An outline of the vegetation of Dubai (UAE)

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Synopsis

After an introduction to the physical environment of Dubai, the vegetation is described by transects and tables. Plant communities are characterized by their floristic composition. They are interpreted in the context of the saharo-arabian vegetation. Some general problems in the application of the phytosociological approach to desert vegetation are discussed.

The Emirates have a hot desert climate. The combination of a tropical temperature regime and winter rain results in a mixture of holarctic and paleotropic elements. The endemic species belong to the omano-makranian chorotype.

The pattern of the plant communities is ruled by the relief. The coastal vegetation complex is characterized by *Limonium stocksii* and *Zygophyllum qatarense*. On the dunes grows the *Cornulaco monacanthae-Sphaerocometum aucheri*, in silty depressions the *Halopeplidetum perfoliatae*. The inland dune vegetation is dominated by *Rhanterium epapposum*. The original *Prosopis cineraria*-woodlands there have been nearly everywhere destroyed and are replaced by the *Leptadenio-Rhynchosietum schimperi*. In the dune valleys we find the *Helianthemum lippii-Fagonia ovalifolia*-community. The ephemeral *Chrozophora sabulosa*-community develops on the inland dunes, the *Frankenio-Zygophylletum simplicis* on salty sand. In the stony desert, the *Pseudogaillonio hymenostephanae-Euphorbietum laricae* colonizes rock outcrops. The *Saccharo griffithii-Nerietum mascatense* is the wadi vegetation type of deep incised canyons. Finally a syntaxonomic survey is given.

Saharo-Arabian vegetation, chorology, phytosociology, desert ecology

1 Introduction

There has been a good progress in the floristic knowledge of the Southeastern parts of the Arabian peninsula by the flora of MANDAVILLE (1990), the Emirate flora of WESTERN (1989) and the more popular introduction to the nature of Dubai by JONGBLOED (1987). But detailed studies about the vegetation of this part of Arabia are still missing. The statement of ZOHARY (1973) is still up-to-date: »We are especially ignorant of the vegetation in the Arabian Peninsula«. The recently published Atlas of the United Arab Emirates (= UAE) (UAE UNIVERSITY 1993) offers no useful information about the vegetation. The survey by SATCHELL (1978) about the ecology of the Emirates is in its geobotanical part based on the brief paper of VESEY-FITZGERALD (1957).

The first aim of this contribution is to give a comprehensive information about the most important vegetation types and land units of Dubai. We concentrate on the coastal region and the foreland of the Musandam Mountains. These data are based on field trips by MÜLLER-HOHENSTEIN in 1986 and by DEIL in 1987.

Secondly, the vegetation of Dubai will be compared with other regions of the Old Wold desert belt and interpreted in a wider geographical context. This comparison is based on a personel knowledge of the desert vegetation in the Maghreb countries and in North Yemen and on the available literature.

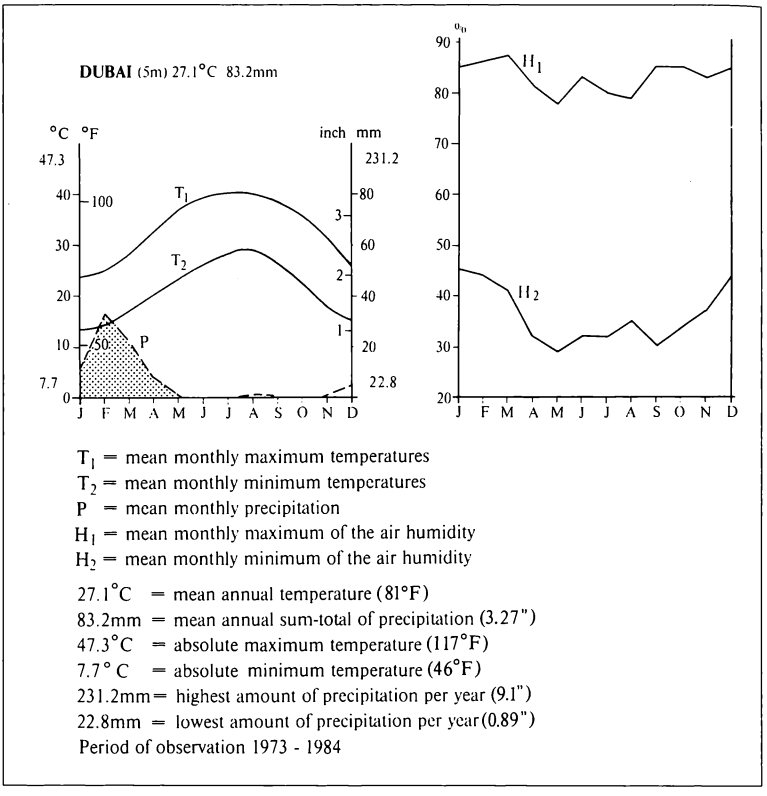
The third topic are chorological aspects. Southern Arabia is the transition zone from the Holarctic to the Paleotropical Kingdom, from extratropical to tropical climate. How is this situation reflected by the plant communities in Dubai and do the different life forms react in a different way? FREITAG (1991) demonstrated, that even the halophytes, growing quite independently from the precipitation regime and therefore often regarded as »azonal«, show a clear geographical pattern around the Arabian peninsula, mostly ruled by temperatures.

2 Methodological and synsystematic problems

Under arid conditions and in extreme habitats like saline depressions, plant communities are often composed of very few species and there exist also monospecific vegetation units like the *Halopeplidetum perfoliatae*. Nevertheless, they can be associations in the sense of the phytosociological approach of BRAUN-BLANQUET (1964). In other cases, they are named and classified according to the dominant species and are fazies of associations sensu strictu. If we have a look at the geobotanical literature of the Middle East, there are some authors, which refer to the Braun-Blanquet approach. But indeed, they use only the values proposed by BRAUN-BLANQUET to estimate the cover-abundance of the species. Their vegetation units are based on dominant species, not on the fidelity of the taxa in a big data set. The result is an infla-

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

Fig. 1
Climatic Diagram of Dubai



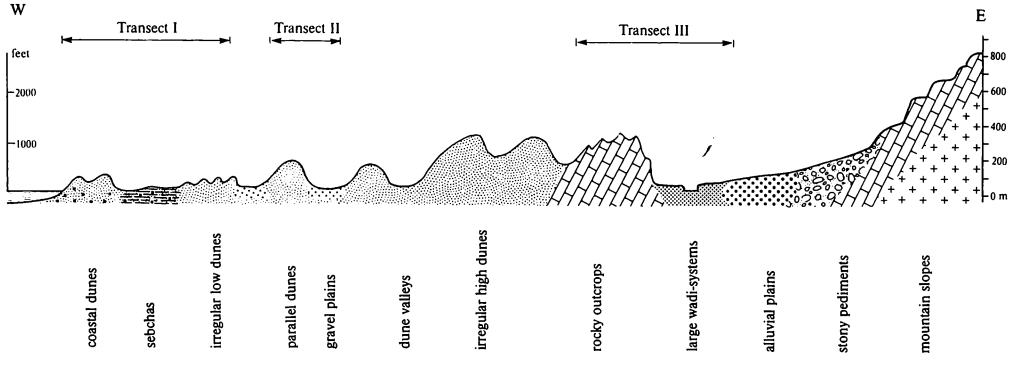


Fig. 2
The natural landscapes of Dubai

tion of »communities«, often documented only by a single relevé or by a constancy column, in some cases even without any tables. These communities are not arranged in an hierarchical system, which would be the expression of the gradual ecological value of the species.

The decision, whether the communities are a typus or not, could be taken by comparative tables, like it has been done by BORNKAMM & KEHL (1990) in their survey of the Western desert of Egypt. But there are two major problems in such studies: First, the criteria of botanists for environmental homogeneity are different. Secondly, we have to deal with taxonomic and nomenclatural problems. Older studies often use collective taxa, for example in the genera *Calligonum, Fagonia, Stipagrostis, Helianthemum, Limonium, Cyperus* (Section Arenarii) or *Zygophyllum.* For *Zygophyllum*, EL-HADIDI (1977) has clearly shown, that a finer taxonomic treatment of an euryoecious and widely distributed taxon ends up with ste-

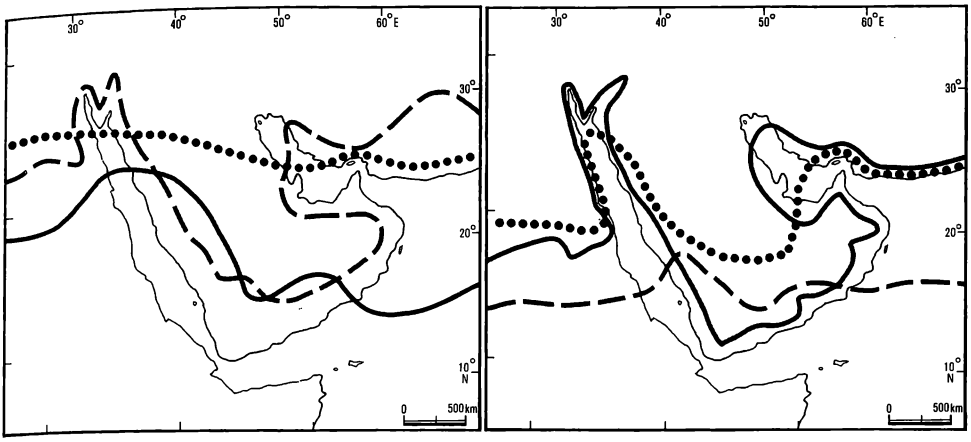


Fig. 3

Phytogeographical and climatical frontiers in Arabia[1] (adopted from MÜLLER-HOHENSTEIN 1988, see further references there)

1 On the left: Borderlines between the Holarctic and the Paleotropical Kingdom after DIELS 1908 (dotted line), AL HUBAISHI & MÜLLER-HOHENSTEIN 1984 (continuous) and KÜRSCHNER 1986a (intermittent)

On the right: Borderlines between subtropical and tropical climatic zones after TROLL & PAFFEN 1965 (dotted line), VON WISSMANN 1962 (continuous) and CREUTZBURG & HABBE 1964 (intermittent)

noecious, regional vicariants: *Zygophyllum qatarense*, one of the most common species in the coastal regions of Dubai, Qatar and Northern Oman is replaced further to the north by *Z. migahidii*, to the southwest by *Z. hamiense* and to the west by *Z. mandavillii*. In other cases, different names are synonymous.

Another problem is, that there exist three syntaxonomical systems of quite different origin: The system of QUEZEL (1965) gives a survey of the vegetation of the Western and Central Sahara. His system is inductive. He started from the association level to the higher syntaxa. In the Near and Middle East, the system of ZOHARY (1973) is widely accepted. His system is deductive, he started from the classes. Both books do not offer comparative tables and do not pay much attention to the syntaxa of medium rank (orders and alliances). LEONARD (1993) has shown the unsharp definition of the »communities« by ZOHARY (1963): Within 24 units, *Artemisia herba-alba* is used as the naming dominant species, but *Artemisia herba-alba* s.str. does not occur at all in Southern Iran. The third proposal is the classification of the vegetation of Eastern Africa by KNAPP (1968). It is very useful for the tropical parts of Arabia, but this contribution was published in a quite unknown series and therefore not taken into account by ZOHARY (1973).

The aim of this contribution is not a syntaxonomical one. We want to characterize the vegetation of a small territory. But we also want to interpret our data in a wider context. Therefore we use the following concept: If the classification and syntaxonomic value of a unit is clear, the association is named according to the rules of the plant sociological system (BARKMAN et al. 1986). In other cases, the term »plant community« is used for a rankless vegetation unit. We use the cover-abundance values of BRAUN-BLANQUET (1964), sociability notes are not given. In the tables, the abbreviation CS stands for character species, DS for differential species. The nomenclature here follows MANDAVILLE (1990), BATANOUNY (1981) and COPE (1985). The herbarium specimen are stored at Bayreuth.

Another problem is, that the vegetation cover can be classified at different spatial scales and several levels of homogeneity: Three common levels are the synusium, the community and the vegetation complex. Here we use the community and the vegetation complex level. A still unsolved problem is the stratum built by ephemeral species: Should we handle them as a synusium in a pluristratified community, as a chronocoenose or as an independent unit? We will discuss this by some examples in chapter 5 (see also the discussions in BAIERLE 1993 to the wadi communities in Southwest Jordan).

3 Physical conditions of the study area

A detailed description of the environmental condition of the UAE is given by SATCHELL (1978) and some information can also be drawn from the recently

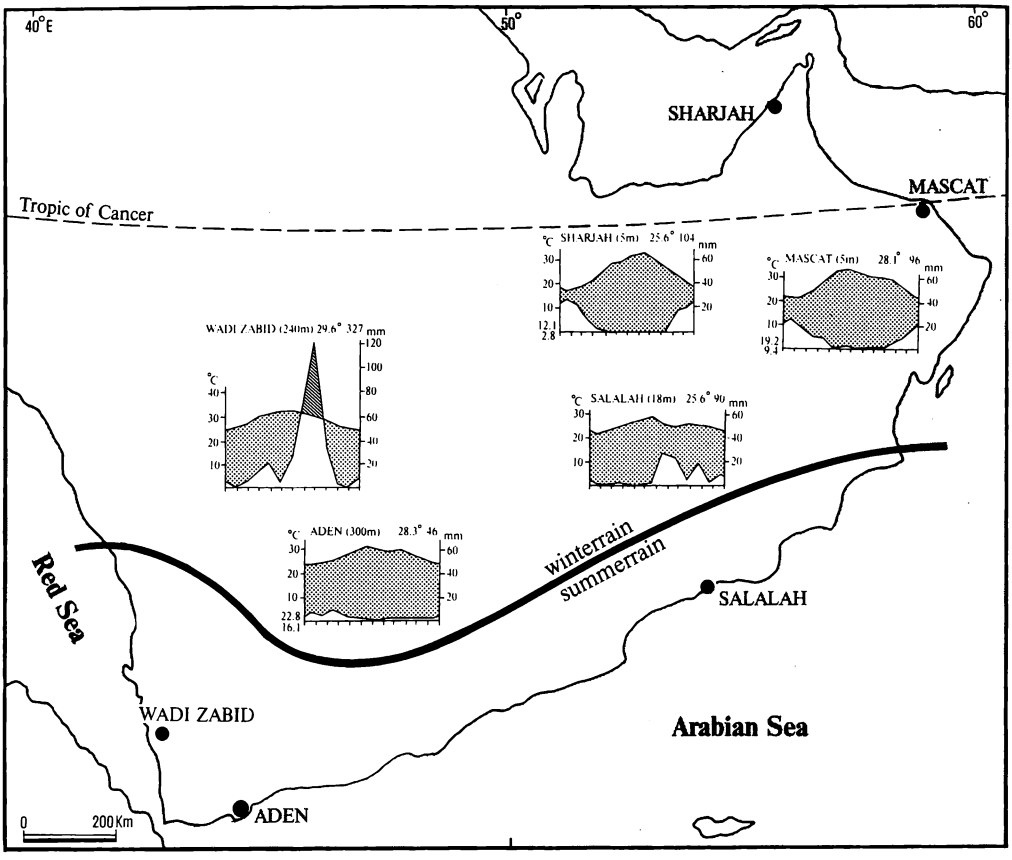


Fig. 4
Climatic conditions of coastal areas in southern Arabia

published Atlas (UAE UNIVERSITY 1993). We concentrate on those data, which are important for an understanding of the spatial pattern of the flora and vegetation of Dubai.

3.1 Climate

Dubai has a hot desert climate. The potential evapotranspiration for the Emirates is more than 1000 mm per year (up to 3.4 mm/h in extreme situations). Mean annual rainfall is less than 100 mm per year. As can be seen from the climatic diagram (Fig. 1), rainfall concentrates on late winter and early spring. Not even at this time, at the 'humid season', monthly precipitation balances the potential evapotranspiration. The climate is arid throughout the year. The winter rain maximum is of the mediterranean type and origin. Erratic thunderstorms in summer are caused by the northernmost influences of the Indian summer monsoon, but most of the winds from the Arabian Sea and the Gulf of Oman are prevented from reaching the Arabian Gulf by the Oman Mountains, which receive considerably higher precipitations (BABIKIR 1985). Rainfall pattern is very variable, both in time and space. Air humidity is high at night throughout the year (see Fig. 1), mean relative humidity is about 60 % in the coastal parts (UAE UNIVERSITY 1993). Water supply for plants is regularly improved by dew at night and sometimes by fog in the late afternoon.

Mean annual temperature for Dubai is 27.1°C, the coastal parts of Eastern and Southern Arabia are frostfree. According to the temperatures and air humidity, the Emirates belong to the tropical climates, according to the genesis and distribution of rainfall to the extratropical ones. This unique mixture (tropical and extratropical) of climatic elements has created a special environment for plants and resulted in endemic plant species in this part of Arabia and Southern Iran as well as in a particular mixture of holarctic and paleotropic phytochoria (see chapter 4).

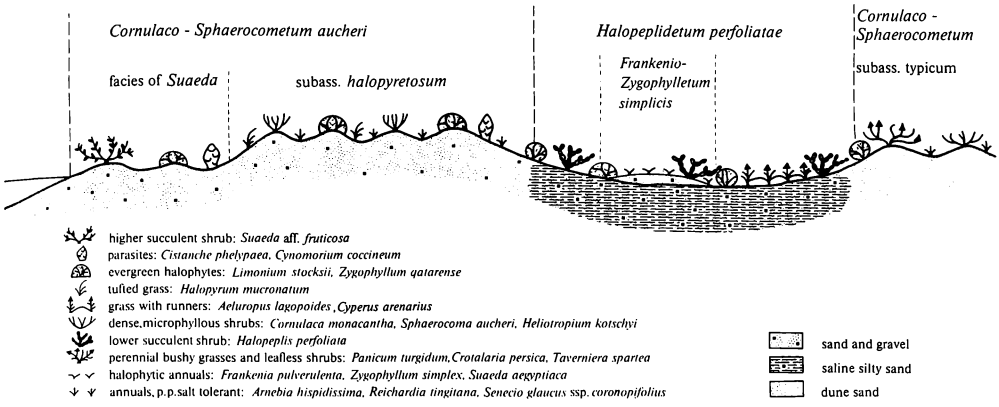


Fig. 5
The coastal dune and sabcha ecosystem

3.2 Relief and substrate

Except for higher precipitation and moderate temperatures in the mountainous area, climatic conditions are quite uniform in the Emirates. The great variety of ecotopes is created by different soil types and relief features. Both factors influence water absorption and storage: Sandy soils show a less intensive evaporation and higher infiltration rate than loamy or silty soils; depressions and floodplains gain run-on water from steep slopes; surface layers of deep soil deposits may comprise a permanent water source for deeply rooting perennial plants. The content of organic matter in the soils is mostly less than 0.5 %. Plant growth is in first line restricted by water-holding capacity and salt content, not by nutrients.

The plant species distribution and the pattern of the plant communities clearly correlate with geomorphology, because water availability is strictly ruled by the relief. BATANOUNY (1981) therefore introduced the term phyto-eco-geomorphological units when discussing the vegetation pattern of Qatar. The large variety of habitats in Dubai, as it can be seen from the schematic transect in Fig. 2, is also expressed by local topographical terms such as Jiri and Sabkha (depression), Rodah (dune valley), Hazm (terrace), Jabal (mountain slope), Hassa (gravel plain), Erg and Barkhan (dunes).

From West to East, from the Arabian Gulf coast to the Musandam Mountains, we can distinguish the following geomorphological units:

The coastal desert: The only natural port is the creek at Dubai City. The coast itself is fringed by white dunes, which overlay low beach ridges consisting of coral and shell fragments. Sabkhas are intercalated in the coastal dune fields. In the coastal dunes, which contain calcareous material, the average EC value is 0.7 mS/cm, a concentration, that already inhibits the growth of salt sensitive plants. The silty and haliferous sabkha soils belong to the solonchaks or salorthids. Here gypsum crusts develop occasionally and EC values can reach 70 mS/cm in the surface horizon. The vegetation of the coastal or salt desert, identical to the white dune and sabkha ecosystem by other authors (SATCHELL 1978, BABIKIR 1984), will be described in chapter 5.1 and by transect I (Fig. 5, Tab. 1 and 2).

The inland dune system: At a distance of 10 to 15 km from the coastline, the dunes become higher. They form longitudinal dune ridges of eolian red sand (torripsamments) and are separated by interdune corridors and gravel plains. The latter consist of well rounded and usually darker remnants of the debris of Quarternary sediments. Phytogenetic mounds, which develop on the lee side of tussock grasses or dwarf shrubs, can be observed quite regularly in the dune valleys and on the gravel plains. No drainage system has developed there, the numerous depressions act as catchments. Further inland huge mobile barchans and stellate dunes follow, which reach heights of more than 50 meters. This landscape unit includes the Red sands of the desert foreland sensu SATCHELL (1978). Its vegetation, the Red Sand associations sensu VESEY-FITZGERALD (1957), will be described in chapter 5.2 and by transect II (Fig. 6 and Tab. 3).

The stony desert: The outset of the Musandam Mountains is indicated by scattered rock outcrops, which consist mainly of dolomitic limestones from the Upper Cretaceous and Lower Jurassic. A wadi system, separating the dune fields from the mountains, follows a tectonic line. The transition from this alluvial plain to the mountains is formed by pediments with a thin gravel layer (torrifluvent). The vegetation of the stony desert is described in chapter 5.3 and is

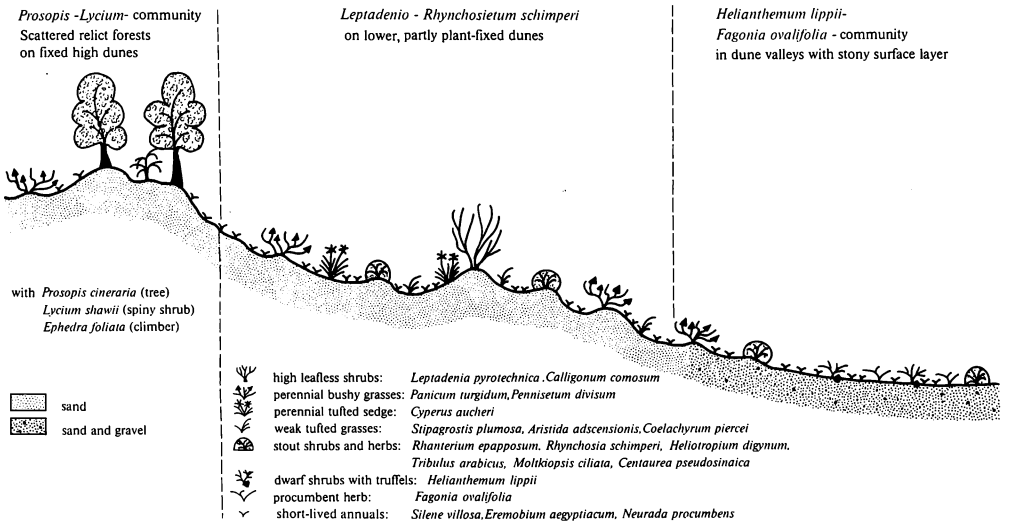


Fig. 6
The inland dune ecosystem

illustrated by transect III, the plant community on bar rock by Tab. 4. The vegetation of the Musandam Mountains, which are rising steeply from the plains, is not discussed here, because we have only insufficient information about this relief unit form the territory of Dubai.

The Wadi systems: The wadi systems are phyto-eco-geomorphological units of their own. Some remarks on this vegetation type are given in chapter 5.4 and by Tab. 5.

4. The phytogeographic position of Dubai

The flora of the UAE is quite heterogenous in the chorological sense due to the fact, that two principal floristic frontiers are meeting there (Fig. 3): a southern, subtropical flora of paleotropic origin (nubo-sindian elements) and a northern, extratropical flora of holarctic origin (saharo-arabian elements). The climatic background of this situation is the transition from subtropical summer rain (monsoon type) to extratropical winter rain (mediterranean type). This is illustrated by the climatic graphs of coastal stations in Southern Arabia (compare especially the climatograms of Wadi Zabid and Sharjah, Fig. 4). The thermal conditions in Dubai are tropical, like in the Yemeni Tihama.

The phytogeographical division of Southern Arabia has been discussed by many authors (MANDAVILLE 1984, ZOHARY 1973, KÜRSCHNER 1986a, MÜLLER-HOHENSTEIN 1988 and others), a synthesis is given by WHITE & LEONARD (1991). If we analyse the flora as a whole, the Emirates show a clear majority of saharo-arabian elements. This is due mainly to the numerous therophytes. A more detailed analysis was carried out by KÜRSCHNER (1986b), who compared the chorological spectra of the *Acacia-Prosopis*-community in Mascat separately for each stratum: The result is, that in each layer different chorotypes are predominant. The tree species are of the nubo-sindian type, the higher shrubs of the saharo-arabian type, the therophytes are a mixture of both geo-elements.

A precise information can also be gained by comparing the chorospectra of communities in the same environment, as it has been done by MÜLLER-HOHENSTEIN (1988) for the dune-communities of Dubai and Yemen. The comparison of a single habitat type shows clearer than a comparison of the whole flora of both territories the shifting from tropical elements in Yemen to extratropical ones in Dubai.

Dubai belongs to the Northern Oman center of endemism in Arabia (MILLER & NYBERG 1991). It has very strong links to Southern Iran and Afghanistan. The coastal lowlands and foothills bordering the Strait of Hormuz contain a large number of species that exist only in this part of the world. KÜRSCHNER (1986a) has underlined this by separating an eastern subprovince from the nubo-sindian region, the omano-makranian region. These elements (for example *Nerium mascatense, Dyerophytum indicum, Saccharum griffithii, Cometes surattensis, Limonium stocksii, Sphaerocoma aucheri, Jaubertia aucheri, Pseudogaillonia hymenostephana, Euphorbia larica, Prosopis cineraria*) play an important role in the characte-

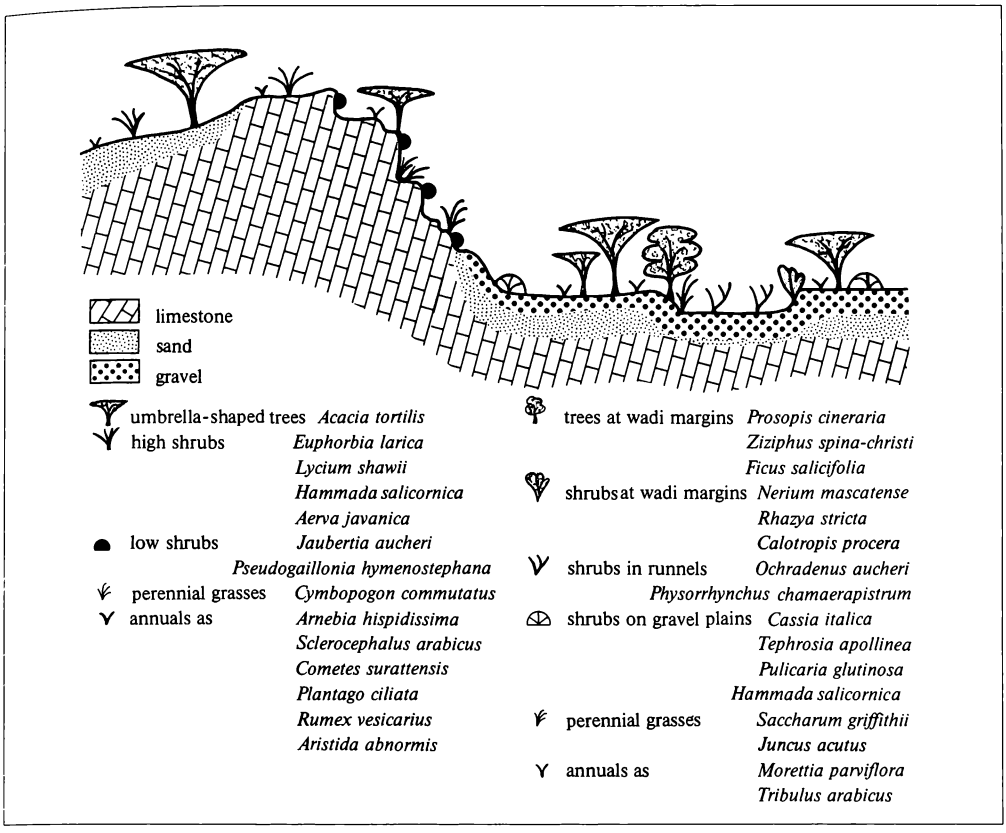


Fig. 7

Ecotope pattern and vegetation structure of rock outcrops and gravel plains.

rization of the plant communities described here (see chapter 5).

The late Tertiary migration road to the Horn of Africa is still reflected in the distribution pattern of some genera like *Ochradenus, Taverniera* and *Pulicaria* (LEONARD 1988/1989). In recent geologicial times (still during the Pleistocene period), a low sea level brought a drying up of most parts of the Arabian Gulf and allowed a free migration of terrestrial organisms (MANDAVILLE 1984). The present conditions have prevailed for the last five to six thousand years BEUG (1971).

5 The landscape units and their vegetation cover

5.1 The coastal ecosystem

A mosaic of flat white sand dunes and silty depressions (sabkhas) formerly covered the Arabian Gulf coast. In both habitats (coastal dunes and sabkhas), salt has a considerable influence on plant life. Therefore this landscape unit has been named the 'salt desert' by other authors. It is identical with the coastal salt-bush-associations sensu VESEY-FITZGERALD (1957). Plants growing there can tolerate salt, some of them are even obligate halophytes like the representatives of the families *Chenopodiaceae, Frankeniaceae* and *Plumbaginaceae.*

This coastal ecosystem has been destroyed nearly everywhere in Dubai by urbanization, but between Jabal Ali and Jumairah it could still be studied in 1987. All relevés in Tab. 1 and 2 have been taken there on 15.3.1987. The relevés might be already historical, because the dunes between Dubai City and Jabal Ali are one of the most important development axes (see plate 95 in the UAE Atlas).

A universal characteristic feature of littoral salt-marshes and dunes is zonation (ZAHRAN 1977). The vegetation sampling was carried out along a transect from the coast to the landward side. The relevés in Tab. 1 are arranged in this way. A scheme of the zonation is also given by Fig. 5.

The coastal ecosystem as a whole is characterized by two dwarf shrubs, which give the name to

Tab. 1
***Limonium stocksii-Zygophyllum qatarense* vegetation complex (Transect I in the coastal ecosystem)**

Releve No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CS of the coastal vegetation complex and DS of omano-makranian variants																				
Limonium stocksii	2	2	3	3	2	.	+	+	2	2	1	+	2	2	2	2	2	2	.	.
Zygophyllum qatarense	+	1	+	1	+	1	+	1	2	2	1	1	1	2	2	2	2	2	2	1
CS Sphaerocometum aucheri and DS of subassociations																				
Sphaerocoma aucheri	+	+	1	1	2	2	2	2	+	.	.	.	.	.	.	.	.	+	1	2
Cyperus arenarius	.	.	.	+	1	+	1	2	.	.	.	.	.	.	.	.	.	.	2	2
Halopyrum mucronatum	.	.	1	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aeluropus lagopoides	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	+	.	.
Lotus garcinii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+
Crotalaria persica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+
Taverniera spartea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.
Indigofera intricata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1
CS of Halopeplidetum perfoliatae																				
Halopeplis perfoliata	.	.	.	.	.	.	.	.	.	1	3	3	2	1	1	+	.	.	.	.
CS Salsolo-Suaedetalia and Halopyro-Sporoboletea																				
Cornulaca monacantha	1	1	1	2	2	+	1	1	+	.	.	.	.	.	+	1	1	1	3	2
Suaeda fruticosa	3	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Suaeda aegyptiaca	.	.	+	+	1	+	1	1	.	1	+	.	.	.	.	.	.	.	.	.
Salsola imbricata	.	.	.	.	.	+	+	.	.	.	.	+	.	.	.	.	.	.	1	.
Salsola nitraria	.	.	.	.	.	+	+	.	.	.	.	+	.	.	.	.	.	.	1	.
Heliotropium kotschyi	.	.	.	+	1	+	1	+	.	.	.	.	.	.	+	+	1	1	1	1
Atriplex leucoclada	1	1	1	1	1	1	1	+	1	1	+	.	.	.	.	.	.	.	.	.
Sporobolus arabicus	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	+	.	.
Cistanche phelypaea	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio glaucus coronopif.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Companions																				
Panicum turgidum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+
Moltkiopsis ciliata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+
Launaea mucronata	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	+	1	+
Launaea capitata	.	.	.	.	.	.	.	.	.	.	.	.	.	/	+	.	.	.	.	+
Launaea nudicaulis	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+
Arnebia hispidissima	.	.	.	.	.	2	2	2	.	.	.	.	.	.	.	.	.	.	.	.
Helianthemum lippii	.	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.

Further rare species:
in 4: *Coelachyrum piercei* +; in 7: *Cyperus aff. conglomeratus* +; in 12: *Halocnemum strobilaceum* 1; in 19: *Prosopis cineraria* (juvenile) +.

this vegetation complex: The mound forming *Limonium stocksii* and the succulent *Zygophyllum qatarense*. Both species are associated to each other from Qatar (BATANOUNY 1981, BATANOUNY & TURKI 1983) to the UAE (see here) and further to Northern Oman (BATANOUNY & ISMAIL 1985, KÜRSCHNER 1986b). *Limonium stocksii* (pp. *L. axillare* of older publications) is a salt-secreting halophyte of omano-makranian distribution. It colonizes the flat coastal dunes and is also fringing the coastal and inland sabkhas, not inundated by sea water. It is a very effective sandbinder. *Zygophyllum qatarense* (pp. *Z. hamiense* of some authors) is one of the most common species in the plant communities of the Arabian Gulf coast, from Qatar to the UAE and also in the Mascat area in Oman. It abounds in shallow depressions with silty-loamy soils and on the flat coastal dunes. In the inland of the UAE it is less common. The germination of *Zygophyllum qatarense* is inhibited by high temperatures and high salt content (ISMAIL 1990, ISMAIL & EL-GHAZALY 1990). It takes place in winter and spring, when salts are temporarily washed out from the topsoil.

Within the *Limonium-Zygophyllum*-complex, we can distinguish four vegetation units and habitat types, which will be discussed separately:

1. The seaward dunes (Tab. 1, rel. 1–9) are colonized by *Sphaerocoma aucheri* and *Cornulaca monacantha*. They are differentiated from the landward dunes by *Halopyrum mucronatum*, *Atriplex leucoclada* and *Suaeda aegyptiaca*.
2. The landward dunes (Tab. 1, rel. 15–20) are also dominated by *Sphaerocoma* and *Cornulaca*. On these dunes, away from the influence of sea spray, appear *Lotus garcinii*, *Crotalaria persica*, *Taverniera spartea* and *Indigofera intricata* and some species of the inland dune system like *Panicum turgidum*.
3. The salty depressions (Tab. 1, rel. 10–14), temporarily inundated at high spring tide, are characterized by *Halopeplis perfoliata*.
4. An ephemeral salt tolerating plant community, the *Frankenio-Zygophylletum simplicis*, grows on flat sandy overlays in the depressions (Tab. 2).

***Cornulaco monacanthae-Sphaerocometum aucheri* ass. nov.**
Tab. 1, rel. 1–9 and 15–20

KÜRSCHNER (1986b) was the first who studied more precisely the ecology of *Sphaerocoma aucheri*. In the Estuary of the Qurm Nature reserve near Maskat this species colonizes, like in Dubai, the coastal white sand dunes, which are calcareous and of marine origin. *Sphaerocoma* ranges, always on coastal dunes, from Bahrain, the UAE and Northern Oman to Balutschistan. In the normal form **Subass. typicum (Tab. 2, rel. 15–20, type relevé N°. 19)**, the omano-makranian endemics *Crotalaria persica*, *Taverniera spartea*, the sokotro-makranian *Indigofera intricata* and the eastafrican-makranian *Lotus garcinii* are associated with *Sphaerocoma*. A similar species composition was noted by KÜRSCHNER (1986b) near Mascat: In small wind protected pockets, he observed a *Lotus garcinii-Cyperus conglomeratus*-community with *Heliotropium kotschyi* and *Suaeda fruticosa*.

On the seaward side of mobile embryonic dunes, *Halopyrum mucronatum* is stabilizing the sand. *Halopyrum* stands have been described as communities by KASSAS & ZAHRAN (1967), BATANOUNY (1981), BATANOUNY & TURKI (1983), BATANOUNY & ISMAIL (1985) and KÜRSCHNER (1986b). In our data (Tab. 2), this differenciation can also be seen, but this unit is treated here as a subassociation, because *Halopyrum* is transgressive from its main hygrohaline habitat. The **Subass. *halopyretosum mucronati*** (Tab. 1, rel. 3–9, type relevé N°. 6) is more influenced by the sea spray. At the coastline itself (rel. 1–2), an unusual form of *Suaeda fruticosa* formes a facies of its own.

Synsystematics: The *Cornulaco-Sphaerocometum* includes the *Sphaerocoma*-association sensu KÜRSCHNER (1986b), but not the *Euphorbia laricia-Sphaerocoma aucheri*-association sensu ZOHARY (1963), which is a mosaic of several vegetation units. The edaphic conditions and the position in the microrelief of the dunes of the *Lotus garcinii-Cyperus conglomeratus*-association (KÜRSCHNER 1986b) is very similar to the subass. typicum, but in Dubai some more species of omano-makranian distribution occur in this community type (*Crotalaria persica, Taverniera spartea, Indigofera intricata*). If more observations were available from southern Iran, this subassociation might become the rank of an association within an alliance, characterized by *Sphaerocoma aucheri*. Character species of syntaxa of higher rank (class and order) are *Cornulaca monacantha*, *Suaeda* spp., *Salsola* spp., *Heliotropium kotschyi*, *Sporobolus arabicus*, *Atriplex leucoclada* and others. These species are mentioned by KNAPP (1968) as *Salsolo-Suaedetalia*- and *Halopyro-Sporoboletea*-CS, by ZOHARY (1973) as *Suaedetea fruticosae deserta*-CS. These syntaxa have to be described more precisely in the future. For the moment, the *Cornulaco-Sphaerocometum aucheri* is included in the *Salsolo-Suaedetalia (Halopepli-Suaedetea)*.

***Halopeplidetum perfoliatae* ass. nov. ex KASSAS 1957**
Tab. 1, rel. 10–14

Halopeplis perfoliata is a semi-woody succulent shrub. It forms monospecific stands or dominates the vegetation in depressions with salorthids in the southern part of the Arabian-Persian Gulf, along the Gulf of Oman and on both coastlines of the Red Sea (for the distribution see FREITAG 1991, for edaphic conditions see KASSAS 1957, KÜRSCHNER 1986b and YOUNES et al. 1983). This hygrohalophyte with C_3 photosynthetic pathway (FREY et al. 1984) germinates after rainfall, when salt content is low (MAHMOUD et al. 1983).

Synsystematics: The *Halopeplidetum perfoliatae* is mentioned very often, but has never been published validly. Most publications do not give single relevés, the syntaxon is not included into higher syntaxa. The validation is made here by selecting a relevé from KASSAS (1957), who gives a table of a *Halopeplidetum* from the Red Sea coast in Sudan.
Lectotypus rel. 11 from KASSAS (1957):
Halopeplis perfoliata 2.2 *Suaeda fruticosa* +.1 *Arthrocnemum glaucum* +.3 *Aeluropus lagopoides* +.2

The *Halopeplidetum* has been recorded from the following regions: Southern Egypt (KASSAS & ZAHRAN 1967), Sudan (KASSAS 1957), Eritrea (HEMMING 1961), Saudi Arabia around Jeddah (VESEY-FITZGERALD 1955, MAHMOUD et al. 1982, YOUNES et al. 1983, FREY et al. 1984), the northern Tihamah in the Asir foreland (KÖNIG 1987), around Aden (AL-GIFRI, pers. comm.), the Mascat area in

Tab. 2
Frankenio-Zygophylletum simplicis

Releve Nº.	1	2	3	4	5	6	7
CS Frankenio-Zygophylletum							
Frankenia pulverulenta	2	1	2	2	2	2	2
Zygophyllum simplex	1	1	2	2	2	2	1
Cyperus aff. tanganyicanus	1	1	1	1	1	2	2
CS Cutandietea							
Oligomeris subulata	.	+	1	1	1	1	1
Arnebia hispidissima	.	.	1	2	2	2	1
Hippocrepis bicontorta	.	.	+	.	.	+	.
Seedlings of perennials							
Zygophyllum qatarense	.	1	.	1	+	+	.
Suaeda aegyptiaca	1	1	1	+	1	1	.
Helianthemum lippii	.	.	+	1	1	+	.
Salsola nitraria	+	.	.	.	.	+	+
Lotus garcinii	.	.	+	.	+	.	2
Sphaerocoma aucheri	.	.	.	.	+	+	.

Further rare species:
in 1: Sporobolus arabicus +;
in 3: Herniaria hemistemon +, Atriplex leucoclada +;
in 6: Ifloga spicata +, Dichanthium foveolatum +;
in 7: Limonium stocksii +, Heliotropium kotschyi 1.

Northern Oman (BATANOUNY & ISMAIL 1985, KÜRSCHNER 1986b), UAE (this contribution) and Qatar (BATANOUNY & TURKI 1983, BABIKIR 1984). Within this area, we can distinguish several geographical races, characterized by vicarious *Limonium* and *Zygophyllum* species. In the omano-makranian race occur *Zygophyllum qatarense* and *Limonium stocksii.*

The *Halopeplidetum* is up to now the only association of the *Halopeplidetalia perfoliatae* Knapp 1968 and belongs to the *Halopeplidi-Suaedetea* Knapp 1968, a class mostly synonymous with the *Suaedetea fruticosae deserta* Zohary 1973.

***Frankenio pulverulentae-Zygophylletum simplicis* ass. nov.**
Tab. 2, type relevé Nº. 2

In the central parts of the Sahara and in southern Arabia, the distribution of two salt tolerant therophytes is overlapping: *Frankenia pulverulenta* and *Zygophyllum simplex.* The first one is to be found from the western Sahara throughout the mediterranean area to Arabia and in the Indian deserts, the synanthropic area has been expanded to South Africa, Australia and to mediterranean region of the Neotropis. The species is almost everywhere restricted to winterrain climate (JÄGER 1992). It is a characteristic species of the class *Frankenietea pulverulentae. Zygophyllum simplex* is missing in the northern Sahara and the mediterranean area. It grows in the central parts and on the southern fringes of the Old World deserts from Senegal to Punjab. Where both species overlap, for example in the central Sahara, in the Sinai, in Qatar and in the UAE, they are associated and characterize an ephemeral, salt tolerant community. In Dubai, they have been noted in coastal depressions between Jabal Ali and Jumairah. The relevés have been taken on 15.3.87 in the coastal vegetation complex (Fig. 5). Within the *Halopeplidetum perfoliatae*, the shortliving *Frankenio-Zygophylletum* covers after rainfall flat sandy overlays of the silty depressions. Further associated species are the seedlings of the surrounding perennial vegetation and annuals of the sandy dunes like *Arnebia hispidissima.* The taxonomic position of an annual *Cyperus*, which has been found only in this community, is still unclear. It looks very similar to *C. tanganyicanus*, endemic in Tanzania.

Synsystematics: In other studies, the salt tolerant ephemeral flora has been treated as an element of the perennial halophytic communities, for example by ZOHARY (1973) within the *Suaedetea fruticosae deserta* or as a differential species of subassociations, for example by QUEZEL (1965) in the *Salsolo sieberi-Zygophylletum cornuti frankenietosum pulverulentae* or by BORNKAMM & KEHL (1990) in the *Zygophyllo coccinei-Schouwietum thebaicae zygophylletosum simplicis.* Because the annuals are submitted exclusively to the edaphic conditions of the top soil (independent from the water content in the depressions, lower salt concentration in the sandy layer after rainfall etc.), this unit can enter several perennial halophyte communities. It can also grow independently from perennial vegetation (both character species enter salinated, abandonned fields). Therefore, it must be treated as an independent plant community, which may also be a temporal therophytic synusium or chronocoenose within perennial vegetation types.

The *Frankenio-Zygophylletum* can be interpreted as the southernmost outpost of the class *Frankenietea pulverulentae.* From the character species of higher rank (see the revision of the class by BRULLO 1988), only *Frankenia pulverulenta, Sphenopus divaricatus* and *Spergularia marina* go to southern Arabia. *Desmazeria* spp., *Parapholis* spp. and other character species are restricted to the extra-tropical parts of Arabia. If more observations of those short-lived communities were available, the delimination of a south-saharo-sindian alliance (***Zygophyllion simplicis* all. nov. prov.**) would become more clear.

In the settlements of the UAE, a subnitrophilous association of the *Frankenietea* has been observed, the *Cressetum creticae* Brullo & Furnari 79. Detailed observations are missing.

5.2 The inland dune ecosystem

Most parts of the territory of Dubai are covered by the inland dune ecosystem, the sandy desert. From Dubai City to Tawi al Hibab we find parallel dunes with intermittent dune valleys and between Tawi al Hibab and Wadi Yudayyah irregular higher dunes. The low dunes are more or less consolidated and consist of white, calcareous sand of marine origin, the high mobile dunes are composed of red silicate sand of terrestrial origin. Within this area, habitat variability is evoked by different grain size and mobility of the sand, by the amount of run-on water in the dune valleys and by grazing intensity.

The sandy desert ecosystem has been studied closer in the area around Nakhalai Palace: Some plots there are sheltered from grazing. Fig. 6 illustrates life forms and structure of this vegetation complex. The dwarf shrub *Rhanterium epapposum* is a common grazing plant on lower sand dunes and in dune valleys, characterizing the inland dune system. The species is confined to the hot deserts around the Arabian Gulf, occupying enormous areas in Central and Northeastern Arabia. VESEY-FITZGERALD (1957) has stated there a *Rhanterium*-belt between the central red-sand associations and the *Stipa*-steppe (*Rhanterietum* s.l. sensu ZOHARY 1973). *Rhanterium* is an oligospecific genus of saharo-arabian distribution. Besides the east-arabian *Rhanterium epapposum*, we find the vicarious *Rhanterium suaveolens* in the Northern Sahara of Algeria and Morocco in *Zillion macropterae*-communities.

The second common species is *Panicum turgidum*, a grass of sub-saharo-sindian distribution. It is also an effective sandbinder as well as an important forage plant. Reproduction is mainly vegetative. Like in Qatar (BATANOUNY 1981), it is associated in Dubai with *Pennisetum divisum*.

Within the inland dune ecosystem, we can distinguish at least three different habitats: High dunes, low dunes and dune valleys.

The high red dunes, mostly fixed, have relicts of the original *Prosopis*-forest. *Prosopis cineraria* is a phreatophyte, concentrated at the margins of large

Tab. 3

***Panicum turgidum-Rhanterium epapposum*-vegetation complex**

(Transect II in the inland dune ecosystem)

Releve Nº.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CS of the Leptadenio-Rhynchosietum schimperi														
Rhynchosia schimperi	.	.	+	+	+	+	.	.	.	.	.	.	.	.
Leptadenia pyrotechnica	1	+	.	.	+	1	1	1	1	.	.	.	.	.
Calligonum comosum	+	2	+	.	+	1	1	1	1	1	1	.	.	.
Tribulus arabicus	1	1	2	1	+	+	+	+	+	+	+	.	.	.
Coelachyrum piercei	1	1	1	1	1	+	.	.	.	.	.	.	.	.
Psammophilous shrubs of unknow syntaxonomic rank														
Heliotropium digynum	1	2	+	1	.	+	.	.	.	.	.	.	.	.
Dipterygium glaucum	1	+	+	.	.	1	.	.	1	.	.	.	.	.
Crotalaria aegyptiaca	.	.	1	+	.	.	.	.	+	.	.	.	+	.
Polycarpaea repens	.	.	+	.	.	+	1	+	.	+	.	+	.	.
CS of Hammadetea and Acacietea (incl. Acacio-Panicion)														
Rhanterium epapposum	.	.	+	.	1	1	2	2	1	2	2	1	2	1
Stipagrostis plumosa	+	1	1	1	.	.	.	.	.	.	1	1	1	1
Lycium shawii	+	.	.	.	+	.	+	+	.	.	.	.	.	.
Ephedra foliata	+	.	.	.	.	.	.	+	.	.	.	.	.	.
Panicum turgidum	1	1	3	2	2	1	1	1	1	1	.	.	.	.
Pennisetum divisum	1	1	1	1	1	+	+	+	1	1	.	.	.	.
Cyperus aucheri	2	1	+	1	.	.	.	.	.	.	.	.	.	.
CS and DS of Helianthemo-Farsetietea and Aervo-Fagonion														
Helianthemum lippii	.	.	.	.	.	.	.	.	.	.	1	1	1	1
Farsetia stylosa	.	.	.	.	.	.	.	.	.	.	2	1	1	1
Monsonia nivea	.	.	.	.	.	.	.	.	.	.	2	2	2	2
Fagonia ovalifolia	.	.	.	.	.	.	.	.	.	.	2	+	2	1
Atractylis carduus	.	.	.	.	.	.	.	.	+	+	+	1	+	+
CS Chrozophora sabulosa-comm. and Cutandietea														
Chrozophora sabulosa	.	+	+	.	+	1	+	+	1	+	.	.	.	.
Cutandia memphitica	1	1	1	2	2	1	2	1	1	1	.	.	.	.
Eremobium aegyptiacum	1	+	.	+	+	1	1	+	+	+	.	+	.	.
Silene villosa	.	.	.	+	2	2	2	2	2	2	+	.	.	.
Moltkiopsis ciliata	+	.	2	1	1	1	.	.	1	.	.	.	.	.
Arnebia hispidissima	.	.	.	.	.	.	.	.	.	+	2	2	2	2
Plantago boissieri	.	.	+	+	.	2	2	2	2	1	+	.	+	+
Hippocrepis bicontorta	.	.	1	.	+	1	1	1	1	1	+	+	.	.
Neurada procumbens	.	+	1	.	1	+	+	+	1	.	+	1	.	1
Lotus halophilus	.	.	.	.	+	+	1	1	+	1	+	+	.	+
Gisekia pharnaceoides	.	+	.	.	+	+	+	.	+	.	.	.	.	.
Schismus barbatus	.	.	.	.	+	+	.	.	.	.	.	.	.	+
Companions														
Aristida adscensionis	1	1	1	2	1	1	1	1	1	1	+	+	1	+
Centaurea pseudosinaica	.	+	.	1	+	2	1	1	1	2	+	1	.	1
Launaea mucronata	.	+	.	+	+	.	+	1	.	1	+	1	+	+
Launaea capitata	.	+	.	.	.	+	+	.	+	+	+	.	1	+
Heliotropium kotschyi	.	.	+	+	.	.	.	.	.	.	.	.	.	.
Bassia muricata	.	.	.	.	+	.	.	.	+	+	.	.	.	.
Paronychia arabica	.	+	+	.	+	+	+	1	+	1	+	+	1	.
Tragus racemosus	.	.	+	+	1	.	+	+	.	.	+	.	.	.
Cenchrus ciliaris	.	.	+	.	.	.	+	.	.	.	.	.	.	.
Asphodelus fistulosus	.	.	.	.	.	.	.	.	.	.	.	+	.	1
Polygala cf. irregularis	.	.	.	.	.	.	.	.	.	.	.	+	.	+

Further rare species:
in 2: Phoenix dactylifera (seedling) +;
in 4: Astragalus biabauensis +; in 5: Hammada salicornia +;
in 9: Zygophyllum simplex +; in 12: Hippocrepis constricta +;
in 14: Chenopodium murale +.
Locality: All relevés taken in fenced area near Nakhali-Palace east of Dubai City, 17.3.1987.

Releve Nº.	1	2	3	4	5	6	7	8
CS of the association and higher units								
Pseudogaillonia hymenostephana	1	1	+	+	.	.	.	.
Jaubertia aucheri	.	1	.	2	1	.	+	.
Euphorbia larica	2	1	1	+	+	1	1	2
Perennial herbs and grasses of rocky environment								
Stipagrostis foexiana	1	+	.	.	.	+	.	+
Viola cinerea	.	.	.	1	+	1	.	.
Morettia parviflora	.	.	.	1	+	.	.	.
DS of ruderal variant								
Aizoon canariense	.	.	.	.	.	.	1	+
Atractylis carduus	.	.	.	.	.	.	+	+
CS of Anabasetea, Hammadetea and Acacietea								
Gymnocarpos decander	1	+	1	+	+	+	1	1
Hammada salicornica	.	+	2	+	+	1	1	1
Rhanterium epapposum	+	+	.	+	.	.	.	.
Reseda aucheri	.	.	+	+	.	+	.	.
Haplophyllum tuberculatum	.	.	.	+	+	.	.	.
Acacia tortilis	+	+	.	1	1	+	+	1
Lycium shawii	.	+	.	+	+	.	1	1
Cymbopogon commutatus	1	+	.	1	+	.	.	+
Companions (perennial)								
Aerva javanica	1	1	+	1	1	1	+	+
Reichardia tingitana	+	1	1	+	+	+	1	+
Forsskaolea tenacissima	.	.	+	.	.	1	1	+
Salvia aegyptiaca	.	+	.	+	.	.	.	.
Leucas inflata	.	.	.	1	1	.	.	.
Fagonia bruguieri	.	.	.	1	1	.	.	.
Companions (annual)								
Sclerocephalus arabicus	1	1	1	+	+	1	1	+
Cenchrus pennisetiformis	.	+	2	1	1	1	2	1
Seetzenia lanata	.	.	+	+	+	+	.	+
Arnebia hispidissima	+	.	+	+	.	1	+	.
Cometes surratensis	.	.	1	+	+	1	+	.
Aristida abnormis	.	.	1	+	+	1	1	.
Ifloga spicata	.	.	+	.	+	+	1	1
Plantago ciliata	.	.	+	+	+	+	.	+
Rumex vesicarius	+	.	.	+	+	+	.	.
Enneapogon desvauxii	1	+	.	+	.	+	.	.
Tetrapogon villosus	1	1	.	.	+	+	.	.
Hippocrepis constricta	.	.	1	.	+	1	.	+
Argyrolobium roseum	.	.	+	.	.	+	.	+
Astragalus eremophilus	+	.	.	.	+	+	.	.
Plantago ovata	1	.	.	+	.	1	.	.
Dactyloctenium scindicum	.	.	.	.	+	.	+	.
Notoceras bicorne	+	+	.	.	.	.	.	.
Oligomeris subulata	+	+	.	.	.	.	.	.
Medicago laciniata	+	+	.	.	.	.	.	.
Erucaria hispanica	.	.	.	1	1	.	.	.

Tab. 4
Pseudogaillonio-Euphorbietum laricae

Further rare species:
in 2: Polygala erioptera +, Cyperus jemenicus +, Savigna parviflora +; in 4: Crotalaria aegyptiaca 1, Blepharis ciliaris 1, Capparis cartilaginea 1; in 5: Grewia tenax +, Ochradenus arabicus +, Vernonica arabica +, Senecio flavus +; in 7: Chenopodium murale 1.
Locality: Relevé 1–3, 6–8: Quarn Nazwa, 18.3.1987; Rel. 4–5: Jabal Buhays, 19.3.1987.

dune fields and along wadis. It ranges from Hadramaut and Mascat to the Sind desert, forming mixed open woodlands with *Acacia tortilis* and other Acacias. Some dense relict stands in the Central Desert of the Emirates are endangered by grazing and cutting and by the dramatic decline of the groundwater table over the last two decades (see Plate 54 in the UAE Atlas). Like in Dubai, also in the Wahiba Sands in Oman no regeneration can be registered outside protected areas (BROWN 1988). From this habitat type, no relevés are available.

The floristic composition of the lower dunes and of the dune valleys has been documented by relevés (Tab. 3) and their vegetation will be discussed in detail.

***Leptadenio-Rhynchosietum schimperi* ass. nov.**
Tab. 3, rel. 1–10, type relevé Nº. 6

The lower, partly fixed dunes are colonized by the shrubs *Leptadenia pyrotechnica, Calligonum comosum* and *Rhynchosia schimperi,* by the tussock grasses *Panicum turgidum* and *Pennisetum divisum* and by psammophilous annuals (*Cutandia memphitica, Silene villosa, Eremobium aegyptiacum* and others). This *Leptadenia-Rhynchosia-Panicum*-community replaces the original *Prosopis* woodlands, which have been almost everywhere destroyed by grazing and wood cutting. Character species of the new association descibed here are *Rhynchosia schimperi, Tribulus arabicus* and *Coelachyrum piercei. Rhynchosia* is a densely grey villous shrub. As it is a high palatable species, it is nowadays difficult to find good specimens and near Nakhila Palace it has been found only inside the fenced area. The species is also known from dune fields south of Jeddah, from the Wahiba Sands in Oman and is restricted in the UAE to the inland dune field. *Tribulus arabicus* is endemic in Southeastern Arabia, from Bahrain to Oman. *Coelachyrum piercei* occurs in Southern Arabia and in Makran. Both are psammophytes. Character species of a high rank syntaxon are *Leptadenia pyrotechnica* and *Calligonum comosum. Leptadenia* is of south-saharo-sindian distribution. In the Sahara, it dif-

ferenciates the southern form of the *Calligonum comosum-Aristida pungens*-community Quezel 1965 and enters also into *Acacio-Panicion*-communities sensu BARRY et al. (1981, 1986). The richly branched leafless shrub *Calligonum comosum* is distributed from Iran to Morocco, always colonizing deep sand. Further character species might by found among the psammophilous shrubs (*Heliotropium digynum* to *Polycarpaea repens*), but more information about the ecology and sociology of those species is necessary.

Synsystematics: In a very broad community concept, like that of VESEY-FITZGERALD (1957), the whole vegetation complex of the inland dune fields of Dubai would be included in the *Rhanterium*-steppe-type. In a community concept, based on dominant species, this would be split up in numerous units. BATANOUNY & TURKI (1983) for example described from Qatar different communities with the following species: *Rhanterium epapposum, Panicum turgidum, Pennisetum divisum, Leptadenia pyrotechnica, Acacia tortilis, Lycium shawii.* We follow a concept in between the two previous ones. We interpret the catena of Fig. 6 and the sampling-transect of Tab. 3 as a repetitive pattern of the ecotopes: dune ridges, dune slopes and dune valleys. The whole forms a vegetation complex of three communities (the stratum of the annuals will be discussed separately). They can also be found in another combination of communities and can be elements of other contact series.

The *Leptadenio-Rhynchosietum* is the southeastern outpost of a saharo-arabian class of perennial vegetation on mobile, non saline dunes with *Calligonum comosum.* This syntaxon has still to be defined by comparative studies with the *Aristidetalia pungentis* Guinochet 1951 from the northwestern Sahara and the *Haloxylo-Retametalia* Zohary 1973 from Northern Arabia and Sinai. Further syntaxa, which have also to be taken into account are: The *Hammadetea salicornicae* Zohary 1973, the *Acacio-Panicion* (BARRY et al. 1981), the *Cassio-Panicion* Foucault 1993 and the Pseudosavannas with *Acacia tortilis* and *Panicum turgidum* sensu ZOHARY (1973). For the moment, there exist more names for high rank syntaxa than detailed studies.

Helianthemum lippii-Fagonia ovalifolia-community

Tab. 3, rel. 11–14

The dune valleys with a stony surface layer are colonized by low shrubs. *Helianthemum lippii, Monsonia nivea, Fagonia ovalifolia* and *Farsetia stylosa* occur there. They are mentioned by BARRY et al. (1986) as characteristic species of the *Aervo-Fagonion*, an alliance, which occupies similar relief units in the Southern Central Sahara. The rankless *Helianthemum lippii-Fagonia ovalifolia*-community is an impoverished outlier of the *Aervo-Fagonion.* This syntaxon has a transitional position between the subtropical class *Boerhavio-Tephrosietea* (BARRY et al. 1986) and the extratropical class *Helianthemo-Farsetietea* (FOUCAULT 1993). A *Helianthemum lippii*-community with more saharo-arabian elements is reported from southern Jordan by BAIERLE (1993).

The ephemeral *Chrozophora sabulosa*-community

After rainfall, mostly in spring, short-lived annuals build a green carpet (the »acheb«) on dunes and in sandy depressions. They finish their life cycle, when the sand is drying out. Some authors, for example ZOHARY (1973), interpret this group as a stratum of the perennial sand community. But GUINOCHET (1951) has already realized in his studies in the Mauretanian Sahara, that this unit is quite independent from the perennials. It can enter different shrub communities, even halophytic groups, as a short-lived overlay if the sand is thick enough (10 cm and more) to »isolate« them from the substrate of the deep rooting perennials. These species grow in an environment which is quite different from that of the perennials. They do hardly interact with them. They are an independent plant community. The species group from *Cutandia memphitica* to *Schismus barbatus* (Tab. 3) is provisionally named ***Chrozophora sabulosa***-community. It is the corresponding unit to the salt-tolerating *Frankenio-Zygophylletum.*

Synsystematics: GUINOCHET (1951) proposed the name *Cutandietea* for a class of ephemeral sand vegetation in the Saharo-Arabian desert belt. From his class characteristics, *Cutandia memphitica, Eremobium aegyptiacum (= Malcolmia a.), Hippocrepis bicontorta, Neurada procumbens, Lotus halophilus* and *Moltkiopsis ciliata* occur in Dubai. The east-saharo-arabian and nubo-sindian *Arnebia hispidissima* is replaced in the Mauretanian Sahara by *A. decumbens*, in the sand deserts of Southern Iran by *A. latebracteata* (FREITAG 1986). The night-flowering *Silene villosa* is also the naming species of the southmoroccan *Echio-Silenion villosae* (LEMEE 1954). The association in Dubai is differentiated from this alliance by subtropical and eastern elements like *Chrozophora sabulosa* (omano-makranian-irano-turanian) and *Gisekia pharnaceoides.* Further studies are necessary to clear the differences between the *Cutandietea* and the following groups: *Notoceretea bicornis* Nègre 1956 em. Foucault 1993 (the unnamed order 3 there!), *Schismo-Crithopsietea* (BRULLO & FURNARI 1978) and the therophytes of the *Haloxylo-Retametalia* Zohary 1973. Northern outposts of an ephemeral psammophytic vegetation unit with *Eremobium aegyptiacum* and *Silene villosa* in the Wadi Araba are mentioned by BAIERLE (1993).

5.3 The stony desert

The stony ecosystems in Dubai comprise very different ecotopes like gravel plains, rock outcrops and the mountain area itself. Differenciating ecological factors in the stony environment are inclination and exposure of slopes, altitude, gravel size and depth of the sediment layer. We will go into details only for a community on bare rock. The vegetation of the gravel plains and of the mountainous areas will be outlined very briefly.

***Pseudogaillonio hymenostephanae-Euphorbietum laricae* ass. nov.**
Tab. 4, type relevé N°. 1

Within the inland dune system and also within the stony pediment, we find some rock outcrops like Qarn Nazwa near the Hatta road and Jabal Buhays. At those localities the relevés of Tab. 4 have been taken. The outcrops are built by compact limestone and boulders and are partly covered by a thin sand layer (Fig. 7). The rock surface shows microerosion, a form of karst weathering caused by frequent dew and fog. This is also indicated by epilithic lichens.

On bare rock (relevé 1–4), with sparce vegetation cover and in southern and western exposure, two Rubiacee are growing in rock fissures: *Pseudogaillonia hymenostephana* and *Jaubertia (= Gaillonia) aucheri*. Both species have an omano-makranian area. *Pseudogaillonia* is found on bare rocks from Mascat to the Punjab, *Jaubertia* on stony foothills and rocky slopes from the Musadam mountains to the coastal mountains of southern Iran, Afghanistan and Baluchistan. The *Pseudogaillonio-Euphorbietum* is very similar to the variety 3 of the *Commiphora myrrha-Euphorbia larica*-community sensu FREY & KÜRSCHNER (1986), growing on karstic limestone at lower altitude of the mountain ranges south of Mascat. On rocky slopes with a layer of boulders and more sandy material in the fissures (relevé 5–8), *Pseudogaillonia* is missing.

Tab. 5
Saccharo-Nerietum mascatense

Releve N°.	1	2	3	4
CS of the wadi community				
Saccharum griffithii	3	3	2	2
Nerium mascatense	1	1	2	1
Dyerophytum indicum	+	+	1	.
CS of the open woodland comm. on slopes				
Moringa peregrina	+		.	+
Lycium shawii	+	.	1	.
Dodonaea viscosa	.	.	+	.
Hygrophilous herbs				
Parietaria lusitanica	+	1	.	+
Onychium melanolepis	+	+	.	.
Galium setaceum decaisnei	+	.	+	.
Companions				
Tephrosia apollinea	+	1	2	1
Echinops spec.	1	1	+	.
Brachypodium distachyon	+	.	.	+
Zoegea purpurea	+	.	+	.
Ziziphus spina-christi	+	.	.	.
Forsskaolea tenacissima	+	.	.	.
Filago desertorum	1	.	.	.
Senecio flavus	.	.	+	.

The two Rubiacee are associated with *Euphorbia larica*, an almost leafless, much-branched shrub with smooth, fleshy stems. It colonizes rocky slopes at low and medium altitudes in the Musadam peninsula and in southern Iran, limestone as well as schists. In Southwest Arabia this species is replaced by *Euphorbia schimperi*, on Masirah-Islands by *Euphorbia masiharensis*, both members of the section *Tirucalli* within the genus *Euphorbia*.

Further species of high constancy are *Gymnocarpos decander, Hammada salicornica (= Haloxylon s.)* and the tufted grasses *Cymbopogon commutatus* and *Stipagrostis foexiana*. *Gymnocarpos* is widespread in stony deserts of the saharo-arabian region (*Anabasetea*-communities in Egypt and Palestine, *Gymnocarpo-Atractyletalia* Quezel 1965 in the Northwestern Sahara), *Hammada* is confined to the hot sand deserts in the Middle East and characterizes psammophilous plant communities (*Hammadetea salicornicae* Zohary 1973). In the UAE, this leafless shrub is the dominating plant of the sandy depressions within the red inland dunes, also growing on sand accumulations over rocky slopes. On gravel plains it forms large mounds by fixing sand. After rainfall, a herb layer with *Sclerocephalus arabicus, Cenchrus pennisetiformis, Cometes surattensis* and other annuals develops. This stratum requires further studies.

Synsystematics: The *Pseudogaillonio-Euphorbietum* can be included into the *Euphorbietea laricae* Zohary 1973. This class is of omano-makranian distribution. Further communities, already described, are the *Euphorbia larica-Gaillonia aucheri*-association Zohary 1963, the *Euphorbia larica-Sphaerocoma aucheri*-association Zohary 1963, the *Commiphora myrrha-Euphorbia larica*-community around Mascat (FREY & KÜRSCHNER 1986) and a still undescribed association with *Euphorbia larica, Barleria candida* and *Iphiona horrida* in the Northern Oman Mountains (GHAZANFAR 1991). The first group is the central association of the class and the relevés 5–8 can be included in this syntaxon. It is know also from southern Iran near Bandar Abbas and from Jabal Akhdar in Oman (MANDAVILLE 1977). The *Euphorbio-Gaillonietum* has higher cover values than the *Pseudogaillonio-*

Euphorbietum, it grows on less extreme rocky slopes and on boulders. Differential species of a ruderal variant are *Aizoon canariense* and *Atractylis carduus* (relevés 7–8, Tab. 4). In higher altitude, the *Euphorbio-Gaillonietum* is followed by the *Euphorbia larica-Convolvulus acanthoclados*-community, stated by MANDAVILLE (1985) in the Musandam Mountains and by ZOHARY (1963) in southern Iran. Even higher up in the Hajar-mountains we have a separate altitudinal belt in climatic and floristic respect: higher precipitations and relicts of an evergreen sclerophyllous woodland with *Moringa peregrina*, *Dodonaea viscosa* and *Reptonia mascatensis* (= *Monotheca buxifolia*). This vegetation belt, which follows the *Euphorbia larica*-zone, has been studied by MANDAVILLE (1985) in the Musandam Mountains and by MANDAVILLE (1977) and GHAZANFAR (1991) in Northern Oman at the Jabal Akhdar.

The genus *Gaillonia* s.l. (LEONARD 1984) includes *Choulettia* (one species in the northwestern Sahara), *Jaubertia* (one omano-makranian species), *Pseudogaillonia* (one omano-makranian species), *Petrogaillonia* (three species, west-saharo-sindian) and *Neogaillonia* (22 species, from Socotra to Turkmenistan). The monospecific genera seem to be confined to the rocky environment. The *Pseudogaillonio-Euphorbietum* is vicarious to a plant community in southern Morocco and Algeria. There, *Gaillonia* (= *Choulettia*) *reboudiana* and *Gymnocarpos decander* are associated on rocks, boulders and stony pediments. They are character species of the *Atractylion babelii* Lemée 1953 (*Gymnocarpo decandris-Atractyletalia serratuloidis* Quezel 1965).

The **stony gravel plains** offer good conditions only for deep rooting perennials which can reach the ground water level. An open woodland can be found here with *Acacia tortilis*, *A. ehrenbergiana*, *Lycium shawii* and *Hammada salicornica*. When the tree layer is destroyed, *Pulicaria glutinosa* becomes the dominant species. Along small runnels and wadis, a kind of gallery-forest with the phreatophytes *Prosopis*, *Ziziphus* and *Ficus* (see Fig. 7) can be found.

5.4 The Wadis

According to frequency and intensity of water flow, stream velocity, depth of groundwater level and grain size of the sediments we can distinguish four wadi vegetation types in the UAE. Just one is described here in detail.

***Saccharo griffithii-Nerietum mascatense* ass. nov.**
Tab. 5, type relevé No. 1

Deep incised, canyon-like wadis of the mountainous area belong to this type. The valley slopes are often cut into the bare rock, the wadi bottom is covered with boulders, stream velocity during erratic water flow is high. Some finer sediments are collected by the dense clumps of the wild sugar cane. The relevés from Table 5 have been taken in Wadi Ham south of the Masafi-Bethha-road (Fujeirah) on 20.3.1987. Character species of the *Saccharo-Nerietum mascatense* are the highgrowing tufted grass *Saccharum griffithii* and the evergreen shrubs *Nerium mascatense* and *Dyerophytum indicum*. All these species are of omano-makranian distribution: The same association can be observed in the Oman mountains as well as in wadis in Southern Iran and Pakistan. The salt secreting *Plumbaginaceae Dyerophytum indicum* is an indo-malayan relict in Arabia (KÜRSCHNER 1986a).

The *Saccharo-Nerietum* is in contact to shrub communities of mountainous character with *Moringa peregrina* and *Dodonaea viscosa*. On fine, humid sand between the boulders and gravels, a synusium of hygrophilous herbs (*Parietaria lusitanica*) and ferns (*Onychium melanolepis*) develops after the run-off.

Synsystematics: DEIL (1986) has shown, that on the Arabian peninsula two wadi vegetation types exist: An extratropical one with *Apocynaceae* and a tropical one with *Jatropha*-species. The wadi communities in the UAE belong to the extratropical type. Wadi communities with *Apocynaceae* (*Nerium, Rhazya*) and tall growing perennial grasses of the Tribus *Andropogoneae*, Subtribus *Saccharinae* (*Saccharum, Imperata*), often in contact or associated with *Tamarix* species, are recorded from the whole saharo-arabian and nubo-sindian region. Vicarious communities to the *Saccharo griffithii-Nerietum mascatense* are the *Saccharum kajkaiense-Nerium indicum* community from Iran and Punjab, the *Saccharum spontaneum-Tamarix nilotica-T. aphylla* community from the Yemeni lowland, the *Nerio-Tamaricetum niloticae* Quezel 65 from the central Sahara and, as the northernmost outlier, the *Equiseto-Erianthetum ravennae* Br.-Bl. & Bolos 1957 from intermittent rivers in the Ebro basin in central Spain.

The syntaxonomy of those wadi communities is still quite unclear. It must be based on supraspecific taxa. Until more records are available from Southwest Asia, the *Saccharo-Nerietum mascatense* is the only association of the omano-makranian alliance **Saccharo griffithii-Nerion mascatense all. nov.**, vicarious to the southwest-mediterranean *Imperato-Erianthion*. Both can be included in the class group *Imperato-Tamaricea* Bolos 68.

When the wadi bottom is broader, filled up with gravel and sandy sediment which store groundwater, the wadis are intensely used by man. This agricultural oasis wadi type is covered by date palms (*Phoenix dactylifera*), mango trees (*Mangifera indica*), pomegranate (*Punica granatum*), various citrus trees and other fruit trees. Remnants of the original vegetation are *Nerium mascatense*, *Ficus salicifolia* and *Acacia*

nilotica. In the tree shadow on walls with dripping water, along water courses and irrigation channels, we find the *Adianto capilli-veneris-Epipactidetum veratrifoliae* Deil 89, for example in Wadi Difta.

In the alluvium of wadis emerging from the mountains, *Physorrhynchus chamaerapistrum* is growing (see Fig. 7). This species is also endemic to the omano-makranian region. It characterizes a community of its own, which has still to be studied in detail. Outside the mountains, the wadis are filled up with deep deposits. On gravels we find the *Acacia tortilis-Rhazya stricta*-type, very similar to the vegetation of the footplains and stony gravel pediments. On fine deposits the *Tamarix-Calotropis*-type indicates groundwater.

6 Concluding remarks

The general zonation of the landscape units in the UAE (coastal dunes, inland dunes, stony desert) is similar to that in other regions of the Arabian-Persian Gulf and of the Read Sea coasts. If we have a closer look at the flora and the vegetation cover in Dubai, we can state quite different chorological affinities of the plant communities. Most of the associations described here (the *Cornulaco-Sphaerocometum*, the *Leptadenio-Rhynchosietum*, the *Pseudogaillonio-Euphorbietum* and the *Saccharo-Nerietum*) can also be found in Southern Iran and Northern Oman. These omano-makranian links are based on common climatic conditions in the southern

Tab. 6
Syntaxonomical survey

Syntaxonomical survey

HALOPEPLIDO-SUAEDETEA KNAPP 1968 (pp. syn. SUAEDETEA FRUTICOSAE DESERTA ZOHARY 1973)
Halopeplidetalia perfoliatae Knapp 1968
?
Halopeplidetum perfoliatae ass. nov. ex Kassas 1957
regional race with Zygophyllum qatarense
Salsolo-Suaedetalia Knapp 1968
?
Cornulaco monacanthae-Sphaerocometum aucheri ass. nov.
Subass. typicum
Subass. halopyretosum mucronati subass. nov.

FRANKENIETEA PULVERULENTAE RIV-MTZ. EX CASTROVIEJO & PORTA EM. BRULLO 1988
?
Zygophyllion simplicis all. nov. prov.
Frankenio pulverulentae-Zygophylletum simplicis ass. nov.

HAMMADETEA SALICORNICAE ZOHARY 1973
?
Acacio-Panicion Barry et al. 1981?
Leptadenio-Rhynchosietum schimperi ass. nov.

BOERHAVIO-TEPHROSIETEA BARRY ET AL. 1986
?
Aervo-Fagonion Barry et al. 1986
Helianthemum lippii-Fagonia ovalifolia-community

CUTANDIETEA MEMPHITICAE GUINOCHET 1951
?
pp. Echio-Silenion villosae Lemée?
Chrozophora sabulosa-community

EUPHORBIETEA LARICAE ZOHARY 1973
?
?
Pseudogaillonio hymenostephanae-Euphorbietum laricae ass. nov.
Euphorbia larica-Gaillonia aucheri-association Zohary 1963

IMPERATO-TAMARICEA BOLOS 68
?
Saccharo griffithii-Nerion mascatense all. nov.
Saccharo griffithii-Nerietum mascatense ass. nov.

part of the Gulf, a common vegetation history and the drying out of the Strait of Hormuz in recent geological times. The chorospectra of these communities show the transitional character of the study area from the Paleotropical to the Holarctic Kingdom. The taxa of tropical origin (the sudanian and eritreo-arabian geno-elements) are predominant among the perennials. The similarities to the Northern Gulf (Kuwait) are not so strong (HALWAGY & HALWAGY 1974).

The salt-influenced coastal sabkha system is colonized by a vegetation complex, which is composed of the same plant communities in Qatar, Mascat and on both sides of the Read Sea. This complex is of circumarabian distribution and always shows the same zonation. The halo-series is ruled by salt content, degree and frequency of inundations and by the intensity of wind erosion. Regional attributes to the common species and communities are vicarious *Limonium* and *Zygophyllum* species. These genera can be used as suprageneric character-taxa to define this vegetation complex.

The annual vegetation units have more floristic affinities to the extratropical desert vegetation than the perennial ones. Most of the species are of saharo-arabian distribution and of extratropical origin. They are spring annuals and are reacting to the mediterranean rainfall regime in Dubai. One perennial plant, which connects the northern and southern parts of the Gulf, is *Rhanterium epapposum*.

The associations described here are sufficiently characterized, both from the floristic and from the ecological point of view, but their syntaxonomical position (see the scheme Tab. 6) is sometimes preliminary, because a summarizing conspectus of the saharo-arabian vegetation has not yet been made.

The authors are grateful to Mr. PLATT (Dubai Wildlife Center), Mrs. JONGBLOED (Dubai) and Mr. GABRIEL (Hamburg) for support of the field work, to the staff of the Royal Botanical Garden Edinburgh, especially Mr. HEDGE and Mr. MILLER for their help in the determination of the specimens, to Mr. KUKKONEN (Helsinki) for identifying *Cyperus*, to FREITAG (Kassel) for *Chenopodiaceae* and to KÜRSCHNER (Berlin) for the *Bryophyta*.

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