Plant Biodiversity in the Western Mediterranean Desert of Egypt

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Introduction

Diversity of plant communities has never been more highly valued than it is now, as they become increasingly threatened by the environmental crisis. In fact, diversity lies at the root of some of the most fundamental and exciting questions in theoretical and applied ecology (MAGURRAN 1988). The objective of this paper is to provide an overview of plant biodiversity in the western Mediterranean desert of Egypt in terms of habitat, community, and species diversity, and to evaluate the impacts of land-use and human manipulations on such diversity.

The flora of the western Mediterranean desert of Egypt includes almost 50% of the species recorded in Egypt. It extends for about 500 km from Alexandria to Salloum. The area is bounded on the north by the Mediterranean sea and extends south for an average distance of about 50 km. The climate can be qualified as "arid Mediterranean" with mild winter (UNESCO, 1977). The mean annual rainfall ranges from 140 to 190 mm depending on the location along the coast.

Methods

Selection of Plant Communities

Twenty plant communities were sampled along five transects at: Burg EL-Arab, Hammam, Omayed, Fuka and Maktala (Figure 1). These transects included plant communities of the major habitats prevailing in the physiographic provinces of the region as well as communities which were disturbed, modified or replaced by different land uses, such as irrigated and rain-fed agriculture, summer resorts, and local industries. The effect of grazing pressure was studied using the records of REMDENE project at Omayed area from 1974 to 1979 (REMDENE 1980).

Assessment of Species Abundance

A number of stands were selected to represent each of the studied communities. The presence of perennial and annual species was recorded in each of the selected stands, and the dominant and codominant species were determined by visual assessement of abundance. Quantitative determinations of abundance of perennial species were carried out. In each of the stands (30 x 40 m each) selected for surveying each community, fifty $2 m^2$ randomly distributed quadrats were used to record the number of individuals of each perennial species, and to assess its density (number of individuals per unit area). Plant nomenclature is according to TÄCKHOLM (1974).

Species richness was estimated by both the presence data recorded in each habitat by the present study as well as those recorded by previous studies (AYYAD 1973, AYYAD & AMMAR 1974, AYYAD 1976, EL-GHAREEB 1975, MIGAHID 1983, EL-KADI 1987, KAMAL 1988, HENEIDY 1991).

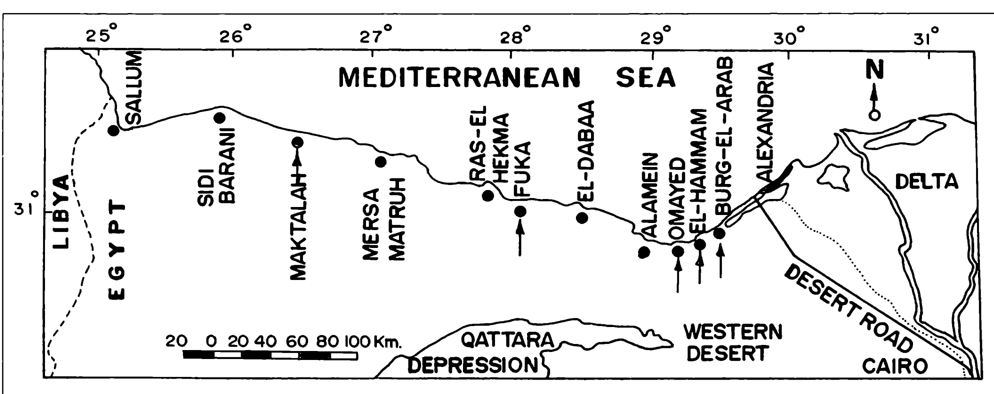

Fig. 1

Map of the western Mediterranean coastal region of Egypt indicating the location of the study area

* Dedicated to Prof. Dr. Reinhard Bornkamm on the occasion of his 65th birthday.

Application of Diversity Indices

As many ecological concepts, diversity is an intuitive concept whose origin is in field observations. Diversity must be a function of the number of species (richness), and of the regularity of individual distribution among the species (evenness or equitability). Diversity measures applied in the present study are according to LUDWIG and REYNOLDS (1988) and MAGURRAN (1988). Since the index of diversity is generally related to the number of individuals of each species, MAGURRAN (1988) and PIELOU (1975) recommended for plants that do not reproduce vegetatively, the number of individuals as the obvious measure. Accordingly relative density was used here as a measure of species abundance in the applied indices.

Results

Species Richness: Species richness (number of species) varies considerably between different habitats (Table 1). The total species richness including perennials and annuals in most habitats is in the range 125–224 species with an exceptionally low value of 30 species in the salt marshes. Relatively high richness is recorded in non-saline depressions (113 perennial species and 111 annual species), ridges (102 perennial species and 104 annual species), and wadis (92 perennial species and 86 annual species).

The high species richness recorded for non-saline depressions and inland ridges is again exhibited in their communities (generally in the range of 23–31 perennial species per community). Notwithstanding the exceptionally high richness in the coastal dune community of Elymus farctus (26 perennial species), and the inland plateau community of Salsola tetrandra (24 perennial species), all other communities exhibit notably lower values. It is also obvious that annual herbs add only little to the total species richness in communities of the coastal dunes and salt marshes as compared with communities of other habitats.

Species Diversity: Five of the more popular indices of alpha diversity (diversity within community samples) were applied on the studied plant communities. In the habitat of coastal dunes the plant communities on stabilized dunes are substantially more diverse than those on active and partly stabilized

Tab. 1
Number of species, genera, and families recorded in different habitats

Habitat		Perennials	Annuals	Total number of species
Coastal Dunes	F	26	17	
	G	66	45	
	S	78	53	131
Salt Marshes	F	10	6	
	G	19	9	
	S	21	9	30
Saline Depressions	F	25	21	
	G	57	55	
	S	65	60	125
Non-Saline Depressions	F	32	25	
	G	87	83	
	S	113	111	224
Ridges	F	29	23	
	G	76	80	
	S	102	104	206
Inland Plateau	F	26	22	
	G	61	51	
	S	77	62	139
Wadis	F	30	22	
	G	73	68	
	S	92	86	178

Tab. 2
Species diversity of plant communities in different habitats of the western Mediterranean region of Egypt

Habitat	Coastal Dunes					Inland Dunes	Salt Marshes				Non-Saline Depressions				Inland Ridges				Inland Plateau	
	community																			
Diversity index	A.ar	p.ma.-A.ar.	p.ma	L.re.	E.fa.	U.ma.	S.fr.	C.cr.	H.po.	A.gl.-H.st.	A.mi.	Z.al.	T.hi.	p.al.	p.al.-A.or.	E.sp	p.al-A.ar.	T.hi.-p.al.	S.te.	H.sc.
Richness (S)P.	6	8	10	17	26	15	8	7	10	10	31	23	26	25	26	23	25	28	24	15
(S)A.	-	1	5	4	7	21	5	1	3	2	37	19	30	22	23	22	18	16	14	25
Simpson (D)	0.738	0.554	0.541	0.395	0.230	0.172	0.496	0.509	0.217	0.513	0.258	0.314	0.277	0.766	0.585	0.077	0.347	0.153	0.353	0.198
Shannon (H')	0.511	0.752	1.005	1.333	1.813	2.059	0.848	0.987	1.594	0.830	2.008	1.829	1.910	0.680	1.134	2.644	1.787	2.302	1.535	1.928
Hill's no. (N1)	1.667	2.121	2.732	3.793	6.131	7.844	2.334	2.728	5.112	2.342	7.445	6.225	6.755	1.975	3.109	14.073	5.971	9.991	4.643	6.873
Hill's no. (N2)	1.355	1.804	1.849	2.531	4.347	5.820	2.016	2.023	4.615	2.003	3.880	3.189	3.611	1.306	1.709	12.969	2.885	6.526	2.833	5.049
Evenness index (E1)	0.285	0.362	0.437	0.471	0.729	0.743	0.542	0.507	0.890	0.589	0.649	0.583	0.586	0.211	0.348	0.843	0.555	0.691	0.483	0.712

Appendix:

Species	Abbreviation	Species	Abbreviation
Ammophila arenaria	*A. ar.*	*Hammada scoparia*	*H. sc.*
Anabasis articulata	*A. ar.*	*Launaea resedifolia*	*L. re.*
Anabasis oropediorum	*A. or.*	*Pancratium maritimum*	*P. ma.*
Arthrocnemum glaucum	*A. gt.*	*Plantago albicans*	*P. al.*
Asphodelus microcarpus	*A. mi.*	*Salicornia fruticosa*	*S. fr.*
Cressa cretica	*C. cr.*	*Salsola tetrandra*	*S. te.*
Echinops spinosissimus	*E. sp.*	*Thymelaea hirsuta*	*T. hi.*
Elymus farctus	*E. fa*	*Urginea maritima*	*U. ma.*
Halimione portulocoides	*H. po.*	*Zygophyllum album*	*Z. al.*
Halocnemum strobilaceum	*H. st.*		

dunes (Table 2). This observation is borne out by the indices which incorporate information on the proportional abundances of species such as Shannon index which estimates the diversity of the stabilized dune community of Elymus farctus (H'= 1.813), and the diversity of the active dune community of Ammophila arenaria (H'= 0.511). Evenness is also greater in the communities of the stabilized dunes than those of the active and partly stabilized dunes (E1 = 0.729 for the former community, and 0.285 for the active dune community). The lower dominance of the stabilized dune communities is reflected by Simpson index (D = 0.230 for the Elymus farctus community), while the highest dominance is noticed in the active dune community of Ammophila arenaria (D = 0.738). The method of Rank/Abundance plots was applied here. In this method the abundance of each species is plotted on a logarithmic scale against the species rank in the sequence of species from most to least dominant. The resulting graphs for successional communities in the habitat of coastal dunes arranged according to community age (degree of dune stabilization) are given in Figure 2. It is notable that the resulting curves of successional communities are initially geometric where a few species are dominant with the remainder fairly uncommon. For example, in the active dune community of Ammophila arenaria the richness is low, and due to the abundance of Ammophila arenaria, evenness is also low. This community approaches the geometric pattern of species distribution which appears as a straight line when plotted on a log abundance/species rank graph. As succession proceeds the curves become less steep as more species are added, and the species abundance pattern grades into those of the log series gradually approaching the log normal distribution with the increase in species with intermediate abundance. The log normal distribution is approached at later stages of succession expressed by the Elymus farctus community where species diversity is relatively high.

Species diversity of the Urginea maritima community of the inland dunes at Maktala is notably high (H'= 2.059). The number of very abundant species (N2) is 5, and the number of abundant species (N1) is 8. Accordingly the dominance in this community (D= 0.172) is low, while evenness is notably high (E1 = 0.743). Thus this community attains high species diversity as confirmed by Shannon index.

In the salt marshes, the applied indices indicate that the Halimione portulocoides community is substantially more diverse than any of the other three communities, and consequently the dominance is lower (D = 0.217). It is also notable that the number of most frequent species (N2) and the number of equally common species (N1) are larger. This illustrates the high evenness of the relative abundances of species in the Halimione portulocoides community as estimated by Shannon-evenness index. Inspection of the data also shows a considerably high dominance

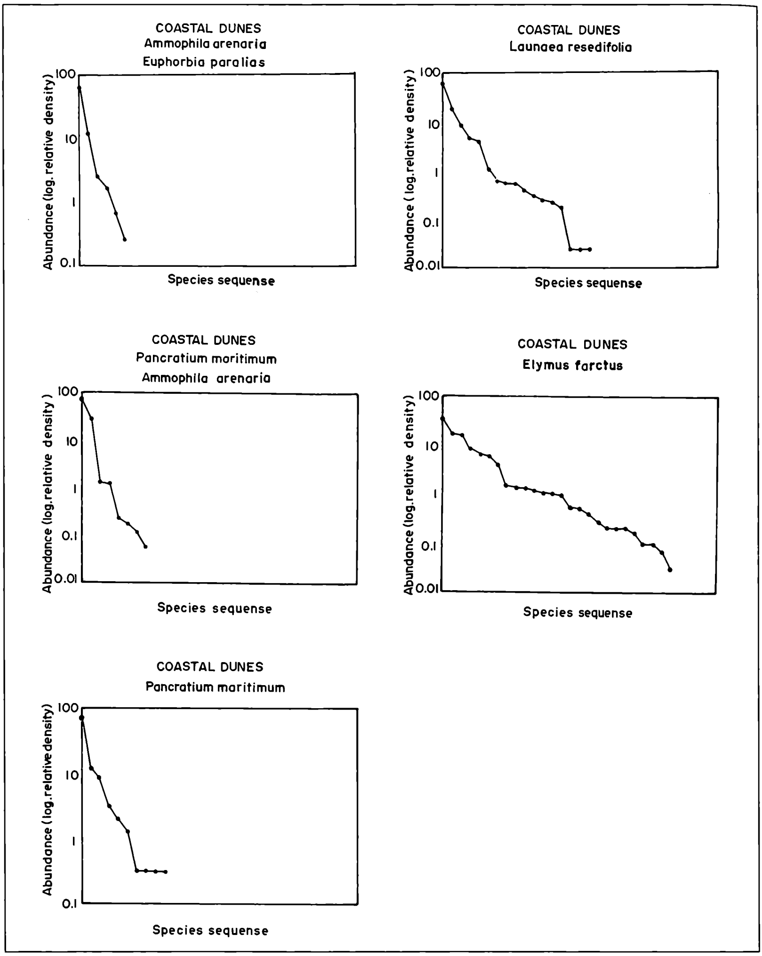

Fig. 2
Rank/abundance plots of successional communities in the habitat of coastal dunes

in the other three communities dominated by Salicornia fruticosa, Cressa cretica, and Arthrocnemum glaucum-Halocnemum strobilaceum (D= 0.49, 0.50 and 0.51 respectively).

In non-saline depressions and plains, species diversity in the Plantago albicans community differs greatly from that in the remaining three communities. This community is considerably less diverse (H'= 0.680) than other communities (H'= 1.8–2.0). Its evenness (E1= 0.211) is notably lower than that in the other communities (E1= 0.58– 0.64), and consequently its dominance (D= 0.766) is much higher due to the high relative abundance of Plantago albicans. This observation is clearly expressed by Hill's number 2 as it estimates the number of very abundant (dominant) species to be only one (Plantago albicans). Inspection of the data shows that the remaining three communities of non-saline depressions dominated by Asphodelus microcarpus, Zygophyllum album, and Thymelaea hirsuta show closely similar species diversity and evenness. For example, the number of species which have equal abundance is estimated by Hill's number 1 as N1 = 6 to 7 species per community. But it is notable that the Zygophyllum album community is slightly less diverse and shows a slightly higher dominance than the other two communities.

In the habitat of inland ridges, large differences are revealed between plant communities occupying different positions on the slopes. It is remarkable that every diversity index tested here (except richness) shows that the plant community found on the middle slope of the ridge which is codominated by Echinops spinosissimus, Anabasis oropediorum, Gymnocarpos decandrum, and Dactylis glomerata is substantially more diverse than any other community in the present study (H'= 2.644). Evenness of species abundances exhibited by this community is also high (E1= 0.843). The number of species of equal abundance as estimated by Hill's number 1 is about 14 species out of a total of 23 perennial species recorded on the middle slope of the ridge. As many species are

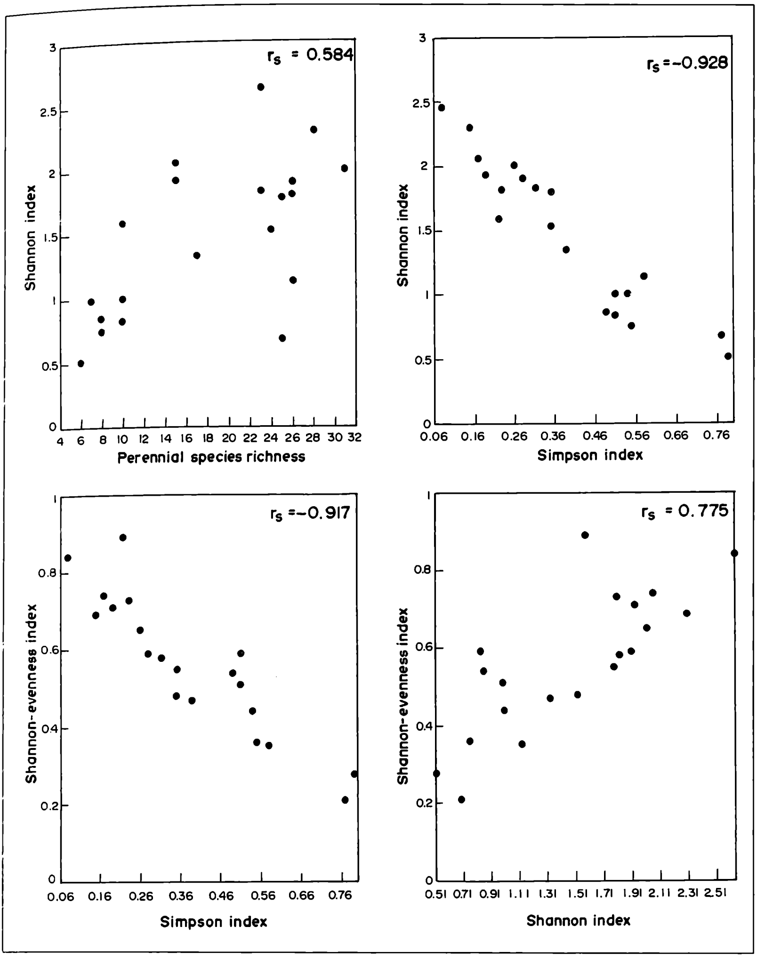

Fig. 3
Correlation between diversity measures

sharing dominance, the value of Simpson index is very low (D= 0.077) as compared with that of the other communities in the present study. On the other hand, the plant community sampled at the top of the ridge and which is codominated by Plantago albicans and Anabasis oropediorum exhibits lower evenness as compared with other communities of the same habitat (E1= 0.348), and hence it is less diverse (H'= 1.134) and shows a considerably high dominance (D= 0.585). The plant community sampled on the rocky elevations at Fuka and which is codominated by Thymelaea hirsuta and Plantago albicans, shows such a high value of evenness of species abundances and hence a high species diversity value that it is rated as the next most even community found in the present study after the Echinops spinosissimus community on the middle slope of EL-Khashm ridge at Omayed. Consequently its dominance is relatively low (D= 0.153) and the number of frequent species (equally abundant species) is 10 as estimated by Hill's number 1 (N1) index.

In the habitat of inland plateau, the two studied communities differ in many aspects. The plant community dominated by Hammada scoparia exhibits high evenness of species abundance (E1= 0.712), while the value is considerably lower for the Salsola tetrandra community (E1= 0.483). As a consequence, the Hammada scoparia community is considered to be more diverse. This observation is borne out by Shannon index which incorporates information on the proportional abundance of species as H'= 1.928 and H'= 1.535 respectively. It is remarkable that Hill's numbers (N1 and N2) are higher (about 7 and 5 species respectively) in the poor (total of 15 perennial species) Hammada scoparia community, and lower (about 5 and 3 species respectively) in the more rich (total of 24 perennial species) Salsola tetrandra community.

Comparison Between Diversity Measures

Inspection of the values of diversity measures of the twenty plant communities distributed among different habitats of the study area reveals that diversity indices are often correlated. The present study looked at this phenomenon in more detail by testing the concordance of ranking of communities as their diversities have been calculated using a variety of indices. For each diversity index the communities were ranked from the highest to the lowest diversity, from 1 to 20. The concordance of rankings between pairs of indices was calculated using Spearman rank correlation coefficient (rs). Significant correlations are plotted in Figure 3. Values of rs> 0.623 mean highly significant correlations (P< 0.01). It is notable that the dominance index (Simpson's index) together with the information theory measures (Shannon and Shannon-evenness indices) gave the best consistent ranking of communities.

Relationship Between Soil Factors and Species Diversity

In the analysis of species diversity and diversity patterns, one cannot look for a single explanation involving only one causal factor. There is a multitude of ways in which the mechanisms can interact and have interacted over evolutionary time to produce the assemblages we see today. In the present study it was possible to consider only soil factors. Correlation between different soil factors (Sand, Clay, O.M., $CaCO_3$, EC and pH) and the most important diversity indices (Richness, Dominance, Diversity and Evenness) was estimated using Spearman rank correlation coefficient (r_s). Highly significant correlations were recorded between diversity (expressed by Shannon's index) and the percentage of sand and clay; the correlation is positive with sand and negative with clay (i.e.; as the soil texture become coarser, species diversity increases). Dominance and evenness also are positively correlated with coarse texture, and negatively correlated with fine texture. It is also remarkable that there is a significant negative correlation between $CaCO_3$ and EC on one hand and species richness and diversity on the other hand.

Effects of Land-Use on Species Diversity

The effect of several land-use practices on species diversity was considered in the present study. These included summer resorts, irrigated agriculture, rainfed agriculture, local industries and grazing.

Summer resorts

The plant communities affected by summer resorts are found on the active and stabilized dunes. The effect of these resorts on species diversity was assessed by comparing communities in disturbed sites with communities in undisturbed ones. The general trend in the disturbed sites of active coastal dunes is a decrease in diversity (H'= 0.19 and 0.25) as compared to the undisturbed site (H'= 0.51). This coincides with maximum dominance of Ammophila arenaria in disturbed sites (relative density 95%, (Table 3). The distribution of individuals among the species is more even in the undisturbed site. Although species richness decreases with disturbance, both Ammophila arenaria and Lotus polyphyllos persist in disturbed sites.

On the more stabilized coastal dunes, the general trend is also a remarkable decrease in both richness and diversity in the disturbed sites (Table 4). This coincides with maximum dominance by Ammophila arenaria although it attains notably lower relative density (70–78%) than in the disturbed sites of active dunes. It is also notable that no annuals were detected in these disturbed sites. The disturbed sites codominated by Ammophila arenaria and Crucianella maritima support a greater number of species (8 and 10 species respectively) than those codominated by Ammophila arenaria and Lotus polyphyllos which exhibit a considerable decrease in species richness (4 species per site compared with 17 species in the undisturbed community). All disturbed sites are obviously less diverse (H'= 0.67–1.02) than the undisturbed site (H'= 1.33), and consequently dominance is lower in the undisturbed site (D= 0.39 as compared with D= 0.53–0.64 in the disturbed sites). Again

Table 3:
Effect of summer resorts on species richness and diversity of an active coastal dune community

Diversity index	Undisturbed community	Disturbed community Site 1	Disturbed community Site 2
Richness (S)	6	2	5
Berger-parker (d)	0.841	0.953	0.949
Berger-Parker (1/d)	1.189	1.049	1.053
Simpson (D)	0.738	0.909	0.901
Shannon (H')	0.511	0.190	0.254
Hill's number (N1)	1.667	1.209	1.289
Hill's number (N2)	1.355	1.099	1.109

Ammophila arenaria and Lotus polyphyllos are the only two species which could persist under disturbance. It is also remarkable that six out of the seventeen recorded species on the undisturbed stabilized dunes are completely missing in all of the four disturbed sites.

Irrigated and rain-fed agriculture

Species diversity of weed communities associated with common crops was assessed in Burg EL-Arab area. These were two rain-fed crops: wheat (Triticum vulgare) and barley (Hordeum sp.), and four irrigated crops: wheat barley, Egyptian clover (Trifolium alexandrinum), and broad beans (Vicia faba).

Species composition of the weed communities in the rain-fed cultivations is more or less similar to that of the "natural" communities of non-saline depressions. The perennial species confined to rain-fed cultivations are Arisarum vulgare, Launaea nudicaulis, Onopordon alexandrinum, Plantago albicans, Salvia lanigera, and the annual species are Chenopodium album, Cutandia dichotoma, Filago desertorum, Linaria haelava, Linaria albifrons, Matthiola longipetala, Parapholis marginata, Roemeria hyprida and Spergularia diandra. A few weeds are common to all the four crops (regardless of the type of cultivation): Lolium perenne, Malva parviflora, Plantago lagopus, Sonchus oleraceous and Anagallis arevensis.

Most weeds are therophytes (Table 5) with a maximum percentage (94%) in the irrigated broad beans community and a minimum percentage (76%) in the rain-fed barley community. Regardless of the type of cultivation, the weed community of rain-fed barley is the richest (33 species); while that of the irrigated barley is the poorest (11 species). On the other hand, within the irrigated crops, the Trifolium community is the richest (25 species). A similar trend is exhibited by species diversity as estimated by Shannon's index H' (Table 6). The weed community of the rain-fed barley attains the highest value (H'= 2.16) and the irrigated barley community the lowest value (H'= 1.35). Within the irrigated crops, the broad beans community attains the highest diversity (H'= 1.78), followed by the Trifolium community (H'= 1.70). Dominance exhibits an opposite trend as estimated by Simpson's index; the highest dominance is attained by the irrigated barley community (D= 0.36), and the lowest by the rain-fed barley community (D= 0.17). This is also clear regarding Hill's numbers for the most frequent and equally abundant species. In general, the weed communities of irrigated and rain-fed cultivations are less diverse as compared with the "natural" communities of non-saline depressions.

Table 4:
Effect of summer resorts on species richness and diversity of a stabilized coastal dune community

Diversity index	Undisturbed community	Disturbed community			
		site 1	site 2	site 3	site 4
Richness (S)	17	4	4	8	10
Berger-Parker (d)	0.595	0.790	0.702	0.737	0.746
Berger-Parker (1/d)	1.682	1.266	1.424	1.357	1.341
Simpson (D)	0.395	0.642	0.537	0.562	0.580
Shannon (H')	1.333	0.676	0.834	1.028	0.912
Hill's number (N1)	3.793	1.966	2.302	2.795	2.488
Hill's number (N2)	2.531	1.557	1.862	1.778	1.724

Table 5:
Life-form spectrum of weed species recorded in different crops at Burg EL-Arab (N= no. of species; P= % of each life form in each crop)

Life forms		Rain-fed		Irrigated			
		wheat	barley	wheat	barley	clover	broad beans
Perennials	N	3	8	3	2	3	1
	P	23.1	24.2	20.0	18.2	12.0	5.6
Annuals	N	10	25	12	9	22	17
	P	76.9	75.8	80.0	81.8	88.0	94.4

Table 6:
Species richness and diversity of weed communities in irrigated and rain-fed cultivations of common crops at Burg EL-Arab

Diversity		**Rain-fed**		**Irrigated**			
		wheat	**barley**	**wheat**	**barley**	**clover**	**broad beans**
Richness	**(S)**	9	18	10	11	12	13
Simpson	**(D)**	0.214	0.173	0.337	0.364	0.285	0.220
Shannon	**(H')**	1.741	2.159	1.394	1.348	1.702	1.784
Hill's no.	**(N1)**	5.706	8.672	4.063	3.851	5.500	5.959
Hill's no.	**(N2)**	4.654	5.769	2.966	2.748	3.520	4.552

S = mean number of species per one site

Table 7:
Effect of a cement factory at El-Hammam on species richness and diversity

Diversity index		**site 1**	**site 2**	**site 3**
Richness (S)	**Perennials**	4	8	6
	Annuals	7	13	19
Simpson (D)		0.290	0.276	0.321
Shannon (H')		1.267	1.512	1.306
Hill's no. (N1)		3.552	4.536	3.691
Hill's no. (N2)		3.450	3.626	3.115

Table 8:
Effect of grazing treatments at Omayed on species richness and diversity

Diversity index	**Grazing treatment**							
	A		**B**		**C**		**D**	
	1974	1979	1974	1979	1974	1979	1974	1979
Richness (S)	10	15	13	14	14	17	14	16
Simpson (D)	0.321	0.258	0.268	0.223	0.192	0.259	0.199	0.185
Shannon (H')	1.351	1.584	1.600	1.725	1.775	1.673	1.785	1.850
Hill's no. (N1)	3.862	4.875	4.956	5.615	5.900	5.329	5.958	6.359
Hill's no. (N2)	3.110	3.879	3.723	4.479	5.209	3.861	5.033	5.414

S: No. of perennial species
A: freely practiced grazing
B: fenced in July 1974 and kept protected
C: fenced in July 1974 and subjected to 50% grazing pressure
D: fenced and subjected to 50% grazing pressure since May 1977

Local industries

The effect of a cement factory located at EL-Hammam on species diversity was evaluated. Three sites were selected: 1- highly affected (200 m from the factory); 2- moderately affected (1 km from the factory); and 3- a control site, presumably unaffected (4 km far from the factory).

It is notable that only three species out of six could resist the high level of disturbance created by the factory: Arthrocnemum glaucum, Atriplex halimus, and Suaeda vera, which also attain higher importance values. One important species, Alhagi maurorum (I.V. 47.7 at site 3) is completely missing in the disturbed sites. On the other hand Salicornia fruticosa is the only species adapted to post-disturbance conditions and attain higher importance value at site 1 (6.75). Few annual species could persist this disturbance: Blackiella inflata, Cutandia memphetica, Mesembryanthemum nodiflorum, Poa annua and Spergularia marina, while eight species are completely missing: Anagallis arvensis, Anthemis microsperma, Bassia muricata, Bromus rubens, Chenopodium album, Malva parviflora, Medicago minima, and Trifolium resupinnatum. Inspection of the data (Table 7) indicate that species diversity attains its maximum value at the intermediate level of disturbance in site 2 (H'= 1.512), while the lowest diversity is attained in the most affected site 1 (H'= 1.267). The change in species richness has a similar trend.

Grazing treatments

The effect of grazing treatments on species diversity was assessed based on the records of REMDENE* project from 1974 to 1979 at Omayed (80 km west of Alexandria). The grazing treatment plots in the study area were: A: freely practiced grazing; B: fenced in July 1974 and kept protected; C: fenced in July 1974 and subjected to 50% grazing pressure; and D: fenced and subjected to 50% grazing pressure since May 1977 (REMDENE 1980).

Under all circumstances, species richness increased from 1974 to 1979 (Table 8). The most obvious observation is that Launaea resedifolia which could hardly be recorded in 1974, attained higher relative abundance in the B,C, and D plots, and so added to the species richness in the fenced plots. In the controlled grazing plots (50% of the freely practiced grazing pressure) dominance exhibited an increase from D= 0.192 in 1974 to D= 0.259 in 1979, which may be attributed mainly to the abundance of Plantago albicans. In the fenced plot with no grazing pressure as well as in the fenced plot subjected to 50% grazing pressure since 1977, dominance decreased as it was the case in the unprotected plot. On the other hand, diversity increased as measured by Shannon index in the plots A, B and D, but it exhibited a slight decrease in the controlled grazing plot C from H' = 1.78 in 1974 to H' = 1.67 in 1979. The number of equally abundant species also exhibited an increase from 1974 to 1979, except in the 50% grazing plot.

Annual species richness in 1974 before fencing was generally lower than in 1979 in the fenced plots as well as in the unprotected plot. The highest annual species richness was in the controlled grazing plot C, (17 species in 1979 compared to 9 species in 1974).

Discussion

Nearly 50% (about 1000 species) of the Egyptian flora occur in the western Mediterranean region (TÄCKHOLM 1974). Species richness and diversity in this region vary along two gradients of habitat factors, moisture availability and physiographic heterogeneity. One end of these gradients is represented by the habitat of salt marshes and saline depressions: moisture stress due to high salinity and monotonous relief. It is conceivable that extreme conitions act as a filter demanding adaptations for which not all genetic lines are able to cope with a harsh environment and survive there (WHITTAKER 1972). Therefore, the communities of this end of the two gradients are expected to be of the lowest richness and diversity and of considerably high dominance. The other end is represented by both the middle slope of rocky ridges and the non-saline depressions. These two habitats are characterized by receiving ample amounts of moisture through run-off from higher elevations as well as by low salinity. They are also characterized by their remarkable physiographic heterogeneity, the rocky ridges by dissection of their surface into a mosiac of microsites, and the non-saline depressions by the variability of structure and texture of sediments according to the velocity of sedimentation during run-off. The communities of this end of the two gradients are of the highest richness and diversity and of low dominance. The heterogeneity of the environment of these two habitats allows satisfaction of the requirement of many species within their communities (WHITTAKER & LEVIN 1977).

Species richness and diversity is also related to ecosystem succession. It is assumed that as ecosystems attain greater stability towards the climax stage, species richness increases and dominance decreases. This is clearly demonstrated in the psammosere of coastal dunes in the study area. At the initial stage of dune formation, the community attains the lowest richness and the highest dominance, and vice versa in the community of stabilized dunes. While this is true in many types of ecosystems (REINES et al., 1971, ODUM 1969 and BAZZAZ 1975), the reverse trend is described by other studies in which the climax or quasiclimax communities are overwhelmingly dominated by one species (LOUCKS 1970; AUCLAIR & GOFF 1971). Species abundance models of the communities of the habitat of coastal dunes also show a clear progressive increase in evenness and richness with dune stabilization, coinciding with decrease in dominance.

As GOODMAN (1975) remarks and as demonstrated by the graphs of the present study, diversity indices are often correlated. MAGURRAN (1981) (as quoted by MAGURRAN 1988) using the Spearman rank correlation found that the indices of the information theory measures and the model based indices all produced significantly concordant ranking of sites, and the indices that reflect dominance and evenness measures gave also a consistent ranking of sites. The present study also shows that the dominance index (Simpson's index) together with the information theory mea-

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sures (Shannon and Shannon evenness indices) gave the best consistent ranking of communities.

One of the notable results of the present study is that soil texture correlates significantly with species diversity, the coarser the texture the higher the species diversity. NOY-MEIR (1973) considers that soil texture and altitude in arid regions play a prominent role in determining the degree of moisture availability. Moisture availability is responsible for the largest component of variability in the spatial distribution of desert species. The classification of desert vegetation into communities is therefore commonly related to soil physical characteristics, as well as to the nature of surface and topographical perculiarities which all act through modifying the amount of available moisture (AYYAD & AMMAR 1974; KASSASS & BATANOUNY 1984; EL-SHARKAWI & RAMADAN 1984). Sandy and gravely soils usually have more favourable moisture conditions and support denser and taller vegetation than silty and clayey soils. This may be attributed to the greater infiltration capacity of coarse soils, which safe-guards against excessive losses by runoff and evaporation, allowing for storage of greater amounts of water in deeply-seated layers.

The primary cause of the decay of biodiversity is not direct human exploitation or malevolence, but the habitat destruction that inevitably results from the expansion of human populations and human activities (WILSON 1988). A variety of human-induced stresses have already taken their toll on ecosystems. With so much habitat being lost, the population of many species are being dramatically reduced. As a broad general rule, reducing the size of a habitat by 90 % will reduce the number of species which can be supported in the long run by about 50 % (SOULE 1986 and MCNEELY 1992). The western Mediterranean coastal desert of Egypt has been subjected to ecosystem degradation and species impoverishment due to the ways in which man has used and misused the natural resources of the region since its early history. The continued uncontrolled wood-cutting, overgrazing and rain-fed farming for cultivation of annual crops have dominated the region for many centuries. The net result has been the reduction of vegetation cover and the impoverishment of flora and fauna. This process has gone at a quicker pace in the nineteenth and twentieth centuries. More recent land-use activities have been even more devastating. For example intensive irrigated agriculture, obilteration of limestone ridges for bricks making which is endangering many chasmophytic species, and the occupation of large areas of the coastal dunes by summer resorts is endangering many psammophytic species. The present study provides estimates about the effect of some of these human manipulations on species diversity. It is notable that the nature of impact of man on biodiversity may be either sudden and radical, such as the establishment of human settlements and summer resorts or it may be gradual such as grazing of wild vegetation. In the first case, loss of species is the ultimate result. The few species which are endowed with the ability to survive such drastic changes of the habitat dominate the community to a considerable extent and species diversity deteriorates. For example, in the plant communities of coastal dunes disturbed by summer resorts no annuals were detected in all disturbed sites. When compared with undisturbed communities they were found to be of remarkably lower richness and diversity. This coincided with maximum dominance of these communities by Ammophila arenaria. It was also notable that both this species and Lotus polyphyllos were the only two species which could persist under different levels of disturbance. On the other hand, seven species out of seventeen were completely missing in all the studied disturbed sites. Most of these species were herbaceous. This indicates that habitat modification or destruction and extinction of species go hand in hand.

In the saline depressions of EL-Hammam only half the number of species could resist the disturbance exerted by the cement factory, one species was completely missing in the disturbed sites and only one species was gained as it was adapted to post-disturbance conditions. There was also a considerable effect of the cement factory on annual species , reducing their richness (8 species out of 19 were completely missing in disturbed sites). However, it was notable that species diversity increased in the moderately disturbed site. Alpha diversity may increase temporarily with ecosystem degradation (ARONSON et al. 1993).

The composition and structure of weed vegetation is mainly determined by ecological selection involved in the crop management techniques (FERRARI et al. 1984). In the present study theorphytes (annuals) represent the most common life-form in the studied sites. Perennial life-forms are relatively common in the rain-fed cultivations. The weed communities of rain-fed barley is characterized by higher species diversity. Generally, species diversity of weed communities was found to be lower than that of the vegetation in the near-by sites of the non-saline depressions. MURDOCH (1975) also found that natural systems are generally more diverse than artificial systems and are also more stable than such artificial systems as crops or laboratory populations.

Effects of grazing on plant species diversity have been discussed by many authors as HARPER (1969) and GRIME (1973, 1979). There would be an optimum grazing pressure at which species diversity attains its maximum. This optimum does not necessarily correspond to that at which maximum productivity or yield occur, and it does not necessarily be the same for all communities (NAVEH and WHITTAKER

1979). In the present study, the period from 1974 to 1979 was too short to reveal the effect of grazing treatments, but the results show a slight increase in diversity in the fenced plots. However, the richness of annual species in particular exhibited a notable increase under different grazing treatments, particularly in the plot subjected to 50% grazing pressure.

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