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**Ecologia**. — *Diversity of plant communities in coastal salt marshes habitat in Kuwait.* Nota (*) di MOHAMAD A.E. EL-SHEIKH, RAFIK M. EL-GHAREEB e ANNA TESTI, presentata dal Socio S. Pignatti.

ABSTRACT. — Integration phytosociology combined with traditional measures of diversity is used to describe the patterns of vegetation diversity along the coastal salt marshes of Kuwait. This study assesses the plant communities and the environmental factors that govern species diversity and distribution in the coastal salt marshes using TWINSPAN, DCA, and regression analysis. The results focus on: (1) the environmental gradients observed are very complex; (2) stressful environments support low plant species diversity but high dominance; also, (3) natural factors (substrate and climate) are important at the zonation and diversity of plant community by changing in the habitat formation. Six vegetation groups were identified at level 3 of TWINSPAN. (I) *Halocnemum strobilaceum-Juncus arabicus*, (II) *Halocnemum strobilaceum-Suaeda vermiculata,* (III) *Nitraria retusa-Zygophyllum qatarense*, (IV) *Zygophyllum qatarense-Haloxylon salicornicum*, (V) *Nitraria retusa*, (VI) *Tamarix aucherana*. The community diversity is negatively correlated with soil salinity, moisture, organic matter, fine texture, minerals, and plant cover and positively correlated with sand. Community diversity is consistently affected by the result of active sand deposition and process of hummock formation (Nabkas). These results are discussed in terms of competition adaptation theory.

KEY WORDS: Community diversity; Ecotones; Heterogeneity; Oligotrophic Stress habitat.

RIASSUNTO. — *La diversità delle comunità vegetali nelle paludi salmastre delle coste del Kuwait*. In questo studio viene usato l'approccio fitosociologico integrato alle tradizionali misure della diversità per un'analisi dei *pattern* di diversità della vegetazione nelle paludi salate della fascia costiera del Kuwait. La distribuzione e la diversità delle comunità vegetali in relazione ai fattori ambientali che le governano vengono analizzate utilizzando la DCA (*Detrended Component Analysis*) e l'analisi delle regressione. I risultati mettono in evidenza che: 1) i gradienti ambientali osservati sono molto complessi; 2) gli ambienti stressati sono caratterizzati da bassa diversità ed elevata dominanza; 3) i fattori naturali (clima e substrati) sono importanti per la zonazione e la diversità delle comunità. Con l'analisi multivariata effettuata con TWINSPAN, sono stati identificati sei gruppi di vegetazione: (I) *Halocnemum strobilaceum-Juncus arabicus*, (II) *Halocnemum strobilaceum-Suaeda vermiculata,* (III) *Nitraria retusa-Zygophyllum qatarense*, (IV) *Zygophyllum qatarense-Haloxylon salicornicum*, (V) *Nitraria retusa*, (VI) *Tamarix aucherana*. La diversità a livello di comunità risulta correlata negativamente con la copertura delle specie, con umidità, salinità, sostanza organica e tessitura del suolo, positivamente con la sabbia. La diversità delle comunità è fortemente influenzata dai processi di attiva deposizione della sabbia e di formazione delle dune (Nabkas). Questi risultati vengono discussi alla luce della teoria della competizione.

## 1. INTRODUCTION

Biodiversity has become an important measure to evaluate the ecosystems (*e.g.* Magurran, 1988) although the role of species diversity in ecosystem functioning is disputed (*e.g.* Schulze and Mooney, 1994; Patrick, 1997). A current challenge in ecology is to focus on how patterns (*i.e.* zonation) and processes vary with scale (Chapin and Korner, 1995) and to search for general principles «assembly rules» which determine the

(*) Pervenuta in forma definitiva all'Accademia il 24 luglio 2006.

species composition of communities (*e.g.* Belyea and Lancaster, 1999). Description of patterns in species assemblages and diversity is an essential step before generating hypotheses in functional ecology (Jonsson and Moen, 1998), and analyzing relations between plant communities and ecological processes (Schluter, 1984; Decocq, 2002).

The vegetation of the salt marsh of the Northern coast of Kuwait Bay has a special interest for several view points: (*i*) As ecotones between fresh water (terrestrial) and marine habitats; estuaries possess unique features which are far from being fully understood by scientists. They are important biotopes particularly from the zoological point of view, serving as habitat for terrestrial and marine organisms, as a reserve for migrating birds and as a refuge and breeding area for endangered species, to name only a few essential functions. In addition, various life cycles of marine organisms take place here, producing a wide range of effects on the marine ecosystem. (*ii*) Salt marshes is a unique habitat in species diversity in Kuwait because it has many native shrubs and perennials species. (*iii*) The vegetation of these marshes shows distinct pattern or zonation: what is the diversity of this zonation? (*iv*) What is the environmental factors effect in the zonation and its diversity? (Halwagy and Halwagy, 1977; Kuschner 1986). Based on its morphology, Kuwait coastal area can be broadly divided into northern and southern geomorphic provinces. The northern coastal salt marshes province occurs mainly along the north of the coast of Kuwait Bay and Khor Al-Sabiyah and on Bubiyan and Warba Islands. The southern coastal province extends from the southern coast of Kuwait Bay to the southern border of the country. It is remarked by a relatively steep beach profile and rocky intertidal flats. The northern coastal salt marshes, which fringe the Bay of Kuwait and Khor Al-Sabiyah have been extensively studied (Halwagy and Halwagy, 1977).

The ecological characteristics of these habitats, such as the salinity and the high temperature, make them particularly suitable for this kind of analysis exploring the relationship between environmental factors and communities diversity, up to now not deeply investigated on this point of view.

## 2. Study Area

The study area extends from northern of Kuwait Bay at Sulibkhat (29⁰ 05′ N - 47⁰ 41′ E) to the northern border of the country at Al-Abdaly (30⁰ 05′ N - 48⁰ 01′ E). This northern coastal province, which includes the coasts of Khor Al-Sabiyah and northern Kuwait Bay, is characterized by extensive and gently inclined intertidal flat (fig. 1). Khor Al-Subbiyah is a tidal channel separating Warba and Bubiyan Islands from the Kuwait mainland. Its western coastal flat is bounded landward by two sedimentomorphic units, namely, Umm Neqqa flat at the extreme north, and Al-Rukham slope which extends as far as Ras Al-Subbiyah in the extreme south (Khalaf *et al.*, 1995).

Umm Neqqa flat is covered by extensive active sand sheets and a few scattered sand dunes and merges gradually within the coastal flat Al-Rukham slope on the other hand is formed of Quaternary gravelly deposits covered with extensive pebbly gravel lag. It is extensively dissected by parallel drainage courses that debouch in the coastal flat. These courses are mostly filled with aeolian sand.

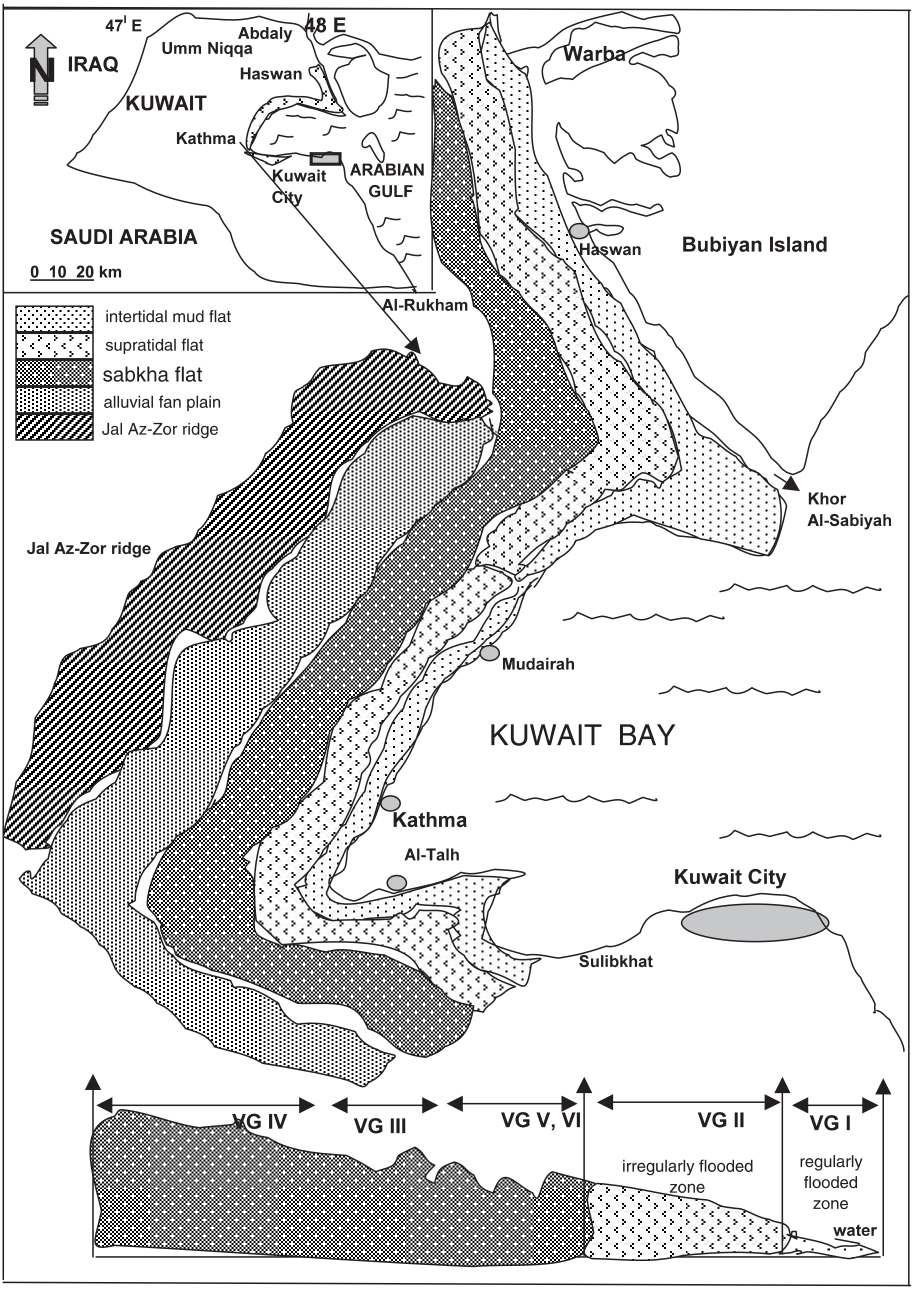



Fig. 1. – Location map showing the study area with their localities, habitats and the schematic representation of the spatial hierarchical organization of vegetation along the profile transects at the salt marshes of the northern coast of Kuwait.

Three sedimentomorphic zones (habitats) can be recognized in the coastal flat of Khor Al-Subbiyah, these are, from east to west: (*a*) Intertidal mud flat, (*b*) Supratidal saline flat, (*c*) Sabkha flat. The intertidal mud flat is separated from the supratidal and sabkha flat by flat terrace covered by elongated Oyster Banks. The supratidal flat is occasionally flooded by sea water during tides. Sabkha flat is wider than the others and hence characterizes into three microhabitats from east to west as the follows: the lower saline edge, the middle flat, and the higher coastal sandy drifts that merges into desert proper. Halophytes are more sporadically scattered within this Sabkha flat. A small accumulation of muddy sediments mixed with shell fragments occurs as wind shadows around these halophytes. On the other hand, sabkha flats are relatively wide in the northern coastal area of Khor Al-Subbiyah and narrow towards the south. Their surfaces are covered with fluffy silt sediments and scattered crystal of gypsum protrudes from them. Shallow trenches in these sabkha flats showed that they are mostly formed of thin interlaminated layers of mud and sand. Mud layers are commonly very dense while sand layers are friable and contain a considerable amount of authigenic saccaroidal gypsum crystals. In the Ras Al-Subbiyah and Al-Maghasel areas, sabkha flats are partially covered with scattered patches of Molluscan shell lag.

The northern coast of Kuwait Bay is bounded landward by Jal Az Zor escarpment. It has a sedimentomorphic zonation similar to that of Khor Al-Subbiyah coastal area, in addition to a fourth zone (habitat), an alluvial fan plain that is located between the sabkha flat and the terrace of Jal Az Zor escarpment. Clusters of Nabkas occur as scattered fields on the inland side of the sabkha flat close to the alluvial fan.

The soil of salt marshes ranges from loamy sand to sandy clay. These marshes are influenced primary by tidal action and by the shallow saline water table. In addition, large areas of these marshes receiving salt spray that support many halophytes plant communities.

## 3. Methods

*Vegetation survey.*

Four belt transects were taken at Al-Talh, Kathma, Mudirah and Haswan (fig. 1). Transects ran perpendicular to the shore line and the vegetation belts. The width of transect was constantly 5 m, their length varied according to site: Al-Talh 5000 m, Kathma 2000 m, Mudairah 1500 and Haswan 1250 m. The belt transect was divided transversely into 5 m$^2$ quadrats; 268 stands were recorded in the study area, to cover the various vegetation and landform types. Being each site different in the topography and in the size of communities inhabiting on it, the mean regarding the variation in length of transects and the number of stands, has been considered in the analysis as important factor for the comparison of the sites.

The sampling process was carried out during spring season when most species were expected to be growing. The stands were distributed as follows: 91 stands at Al-Talh, 76 stands at Kathma, 56 stands at Mudairah, and 45 stands at Haswan. The vegetation parameters included listing of all species, visual estimation of cover-abundance of each species and classification according to Domin-Kraijina scale (Krajna, 1933 as described in

Halwagy *et al*., 1982) and nomenclature was done according to Daoud and Al-Rawi (1985), Al-Rawi (1987), Boulos and Al-Dosari (1994).

*Soil analysis.*

For each stand, soil samples were collected at different profiles of 0-2 cm, until to 60-80 cm deep. Average of the data of these samples for each stand has been calculated. Soil moisture was determined as a percentage of oven-dry matter. Soil texture was determined by Bouyoucos hydrometer. Total organic matter was determined based on loss-on-ignition at 450°C. Soil water extracts (1:5) were prepared for estimation of pH, electrical conductivity (EC) as mS $cm^{-1}$. Total water soluble salts (TSS) were determined gravimetrically by digesting the soil water extract with $H_2O_2$, evaporating to dryness and oven-drying. Water soluble carbonates and bicarbonates were determined on soil water extract by titrating against 0.1N HCl using phenolphethaline and dimethyl yellow as indicators. Calcium carbonates were determined on dry soil by calcimeter. Chlorides were determined by using the Radiometer pH meter, with a calomel 14 - 140 reference electrode and chloride S electrode F 101 indicator electrode. Soil nutrients (Ca, K, Na, and Mg) were determined by using an atomic Absorption spectrophotometer (Jackson, 1962; Allen *et al*., 1974).

*Multivariate and diversity analysis.*

The cover estimates of 83 species in 268 stands were subjected to *a*) two-way indicator species analysis (TWINSPAN), as a classified technique; *b*) detrended correspondence analysis (DCA), as an ordination method. This follows the procedure of Hill (1979*a*, *b*). Species richness ($\alpha$-diversity) of each vegetation cluster was calculated as the average number of species $stand^{-1}$. Species turnover ($\beta$-diversity) was calculated as the ratio between the total numbers of species recorded in a certain vegetation cluster and its ($\alpha$-diversity). Equitability or evenness of the relative importance values of species was expressed according to Shannon-Wiener index $\left(\hat{H} = -\sum_{i=1}^{s} \pi \log \pi\right)$. Relative concentration of dominance was expressed by the 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 (*i.e.*, relative cover) of the *i*th species (Pielou, 1975; Magurran, 1988). The dominance-diversity curves representing a method of Rank/Abundances of the species in the 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 species.

*Statistical data treatment.*

The variation in the species diversity and soil variables in relation to vegetation clusters were assessed using one way analysis of variance (ANOVA). Relationships between the community (*i.e.* vegetation clusters) and soil variable were tested using Pearson's simple linear correlation coefficient (r). The probable environment significance of the ordination axes was investigated by the simple linear correlation analysis and the forward selection of stepwise multiple regression. The forward selection starts with the best single regressor, then finds the best one to add to what exists, and so on (SAS, 1985).

## 4. Results

*Classification of plant communities.*

The vegetation of these salt marshes shows distinct zonation. Different communities occupy belts that run parallel to the shoreline. TWINSPAN divided the set of 283 stands into six vegetation clusters (*i.e.* six plant communities) at level 3. They are named using the characteristic species as follows: (I) *Halocnemum strobilaceum-Juncus arabicus*, (II) *Halocnemum strobilaceum-Suaeda vermiculata,* (III) *Nitraria retusa-Zygophyllum qatarense*, (IV) *Zygophyllum qatarense-Haloxylon salicornicum*, (V) *Nitraria retusa*, (VI) *Tamarix aucherana*. The second DCA axis revealed clear salinity, microtopography, plant cover and the shallow saline water table, which form belts parallel to the shore line (table I, fig. 2). Zonation differs from one site to another and appears to be influenced by the horizontal distance from the shoreline and ground level in relation to high water mark.

Table I. – *Mean cover (%) of the recorded species in the six vegetation clusters after the application of TWINSPAN.*

| Species | Chorotype | Life form | Vegetation group | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | I | II | III | IV | V | VI |
| **AIZOACEAE** | | | | | | | | |
| *Mesembryanthemum nodiflorium* L. | SA,ES | AH | | 0.2 | 3.0 | 1.0 | | |
| **BORAGINACEAE** | | | | | | | | |
| *Anchusa hispida* Forssk. | SA,IT | AH | | | | 0.4 | | |
| *Arnebia decumbens* (Vent.) Coss. & Kralik | SA,IT | AH | | | | 1.2 | | |
| ***Helotrobium bacciferum*** Forssk. | SA,SU | PS | | | | 0.1 | | |
| *Moltkiopsis ciliate* (Forssk.) I.M. Johnst. | SA,ME,SU | PH | | | | 0.7 | | |
| **CARYOPHYLLACEAE** | | | | | | | | |
| *Gypsophila capillaries* (Forssk.) C. Chr. | SA | AH | | | | 1.1 | | |
| *Loeflingia hispanica* L. | SA,ME | AH | | | | 0.8 | | |
| *Paronychia arabica* (L.) DC. | SA | AH | | | | 0.8 | | |
| *Silene arabica* Boiss. | SA | AH | | | | 0.6 | | |
| *Spergularia diandra* (Guss.) Heldr. & Sart. | ME,IT,SA | AH | | | | 0.8 | | |
| **CHENOPODIACEAE** | | | | | | | | |
| *Bassia muricata* (L.) Asch. | SA | AH | | | | 0.1 | | |
| *Bienertia cycloptera* Moq. | IT | AH | | 0.2 | 2.3 | 3.0 | | |
| *Cornulaca monacantha* Delile | SA | AH | | | 1.3 | 1.5 | | |
| *Halocnemum strobilaceum* (Pall.) M. Beib. | SA,ME,IT,ES | PS | 42.1 | 72.4 | | 0.3 | | |
| *Haloxylon salicornicum* (Moq.) Bunge ex Boiss. | SU,IT | PS | | | | 19.0 | | |
| ***Salicornia herbacea*** | | PS | | 0.2 | | | | |
| ***Salsola bryosma*** | | PS | | 0.2 | 0.3 | 2.2 | | |
| ***Salsola cyclophylla*** Baker | | PS | | | | 0.1 | | |
| ***Salsola imbricate*** Forssk. | SA,SU | PS | | 0.2 | | 2.8 | | |
| *Seidlitzia rosmarinus* Bunge ex Boiss. | SA,IT,ME | PS | | 10.6 | 8.6 | 4.9 | | |
| *Suaeda aegyptiaca* (Hasselq.) Zohary | SA | AH | | 0.2 | 0.6 | 1.3 | | |

*continued*

TABLE I. – *Continued.*

| Species | Chorotype | Life form | Vegetation group | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | I | II | III | IV | V | VI |
| ***Suaeda vermiculata*** Forssk. ex J.F. Gmel. | | PS | | 14.8 | | 0.9 | | |
| *Traganum nudatum* Delile | | AH | | | | 1.0 | | |
| **CISTACEAE** | | | | | | | | |
| *Helianthemum lippii* (L.) Pers. | SU,SA | PS | | | | 0.2 | | |
| **COMPOSITAE** | | | | | | | | |
| *Anthemis deserti* Boiss. | ES,ME,IT | AH | | | | 1.0 | | |
| *Atractylis carduus* (Forssk.) C. Chr. | SA,ME | PH | | | | 1.2 | | |
| *Carduus pycnocephalus* L. | SA | AH | | | | 0.1 | | |
| *Filago pyramidata* L. | ME,IT | AH | | | | 1.9 | | |
| *Gymnarrhena micrantha* Desf. | SA,IT | AH | | | | 0.6 | | |
| *Ifloga spicata* (Forssk.) Sch. Bip. | SA,E | AH | | | | 4.0 | | |
| *Koelpinia linearis* Pall. | SA,IT | AH | | | | 0.5 | | |
| *Launaea capitata* (Spreng.) Dandy | SA,SU | AH | | | | 1.6 | | |
| *Launaea mucronata* (Forssk.) Muschl. | SA | PH | 0.6 | | | 1.0 | | |
| *Picris babylonica* Hand. Mazz. | SA,E | AH | | | | 0.8 | | |
| *Rhanterium epapposum* Oliv. in Hook. | SA,IT | PS | | | | 2.8 | | |
| *Senecio glaucus* L. | SA,IT | AH | | | | 0.6 | | |
| **CONVOLVULACEAE** | | | | | | | | |
| *Convolvulus oxyphyllus* Bioss. | SA,IT | PH | | | | 0.9 | | |
| ***Cressa cretica*** L. | ME,IT,TR | PS | | | 0.2 | 0.3 | | 33.8 |
| **CRUCIFERAE** | | | | | | | | |
| *Brassica tournefortii* Gouan | SA,ME | AH | | | | 0.1 | | |
| **CUCURBITACEAE** | | | | | | | | |
| *Citrullus colocynthis* (L.) Schrad. | SA | AH | | | | 0.1 | | |
| **CYPERACEAE** | | | | | | | | |
| ***Cyperus conglomeratus*** Rottb. | P,SA,SU,ME | SD | | | | 0.1 | | |
| **DIPSACACEAE** | | | | | | | | |
| *Scabiosa olivieri* Coult. | IT | AH | | | | 0.2 | | |
| **EUPHORBIACEAE** | | | | | | | | |
| *Euphorbia dense* Schrenk | | AH | | | | 0.6 | | |
| *Euphorbia granulate* Forssk. | | AH | | | | 0.3 | | |
| **FRANKENIACEAE** | | | | | | | | |
| *Frankenia pulverulenta* L. | ES,ME,IT | AH | | | | 0.3 | | |
| **GERANIACEAE** | | | | | | | | |
| *Erodium laciniatum* (Cav.) Willd. | SA,ME,IT | AH | | | | 0.8 | | |
| **GRAMINEAE** | | | | | | | | |
| *Aegilops kotschyi* Boiss. | SA,IT | AG | | | | 0.2 | | |
| *Aeluropus lagopoides* (L.) Trin. ex Thwaites | SA,ME,IT | PG | 10.6 | | 1.1 | 0.6 | | 0.7 |
| *Aaronsohnia factorovskyi* Warb. & Eig in Eig | | AH | | | | 0.5 | | |
| *Cutandia memphitica* (Spreng.) K. Richt. | SA,IT,ME | AG | | | | 0.5 | | |
| *Cynodon dactylon* (L.) Pers. | TR | PG | | | | 0.1 | | |
| *Panicum turgidum* Forssk. | SA,SU | PG | | | | 0.7 | | |
| *Rostraria pumila* (Desf.) Tzvelev | – | AG | | | | 0.1 | | |
| *Schismus arabicus* Nees | SA,IT,ME | AG | | | | 1.1 | | |
| *Schismus barbatus* (L.) Thell. | SA,IT,ME | AG | | | 0.3 | 3.5 | | |
| *Sporobolus arabicus* | | | | | | 0.1 | | |
| *Stipagrostis ciliate* (Desf.) de Winter | SA | PG | | | | 1.0 | | |
| *Trachynia distachya* (L.) Link | SA,ME,IT | AG | | | | 0.2 | | |
| **JUNCACEAE** | | | | | | | | |
| *Juncus rigidus* | | PG | 32.4 | 0.7 | | 0.1 | | |
| **LEGUMINOSAE** | | | | | | | | |
| *Alhagi graecorum* | | PS | | | | 0.1 | | |

*continued*

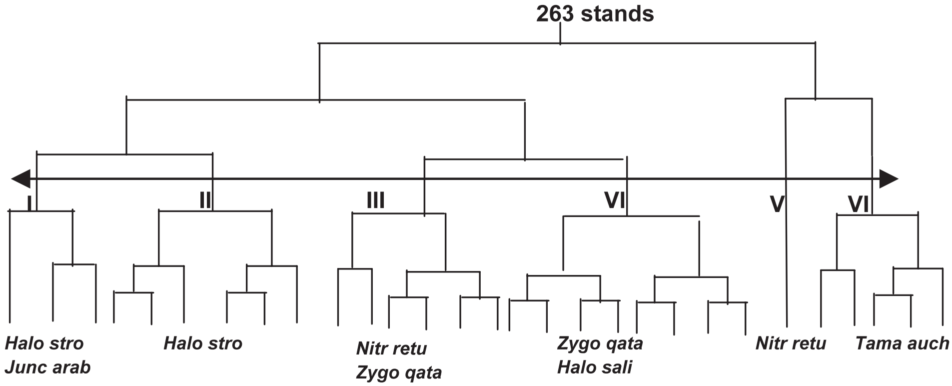
TABLE I. – *Continued.*

| Species | Chorotype | Life form | Vegetation group | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | I | II | III | IV | V | VI |
| *Astragalus annularis* Frossk. | SA,ME,IT | AF | | | | 0.4 | | |
| *Astragalus hauarensis* Boiss. | SA | AF | | | | 0.7 | | |
| *Astragalus spinosus* (Forssk.) Muschl. | SA,IT | PF | | | | 0.1 | | |
| *Hippocrepis aneolata* Boiss. | SA,IT | AF | | | | 0.6 | | |
| *Lotus halophilus* Boiss. & Sprun in Boiss. | SA,ME,IT | AF | | | | 0.7 | | |
| *Medicago laciniata* (L.) Mill. | SA,IT | AF | | | | 0.5 | | |
| *Trigonella stellata* Forssk. | SA,IT | AF | | | | 0.2 | | |
| **LILIACEAE** | | | | | | | | |
| *Asphodelus tenuifolius* Cav. | SA,SU,ME | AH | | | | 0.7 | | |
| **NEURADACEAE** | | | | | | | | |
| ***Neurada procumbens*** L. | SA,SU | AH | | | | 1.3 | | |
| **OROBANCHACEAE** | | | | | | | | |
| *Cistanche tubulosa* (Schrenk) Wight | SA,IT,SU | PA | | | | 0.4 | | |
| **PLANTAGENACEAE** | | | | | | | | |
| *Plantago ciliate* Desf. | SA,IT | AH | | | | 1.5 | | |
| *Plantago coronopus* L. | SA,IT | AH | | | | 0.7 | | |
| *Plantago ovata* Forssk. | SA,IT | AH | | | | 1.6 | | |
| **POLYGONACEAE** | | | | | | | | |
| *Emex spinosa* (L.) Campd. | ME,IT | AH | | | | 0.7 | | |
| **RESEDACEAE** | | | | | | | | |
| *Oligomeris linifolia* (Webb & Berth) Webb | SA,SU | AH | | | 1.2 | 1.2 | | |
| *Reseda arabica* Boiss. | SA | AH | | | | 0.4 | | |
| **SOLANACEAE** | | | | | | | | |
| *Lycium shawii* Roem. & Schult. | IT | PS | | | | 0.1 | | |
| **TAMARICACEAE** | | | | | | | | |
| *Tamarix aucheriana* (Decne.) B.R. Baum | SA | PS | | | | | 34.8 | 65.5 |
| **UMBELLIFERAE** | | | | | | | | |
| *Bupleurum semicompositum* L. | SA,ME,IT,TR | AH | | | | 0.4 | | |
| **ZYGOPHYLLACEAE** | | | | | | | | |
| *Fagonia bruguieri* DC. | SA,IT | PS | | | | 0.2 | | |
| *Nitraria retusa* (Forssk.) Asch. | SA,SU | PS | | | 59.1 | 1.0 | 65.2 | |
| *Zygophyllum qatarense* Hadidi in Boulos | SA | PS | | 0.8 | 16.7 | 23.3 | | |

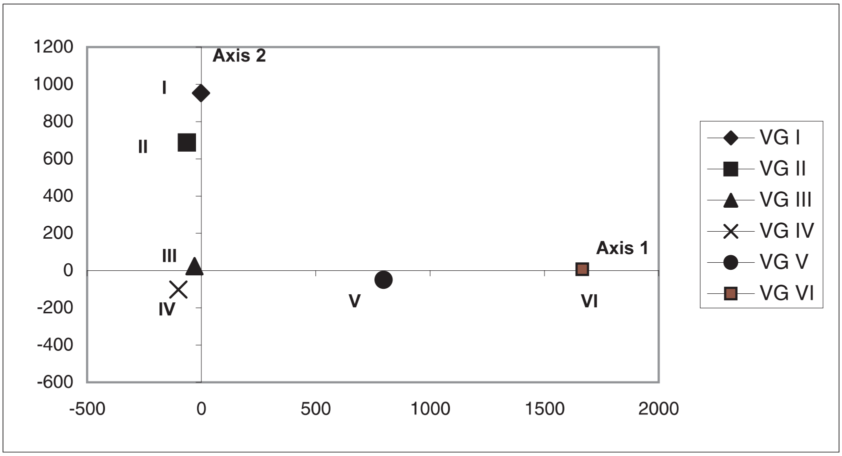
The life forms are: AH: annual herbs; AG: annual grasses; AF: annual forbs; PH: perennial herbs; PG: perennial grasses; PF perennial forbs; PS: perennial shrubs; TR: trees; SD: sedges and rushes; PA: parasites.
The vegetation clusters are named as follows: (I) *Halocnemum strobilaceum-Juncus arabicus,* (II) *Halocnemum strobilaceum-Suaeda vermiculata,* (III) *Nitraria retusa-Zygophyllum qatarense,* (IV) *Zygophyllum qatarense-Haloxylon salicornicum,* (V) *Nitraria retusa,* (VI) *Tamarix aucherana.*

CLUSTER I. *Halocnemum strobilaceum-Juncus arabicus* is confined to the lower marshes (the intertidal mud flat). Its seaward edge inundated by tides about 500 times per year, and occurs on the mud flats saline soil. They are influenced chiefly by tidal action (maximum tidal range 4.00 m, minimum 0.05 m), the saline water table and microrelief. This community is formed by low sparse shrubs. Often, they are dominated by a single species of *Halocnemum strobilaceum*, but sometimes form mixed with one or two co-dominant species in further landwards, *e.g. Juncus arabicus*. The latter species occurs on the wet mudbanks of drainage creeks (fig. 3).

CLUSTER II. *Halocnemum strobilaceum-Suaeda vermiculata* occurs further landwards of the supratidal flat and is much wider than that of *Halocnemum strobilaceum-Juncus*




(a)




(b)

Fig. 2. – Relation between the six plant clusters resulting from the application of TWINSPAN (*a*) and DCA technique (*b*).

*arabicus*. The ground is more or less flat and varies in height from 4.30 to 4.80 m above sea level. This community is luxuriant, forming small sand mounds and shelters a number of perennials, which are mostly halophytic. Annuals halophytic and nonhalophytic species are also predominant (fig. 4).

Cluster III. *Nitraria retusa-Zygophyllum qatarense* community is further land wards on the sabkha flat and much wider than that of *Halocnemum* belts. This community forms two parallel belts separated by a strip dominated by *Nitraria retusa-Zygophyllum qatarense* in the middle of sabkha flat. The first belt (and most sea ward) is about 700 m in width; the ground rises from 5 m to 6 m above sea level, when the

Fig. 3. – View at Kathma showing the habitat of the intertidal mud flat regularly flooded by water and inhabited by vegetation group (I) *Halocnemum strobilaceum-Juncus arabicus*. Note the lower diversity of this community, white saline mud flat and migration birds in the background.

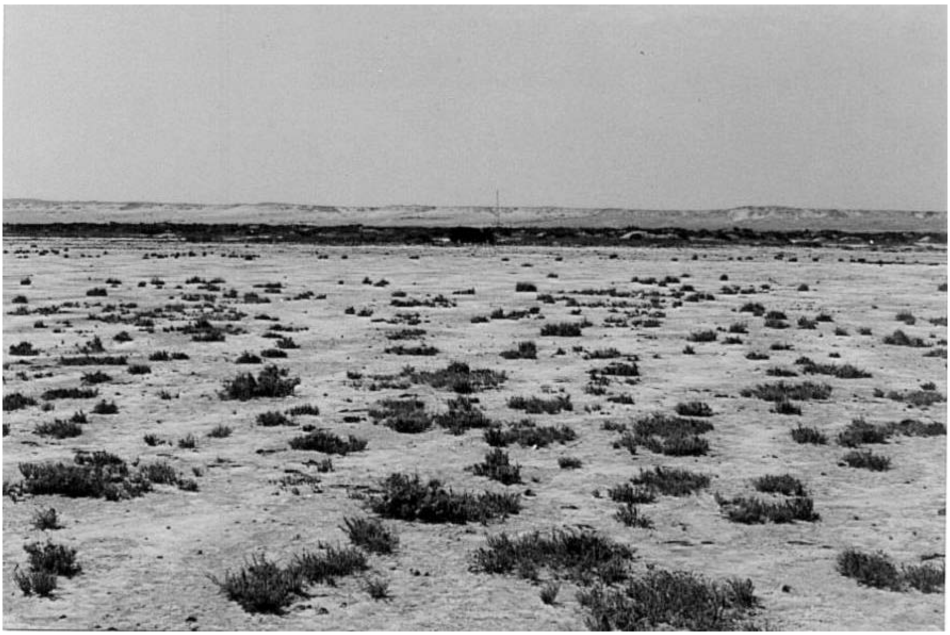


Fig. 4. – Vegetation group (II) *Halocnemum strobilaceum-Suaeda vermiculata* along supratidal flat in the foreground; vegetation groups (III) *Nitraria retusa-Zygophyllum qatarense* and (IV) *Zygophyllum qatarense-Haloxylon salicornicum* in the midground. Jal Az Zor ridge appears in the background at Al-Talh.

saline soil is overlapped by sandy soils. The second belt is about 350 m in width; the ground rise from 6 m to 10 m above sea level and it is located on relatively high Sabkha (fig. 4).

CLUSTER IV. *Zygophyllum qatarense-Haloxylon salicornicum* community occurs on the higher part of sabkha flat «coastal sandy drifts»; as the salt marsh merges into the desert proper, *Zygophyllum qatarense* disappears being replaced by a typical desert community dominated by *Haloxylon salicornicum* and forming also small Nabkas (sand mounds). This community supports a greater species diversity, with larger proportion of non halophytic elements at the landward end between salt marsh and the desert plain and can be considered a transitional zone between salt marshes and desert (fig. 4).

CLUSTER V. *Nitraria retusa* community is about 1300 m in width on the lower saline edge of sabkha flat habitat of Al-Talh locality, where the saline water table is very near to soil surface. *Nitraria retusa* is a more or less pure dominant and does not grow luxuriantly (represented by short depauperate shrubs) in this zone because of intensive camel browsing and possibly because of edaphic factors (fig. 5).

CLUSTER VI. *Tamarix aucherana* community inhabits further inland on the lower saline edge of sabkha flat habitat of Al-Talh locality and is about 1700 m in width. The ground rising gently gradually landwards and saline water table is very near to soil surface. *Tamarix* is practically the only dominant species, associated with *Cressa cretica*.

Fig. 5. – Dense growth of *Zygophyllum qatarense*. Note the sand mounds (small Nabka) in the foreground and vegetation group (V) *Nitraria retusa* in the background at Kathma.

*Diversity of plant communities.*

In salt marshes habitat, the applied indices indicate that the *Zygophyllum qatarense-Haloxylon salicornicum* cluster (IV) (a transitional zone between saline sites and desert habitats which inhabited along the higher zone of salt marshes «coastal sandy drifts») is substantially more diverse than any of the other communities (table II). This community presents the highest values of total species (80 species, 44 annuals and 36 perennials), total genera (71), total families (26), species richness ($\alpha = 11$ spp stand$^{-1}$), species turnover ($\beta = 7.0$), relative evenness by Shannon-Winer index ($\hat{H} = 0.80$), and consequently the relative concentration of species dominance by Simpson index is lower ($C = 0.21$).

TABLE II. – *Mean ± standard deviation of diversity indices and soil characters of the six vegetation clusters identified in the study area.*

| **Vegetation groups** | **I** | **II** | **III** | **IV** | **V** | **VI** | **Total mean** |
|---|---|---|---|---|---|---|---|
| **Number of stand** | **7** | **47** | **37** | **135** | **3** | **34** | **263** |
| | | | | **Diversity indices** | | | |
| Annuals | 1 | 2 | 4 | **44** | — | — | 13±18.1 |
| Perennials | 3 | 9 | 8 | **36** | **2** | 3 | 10±11.8 |
| Genera | 4 | 9 | 12 | **71** | **2** | 3 | 17±24.4 |
| families | 4 | 4 | 6 | **26** | **2** | 3 | 8±8.3 |
| Species number | 4 | 11 | 12 | **80** | **2** | **3** | 19 |
| Species richness (Spp stand$^{-1}$) | 2.6±0.4 | 1.7±0.6 | 2.6±1.5 | **11.4±6.0** | 2.0±0.0 | **1.1±2.6** | 6.15±6.8 |
| Species turnover ($\beta$) | 1.5±0.4 | 6.4±3.5 | 4.8±1.3 | **7.0±5.7** | **1.0±0.0** | 2.7±0.1 | 3.9±2.3 |
| Shannon-Winer index (H′) | 0.35±0.1 | 0.16±0.1 | 0.23±0.2 | **0.80±0.3** | 0.23±0.1 | **0.02±0.03** | 0.44±0.4 |
| Simpson index (C ) | 0.40±0.1 | 0.33±0.2 | 0.31±0.2 | **0.21±0.1** | 0.61±0.1 | **0.96±0.2** | 0.23±0.2 |
| Species cover (%) | **47.6±14** | 21.8±9.5 | **16.7±9.5** | 35.2±17 | 30.7±9 | 17.0±3.7 | 27.3±16.9 |
| Cover of first two dominant species (%) | 74.5 | 87.2 | 75.8 | **23.5** | **100** | 99.3 | 76.7 |
| | | | | **Soil variables** | | | |
| Moisture (%) | **10.2**±0.7 | 8.9±1.5 | 2.5±1.1 | **1.9**±0.6 | 9.6 | 9.3 | 7.0±3.4 |
| Org. matter (%) | 0.37±0.1 | 0.25±0.1 | 0.21±0.1 | **0.09**±0.04 | 0.30 | 0.46 | 0.28±0.11 |
| Total soluble salt (%) | 3.1±0.3 | **6.7±0.2** | 3.9±1.2 | **0.6**±0.2 | 4.7 | 5.7 | 4.1±1.9 |
| Ca $CO_3$ (%) | **51.6**±12 | 11.2±1.9 | **8.7**±0.8 | 9.3±0.8 | 9.0 | 11.8 | 16.9±15.5 |
| Sand (%) | 63.1±15 | 59.0±11 | **76.8**±11 | **75.0±9.6** | 72.0 | 71.6 | 69.5±6.8 |
| Silt (%) | 13.5±2.8 | **17.9±1.2** | 6.2±4.2 | 7.8±0.1 | 15.2 | **4.8** | 10.9±5.3 |
| Clay (%) | 22.4±1.7 | 22.7±3.7 | 17.1±0.1 | **16.7**±0.1 | 22.8 | **23.7** | 20.9±2.8 |
| pH | 7.78±0.5 | 7.84±0.1 | 7.78±0.1 | **8.08±0.1** | **7.75** | 7.80 | 7.83±0.11 |
| EC mS cm$^{-1}$ | 19.9±5.7 | **28.6±2.5** | 20.5±4.7 | **3.0**±1.9 | 17.8 | 21.3 | 18.5±7.7 |
| Cl (meq 100g$^{-1}$) | 32.0±0.6 | **88.9±5.4** | 27.4±11 | **3.6**±2.4 | 47.2 | 70.4 | 44.9±90.8 |
| Na (meq 100g$^{-1}$) | 30.4±7.6 | **51.5±3.7** | 21.3±1.0 | 7.3±5.1 | 38.0 | 47.3 | 32.6±15.1 |
| K (meq 100g$^{-1}$) | **2.6±0.5** | 2.0±0.1 | 2.1±0.2 | **1.5±0.4** | 1.9 | 2.3 | 2.1±0.3 |
| Ca (meq 100g$^{-1}$) | 2.8±0.5 | 2.6±0.1 | 2.7±0.2 | **1.8±1.0** | **3.8** | 3.5 | 2.9±0.6 |
| Mg (meq 100g$^{-1}$) | 4.9±0.2 | **6.7±1.0** | 5.5±0.4 | **1.5±0.9** | 5.8 | 4.2 | 4.8±1.6 |
| $Co_3$ (meq 100g$^{-1}$) | 0.12±0.1 | 0.13±0.1 | 0.19±0.1 | 0.20±0.01 | 0.16 | **0.25** | 0.18±0.04 |
| $HCo_3$ (meq 100g$^{-1}$) | 0.33±0.1 | 0.26±0.1 | 0.25±0.1 | 0.33±0.04 | 0.24 | **0.41** | 0.30±0.05 |

(I) *Halocnemum strobilaceum-Juncus arabicus,* (II) *Halocnemum strobilaceum-Suaeda vermiculata,* (III) *Nitraria retusa-Zygophyllum qatarense,* (IV) *Zygophyllum qatarense-Haloxylon salicornicum,* (V) *Nitraria retusa,* (VI) *Tamarix aucherana.*

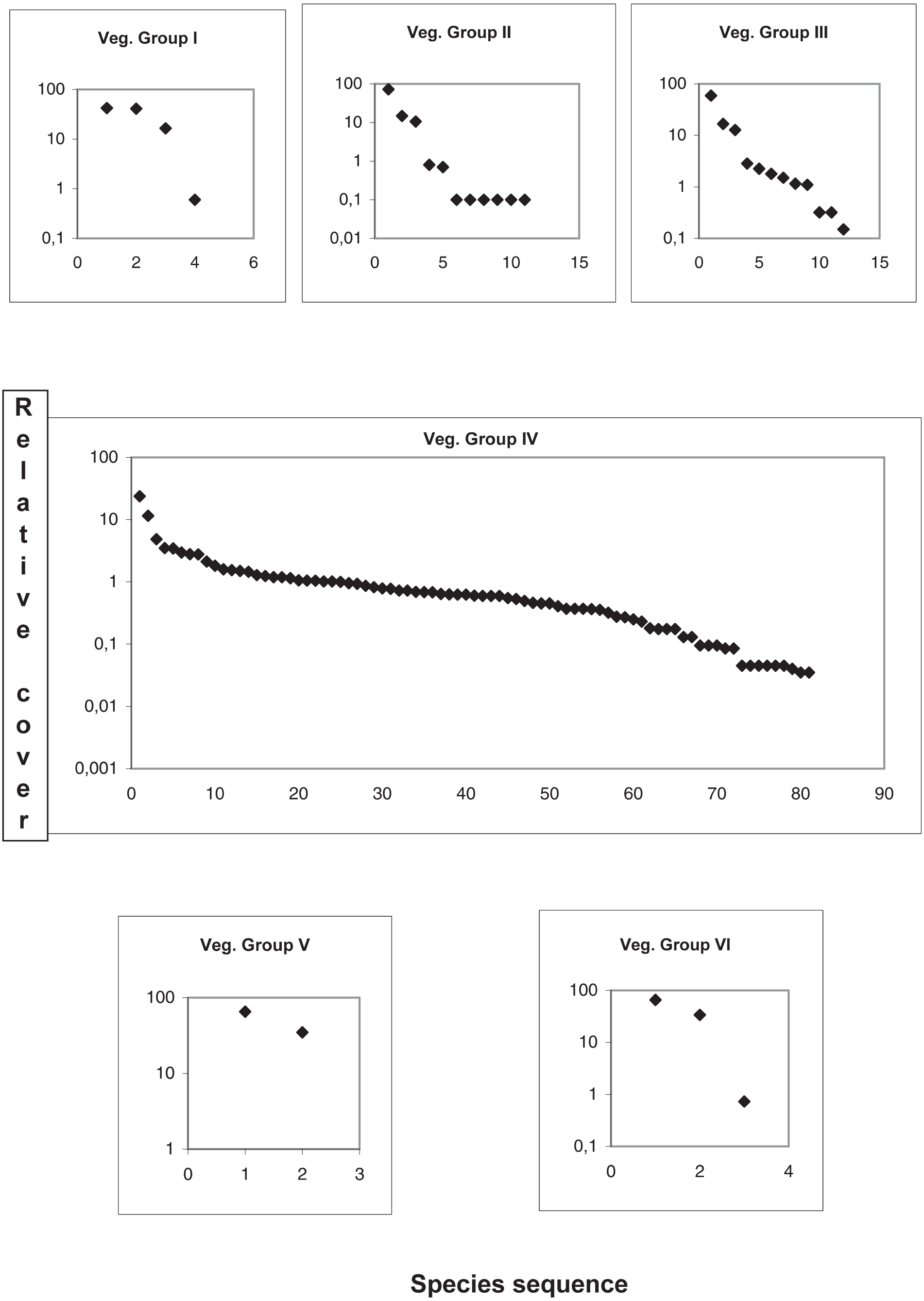



Fig. 6. – Dominance-diversity curves of the six plant clusters inhabiting the environmental gradient characterizing the salt marshes in northern coast of Kuwait.

Inspection of the data also shows a considerably high species dominance in the other communities: *Halocnemum strobilaceum-Juncus arabicus* (cluster I), *Nitraria retusa* (cluster V) and *Tamarix aucherana* (cluster VI), inhabited on the saline soil of tidal mud flat and on the lower saline edge of sabkha habitats, show the highest values (C = 0.40, 0.61 and 0.68 respectively) and consequently the lowest values of species diversity. It is also notable that the *Halocnemum strobilaceum-Juncus arabicus* community (I) has the highest value of total plant cover (47.6%), and *Nitraria retusa-Zygophyllum qatarense* community (III), inhabited on the middle sabkha flat, shows the relatively intermediate values of species diversity and the lowest value of total plant cover (16.7%).

The dominance-diversity curve of *Zygophyllum qatarense-Haloxylon salicornicum* community (IV) is less steep than those of other communities (fig. 6). This also corresponds to the lower value of the relative concentration of dominance. On the other hand, the steepest curves have been obtained for the saline soil of tidal mud flat and saline lower edge of sabkha flat habitats, dominated by *Halocnemum strobilaceum-Juncus arabicus* (cluster I), *Halocnemum strobilaceum-Suaeda vermiculata* (cluster II), *Nitraria retusa* (cluster V), and *Tamarix aucherana* (cluster VI), showing the highest values of concentration of dominance. Moreover, the first two dominant species contribute by 23.5% to total cover of *Zygophyllum qatarense-Haloxylon salicornicum* community, inhabited along the higher zone of salt marshes (coastal sandy drifts), by 74.5% in *Halocnemum strobilaceum-Juncus arabicus* community, 87.2% in *Halocnemum strobilaceum-Suaeda vermiculata* community, 100% in *Nitraria retusa* community and 99.3% in *Tamarix aucherana* community; the last three communities are inhabited on the saline soil of tidal mud flat and lower saline edge of sabkha flat habitat (table II).

*Soil of plant communities.*

In general, the soil of *Zygophyllum qatarense-Haloxylon salicornicum* community presents the lowest values for the most soil measured variables, except for sand (75%) and pH (8.08), displaying higher values. On the other hand, the clusters dominated by *Halocnemum strobilaceum-Juncus arabicus* cluster (I), *Halocnemum strobilaceum-Suaeda vermiculata* cluster (II), *Nitraria retusa* cluster (V), and *Tamarix aucherana* cluster (VI) presents the highest values of moisture, organic matter, total soluble salt, calcium carbonates, silt, clay, salinity, minerals and the lowest values of sand (51.6%) in *Halocnemum strobilaceum-Juncus arabicus* cluster (I), and pH (7.75) in *Tamarix aucherana* cluster (VI) (table II).

*Soil - Species diversity relationship.*

Species number, relative evenness are negatively correlated with several soil variables such as: pH, salinity, total soluble salt, organic matter, moisture, Ca, Na, Mg, and Cl. Concentration of dominance is positively correlated with total soluble salt, organic matter, Na and Cl (table III); it is also positively correlated with DCA axis 1. The variables that contribute significantly to the regression model of this axis are concentration of

TABLE III. – *Relationships between the species diversity indices and soil variables.*

| Variable | | r |
|---|---|---|
| Species number | pH | −0.84*** |
| | EC | −0.82*** |
| | T.S.S. | −0.77** |
| | Org. Matter | −0.71** |
| | Moisture | −0.71** |
| | Ca | −0.74** |
| | Na | −0.75** |
| | Mg | −0.76** |
| | Cl | −0.67** |
| Shannon index | EC | −0.67** |
| | T.S.S. | −0.72** |
| | Org. Matter | −0.82*** |
| | Moisture | −0.69** |
| | Na | −0.85*** |
| | Ca | −0.72** |
| | Cl | −0.70** |
| Simpson index | T.S.S. | 0.61* |
| | Org. M. | 0.78** |
| | Na | 0.77** |
| | Cl | 0.62* |

dominance, carbonates, clay, sand and calcium carbonates. These variables explain about 99% of the total variation along this axis (model $R^{**} = 0.9952$). Axis 2 is positively correlated with silt. Silt, concentration of dominance, total soluble salts, salinity, plant cover and chlorides are the factors contributing to the regression model of this axis, explaining about 100% of the total variation along this axis (model $R^{**} = 1.0000$) (table IV).

TABLE IV. – *Summary of forward selection procedure for dependent variables.*

| Step | Variable intered | Partial R** | Model R** | F value | r |
|---|---|---|---|---|---|
| | | | **Axis 1** | | |
| 1 | **Simpson index** | 0.5827 | 0.5827 | 13.96** | 0.76** |
| 2 | **Carbonate** | 0.2053 | 0.7880 | 8.71** | 0.70** |
| 3 | **Clay** | 0.1381 | 0.9261 | 14.95** | 0.49 |
| 4 | **Sand** | 0.0488 | 0.9749 | 13.58** | 0.44 |
| 5 | **Calcium carbonate** | 0.0204 | 0.9952 | 25.71** | −0.22 |
| 6 | **Plant cover** | 0.0020 | 0.9972 | 3.6 | 0.09 |
| | | | **Axis 2** | | |
| 1 | **Silt** | 0.8189 | 0.8189 | 45.21*** | 0.90*** |
| 2 | **Shannon index** | 0.0999 | 0.9188 | 11.08** | −0.24 |
| 3 | **T.S.S.** | 0.0613 | 0.9801 | 24.69*** | 0.32 |
| 4 | **Na** | 0.0057 | 0.9858 | 2.79 | 0.44 |
| 5 | **Ca** | 0.0060 | 0.9918 | 4.35 | −0.09 |
| 6 | **EC** | 0.0060 | 0.9977 | 13.17** | 0.54 |
| 7 | **Plant cover** | 0.0021 | 0.9998 | 42.57*** | 0.04 |
| 8 | **Cl** | 0.0002 | 1.0000 | 15.87** | 0.38 |

## 5. Discussion

*Structure of plant communities.*

The classification into six zonal communities running parallel to the coast was successful and resembled the classification reported in the earlier studies in coastal regions throughout the Arabian Peninsula and Kuwait (*e.g.* Dickson, 1955; Halwagy and Halwagy, 1977; Batanouny, 1981; Halwagy *et al.*, 1982; Batanouny and Turki, 1983; Abbadi and El-Sheikh, 2002; El-Sheikh and Abbadi, 2004). The study of Halwagy and Halwagy (1977) identified and described 7 major zonal plant communities and 6 other minor plant communities in the same study area, which are very comparable to our study. Most of the characteristic species of the identified plant communities are salt tolerant perennials plants, which vegetate during the hot dry months on subsoil moisture (Vesey-Fitzgerald, 1957).

In the study area the conspicuous trends of zonation within the zonal halobiomes vary along a composite environmental gradient including habitat factors, salinity and microtopography variation; *e.g.* horizontal distance from the shore line and ground level, in relation to tide or saline water table, plays a role in determining plant distribution, possibly through affecting soil moisture and salt content. The occurrence of sand hummocks «Nabkas» also has a great effect on the community structure. *Halocnemum* (I and II) communities, instead, occur on low, inundated marsh where frequent inundation reduce the soil salinity to 3.6% and this salinity is suitable for growing seedling of *Halocnemum* (see Waisel, 1958). *Nitraria* and *Tamarix* (V and VI) communities are distributed on places (lower saline edge of sabkha flat) not reached by tides but where the saline water table is usually very near, since evaporation is greater than precipitation and soil water moves upward capillarity and deposits salts on the surface (salinity is about 10% or more, and drops sharply to 1.5% in lower horizon). *Nitraria-Zygophyllum* community occurs on the middle part of sabkha flat and *Zygophyllum* (IV) community on elevated coarse sandy sites away from tidal or water table influence, in a transitional zone between saline sites and desert habitats.

*Diversity of plant communities.*

Species diversity, though varying within the zonal halobiomes, showed an increased trend from the shoreline towards the inland (table V). Hence, the most humid sites have the highest shrub abundance and the lowest diversities, and the most xeric sites have the lowest shrub abundance and the highest diversities. The over-all trend is marked by diversity increase with drought increase (see Noy-Meir, 1973; Naveh and Whittaker, 1979; El-Sheikh *et al.*, 2003). Here, the first general trend shows that the species diversity is negatively correlated with soil salinity, moisture, organic matter, clay and minerals. Similar trends have been found in other related areas (Halwagy and Halwagy, 1977; Batanouny, 1981; Shaltout and El-Ghareeb, 1992; Abbadi and El-Sheikh, 2002; El-Sheikh *et al.*, 2003; El-Sheikh and Abbadi, 2004).

TABLE V. – *General trends of habitat factors affecting diversity of plant communities in Northern coast of Kuwait.*

| **Character** | **Habitat** | | | | |
|---|---|---|---|---|---|
| | Intertidal flat | Supratidal flat | Sabkha flat | | |
| **Micro habitat** | — | — | Lower saline Sabkha edge | Middle Sabkha flat | Higher Sabkha edge (coastal sand drifts) |
| **Clusters** | I | II | V & VI | III | IV |
| **Altitude** | 0-2 m | 2-3 m | 3-4.5 m | 4-5 m | 5.5-7.5m |
| **Flooded** | regularly | Irregularly | Not reached | Not reached | Not reached |
| **Moisture** | increase | increase | increase | Slightly decrease | decrease |
| **Salinity** | increase | increase | increase | Slightly decrease | decrease |
| **Minerals** | increase | increase | increase | Slightly decrease | decrease |
| **Clay** | increase | increase | increase | Slightly decrease | decrease |
| **Org. matter** | increase | increase | increase | Slightly decrease | decrease |
| **Sand** | decrease | decrease | decrease | Slight increase | increase |
| **pH** | decrease | decrease | decrease | Slight increase | increase |
| **Total species** | decrease | decrease | decrease | Slight increase | increase |
| **Sp. richness** | decrease | decrease | decrease | Slight increase | increase |
| **Rel. evenness** | decrease | decrease | decrease | Slight increase | increase |
| **Dominance** | increase | increase | increase | Slightly decrease | decrease |
| **Plant cover** | increase | increase | increase | Slightly decrease | decrease |
| **Shrubs %** | increase | increase | increase | Slightly decrease | decrease |

Plant communities I, II, V and VI inhabited on the habitats of intertidal, supratidal mud flat and the lower saline edge of sabkha flat (*i.e.* high stressed habitats) are also submitted to frequent and intensive inundations, saline water table, and sea spray that seriously limits colonization by plants; a low competition allows these salt tolerant plants of adaptive strategies to get established with high biomass (*i.e.* cover), high dominance and low species richness. This is consistent with numerous previous studies, showing that stress has negative effects on biodiversity by reducing individual survival and colonization (Grime, 1979; Tilman, 1982; Holzapfel and Schmidt, 1990; Ayyad and Fakhry, 1996; El-Sheikh and Abbadi, 2004). It is conceivable that extreme conditions 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).

The negative correlation found between species diversity and total plant cover (*i.e.* phytomass), means that the species diversity decreases as plant phytomass and soil salinity increase in these humid sites with shruby community. The plant communities of these stressed habitats are characterized by a simplified structure, uniformity of composition. Each community has two dominant shrubs (*e.g.* clusters I, V, VI of *Halocnemum*, *Nitraria* and *Tamarix*) that can make the best use of available resources, because of their high competition capacities, and adaptation to stressed environments with oligotrophic saline soils, often shallow, and waterlogged. These halophytic shrubs also have high internal osmotic potentials and efficient mechanisms for salt uptake, transport and secretion. Salinity is a stress factor for growth of many species and hence relatively poor vegetation (Shaltout and El-Ghareeb, 1992; Garica *et al.*, 1993; Abbadi and El-Sheikh, 2002; Decocq, 2002; El-Sheikh and Abbadi, 2004).

*Nitraria retusa-Zygophyllum qatarense* community on the middle sabkha flat presented relatively intermediate values of species diversity and the lowest value of total plant cover. This is due to the active formation of hummocks «Nabkas» by sand binding plants as *Nitraria* and *Zygophyllum* in this site of middle sabkha flat. *Nitraria* nabkas is the first belt towards the shore line in low-laying areas with fine texture and covered by thin salt crust, forming an island in this site «macro-nabka». *Zygophyllum* nabkas lyes in more landward of higher areas of this site of middle sabkha flat and is dominated by coarse sand and forms «minor-nabka». *Zygophyllum* Nabka improvements the substrate and acts as a shelter of some many halophytic perennials and annuals on the top of the nabka, where the ground level is raise and the depth of saline water table become relatively deep (Brown and Porembski, 1997). As the result of the direction of wind from west to east, the nabkas lying towards the sea shore are dominated by fine deposition, whereas that lying in the inland ward is dominated by coarse sand, because the coarse sand is heavely deposited, firstly in the inland side of sabkha, but later near the shore with *Nitraria* shrub (see Khalaf *et al.,* 1995).

Generally, the communities occurring in severe environments (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 quite clear regarding the dominance-diversity curves representing the communities (I, II, V, VI) that inhabit the saline sites as compared with those of *Zygophyllum qatarense-Haloxylon salicornicum* cluster (IV) which inhabited along the higher zone of salt marshes «coastal sandy drifts» which represents a transitional zone between saline sites and desert habitats. The curves of the saline sites are steeper and are characterized by higher values of the relative concentration of dominance and the lowest value of species richness. Hence, they are more profitable for approximating the geometric series (Whittaker, 1965, 1972; Pielou, 1975). This means that the community inhabiting these saline sites is the less diverse among the community of the transitional zone. The behavior of these communities is controlled by tidal action, saline water table and microtopographic variation.

The curves representing the *Zygophyllum qatarense-Haloxylon salicornicum* community (IV) inhabiting along the higher zone of salt marshes «coastal sandy drifts» present sigmoid distributions of moderate slope throughout. These distributions approximate to the log normal distribution; consequently these are many species of intermediate abundance values and a few rare or common species (Whittaker, 1965; Pielou, 1975; Shaltout and El-Ghareeb, 1992). The high species diversity of this transitional community may be explained in terms of the theory of spatial and temporal heterogeneity, as they are ecotonic areas embracing the characteristics of habitats on both sides. A higher level of species diversity would be brought by local differentiation in soil properties around individual plants, since heterogeneity of environments allows satisfaction of requirements of diverse species within a community (Mellinger and McNaughton, 1975; Whittaker and Levin, 1977; Abbadi and El-Sheikh, 2002; El-Sheikh and Abbadi, 2004).

Other remarkable results of the present study show the positive correlation between sand and species diversity (*i.e.* the coarser texture gives the higher species diversity). The transitional habitat of the higher zone of sabhka «coastal sandy drifts» is characterized by a heavy deposition and consequently by the active formation of small hummocks, *i.e.*

«micro-nabkas». These small hummocks are dominated by species of *Zygophyllum* and *Haloxylon* as sand binding species. This habitat lyes towards the inland where the heavy coarse sediments (sand) are deposited firstly by these shrubs. This sand comes from active sand sheets and sand dunes of Umm Neqqa flat and Jal Az-Zor hill in the west. 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. Sandy soils usually have more favorable moisture conditions and support denser 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, that suitable for growth of *Zygophyllum* and consequently its nabkas. This improvement in soil condition and local differences in microtopography reflected a greater species diversity including many glycophytes and some annuals around the nabkas. As the salt marsh merges into the desert proper, *Zygophyllum* nabkas disappears being replaced by a typical desert community dominated by *Haloxylon* on elevation land (7.0 m-13.0 m): halophytes species are encountered at first but soon disappear and are replaced by desert ephemeral and perennial species that contribute to increase the diversity of species.

The role of these nabkas in variation of spatial and temporal heterogeneity and consequently increasing the species diversity is due to some reasons, firstly, according to Evenari *et al.* (1971), variation soil moisture availability is possibly one of the most important causes of spatial heterogeneity of plant community in arid ecosystem. Olsvig-Whittaker *et al.* (1983) pointed out that therophytes with their comparatively short rooting systems exploit primarily the upper layer of the soil. As consequently, spatial heterogeneity of therophytes is direct response to the heterogeneous moisture condition near the soil surface. It therefore seems that nabkas particularly on their leeward size, represent «favorable microsites» with this community, where moisture seepage around their perimeter of their miniature dunes provides a relatively source of water; moisture seepage acts as moisture storage protecting the water from evaporation after rainfall and enhancing nutrients availability for ephemeral plants around the base of nabkas under tall shrubs (Vesey-Fitzgerald, 1957; Mott and McComb, 1974; Brown and Porembski, 1997). Halwagy *et al.* (1982), note that years of low rainfall in Kuwait are characterized by an almost complete absence of ephemeral vegetation. It is conceivable that in some years, ephemerals on the nabkas will set seeds, whereas plants in the inter-dune space may not reach this stage of development. A further point in this context is that a part of spatial and temporal heterogeneity of vegetation development is a pronounced feature in the sand-depleted *Zygophyllum qatarense-Haloxylon salicornicum* community. As described by Brown and Porembski (1997), both germination and general vegetation development proceed somewhat earlier on the nabkas than on the inter-dune space. Moreover, the interspecific competition and Shannon diversity are higher on nabkas than on inter-dune space.

The observed patterns of the diversity allow to suggest a management of these habitats at micro-sites level, taking into account the small differences recorded in the distribution of species and communities, and monitoring the variations of the vegetation.

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