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Ecology of the Littoral Salt Marsh Vegetation at Al-Magawah on the Gulf of Aqaba, Saudi Arabia

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ABSTRACT. The littoral salt marsh vegetation at Al-Magawah, near Ras Sheikh Humeid on the Gulf of Aqaba, Saudi Arabia, is characterized by its zonal arrangement. The *Arthrocnemum glaucum* zone is followed successively landward by the *Suaeda pruinosa*, *Nitraria retusa* and *Zygophyllum coccineum* zones. Inundation, the dynamic process of accretion, differences in ground level, distance from the shore, vertical elevation above the saline water table, salinity gradient, soil texture and aridity all contribute to the pattern of distribution, structure and composition of the vegetation

Mahmoud *et al.* (1982) showed that numerous halophytic plant communities are associated with the Red Sea coast of Saudi Arabia and that the littoral salt marsh vegetation comprises distinct sociological units, especially in areas, *e.g.* at Rabigh, which are less subjected to human interference. The salt marsh vegetation at Al-Magawah near Ras Sheikh Humeid on the Gulf of Aqaba presents another good example. A characteristic of this salt marsh vegetation is the zonal arrangement of its plant communities, thought to be caused by a complex of factors. The data presented by Kassas and Zahran (1967) on the vegetation of the littoral salt marshes of Egypt showed that 'zonation is usually attributed to varying gradients in soil salinity ... The development of salinity, amount of salts, patterns of salt content within the soil profile and kinds of salts associated with the increase in ground level may differ in different zones. Again, the dynamic process of accretion seems to produce different types of habitat within the different zones of the salt marsh'.

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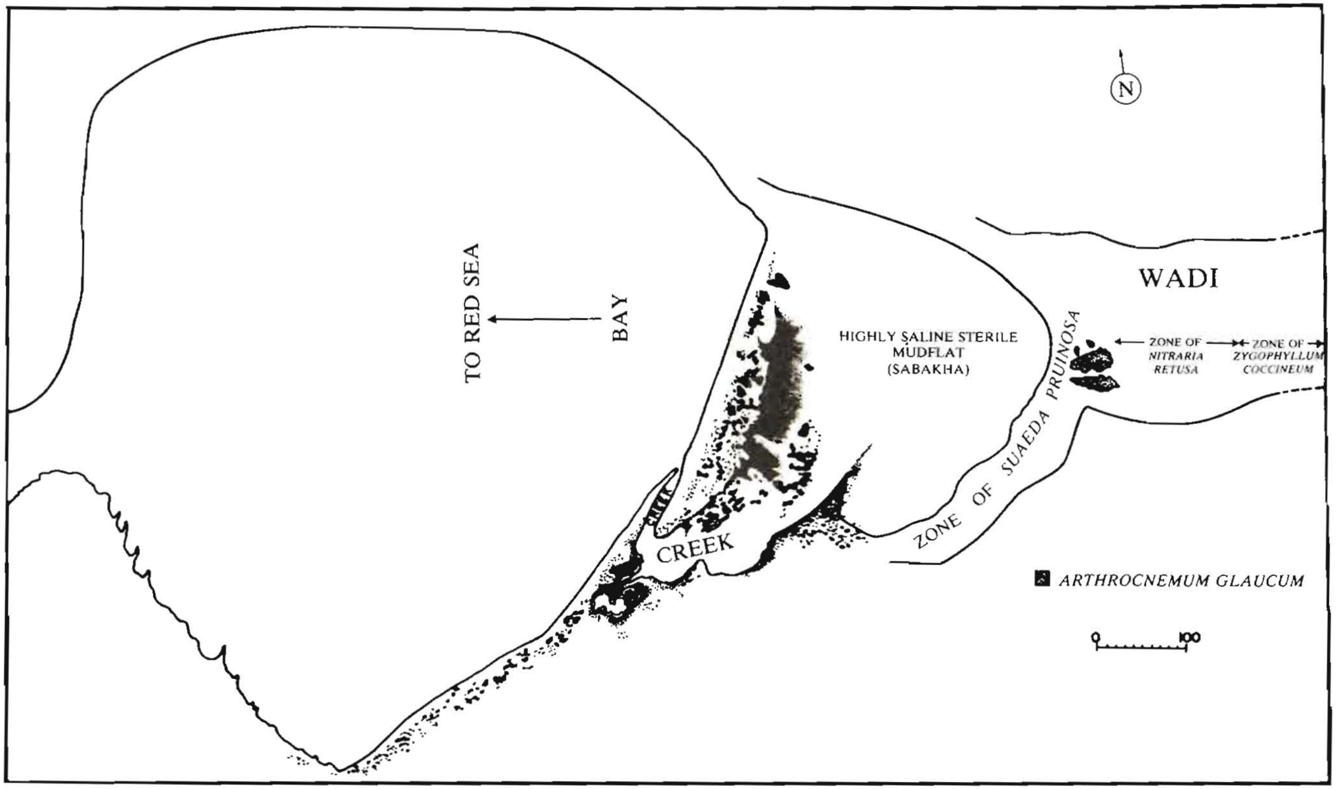

Fig. 1. Map of the salt marsh at Al-Magawah showing the position of the *Arthrocnemum glaucum* community type and the zones of *Suaeda pruinosa*, *Nitraria retusa* and *Zygophyllum coccineum* community types.

Zahran (1973), in his work at Bank End Marsh, northwestern England, reported that 'the pattern of zonation of the littoral salt marsh is primarily controlled by tidal inundation and relief of the land. Salinity is also an important factor that plays a role which is second in importance to the elevation-inundation factor'; while later (1977) he wrote 'Several factors (tidal movement, relief of ground, seawater spray, soil salinity, etc.) seem to play certain roles in determining the zonation patterns of the vegetation of the littoral salt marshes, but their individual effects vary'. Mahmoud *et al.* (1982) reported that the differences in ground level, horizontal distance from the shore, vertical elevation above the saline water table, salinity gradient, soil texture, aridity and competition all contribute to the pattern of distribution, structure and composition of the salt marsh vegetation at Rabigh on the Red Sea coast of Saudi Arabia. The work described below comprises a description of the vegetation in different zones of the littoral salt marsh at Al-Magawah and the various factors which influence the zonation pattern.

The Study Area

The study area comprises a large pear-shaped bay (Fig. 1). The landward western shoreline of the bay consists of a bar of sand heaped up by wave and tidal action.

Further inland is a mud-flat (Plate 1 and Fig. 1) which is partly frequently inundated by seawater carried *via* the numerous creeks which traverse the sand bar; one of these creeks is fairly large and deep (Fig. 1) and transports a large

Plate 1. Sterile saline mud-flat (Sabakha) at Al-Magawah salt marsh.

Table 1. (a) Mean monthly and annual rainfall (mm) at Hagl, Al-Majh, Duba, and Al-Mumaylih.

Station	J	F	M	A	M	J	J	A	S	O	N	D	Total
Haql	9.2	10.39	3.98	2.51	0.26	0	0	0	0	0.30	2.02	11.11	39.77
Al-Wajh	2.86	0.95	3.79	0.07	2.8	0	0	0	0	0	3.98	6.49	20.94
Duba	14.23	7.85	4.3	2.88	0.75	0	0	0	0	0	8.53	4.88	43.42
Al-Muwaylih	31.93	2.75	2.27	1.50	0.21	0	0	0	0	0	10.49	2.57	51.72

(b) Mean daily maximum and minimum temperatures (°C) at Al-Wajh. Data (for both a and b) are based on records for 10 years (1970-9).

Station		J	F	M	A	M	J	J	A	S	O	N	D
Al-Wajh	Mean Max	23.5	24.6	25.4	27.7	30.3	31.1	32.4	32.7	31.1	31.6	28.2	24.4
	Mean Min	13.1	14.4	15.4	17.8	22.0	23.0	24.5	24.9	23.3	21.4	18.0	14.2

volume of seawater into the marsh, particularly when the wind is strong. On the western and the southern perimeters of the bay, the land rises gradually to the surrounding hills, and on its northern perimeter the mountains rise almost directly from the water. A shallow wadi which drains the neighbouring high ground leads into the south western side of the marsh (Fig. 1).

Climate

The Red Sea coast and its landward margins are parts of the hot desert (Zahran 1977). Because of the absence of a meteorological station at Al-Magawah, records of rainfall (Table 1) were obtained from the nearest coastal stations at Haql, Al-Wajh, Duba, and Al-Muwaylih and temperature records at Al-Wajh station (since this is not recorded at the other stations). These data indicate a climate that is hot, with temperature extremes, and arid with low erratic rainfall.

Plate 2. Pure stand of *Arthrocnemum glaucum* at Al-Magawah salt marsh.

Table 2. Analysis of the vegetation in the different zones in Al-Magawah salt marsh. Density = number of individuals per 40 m^2 in the *Nitraria retusa* zone and per 10 m^2 in the other zones. Cover-abundance estimates were made according to the Braun-Blanquet scale: +, very rare, less than 1%; 1, rare, 1-5%; 2, occasional, 6-25%; 3, frequent, 26-50%; 4, common, 51-75%; 5, abundant, 76-100%. The scale is upgraded by one unit (*e.g.* + = 1).

Zone	Species	Mean density	Mean cover-abundance estimate	Frequency %
Suaeda pruinosa	*S. pruinosa*	5.65 ± 3.05	2.05 ± 0.46	100
	Zygophyllum coccineum	1.3 ± 4.65	0.35 ± 1.02	35
Nitraria retusa	*N. retusa*	5.7 ± 4.40	3.6 ± 1.16	100
	Cyperus conglomeratus	17.9 ± 31.61	1.20 ± 0.95	100
	Z. coccineum	17.8 ± 29.27	1.10 ± 0.71	100
	Z. album	15.2 ± 22.86	1.10 ± 0.71	100
	S. pruinosa	13.5 ± 32.52	1.10 ± 0.71	100
	Tamarix amplexicaulis	0.20 ± 0.95	0.40 ± 1.96	20
Zygophyllum coccineum	*Z. coccineum*	49.25 ± 43.92	2.90 ± 1.50	100
	C. conglomeratus	9.75 ± 12.82	1.0 ± 0.00	100
	Fagonia bruguieri	1.10 ± 0.64	0.60 ± 1.05	45

Methods

The vegetation units are arranged in different zones and are referred to here by the dominant species as:

(1) *Arthrocnemum glaucum* (Del.) Ung.-Sternb. (= *Salicornia macrostachya* Moric)

(2) *Suaeda pruinosa* Lange (= *S. vera* Boiss., non Forssk., *S. kochii* Tod)

(3) *Nitraria retusa* L. and

(4) *Zygophyllum coccineum* L. zones (Fig. 1).

Vegetation characters were derived from the detailed study (except for *A. glaucum* community type) of a representative stand. Within the stand (except in the *N. retusa* zone) twenty juxtaposed quadrats each 10 × 10 meters were set. In the *N. retusa* zone, ten 40 × 40 meters quadrats were sampled. The species within each quadrat were listed and the number of individuals of each species was recorded. From these data, it was possible to evaluate the frequency and the density (number of individuals per sampled area) for each species in the different communities. The cover-abundance estimates for each species in each quadrat were made according to the Braun-Blanquet 5 point scale (see legend to Table 2). Since *A. glaucum*, in most parts of the marsh, formed pure dense extensive growth (Plate 2) in which individual plants are not clearly identifiable and since the species represents the bulk of the vegetation in the marsh, its growth was shown in a vegetation map (Fig. 1). The data for density and cover-abundance estimates were analysed; for this purpose, the Braun-Blanquet scale was upgraded by one unit (*e.g.* + = 1).

Soil profiles in each zone were examined; soil samples were collected from each for the determination of texture, chemical properties and moisture content. The depth of the saline water table was measured in several sites in the different zones. Mechanical analysis was done by the Pipette Method (Day 1965), and total soluble salts according to Richards (1954); pH of soil extracts was determined by a pH-meter. Moisture content was determined by weighing fresh and oven-dried soil samples.

Vegetation characteristics

(a) *Arthrocnemum glaucum*

The community type dominated by *A. glaucum* is pure stands (Plate 2). Its growth on the sand bank, heaped by the tidal and wave action, forms a belt (Plate 3, Fig. 1). On the part of the mud flat which is frequently inundated by seawater (Plate 4) brought into the marsh *via* the creeks, the growth of *A. glaucum* forms initially wide spaced circular islands (Plate 5a). The vegetative growth of the plants (shoots spread laterally producing shallow adventitious roots) increases the areas

Plate 3. Growth of *Arthrocnemum glaucum* community type on a bar of sand heaped by tidal and wave action. Note the bare low sand bar which separates the free water from the plant growth.

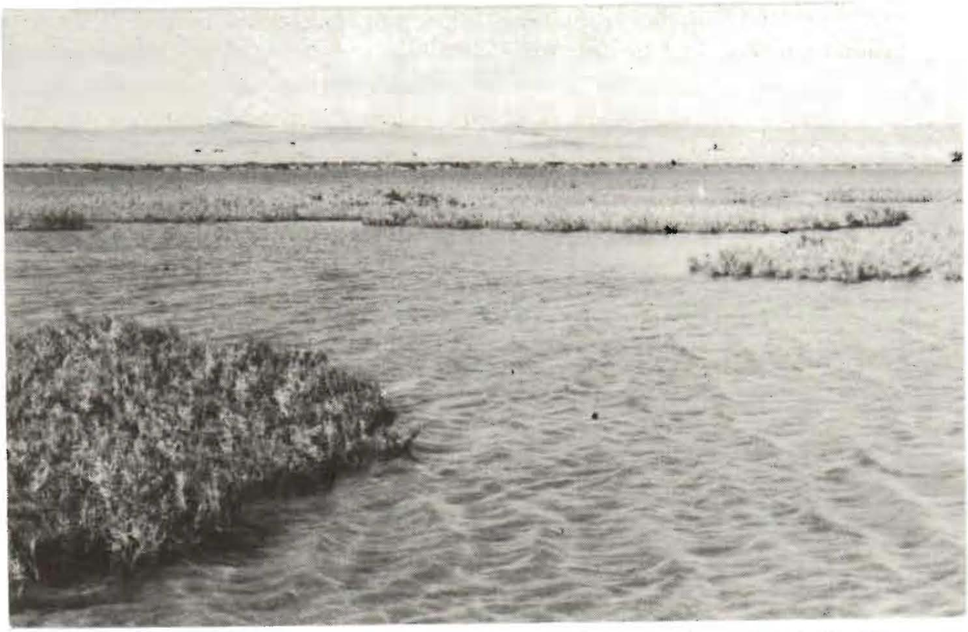

Plate 4. Growth of *Arthrocnemum glaucum* in the frequently inundated mud flat at Al-Magawah salt marsh.

a

b

Plate 5. (a) Growth of *Arthrocnemum glaucum* forming circular islands in the mud-flat at Al-Magawah salt marsh. In the background, the growth in neighbouring islands coalesces forming a continuous mat (5 b).

of these islands which eventually coalesce and form a continuous mat (Plates 1 & 5b).

(b) *Suaeda pruinosa* (Plate 6)

The community type dominated by *S. pruinosa* is pure stands or it is associated with *Zygophyllum coccineum* (F = 35%).

(c) *Nitraria retusa* (*Plates 7a, b*)

Species associated with *N. retusa* inlcude *Cyperus conglomeratus* Rottb (= *C. pungens* Boeck) (F = 100%), *Z. coccineum* (F = 100%), *Z. album* L.f. (F = 100%), *S. pruinosa* (F = 100%) and *Tamarix amplexicaulis* Ehrenb. *T. pauciovulata* J. Gay, teste Baum, *T. balansae* J. Gay ex Batt et Trab, *T. trabutii* Maire (F = 20%) (Plate 8).

(d) *Z. coccineum* (*Plate 9*)

Associated species with *Z. coccineum* include *C. conglomeratus* (F = 100%) and *Fagonia bruguieri* DC. (F = 45%).

Plate 6. Growth of *Suaeda pruinosa* at Al-Magawah salt marsh. Note the sterile mud-flat in the background.

a

b

Plate 7. (a) Growth of *Nitraria retusa* forming hillocks at Al-Magawah salt marsh. Observe the dwarfed heavily camel-grazed plant on the left.

(b) Close up of heavily camel-grazed growth of *Nitraria retusa* forming a phytogenic hillock.

Plate 8. Growth of *Tamarix amplexicaulis* at Al-Magawah salt marsh. The effect of unidirectional wind action is shown.

Plate 9. Growth of *Zygophyllum coccineum* community type in the wadi at Al-Magawah salt marsh. Observe the stumps of the drought-deciduous *Cyperus conglomeratus* and the coarse sandy soil.

Edaphic Characteristics

Tables 3 and 4 show water table depth and moisture contents and give values of analysis of a series of soil samples representing sites within various zones of the vegetation of the salt marsh.

Discussion and Conclusions

Zonation is a universal characteristic of littoral salt marsh vegetation (Penfound and Hathaway 1938, Stephenson and Stephenson 1949, Tansley 1949, Kassas 1957, Hemming 1961, Kassas and Zahran 1967, Zahran 1973, Mahall and Park

Table 3. Water table depths in the various zones of the vegetation of the salt marsh at Al-Magawah.

Community type	Habitat	Site No.	Depth of water table (cm)
Arthrocnemum glaucum	Shore line	1	50
		2	47
		3	54
		4	36
	Mud flat where plant growth assumes circular islands-frequently inundated	5 6	54 56
	Extreme landward edge of zone adjacent to *Suaeda pruinosa*, habitat frequently receives sea water *via* the main creek	7 8	67 64
	Extreme landward edge of zone towards the Wadi; habitat frequently receives sea water *via* the main creek	9 10	73 76
Suaeda pruinosa	Extreme seaward end of zone	11	85
	Within the zone	12	150
Nitraria retusa	Middle of the zone	13	142
	Seaward end of the zone	14	100
Zygophyllum coccineum	Lowest seaward part of the zone, bordering *Nitraria* zone	15	170
	Upper landward part of the zone 500 m from site 15	16	No sign of water table even at 3 m depth

Table 4. Analysis of a series of soil samples from profiles within the different zones of the vegetation of the salt marsh at Al-Magawah.

Zone	**Habitat**	**Pro-file**	**Sam-ple**	**Depth (cm)**	**Coarse sand %**	**Fine sand %**	**Clay %**	**Silt %**	**pH**	**Total Soluble salts (ppm)**	**Moisture content %**
Zygophyllum coccineum	Middle of zone	1	1	0-5	71.8	16.3	8	2	8.1	1920	0.30 ± 0.05
			2	5-25	83.8	11.7	2	2	8.7	1580	0.31 ± 0.04
			3	25-50	83.9	9.5	2.6	4	8.7	1230	0.41 ± 0.13
	Wadi-extreme seaward end of zone adjacent to landward end of *Nitraria retusa* zone	2	4	0-5	71.5	20.1	0	8	8.0	3500	0.53 ± 0.15
			5	5-25	80.9	14.8	0	4	8.5	1960	0.64 ± 0.06
			6	25-50	80.0	14.0	0	6	8.6	1350	0.78 ± 0.07
Nitraria retusa	Wadi-middle of zone	3	7	0-5	73.2	15.7	4	7.1	8.1	14720	1.60 ± 0.74
			8	5-25	61.9	23.7	6	8.4	8.0	12800	3.48 ± 0.20
			9	25-50	64.7	25.4	4	5.9	8.2	4800	3.47 ± 0.36
	Extreme seaward end of zone	4	10	0-5	77.4	13.8	2	6.8	8.7	35600	2.24 ± 0.59
			11	5-25	64.1	25.3	10	0.6	8.7	25840	3.64 ± 0.60
			12	25-50	75.7	15.9	2	6.4	8.8	24640	4.71 ± 0.26
Suaeda pruinosa	Extreme landward end of zone	5	13	0-5	76.0	15.9	2	4.1	8.3	3520	0.30 ± 0.05
			14	5-25	80.9	11.1	2	4	8.1	6400	0.49 ± 0.07
			15	25-50	81.1	10.2	2	6	8.0	6080	0.58 ± 0.12
	Middle of zone	6	16	0-5	72.4	15.3	4	8.3	8.3	29700	3.73 ± 0.19
			17	5-25	70.4	10.2	10	9.4	8.0	25600	5.52 ± 0.37
			18	25-50	78.8	8.6	4	6.6	8.1	21060	7.91 ± 1.07
	Extreme seaward end of zone adjacent to landward end of *A. glaucum* zone	7	19	0-5	33.0	15.7	10	38	8.2	90880	16.78 ± 0.48
			20	5-25	28.0	13.8	6	34	8.5	48000	22.43 ± 1.63
			21	25-50	25.5	20.3	4	50	8.4	43520	25.74 ± 0.96

Arthrocnemum glaucum	Extreme landward end of zone, adjacent to extreme seaward end of *Suaeda* zone	8	22	0-5	19.0	10.2	2	2	8.4	126772	19.02 ± 0.73
			23	5-25	31.1	14.6	6	28	8.5	57600	25.35 ± 1.47
			24	25-50	50.6	25.0	4	20	8.5	21120	25.37 ± 1.78
	Extreme landward end of zone, adjacent to seaward end of *Nitraria* zone	9	25	0-5	57.6	12.8	2	12	8.8	102400	5.64 ± 0.59
			26	5-25	38.4	33.6	8	20	8.4	19520	15.28 ± 1.56
			27	25-50	26.4	58.3	2	14	8.5	18880	16.59 ± 1.26
	Bar of snad heaped by tidal and wave action	10	28	0-5	49.5	7.5	13	30	8.7	46080	4.31 ± 1.16
			29	5-25	81.2	6.0	4	8.8	8.8	17280	10.26 ± 2.80
			30	25-50	84.7	5.8	2	7.5	8.8	8640	11.55 ± 1.20
	Same as 10	11	31	0-5	81.1	4.6	6	8	9	51200	3.96 ± 0.98
			32	5-25	60.6	13.4	12	14	8.8	16640	17.71 ± 1.03
	Mud-flat where plant growth forms circular islands	12	33	0-5	11.1	10.8	36.1	42	8.7	28800	23.96 ± 1.39
			34	5-25	10.2	3.6	38.2	48	8.6	23680	31.56 ± 1.48
			35	25-50	15.9	3.3	26.8	54	8.6	13440	31.42 ± 1.63

1976, Halwagy and Halwagy 1977, Zahran 1977, Mahmoud *et al.* 1982). The salt marsh vegetation at Al-Magawah with its characteristic organization is no exception. The zones appear to be caused by a complex of factors: tidal inundation, differences in soil moisture, differences in ground level, distance from the shoreline, elevation above the water table, salinity gradient, the dynamic process of accretion, soil texture and climatic aridity. *A. glaucum* seems to be the most moisture demanding species in the marsh. Its zone is nearest to the sea and its growth on the sand bank, heaped by wave and tidal action, forms a belt bordering the inside sandy beach along the shoreline (Plate 3 and Fig. 1). Here the vegetation receives seawater which overflows the inside sandy beach as a result of wave action caused by, almost daily, strong winds and also *via* numerous creeks traversing the sandy beach. The growth of *A. glaucum* further landward in the mud-flat is confined to areas which are frequently inundated by seawater (Plate 4) brought by the main creek (Fig. 1) and several others which also traverse the shore line belt of *A. glaucum*; in addition the habitat of *A. glaucum* has the highest water table (Table 3), and the soil has a high moisture content (Table 4). Germination and growth of *A. glaucum* seem to require special high moisture conditions; in the Dead Sea region its germination and seedling establishment are confined to areas fringing the water (Waisel 1972). Waisel (1972) also noted that plants of *A. glaucum* show only small seasonal growth, but a major growth flush occurs in summer, while plants which are exposed to continuously inundated habitats show practically uninterrupted growth. The rich growth of *A. glaucum* depicted in Plates 1 and 5b characterises areas in this marsh which experience more frequent and longer periods of inundation than elsewhere.

The habitat of *A. glaucum* is characterised by high salt content (Table 4). The plants are highly salt resistant as long as the medium is wet and growth is best in presence of NaCl (Waisel 1972). These conditions prevail within its present habitat at Al-Magawah salt marsh. The soil in the habitat of *A. glaucum* ranges from sandy (Profiles 9-11) to clayey (Profile 12, Table 4).

As the ground level rises gradually landwards, and in areas which are not inundated, the *A. glaucum* community type is replaced successively by *S. pruinosa*, *N. retusa* and *Z. coccineum* community types (Fig. 1).

In the *S. pruinosa* zone, the saline water table is deeper than in the *A. glaucum* zone (Table 3), and the soil is comparatively less moist (Table 4). However, during the brief rainy season, this zone is flushed by additional drainage water from neighbouring surrounding high ground and hills. Unlike *A. glaucum*, *S. pruinosa* does not seem to tolerate periodic inundation by seawater. In its extreme seaward limit, where it closely borders the former species, its growth is associated with slightly higher ground which is out of reach of seawater. The seaward limit of *S. pruinosa* is also probably determined by high saline water table (Sites 7 and 8, Table 3) and high salinity (Profiles 7 and 8, Table 4). The species is summer-deciduous; its renewed vegetative growth during the rainy season is probably attributed, in addition to the available favourable moisture conditions, to leaching of excessive salts to levels tolerated by the plant and which permit active growth. The soil is coarse-textured (Table 4).

The zone of *N. retusa* occupies the seaward lower sector of the wadi which receives, during the brief rainy season drainage water (and water-borne soil) from the neighbouring hills and high ground and probably from other far distant catchment areas, thus its resources may be greater than the actual local rainfall. Evenari *et al.* (1971) have observed that local run-off of mountain rain-water in the Negev desert may increase the rainfall effectively received by level, high-altitude sites by 100 to 200 mm per annum. Locally deep soils in the wadis or terraces may retain a high proportion of this, thus compounding the effect. The depth of the water table decreases with decreased elevation towards the extreme seaward limit of the zone (170-100 cm, sites 13 to 15, Table 3). Because of the improved edaphic conditions, especially during the rainy season (availability of adequate moisture, low salt content because of leaching in addition to the comparatively deep saline water table) the vegetation in the *N. retusa* zone is more elaborate than in the other zones and shows clear stratification into a shrub layer represented by *N. retusa* and *Tamarix amplexicaulis* and an herbaceous layer which includes *C. conglomeratus*, *Z. album*, *Z. coccineum* and *S. pruinosa*. The vegetation in the other zones consists solely of the herbaceous layer. The seaward limit of the growth of *N. retusa* plants is probably determined by (a) high water table (Table 3) which may create anaerobic conditions to this deeply rooted desert plant, and (b) high salinity (Profile 4, Table 4).

Z. coccineum community type occupies the upper highest sector of the wadi (Fig. 1); the water table lies below 3 meters and only at its seaward edge (Site 15, Table 3) if it reached at 170 cm. The *Z. coccineum* community type inhabits the driest part of the marsh (Profiles 1-2, Table 4), though it becomes wet during the brief rainy season and receives additional drainage water. Because of leaching and the deeply seated saline water table, salinity in the zone of *Z. coccineum* is lower than in the rest of the marsh. The soil is coarse-textured (Table 4). The ecology of this zone is very similar to that in the salt marshes of Kuwait. 'The community of *Z. coccineum* which is also a constant member of the salt marsh vegetation seems to occupy the highest ground and usually represents the landward edge of the salt marsh. It appears that the horizontal distance from the shoreline and/or vertical elevation above the saline water table aided by a large proportion of coarse and fine sand, all contribute to produce a slightly coarse-textured soil suitable for the growth of *Z. coccineum*.' (Halwagy and Halwagy 1977). *Z. coccineum* has a similar ecology in the littoral salt marsh at Rabigh, on the Red Sea coast, Saudi Arabia (Mahmoud *et al.* 1982).

The vegetation, generally, is characterized by low numbers of species; the perennials recorded were: 6, 3, 2 and 1, respectively in the *N. retusa*, *Z. coccineum*, *S. pruinosa* and *A. glaucum* zones. Grime (1973) and Mahmoud *et al.* (1982)

reported that environmental stress may reduce species density. The remarkable difference in numbers of species between the *A. glaucum* zone on one hand, and those of *N. retusa*, *Z. coccineum* and *S. pruinosa* on the other, may be attributed to environmental stress. Only *A. glaucum* is adapted to withstand the severe stresses arising from inundation and high salinity.

The dynamic process of accretion seems to have cut off seawater supply from certain parts of the mud-flat which became sterile (Plate 1 and Fig. 1). Here, the habitat was apparently not suitable for germination and subsequent growth of *A. glaucum*. The other components of the vegetation of the marsh probably failed to germinate and/or establish because of excessive salinity and heavy-textured soil. Here, the accumulation of surface crusts of salts makes the habitat unfavourable.

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دراسة بيئية عن الكساء النباتى فى مستنقع المجوَّه على شاطىء خليج العقبة، المملكة العربية السعودية

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ص.ب ٢٤٥٨

**قسم النبات - كلية العلوم - جامعة الملك سعود - الرياض
ص.ب ٢٤٥٥ المملكة العربية السعودية

يتميز الكساء النباتى فى مستنقع المجوه الملحي بتوزيعه فى مناطق متتالية من شاطىء البحر الأحمر إلى اليابسة.

تتبع منطقة *Arthrocnemum glaucum* على التوالى مناطق *Nitraria retusa, Suaeda pruinosa, Zygophyllum coccineum*. تتضافر عدة عوامل فى تشكيل وتكوين وتوزيع الكساء النباتي: الغمر بالماء والاختلاف فى مستوى سطح الأرض، البعد من الشاطىء، عمق الماء الأرضي المالح، التدرج فى درجة الملوحة، قوام التربة والمناخ الجاف.

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