticosa</i>							+			+	2	+	+	+				3
<i>Schismus barbatus</i>				+							1	+		+				2
<i>Senecio glaucus</i> subsp. <i>coronopifolius</i>				+							1				+			1
<i>Senecio vulgaris</i>							+			+	2	+		+				2
<i>Silybum marianum</i>			+			+					2	+		+	+			3
<i>Sonchus oleraceus</i>				+							1	+			+			2
<i>Tamarix nilotica</i>		+	+				+				3	+	+	+				3
<i>Zygophyllum aegyptium</i>							+				1	+		+			+	3
<b>Total</b>	3	3	11	4	1	3	16	1	1	8		26	9	27	8	1	8	

Br: bank retainer, FU: fuel, GR: grazing, HF: human food, In: water invaders, ME: medicinal use, Nf: nitrogen fixers, OT: other uses, Pa: parasites, Po: poisoners, Ru: ruderals, Sc: sand controllers, Sh: shaders, Sw: segetal weed, TI: timber Wc: weed controllers, and Wp: water purificators. EI: economic index (out of 6)

Thirty species have at least one potential or actual economic uses (Table 2). *Phoenix dactylifera* has six uses and *Phragmites australis* has five uses. *Echinops spinosus* has four uses. A total of 14 species have three uses such as *Silybum marianum* (grazing, medicinal and human food uses) and *A. macrostachyum* and *S. fruticosa* (grazing, fuel and medicinal uses). A total of 9 species have two uses such as *H. strobilaceum* and *R. tingitana* (grazing and medicinal uses) and *Sonchus oleraceus* (grazing and human food uses). Four species have only on use such as *Cutandia memphitica* (grazing), *C. phelypaea* (medicinal use) *S. glaucus* subsp. *coronopifolius* (human food).



**Figure 3.** Life forms of the recorded species in the Deltaic coastal strip under study



**Figure 4.** Chorological elements of the recorded species in the Deltaic coastal strip under study

### Vegetation analysis

The application of multivariate analysis on the cover of 32 species in 25 sampled stands produced five vegetation groups (Figs. 5 and 6). These vegetation groups are named based on the first and occasionally the second dominant species (Table 3):

- Sarcocornia fruticosa*- *Tamarix nilotica* group: This group included only two species, which dominated the sand formations.
- Arthrocnemum macrostachyum*-*Zygophyllum aegyptium* group: This group comprised seven species recorded in three stands. It characterizes the salt



- marsh habitat. *Ephedra alata*, *Phragmites australis* and *Senecio glaucus* subsp. *coronopifolius* are the common associated species.
- c. *Halocnemum strobilaceum* group: Ten species recorded in six stands represented this group. It was commonly represented in the sand formations habitat. The most common species are: *Senecio glaucus* subsp. *coronopifolius*, *Salsola kali*, *Rumex pictus* and *Cakile maritima*.
- d. *Zygophyllum aegyptium*-*Ephedra alata* group: This group was represented by 17 species monitored in 13 stands. It was dominant in the salt marsh and sand bar habitats. The common associated species are: *Senecio glaucus* subsp. *coronopifolius*, *Arthrocnemum macrostachyum*, *Salsola kali* and *Phragmites australis*.
- e. *E. Phragmites australis* group: Five species constituted this group and are recorded in two stands, which dominated the sand bar habitat in the study site. *Salsola kali*, *Sarcocornia fruticosa*, *Senecio glaucus* subsp. *coronopifolius* and *Zygophyllum aegyptium* were the common associates.

**Table 3.** Presence percentage of the recorded species in the 5 vegetation groups produced from TWINSPAN

Vegetation group	A	B	C	D	E
<i>Anabasis articulata</i>				7.7	
<i>Arthrocnemum macrostachyum</i>		66.6	1	53.8	
<i>Atractylis carduus</i>				7.7	
<i>Cakile maritima</i>			16.7		
<i>Cistanche phelypaea</i>				7.7	
<i>Cutandia dichotoma</i>			16.7		
<i>Ephedra alata</i>		33.3		84.6	
<i>Halocnemum strobilaceum</i>		1	66.7	7.7	
<i>Iflago spicata</i>				7.7	
<i>Launaea fragilis</i>				23.1	
<i>Lotus glaber</i>				7.7	
<i>Senecio vulgaris</i>				7.7	
<i>Phragmites australis</i>		33.3		23.1	100
<i>Reichardia tingitana</i>				7.7	
<i>Rumex pictus</i>			16.7		
<i>Salsola kali</i>			16.7	46.2	50
<i>Sarcocornia fruticosa</i>	100	33.3	5	7.7	50
<i>Schismus barbatus</i>					
<i>Senecio glaucus</i> subsp. <i>coronopifolius</i>		33.3	33.3	61.5	50
<i>Soncuhs oleraceous</i>				7.7	
<i>Tamarix nilotica</i>	100		16.7		
<i>Zygophyllum aegyptium</i>		66.7	5	100	50

### Species diversity

Species diversity of the recorded species along the study habitats of the Deltaic strip of the study area (Table 4) showed that vegetation group (D) was the most diverse, which had the highest number of species (17 species), species richness (4.8 species

stand<sup>-1</sup>), turn over (3.5), relative evenness (2.4) and relative concentration of dominance (8.2). On the other side, vegetation group (A) was the least diverse with the lowest number of species (2 species), species richness (2.0 species stand<sup>-1</sup>), turn over (1.0), relative evenness (0.7) and relative concentration of dominance (2.0).

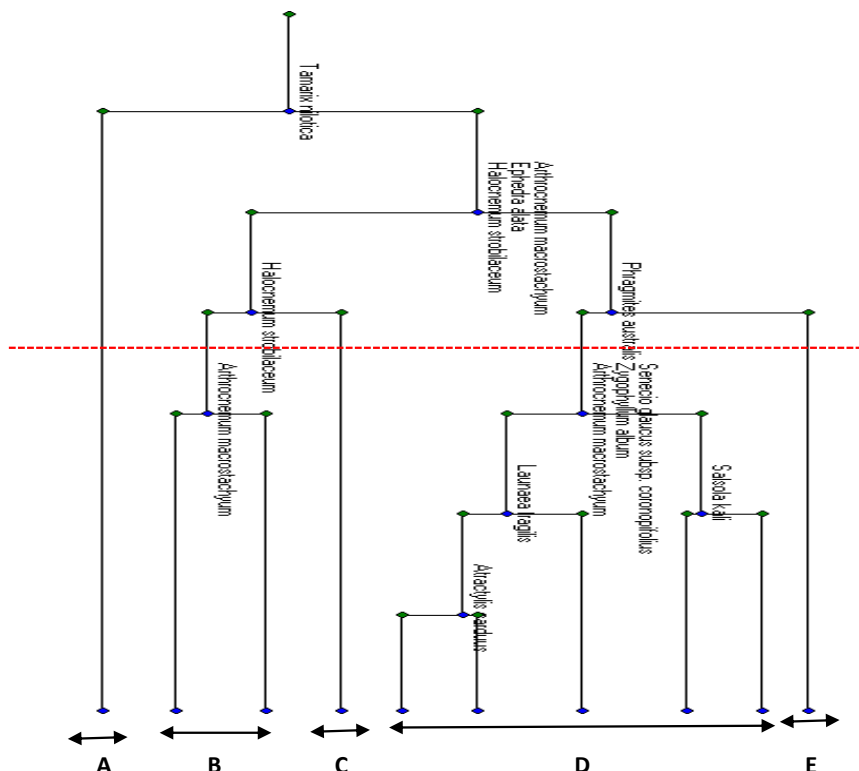


Figure 5. The dendrogram of the 5 vegetation groups produced from TWINSpan classification

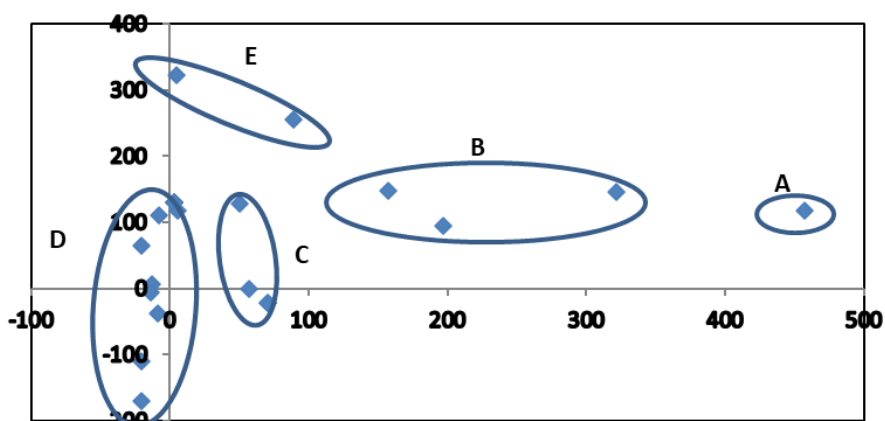


Figure 6. DCA-ordination of the 5 vegetation groups identified from TWINSpan

## Discussion

The study area comprised 32 species (21 perennials and 11 annuals) of vascular plants belonging to 14 families, while Galal and Fawzy (2007) recorded 69 species and Shaltout and Al-Sodany (2000) recorded 197 species in the sand dunes and Burullus

wetland, respectively at Northern Nile Delta. This low number of species may be attributed to the smaller sampled area and the survey time. *Zygophyllum aegyptium*, which predominates the sand formations of the deltaic Mediterranean coast was recorded in the present study (Zahran and Willis, 2009) but was not recorded in the black sand dunes (Galal and Fawzy, 2007). Species composition of the study area varied markedly from that of the western Mediterranean coast, and this may be attributed to the difference in the climatic conditions and the soil chemical composition. Whereas the floristic taxa of the Western Mediterranean coastal belt were characterized with favourable climatic conditions compared with those of the other parts of Egypt (Zahran and Willis, 2009). Moreover, the number of species in the present study was lower figure than that recorded by Scholten et al. (1981), and Shaltout and Khalil (2005) on the Deltaic coast and this may be due to the smaller and less diverse habitats of the study area. Asteraceae, Chenopodiaceae, Brassicaceae, and poaceae, constituting most floristic elements of the study area, were in a harmony with Shehata and Galal (2015) in the Nile Delta, Galal et al. (2012) in the Northern Deltaic Lakes, Shalaby (1995) in Kafr El-Sheikh, Abd El-Fattah et al. (1992) in the fallow-lands of Zagazig city, and Mashaly (1987) in Dakahlia-Damietta coastal region.

**Table 4.** Diversity indices of the recorded species in the northern Nile Delta

Vegetation group	No. of stands	Total species	Species richness	Species turnover	Shannon index	Simpson index
A	<u>1</u>	<u>2</u>	<u>2.0</u>	<u>1.0</u>	<u>0.7</u>	<u>2.0</u>
B	3	7	3.7	1.9	1.7	5.4
C	6	10	3.8	2.6	1.9	5.6
D	<u>13</u>	<u>17</u>	<u>4.8</u>	<u>3.5</u>	<u>2.4</u>	<u>8.2</u>
E	2	5	3.0	1.7	1.6	4.6

Plant life forms are important in assessing the vegetation response to the environmental variations (Al-Yasi et al., 2019; Galal et al., 2021). The Mediterranean basin was considered a “therophyte climate” due to the high percentage of this life form in most Mediterranean floras (Raven, 1971). Therophytes were the dominant life forms, followed by chamaephytes, geophytes-helophytes, hemicryptophytes, phanerophytes, and parasites. Shehata and Galal (2015) and Heneidy and Bidak (2001) attributed the predominance of therophytes over the other life forms to the hyper-aridity, topography, and biotic effects in the study area. The chorology of the recorded species revealed the dominance of bi-regional taxa over the pluriregional, cosmopolitan and monoregional elements in accordance with Galal and Fawzy (2007) in their study on the sand dunes of the Deltaic coast. According to Hamed et al. (2018) and Alsherif (2019), the inter-regional species (bi-, tri- and pluri-regionals) dominated over mono-regionals, which may be due to the presence of interzonal variations, such as psammo-, halo- and hydrophilous habitats. According to the IUCN red data list, four recorded species (*Ephedra alata*, *Silybum marianum*, *Juncus acutus* and *J. rigidus*) were evaluated as least concern.

The classification of the vegetation of the study area by TWINSpan led to identify 5 vegetation groups, which were separated along the DCA ordination axes reflecting moisture gradient. These vegetation groups inhabited the different habitats of the study area along moisture and salinity gradients. Similar results were reported by Galal and

Fawzy (2007) and Shaltout and Khalil (2005) on the northern Mediterranean Coast. In addition, the recorded communities are mostly related to the communities described by Zahran et al. (1990) on the Mediterranean deltaic coast. The diversity of plant communities generated from multivariate analysis indicated that the communities that represent the sand bar are more diverse than the other communities, and this may be attributed to the high number of species transferred by the wind action (Zahran et al., 1990). In addition, the high plant diversity of such habitat is related to the increase in annuals during spring as reported by El-Kady et al. (2000) and Galal and Fawzy (2007).

## Conclusion

Thirty-two species were recorded in the different habitats in the area under investigation. All recorded species are common in the different habitats along the Mediterranean coast. The vegetation of the study area is characterized by lower number of species compared with the number of the same habitats along the Mediterranean coast. The salt marsh habitat had the highest species diversity, while the tidal flats had the lowest. The common plant communities are: *Arthrocnemum macrostachyum*, *Sarcocornia fruticosa* and *Halocnemum strobilaceum* are dominant in salt marshes; *Ephedra alata*, *Zygophyllum aegyptium*, *Senecio glaucus* subsp. *coronopifolius* and *Salsola kali* are dominant in sand bar and sand formations. Twenty-seven species have medicinal, 26 grazing, 9 fuel and 8 human food uses. On the other hand, 16 species are sand controller and 11 are ruderals. Further study on the effect of environmental factors on the vegetation was required.

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