Mediterranean Sand Dunes in Egypt: Threatened Habitat and Endangered Flora

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Abstract: The present study aims at assessing the flora and vegetation of the Western Mediterranean sand dunes, a threatened habitat in North Egypt. It aims also to evaluate the threats upon species and habitats in the study area. One hundred and ten species were recorded, therophytes were the most represented life form followed by chamaephytes, while parasites were the least. one endemic (*Zygophyllum album*) and four near endemics (*Centaurea alexandrina*, *Centaurea glomerata*, *Onopordum alexandrinum* and *Plantago crypsoides*) were recorded, in addition to 9 species of unique occurrence to this habitat in the study area. Two trends of multivariate analysis (TWINSPAN and DCA) were applied to the floristic composition of 124 stands and led to identify 24 vegetation groups at level six and 8 vegetation groups at level three: group **I** (*Echinops spinosus* - *Launaea fragilis* subsp. *fragilis*) characterized the partially stabilized dunes, groups **II** (*Echinops spinosus* - *Allium erdelii*) and **V** (*Echinops spinosus* - *Thymelaea hirsuta*) the stabilized dunes, group **III** (*Ammophila arenaria* - *Ononis vaginalis*) the embryonic dunes and group **IV** (*Crucianella maritima* - *Erodium crassifolium*) the coastal ridges. In addition, group **VI** (*Launaea nudicaulis* - *Thymelaea hirsuta*) characterized the embryonic and stabilized dunes as well as the salt affected parts, group **VII** (*Lygeum spartum* - *Nitraria retusa*) the partially stabilized dunes, salt affected parts and coastal ridges and group **VIII** (*Ammophila arenaria* -*Crucianella maritima*) the embryonic and stabilized dunes and the coastal ridges. Ninety two species suffer from at least one type of threats, 66 species suffer from habitat loss due to the construction of summer resorts, 64 species from over-collecting and over-cutting to be used for medicinal and fuel purposes, while only 10 species suffer from disturbance by cars or trampling. On the other hand, 10 species suffer from one type of threats, 29 species from two threats, 31 species from three threats, while only three species from six types of threats.

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1. Introduction

Egypt has attracted the attention of explorers and botanists due to its unique position as a midway between Africa and Asia, with its long coasts of the Mediterranean Sea in the north (c. 970 km) and the Red Sea in the east (c. 1100 km). Egypt has diverse habitats with micro-climates that host many plant species and communities. Terrestrial and aquatic habitats include desert areas, mountains, plains, slopes, dunes, salt marshes, wetlands and fresh and marine waters (Shaltout and Al-Sodany, 2002). Egyptian Mediterranean coastal region provides a clear example of anthropogenic disturbance that resulted in habitat loss and fragmentation leading to diminish the germplasm reservoir (Ayyad and Le Floc'h, 1983 and El-Sadek and Ayyad, 2000). The major part of this region is bordered by sand dunes of different natures and type (Batanouny 1999). Unfortunately; about 75 % of these sand dunes has been destroyed due to the continuous construction of summer resorts and other human activities (Shaltout and Ahmed, 2012).

Threats to the world's plant diversity continue to increase as a result of human activities (Raven 2006), which severely impacted the plant population, particularly the rare ones. Threats include: residential, commercial development and tourism, commercial agriculture, wood plantations, logging and wood extraction, mining and transportation, pollution, human disturbances such as war and recreational activities, harvesting for food and medicine and competition with invasive species (Burgman *et al.,* 2007). Among the well-documented threats in Egypt are habitat loss, invasive species, over-collection, climate change and atmospheric nitrogen depositions (Shaltout *et al.,* 2009). The present study aims to assess the flora and vegetation of the coastal sand dunes, a threatened habitat in the Western Mediterranean region of Egypt. It aims also to evaluate the threats upon species and habitats in the study area. This study may help people how to select and use plants taking into account the coastal stabilization and habitat restoration.

2. Study Area

The study area extends along 500 km from Alexandria in the east to Sallum in the west (Figure 1).

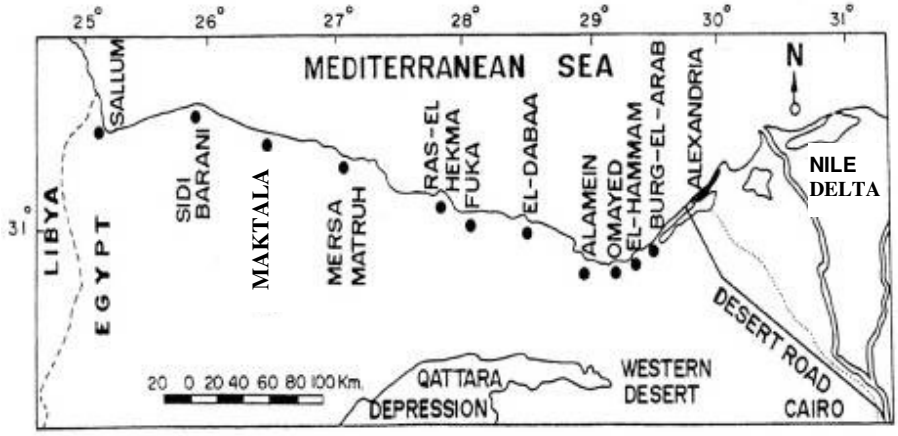

Figure 1. Map of the Mediterranean region of Egypt indicating the study sites (•).

The belt of sand dunes develops south of the shore; the dunes have an uneven surface, creating many microhabitats that support different types of plant growth. In general, the distribution of plant communities in the north western coastal region is controlled by: the topographic location, origin and nature of parent material and the intensity of human activities (Ayyad and Ghabbour, 1986). These dunes are composed mainly of snow white oolitic calcareous grains and distinguished into four minor habitats depending on the shore winds which are predominantly north-western: 1- active embryonic dunes lying close to the shore where the erosion and deposition taking place, 2- partially stabilized dunes, 3- stabilized dunes where almost no erosion or deposition taking place and 4- shallow substrates of the coastal ridge (Ayyad, 1973 and Batanouny, 1999).

The soils of the western coastal region of Egypt are young and essentially alluvial. Diagnostic horizons are characteristically absent (Harga, 1967). They are derived from two main sources: 1- Mariut tableland (inland plateau) composed essentially of limestone alternating with strata of limestone and 2- shale and beach deposits composed of calcareous oolitic grains. Soils of the coastal ridge and dunes are loose or moderately consolidated calcareous grains of sand dimensions. They consist of 90 % of $CaCO_3$, and are almost free from salts. On the slopes, the soils are pale brown and loamy in texture; while on the upper and middle parts, they are mixed with cobbles and gravels of various sizes throughout the profile (Rashad, 2002).

The climate of the area is arid, with an average annual rainfall ranging from about 80 - 150 mm. Most of the rain falls during winter (60 % or more from November to February), and the summer is virtually dry. Rainfall of torrential nature may be expected: values up to 120 mm in one day were recorded (Shaltout, 1992). Sometimes the heavy rainfall causes floods which carry large amounts of soil, causing gully erosion in many parts of the plain south of the dune belt. Part of this soil may reach the southern fringes of the coastal sand dunes (Batanouny, 1999). January is the coldest month, while August is the hottest. The lowest mean minimum air temperature varies between 7.3 °C at El-Dabaa in January and 23.5 °C at Dekheila in August. The highest mean maximum air temperature varies between 17.1 °C at Ras El-Hekma in January and 30.6 °C at Alexandria in August. The relative humidity varies between 54 % at Sallum in March and 80 % at Ras El-Hekma in June and July. In winter months, the evaporation varies between 3.8 mm day^{-1} in December at Alexandria and 7.3 mm/day in February at Mersa Matruh. In summer months, the records vary between 5.6 mm/day in July at Alexandria and 9.7 mm day^{-1} in June at Sallum (Batanouny, 1999).

3. Material and Methods

3.1. Field study

Thirty field trips were conducted to many locations from west of Alexandria till Sallum during the period from spring 2010 to spring 2011. One hundred and twenty four stands (each of about 20 x 20 m) were sampled to represent the variation in the vegetation of the study area . In each stand, floristic records were carried out; based on the presence/absence of species. Life forms of the recorded species were identified following the system of Raunkiaer (1937). The actual and relative number of species belonging to each life form (i.e. biological spectrum) were calculated. Endemics, which are usually rare and restricted to rather small geographical regions, were gathered from Boulos (2009); while the unique species were gathered from Ahmed (2009).

3.2. Types of threats

Threats are the direct and indirect causes for ecosystem degradation and species impoverishment. Six types of threat were identified in the study area (Seif El-Nasr and Bidak, 2005a): 1- browsing and over grazing, 2- over-collecting and over-cutting, 3- clearance for agriculture, 4- Construction of summer resorts (industrial/urban growth, coastal development), 5- disturbance by cars or trampling, and 6- mining and quarrying.

3.3. Statistical analysis

Two trends of multivariate analysis were applied in the present study: two-way indicator species analysis (TWINSPAN), as a classification technique (Hill, 1979a), and detrended correspondence analysis (DCA), as an ordination one (Hill, 1979b). Both trends have their merits in helping to understand the vegetation and environmental phenomena. Some of the species diversity indices were calculated for the micro-habitats and vegetation groups. Such indices could be considered as macroscopic properties of communities encompassing both the number of species present and the distribution of the individuals between them (De Jong, 1975). Species richness (alpha-diversity) for each micro-habitat and vegetation group was calculated as the average number of species per stand. On the other hand, species turnover (beta-diversity) was calculated as the total number of species in each micro-habitat or vegetation group divided by its species richness (Magurran, 1988).

4. Results

One-hundred and ten species were recorded: 71 perennials and 39 annuals. According to the habitat variation, 38 species were recorded in the embryonic dunes (e.g. *Ammophila arenaria* (L.) Link and *Arisarum vulgare* Targ. Tozz); 50 species in the partly stabilized dunes (e.g. *Echinops spinosus* L. and *Bupleurum semicompositum* L.), 71 in the stabilized dunes (e.g. *Echinops spinosus* and *Devera tortuosus* (Desf.) DC.), 42 in the shallow substrate of coastal ridge (e.g. *Pancratium maritimum* L., *Crucianella maritima* L. and *Scorzonera undulata* Vahl) and 40 in the ecotonic zone between the dunes and salt marshes (e.g. *Zygophyllum album* L. and *Thymelaea hirsuta* (L.) Endl.). The stabilized dunes had the highest species richness (16.8 species stand^{-1}), while the embryonic dunes had the lowest (8.6 species stand^{-1}). On the other hand, the highest value of species turnover (4.4) was that of the embryonic dunes, while the lowest (3.5) was that of shallow substrate of coastal ridge (Figure 2). Therophytes were the most represented life form (39 species = 35.5% of the total species), followed by chamaephytes (29 species = 26.4 % of the total species) and hemicryptophyte (22 species = 20%). On the other hand, parasites were represented by only one species (*Orobanche crenata* Forssk.) (Figure 3). one endemic (*Zygophyllum album*) and 4 near endemics (*Centaurea alexandrina* Delile, *Centaurea glomerata* Vahl, *Onopordum alexandrinum* Boiss and *Plantago crypsoides* Boiss) were recorded (3.8% of the total recorded species) (Table 1). In addition, 9 species had unique occurrences in this habitat in the study area (Table 2).

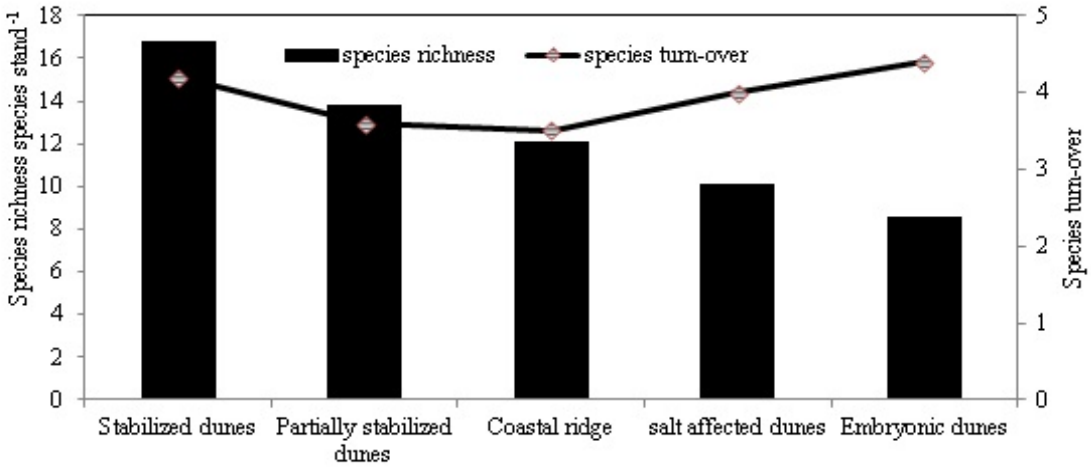

Figure 2. Species diversity of the habitats identified in the Western Mediterranean sand dunes, Egypt.

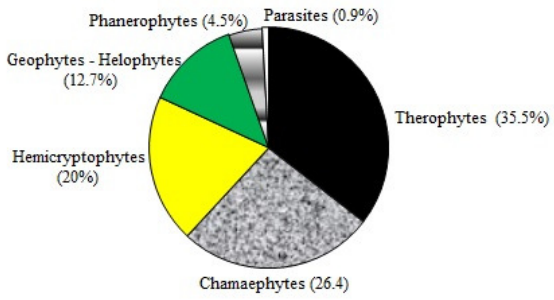

Figure 3. Life form spectrum of the species recorded in the Western Mediterranean sand dunes.

Table 1. Endemic and Near endemic species recorded in the Western Mediterranean coastal sand dunes.

Species	Family
a - Endemics	
Zygophyllum album L.	Zygophyllaceae
B – Near endemics Egypt and Palestinian Authority	
Onopordum alexandrinum Boiss	Asteraceae
Plantago crypsoides Boiss	Plantaginaceae
Egypt and Libya	
Centaurea alexandrina Delile	Asteraceae
Centaurea glomerata Vahl	Asteraceae

The application of TWINSPAN classification on the floristic composition of 124 stands led to classify them into 8 vegetation groups at level three (Appendix 1). They were segregated along the ordination plane of the first and second axes of DCA (Figure 4 and Table 3). These groups were named after the first and occasionally the second dominant species. Five of them occur in only one habitat: group **I**- *Echinops spinosus* - *Launaea fragilis* (Asso) Pau subsp. *fragilis* (8 stands) in the partially stabilized dunes, **II-** *Echinops spinosus* - *Allium erdelii* Zucc. (10 stands) in the stabilized dunes, **III-** *Ammophila arenaria* - *Ononis vaginalis* Vahl (10 stands) in the embryonic dunes, **IV-** *Crucianella maritima* - *Erodium crassifolium* L' Hér. (8 stands) in

Table 2. Species of unique occurrence in the Western Mediterranean sand dunes, Egypt.

Species	Family
Ammophila arenaria (L.) Link	Poaceae
Centaurea dimorpha Viv.	Asteraceae
Hyoseris radiata L.	Asteraceae
Juncus hybridus Brot.	Juncaceae
Nigella arvensis L.	Ranunculaceae
Ononis vaginalis Vahl	Fabaceae
Pseudorlaya pumila (L.) Grande var. *pumila*	Apiaceae
Pseudorlaya pumila (L.) Grande var. *breviaculeata* (Boiss.) Täckh. ex Zohary	Apiaceae
Spergula fallax (Lowe) E. H. L. Krause	Caryophyllaceae

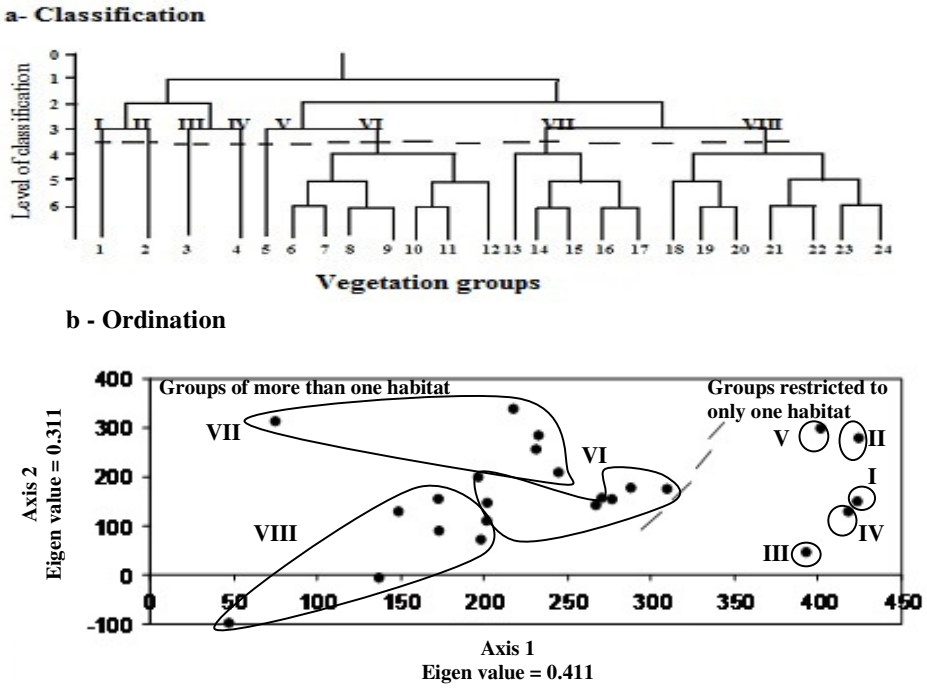

Figure 4. TWINSPAN classification (a) and DCA ordination (b) of the vegetation of the Western Mediterranean sand dunes in Egypt. The 8 vegetation groups identified at level 3 are I: *Echinops spinosus* - *Launaea fragilis* subsp. *fragilis*, II: *Echinops spinosus* - *Allium erdelii*, III: *Ammophila arenaria* - *Ononis vaginalis*, IV: *Crucianella maritima* - *Erodium crassifolium*, V: *Echinops spinosus* - *Thymelaea hirsuta*, VI: *Launaea nudicaulis* - *Thymelaea hirsuta*, VII: *Lygeum spartum* - *Nitraria retusa* and VIII: *Ammophila arenaria* -*Crucianella maritima*.

Table 3. Characteristics of the 8 vegetation groups in the Mediterranean sand dunes of Egypt identified at the level three of TWINSPAN classification technique.

Level of classification		No. of stands	Total species	Species richness	Species turnover	Dominant species	Codominant species
Three	Six						
I	1	8	33	14	2.4	*Echinops spinosus*	*Launaea fragilis* subsp. *fragilis*
II	2	10	48	17	2.8	*Echinops spinosus*	*Allium erdelii*
III	3	10	51	25	2.0	*Ammophila arenaria*	*Ononis vaginalis*
IV	4	8	20	11	1.8	*Crucianella maritima*	*Erodium crassifolium*
V	5	9	17	17	1.0	*Echinops spinosus*	*Thymelaea hirsuta*
VI	6 -12	25	63	7.8	8.1	*Launaea nudicaulis*	*Thymelaea hirsuta*
VII	13 - 17	27	56	4.9	11.4	*Lygeum spartum*	*Nitraria retusa*
VIII	18 - 24	27	43	2.8	5.4	*Ammophila arenaria*	*Crucianella maritima*

the coastal ridges, and group **V-** *Echinops spinosus* - *Thymelaea hirsuta* (9 stands) in the stabilized dunes. On the other hands, 3 groups occupy more than one habitat including group **VI** (*Launaea nudicaulis* (L.) Hook. f.- *Thymelaea hirsuta*: 25 stands) in the embryonic, stabilized and salt affected part of dunes, **VII** (*Lygeum spartum* Loefl. ex L.- *Nitraria retusa* (Forssk.) Asch.: 27 stands) in the stabilized and salt affected part of dunes and **VIII** (*Ammophila arenaria* -*Crucianella maritima*: 27 stands) in the embryonic and stabilized dunes and coastal ridge. Group III had the highest species richness (25 species stand^{-1}), while group VIII had the lowest (2.8 species stand^{-1}). On the other hand, group VII had the highest species turnover (11.4), while group V had the lowest (1.0).

Ninety two species suffer from at least one threat type (Appendix 2). The stresses on the recorded species could be arranged descendingly as follows (Figure 5): constructions of summer resorts (66 species: e.g. *Ammophila arenaria* and *Salsola longifolia* Forssk.) → over-collecting and over-cutting (64: e.g. *Filago desertorium* Pomel and *Crucianella maritima*) → browsing and over-grazing (57: e.g. *Lygeum spartum* and *Helianthemum stipulatum* (Forssk.) C. Chr.) → mining and quarrying (33: e.g. *Lotus polyphyllos* E. D. Clarke and *Scorzonera undulata*) → clearance for agriculture (32: e.g. *Adonis dentata* Delile and *Otanthus maritimus* (L.) Hoffmanns. & Link) → disturbance by cars or trampling (10: e.g. *Atriplex halimus* L. and *Thmelaea hirsuta*). Ten of the recorded species have exposed to only one threat (10.9 % of the total threatened species: e.g. *Atriplex halimus* and *Bassia muricata* (L.) Asch.); 29 species to two threats (31.5 %: e.g. *Achillea santolina* L. and *Juncus hubridus* Brot.); 31 species to three threats (33.7 %: e.g. *Arisarum vulgare* and *Lygeum spartum*), 14 species to four threats (15.2 %: e.g. *Chiliadenus candicans* (Delile) Brullo and *Reseda decursiva* Forssk.); 6 species to five threats (6.5 %: e.g. *Echiochilon fruticosum* Desf.and *Salsola tetrandra* Forssk.) and 3 species to all threats (3.3%: *Thymelaea hirsuta*, *Adonis dentata* and *Carduncellus eriocephalus* Boiss.).

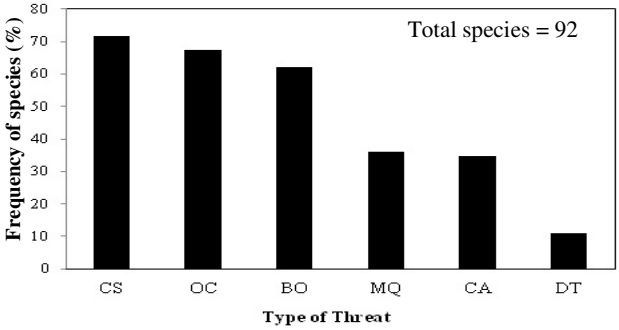

Figure 5. Descending arrangement of the threats upon the recorded species in the Mediterranean sand dunes of Egypt. CS: construction of summer resorts, OC: over-collecting and over-cutting, BO: browsing and overgrazing, MQ: mining and quarrying, CA: clearance for agriculture and DT: disturbance by cars or trampling.

5. Discussion

Of the some 1000 species recorded in the Western Mediterranean of Egypt, 208 species was recorded in the coastal dunes (Shaltout and Ahmed, 2012); of which 110 species were recorded in the present study (11.4 % of the total species in the western Mediterranean region and 52.9 % of the total species in the coastal dunes). The life form spectra provide information which may help in assessing the response of vegetation to variations in environmental factors (Ayyad and El-Ghareeb, 1982). Raven (1971) designated the Mediterranean climate type as a "therophyte climate" because of the high percentage (> 50% of the total species) of this life form in several Mediterranean floras. In the present study, the therophytes are the most frequent life form in the study area, followed by the chamaephytes and hemicryptophyte. The dominance of therophytes over the other life forms seems to be a response to the hot-dry climate, topographic variation and biotic influence (Heneidy and Bidak, 2001). The adverse climatic conditions, moisture deficiency and substrate instability probably lead to the frequent occurrence of therophytes during the favorable seasons. In general, the Mediterranean region is defined according to temperature conditions (mean annual range is 10 – 25 °C), but the

precipitation regime is the most distinctive (275 – 900 mm year^{-1} with at least 65 % falling during winter). The Mediterranean vegetation is dominated by evergreen sclerophyllous shrubs that form maquis (over 2m in height), garrigue and jaral (0.6 – 2 m), phrygana or batha (< 0.6 m) plant communities (Archibold, 1995). Regarding the Mediterranean coastal region of Egypt, many Mediterranean elements occur, but its climate is too dry to support Mediterranean vegetation (Dallman, 1998).

The present study indicates that the stabilized dunes have the highest species richness, while the embryonic dunes have the lowest. This finding could be interpreted in the view that the embryonic dunes usually suffer from continuous sand movement, thus they are inhabited by specialized plant species which can tolerate the burial of their shoot system in sand and the exposure of their roots, and they are capable of producing adventitious roots from the buried vegetative parts. They also produce long fibrous roots that run parallel to the soil surface at very shallow depths (Batanouny, 1999). These species include *Ammophila arenaria*, *Euphorbia paralias* L. and *Pancratium maritimum* (Ayyad, 1976). On the other hand, the stabilized dunes are protected by the plant cover and occupied by shrubby species such as *Crucianella maritima* and *Thymelaea hirsuta.* The dunes affected by the leached salts from the salt marshes and salt spray from the sea are occupied by *Zygophyllum album* and *Salsola longifolia*. Sand shadows are occupied by *Ononis vaginalis* and *Echium angustifolium* Mill. subsp. *sericeum* (Vahl) Klotz, while shallow substrates of the coastal ridge are occupied by *Chiliadenus candicans*, and *Asphodelus aestivus* Brot. (Kamal, 1988). Of these species, nine are solely found in this habitat, thus the continuous destruction of this habitat will led to the extinction of these species at the national level.

Egyptian deserts provide a clear example of anthropogenic disturbance that resulted in habitat loss and fragmentation leading to diminishing of the germplasm reservoir (Ayyad, 2003). One of the major processes causing degradation in the ecosystems of the western Mediterranean region of Egypt is by destruction of plant cover that acts as obstacles to run-off and provide physical resistance to wind (Shaltout and Ahmed, 2012). In the present study, 66 species are exposed to habitat loss due to the construction of summer resorts (71.7% of the total threatened species). Urban expansion and tourism development has consumed large areas of the coastal strip between Alexandria and Matruh. An almost continuous row of summer resorts occupies the coastline between Alexandria and Alamein, and there are plans to develop the rest of the north coast in a similar manner. This has not only led to the complete destruction of the habitats, but also the degradation of vast areas of habitat surrounding them. A small portion of the coastal region to the west of Matruh has also started to be developed in recent years (Seif El-Nasr and Bidak, 2005a). In addition, 64 species (69.6%) were threatened due to over-collecting and over-cutting for commercial trade by the local inhabitants and herbalists for medicinal plants. The most serious aspect of this practice is that it usually targets rare and localized flora leading to damage them further. On the other hand, there is an increasing demand by local Bedouin populations for fuel woods, which targets larger woody perennials; the most targeted are species that develop woody branches and roots. In fact, the removal of woody perennials probably initiates the first steps in a process of complete transformation of the natural landscape (Seif El-Nasr and Bidak, 2005b).

The domestic animals (mainly sheep and goats) graze almost 57 species, which severely deplete the natural vegetation in the study area. In other situations the better forage-producing plants have given way to unpalatable or grazing-resistant plants (Heneidy and Bidak, 1998). Unlike the impact of agriculture, which is very easy to observe even from long distances (the complete removal of natural vegetation), the impact of grazing is more subtle, but is probably serious. Traditional pastoralism in the past was more limited than today. The human population was much smaller, and summer grazing opportunities were very limited (thus limiting the possibility of maintaining excessively large herds). In modern times however, the use of trucks has enabled local people to transport their herds from one grazing site to another at high speed, rapidly depleting grazing grounds in large areas. Supplementary food and water transportation by trucks make it possible to take herds further to graze marginal habitats in distant localities. These were difficult to reach and could only support grazing during very short periods of the year. All these techniques have allowed locals to maintain larger herds, far exceeding the carrying capacity of their environment (Heneidy and Bidak, 1998).

The reduction of plant cover as a result of wood-cutting, over grazing, over-collecting and ploughing; leads to regress the soil surface layer under the effect of water erosion or wind deflation. Sedentarization; application of new technologies in cultivation, and establishment of quarries and new villages have had an increasing human pressure on the natural environment during the last few decades (Shaltout and Ahmed, 2012). On the other hand, 32 species are damaged during agriculture process, which perhaps is the most serious threat to the vegetation in the region. Today, with the growth of local populations and the introduction of modern machinery, almost all seemingly cultivable land receiving sufficient rain to grow a crop, is ploughed annually to cultivate winter cereals. In general, the economic value of maintaining rangelands versus agriculture reclamation has not been adequately assessed. Plowing with modern machinery is the most destructive recent development on the agricultural front. Modern

machinery, however, indiscriminately and completely removes perennial shrubs, which provide complexity and shelter to wildlife. It also flattens the landscape, penetrating through areas previously difficult to cultivate by traditional technology and probably killing animals during this process, and after the crop is harvested in late spring/early summer, the land lays barren and completely devoid of any kind of vegetation, throughout the remainder of the year. Here soil erosion is often severe, compounding the problem further. This in turn means that grazing pressure is increasing dramatically in any remaining patches of natural habitats, as well as, in marginal areas not suited for cultivation, degrading them further. It is widely accepted that this fragile desert ecosystems is unable to sustain this type of intensive mono-cropping which causes depletion of soil nutrients and erosion (Heneidy and El-Darier, 1995). In order to conserve the biota of this ecosystem, particularly the flora and vegetation including the unique, endemic and near endemic species, from the result of the present study, damage of the coastal dunes and ridges for constructing the summer resorts and any other land uses along the Mediterranean coast must to stop.

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Appendix 1. Presence percentage of the recorded species in the 8 vegetation groups in the Mediterranean sand dunes of Egypt identified after the application of TWINSPAN classification.

Species	Vegetation group								Total
	I	II	III	IV	V	VI	VII	VIII	
Deverra tortuosa (Desf.) DC.	33.3	75	66.6	66.6	100	44	22.2	10.3	8
Echinops spinosus L.	100	100	100	66.6	100	48	22.2	55.2	8
Gymnocarpos decandrus Forssk.	33.3	50	33.3	33.3	100	12	7.4	13.8	8
Ammophila arenaria (L.) Link	33.3	25	100	33.3		52	33.3	63.8	7
Crucianella maritima L.		50	66.6	100	100	44	18.5	34.5	7
Launaea fragilis (Asso) Pau subsp. *fragilis*	100	50	33.3	66.6	100	48	14.8		7
Launaea nudicaulis (L.) Hook. f.		25	33.3	66.6	100	56	11.1	25.9	7
Thymelaea hirsuta (L.) Endl.	33.3	75	100	66.6	100	44	18.5		7
Atractylis carduus (Forssk.) C. Chr. var. *glabrescens* (Boiss.) Täckh. & Boulos		25		33.3	100	8	11.1	3.4	6
Echium angustifolium Mill. subsp. *sericeum* (Vahl) Klotz	33.3		66.6	33.3		28	22.2	15.5	6
Helianthemum stipulatum (Forssk.) C. Chr.		25	66.6	66.6		20	14.8	10.3	6
Lycium europaeum L.	33.3		33.3	33.3		32	29.6	10.3	6
Ononis vaginalis Vahl		25	100	100	100	64	51.9		6
Zygophyllum album L.	33.3	50	100			52	18.5	44.8	6
Atriplex halimus L.		50			100	16	7.4	10.3	5
Centaurea glomerata Vahl.		25	33.3			8	7.4	3.4	5
Centaurea pumilio L.			33.3	33.3		44	22.2	32.8	5
Echiochilon fruticosum Desf.		50	66.6		100	24		12.1	5
Euphorbia paralias L.	33.3		33.3			4	11.1	27.6	5
Lotus glaber Mill.		50			100	4	25.9	8.6	5
Lotus polyphyllos E. D. Clarke	33.3		66.6			40	7.4	15.5	5
Plantago albicans L.	33.3	50	66.6			28	3.7		5
Bassia muricata (L.) Asch.	33.3		33.3			8		15.5	4
Herniaria hemistemon J. Gay		25				16	3.7	43.1	4
Hyoseris radiata L. subsp. *graeca* Halácsy		50	33.3			52	25.9		4
Limbarda crithmoides (L.) Dumart.		50			100	8	25.9		4
Limoniastrum monopetalum (L.) Boiss.		25				8	33.3	10.3	4
Limonium tubiflorum (Delile) Kuntze var. *tubiflorum*		25				4	7.4	3.4	4
Lygeum spartum Loefl. ex L.	33.3	25				12	25.9		4
Nitraria retusa (Forssk.) Asch.	33.3	25				8	51.9		4
Pancratium maritimum L.	33.3		66.6			40	48.1		4
Reaumuria hirtella Jaub. & Spach		25			100	12	14.8		4
Salsola longifolia Forssk.		50				16	37	12.1	4
Salvia lanigera Poir.	33.3		100	66.6		52			4
Salvia verbenaca L.		50				16	25.9	13.8	4
Sarcocornia fruticosa (L.) A. J. Scott	33.3				100	8	18.5		4
Scorzonera undulata Vahl	66.6	50			100			3.4	4
Aeluropus lagopoides (L.) Trin. ex Thwaites						28	29.6	8.6	3
Allium erdelii Zucc.		75		33.3		16			3
Asphodelus aestivus Brot.	33.3	50	33.3						3
Cakile maritima Scop. subsp. *aegyptiaca* (Willd.) Nyman						12	7.4	6.9	3
Centaurea alexandrina Delile		25	33.3			16			3
Centaurea calcitrapa L.		25	33.3			8			3
Centaurea dimorpha Viv.			33.3				7.4	3.4	3
Cynodon dactylon (L.) Pers.		50				16	25.9		3
Elymus farctus (Viv.) Runemark ex Melderis	33.3					32		32.8	3
Erodium crassifolium L' Hér.	33.3			100			7.4		3
Helianthemum lippii (L.) Dum. Cours.	33.3	25			100				3
Limonium pruinosum (L.) Chaz. var. *pruinosum*		25				8	25.9		3
Otanthus maritimus (L.) Hoffmanns. & Link						4	3.7	31	3
Phagnalon rupestre (L.) DC.		75		33.3				20.7	3
Salsola tetrandra Forssk.		25				16	51.9		3
Silene succulenta Forssk.			66.6			16	11.1		3
Sporobolus pungens (Schreb.) Kunth	33.3					8	37		3
Teucrium polium L.	66.6	25	66.6						3
Arisarum vulgare Targ. Tozz.	33.3	25							2
Suaeda pruinosa Lange	33.3	25							2

Appendix 1. Cont.

Species	Vegetation group								Total
	I	II	III	IV	V	VI	VII	VIII	
Cutandia dichotoma (Forssk.) Batt. & Trab.	33.3		66.6						2
Noaea mucronata (Forssk.) Asch. & Schweinf.	33.3							46.6	2
Bromus diandrus Roth		25	33.3						2
Astragalus peregrinus Vahl						8	33.3		2
Astragalus spinosus (Forssk.) Muschl.						8	33.3		2
Carduncellus eriocephalus Boiss.						16	11.1		2
Erodium laciniatum (Cav.) Willd. subsp. *pulverulentum* (Boiss.) Batt.						8	7.4		2
Limonium pruinosum (L.) Chaz. var. *hirtiflorum* (Cavara) Täckh. ex Feinbrun						8	25.9		2
Pseudognaphalium luteo-album (L.) Hilliard & B. L. Burtt						4	33.3		2
Frankenia hirsuta L.		25					11.1		2
Onopordum alexandrinum Boiss.		50		33.3					2
Plantago crypsoides Boiss		25						5.2	2
Polygonum equisetiforme Sm.		25				4			2
Spergula fallax (Lowe) E. H. L. Krause		25					11.1		2
Spergularia marina (L.) Bessler		25						15.5	2
Globularia arabica Jaub. & Spach.			33.3				3.7		2
Orobanche crenata Forssk.			66.6					1.7	2
Reseda decursiva Forssk.			33.3			4			2
Sphenopus divaricatus (Gouan) Rchb.			33.3					3.4	2
Volutaria lippii (L.) Cass. ex Maire			33.3				18.5		2
Stipa capensis Thunb.				33.3				18.9	2
Juncus hybridus Brot.						4		18.9	2
Lotus creticus L.						4		41.4	2
Retama raetam (Forssk.) Webb & Berthel. subsp. *raetam*						8		5.2	2
Salsola tetragona Delile						8		15.5	2
Salsola kali L.							11.1	15.5	2
Anabasis articulata (Forssk.) Moq.							18.5	3.4	2
Anacyclus monanthos (L.) Thell. subsp. *monanthos*	33.3								1
Hippocrepis areolata Desv.	33.3								1
Ifloga spicata (Forssk.) Sch. Bip.	33.3								1
Medicago intertexta (L.) Mill. var. *cilliaris* (L.) Heyn	33.3								1
Allium roseum L. var. *tourneauxii* Boiss.		25							1
Adonis dentata Delile			33.3						1
Alhagi graecorum Boiss.			33.3						1
Bromus rubens L.			33.3						1
Bupleurum semicompositum L.			33.3						1
Carrichetera annua (L.) DC.			33.3						1
Chiliadenus candicans (Delile) Brullo			33.3						1
Eryngium campestre L.			66.6						1
Filago desertorum Pomel			33.3						1
Lobularia maritima (L.) Desv.			33.3						1
Medicago polymorpha L.			33.3						1
Nigella arvensis L.			33.3						1
Pseudorlaya pumila (L.) Grande var. *pumila*			66.6						1
P. pumila (L.) Grande var. *breviaculeata* (Boiss.) Täckh. e*x* Zohary			66.6						1
Rumex pictus Forssk.			33.3						1
Thymus capitatus (L.) Link			33.3						1
Asparagus aphyllus L.						8			1
Asparagus stipularis Forssk.						8			1
Achillea santolina L.						8			1
Arthrocnemum macrostachyum (Moric) K. Koch							3.7		1
Glebionis coronaria (L.) Tzvelev							18.5		1
Reseda alba L.								18.9	1
Total species	33	48	51	20	17	63	56	43	110
Species richness	14	17	25	11	17	7.8	4.9	2.8	11.5
Species turnover	2.4	2.8	2	1.8	1	8.1	11.4	15.4	9.6

Appendix 2. Threats of the species recorded in the Mediterranean sand dunes of Egypt. Threats are coded as BO: browsing and over grazing, OC: over collecting and over cutting, CA: clearance for agricultures, CS: construction of summer resorts, MQ: mining and quarrying and DT: disturbance by cars or trampling.

Latin names	Types of threats						Total
	BO	OC	CA	CS	MQ	DT	
Adonis dentata Delile	+	+	+	+	+	+	6
Carduncellus eriocephalus Boiss.	+	+	+	+	+	+	6
Thymelaea hirsuta (L.) Endl.	+	+	+	+	+	+	6
Anabasis articulata (Forssk.) Moq.	+	+	+	+		+	5
Astragalus spinosus (Forssk.) Muschl.	+	+	+	+	+		5
Centaurea calcitrapa L.	+	+	+	+	+		5
Echiochilon fruticosum Desf.	+	+	+	+		+	5
Salsola tetrandra Forssk.	+	+	+	+	+		5
Suaeda pruinosa Lange	+	+	+		+	+	5
Asparagus stipularis Forssk.	+	+		+	+		4
Asphodelus aestivus Brot.	+		+	+	+		4
Bupleurum semicompositum L.		+	+	+	+		4
Chiliadenus candicans (Delile) Brullo	+	+	+	+			4
Helianthemum lippii	+	+			+	+	4
Helianthemum stipulatum (Forssk.) C. Chr.	+	+		+	+		4
Lobularia maritima (L.) Desv.	+	+	+	+			4
Lotus creticus L.	+	+	+	+			4
Lotus polyphyllos E. D. Clarke	+	+		+	+		4
Lycium europaeum L.	+	+		+	+		4
Reseda alba L.	+	+	+	+			4
Reseda decursiva Forssk.	+	+	+	+			4
Salsola tetragona Delile	+	+		+	+		4
Volutaria lippii (L.) Cass. ex Maire	+	+	+	+			4
Allium erdelii Zucc.		+		+	+		3
Arisarum vulgare Targ. Tozz.		+		+	+		3
Arthrocnemum macrostachyum (Moric) K. Koch	+	+	+				3
Asparagus aphyllus L.	+	+		+			3
Astragalus peregrinus Vahl	+			+	+		3
Atractylis carduus (Forssk.) C. Chr. var. *glabrescens* (Boiss.) Täckh. & Boulos	+	+		+			3
Cakile maritima Scop. subsp. *aegyptiaca* (Willd.) Nyman		+	+	+			3
Carrichetera annua (L.) DC.	+	+				+	3
Centaurea alexandrina Delile	+	+	+				3
Centaurea pumilio L.	+	+		+			3
Echium angustifolium Mill. subsp. sericeum (Vahl) Klotz	+			+	+		3
Erodium laciniatum (Cav.) Willd. subsp. *pulverulentum*		+	+		+		3
Frankenia hirsuta L.	+	+	+				3
Glebionis coronaria (L.) Tzvelev		+	+	+			3
Globularia arabica Jaub. & Spach.		+		+	+		3
Launaea fragilis (Asso) Pau subsp. *fragilis*	+			+	+		3
Launaea nudicaulis (L.) Hook. f.	+			+	+		3
Limbarda crithmoides		+	+	+			3
Limonium tubiflorum (Delile) Kuntze var. *tubiflorum*	+	+		+			3
Lygeum spartum Loefl. ex L.	+			+	+		3
Medicago intertexta (L.) Mill. var. *cilliaris* (L.) Heyn	+		+	+			3
Medicago polymorpha L.	+	+		+			3
Noaea mucronata (Forssk.) Asch. & Schweinf.	+	+		+			3
Onopordum alexandrinum Boiss.	+	+		+			3
Pancratium maritimum L.		+		+	+		3
Rumex pictus Forssk.	+	+	+				3
Salsola longifolia Forssk.		+	+	+			3
Scorzonera undulata Vahl	+			+	+		3
Silene succulenta Forssk.	+		+	+			3
Thymus capitatus (L.) Link	+	+		+			3
Centaurea dimorpha Viv.	+	+					2
Centaurea glomerata Vahl	+	+					2
Centaurea dimorpha Viv.	+	+					2
Centaurea glomerata Vahl	+	+					2
Filago desertorum Pomel	+	+					2
Ifloga spicata (Forssk.) Sch. Bip.	+	+					2
Polygonum equisetiforme Sm.	+	+					2
Salvia lanigera Poir.	+	+					2
Teucrium polium L.	+	+					2
Nitraria retusa (Forssk.)Asch.		+	+				2

Appendix 2. Cont.

Latin names	Types of threats						Total
	BO	OC	CA	CS	MQ	DT	
Gymnocarpos decandrus Forssk.		+	+				2
Achillea santolina L.		+		+			2
Echinops spinosus L.	+			+			2
Juncus hybridus Brot.	+			+			2
Spergula fallax (Lowe) E. H. L. Krause in Sturm	+			+			2
Sporobolus pungens (Schreb.) Kunth	+			+			2
Ammophila arenaria (L.) Link		+		+			2
Eryngium campestre L.		+		+			2
Hippocrepis areolata Desv.		+		+			2
Limonium pruinosum (L.) Chaz. var. *hirtiflorum* (Cavara) Täckh. ex Feinbrun				+	+		2
Limonium pruinosum (L.) Chaz. var. *pruinosum*				+	+		2
Lotus glaber Mill.				+	+		2
Ononis vaginalis Vahl				+	+		2
Zygophyllum album L.				+	+		2
Otanthus maritimus (L.) Hoffmanns. & Link			+	+			2
Herniaria hemistemon J. Gay				+	+		2
Phagnalon rupestre (L.) DC.		+		+			2
Reaumuria hirtella Jaub. & Spach		+		+			2
Retama raetam (Forssk.) Webb & Berthel. subsp. raetam		+		+			2
Salsola kali L.		+		+			2
Stipa capensis Thunb.	+				+		2
Anacyclus monanthos (L.) Thell. subsp. *monanthos*	+						1
Spergularia marina (L.) Bessler	+						1
Crucianella maritima L.		+					1
Limoniastrum monopetalum (L.) Boiss.		+					1
Sarcocornia fruticosa (L.) A. J. Scott		+					1
Plantago crypsoides Boiss			+				1
Euphorbia paralias L.				+			1
Hyoseris radiata L. subsp. *graeca* Halácsy				+			1
Atriplex halimus L.						+	1
Bassia muricata (L.) Asch.						+	1
Total	57	64	32	66	33	10	92

9/23/2014