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Diversity of the salt marsh plant communities in the western Mediterranean region of Egypt

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ABSTRACT

The present study is an attempt to assess the effect of soil salinity and some other environmental factors on the plant community diversity in saline and marshy depressions of the western Mediterranean region of Egypt. The community diversity is negatively correlated with soil salinity and with the other related soil variables (clay, organic matter and water holding capacity). The habitat change, as a result of active sand deposition and process of hummock formation, also has a great impact on community diversity. The plant cover is negatively correlated with diversity. These findings are discussed in terms of adaptation theory.

INTRODUCTION

The eastern part of the western Mediterranean region of Egypt extending from Alexandria (31°10′ N, 29°51′ E) to El-Alamein (30°48′ 25″ N, 28°56′ 45″ E) is differentiated into a northern coastal plain and a southern plateau. The former is characterized by alternate ridges and depressions. Near the coast, the depressions approach the sea level, become waterlogged and form salt marshes with high salinity and shallow water table. To the south, the building up of soil, as a result of the stormy southern winds and the process of hummock formation, leads to deeper water table and decrease in salinity, hence the depressions change to non-saline ones. Such change in landforms along a salinity gradient is associated with prominent changes in the structure of the vegetation (Ayyad & El-Ghareeb 1982).

Much attention has been paid to species diversity in the ecological literature: first, in the development and comparison of different measures of diversity; second, in searching for general trends in diversity along environmental gradients; and third, in trying to attribute functional explanations of diversity gradients and adaptive advantages that diversity might impart to communities (MacArthur 1965, 1972; Hurlbert 1971; Whittaker 1972, 1975; Peet 1974; Grubb 1977; Pielou 1975; Routledge 1977; Connell 1978; Yodziz 1978; Huston 1979; Werner 1979; Wilson & Mohler 1983; Shmida & Wilson 1983; Wilson & Shmida 1984; El-Fahar 1989).

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It is generally accepted that in extreme deserts, species diversity is low (Williams 1964; Danin 1978). Quezel (1965) as quoted by Danin (1978) presents data on the extreme species poverty of several parts of the Sahara, where an area of 150,000 km^2 supports only 2 species of vascular plants. The main factors influencing species diversity of a given area include the mildness and heterogeneity of environmental conditions (Hamilton *et al.* 1963; MacArthur & Wilson 1967; Johnson *et al.* 1968; MacArthur 1972; Whittaker 1972). Danin (1978) reports that in deserts, edaphic diversity affects species diversity more than climate does.

In the western Mediterranean region of Egypt little attention has been paid to plant species diversity (Shaltout 1985). The present study concerns the effect of soil salinity and some other environmental factors on the diversity of plant communities that characterize different land-forms of the saline and marshy depressions of the eastern part of the western Mediterranean region of Egypt. The area selected for the present study is located near Burg El-Arab, 48 km southwest of Alexandria (30°54′ N, 29°33′ E). An account of the vegetation, climate, soil and topography of this area has been given by Ayyad & El-Ghareeb (1982) and Ayyad & Le Floc'h (1983).

METHODS

Fifty representative stands (20 × 20 m) were selected from sites representing the different situations of saline and marshy depressions in the study area (10 stands per site). These sites were: (I) transitional zone between the coastal ridge and salt marshes; (II) salt marshes with high salinity and shallow water table (<1 m); (III) depressions with high salinity and relatively deep water table (>1 m); (IV) depressions with medium salinity and deep water table—these are subjected to active process of sand deposition and hummock formation; and (V) tansitional sites to non-saline depressions, where neither salinity nor water table is a controlling factor.

Within each stand, a list of species was recorded, and the cover of each species was determined using the line-intercept method (Canfield 1941). The cover of each species relative to the total plant cover was estimated and used as a relative importance value of this species. Nomenclature follows Täckholm (1974).

Soil sampling was carried out in three locations in each stand. A hole was dug to a depth of 50 cm, and samples were collected along the whole depth. Earlier studies in the study area (Ayyad & El-Ghareeb 1972) suggested that measurements of soil factors can be restricted to this depth (50 cm), where the greatest amount of plant material occurred. The three samples from each stand were mixed, air-dried and passed through a 2-mm sieve in order to separate gravel and debris. Samples finer than 2 mm were analyzed for texture, organic carbon (OC), water holding capacity (WHC), calcium carbonate and total soluble salts (TSS) according to the procedures described by the United States Salinity Laboratory Staff (1954).

Species richness (alpha-diversity) for each site was calculated as the average number of species per stand. The extent of species replacement or biotic change along environmental gradients (beta-diversity) was calculated as the ratio between the total number of species recorded in the site as a whole (gamma-diversity) and its alpha-diversity minus one (Whittaker 1972; Wilson & Shmida 1984). Equitability or evenness of the relative importance values of species was expressed according to

Shannon-Weaver's index:

$$H' = \sum_{i=1}^{S} (Pi)(\log Pi)$$

and the concentration of dominance was expressed using Simpson's index:

$$C = \sum_{i=1}^{S} (Pi)^2$$

where S is the total number of species and Pi is the relative importance value (relative cover) of *i*th species. For a review of these indices see Pielou (1975).

RESULTS

As shown in Fig. 1, there is a close relationship between soil salinity and the other soil variables. The correlation coefficient between salinity on one hand and the other soil variables is significant positive ($P < 0{\cdot}05$) except with $CaCO_3$ which is negative but not significant ($P > 0{\cdot}05$).

Looking at Fig. 2, we note that the variation in the total cover of species has a similar trend to that of salinity, while the diversity indices have a reverse trend. Calculating the simple linear correlation coefficients between soil and vegetation variables, we find that the total cover has significant positive correlations with all

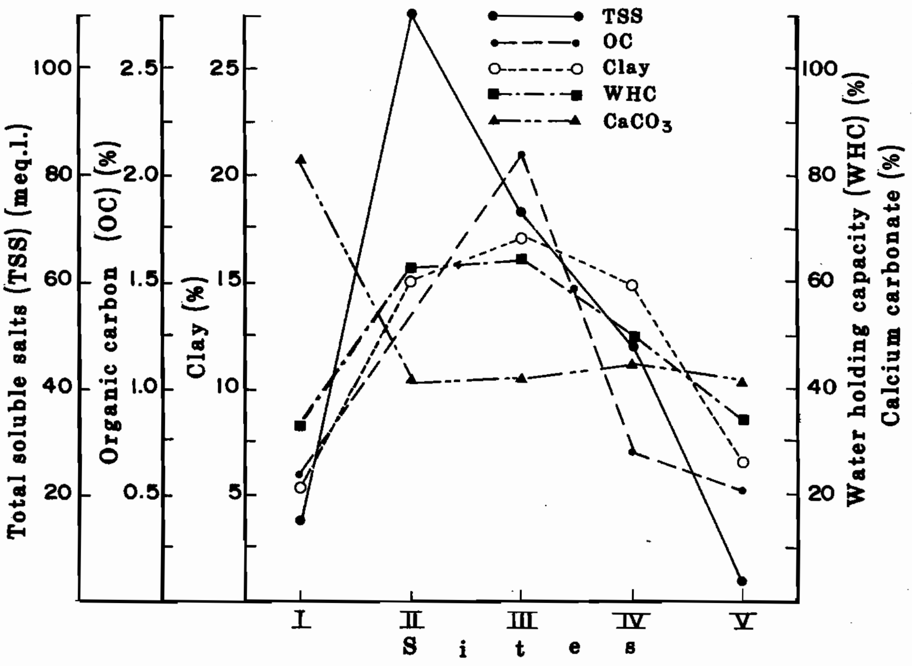

Fig. 1. Variation in some soil properties along the environmental gradient that characterizes the salt marshes in the study area. Key to sites as in Table 2.

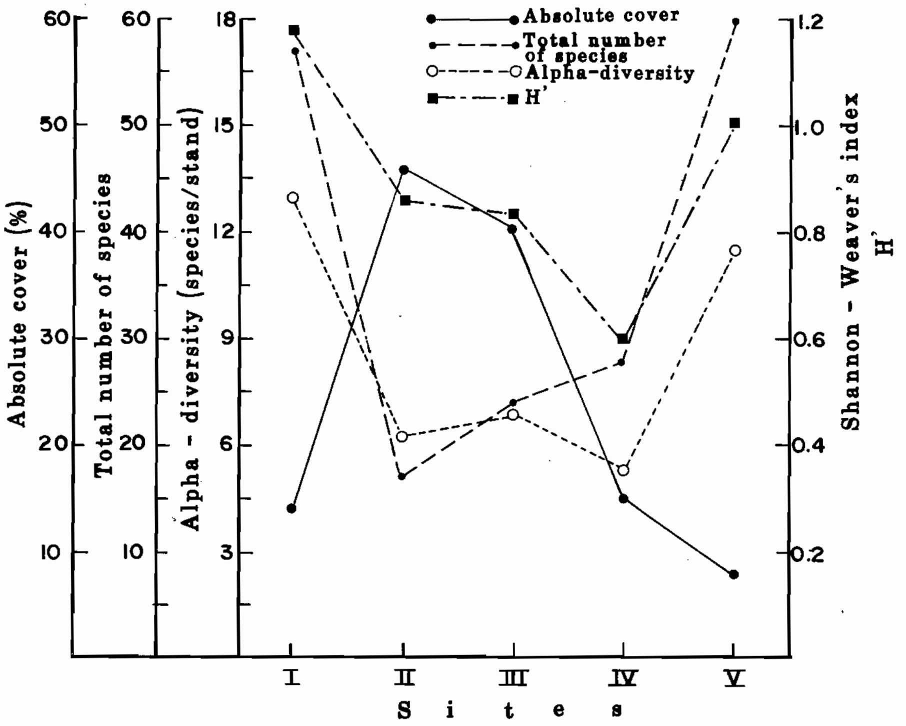

Fig. 2. Variation in vegetation cover and some diversity indices along the environmental gradient that characterizes the salt marshes in the study area. Key to sites as in Table 2.

soil variables except $CaCO_3$ content (Table 1). Most of the significant correlations between the soil variables and diversity indices are negative correlations; the $CaCO_3$ content is the only factor that has significant positive correlation with some of the diversity indices. It is of interest to report that the "r" values between beta-

Table 1. The correlation coefficient (*r*) between the vegetation and soil variables. H' is the Shannon-Weaver index. Underlined values are the *r* values between beta-diversity and the coefficient of variation of the means of soil variables

	Soil variable			
Vegetation variable	Total soluble salts (meq/100 g)	Organic carbon (%)	$CaCO_3$ (%)	Clay (%)
Total cover	0·94***	0·86***	−0·39	0·75**
Number of annuals	−0·86***	−0·63*	0·04	−0·74**
Number of perennials	−0·70*	−0·53	0·93***	−0·86***
Total number of species	−0·94***	−0·70*	0·55	−0·96***
Alpha-diversity	−0·74**	−0·49	0·65*	−0·94***
Beta-diversity	0·29	−0·40	0·64*	−0·12
	0·77**	0·32	−0·61*	0·77**
H'	−0·47	−0·29	0·67	−0·82**

*, P < 0·05; **, P < 0·01; ***, P < 0·001.

diversity and the coefficient of variations of the means of total soluble salts and clay percentage are significant positive, and that of $CaCO_3$ is significant negative.

The dominance-diversity curves of the transitional zone to coastal ridge and non saline depressions (sites I and V respectively) are less steep (sigmoid curves) than those of other communities (Fig. 3). They have the smallest C values (0·10, 0·14 for sites I and V respectively). The steepest curve is that of the depressions with medium salinity and deep water table (IV) which has also the highest C value (0·32). The interpretation of the variation in the relative concentration of dominance in relation to the different sites is indicated in Table 2. While the first five dominant species contribute 58·5% and 67·8% to the total cover of the transitional zones (I & V respectively), they contribute 97·1% to the total cover of site IV. Even the relative cover of only the first two species of site IV (77·1%) exceeds that of the first five species of sites I and V.

DISCUSSION

The purpose of measuring a community's diversity is usually to judge its relationship to other community properties such as productivity and stability, or to the environmental conditions to which the community is exposed (Pielou 1975). The community diversity increases as the number of species per sample increases and the abundance of species within a sample becomes even (Pielou 1969; Shafi & Yarranton 1973).

The present study indicates that the species diversity is negatively correlated with soil salinity and the percentages of clay, organic matter and water holding capacity. Such salinity stress on the species diversity in the area of the present study and related areas have been reported by Shaltout (1985) and El-Fahar (1989).

In general, the communities occurring in severe environments (e.g. saline ones) have a good fit to the geometric series of the niche-pre-emption that characterizes the communities with low diversity (Whittaker 1972). This is quite clear regarding the dominance-diversity curves representing the communities that inhabit the saline sites as compared with those of transitional zones (either to coastal dunes or to non-saline depressions). The curves of the former sites are more steep and characterized by higher values of the index that measures the relative concentration of dominance (Simpson's index). Hence, they are more profitable for approximating the geometric series (Whittaker 1965, 1972; Pielou 1975). Among these curves, that of the depressions with medium salinity and deep water table (site IV) is the steepest and associated with the highest value of Simpson's index and the lowest value of species richness. This means that the community which inhabits this site is the less diverse among all the studied communities. One of the reasonable causes for the behaviour of this community is the instability of its environment due to the heavy deposition of sand and the active formation of hummocks by the sand binding plants (*Limoniastrum monopetalum* and *Suaeda vera*) which contribute more than 77% of the total species cover in this site.

In the present study, the curves representing the plant communities in transitional sites have sigmoid distributions of moderate slope throughout. These distributions approximate to the log normal distribution which implies that there are many species of intermediate abundance and a few rare or common species (Whittaker 1965; Pielou 1975). The relatively high diversity of these communities

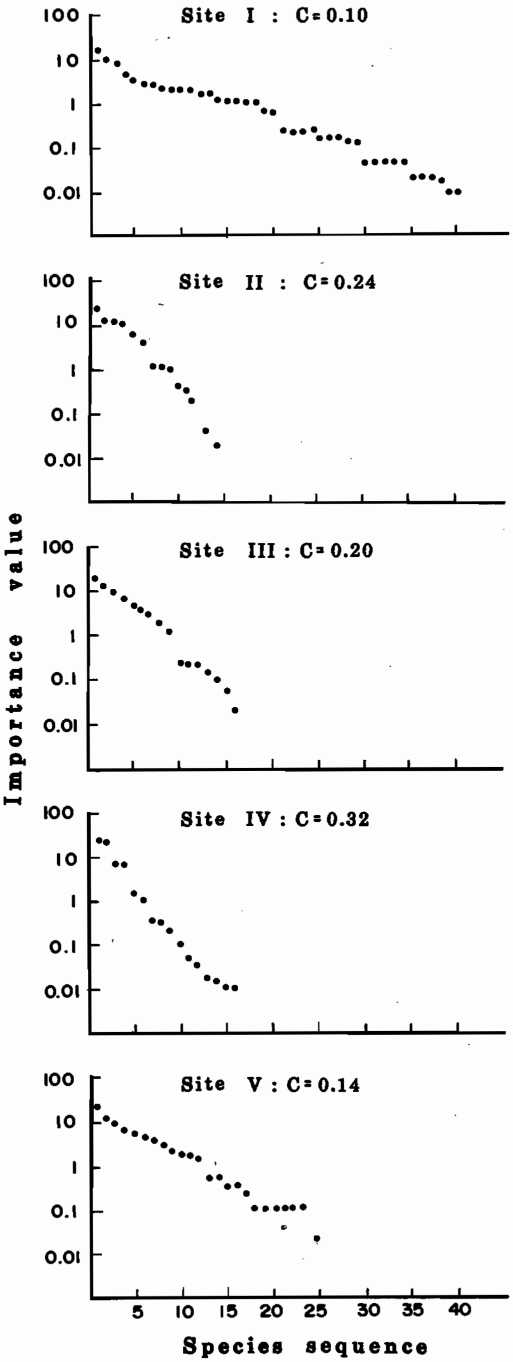

Fig. 3. Dominance-diversity curves of the five plant communities inhabiting the environmental gradient that characterizes the salt marshes in the study area. Key to sites as in Table 2.

Table 2. The first five dominant species, their absolute (AC) and relative (RC) cover for the five plant communities inhabiting the environmental gradient in the salt marshes of the study area

Site*	The first five dominant species	AC (%)	RC (%)
I	*Plantago albicans*	3·2	23·1
	Juncus rigidus	2·0	14·3
	Nitraria retusa	1·3	9·5
	Aeluropus lagopoides	0·9	6·3
	Zygophyllum album	0·7	5·3
	Total	8·1	58·5
II	*Salicornia fruticosa*	18·8	41·2
	Juncus rigidus	6·9	15·2
	Halocnemum strobilaceum	6·1	13·3
	Arthrocnemum glaucum	5·2	11·5
	Inula crithmoides	3·7	8·2
	Total	40·7	89·4
III	*Arthrocnemum glaucum*	13·0	32·2
	Juncus rigidus	10·2	25·2
	Salicornia fruticosa	3·9	9·6
	Halimione portulacoides	3·4	8·5
	Plantago crassifolia	3·2	7·8
	Total	33·7	83·3
IV	*Limoniastrum monopetalum*	6·3	41·0
	Suaeda vera	5·3	36·1
	Salsola tetrandra	1·3	9·1
	Alhagi maurorum	1·3	9·1
	Suaeda pruinosa	0·3	1·8
	Total	14·5	97·1
V	*Asphodelus microcarpus*	2·4	29·3
	Atriplex halimus	1·1	13·7
	Anabasis articulata	0·8	9·4
	Noaea mucronata	0·7	7·8
	Limoniastrum monopetalum	0·6	7·6
	Total	5·6	67·8

* I: transitional zones between coastal ridge and salt marshes; II: salt marshes; III: depressions with high salinity and relatively deep water table (>1 m); IV: depressions with medium salinity and deep water table; V: transitional zones to non-saline depressions.

may be explained in terms of the theory of substrate heterogeneity, as they are ecotonic areas that embrace the characteristics of habitats on both sides. Mellinger & McNaughton (1975) provide evidence that a higher level of species diversity would be brought about by a local differentiation in soil properties around individual plants, since heterogeneity of environments allows satisfaction of the requirements of diverse species within a community (Whittaker & Levin 1977). High species diversity due to substrate heterogeneity in some Mediterranean plant communities has been described by many authors (Houssard *et al.* 1980; Shaltout 1985; Kutiel & Danin 1987).

The present study indicates not only a negative correlation between soil salinity and species diversity, but also a negative correlation between species diversity and total species cover which gives a measure of phytomass (Muller-Dombois & Ellenberg 1974). This means that the species diversity decreases as plant phytomass and soil salinity increase. Most of the phytomass is accounted for by one or two species that apparently can make the best use of available resources, because of their high competition capacities under this environmental stress. As reviewed by Kutiel & Danin (1987), the existing literature contains conflicting evidence on the relationship between diversity and production of plants. The direction of correlation between both community properties appears to depend on the position of a given stand on the production scale (Grime 1979; Kutiel & Danin 1987).

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تنوع مجتمعات المنخفضات الملحية النباتية بالساحل الشمالي الغربي لمصر

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خلاصة

تعتبر هذه الدراسة محاولة في اتجاه تقييم تأثير ملوحة التربة وبعض العوامل البيئية الأخرى على تنوع المجتمعات النباتية بالمنخفضات الملحية الموجودة بالساحل الشمالي الغربي لمصر .

توصلت الدراسة إلى ما يلي :

١ ـ أن تنوع المجتمعات النباتية بمنطقة الدراسة يرتبط ارتباطا سالبا مع ملوحة التربة ، ومع بقية عوامل التربة الأخرى المرتبطة بالملوحة .

٢ ـ أن عدم ثبات الوسط ، كنتيجة لعملية الترسيب النشط للرمل وتكوين التلال حول النباتات ، له أيضا وقع كبير على التنوع .

٣ ـ أن الغطاء النباتي (كدليل للكتلة الحية للنباتات) له علاقة سالبة بتنوع المجتمعات النباتية المدروسة ، وقد نوقشت هذه النتيجة في ضوء نظرية التأقلم .

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