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A Study of the Vegetation of the Qurm Nature Reserve,* Muscat Area, Oman

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ABSTRACT. This study is the first documentation to be made of the vegetation and flora of the Sultan Qaboos Public Park & Nature Reserve in Oman (Muscat area). The characteristic vegetation units are described by means of a vegetation map (1:10,000) and selected transects. In the final chapter, attention is called to the special importance of the Nature Reserve and proposals are made for its future conservation. An appendix contains a list of the phanerogamic taxa which have been found there up to now.

Oman is one of the countries of SW Asia where environmental consciousness - the prerequisite for action at political and administrative levels - has made great advances. Here vigorous efforts are being made to set aside representative biotopes in which the preservation of nature is given priority. Organisms are protected within the context of their natural habitat in order to safeguard the natural potential and to enable it to be studied. In this way, the country is meeting its responsibility to future generations.

Among the nature reserves in Oman there is a mangrove area which is one of the most important ecosystems of the subtropical coastal region on the Gulf of Oman. It is an estuary influenced by the tides and plays an important part in the food chain of marine organisms (biological resource in the detritus food chain). This makes it economically important as well. As a result of these ecological, economic, educational and touristic considerations, and especially because of the

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personal commitment of the Sultan to environmental protection, the Sultan Qaboos Public Park and Nature Reserve was established. Thus, one of the best-preserved estuary systems of Oman was placed under protection along with its plant and animal population.

Scientists now have the task of recording the diverse flora and fauna, of investigating the ecological and physiological tolerance of the organisms and their habitats, and of determining the importance of the Nature Reserve from the point of view of natural and cultural history. At the same time, however, they must see to it that the welcome efforts in support of the Nature Reserve do not become an alibi for negligence elsewhere or a mere public relations gesture. In addition, they must help to find a reasonable compromise between the public interest (aesthetic and recreational value) and the protection of nature.

The present study, following upon the investigation by Smythe (1983) on the molluscs of the Nature Reserve, gives a preliminary survey from the botanical point of view. By means of a vegetation map, selected vegetation transects and a list of species, it depicts the dominant vegetation units, thus serving as a basis and a stimulus for further investigations.

Study site

The Sultan Qaboos Public Park and Nature Reserve is situated in the former delta of Wadi Aday near Qurm (Muscat area, Fig. 1, 2) and covers an area of about 1.5 km^2. The estuary here was created by sand banks and is connected to the sea by two tidal channels. Through subterranean inflow of ground water from Wadi Aday and smaller neighbouring wadis fresh water is mixed with sea water in a manner determined by the rhythm of the tides. As a result, there is a diversity of salt contents and environmental conditions. In hydro-geographical terms, this is a polyhaline, vertically homogeneous estuary with horizontal variations in salinity (Fig. 2). In pools which are isolated at low tide and in hollows which dry up completely there are sharp increases in the salt content during the course of the day on account of the high rate of evaporation in the summer. Organisms inhabitating such transition zones must therefore be euryhaline.

This ecosystem, characterized by a fluctuating water level (the Qurm Nature Reserve proper, covering roughly 1 km^2), is occupied by mangroves. Adjacent to the mangroves, there are Nubo-Sindian-influenced halophyte communities, which in turn are followed by thorn woodlands (*Acacia* woodlands) and a former date-palm oasis in the south-eastern part of the Reserve (planned Sultan Qaboos Public Park).

On the basis of the morphology of the terrain six physiographic units can be distinguished (Fig. 2):

A Beach zone, overflooded at high tide. Mainly marine deposits.

B Coastal dunes (marine and eolian deposits).

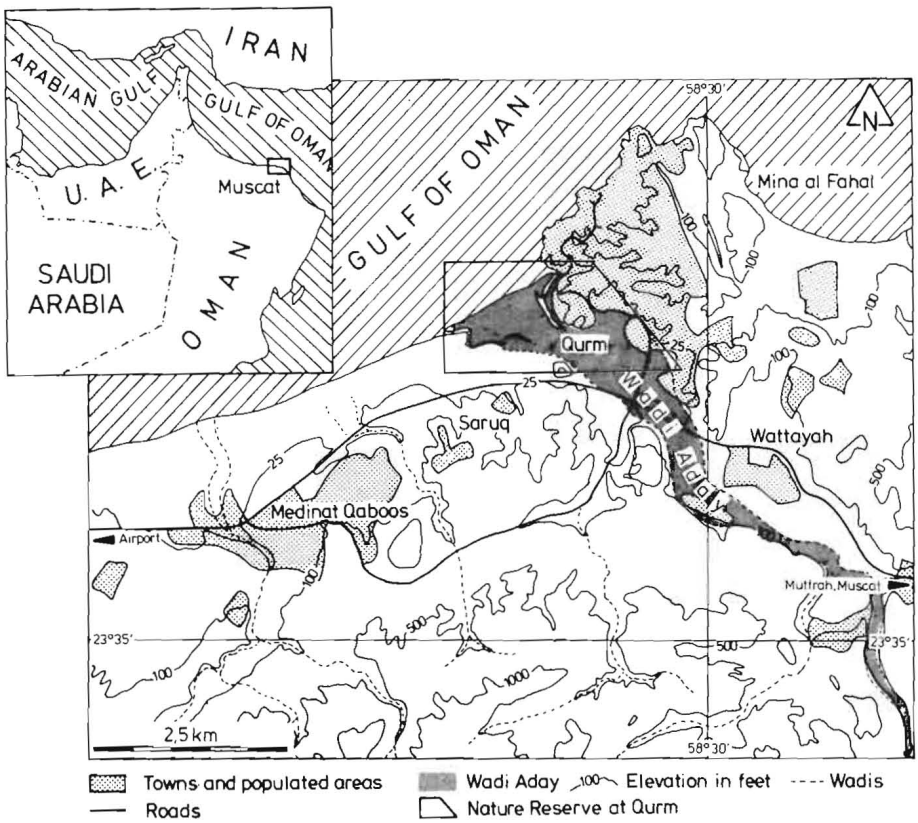

Fig. 1. Study site

a) partly stabilized large dunes
b) eolian, deep and loose sands, strongly affected by wind erosion

C Central plain (Sabkha deposits).

D Area of the tidal channels, gullies and runnels, permanent flooded or overflooded at high tide.

E Alluvial plain (alluvial fans, fluvial sands and gravel, partly with a surface layer or reg gravel.

F Karstic rocks and plateaus of the coastal terraces.

Climatically the Nature Reserve is charcterized by an arid desert climate (subtropical dry zone, Walter 1977) with hot summers; there is only a slight degree of continentality (mild winter temperatures, Fig. 2).

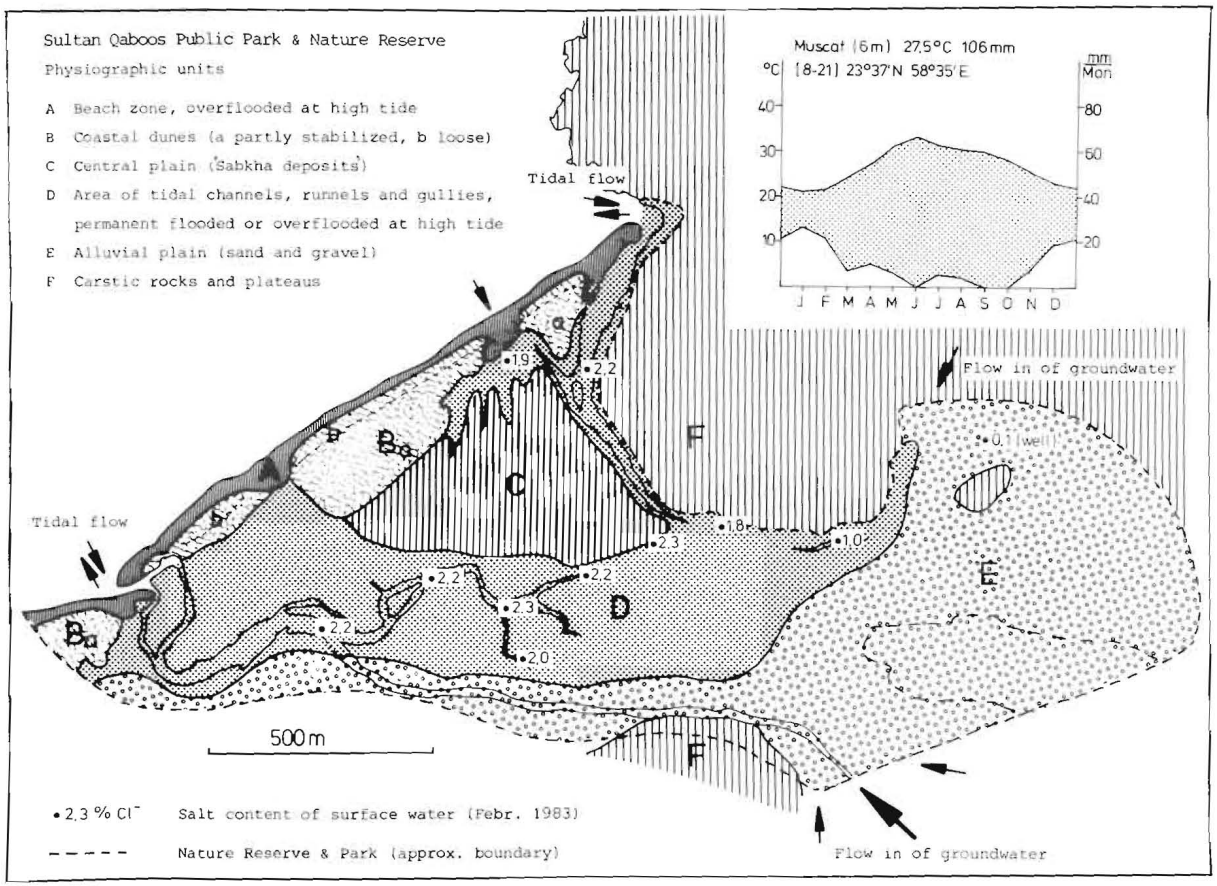

Fig. 2. Sultan Qaboos Public Park and Nature Reserve. Physiographic units and climatic conditions

Material and Methods

The map in Fig. 4 is based on vegetation surveys (plant sociology and quantitative analysis), extensive field checking and mapping in the spring of 1983, and evaluation of aerial photographs (aerial photography by B.K.S. Surveys Limited, P.O.B. 7149, Mutrah, November 1982, OM82 No. 54008, OM82 No. 54009). The vegetation transects (Transect 1,2: Fig. 4), which are intended to illustrate the characteristic, edaphically determined zonation of the littoral salt marshes of the Nature Reserve, were constructed by means of vegetation analysis. Quadrats (2 × 2 m) were marked out in a regular fashion along the suspected edaphic gradient (*see* Fig. 6, transect method, *cf.* Kürschner 1982, Frey and Kürschner 1983, 1984 Frey *et al.* 1984), and the species found in them were subjected to an association analysis (Normal Association Analysis; for the methods compare Williams and Lambert 1959, Kürschner 1982, 1983). With the aid of this procedure, homogeneous groups (habitat groups, associations) were obtained in which a relation was evident between the species population and the gradient at particular locations. Thus, it was possible to document a distribution pattern of internally homogeneous habitat groups and to interpret their arrangement and spread as being attributable to ecological causes (an underlying ecological gradient).

Since it was expected that edaphic factors would be responsible in part for the zonation, soil samples (from the surface and from a depth of 50 cm) were taken and analysed (German Standard Procedure, Tab. 2).

Fig. 3. Sultan Qaboos Public Park and Nature Reserve. Aerial photography

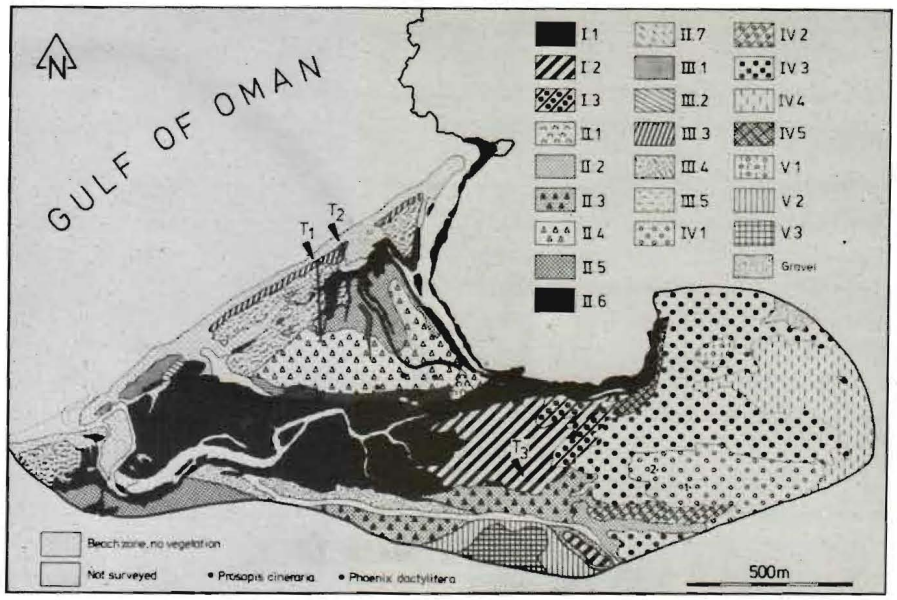

Fig. 4. Vegetation map of the Sultan Qaboos Public Park and Nature Reserve (explanations in the text)

Results and Discussion

A) *Vegetation map* (Figs. 3, 4)

Owing to pronounced edaphic and ecological factors many communities in the study area are characterized by only one or a few species. The vegetation was therefore classified on the basis of the dominance principle, which is also employed by Kassas and Zahran (1967), Zahran (1982) and Batanouny (1981) (Zahran 1982 uses the term "community type" in order to make it clear that he is not referring to communities in the sense of the Braun-Blanquet system). Through the inclusion of a limestone hill the map was extended beyond the boundaries of the Nature Reserve in the southern part. These karstic rocks and plateaus of the Batinah (Pleistocene coastal terraces) are occupied by highly degraded scrub remnants, which are extremely interesting from the point of view of floristics and floral history.

I. *Mangrove Formations*

(Avicennietea marinae Zohary 1973, *Avicennia marina* community Kassas and Zahran 1967, Batanouny 1981, *Avicennia marina* community type Zahran 1982, *Avicennia marina* association Frey *et al.* 1984; Photo 1). Characteristic of the

tidal channels, gullies and runnels which are permanently flooded or overflooded at high tide (lagoonal silts and mudbanks, Peat Mangrove Chapman 1940). Three developments can be observed:

I.1 Pure stands of *Avicennia marina*. Characteristic of muddy, loamy-sandy, wet and moderately saline soils which are poor in oxygen and rich in organic substances. The densest stock of trees will be found along the two tidal channels.

I.2 *Avicennia marina, Suaeda aegyptiaca* forming a mixed formation in the sandy central part of the Nature Reserve. Densely interspersed with halophytes. A detailed investigation of this mixed formation (T. 3, Fig. 4) shows a clear zonation which is attributed to edaphical parameters shown in Fig. 5. The elevated, dry, calcareous-rich sands are characterized by *Suaeda aegyptiaca* and *Indigofera oblongifolia*. They are followed in the transition zone to the runnels by very wet, polyhaline, sandy silty soils which are poor in $CaCO_3$ and typical of *Aeluropus lagopoides* and *Halopeplis perfoliata* communities. The very wet, calcareous-rich, muddy soils of the runnels which are only moderately saline (as a result of washing out of water soluble ions) are dominated by shrubs of *Avicennia marina*. Increasing accumulation of sand in the central part leads to desiccation and sanding up of the mangroves.

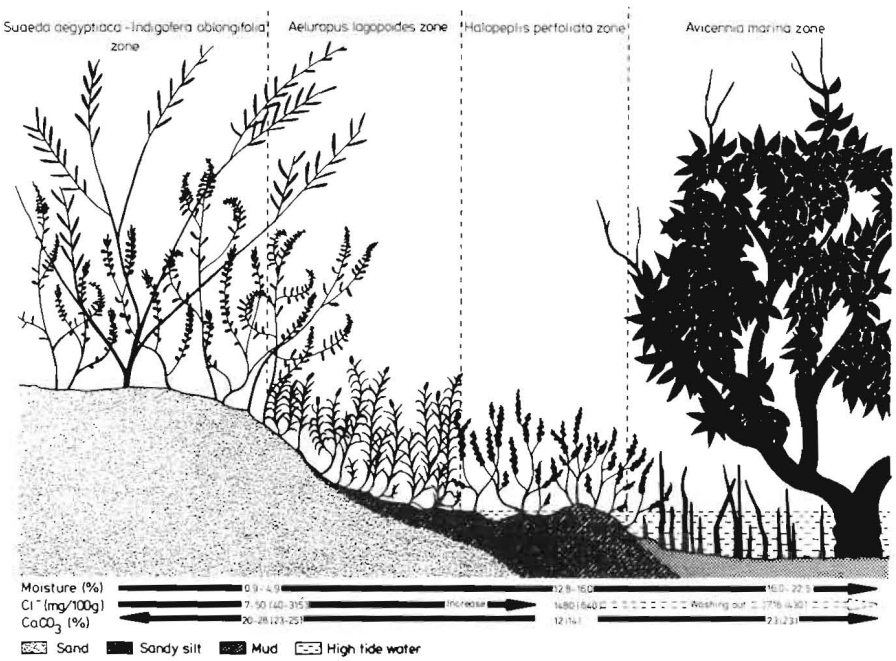

Fig. 5. Correlation of vegetation and edaphical factors in the central part of the study site (surface values and values at 50 cm depth; in brackets)

I.3 *Avicennia marina, Phoenix dactylifera* as a transition zone to the alluvial plain (former cultivated date garden).

II. *Halophytic Formations*

(Suaedetea fruticosa deserti Zohary 1973, Photo 2). On "Sabkha deposits" and highly saline depression soils. Mainly in the vicinity of the tidal channels and in the central plain (7 different communities).

II.1 Pure stands of *Suaeda aegyptiaca*. Only locally in the central part.

II.2 *Aeluropus lagopoides, Suaeda aegyptiaca* (*Aeluropus lagopoides* community Kassas and Zahran 1967, Batanouny 1981, *Aeluropus lagopoides* community type Zahran 1982). Well-developed mixed formation on coarse sand in the SE part of the Nature Reserve. Associates are *Cressa cretica, Halopeplis perfoliata, Zygophyllum qatarense*.

II.3 *Suaeda aegyptiaca, Halopeplis perfoliata*. Forming a mixed formation on the border of the upper part of the western channel (outflow of Wadi Aday). *Suaeda* is typical of moderately dry sands, whereas *Halopeplis* dominates the strongly saline, wet runnels (hygric differentiation).

II.4 Pure stands of *Suaeda fruticosa*. Largely distributed on the Sabkha deposits in the central part of the Nature Reserve.

II.5 *Suaeda fruticosa, Halopeplis perfoliata,* forming a transition zone to the mangroves.

II.6 *Halopeplis perfoliata* (*Halopeplis perfoliata* community Kassas and Zahran 1967, Batanouny 1981, *Halopeplis perfoliata* community type Zahran 1982, *Halopeplis perfoliata* association Frey *et al.* 1984). Characteristic of the wet and strongly saline border of the tidal channels and runnels.

II.7 *Arthrocnemum macrostachyum* (*Arthrocnemum glaucum* community Batanouny 1981). Represented cartographically only in the central plain. This species is also dominant in the mixed formation of *Suaeda fruticosa* and *Halopeplis perfoliata* but also occurs in the dune vegetation.

III. *Psammophytic Formations.*

On coastal dunes consisting of loose or slightly fixed white, calcareous sands of marine origin, mixed with broken snail shells. Depending on their mobility, texture and exposure, coastal dunes are colonized by five different communities.

III.1 *Halopyrum mucronatum* community Kassas and Zahran 1967, Batanouny 1981, Batanouny and Turki 1983, *Halopyrum mucronatum* community type Zahran 1982). Sand-stabilizing community on eolian, deep and loose sands with dunal landform. *Halopyrum* has a well-developed root system, capable of vegetative regeneration. Therefore, it can also survive periods of burial.

III.2 *Halopyrum mucronatum, Suaeda fruticosa.* Forming a small belt as a transition zone to the *Avicennia* zone.

III.3 *Sphaerocoma aucheri, Suaeda vermiculata.* On eolian, deep and loose sands. Strongly affected by wind erosion.

III.4 *Suaeda vermiculata, S. fruticosa* (*Suaeda fruticosa-S.vermiculata* community type Zahran 1982, *Suaeda vermiculata* community Batanouny 1981). Characteristic of poorly to moderately fixed dunes. Co-dominant are *Cistanche phelypaea, Cyperus conglomeratus, Limonium stocksii.* Small depressions are dominated by *Lotus garcinii.* This formation comprises several communities. The factors responsible for their mosaic like pattern are not yet well understand and need further study (comp. Fig. 8).

III.5 *Calligonum comosum.* Distributed only sporadically in the Nature Reserve. But large areas outside on older eolian dunes are characterized by *Calligonum comosum* and *Cornulaca monacantha.*

IV. *Woodlands, Open Stands of Trees (Photo 3).*

On alluvial fans and fluvial sands and gravel with soils generally sandy and moderately drained. Scattered arboral and scrubby vegetation, cartographically represented in 5 varieties.

IV.1 *Acacia tortilis, Prosopis cineraria* (Acacietea flavae-iranica Zohary 1973, *Acacia flava-Prosopis spicigera* association Zohary 1963, *Acacia tortilis* community Batanouny 1981). Extremely xeromorphic woodlands (pseudo-savannas, thorn woodlands) are characteristic of large areas of the coastal plain (Batinah). They colonize on sand and fluvial gravel in the eastern part of the reserve, but are highly dependent upon ground water. The common associates are *Lycium shawii, Ziziphus spina - christi* and *Acacia ehrenbergiana* (Syn. *A. flava*) which is very rare in the vicinity of the Nature Reserve. The herb layer is characteristic of numerous ephemeral psammophytes, especially during spring (for detail information compare Tab. 1, Fig. 6).

Table 1. *Acacia tortilis - Prosopis cineraria* community (*Acacia* woodlands on sand and fluvial gravel)

Sample		1	2	
Elevation (m)		10	15	
Area (m^2)		300	400	Life
Coverage (%)	Tree layer	10	30-35	form
	Shrub layer	30-35	40	
	Herb layer	10-15	15-20	
Total number of species		34	27	
Tree layer :				
Acacia tortilis		2b	2a	P
Prosopis cineraria		2a	2b	P

Table 1. *Acacia tortilis - Prosopis cineraria* community (*Acacia* woodlands on sand and fluvial gravel)

Table 1. *Continued*

Sample	1	2	
Elevation (m)	10	15	
Area (m^2)	300	400	Life
Coverage (%) Tree layer	10	30-35	form
Shrub layer	30-35	40	
Herb layer	10-15	15-20	
Total number of species	34	27	
Shrub layer :			
Calligonum comosum	2a	2a	N
Lycium shawii	1	1	N
Dwarf shrub and herb layer :			
Bassia muricata	2m	2a	C
Zygophyllum simplex	2m	2m	T
Eragrostis ciliaris	2m	2m	T
Dactyloctenium aristatum	2m	2m	T
Sisymbrium irio	2m	2m	T
Aizoon canariense	2m	1	T
Aristida adscensionis	2m	1	T
Spergula fallax	2m	·	T
Setaria adhaerens	1	2m	T
Suaeda aegyptiaca	·	2m	C
Pentatropis spiralis	1	1	Pli
Suaeda fruticosa	1	1	C
Rhazya stricta	1	1	C
Schismus barbatus	1	1	T
Cenchrus ciliaris	1	1	T
Eragrostis cilianensis	1	+	T
Arnebia hispidissima	1	+	T
Aerva javanica	+	+	C
Cenchrus pennisetiformis	+	+	H
Cyperus conglomeratus	+	+	H
Astragalus vogelii ssp. *fatimensis*	+	+	T
Asphodelus fistulosus var. *tenuifolius*	+	+	G
Plantago ovata	1	·	T
Tribulus parvispinos	1	·	T
Crotalaria aegyptiaca	+	·	C
Dipterygium glaucum	+	·	C
Indigofera intricata	+	·	C
Cassia italica	+	·	H
Cymbopogon commutatus	+	·	H
Oligomeris linifolia	+	·	T
Erodium laciniatum var. *pulverulentum*	+	·	T
Heliotropium kotschyi	·	+	C
Eragrostis barrelieri	·	1	T

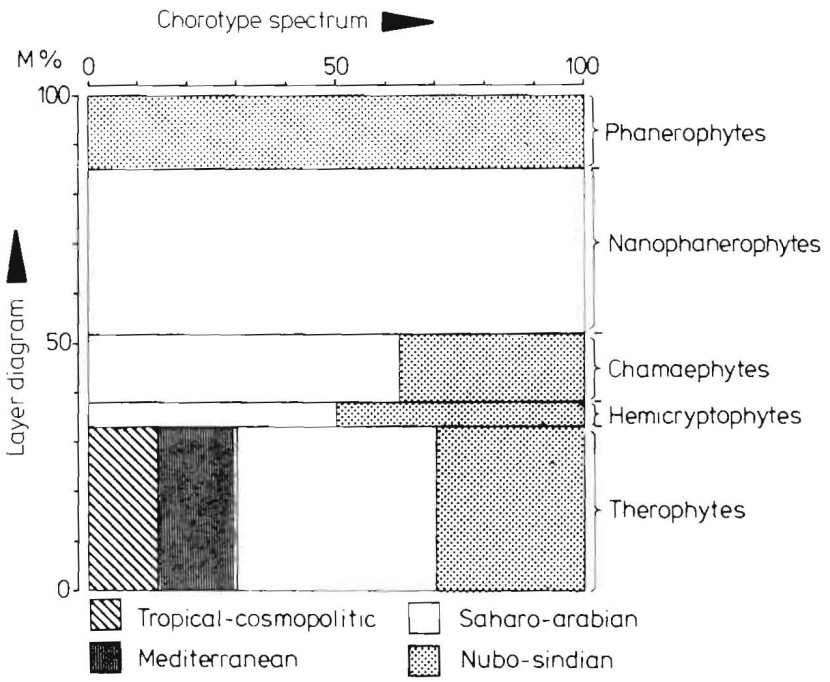

Fig. 6. Layer diagram and chorotype spectrum of the *Acacia* woodlands in the Nature Reserve

This high percentage of annuals (average group abundance M = 33.7% as compared to 47.5% of the woody plants) is clearly seen in the combined chorological spectrum and stratification diagram (Fig. 6) (modified presentation taking into account the various species magnitudes, expressed in M, average group abundance). The diagram also shows the large Saharo-Arabian component in the undergrowth of these Nubo-Sindian-influenced woodlands, which can be explained by the fact that the study area is located on the boundary between the Saharo-Arabian region of the Holarctic kingdom and the Nubo-Sindian region of the Palaeotropic kingdom (as described by Zohary 1973). Thus, the shrub layer is composed only of taxa with a Saharo-Arabian focus of distribution, whereas in the chamaephytes and hemicryptophytes the two elements are roughly equally represented. Mediterranean taxa and taxa which are widely distributed in the tropics and subtropics (tropical-cosmopolitan, pantropical) occur only in the therophyte layer. Similar results are obtained from an analysis of all the species found up to now in the Nature Reserve (see Appendix).

IV.2 Transition zone of *Acacia tortillis*, *Prosopis cineraria*, *Bassia muricata*

and *Suaeda aegyptiaca*. Generally on sandy, moderately saline soils in the area of contact between the woodlands and the halophytic communities.

IV.3 *Prosopis cineraria, Phoenix dactylifera*. Remnants of a former date garden (abandoned ground water oasis) which has now almost regained a natural appearance. The herb layer is dominated by *Suaeda aegyptiaca* and weeds (e.g. *Dactyloctenium aristatum, Eragrostis barrelieri, Setaria adhaerens, Sisymbrium irio*).

IV.4 Very open stands of *Phoenix dactylifera* and *Prosopis cineraria* on sandy, alluvial gravel. Strongly ruderal influenced (*Chenopodium murale, Euphorbia granulata, Reichardia tingitana, Tribulus parvispinos, Zygophyllum simplex*). Here also *Azadirachta indica* (cult.) occurs.

IV.5 *Phoenix dactylifera, Juncus rigidus*. Forming a narrow, well developed stripe on the end of the northern channel were ground water flows in. Here also pure stands of *Juncus* (Juncetum arabici Zohary 1973, *Juncus arabicus* community Halwagy and Halwagy 1977) are found. Associates are *Aeluropus lagopoides, Atriplex leucoclada, Sporobolus arabicus, S. spicatus*.

V. *Shrublands* (Photo 4).

On the lower hills with soils often deriving from weathered calcareous formations. Very rugged relief, rapid run-off and pronounced erosion (karstic rocks). Scattered with remnants of a former shrub formation rich in endemic species, which is typical of the lower hill zone along the Arabian Gulf (Oman, Khuzestan, Laristan, Makran). Cartographically represented in 3 varieties.

V.1 *Acacia tortilis, Lycium shawii*. Characteristic of the small hill in the eastern part of the alluvial plain are shrubby acacias and dwarf-shrubs.

V.2 *Acacia tortilis, Euphorbia larica*. Forming a transition zone to the *Acacia* woodlands of the alluvial plain.

V.3 *Euphorbia larica* (Euphorbietea laricae Zohary 1973). The characteristic formation of the lower hills, foothills and pleistocenic old beach terraces of the Batinah. Co-dominant are *Commiphora myrrha*, a rainy-green, thorny tree with assimilating bark, *Grewia tenax* and *Ochradenus arabicus* (endemic). The dwarf-shrub and herb layer is dominated by *Cenchrus pennisetiformis, Cleome brachycarpa, Cometes surattensis, Leucas inflata, Pseudogaillonia hymenostephana, Seddera latifolia* and *Vernonia arabica*. These devastated scrubs are the remnants of the natural vegetation of the lower hill zone (remnants of dry deciduous, microphyllous woodlands).

B) Zonation of the Littoral Salt Marshes

The Nubo-Sindian-influenced littoral salt marshes (Suaedetea fruticosa deserti Zohary 1973) and coastal dunes of the Nature Reserve exhibit a pronounced

zonation. In the following, this zonation will be depicted again in detail by means of a profile running from the central plain to the coastal dunes to the beach zone (Transects 1, 2: Fig. 4).

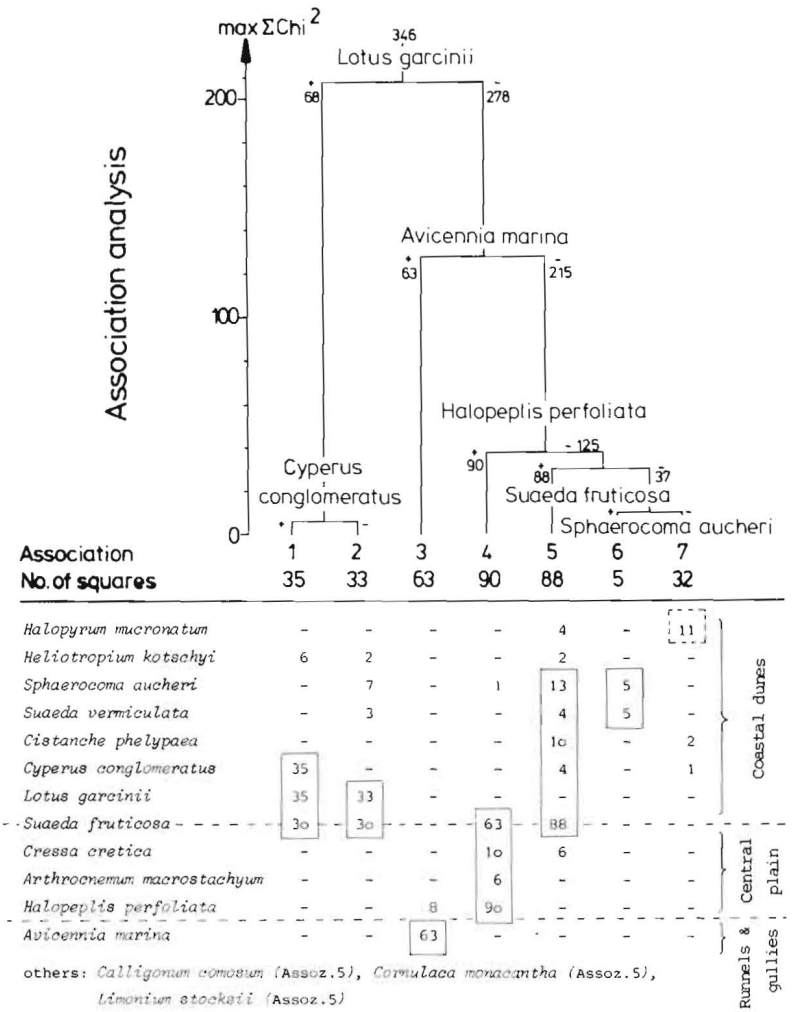

Fig. 7. Association analysis of the littoral salt marshes and coastal dunes

Figure 7 shows the result of the association analysis. The hierarchic division of the heterogeneous transect yields seven habitat groups (associations); their constituent species are characteristic of various areas of the transect (Fig. 8). The overlaps which can be observed between the constituents of the associations (Fig. 7) are in accordance with the continuity concept of vegetation (Ramensky 1926, Goodall 1963, Whittaker 1962, 1978).

Group 1,2. ***Lotus garcinii-Cyperus conglomeratus*** *association,* ***Lotus garcinii*** association (Fig. 7, 8).

On the coastal dunes, which are more or less stabilized, there are small hollows in level, wind-protected areas which are occupied by these associations (Scarcely vegetated sand-dunes). Associates are *Heliotropium kotschyi* and *Suaeda fruticosa.*

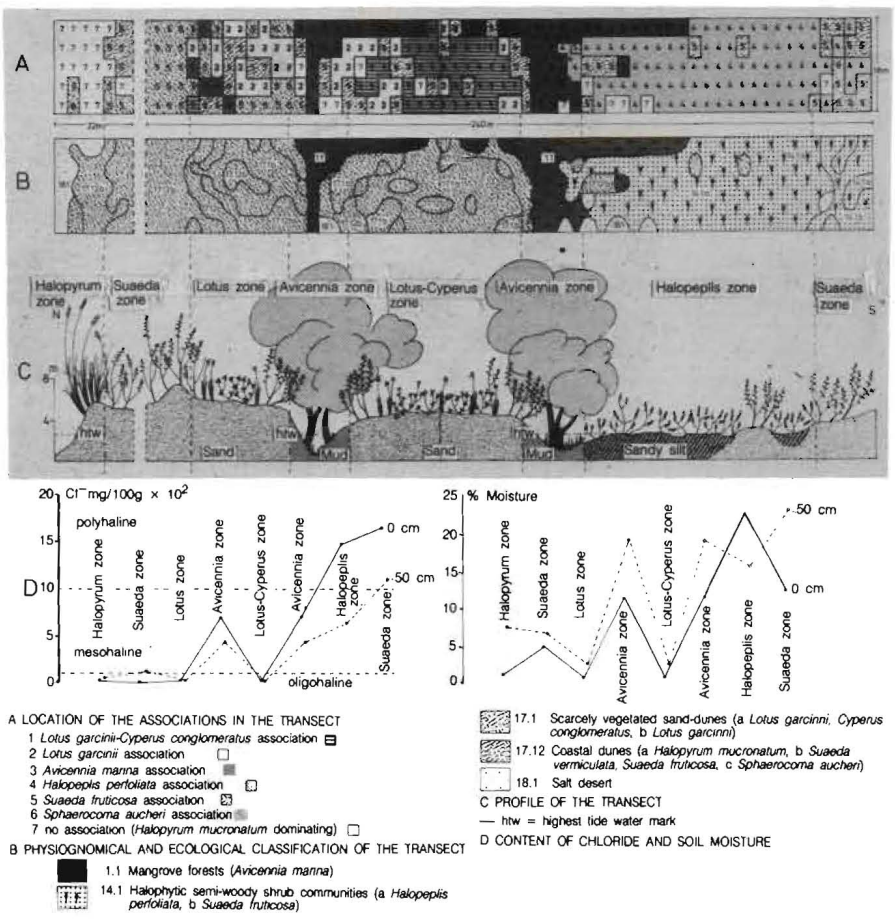

Fig. 8. Distribution of the associations dependent on relief, chloride and soil moisture (physiognomical classification according to Frey and Probst 1977)

Group 3. ***Avicennia marina*** *association* (Fig. 7, 8).

The gullies and runnels flowing through these dunes are characterized by lime-rich, polyhaline, sandy loam (Tab. 2, type: psammaquents USDA 1975), in which *Avicennia* forms dense mangrove forests. Although these mangroves are very monotonous from the botanical point of view, they are the most important productive biotopes of the Nature Reserve and are also of particular importance in cultural history (on the role of estuaries in marine food chains *cf.* Pritchard 1967a and b, Odum 1968, Heald and Odum 1970). They are the habitat of the large mud creeper (*Terebralia palustris*), which, along with oysters (e.g. *Saccostrea cucullata*), played an important part in the diet of the Stone Age fishing cultures of the Ras al-Hamra (approx. 6000 years ago) during certain seasons (H.-P. Uerpmann, pers. comm., Durante and Tosi 1977). Because they shed large numbers of leaves and hold on to clumps of organic matter, mangroves make up the first link in the detritus food chain of marine organisms and give nourishment to numerous inhabitants of the channels and gullies (on the zonation of marine molluscs in the Nature Reserve *cf.* Smythe 1983). Since this "food trap" is connected to the open sea, there is a daily transport of nutrients and wastes (export of plankton and detritus) which increases the secondary production of the coastal waters and is among other factors responsible for the wealth of fish near Ras al-Hamra (W. Torke, pers. comm.).

Group 4. ***Halopeplis perfoliata*** *association* (Fig. 7, 8).

These Halopytic semi-woody shrub communities grow along the runnels and gullies which are inundated at very high tide. They colonize very moist, sandy-loamy soils which are extremely rich in chlorides and sulphates, and poor in $CaCO_3$ (Tab. 2, type: salorthids USDA 1975). Because of the high rate of summer evaporation salt efflorescences are found here at the surface.

Group 5. ***Suaeda fruticosa*** *association* (Fig. 7, 8).

This group characterizes the sandy, polyhaline sabkha deposits of the central plain (Halophytic semi-woody shrub communities) as well as the salt-free dune regions next to the *Halopyrum* zone. In the extremely saline sabkha deposits, this association is almost restricted to one species (only sporadically with *Cressa cretica*), and it typically occurs on small sand accumulations which are dry at the surface and lie beyond the range of the high tide. In this area, it intermingles considerably with the *Halopeplis perfoliata* association (hygric differentiation). In the oligohaline, dry dune area, this formation contains more species; there also occur *Cistanche phelypaea, Cyperus conglomeratus, Sphaerocoma aucheri* and *Suaeda vermiculata.*

Group 6. ***Sphaerocoma aucheri*** *(association* (Fig. 7, 8).

On coastal dunes consisting of oolithic sands of marine origin. Calcareous sand

Table 2. Analysis of soil samples within the different vegetation zones of the salt marsh at Qurm. Surface values and values at 50 cm depth (in brackets)

		DUNES			CENTRAL PLAIN		RUNNELS
		Halopyrum mucronatum zone	**Suaeda vermiculata-Sphaerocoma aucheri zone**	**Lotus garcinii zone**	**Halopeplis perfoliata zone**	**Suaeda fruticosa zone**	**Avicennia marina zone**
TEXTURE (%)	Coarse sand	7.2–21.9			—		—
	Fine sand	77.9–92.8			42.1–62.3		44.3
	Silt	0.1–1.4			35.1–56.8		54.1
	Clay	—			1.1–2.6		1.6
WATER SOLUBLE IONS (MG/10 G)	Na^+	2.3 (2.7)	2.2 (4.4)	2.4 (2.7)	19.7 (10.3)	20.7 (15.6)	12.3 (7.7)
	K^+	1.8 (0.9)	2.4 (1.7)	0.9 (0.3)	4.1 (2.2)	2.1 (3.3)	1.3 (1.1)
	Mg^{++}	105.0 (105.0)	115.0 (102.5)	98.0 (115.0)	85.0 (115.0)	86.0 (88.0)	109.0 (105.0)
	Ca^{++}	530.0 (480.0)	440.0 (440.0)	530.0 (540.0)	300.0 (430.0)	260.0 (285.0)	510.0 (540.0)
	Cl^{---}	1.8 (5.2)	0.7 (13.8)	0.4 (1.8)	148.0 (64.0)	163.8 (109.9)	71.6 (42.5)
	SO_4	0.4 (1.7)	0.5 (2.9)	4.8 (5.8)	241.9 (11.5)	220.7 (8.5)	12.5 (6.8)
	$CaCO_3$ (%)	25.5 (23.7)	20.1 (25.1)	27.8 (24.3)	13.4 (20.3)	11.6 (14.8)	23.1 (23.5)
	pH	8.1 (7.3)	8.4 (7.6)	7.5 (7.7)	8.4 (7.4)	7.9 (7.4)	8.0 (7.4)
	EC (mS)	0.2 (0.4)	0.2 (1.0)	0.1 (0.2)	13.1 (4.3)	14.4 (6.8)	4.4 (2.9)
	Moisture (%)	1.1 (7.9)	4.9 (6.7)	0.9 (2.7)	22.9 (16.0)	12.8 (23.8)	11.9 (19.5)

(more than 20% $CaCO_3$), poor in chlorides and sulphates (Tab. 2). Dunes partly stabilized.

Group 7. No association, but ***Halopyrum mucronatum*** *dominating* (Fig. 7, 8).

The vegetation-free beach zone is followed by a dune up to 5 m in height in which an ammophilous community predominates. This community is made up almost exclusively of *Halopyrum mucronatum*. These relatively young, mobile dunes with active erosion and wind-deposited sand are nearly salt-free (oligohaline). They are very dry at the surface, but the moisture content increases with depth (Table 2).

This conspicuous zonation within the azonal halobiomes is due in part of eco-physiological adaptive strategies and to variations in relief. To a large extent it is also attributable to the edaphic parameters salinity and soil moisture, which exert a selective influence. These parameters vary along a pronounced gradient leading inland (Tab. 2), resulting in the formation of vegetation zones running more or less parallel to the coast, which is typical of coastal regions throughout the Arabian Peninsula (Batanouny 1981, Batanouny and Turki 1983, Frey *et al.* 1984, 1985, Frey and Kürschner 1983, 1984, Kassas and Zahran 1967, Mahmoud *et al.* 1982, Younes *et al.* 1983, Zahran 1967, 1982).

Remarks on the importance of protecting the Sultan Qaboos Nature Reserve

In the following, some concluding remarks are made about the special importance of the Nature Reserve, and some suggestions are offered with regard to its conservation.

1. As ecotones between freshwater (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 a 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.

2. With its mangrove stands the Nature Reserve is an important primary producer for marine ecosystems (system of potentially high productivity). The nutrients produced here nourish the fauna of the biotope itself as well as the organisms of the adjacent coastal region, to which material is transported by the action of the tides. Thus, by means of various food chains, the food supply of large fish is also enhanced. As a result, the Nature Reserve has an economic value besides its ecological value.

3. In addition to having important ecological and economic functions, the Nature Reserve is of particular interest from the point of view of cultural history. Excavations of Stone Age sites by the working groups of M. Tosi and H.-P.Uerpmann have shown, that man lived in the present day Nature Reserve and on the calcareous hills around it 6000 years ago. These people lived on organisms closely correlated with the mangroves.

4. By means of appropriate protective measures it would be possible to preserve the characteristic vegetation units of the Batinah. Within a very small area one finds shrub communities of the coastal terraces, *Acacia* woodlands of the coastal plain, salt marshes of sabkha deposits, and mangroves, which are becoming increasingly rare as a result of urbanization of the Batinah. Outside of the Nature Reserves interference by man and animals has caused these formations to occur only in forms which have been altered by pastoral selection and which are usually impoverished.

The Nature Reserve's unique biological status in the Batinah can only be maintained, however, if steps are taken to ensure the protection of the area and its organisms in the future. In addition to the measures already taken, the following must be given special consideration:

1. Public traffic in the Nature Reserve must be prohibited. Particularly in the border areas (western channel - area influenced by the Intercontinental Hotel, northern channel - adjoining residential district and *Acacia* woodlands) there are repeated instances of interference, destruction and pollution. Use of the *Acacia* woodlands (cropping of leaves and young shoots to feed cattle, grazing by goats), which has continued despite the erection of a fence, must be stopped in order to allow a progressive succession to take place until the plant population has gained a near-natural appearance. Nutrient-value analysis of such regenerated stands could provide important information about the grazing potential of the woodlands remaining in the Batinah.

2. The buildings and infrastructural measures (information centre, parking lot, administration building, etc.) planned in the Sultan Qaboos Public Park (south-east part of the Nature Reserve) should be restricted to a minimum, because they could have deleterious effects on ecological conditions in the adjacent mangrove area (*see* item 3). Consideration should be limited to parts of the former oasis and areas along the road (area IV.4, Fig. 4). As important as it is to provide access to information and offer educational opportunities, it is advisible for ecological reasons to influence the area as little as possible.

3. Because the Nature Reserve is an estuary associated with man (estuary in an urban area), it is subject to a particularly high degree of stress from various kinds of pollution. Estuaries have a natural tendency towards eutrophication and are, therefore, especially susceptible to additional contamination. Even intact systems have only a limited ability to eliminate decomposable substances. It is

therefore necessary to keep the level of stress below certain limits and to avoid sudden interferences (discharge of industrial effluent, dumping, oil pollution). Of vital importance is the action of the tides, by means of which the system is enabled to purify itself and to transport nutrients and the inflow of ground water of the Wadi Aday. Care must, therefore, be taken that the tidal channels remain open and that a continuous inflow of ground water exists.

4. It is proposed to expand the Nature Reserve towards the south, incorporating the adjoining limestone hill (*see* Fig. 2). These Pleistocene coastal terraces are occupied by remnants of the potential natural vegetation, characterized by numerous interesting endemic species of the coastal area of Oman and Makran (*e.g. Convolvulus virgatus, Euphorbia larica, Limonium stocksii, Ochradenus arabicus*). The limestone terraces are jeopardized everywhere by the expansion of the capital area, and it is feared that this characteristic hill vegetation will soon disappear.

Appendix

Preliminary list of species collected from the Sultan Qaboos Public Park and Nature Reserve at Qurm (Muscat area, Oman), based on collections of M.D. Gallagher (G, 16.8.81 No. 6235/1-18, 16.10.81 No. 6297/1-15, 1.3.82 No. 6379/1-9) and W. Frey and H.Kürschner (K, February 1983). The specimens are deposited in the BSB-Herbarium Vorderer Orient. Duplicates were distributed to the following herbaria: E, Oman Natural History Museum, Ministry of National Heritage & Culture (Muscat).

Aizoaceae
Aizoon canariense L. (K 83-31)
Amaranthaceae
Aerva javanica (Burm.f.) Spreng. (G 6235/14, K 83-215)
Apocynaceae
Rhazya stricta Decne. (G 6379/1)
Arecaceae
Phoenix dactylifera L. (K 83-311 a)
Asclepiadaceae
Pentatropis spiralis (Forssk.) Decne. (G 6297/5)
Asteracease
Centaurea pseudosinaica Czerep. (K 83-241)
Ifloga spicata (Forssk.) Sch.-Bip. (K 83-236)
Pulicaria glutinosa Jaub. & Spach (K 83-258)
Vernonia arabica F.G. Davies (K 83-133)
Boraginaceae
Arnebia hispidissima (Lehm.) Dc. (K 83-100)
Heliotropium kotschyi (Bge.) Guerke (K 83-77, 83-200)

Brassicaceae
Morettia parviflora Boiss. (G 6235/18, 6379/7)
Morettia philaeana (Del.) Dc. (K 83-213)
Physorrhynchus chamaerapistrum (Boiss.) Boiss. (G 6297/15)
Sisymbrium irio L. (K 83-223)
Burseraceae
Commiphora myrrha (Nees) Engl. (K 83-130)
Caesalpinaceae
Cassia italica (Mill.) Lam.ex Andrews (K 83-97)
Parkinsonia aculeata L. (cult.)
Capparaceae
Capparis cartilaginea Decne. (K 83-199)
Dipterygium glaucum Decne. (G 6235/12, K 83-82)
Caryophyllaceae
Cometes surattensis L. (K 83-145)
Paronychia arabica (L.) DC. (K 83-221)
Polycarpaea spicata Wight. & Arn. (K 83-238)
Spergula fallax (Lowe) Krause (K 83-212)
Sphaerocoma aucheri Boiss. (K 83-85b)
Chenopodiaceae
Anabasis setifera Moq. (K 83-197)
Arthrocnemum macrostachyum (Moric.) Moris & Delp. (K 83-81)
Atriplex leucoclada Boiss. (K 83-191)
Bassia muricata (L.) Murr. (K 83-226, 83-247)
Chenopodium murale (L.) (K 83-225)
Cornulaca aucheri Moq. (K 83-210)
Cornulaca monacantha Del. (K 83-80)
Halopeplis perfoliata (Forssk.) Bge. (K 83-74)
Halothamnus bottae Jaub. & Spach (K 83-125)
Salsola baryosma (Schult.) Dandy (G 6235/1)
Salsola rubescens Franch. (K 83-459)
Suaeda aegyptiaca (Hasselq.) Zoh. (G 6235/15, 6297/6, K 83-202)
Suaeda fruticosa Forssk. ex. Gmel. (G 6297/7,8, K 83-85 a, 83-259)
Suaeda vermiculata Forssk. ex Gmel. (K 83-201)
Cichoriaceae
Launaea intybacea (Jacq.) Beauv. (K 83-134)
Launaea mucronata (Forssk.) Muschl. (K 83-144)
Reichardia tingitana (L.) Roth (K 83-240)
Cleomaceae
Cleome brachycarpa Vahl ex Dc. (K 83-138)
Convolvulaceae
Convolvulus virgatus Boiss. (G 6379/4B)
Cressa cretica L. (G 6297/9, K 83-195, 83-257)

Seddera latifolia Hochst. ex Steud. (K 83-127)

Cucurbitaceae

Citrullus colocynthis (L.) Schrad. (G 6297/2)

Cyperaceae

Cyperus conglomeratus Rottb. (G 6235/6A, K 83-83)
Cyperus kali (Forssk.) Murb. (K 83-206)
Cyperus cf. rotundus L. (G 6235/8)
Fimbristylis ferruginea Vahl (G 6297/11)

Ephedraceae

Ephedra ciliata Fisch. & C.A. Mey. (K 83-216)

Euphorbiaceae

Andrachne aspera Spreng. (K 83-86)
Euphorbia arabica (Hochst. & Steud.) Boiss. (K 83-237)
Euphorbia granulata Forssk. (K 83-222)
Euphorbia larica Boiss. (K 83-9)

Fabaceae

Argyrolobium roseum (Camb.) Jaub. & Spach (K 83-229)
Astragalus eremophilus Boiss. (K 83-219)
Astragalus vogelii (Webb) Bornm. ssp. *fatimensis* Maire (K 83-220)
Crotalaria aegyptiaca Benth. (G 6379/4A, K 83-227)
Indigofera arabica Jaub. & Spach (K 83-157)
Indigofera intricata Boiss. (K 83-91)
Indigofera oblongifolia Forssk. (K 83-217, 83-254)
Lotus garcinii Dc. (K 83-76)
Taverniera glabra Boiss. (K 83-255)
Tephrosia apollinea (Del.) Dc. (K 83-14)

Geraniaceae

Erodium laciniatum (Cav.) Willd. var. *pulverulentum* (Cav.) Boiss. (K 83-104)

Juncaceae

Juncus rigidus C.A. Mey. (G 6297/13, K 83-192)

Lamiaceae

Leucas inflata Benth. (K 83-124)

Liliaceae

Asphodelus fistulosus L. var. *tenuifolius* Cav. (K 83-8)

Meliaceae

Azadirachta indica A. Juss. (Cult., G 6297/1, K 83-211)

Mimosaceae

Acacia ehrenbergiana Hayne (G 6379/6)
Acacia tortilis (Forssk.) Hayne (K 83-12)
Prosopis cineraria (L.) Druce (K 83-56)

Nyctaginaceae

Boerhavia diffusa L. (K 83-239)
Boerhavia elegans Choisy (G 6379/8)

Orobanchaceae
Cistanche phelypaea (L.) Cout. (K 83-75)
Plantaginaceae
Plantago ovata Forssk. (K 83-233)
Plumbaginaceae
Limonium stocksii (Boiss.) O. Kuntze (K 83-73)
Poaceae
Aeluropus lagopoides (L.) Trin. ex Thw. (G 6235/2, 6297/10, K 83-193)
Aristida abnormis Chiov. (K 83-35)
Aristida adscensionis L. (K 83-244 a)
Aristida mutabilis Trin. & Rupr. (G 6235/7, 6235/10,11 K 83-244 b)
Cenchrus ciliaris L. (G 6235/4, 6235/16, K 83-243 b, 83-245)
Cenchrus pennisetiformis Hochst. & Steud. ex Steud. (K 83-243 a)
Chrysopogon plumosus Hochst. (K 83-121)
Cymbopogon commutatus (Steud.) Stapf (K 83-132)
Dactyloctenium aegyptiacum (L.) P. Beauv. (G 6235/9)
Dactyloctenium aristatum Link (K 83-235)
Eragrostis barrelieri Dav. (K 83-242)
Eragrostis cilianensis (All.) Vign. ex Janchen (K 83-232)
Eragrostis ciliaris (L.) R.Br. (K 83-248)
Eremopogon foveolatus (Del.) Stapf (G 6235/5, 6235/6B)
Halopyrum mucronatum (L.) Stapf (K 83-84)
Lophochloa pumila (Desf.) Bor (K 83-228)
Schismus barbatus (L.) Thell. (K 83-103)
Setaria adhaerens (Forssk.) Chiov. (K 83-234)
Sporobolus arabicus Bioss. (G 6297/12, K 83-190)
Sporobolus spicatus (Vahl) Kunth (K 83-189)
Tetrapogon villosus Desf. (K 83-146)
Polygonaceae
Calligonum comosum L'Her. (K 83-79)
Pteropyrum scoparium Jaub. & Spach (G 6379/3A)
Potamogetonaceae
Potamogeton pectinatus L. (K 83-260)
Resedaceae
Ochradenus arabicus Chaudhary, Hillcoat & Miller (K 83-1)
Oligomeris linifolia (Vahl) Macbride (K 83-218)
Rhamnaceae
Ziziphus spina-christi (L.) Willd. (G 6297/14)
Rubiaceae
Jaubertia aucheri Guill. (G 6379/5)
Kohautia retrorsa (Boiss.) Brem. (K 83-123)
Pseudogaillonia hymenostephana (Jaub. & Spach) Lincz. (K 83-156)
Scrophulariaceae

Anticharis arabica Endl. (G 6235/17)
Schweinfurthia papilionacea (Burm.f.) Boiss. (K 83-39)

Solanaceae
Lycium shawii Roem. & Schult. (G 6379/3B, 6379/9)

Tamaricaceae
Tamarix axabica(Ehrenb.) Bge. (K 83-196, 83-256)

Tiliaceae
Grewia tenax (Forssk.) Fiori var. *tenax* (K 83-129)

Urticaceae
Forsskaolea tenacissima L. (K 83-261 a)

Verbenaceae
Avicennia marina (Forssk.) Vierh. (K 83-78)

Zygophyllaceae
Fagonia bruguieri Dc. (K 83-128)
Fagonia indica Burm.f. (K 83-46)
Tribulus parvispinos Presl (K 83-231)
Zygophyllum qatarense Hadidi (K 83-198)
Zygophyllum simplex (G 6235/13, K 83-194)

Chorotype analysis
(phytogeographical elements in %)

Nubo-sindian taxa	:	47.1
Saharo-arabian taxa	:	35.1
Mediterranean-Irano-turanian taxa	:	6.8
Tropical cosmopolitan taxa	:	3.4
Cosmopolitan taxa	:	2.6
Endemic taxa (Oman, Laristan, Makran)	:	5.0

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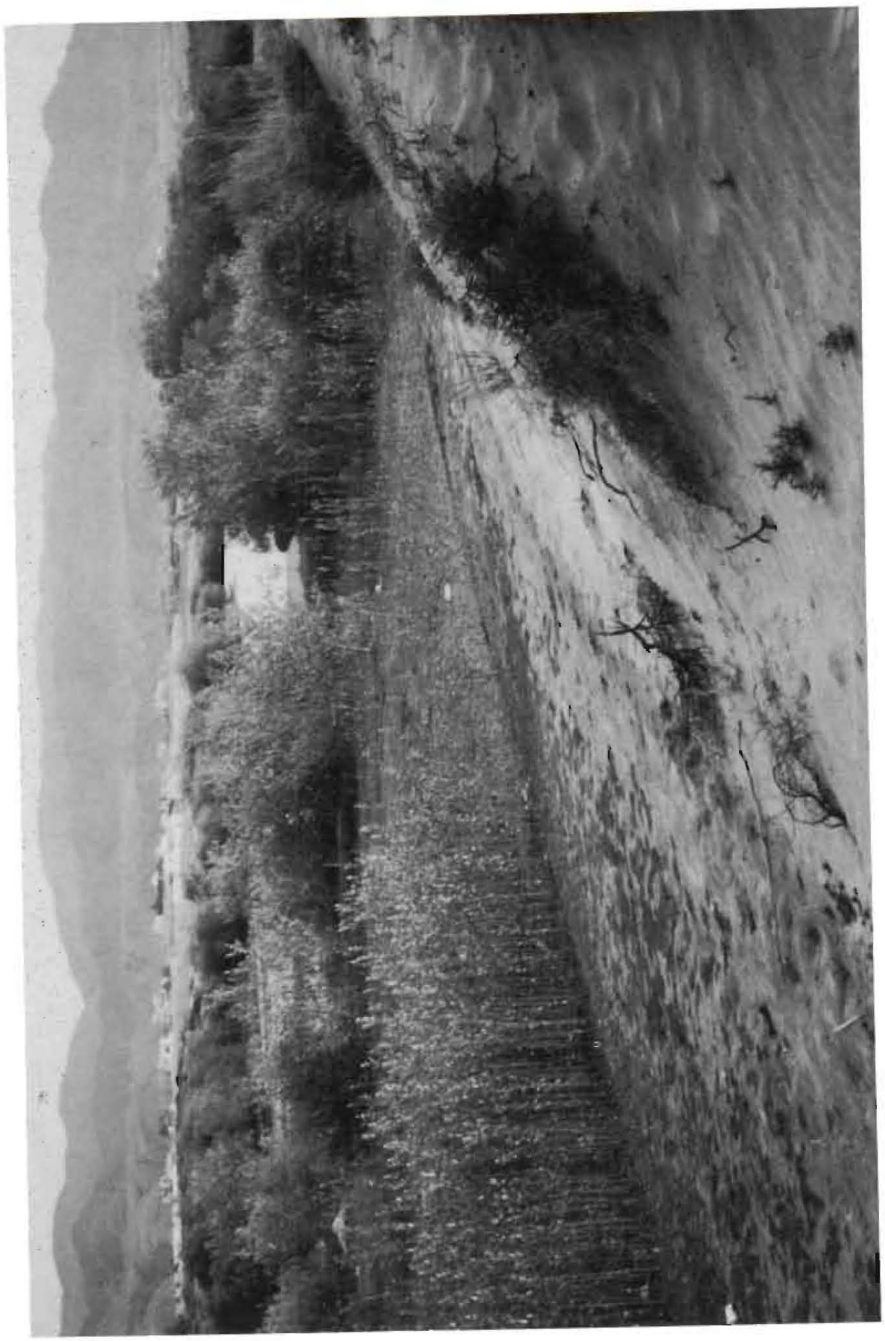

Photo 1. Mangrove formations in the area of the tidal channels

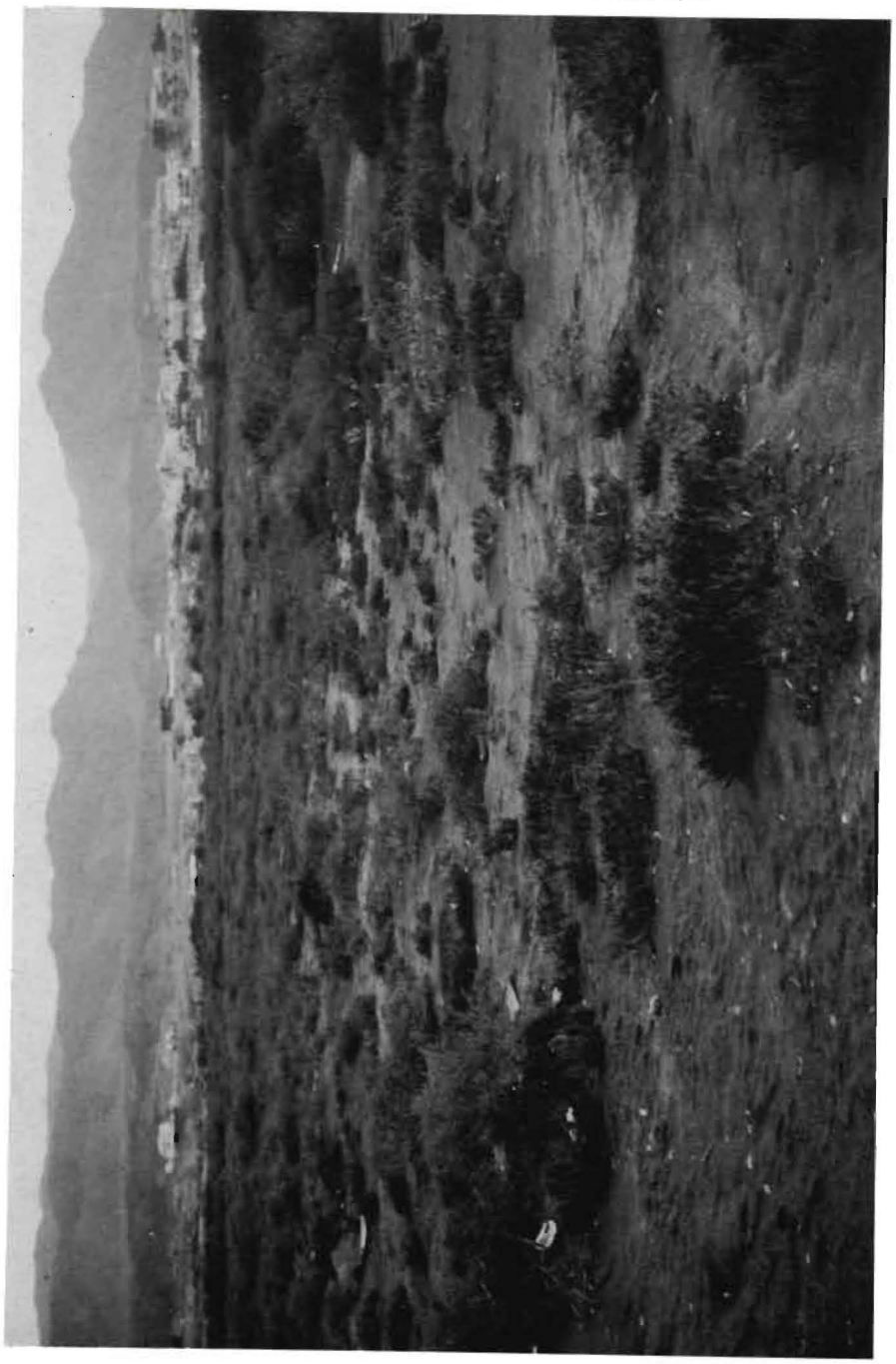

Photo 2. Halophytic formations (*Halopeplis perfoliata* community) of the central plain

Photo 3. Xeromorphic woodlands (*Acacia tortilis* - *Prosopis cineraria* community) of the alluvial plain

Photo 4. Devastated shrublands (Euphorbietea laricae) on the lower hills (pleistocenic coastal terraces)

دراسة الإنماء النباتي لاحتياطي الطبيعة لمنطقة قرم في مسقط عُمان

هارالد كورشنر

معهد تصنيف النباتات والجغرافية النباتية
لجامعة برلين الحرة - برلين الغربية

تمثل هذه الدراسة أول توثيق للإنماء النباتي والزهور في متنزه السلطان قابوس العام واحتياطي الطبيعة في عُمان (منطقة مسقط).

إن خصائص وحدات النماء النباتي قد وصفت بواسطة خارطة النماء النباتي (١ : ١٠,٠٠٠) ومقاطع عرضية مختارة. كما جُلبَ الانتباه في الفصل الأخير إلى الأهمية الخاصة لاحتياطي الطبيعة مع مقترحات للحفاظ عليه مستقبلاً.

كما ثبت ملحق يحتوي على قائمة بالتصنيفات التي وجدت حتى الآن.