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Research Article

Floristic Diversity and Phytogeography of the Gebel Elba National Park, South-East Egypt

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Abstract: The floristic composition and phytogeographical analysis of the Gebel Elba National Park in the south-east corner of Egypt were studied using multivariate analysis techniques. Its flora was poorly documented; therefore, 5 recent expeditions between 1998 and 2004 were carried out, which resulted in the collection of 179 species that belong to 51 families. Six major wadis (sites) were investigated to cover adequately the territory of the Park (35,600 km^2) and to attain as complete an inventory of its vascular flora as possible. The floristic composition and species diversity among the wadis showed variations in species richness, yet W. Yahameib was the most diversified. The most species-rich families were *Compositae* (12%), *Leguminosae* (9%), *Gramineae* (6.7%), *Caryophyllaceae, Convolvulaceae* and *Euphorbiaceae* (4.4% for each). This study revealed that the Gebel Elba Park is more diverse compared with other, well-studied phytogeographic territories in Egypt. Ninety-two species (51.4%) demonstrated a certain degree of consistency, where they were exclusively recorded in or confined to a certain wadi (site) or group of wadis. The life-form spectrum was dominated by therophytes, denoting a typical arid desert flora, while phanerophytes, chamaephytes and hemicryptophytes were of equal importance. The distribution of the phytogeographic elements in the distinguished life-form categories showed the prevalence of the Saharo-Arabian geoelement (48%), whereas the Sudano-Zambezian and Mediterranean geoelements ranked second, with 19.6% and 14 %, respectively. Therefore, the Gebel Elba Park represents a continuation of the Sudanian tropical region, which still needs further intensive study. A very special study undertaken to examine the diversity-altitude relationships along an altitudinal gradient in W. Yahameib revealed that the highest diversity occurred at middle altitudes on the mountain, which may be more typical of arid mountains in desert regions.

Key Words: Altitudinal zonation, Arid coastal mountain, Biogeography, Distribution patterns, Floristic richness, Egypt, Multivariate analysis

Introduction

The coastal mountain ranges of the Red Sea represent a conspicuous habitat type of special interest for their complex patterns of natural communities interrelating the floras and faunas of Egypt, Sudan and Ethiopia. One of these ranges is the Gebel Elba mountains of south-eastern Egypt. This mountain range is considered a continuation of the granitic formation of the Red Sea highland complex between Egypt and Sudan, situated between 36º and 37º of the eastern longitudes and about 22º of the northern latitude. The flora and fauna of this area comprise hundreds of species of plants and animals; these include a number of endemics and a number of species that represent the northern outpost of the biota of the Ethiopian highlands.

The geographic position of this group of mountains combines the following: (a) the bend of the coastal line, (b) the proximity to a large water body (Red Sea), (c) altitudinal and seaward direction of slope, and (d) a coastal plain with few topographic features. The combination of these features allows for orographic condensation of cloud moisture, particularly on the seaward slopes, which forms an essential source of water for plants in this area. This provides for rich plant growth and creates “mountain oases” or “mist oases” (Troll, 1935; Kassas, 1955). The floristic richness of the Gebel Elba area is noticeable, compared to the rest of Egypt, and this is considered one of the main phytogeographical territories of the country (El Hadidi, 2000a) as it borders the Saharo-Arabian and Sudanian floristic regions. The

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flora and vegetation of the Gebel Elba group is much richer than that of the other coastal mountain groups (Drar, 1936; Hassib, 1951), where the Palaearctic and Afro-tropical regions meet. It comprises elements of the Sahelian regional transition zone (*sensu* White & Léonard, 1991) and represents the northern limit of this geoelement in Africa. Within its massive, the vegetation on the north and north-east flanks is much richer than that on the south and south-west (Kassas & Zahran, 1971). Its ecological features, together with its particular geographic position, seem to have promoted plant diversity, singularity and endemism in this area, and favoured the persistence of an extensive woodland landscape dominated by thickets of *A. tortilis* (Forssk.) Hayne subsp. tortilis which is not known elsewhere in the Eastern Desert of Egypt (Zahran & Willis, 1992).

Geographical areas containing high species richness, a high level of endemism, and/or harbouring a high number of rare or threatened species have been defined as biodiversity hotspots, and have been considered to set priorities for conservation planning (Myers, 1990; Reid, 1998). In spite of the interesting biogeographical and botanical features of the Gebel Elba mountain range, it has been overlooked in most global biodiversity assessments (Heywood & Watson, 1995). Of the 142 woody perennial threatened plant species that were included in the Plant Red Data Book of Egypt (El Hadidi et al., 1992), 56 or 39.4% were known from the Gebel Elba district. Therefore, this area was protected in 1986 as the Gebel Elba National Park (Prime Ministerial Decrees 450/1986, 1185/1986 and 642/1995), covering 35,600 km^2, aiming to promote the sustainable management of natural resources and maintain its biodiversity. To fulfil this mandate, it is essential that each national park has adequate knowledge of its biodiversity (Hawksworth & Kalin-Arroyo, 1995). Inventorying is, therefore, the fundamental starting point for any strategy of conservation, sustainable use, or management (Strok & Samways, 1995). Biodiversity conservation in Egypt is supported by a network of number of important protected areas (21 representing 8% of the country's land surface, and a further 19 area are proposed for protection), based on natural region classification of the land, and having a mandate to preserve a representative sample of the ecosystem characteristic of each region.

The rugged topography and inaccessibility of the mountainous escarpment of the Gebel Elba district have resulted in a paucity of studies on its vegetation and no complete survey of the flora. Previous studies on the flora and vegetation of the Gebel Elba mountain range were fragmentary and relied on a qualitative description of the vegetation (Drar, 1936; Fahmy, 1936; Kassas & Zahran, 1971). It is worth noting that a complete modern flora (or at least checklist giving a precise account of its extant plant taxa) is still lacking. A complete list of the plant taxa of this area is therefore essential.

This work seeks to provide a detailed floristic analysis of the Gebel Elba National Park, and to assess its phytogeographic affinities. The results presented in this paper are the first contribution to study the floristic diversity of the Park, and to increase knowledge of the Gebel Elba region.

The study area

The Gebel Elba mountainous group is one of 3 coastal mountains in the south-east corner of Egypt that faces the Red Sea, extending between latitude 24° 50'N and 22° N on the Sudano-Egyptian border (Figure 1). This group is mainly of igneous basement nature, forming a complex of high summits such as Asotriba (2217 m), Shendib (1912 m), Shendodin (1526 m), Elba (1465 m), and Shellal (1409 m). A wide coastal desert plain separates the Gebel Elba mountain range from the Red Sea coast. Although not the highest of its group, Gebel Elba is nearest to the sea (20-25 km). The igneous mountains extend southwards from latitude 28° N to beyond latitude 22° N (the Sudano-Egyptian frontier). Fahmy (1936) reported that Gebel Elba is a compact mass of light-coloured granite, covered with jagged peaks and numerous precipitous gorges. It is separated from the chain extending further south by the broad deeply wadis of Osir Hadal and Sarimtai. The peak of Gebel Elba (22° 10' 33''N and 36° 21' 52'' E) represents the centre from which drainage systems (wadis) radiate in all directions. The principal of these wadis is Wadi Yahameib, which with its tributaries Wadi Akaw and Wadi Kansisrob, drains the north faces of the mountains (Figure 1). Except for the alluvial wadi fan at the foot of the mountain, which consists of gravel and sandy soil, the surface is of bare exposed rocks. Slopes are steep with sharp rocks. Most of the vegetation grows in soil pockets in the drainage cracks and runnels. Large boulders, small stones and gravel are found in the steep runnels. Said

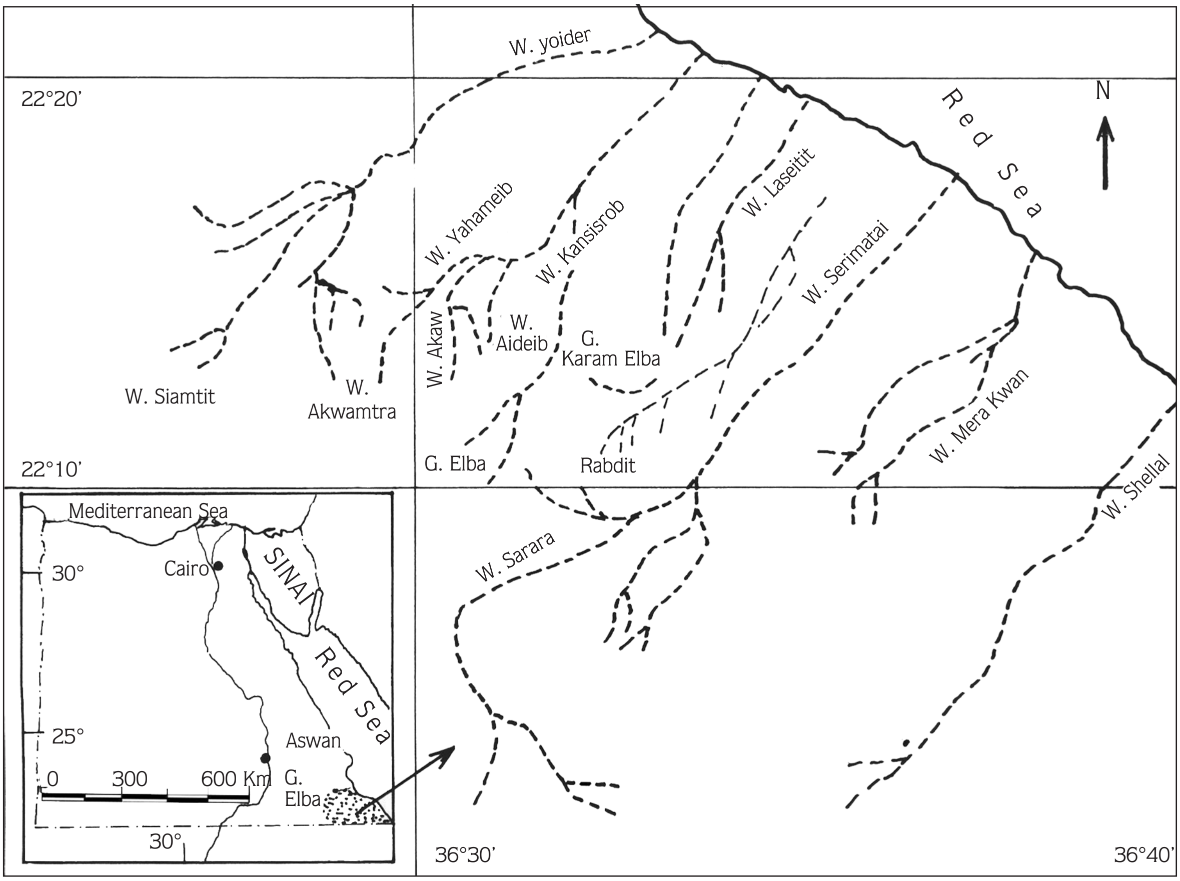

Figure 1. Location map of Gebel Elba region, showing the dissecting wadis.

(1962) described the rock formations in the study area as mainly igneous and metamorphic deposits of very ancient origin. The igneous rocks cover one-third of south-eastern Egypt, forming irregularly distributed tracts alternating with others occupied by metamorphic rocks. In general, gneisses, schists, breccias and many other minerals comprise the metamorphic rocks in this district. On the other hand, the sedimentary deposits can be classified as recent, gypsum and gypseous limestone, and Nubian sandstone (Cretaceous).

Within the complex biological and physical framework that constitutes the biodiversity resources of the Gebel Elba National Park, rich ethnic inheritance has lived in, used and modified the natural habitats in different ways through time. The *Bishari* tribe, the principal of 3 tribes, inhabit the immediate vicinity of Gebel Elba. They are sedentary to semi-nomadic, related to the tribes in Sudan and Ethiopia and speak their own language. The *Ababda* tribe, ranked second, are a sedentary to semi-nomadic people found in the northern areas of the park, and are considered Arab in origin. The *Rashayda* tribe are a non-indigenous tribe inhabiting the coastal plain. The human activities from ancient up to the present time must be considered factors which have contributed to the disturbance of the natural ecosystems, the banality of the flora, and the more or less uniformity of the vegetation in our area. The main socio-economic activities of the local community are livestock herding and charcoal production (especially from *Acacia* Mill. trees). The local community relies heavily on the natural flora for their way of life, particularly wood for fuel, building materials, fodder, tools, handicrafts and other goods, some of which are sold or traded. Plants and animals are also used for medicinal purposes. Other activities include small-scale cultivation along the coastal plain and fisheries in the offshore waters. In the coastal communities there are commercial enterprises, including trade between the Sudan and Egypt. These activities have produced environmental alterations and in some instances positively influenced the genetic maintenance of some ecosystems.

The climate of the study area seems to occupy an intermediate position between those of the regions of the tropical rains and those of the dry Egyptian rocky deserts with their occasional precipitation in winter months (Fahmy, 1936). According to Ayyad & Ghabbour (1986), the study area lies in the arid climatic province characterised by spring rainfall ranges between 50 and 10 mm year^{-1}, mild winters (18-22 °C) and hot summers (28-33 °C). As for its geographical position and peculiar set of environmental conditions, Gebel Elba receives greater water revenue from orographic precipitation than the other northern blocks (Kassas & Zahran, 1971). Unfortunately, recent climatic records for the Gebel Elba area are not available.

Methods

An inventory of all available herbarium collections from the study area (1936-1962) was compiled, and taxonomic determinations were revisited. Specimens were examined from the Herbarium of Cairo University (CAI), the herbarium of the Agriculture Museum (CAIM), the Herbarium of Assiut University (ASUH), and the Herbarium of South Valley University. More recent collections (March 1998-January 2004) were made from field surveys that were conducted mainly for the study of the botanical diversity of Gebel Elba National Park. Each taxon observed within the Park was vouchered by at least 3 specimens. When a taxon identification appeared uncertain in the field, more specimens were collected for later validation. Information from herbarium labels and from field observations was compiled in a database.

Life-form categories were identified according to Raunkiaer's system of classification (Raunkiaer, 1934). When several life forms were given for a taxon, the most representative taxon was chosen; variation in the life form in the field was not considered. The phytogeographical affinity of each taxon was also included. The latter information was determined largely from sources such as Wickens (1976), Abd El-Ghani (1998), and Springuel et al. (1997). When these resources for a single taxon gave more than one phytogeographical element, the most appropriate was chosen. Only higher plants were collected. Our specimens were deposited at CAI, and the Herbarium of South Valley University. The nomenclature used follows Täckholm (1974), updated using Boulos (1995, 1999-2002), Cope & Hosni (1991) and El Hadidi (2000b).

In order to follow a random stratified strategy for sampling (Ludwig & Reynold, 1988) within each of the 6 major studied wadis (Figure 1), the presence or absence of plant species was recorded using a number of sample plots randomly positioned, georeferenced using GPS model Trimble SCOUT[M], and distributed along the studied wadis. These wadis include W. Aideib, W. Yahameib, W. Darawina, W. Shellal, W. Topeet and W. Sarara (see Appendix). Our sampling strategy was designed to cover adequately the territory of the Park and to attain as complete an inventory of its vascular flora as possible. The number of samples was determined by the species richness of the wadi, i.e. we stopped sampling once no new species were detected in the plots. The area of the sampled plots was unlimited and varied from a few hundred square metres (200-300 m^2) to about 1.0 linear kilometre (wadi channels). Species richness (alpha diversity) was calculated as the total number of species per site (wadi). Species turnover (beta diversity) was calculated using I-Jaccard's index of similarity since it provides a way to measure the species turnover between different areas (Magurran, 1988). The calculation of the index has been designed to equal 1 in cases of complete similarity. Fifty percent turnover of species composition, termed half change, has been used as the unit of beta diversity (Whittaker, 1960).

A floristic data matrix of 83 species and 6 sites (wadis) was constructed after the removal of 96 unicates occurring in a single sample plot. Based on a binary presence-absence of species and sites, the resultant data matrix was processed by multivariate analysis using the Multivariate Statistical Package MVSP for Windows, version 3.1 (Kovack, 1999). For the classification of sites, cluster analysis using minimum variance as the agglomeration criterion (Orloci, 1978) was applied to a squared Euclidean distance dissimilarity matrix. In order to reveal possible intrinsic patterns in site subsets, site ordination via Detrended Correspondence Analysis (DCA) based on species frequency data was applied using the computer program PC-ORD for Windows version 4.14 (McCune & Mefford, 1999). Sites more similar in vegetation structure (species composition and abundance) were depicted as being closer together in the diagram. Sites that differ by 4 standard deviations (4SD, the axes units) in score can be expected to have no species in common (Jongman et al., 1987). Preliminary analyses were performed by applying the default option of the DCA (Hill & Gauch, 1980) in the PC-ORD program, to check the magnitude of change in species composition along the first ordination axis (i.e. gradient length in standard deviation (SD units)). All the statistical analyses were carried out using SPSS for Windows version 10.0.

Table 1. Floristic richness of the Gebel Elba Park.

Plant group	Families	Genera	Species	Infraspecific taxa
Ferns and allied groups	3	3	3	-
Gymnosperms	1	1	1	-
Angiosperms	47	120	175	23
Monocotyledons	7	16	22	3
Dicotyledons	40	104	153	20
Total of vascular flora	51	124	179	23

Results and Discussion

Floristic richness and taxonomic diversity

As a result of our fieldwork, the vascular flora of the Gebel Elba Park contains a total of 179 taxa from 51 families and 124 genera (Table 1). More than 50% of the recorded taxa (see Appendix) belong to only 10 species-rich families (Figure 2). The largest families in terms of the number of genera were *Compositae* (14), *Gramineae* (10), *Leguminosae* (9), *Caryophyllaceae* (6), and *Asclepiadaceae*, *Cruciferae*, *Scrophulariaceae* and *Zygophyllaceae* (4 for each). These families represent the most common in the Mediterranean North African flora (Quézel, 1978). On the other hand, *Gramineae*, *Leguminosae*, *Compositae* and *Cruciferae* constitute the main bulk of the alien plant species in Egypt, and also in the agro-ecosystems of other, adjacent countries such as Saudi Arabia and Kuwait (Abd El-Ghani & El-Sawaf, 2004). A comparison of families in terms of the largest number of species recorded in this investigation and in similar studies in neighbouring countries (Table 2) revealed an agreement with such studies, e.g., Wickens (1976) in Jebel Marra of the Sudan, Hassan (pers.

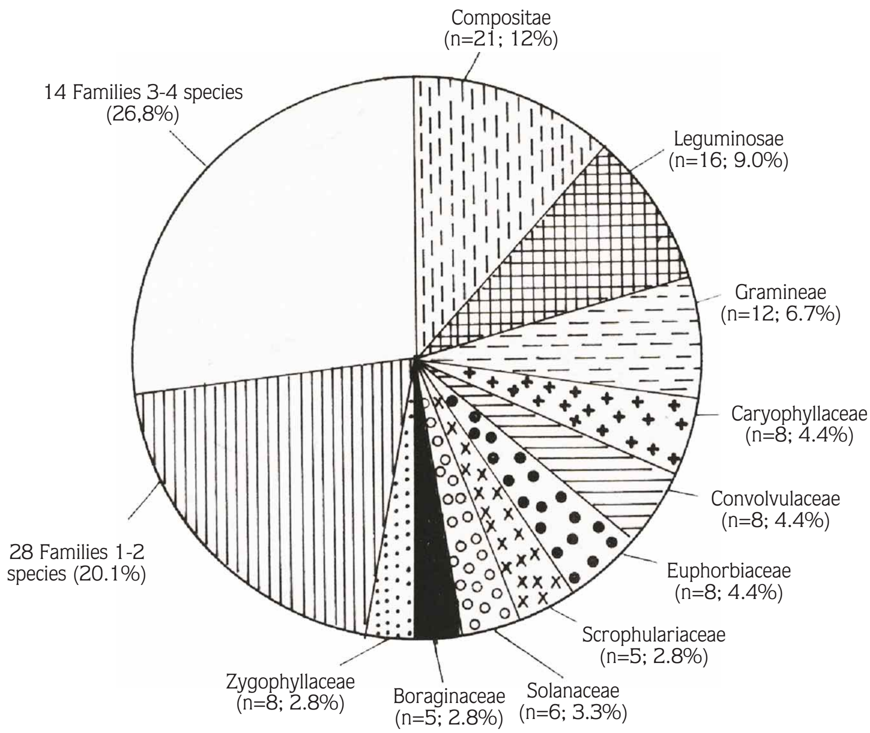

Figure 2. Diagram of floristic composition with the ten families richest in species separately notated (n= number of species).

Table 2. Comparison of the 8 families containing the most species in studies conducted in Egypt and neighbouring countries, with their numbers and percentages (in parentheses). Sources: 1= Boulos (1995, 1999-2002); 2 = Hassan (1987); 3 = Wickens(1976; 4 = Boulos (1986); Hosni & Hegazy (1996).

Families	Estimated number of species in Egypt[1]	Egypt		Jebel Marra (Sudan)[3]	Asir Mountains (Saudi Arabia)[4]
		Present study	Eastern Desert (Egypt)[2]		
Compositae	230 (11.0)	21 (12)	57 (13.2)	76 (8.1)	21 (9.6)
Leguminosae	233 (11.1)	16 (9)	33 (7.6)	108 (11.6)	26 (11.9)
Gramineae	250 (11.9)	12 (6.7)	38 (8.8)	105 (11.3)	40 (18.3)
Caryophyllaceae	85 (4.0)	8 (4.4)	24 (5.5)	10 (1.1)	5 (2.3)
Convolvulaceae	48 (2.3)	8 (4.4)	7 (1.6)	18 (1.9)	3 (1.4)
Euphorbiaceae	55 (2.6)	8 (4.4)	5 (1.1)	21 (2.2	10 (4.6)
Solanaceae	33 (1.6)	6 (3.3)	7 (1.6)	10 (1.1)	8 (3.7)
Scrophulariaceae	62 (2.9)	5 (2.8)	11 (2.5)	23 (2.5)	7 (3.2)

comm.; 1987, Ecological and Floristic Studies on the Eastren Desert, Egypt), and Boulos (1985) and Hosni & Hegazi (1996) in the Asir Mountains of Saudi Arabia. *Compositae* (the largest family in our list) is not only the largest family in the Flora of Egypt (Täckholm, 1974; Boulos, 2002), but also the largest and most widespread family of flowering plants in the world (Good, 1974). This can be attributed to their wide ecological range of tolerance, and to their high seed dispersal capability. The largest genera were *Euphorbia* L. (6), *Launaea* Cav., *Solanum* L. (5 for each), *Acacia* and *Convolvulus* L. (4 for each). The species composition of the Park was greatly influenced by disturbances such as severe cutting of trees and shrubs either for domestic fuel or charcoal production, and browsing. These factors affect particularly *A. tortilis* (Forssk.) Hayne subsp. *tortilis*, *Balanites aegyptiaca* (L.) Del. and *Maerua crassifolia* Forssk. regrowth, while favouring an increase in density of species not browsed, such as *Calotropis procera* (Ait.) Ait., *Leptadenia pyrotechnica* (Forssk.) Decne and *Senna italica* Mill. The latter were the most frequent species of the Park. On the tropical scale, Vetaas (1992) detected some similar taxa on an arid misty mountain plateau in Sudan and concluded that the species composition, at all spatial scales, was directly or indirectly related to variation in temperature and moisture. Frederiksen & Lwesson (1992), while dealing with the vegetation types and patterns in Senegal, described communities dominated by *Calotropis procera*, *Acacia tortilis* and *Ziziphus* Mill. spp. in the Sahelian grassland.

The floristic richness of the Gebel Elba Park might be better understood by comparing it to other known taxonomic groups and/or regions located in Egypt. The Park contains approximately 9% of the 2094 vascular plant species found in Egypt (Boulos, 1995) (Table 2). The floristic richness of the Park can be compared also to that of other floristically known regions in Egypt, which show different physiographic and geomorphologic features and vegetation communities (Figure 3). The ratios species/genera and genera/families for the Gebel Elba Park and other floristically known regions in Egypt (Table 3) indicated higher taxonomic diversity (lower ratios) in the Park than in other regions. Pielou (1975) and Magurran (1988) pointed out that, in intuitive terms, hierarchical (taxonomic) diversity will be higher in an area in which the species are divided amongst many genera as opposed to one in which most species belong to the same genus, and still higher as these genera are divided amongst many families as opposed to few. The present study revealed that the Gebel Elba Park is more diverse than other, well-studied regions in Egypt.

Life forms

The life-form spectrum in the present study is characteristic of an arid desert region with the dominance of therophyes (48% of the recorded species; Figure 4), followed by phanerophytes and chamaephytes (16.2% for each) and hemicryptophytes (13.5%). The majority of annuals were winter species or cool season species; some

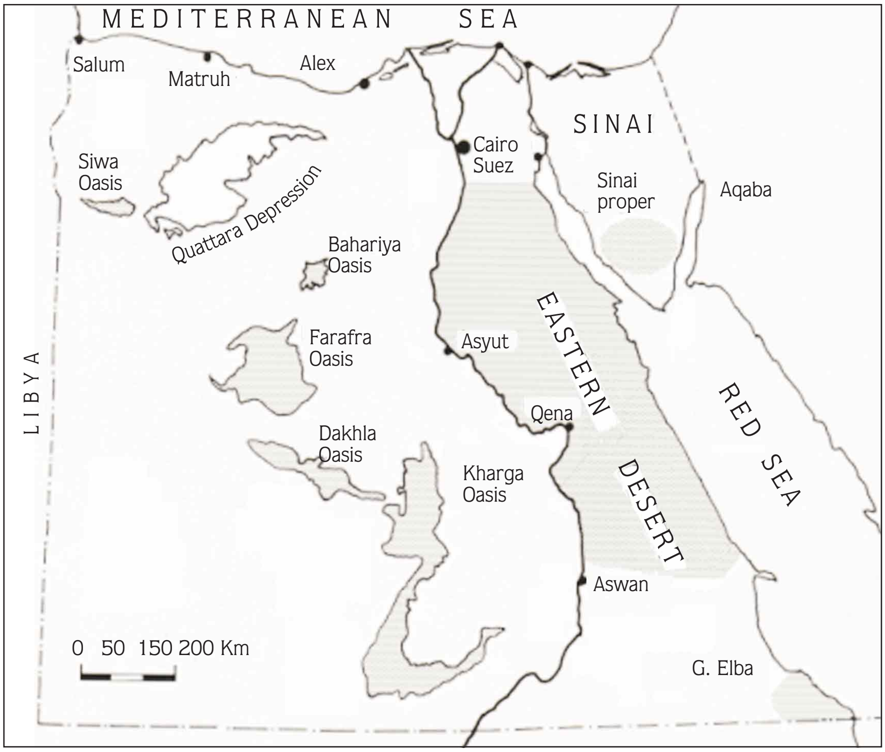

Figure 3. Geographical distribution of the floristic richness of the Gebel Elba Park with other well-studied regions in Egypt (see Table 3).

Table 3. Comparative floristic richness and taxonomic diversity in some Egyptian regions and in the Gebel Elba Park (see Figure 3). Sources:1 = Hassan (1987); 2 = Ayyad et al. (2000); 3 = Abd El-Ghani & El-Sawaf (2004).

	Gebel Elba Park	Eastern Desert (the whole area)[1]	Sinai Peninsula (the whole area)[2]	Sinai proper (S El-Tih Desert)[2]	Western Desert[3]
Total number of species (S)	179	433	1217	716	328
Total number of genera (G)	124	266	566	422	212
Total number of families (F)	51	64	125	105	59
S/G	1.4	1.6	2.1	1.7	1.5
G/F	2.2	4.1	4.5	4.0	3.6

were hot-weather species (e.g., *Amaranthus graecizans* L. subsp. *graecizans, Portulaca oleracea* L., *Eragrostis ciliaris* (L.) R.Br., *Corchorus depressus* (L.) Stocks and *Setaria viridis* (L.) Beauv.), and a few were non-seasonal species responding to rainfall at any time of the year (e.g., *Tribulus terrestris* L., *Chenopodium murale* L. and *Launaea capitata* (Spreng.) Dandy. The occurrence of the 2 parasitic plants *Cuscuta chinensis* Lam. and *C. pedicellata* Ledeb. (leafless or functionally so) denotes the importance of water conservation. As in most arid regions, the desert vine species were few, i.e. *Plicosepalus acaciae* (Zucc.) Wiens & Polhill, *P. curviflorus* (Benth. ex Oliv.) Tiegh., *Citrullus colocynthis* (L.) Schrad., *Coccinia grandis* (L.) Voigt, *Cocculus pendulus* (J.R. & G.Forst.) Diels and *Cucumis prophetarum* Juss. subsp. *prophetarum*. The dominance of shrubby plant species over the grasses was evident. The relative advantage of shrubs over grasses when water is limited, as in this area, can be explained by their extensive root systems, which are capable of utilising water stored at different soil

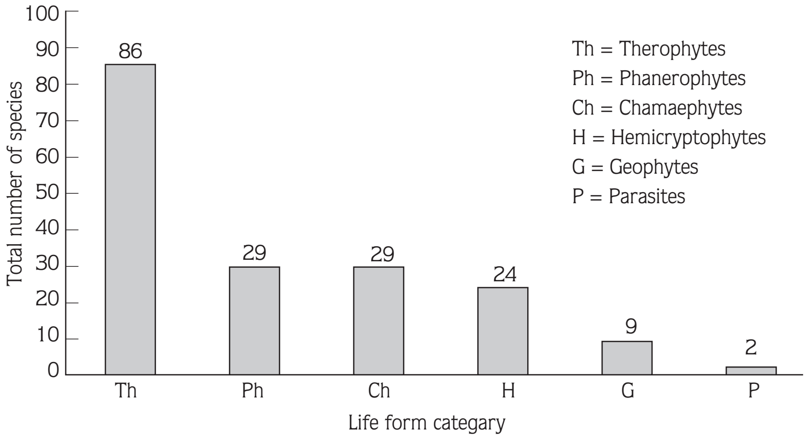

Figure 4. Life form spectrum of the vascular flora of Gebel Elba Park.

depths, whereas grasses utilise the transient water stored in the upper soil synchronic with precipitation pulses. Besides the spatial variations in the species composition of plant communities, the composition of life forms reflects the response of vegetation to variations in certain environmental factors. In this study, the dominance of therophytes, phanerophytes and chamaephytes over other life forms seem to be a response to the hot dry climate, topographic variations and human and animal interference.

Therophytes (annuals) are drought evaders in the sense that the whole plant is shed during the unfavourable conditions. Moreover, the high proportion of therophytes in this study is also attributed to human activities according to Barbero et al. (1990). It is also necessary to point out that the increase in both *Leguminosae* and therophytes in a local flora can be considered a relative index of disturbance for Mediterranean ecosystems. Regardless of the altitude or type of ecosystem, it was noted that the increase in grazing pressure throughout the southern Mediterranean ecosystems leads to the occupation of the understories by invasive therophytes and indicates hyperdegradation (forest therophytisation).

The remarkably high percentages of phanerophytes and chamaephytes (16.2% for both) must also be emphasised. The dominant perennials were the non-succulent trees and shrubs (or subshrubs) and the perennial herbs. Some of these perennials are drought enduring plants in which the photosynthetically and transpiring organs were maintained at nearly constant proportion (Abdel-Razik et al., 1984). A comparison of the life-form spectra of the northern part of the Eastern Desert of Egypt (Abd El-Ghani, 1998), and those in the Tihama coastal plains of Jazan region in south-western Saudi Arabia (El-Demerdash et al., 1994) showed the same results.

Spatial distribution patterns of species

None of the 93 perennial species occurred at all the 16 studied sites, whereas the annuals, i.e. *Amaranthus graecizans* subsp. *graecizans, Achyranthes aspera* L. var. *sicula* L. and *Sisymbrium erysimoides* Desf., showed the highest species occurrences (56% for the first, 50% for the other two species) in the flora. Ninety-two species or 51.4% of the total recorded species (179) demonstrated a certain degree of consistency, where they were exclusively recorded in or confined to a certain site or groups of sites. These species were distributed as follows: 12 in W. Aideib (e.g., *Plicosepalus acaciae, Indigofera spinosa* Forssk., *Coccinia grandis* (L.) Voigt, *Commicarpus boissieri* (Heimerl) Cufod. and *Delonix elata* (L.) Gamble), 58 in W. Yahameib (e.g., *Acacia oerfota* (Forssk.) Schweinf. var. *oerfota*, A. asak (Forssk.) Willd., *Balanites aegyptiaca*, *Cocculus pendulus, Ochradenus baccatus* Del., *Dracaena ombet* Ky & Peyr., *Dodonaea viscose* Jacq., *Rhus tripartita* (Ucria) Grande, *Euclea racemosa* Murray subsp. *schimperi* (A.DC.) F.White, *Ophioglossum polyphyllum* A.Br. and *Aneilema tacazzeanum* Hochst. ex C.B.Cl.), 9 in W. Darawina (e.g., *Ruellia patula* Jacq., *Peristrophe paniculata* (Forssk.) Brummitt, *Euphorbia granulata* Forssk. var. *glabrata* Boiss. and *Blainvillea acmella*), 6 in W. Shellal (e.g., *Ficus palmata* Forssk., *Acacia mellifera* (Vahl) Benth., *Ziziphus spina-christi* (L.) Willd. and *Boerhavia elegans* Choisy), 2 in W. Topeet (*Launaea procumbens* (Roxb.) Lack and *Senecio flavus* (Decne.) Sch.) and 5 in W. Sarara (e.g., *Melanoloma pullatum* (L.) Fourr. and *Leptothrium senegalense* (Kunth) Clayton).

Sørensen's coefficients of floristic similarities between the 6 studied wadis were generally low, indicating smooth species composition changes among the wadis (Table 4). Significant positive similarity and the highest beta diversity were between W. Yahameib and W. Aideib, but a negative significant correlation was estimated between W. Sarara and W. Yahameib. Floristic composition in the 6 studied sites showed differences in species richness. The highest species richness value was recorded in W. Yahameib (123 species), whereas the lowest was recorded in W. Sarara (12 species). W. Yahameib, therefore, was the most diversified among the other studied wadis.

From the dendrogram in Figure 5, 4 main groups (I-IV) can be recognised. Wadi Darawina (group IV) was markedly dissimilar from the others. Two other large groups were closely associated; the first includes W. Yahameib and W. Aideib (group I) and the other includes W. Sarara and W. Shellal (group II). DCA supported this classification, which indicates a reasonable segregation among these groups along the ordination plane of axes 1 and 2 (Figure 6). In the present study, DCA estimated the compositional gradient in the vegetation data along DCA axis 1 to be larger than 4.8 SD-units for all subset analyses, indicating that a complete turnover in species composition took place (Hill, 1979). The 4 DCA axes explain 30.1% of the total variation in the species data. This low percentage of variance explained by the axes was attributed to the many zero values in the data set. DCA axis 1 may represent a geographical trend in the floristic data set, where W. Shellal and W. Sarara are located in the southern part of the region, while the other wadis are located in the northern part.

Table 4. Sørensen's coefficients of floristic similarity (lower half), and the beta diversity (upper half) between the studied wadis in the Gebel Elba Park. A = Wadi Aideib, Y = W. Yahameib, D = W. Darawina, Sh = W. Shellal, T = W. Topeet, and S = W. Sarara. ** = P significant at 0.01 level, * = P significant at 0.05 level

Wadis	A	Y	D	Sh	T	S
A		0.60	0.3	0.1	0.2	0.05
Y	0.3**		0.3	0.2	0.2	0.07
D	0.1	0.07		0.2	0.07	0.03
Sh	-0.07	-0.07	0.04		0.1	0.1
T	0.1	0.15	-0.05	0.15		0.1
S	-0.06	-0.15*	-0.09	0.08	0.04	

Species richness versus altitudinal gradient: a case study

Our study showed variations in floristic composition and species richness along an altitudinal gradient in Wadi Yahameib (Figure 7). These variations may be attributed

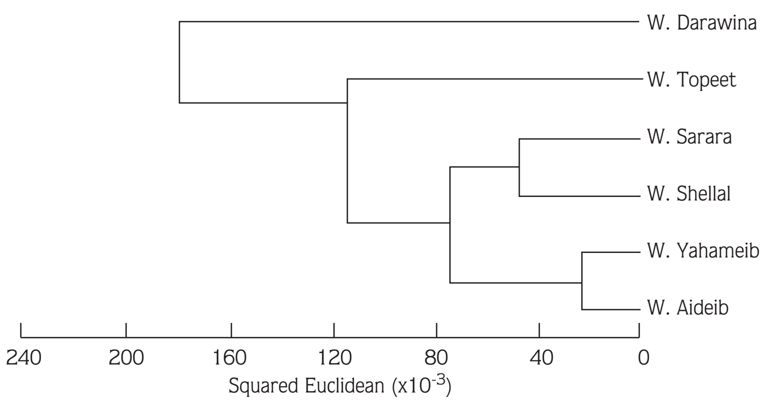

Figure 5. Dendrogram of similarity among the wadis analysed.

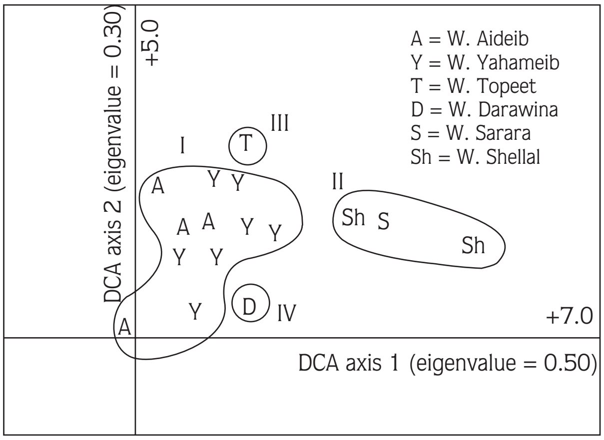

Figure 6. Detrended correspondence analysis (DCA) ordination diagram of 16 sample plots and sites represent the four cluster groups (I-IV) resulted in Figure 5.

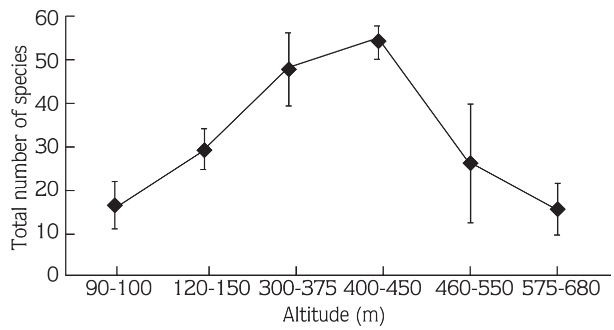

Figure 7. Species richness along the altitudinal gradient of W. Yahameib.

to the climatic differences, substrate discontinuities and mountainous escarpment along the altitudinal gradient. It may be noted that species richness on W. Yahameib was highest (ranged from 47 ± 7.3 to 53 ± 11.0 species) in the middle altitudes from 300m to 450m. This zone on the mountain was probably more climatically equable for plant growth and diversity than either lower (90 to 250m) or higher (460 m to 680 m) altitudes. At lower altitudes (species richness ranged between 15 ± 6.4 and 28 ± 8.6), the temperature is higher and the climate more arid, and although higher altitudes (species richness ranged between 13 ± 5.5 and 24 ± 9.4) are less arid the temperatures are much lower. Records of some ferns such as *Actinopteris semiflabellata* Pic. Serm, *Onychium divaricatum* (Poir.) Alston and *Ophioglossum polyphyllum* A. Braun of less arid habitats was further evidence of this. It can also be noted that trees were frequently occurred and constitute the main bulk of the plant cover, and in certain instances may form forest-like growth at the middle and higher altitudes of the wadi. Trees and shrubs of *Olea europaea* L. subsp. *africana, Ficus salicifolia*, *Acacia tortilis* subsp. *tortilis, Dracaena ombet, Euclea* spp., *Dodonaea viscosa, Delonix elata* and *Rhus* spp. were recorded. *Dracaena ombet* was recorded in the middle and higher zones of the north and east slopes of Gebel Elba. In several localities there were limited groves of this tree, otherwise there were isolated individuals. Reference may be made to the studies on the growth of *D. ombet* within the Sudanese coastal mountains including the mist oasis of Erkwit (Kassas, 1956, 1960). The occurrence of *Dracaena* in the Gebel Elba area represents its most northern limit within the Red Sea coastal mountains (Kassas & Zahran, 1971). This pattern of altitudinal variation in species diversity can be contrasted with that of wet tropical mountains, where species richness decreases linearly with increasing altitude (Oshawa et al., 1985). The altitudinal pattern of plant diversity in W. Yahameib, where the highest diversity occurs at middle altitudes on the mountain, may be more typical of arid mountains in desert regions. These results were consistent with other studies on diversity-altitude relationships from the arid region as in Asir Mountains of southwestern Saudi Arabia (Abulfatih, 1984; Hegazy et al., 1998), in Jebel Tageru of the southern Libyan Desert (Neumann, 1987), in Jabal Shams of Oman (Ghazanfar, 1991), in the central Hijaz mountains of Saudi Arabia (Abd El-Ghani, 1997), on the eastern and western sides of the Red Sea (Hegazy & Amer, 2001), in Al-Jabal Al-Akhadar of Libya (Al-Sodany et al., 2003), and in the arid parts of Chile (Hoffmann & Hoffmann, 1982).

Phytogeographical affinities

The present attempt at a phytogeographical analysis of the studied area must be regarded as provisional, due to the still poorly known overall distribution features of many taxa. With regard to the relation between biogeographic elements (geoelements) and life forms (Table 5), therophytes, the most abundant life form, were important in all categories. Trees and shrubs were also more or less fairly represented in almost all categories. Annuals contributed largely to the Saharo-Arabian element. In turn, the Saharo-Arabian element was well represented in the flora of the Gebel Elba Park, and constituted 48% of the recorded taxa. In fact,

Table 5. Distribution of the geoelements among life forms (%). N = Number of species, Ph = Phanerophytes, Ch = Chamaephytes, H = Hemicryptophytes, G = Geophytes, Th = Therophytes, P = Parasites, COSM = Cosmopolitan, PAL = Palaeotropical, PAN = Pantropical, ME = Mediterranean, IT = Irano-Turanian, SA = Saharo-Arabian, SZ = Sudano-Zambezian, Afr. mont..= Afromontane, Afr. alp.= Afroalpine.

Life Form	COSM		PAL		PAN		ME		IT		SA		SZ		Afr. mont., Afr. alp.	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	M	%
Ph (29)	-	-	1	3.4	-	-	1	3.4	-	-	18	62.1	9	31.1	-	-
Ch (29)	1	3.4	1	3.4	1	3.4	1	3.4	-	-	20	69.1	5	17.3	-	-
H (24)	-	-	3	12.5	-	-	3	12.5	-	-	14	58.3	4	16.7	-	-
G (9)	1	11.1	1	11.1	1	11.1	-	-	-	-	4	44.4	2	22.3	-	-
Th (86)	4	4.7	11	12.8	5	5.8	20	23.2	1	1.2	28	32.6	15	17.4	2	2.3
P (2)	-	-	-	-	-	-	-	-	-	-	2	100.0	-	-	-	-
Total (179)	6	3.3	17	9.5	7	3.9	25	14.0	1	0.6	86	48.0	35	19.6	2	1.1

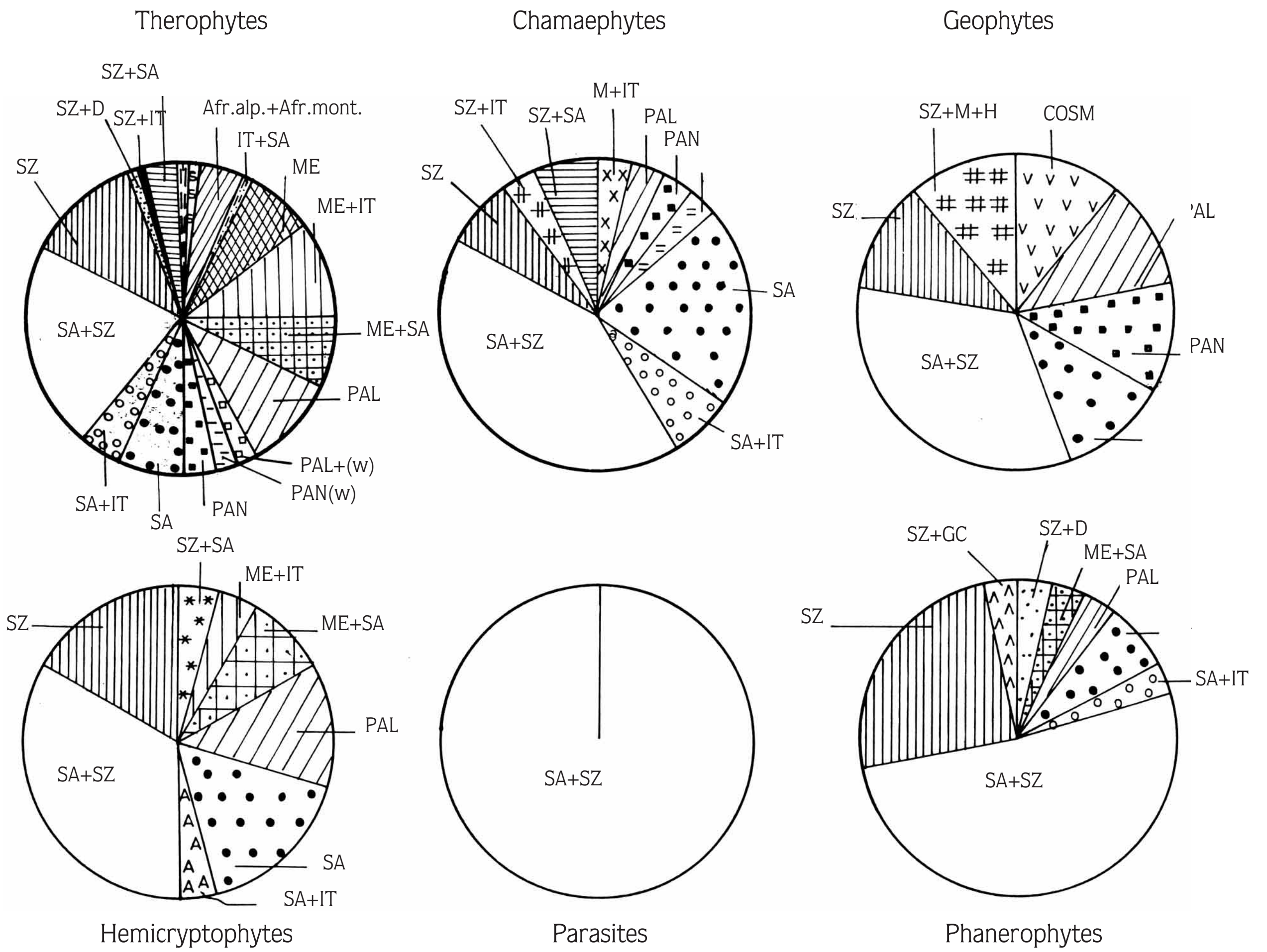

Figure 8. Distribution of the chorotypes in the life form categories. D= Deccan, H= Himalayan, M= Madagascan, GC= Guineo-Congo. For other chorotype abbreviations, see Table 5.

chamaephytes, phanerophytes and hemicryptophytes make a substantial contribution to the Saharo-Arabian and Sudano-Zambezian geoelements.

The importance of the study area from a phytogeographical point of view may be due to its position straddling the boundaries of the Arabian Desert (with its typical Saharo-Arabian geoelement) to the north and the highlands of the Sudan (with its typical Sudanian geoelement) to the south. As the study area is within the Saharo-Arabian belt of the Holarctic floristic realm, the analysis of the floristic data showed the prevalence of the Saharo-Arabian geoelement (Figure 8). The Sudano-Zambezian geoelement ranked second. According to Wickens (1976), the Sudano-Zambezian region is bounded to the north by the desert and semi-desert of the Saharao-Arabian region, while in the south it extends to the desert and semi-desert of the Karoo-Namib region. The extent of this geoelement in south-eastern Egypt and along the western coast of the Red Sea has not yet been satisfactorily determined.

It is worth mentioning that the monoregional (pure) Sudano-Zambezian geoelement was not represented further north in the Arabian Desert (Abd El-Ghani, 1998), whereas it constituted 14% of the flora of the studied area. These geoelements are more typical of the southern Egyptian Desert (Bornkamm & Kehl, 1990; Springuel et al., 1997; Abd El-Ghani et al., 2003). Thus, the tree and shrub layer is composed mainly of Saharo-Arabian geoelement with a Sudano-Zambezian focus of distribution. The Mediterranean geoelement was modestly represented in the tree and shrub layer. This may be attributed to the fact that plants of the Saharo-Arabian and Sudano-Zambezian geoelements are good indicators for harsh desert environmental conditions, while Mediterranean species stand for more mesic conditions. It can be, therefore, concluded that the flora of the Gebel Elba Park represents a continuation of the Sudanian tropical region with very similar climatic and topographic conditions. Further studies should attempt to define the environmental constraints on the species distribution recorded here.

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APPENDIX

The floristic list. Studied wadis: 1 = Wadi Aideib, 2 = W. Yahameib, 3 = W. Darawina, 4 = W. Topeep, 5 = W. Shellal, 6 = W. Sarara. + = recrorded, - = not recorded, LF = Life form. For life forms and chorotype abbreviations, see Table 5 and Figure 8.

Family	Species	LF	Studied wadis						Chorotype
			1	2	3	4	5	6	
Acanthaceae	*Justicia heterocarpa* T. Anderson subsp. *heterocarpa*	Th	+	-	-	-	-	-	SA + SZ
	J. ladanoides Lam.	Th	-	+	-	-	-	-	SZ
	Peristrophe paniculata (Forssk.) Brummitt	Th	-	-	+	-	-	-	SZ + D
	Ruellia patula Jacq.	Ch	-	-	+	-	-	-	SZ + M + D
Actiniopteridaceae	*Actiniopteris semiflabellata* Pic.Serm.	G	-	+	-	-	-	-	SZ + M + H
Adiantaceae	*Onychium divaricatum* (Poir.) Alston	G	-	+	-	-	-	-	COSM (Weed)
Agavaceae	*Dracaena ombet* Ky & Peyr.	Ph	-	+	-	-	-	-	SZ
Aizoaceae	*Aizoon canariense* L.	Th	+	+	+	-	-	-	SA + SZ
Amaranthaceae	Achyranthes aspera L. var. sicula L.	Th	+	+	+	-	-	-	PAN
	Aerva javanica (Burm.f.) Juss. ex Schult. var. *javanica*	Ch	+	+	-	-	-	-	SA + SZ
	A. lanata (L.) Juss. ex Schult.	Ch	+	+	-	-	-	-	SA + SZ
	Amaranthus graecizans L. subsp. *graecizans*	Th	+	+	+	-	-	+	PAL
Amaryllidaceae	*Pancratium tortuosum* Herb.	G	-	+	-	-	-	-	SA
Anacardiaceae	*Rhus abyssinica* Hochst.	Ph	-	+	-	-	-	-	SA + SZ
	R. flexicaulis Baker	Ph	-	+	-	-	-	-	SA + SZ
	R. tripartita (Ucria) Grande	Ph	-	+	-	-	-	-	SA + SZ
Asclepiadaceae	*Glossonema boveanum* (Decne.)								
	Decne. subsp. *nubicum* (Decne.) Bullock	H	-	+	-	-	-	-	SZ
	Pergularia tomentosa L.	Ch	-	+	-	-	-	-	SA + SZ
Boraginaceae	*Arnebia hispidissima* (Lehm.) DC.	Ch	+	-	-	-	-	-	SA + SZ
	Heliotropium aegyptiacum Lehm	Ch	-	+	-	+	-	-	SA + SZ
	H. arbainense Fres.	Ch	-	+	-	-	-	-	SA + SZ
	H. zeylanicum (Burm.f.) Lam.	Th	+	+	-	-	-	-	SA + SZ
	Trichodesma ehrenbergii Schweinf.	Ch	-	+	+	+	-	-	SZ
Caryophyllaceae	*Cometes abyssinica* R.Br. ex Wall	Ph	+	-	-	-	-	-	SZ
	Paronychia argentea Lam.	Th	-	+	-	-	-	-	ME
	Polycarpaea robbairea (Kuntze) Greuter & Burdet	Th	-	+	-	-	-	-	SA + SZ
	Sclerocephalus arabicus Boiss.	Th	-	+	-	-	-	-	ME + IT
	S. linearis Decne.	Th	+	-	-	-	-	-	SA
	Spergula diandra (Guss.) Boiss.	Th	+	-	-	-	-	-	ME + SA + IT
	S. fallax (Lowe) E.H.L.Krause	Th	+	+	+	-	-	-	ME + SA + IT
Chenopodiaceae	*Chenopodium murale* L.	Th	+	+	+	-	-	-	COSM (Weed)
Cleomaceae	*Gynandropsis gynandra* (L.) Briq.	Th	-	+	-	-	-	-	PAL (Weed)
Commelinaceae	*Aneilema tacazzeanum* Hochst. ex C.B.Cl.	Th	-	+	-	-	-	-	SZ
	Commelina benghalensis L.	Th	+	+	-	-	-	-	PAN (Weed)
	C. forsskalei Vahl	Th	+	+	-	-	-	-	SZ
Compositae	*Bidens bipinnata* L.	Th	+	-	-	-	-	-	PAN (Weed)
	B. schimperi Sch.Bip.	Th	-	+	+	-	-	-	SZ
	Blainvilla acmella (L.) Philipson	Th	-	-	+	-	-	-	PAL (Weed)
	Calendula arvensis L.	Th	-	+	+	-	-	-	PAN (Weed)
	C. tripterocarpa Rupr.	Th	-	+	-	-	-	-	SA + IT
	Carthamus nitidus Boiss.	Th	-	-	-	-	-	+	IT + SA
	Centaurea aegyptiaca L.	Th	-	-	-	-	-	+	SA
	Echinops hussonii Boiss.	H	-	+	-	-	-	-	SA + SZ
	Filago prolifera Pomel	Th	-	-	+	-	-	-	SA + IT
	Helichrysum glumaceum DC.	Th	+	+	-	-	-	-	SZ
	Ifloga spicata (Forssk.) Sch. Bip. subsp. *elbaensis* Chrtek	Th	-	+	-	-	-	-	SA + SZ
	Launaea capitata (Spreng.) Dandy	Th	-	+	-	-	-	-	SA
	L. massauensis (Fresen.) Sch.Bip. ex Kuntze	Th	+	-	-	-	-	-	SA + SZ
	L. nudicaulis (L.) Hook.f.	H	-	-	-	+	-	+	SA + SZ + IT
	L. procumbens (Roxb.) Lack	Th	-	-	-	+	-	-	SA + IT
	Osteospermum vaillantii (Decne) T.Norl.	Th	+	-	-	-	-	-	Afr.mont.
	Reichardia picroides (L.) Roth	Th	-	-	+	-	-	-	ME

Appendix con.

	R. tingitana (L.) Roth	Th	+	+	-	-	-	-	ME + SA + SZ
	Senecio flavus (Decne.) Sch.	Th	-	-	-	+	-	-	SA + SZ
Convolvulaceae	*Convolvulus hystrix* Vahl	H	+	+	-	-	-	-	SA + SZ
	C. rhyniospermus Choisy	Th	-	+	-	-	-	-	SZ + IT
	C. siculus L. subsp. *agrestis* (Hochst. ex Schweinf.) Verdc.	P	-	+	-	-	-	-	ME + IT
	Cuscuta chinensis Lam.	P	+	+	-	-	-	+	SA + SZ
	C. pedicellata Ledeb.	H	-	-	+	-	-	-	SA + SZ
	Ipomoea obscura (L.) Ker-Gawl.	Ch	+	+	-	-	-	-	PAL
	Seddera arabica (Forrsk.) Choisy	Ch	+	-	-	-	-	-	SZ
Cruciferae	*Diceratella elliptica* (DC.) Jonsell	H	+	+	-	+	-	-	SZ
	Diplotaxis erucoides (L.) DC.	Th	-	+	-	-	-	-	ME + IT
	Farsetia longisiliqua Decne.	Ch	+	+	-	+	-	-	SZ + SA
	Sisymbrium erysimoides Desf.	Th	+	-	+	+	-	-	ME + SA
Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	H	+	+	-	+	-	-	ME + SA
	Coccinia grandis (L.) Voigt	H	+	-	-	-	-	-	PAL
	Cucumis prophetarum Juss. subsp. *prophetarum*	H	-	+	-	-	-	-	SA + SZ
Cyperaceae	*Cyperus bulbosus* Vahl	G	-	+	-	-	-	-	SA + SZ
	C. conglomeratus Rottb. var. *multiculmis* (Boeck.) Kukenth.	G	-	+	-	-	-	-	SA + SZ
	C. rotundus L.	G	-	+	-	-	-	-	PAN (Weed)
Ebenaceae	*Euclea racemosa* Murray subsp. *schimperi* (A.DC.) F.White	Ph	-	+	-	-	-	-	SZ + GC
Ephedraceae	*Ephedra ciliata* Fisch. & Mey ex C.A.Mey	Ph	+	+	-	-	-	-	ME + SA
Euphorbiaceae	*Chrozophora oblongifolia* (Delile) Spreng.	Ch	-	+	-	-	-	-	ME + IT
	Euphorbia arabica T.Anderson	H	+	-	-	-	-	-	SZ
	E. consobrina N.E.Br.	Ch	+	+	-	-	-	-	SZ
	E. forsskaolii J.Gay	H	+	+	-	-	-	+	SZ
	E. granulata Forssk. var. *glabrata* Boiss.	H	-	-	+	-	-	-	SA + SZ
	E. grossheimii (Prokh.) Prokh.	H	-	-	-	-	-	+	SA + IT
	Phyllanthus rotundifolius Willd.	Th	+	+	+	-	-	-	PAL
Geraniaceae	*Erodium laciniatum* (Cav.) Willd. subsp. *laciniatum*	Th	+	+	-	-	-	-	ME
	E. neuradifolium Del. ex Godron	Th	+	+	-	-	-	-	ME + SA + SZ
	Geranium biuncinatum Kokwaro	Th	+	+	+	-	-	-	SZ + SA
Gramineae	*Cenchrus setigerus* Vahl	Th	-	+	-	-	-	-	PAL
	Eragrostis ciliaris (L.) R.Br.	Th	-	+	-	+	-	-	PAN
	E. tenella (L.) P.Beauv. ex Roem. & Sch.	Th	+	+	-	-	-	-	PAL
	Leptothrium senegalensis (Kunth) Clayton	G	-	-	-	-	-	+	SZ
	Melanoloma pullatum Cass.	H	-	-	-	-	-	+	SA + SZ
	Panicum turgidum Forssk.	G	-	+	-	-	-	-	SA + SZ
	Pennisetum setaceum (Forssk.) Chiov.	H	-	+	-	-	-	+	SA
	Setaria verticillata (L.) P.Beauv.	Th	-	+	-	-	-	-	ME
	S. viridis (L.) Beauv.	H	-	+	-	-	-	-	COSM (Weed)
	Stipa capensis Thunb.	Th	-	+	-	-	-	-	PAL
	Stipagrostis ciliata (Desf.) De Winter	H	-	+	-	-	-	-	ME + IT + SA
Juncaceae	*Juncus rigidus* C.A.Mey.	H	-	+	-	-	-	-	PAL
Labiatae	*Lavandula coronopifolia* Poir.	Ch	-	+	-	-	-	-	SA + SZ
	L. multifida L.	H	-	+	-	-	-	-	ME + SA
	Ocimum forsskaolii Benth.	H	+	+	-	-	-	-	SA
	Salvia aegyptiaca L.	H	+	+	-	-	-	-	SA + SZ
Leguminosae	*Acacia asak* (Forssk.) Willd.	Ph	-	+	-	-	-	-	SA + SZ
	A. mellifera (Vahl) Benth.	Ph	-	-	-	-	+	-	SA + SZ
	A. oerfota (Forssk.) Schweinf.	Ph	-	+	-	-	-	-	SA + SZ
	A. tortilis (Forssk.) Hayne subsp. *tortilis*	Ph	-	+	-	-	-	-	SZ
	Crotalaria impressa Nees ex Walp.	Th	+	-	-	-	-	-	SA + SZ
	C. microphylla Vahl	Th	+	+	-	+	-	-	SZ + SA
	C. senegalensis (Pers.) DC.	Th	+	+	-	-	-	-	SA + SZ
	Delonix elata (L.) Gamble	Ph	+	-	-	-	-	-	SZ
	Indigofera spinosa Forssk.	Ch	+	-	-	-	-	-	SA + SZ
	Lotus glinoides Delile	Th	-	+	-	+	-	-	SA + SZ
	Rhynchosia pulverulenta Stocks	Ph	-	+	-	-	-	-	SZ
	Senna italica Mill.	H	-	+	-	-	-	+	SA + SZ

Appendix con.

	Tephrosia purpurea (L.) Pers. subsp. *apollinea* (Delile) Hosni & El-Karemy	Ch	+	-	-	-	-	-	SA
Liliaceae	*Asphodelus fistulosus* L. var. *tenuifolius* Cav.	Th	+	+	-	-	-	-	SA + SZ + ME
Loranthaceae	*Plicosepalus acaciae* (Zucc.) Wiens & Polhill	Ph	+	-	-	-	-	-	SZ
	P. curviflorus (Benth. ex Oliv.) Tiegh.	Ph	+	+	-	-	-	-	SZ
Malvaceae	*Abutilon bidentatum* A.Rich.	Ch	-	+	-	-	-	-	SA
	A. pannosum (G.Forst.) Schltdl.	Ch	-	-	+	-	-	-	SA
	Hibiscus vitifolius L.	Ch	+	+	-	-	-	-	PAL
	Malva parviflora L.	Th	-	+	-	-	-	-	ME + IT
Menispermaceae	*Cocculus pendulus* (J.R. & G.Forst.) Diels	Ph	-	+	-	-	-	-	SA + SZ
Molluginaceae	*Gisekia pharnaceoides* L. var. *pharnaceoides*	Th	-	+	-	-	+	-	SA
Moraceae	*Ficus palmata* Forssk.	Ph	-	-	-	-	+	-	SA
	F. salicifolia Vahl	Ph	+	+	+	-	-	-	SA + SZ
Neuradaceae	*Neurada procumbens* L.	Th	-	+	-	-	-	-	SA + SZ
Nyctaginaceae	*Beorhavia elegans* Choisy	Ch	-	+	-	-	+	-	PAN (Weed)
	B. repens L. subsp. *viscosa* (Choisy) Maire	Ch	-	+	-	-	-	-	SA + SZ
	Commicarpus boissieri (Heimerl) Cufod.	Ch	+	-	-	-	-	-	SA + IT
	C. helenae (Schult.) Meikle	Ch	+	+	-	+	-	-	SA + IT
Ophioglossaceae	*Ophioglossum polyphyllum* A.Br.	G	-	+	-	-	-	-	PAL
Plantaginaceae	*Plantago afra* L.	Th	+	+	-	-	-	-	ME + IT
	P. amplexicaulis Cav.	Th	+	-	-	+	-	-	ME + SA + SZ
Polygonaceae	*Calligonum polygonoides* L. subsp. *comosum* (L' Hér.) Soskov	Ph	-	+	-	-	-	-	SA + IT
	Oxygonum sinuatum (Meisn.) Dammer	Th	-	+	-		-	-	SZ
	Rumex simpliciflorus Murb.	Th	+	+	+	-	-	-	SA + SZ
	R. vesicarius L.	Th	-	+	-	-	-	-	SA
Portulacaceae	*Portulaca oleracea* L. subsp. *oleracea*	Th	-	+	-	-	-	-	COSM (Weed)
Primulaceae	*Anagallis arvensis* L. var. *caerulea* Gouan	Th	-	-	+	-	-	-	COSM (Weed)
Resedaceae	*Caylusea hexagyna* (Forssk.) M.L.Green	Th	+	+	+	-	-	-	SA + SZ
	Ochradenus baccatus Del.	Ph	-	+	-	-	-	-	SA + SZ
Rhamnaceae	*Ziziphus spina-christi* (L.) Willd.	Ph	-	-	-	-	+	-	SA + SZ
Rubiaceae	*Galium setaceum* Lam.hb	Th	-	+	-	-	-	-	ME + IT
Sapindaceae	*Dodonaea viscosa* Jacq.	Ph	-	+	-	-	-	-	PAL
Scrophulariaceae	*Kickxia hastata* (R. Br. ex Benth.) Dandy	Ch	-	-	+	-	+	-	SA
	K. heterophylla (Schousb.) Dandy	Th	-	+	-	-	+	-	SA
	Lindenbergia indica (L.) Vatke	Th	-	+	+	-	+	-	PAL
	Misopates orontium (L.) Rafin.	Th	-	+	+	-	-	-	SZ
	Scrophularia arguta Sol.	Th	-	+	+	-	-	-	SA + SZ
Solanaceae	*Lycium shawii* Roem. & Schult.	Ph	+	+	+	-	-	-	SA + SZ
	Solanum forsskaolii Dunal	Ph	+	+	-	+	-	-	SZ
	S. incanum L.	Ch	+	-	-	-	-	-	SA
	S. nigrum L. var. *elbaensis* Täckh. & Boulos	Ch	+	+	+	-	-	-	COSM (Weed)
	S. schimperianum Hochst. ex A.Rich.	Th	-	+	-	-	-	-	SZ
	S. villosum Mill. subsp. *villosum*	Th	-	-	-	-	+	-	SA + SZ
Tiliaceae	*Grewia tenax* (Forssk.) Fiori	Ph	-	+	-	-	-	-	SA + SZ
Umbelliferae	*Ammi majus* L.	Th	-	-	+	-	-	-	ME
	Pimpinella etbaica Schweinf.	Th	-	+	-	-	+	+	SZ
Urticaceae	*Forsskalea tenacissima* L.	H	+	+	+	-	-	-	SA + SZ
	F. viridis Her. ex Webb	Th	+	-	+	-	-	-	SA + SZ
	Parietaria debilis G.Forster	Th	-	-	+	-	-	-	PAL
	Urtica urens L.	Th	-	+	-	-	-	-	ME + IT + ES
Zygophyllaceae	*Balanites aegyptiaca* (L.) Del.	Ph	-	+	-	-	-	-	SA + SZ
	Tribulus bimucronatus Viv.	Th	-	+	-	-	-	-	SA + SZ
	T. terrestris L.	Th	-	+	-	-	-	-	PAL
	Zygophyllum simplex L.	Th	-	+	-	-	-	-	PAL

Other species were confined to Gebel Karam Elba (Figure 1), and include: *Calotropis procera*, *Leptadenia pyrotechnica*, *Capparis sinaica*, *Maerua crassifolia*, *Silene burchelli* var. *schweinfurthii*, *Iphiona scabra*, *Launaea mucronata* subsp. *mucronata*, *Convolvulus prostratus*, *Euphorbia dracunculoides* subsp. *dracunculoides*, *Melanocenchris abyssinica*, *Hippocrepis constricta*, *Indigofera coerulea* var. *coerulea*, *Tephrosia uniflora*, *Corchorus depressus* and *Fagonia paulayana.*