Taeckholmia 26: 00-00 (2006)

Regional patterns of rarity and life history elements in the flora of Egypt

Abdel-Hamid A. Khedr

Department of Botany, Mansoura University, New Damietta, 34517, Egypt
Fax:057-2403868, Mobile-0120520698. Email: abdelkhedr@yahoo.com

Khedr, A.A. 2006. Regional patterns of rarity and life history elements in the flora of Egypt. Taeckholmia 26: 00-00

The phytogeographic patterns displayed by 2446 taxa of vascular plants, was analyzed in relation to regional abundances (designated as very common, common, rare, or very rare), in 13 geographic regions, native or introduced status, lifespan, life-form and preferred habitat for the flora of Egypt. More than 70% of the entire flora has been classified as either “very rare” (42.2%) or “rare” (28%). Only 3% of the flora are introduced species. Land use appears to have a critical effect on plant abundance; intensely populated areas in the Nile region have more common or very common species rather than rare and very rare. Annuals and perennials account for approximately equal fractions of the flora (47% each). The spectrum of life-forms is dominated by herbs (75%), Shrubs and shrublets are well-represented while trees are poorly represented (1.3%) in the flora of Egypt.
Floristic diversity was high in the Mediterranean coastal regions and low in all desert areas. Frequency of abundance classes and life history traits varied according to the major habitats (weedy, sandy, saline, freshwater, rocky and gravely). Implications of these results for conservation policy are discussed.

Key words: Conservation, Egypt, flora, Life-forms, plant diversity, rarity

Introduction

To some extent, rarity exists in the eye of beholder; judgments about rarity are often influenced by sometimes arbitrary limits of political boundaries. Thus a globally or regionally cosmopolitan species may be rare in one country and common in another, and be of no conservation interest in the latter but of much concern in the former.

Received 00 October 2006, Revision accepted --------

It is well-recognized that plants may be rare in several ways. For example, they may occur only in rare habitats, or may be localized to a small geographic area, or they may have few individuals distributed across a large area. Rabinowitz *et al.* (1986) distinguished three traits that all species possess. 1) Geographic range: whether a species occurs over a broad area or whether it is endemic to a particular small area. 2) Habitat specificity: the degree to which a species occurs in a variety of habitats or is restricted to one or a few specialized sites. 3) Local population size: whether a species is found in large populations somewhere within its range or consistently has small populations wherever it is found.

Gaston (1994) defined a rare species as one that has a restricted distribution, or that occurs at low densities. This recognizes a dependence on scale, and provides perspective largely based upon the individual autecology and biogeographic extent of a species. Some authors have separated aspects of regional and local rarity, creating designations such as locally abundant, local and rare, etc. (see Clapham *et al.*, 1987). Gaston (1994) made a strong case for abandoning a categorical approach to rarity and suggested that it should instead be viewed as a continuous variable. Unfortunately, however, the kind of distribution and abundance data that would be required to characterize the rarity of members of a flora in quantitative terms are not, so far, available.

A number of authors have correlated elements of plant biology with distributional status and rarity in regional floras (Harper, 1979; Hodgson 1986a, b, c, d; Kunin & Gaston, 1993; Schwartz, 1993; Gaston & Kunin, 1997; Kunin & Schmida, 1997; Médail & Verlaque, 1997; Orians, 1997). In general, rare species are associated with specific (usually restricted) habitats; and often lack the ability to colonize successfully new habitats. They are also more likely to be inbreeders, and capable of clonal growth.

The habitats of an organism and its life history traits have an obvious relationship. I hypothesized that habitat-based associations and life history traits may directly determine the distribution of a species at a regional scale. It seems important to test the generality of such associations in the flora of Egypt.

Among the floras of the Middle East and the Mediterranean region, that of Egypt is comparatively well known. According to Zohary (1973), the native flora of Egypt consists of about 1800 species, very unevenly distributed over the country. The highest density and diversity of species is found in the Mediterranean coastal region, the Nile valley, Gebel Elba, and the mountains of Sinai (see Fig. 1). However, in the country overall, the number of species in proportion to the surface area (total area is a little more than one million [1,001,450] km^2 (Abu Al-Izz, 1971) is exceedingly small, reflecting the fact that extensive areas are sparsely vegetated desert.

The present study examines ecological elements of the flora of Egypt, in relation to the regional distribution and abundance of species. I test the hypothesis that there are differences between rare and common species in terms of their habitat associations and life history traits

Materials and Methods

Egypt: a phytogeographic overview

Egypt extends over about 10 degrees of latitude from 22^oN to 32^oN, including about 1229 km from north to south and about 1073 km from east to west. The country lies mostly within the warm temperate zone, with less than a quarter being south of the Tropic of Cancer. It includes part of a vast desert belt that stretches from the Mediterranean across the whole of North Africa, eastwards to Arabia.

Egypt is characterized by a hot and almost rainless climate (mean annual rainfall over the whole country is only about 10 mm). Even along the narrow northern strip of the Mediterranean coastal land, where most of the precipitation occurs, average annual rainfall is usually less than 200 mm and the amount decreases very rapidly inland (Zahran & Willis, 1992). Figure 1 Boulos (1995) shows the major topographical features of Egypt and the 13 phytogeographic regions recognized in the present study.

In part due to its ancient history, but also because of its geographic position in Africa, with the long coasts of the Mediterranean Sea to the north (c. 970 km) and the Red Sea to the east (c. 1100 km), Egypt has an extensive history of botanical exploration. Phytogeographically, the vegetation of Egypt belongs to the “northern zone of hot summers” (Hassib, 1951), meaning that there is no real winter, though there may be some interruption of growth in January.

Database

I utilized the standard floras for Egypt (Täckholm, 1974, Boulos, 1995, 1999-2005) to create an electronic database, tabulating for each taxon an array of variables including distribution and abundance, botanical features, and life history components. For each species the presence % and abundance in the different regions are used as a measure to define its rarity.

-Abundance of each taxon (within Egypt as a whole and within each of 13 sub-regions) was ranked following the categories of Täckholm (1974, Zahran and Willis 1992 and 2003, Boulos, 1995 and Boulos, 1999-2005): very rare; rare; common; and very common. For certain calculations these were transformed to numerical scores of 1, 2, 3, and 4, respectively.
-Life-form (tree, shrub, shrublet, herb, liana or parasite).
-Lifespan (annual, biennial, perennial, or combination of these)
-Whether a species is native to Egypt or introduced, and if introduced, whether it has become naturalized or not.
-Distribution of each taxon in Egypt was recorded within each of 13 sub-regions according to (Täckholm, 1974).

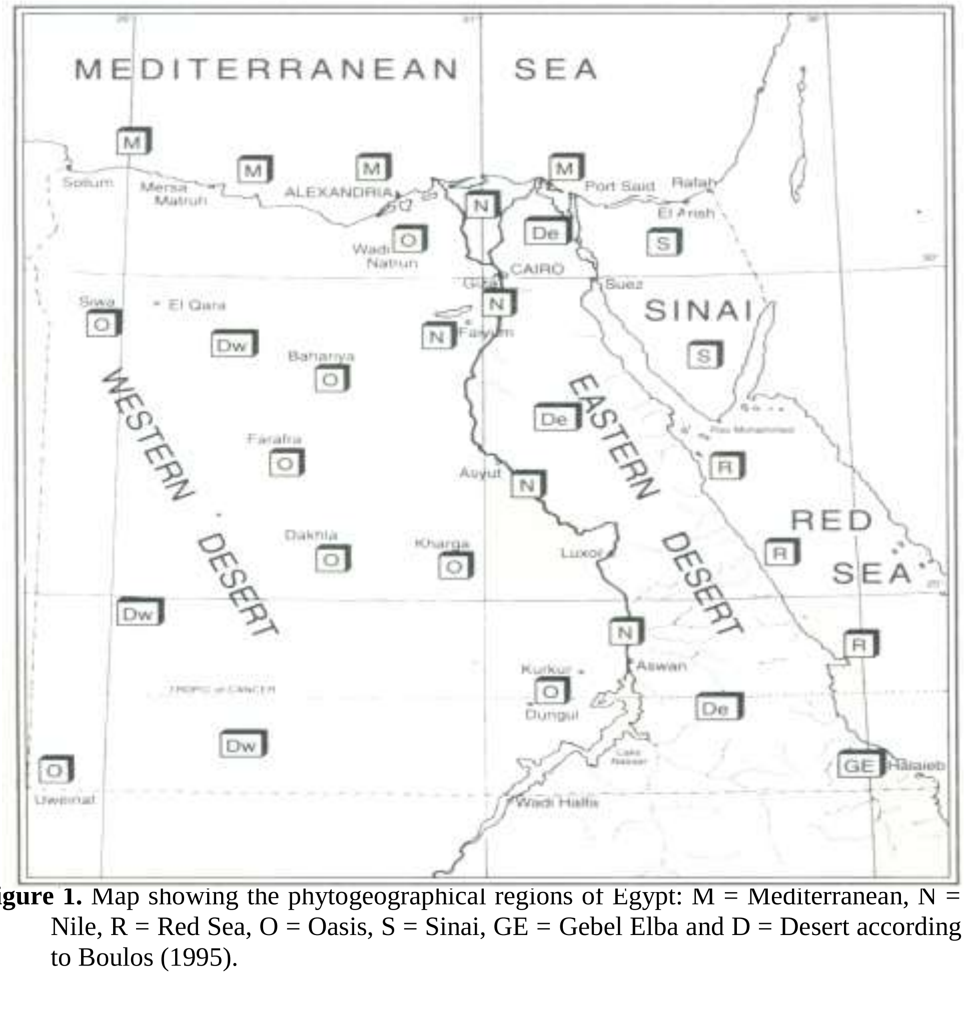

Figure 1. Map showing the phytogeographical regions of Egypt: M = Mediterranean, N = Nile, R = Red Sea, O = Oasis, S = Sinai, GE = Gebel Elba and D = Desert according to Boulos (1995).

1) Nile Delta (‘Lower Egypt’): total area about 24,000 km^2. At the base of the delta, the river splits into two main branches (Rosetta [c. 239 km] and Damietta [c. 245 km]) which are linked by a dense network of canals and drainage channels.

2) Nile Valley (‘Upper Egypt’): total area about 12,000 km^2.

3) Nile Fayium (total area c. 1700 km^2).

4) Oases. The Western Desert is characterized by a number of oases and depressions, fed by underground aquifers and artesian water, including: Siwa Oasis (c. 2100 km^2), Bahariya Oasis (1800 km^2), Dakhla Oasis (c. 850 km^2), Kharga Oasis (c. 4100 km^2), Moghra Oasis (4 km^2), Qattara Depression (c. 19,500 km^2), Wadi El-Natrun Depression (c. 1000 km^2), Gebel Uweinat (c. 1500 km^2), plus many other, smaller oases and depressions such as Farafra Oasis, Dungul Oasis and Kurkur Oasis, (total area of oases c. 31,000 km^2).

5) Western Mediterranean coast (total area c. 11,000 km^2). Coastal strip extending 550 km from Sollum to Rosetta.

6) Eastern Mediterranean coast (total area c. 4800 km^2). Extends 240 km between Port Said and Rafah [Latitude 31^o 12'N]).

7) Western (‘Libyan’) Desert: total area c. 681,000 km^2. The huge Western Desert extends from the Mediterranean coast in the north to the Sudanese border in the south (c.1073 km) and from the Nile Valley in the east to the Libyan border in the west (width ranges between 600-850 km).

8) Northern part of the Eastern Desert (from Wadi Tumilat to Qena-Qosseir Road).

9) Southern part of the Eastern Desert (from Qena-Qosseir Road southward to the Sudan border).

10) Isthmic desert. Includes all of the El-Tih desert in Sinai Peninsula and the region north of Wadi Tumilat.

11) Red Sea coastal region.

12) Gebel Elba (total area c. 1200 km^2). Includes an extensive group of granitic mountains situated on the Sudanese border (Latitude 22^o N) close to the Red Sea. The richness of the vegetation compared to the rest of Egypt has made this one of the main phytogeographical regions (Hassib, 1951).

13) Southern Sinai (total area c. 20,000 km^2). Plateau and mountainous region south of the El-Tih desert, including all of the Sinai Peninsula southward from Suez to Aqaba. (Total area of entire Peninsula = 61,000 km^2).

For some analyses, the 13 sub-regions were consolidated (Boulos, 1995) into 7 regions, (see Fig. 1)as follow.

A) The Nile Region (including sub-regions 1, 2, 3, above).

B) The Desert Regions (including sub-regions 7 - 11, above)

The Mediterranean Coast Region (including sub-regions 5, and 6, above).

D) Oases (sub-region 4, above).

E) Gebel Elba (sub-region 12, above).

F) Southern Sinai (sub-region 13, above).

The habitat in which a species is typically found was specified by Täckholm (1974) for 900 taxa in the Egyptian flora. These are categorized into six major habitats, in the six major geographical regions (A - F, above) as follow:

1. Weedy habitat: includes fields, gardens, ditches, along roads and in channels; 2. Salt; 3. Freshwater; 4. Sandy habitat: includes sand dunes, sand plains, maritime sand, seashore and sandy slopes of mountains; 5. Gravely habitat: includes gravely desert, stony places; and 6. Rocky habitat: consists of granitic and calcareous rocks, fissures, crevices, steep cliffs, and shady rocks.

Statistical analysis

Statistical analysis focused on comparisons between sub-regions and overall characteristics across Egypt. Chi-square tests were used to assess frequencies of abundance, origin, habitat, lifespan, and life-form classes of plant taxa by comparing the observed frequencies with those expected based upon overall patterns. Results are presented mainly as frequency distributions, plus results of Chi-square tests.

Regional diversity was calculated using an index of abundance (IA) for plant taxa in each sub-region. (IA= no. of sub-regions in which taxa occur x abundance value [1 = very rare, 2 = rare, 3 = common, 4 = very common]). Values for IA were log-transformed and used to calculate Shannon-Wiener diversity index (Pielou, 1975). $H` = \sum Pi \ln Pi$, where Pi =IA. In order to use a standardized estimate of floristic diversity for each sub-region and for major geographical regions in Egypt, the mean diversity value for each region (using all the species in a region) was divided by the area of the region.

Results

A total of 2088 species and some 2446 taxa are represented in the Egyptian flora (Table 1). They are distributed in the following classes of abundance. Very rare: 1031 species, 43%; Rare: 486 species, 29%; Common: 404 species, 17%; and Very common: 256 species, 11%.

Patterns of regional distribution

Table 1. Regional abundance classes and diversity values in the flora of Egypt. The underlined observed values are higher than the expected values according to Chi-square analysis. The values superscripted with *,** or *** are significantly different from expected values according to X^2 at p<0.05, 0.01 or 0.001 respectively.

Regions	Abundance classes				Number of Endemic species	Total taxa	Diversity index (H` x10^{-3})	X^2	P
	Very rare	Rare	Common	Very common					
Nd	102	<u>167</u>	<u>194</u>**	<u>167</u>	2	630	0.26	233.6	***
Nv	61***	134	<u>49</u>	<u>160</u>*	2	504	0.50	268.7	***
Nf	18***	49***	<u>109</u>**	<u>131</u>***	1	307	0.36	354.3	***
O	63***	125	<u>143</u>	<u>163</u>**	4	494	0.19	271.2	***
Mw	212	<u>329</u>**	<u>298</u>	206***	13	1045	0.57	198.2	***
Me	131	<u>210</u>	<u>225</u>***	170	9	736	1.20	211.8	***
EDn.	72**	<u>164</u>	<u>147</u>	<u>157</u>	10	540		255.8	***
EDs	<u>70</u>	110	81*	<u>101</u>	1	362		216.3	***
EDi	<u>176</u>	<u>225</u>**	<u>221</u>	180*	15	802		101.5	***
WD	38***	77	<u>115</u>*	<u>124</u>**	3	354	0.009	166.0	***
R	63	<u>105</u>**	54**	<u>81</u>	2	303		258.1	***
GE	199***	<u>142</u>**	48***	54***	3	443	3.70	11.4	**
S	275***	225	159*	153*	34	812	0.28	46.7	***

The number of species in each of the four abundance categories in different geographical regions are shown in Table 1. Highest representation of very rare plant species was in Sinai (275; 33.9% of species there) and Gebel Elba (199; 44.4%). Lowest values for very rare species were in the Nile Fayium (18, 5.9%), Western Desert (38; 10.7%), Nile Valley (61; 12.1%), Red Sea coastal region (63; 20.8%), and Oases (63; 12.7%). The highest number of plant taxa was recorded in the western Mediterranean coastal region (1045 species), and these species are approximately equally distributed among the four abundance classes. The flora is of low diversity along the Red Sea coast (303 species) and in the Western Desert (354 species). The Isthmic Desert and the southern part of the Eastern Desert had the highest number of very rare taxa (Table 1). Results of Chi-square analyses indicate that the pattern of abundance values within regions differed significantly for all regions.

Floristic richness (both in terms of species number and the frequency of endemics) differed between regions. The highest numbers of endemic species were recorded in southern Sinai (34 species), the Isthmic Desert (15 species), and the western Mediterranean coast region (13 species). Very few endemics occur elsewhere.

Values for the area standardized floristic diversity show an interesting pattern (in the different regions). Greatest values were recorded in Gebel Elba, the eastern and western Mediterranean coast, and Nile valley (3.7, 1.2, 0.75 and 0.5 $x10^{-3}$ respectively). The lowest value is recorded in the Western Desert (0.01 $x10^{-3}$).

Origin of the flora

Of the 2446 taxa in the Egyptian flora, only 84 (3.4%) are not native; 55% of these introduced species have become naturalized and 27% are regarded as 'casuals'. Despite the relatively low number of introduced species in the Egyptian flora overall, the Nile sub-regions (Delta and Valley) and the Oases have significantly more introduced species than expected based on values for the country as a whole (Table 2).

Table 2. Regional variation in origin in the flora of Egypt. The underlined observed values are higher than the expected values according to Chi-square analysis. The values superscripted with *,** or *** are significantly different from expected values according to X^2 at $p<0.05$, 0.01 or 0.001 respectively. ns= not significant.

Regions	Origin		Total	X^2	P
	Native	Introduced			
Nd	537	<u>63</u>***	600	52.1	***
Nv	469	<u>42</u>***	511	32.6	***
Nf	296	<u>14</u>	310	0.91	ns
O	480	<u>24</u>	504	2.10	ns
Mw	1015	37	1052	0.01	ns
Me	<u>717</u>	20	737	0.95	ns
EDn.	<u>535</u>	11*	453	2.95	ns
EDs	<u>363</u>	6*	274	3.41	ns
EDi	<u>797</u>	12***	809	8.10	**
WD	<u>347</u>	11	358	0.13	ns
R	<u>306</u>	2*	308	7.10	**
GE	<u>444</u>	6*	450	5.60	*
S	<u>803</u>	15*	819	4.60	*

Lifespan and Life-form

Of 2446 taxa in Egypt, 1168 (46.8%) are annuals, 1147 (46.9%) are perennials, and 37 (1.5%) are biennial. The desert sub-regions all have significantly more perennial species than expected (Table 3); the Nile sub-regions, Oases and the western Mediterranean coast all had significantly more annual taxa than expected. There is no significant difference between the observed number of annuals and perennials in Oases, Western Desert or Isthmic Desert regions, and the expected number based on the overall national pattern.

Table 3. Regional variation in life cycle in the flora of Egypt. The underlined observed values are higher than the expected values according to Chi-square analysis. The values superscripted with *, ** or *** are significantly different from expected values according to X^2 at $p<0.05$, 0.01 or 0.001 respectively. ns= not significant.

Regions	Life cycle		Total	X^2	P
	Annual	perennial			
Nd	<u>391</u>***	203***	594	44.4	***
Nv	<u>286</u>***	184***	470	16.7	***
Nf	<u>172</u>*	116*	288	8.7	**
O	<u>240</u>	223	463	0.3	ns
Mw	<u>585</u>***	413***	998	18.3	***
Me	<u>409</u>*	296*	705	12.1	***
EDn.	211*	<u>302</u>*	513	14.9	***
EDs	137	<u>212</u>	349	15.4	***
EDi	380	<u>386</u>	766	0.2	ns
WD	165	<u>173</u>	338	0.4	ns
R	101***	<u>187</u>***	288	24.5	***
GE	164***	<u>267</u>***	431	22.7	***
S	352*	<u>422</u>*	774	5.9	*

Herbs are well-represented in the Egyptian flora (1851 taxa; 75.7%), while trees are poorly-represented (33 taxa; 1.3%). Shrubs and shrublets are modestly-represented (261 taxa; 10.7% and 180 taxa; 7.4%, respectively). The number of tree species was significantly higher than expected in five of the regions (Nile Valley, Oases, southern part of the Eastern Desert, the Red sea coast and Gebel Elba regions). The incidences of shrubs and shrublets were higher than expected in the Egyptian deserts. Herbs are more frequent than expected based on overall national values, in the Nile, Mediterranean and Oasis regions (Table 4).

Table 5 showed the results of Chi-square analysis for all of the major variables in each of the major regions of Egypt. Abundance frequencies differed significantly in the 13 geographical regions (X^2=574, df =36, $p<0.001$). Abundance classes varied significantly vary within the Nile sub-regions (X^2 =54.2, df =6, $p<0.001$) and desert subregions (X^2 =68, df =12, $p<0.001$). There is no sig. variation among the Mediterranean sub-regions.

In comparing introduced vs. native status of species in the different sub-regions, only the Nile sub-regions differed significantly (X^2 =5.8, df =2, $p<0.05$).

Table 4. Regional variation in life forms in the flora of Egypt. The underlined observed values are higher than the expected values according to Chi-square analysis. The values superscripted with *,** or *** are significantly different from expected values according to X^2 at $p<0.05$, 0.01 or 0.001 respectively. ns= not significant.

Region	Life form					Total	X^2	P
	Tree	Shrub	Undershrub	Herb	Others			
Nd	4*	23***	9***	575***	25***	636	73.4	***
Nv	12	32***	12***	433	22***	511	36.5	***
Nf	4	12***	4***	281***	9	310	33.9	***
O	11	47	32	402	12*	504	3.4	ns
Mw	4***	74***	54***	897	23***	1052	26.7	***
Me	3**	48***	38**	636**	12	737	24.3	***
EDn.	11	86***	60***	376*	13	546	23.6	***
EDs	12	63***	37***	247*	10*	369	27.1	***
EDi	7	87	65***	643	11***	813	3.9	ns
WD	5	53***	29*	264	7	358	5.9	ns
R	12***	55***	34***	201***	6	308	33.9	***
GE	21***	82***	45***	287***	15***	450	56.2	***
S	3	118***	69***	596***	22	818	11.3	*

Variation in lifespan was highly significant in the desert sub-regions (X^2 =27.2, df =4, $p<0.001$) and not significant in the Nile and Mediterranean sub-regions (Table 5).

Table 5. Chi-square analysis of the overall variation in characters of the Egyptian flora in the major regions. The values superscripted with *, ** or *** are significantly different according to X^2 at $p<0.05$, 0.01 or 0.001 respectively. ns= not significant.

Regions	Abundance			Origin			Life cycle			Life form			Diversity
	df	X^2	P	df	X^2	P	df	X^2	P	df	X^2	P	(H` x 10^{-3})
Nile	6	54.2	***	2	5.8	*	2	2.6	ns	8	15.1	*	0.12
Medter.	3	0.13	ns	1	0.2	ns	1	0.3	ns	4	0.93	ns	0.39
Desert	12	68.0	***	4	6.4	ns	4	27.2	***	16	45.2	***	0.005
Overall	36	574	***	12	159	***	12	224	***	48	428	***	0.03

The frequency of plant life-form classes significantly differ among the desert sub-regions (X^2 =45.2, df =16, $p<0.001$) and (though with less marked difference) in the Nile sub-regions (X^2 = 15.1, df =8, $p<0.05$).

The index floristic diversity in the main regions of Egypt is relatively high in the Mediterranean (0.39x10^{-3}) than in the desert region (0.01x10^{-3}).

Habitat patterns

Habitat details recorded for 900 species are analyzed in relation to their geographical range. The frequency of species of particular abundance classes associated with each habitat was shown in Table 6. The weedy and sandy habitats were represented in all of the six major regions in Egypt. The pattern of abundance classes of weedy species significantly differ in four regions (and not significantly in the Nile and Gebel Elba regions). The abundance classes in the sandy habitat do not differ significantly in the desert or Gebel Elba regions. Salt habitat was represented in three major regions (Nile, Oases and Mediterranean coast) and the pattern of abundance classes there did not differ significantly. Freshwater habitat is represented only in the Nile region, with no significant variation in the abundance classes. Rocky and gravely substrates occur mainly in the desert and mountains.

Table 6. Habitat abundance classes in the flora of Egypt. *, ** or *** express the significant variation according to X^2 at $p<0.05$, 0.01 or 0.001 respectively. • Habitat included by less than 10% of the species in a region is omitted.

Regions	Habitats•	Abundance classes				X^2	P
		V. rare	Rare	Common	Very common		
Nile	Weedy	40	54	67	81	7.1	ns
	Salt marsh	9	16	22	15	4.0	ns
	freshwater	5	1	3	4	0.3	ns
	Sandy	8	16	15	21	11.9	**
Oasis	Weedy	15	20	37	67	25.5	***
	Salt marsh	18	10	12	14	4.7	ns
	Sandy	5	10	13	24	26.2	***
Med.coast	Weedy	26	48	58	73	12.9	**
	Salt marsh	10	20	22	16	2.9	ns
	Sandy	15	22	8	4	11.0	**
	Rocky	33	43	52	35	5.36	ns
Desert	Weedy	13	16	33	61	26.4	***
	Rocky	31	33	11	7	9.0	*
	Sandy	32	54	40	34	3.2	ns
	Gravely	22	18	12	10	0.5	ns
Gebel Elba	Weedy	3	2	3	9	5.2	ns
	Rocky	26	33	4	1	8.9	*
	Sandy	12	19	9	11	2.6	ns
	Gravely	10	9	5	4	0.1	ns
Sinai	Weedy	11	9	15	45	24.3	***
	Rocky	59	22	7	7	3.4	ns
	Sandy	10	28	20	29	16.1	***
	Gravely	4	14	9	8	7.9	*

Table 7 shows that the different habitats which do not differ significantly in the frequency of native or introduced taxa across the six major regions in relation overall in each habitat. The only exception was for freshwater habitat in the Nile (X^2 =7.8, $p<0.01$), where a lower number of native species occur (11) than expected (38 species).

Table 7. Plant origin in the different habitats of Egyptian flora. *, ** or *** express the significant variation according to X^2 at $p<0.05$, 0.01 or 0.001 respectively. • Habitat included by less than 10% of the species in a region is omitted.

Regions	Habitats•	Origin		X^2	P
		Native	Introduced		
Nile	Weedy	222	21	0.18	ns
	Salt marsh	62	2	0.06	ns
	freshwater marsh	11	2	7.8	**
	Sandy	59	1	1.8	ns
Oasis	Weedy	133	8	0.6	ns
	Salt marsh	44	1	1.2	ns
	Sandy	51	1	0.1	ns
Med.coast	Weedy	196	10	1.6	ns
	Salt marsh	64	2	0.1	ns
	Sandy	162	1	0.5	ns
	Rocky	49	0	1.4	ns
Desert	Weedy	113	70	0.4	ns
	Rocky	78	0	0.0	ns
	Sandy	152	2	0.2	ns
	Gravely	61	0	0.0	ns
Gebel Elba	Weedy	16	1	0.1	ns
	Rocky	64	0	0.0	ns
	Sandy	52	0	0.4	ns
	Gravely	28	0	0.0	ns
Sinai	Weedy	75	5	0.2	ns
	Rocky	95	0	0.0	ns
	Sandy	86	1	0.1	ns
	Gravely	35	0	0.0	ns

Table 8 shows frequencies of annual and perennial species in different habitats in Egypt. Plant lifespans differed significantly in the weedy habitat in the Nile region (X^2 =166, $p<0.001$) and in sandy habitat in the Mediterranean coastal region (X^2 =12.3, $p<0.001$). Lifespan frequencies also significantly differ in the Salt habitats in the Oases and in the Mediterranean coastal region ($p<0.05$).

Table 8. Plant life cycle in the different habitats of Egyptian flora. *, ** or *** express the significant variation according to X^2 at $p<0.05$, 0.01 or 0.001 respectively. • Habitat included by less than 10% of the species in a region is omitted.

Regions	Habitat•	Life cycle		X^2	P
		Annual	Perennial		
Nile	Weedy	165	61	166	***
	Salt marsh	16	46	0.3	ns
	freshwater marsh	4	9	0.6	ns
	Sandy	28	28	0.5	ns
Oasis	Weedy	49	37	4.9	*
	Salt marsh	8	36	5.4	*
	Sandy	20	28	0.6	ns
Med.coast	Weedy	133	61	0.1	ns
	Salt marsh	18	48	5.6	*
	Sandy	67	93	12.3	***
	Rocky	8	40	0.1	ns
Desert	Weedy	77	37	0.2	ns
	Rocky	20	56	0.1	ns
	Sandy	70	77	0.3	ns
	Gravely	14	45	0.5	ns
Gebel Elba	Weedy	14	2	2.3	ns
	Rocky	17	44	0.1	ns
	Sandy	26	21	1.8	ns
	Gravely	8	18	0.1	ns
Sinai	Weedy	60	15	3.1	ns
	Rocky	22	73	0.3	ns
	Sandy	37	45	0.1	ns
	Gravely	7	26	0.8	ns

Table 9 shows the frequency of species of different life-forms associated with each of the habitats in the different geographic regions in Egypt. The different life-forms in weedy habitat shows highly significant frequencies in all regions, while those associated with sandy habitat significantly differ only in Sinai. Plant life-forms associated with rocky habitat showed highly significant variation in the Desert, Gebel Elba, and Sinai regions.

Results of an overall Chi-square analysis showing the interaction between geographic region and species abundance, native-introduced status, length of the life cycle and plant life-form in the array of habitats were presented in Table 10. Most of these factors significantly differ in the six major regions in Egypt. However, the native or introduced status of plant taxa do not differ significantly in the Nile and Oasis regions.

Table 9. Plant life form in the different habitats of Egyptian flora. *, ** or *** express the significant variation according to X^2 at $p<0.05$, 0.01 or 0.001 respectively.
• Habitat included by less than 10% of the species in a region is omitted.

Regions	Habitat•	Life form				X^2	P
		Tree	Shrub	Shrublet	Herb		
Nile	Weedy	2	4	2	234	534	***
	Salt marsh	0	6	3	55	0.0	ns
	freshwater marsh	0	0	0	13	0.0	ns
	Sandy	0	5	1	4	0.0	ns
Oasis	Weedy	1	1	2	136	434	***
	Salt marsh	0	8	8	38	0.0	ns
	Sandy	1	6	4	41	0.0	ns
Med.coast	Weedy	2	2	2	199	495	***
	Salt marsh	0	12	10	46	0.0	ns
	Sandy	0	11	13	138	0.0	ns
	Rocky	0	4	8	37	0.0	ns
Desert	Weedy	2	1	2	114	402	***
	Rocky	2	12	9	54	261	***
	Sandy	0	13	11	129	0.0	ns
	Gravely	0	10	8	41	0.0	ns
Gebel Elba	Weedy	0	1	0	16	0.0	ns
	Rocky	6	14	4	37	229	***
	Sandy	0	1	2	49	0.0	ns
	Gravely	0	3	3	21	0.0	ns
Sinai	Weedy	1	1	1	76	379	***
	Rocky	2	19	6	66	263	***
	Sandy	1	7	7	72	320	***
	Gravely	0	6	5	23	0.0	ns

Table 10. Chi-square analysis of the habitat characters of the Egyptian flora in the six major regions. The values superscripted with *, ** or *** are significantly different according to X^2 at $p<0.05$, 0.01 or 0.001 respectively. ns= not significant.

Characters		Regions					
		Nile	Oasis	Mediterranean	Desert	Gebel Elba	Sinai
Abundance	df	9	6	9	9	9	9
	X^2	20.1	13.5	36.1	80.9	38.3	112.1
	P	*	*	***	***	***	***
Origin	df	3	2	3	3	3	3
	X^2	6.5	1.4	7.7	11.2	8.5	9.9
	P	ns	ns	*	**	*	*
Life-cycle	df	3	2	3	3	3	3
	X^2	452.1	11.5	63.4	45.1	23.1	63.1
	P	***	**	***	***	***	***
Life-form	df	9	6	9	9	9	9
	X^2	21.4	21.7	50.9	37.2	27.8	8.3
	P	**	***	***	***	***	***

Discussion

Distribution and ecological features in the flora of Egypt

This study provides insight on the regional distribution of abundance and life history traits of species in the flora of Egypt. The strikingly high occurrence of rarity in the Egyptian flora (more than 70% of species are rare or very rare) is striking, and implies a need for immediate action to assess and conserve these species. The high percentage of native taxa (97%) in the flora underscores its uniqueness in general and, at least historically, suggests resistance to species invasions. This may be a result of past selection for drought resistance, both physiologically and in terms of plant life-forms and life history strategies (Khedr et al., 2002).

Greuter (1991) reviewed botanical diversity, endemism, rarity and extinction in the entire Mediterranean area. He concluded that the high diversity (c. 24,000 species of vascular plants in the region) does not result from high species density in particular local floras, but rather from an increased frequency of small areas, specially but not exclusively for endemic taxa. A high proportion of rare, local endemics (as compared to non-Mediterranean Europe) is characteristic of the overall Mediterranean region and accounts both for the richness and for the vulnerability of its flora. He related taxon numbers to land area and observed a significant linear correlation, with one general exception, namely that countries having large desert surface areas have disproportionately fewer species. The countries having the greatest deficits are in rank orders, Egypt, Libya, Algeria, Tunisia, and Palestine.

It is evident that both geographical position and extent of aridity reflect important effects both on species richness and the number of endemic taxa in a region. In North Africa generally, the western Mediterranean countries (the Magreb) are considered floristically richer both in terms of total number of species and of endemics, compared with eastern Mediterranean countries (Libya and Egypt) due to historical and geomorphological factors. Within Egypt, the highest number of species and endemics is recorded from the western Mediterranean coast and southern Sinai respectively. Habitat heterogeneity and relatively high annual rainfall would seem to be among the more important factors enabling increased species richness in the western Mediterranean coast. Furthermore, the position of the Sinai Peninsula, between the Asian and African landmasses, increases the chance of recruitment of species from different sources.

Species having a wide geographic range combined with restricted but high local population size are the most abundant category of rarity identified by Rabinowitz *et al.*, (1986) in the flora of the British Isles. Such species should have abundances that directly reflect the abundance of their habitats. At the same time, several studies have found that species occurring over large geographic areas tend to have greater local abundances than do more restricted species (Gaston, 1994). A simple explanation for this result is that species which exploit a wide range of resources become both widespread and locally abundant, whilst more specialized species may fail to do so (Brown, 1984).

In Egypt, weedy species have wide geographical ranges across the six major geographic regions. These species have relatively localized abundances; their range of distribution significantly differ in four regions, but show no significant difference in the Nile and Gebel Elba regions.

The second most common form of rarity in the Egyptian flora is the endemic: habitat specialists, having small ranges, existing in local populations. Such rarities have been the subject of study for decades (Cain, 1944; Stebbins & Major, 1965; Rabinowitz *et al.,* 1986). In Egypt, the number of endemic species is very low (71 species, 2.9% of total taxa), a figure far lower than observed in most other Mediterranean countries: e.g., Lebanon (311 species) and Israel (165 species) (Davis *et al.,* [1994]), Cyprus (171 species) (Alziar [1995]) and Southern France (215 species) (Médail & Verlaque, [1997]). More than sixty percent of endemics in Egypt are known from Sinai (Boulos, 1995). The positive relationship between floristic richness and number of endemics noted by Stebbins & Major (1965) for California is not apparent in Egypt. The harsh environmental conditions and geological discontinuities, along with geographic isolation (mountains and rift valleys), may be more important determinants of endemism than floristic richness (Médail & Verlaque, 1997; Pueyo & Alados, 2007).

It appears that habitat type plays an important role in the distribution pattern of Egyptian endemics; where most are associated with the rocky habitat types in Sinai. This trend supports the results of Stebbins (1980), Major (1988) and Médail & Verlaque, (1997), all of whom related the frequency presence of endemics to hard substrates such as granite, coarse sands, cliffs and eroded soils. The exclusion of endemics from productive habitats can probably be explained by their typically weak ecological flexibility and lower competitive ability (Kruckeberg & Rabinowitz, 1985).

The low frequency of some plant life-forms in Egypt (e.g., trees constitute only 1.3% of total taxa), particularly in the Mediterranean coastal region may be due to the fragmented landscape and low annual rainfall in the country as whole. Hassib (1951 cited in Zohary 1973) described a coastal strip ranging in width from 25 to 33 km along the Mediterranean coast. However, the mean annual rainfall in this coastal belt does not exceed 200 mm, which tends to exclude the persistence of any arboreal Mediterranean vegetation, even there. The infrequent and unpredictable occurrence of annual rainfall in excess of 250 mm is not sufficient to support trees.

Implications for conservation

Freitag & van Jaarsveld (1997) have pointed out that, whereas scale-invariant extinction risk has an important ecological and evolutionary basis, it does not directly address the practical realities of national and regional biodiversity conservation planning.

Plant species are disappearing at an alarming rate throughout the world, with 10% of recorded species classified as rare or endangered (Newton & Bodasing, 1994). Egypt, with a flora comprising 70% rare species, requires immediate attention. The survival of rare species is further jeopardized by unscrupulous specialist collectors (Maggs *et al.*, 1998). Efforts should focus not only on *in situ* protection of rare species, but also on controlling their commercial exploitation (e.g., Maggs *et al.*, 1998). The degradation of plant communities through loss of diversity also has economic implications for land use. Tourism and sustainable conservation of pastoralism and agriculture form an important basis of human cultures. Effective assessment of conservation status will depend upon the co-ordinated collection of systematic and ecological data for the Egyptian vascular flora.

Major threats to floristic diversity in Egypt

Plant diversity is primarily threatened by rapidly increasing anthropogenic land use conversion. For example, conversion of land to agriculture without incorporating incentives for good environmental management has led to the destruction of many rare species. The current situation of the Egyptian vascular flora is more serious than had been anticipated. Although much earlier valuable floristic work has been undertaken in Egypt in the past, consistent and systematic survey and data analysis is required to guide future conservation management.

References

Abu Al-Izz, M.S. 1971. *Land forms of Egypt*. Translated by Y.A. Fayid. The American University in Cairo Press, Cairo, Egypt.

Alizar, G. 1995. La flore de Chypre. *Ecologia Mediterranea*, 21: 47-52.

Boulos, L. 1995. *Flora of Egypt*. *Checklist*. Al-Hadara Publishing, Cairo.

----------- 1999-2005. *Flora of Egypt*. *Volumes 1-4*. Al-Hadara Publishing, Cairo.

Brown, J.H. 1984. On the relationship between abundance and distribution of species. Am. Nat. 124: 255-279.

Cain, S.A. 1944. *Foundations of Plant Geography*. Harper and Brothers, New York.

Clapham, A.R., Tutin, T.G. and Moore, D.M. 1987. Flora of the British Isles, 3rd. Edn. Cambridge Univ. Press.

Davis, S.D., Heywood, V. H. and Hamilton, A. C. 1994. *Centres of plant biodiversity. A guide and strategy for their conservation. Vol. 1. Europe, Africa, South West Asia and the Middle East*. WWF and IUCN; IUCN Publication Unit, Cambridge.

Freitag, S. and van Jaarsveld, A.S. 1997. Relative occupancy, endemism, taxonomic distinctiveness and vulnerability: prioritizing regional conservation actions. *Biod. & Cons.* 6: 211-232.

Gaston, K.J. 1994. *Rarity*. Chapman and Hall, London.

------------- and Kunin, W.E. 1997. Rare-common differences: an overview. In: Kunin W.E. and Gaston K.J. (eds) *The Biology of rarity: Causes and consequences of rare-common differences*. Chapman and Hall, London. pp 12-29.

Gentry, A.H. 1986. Endemism in tropical versus temperate plant communities. In: Soulé M.E. (ed) *Conservation biology: The biology of scarcity and diversity*. Sunderland, MA: Sinauer Associates, pp 153-181.

Good, R. 1964. *The Geography of the Flowering Plants*. 3rd ed. 518 pp. Longman, Green and Co., London.

Greuter, W. 1991. Botanical diversity, endemism, rarity, and extinction in the Mediterranean area: an analysis based on the published volumes of Med-Checklist. Bot. Chron. 10: 63-79.

Harper, K.T. 1979. Some reproductive and life history characteristics of rare plants and implications for management. *Great Basin Nat. Memoirs* 3: 129-137.

Hassib, M. 1951. Distribution of plant communities in Egypt. *Bull. Fac. Sci. Fouad I Univ.*, Cairo, 29: 59-261.

Hodgson, J.G. 1986a. Commonness and rarity in plants with special reference to the Sheffield Flora. Part I: the identity, distribution and habitat characteristics of the common and rare species. *Biol. Cons*. 36: 199-252.

---------------- 1986b. Commonness and rarity in plants with special reference to the Sheffield Flora. Part II: the relative importance of climate, soils and land use. *Biol. Cons.* 36: 253-274.

---------------- 1986c. Commonness and rarity in plants with special reference to the Sheffield Flora. Part III: taxonomic and evolutionary aspects. *Biol. Cons*. 36: 275-296.

---------------- 1986d. Commonness and rarity in plants with special reference to the Sheffield Flora. Part IV: a European context with particular reference to endemism. *Biol. Cons*. 36: 297-314.

Khedr, A.A., Cadotte, M., El-Keblawy, A. and Lovett-Doust, J. 2002.. Phylogenetic diversity and ecological attributes in the Egyptian flora. Biod. & Cons. 11**:** 1809–1824.

Kruckeberg, A.R. and Rabinowitz, D. 1985. Biological aspects of endemism in higher plants. Annu. Rev. Ecol. Syst., 16: 447-479.

Kunin, W.E. and Gaston, K. J. 1993. The biology of rarity: patterns, causes and consequences. *TREE*, 8: 298-301.

------------ and Schmida, A. 1997. Plant reproductive traits as a function of local, regional, and global abundance. *Cons. Biol*. 11: 183-192.

Maggs, G.L., Craven, P. and Kolberg, H.H. 1998. Plant species richness, endemism and genetic resources in Namibia. *Biod.* & *Cons*. 7: 435-446.

Major, J. 1988. *Endemism. a botanical perspective*. In: Myers A.A. and Giller P.S. (eds), *Analytical biogeography*. Chapman and Hall, London and New York, pp 117-146.

Médail, F. and Verlaque, R. 1997. Ecological characteristics and rarity of endemic plants from southeast France and Corsica: implications for biodiversity conservation. Biol. Cons. 80: 269-281.

Newton, D.J. and Bodasing, A. 1994. TRAFFIC, Wildelife trade monitoring and the South African plant trade. In: Huntley B.J. (ed) *Botanical diversity in South Africa*, *Strelitzia*, 1: 319-328.

Orians, G.H. 1997. Evolved consequences of rarity. In: Kunin, W.E. and Gaston, K.J. (eds), *The Biology of rarity: Causes and consequences of rare-common differences*. Chapman and Hall, London pp 190-208.

Pielou, E.C. 1975. *Ecological diversity*. Wiley, Interscience, New York.

Pueyo, Y. & Alados, C.L. 2007. Abiotic factors determining vegetation patterns in a semi-arid Mediterranean landscape: Different responses on gypsum and non-gypsum substrates. *J. Arid Enviro*. 69: 490–505.

Rabinowitz, D., Cairns, S. and Dillon, T. 1986. Seven forms of rarity and their frequency in the flora of the British Isles. In: Soulé M.E. (ed) *Conservation biology: the biology of scarcity and diversity*. Sinauer Associates, pp 182-204.

Schwartz, M.W. 1993. The search for pattern among rare plants: are primitive species more likely to be rare? *Biol. Cons*. 64: 121-127.

Stebbins, G.L. 1980. Rarity of plant species: a synthetic viewpoint. *Rhodora* 82: 77-86.

--------------- and Major, J. 1965. Endemism and speciation in the California flora. *Ecol. Monog*. 35: 1-35.

Täckholm, V. 1974. *Students' Flora of Egypt, 2nd edn*. Cairo University, Cairo, Egypt.

Zahran, M.A. and Willis, A. J. 1992. *The Vegetation of Egypt*. Chapman and Hall, London.

-------------- and Willis, A. J. 2003. *Plant life in the River Nile in Egypt*. MARS Publ. House.

Zohary, M. 1973. *Geobotanical foundations of the Middle East*. Vol. 1-2. Gustav Fisher Verlag, Stuttgart.