2.1.7.3. Results

1. Vegetation

1-1. Vegetation type

69 quadrat (spot) surveys were carried out at 25 sites (Appendix 12). Spot data are compiled into floristic composition tables according to the dominant species (Table 59-1, 2, 3). The plant communities are classified into the following eight vegetation types according to physiognomy, life forms and habitats: mangrove thicket, desert shrub, succulent salt marsh, desert succulent half-shrub, grassland salt marsh, reed, desert grassland, and others (Table 60). The features of each vegetation type are as follows.

1). Mangrove thicket

Avicennia marina formed dense thickets 1 - 5.5m in height along the shoreline at eight sites, which were either in sheltered inlets (sharms) behind reef flat, on seashores of alluvial coral sand, or on coral flats on offshore islands. *Rhizophora mucronata*, on the other hand, formed communities at two sites as a small patch on a coral flat offshore island (V19: Jazirat Shaybarah) and on one inland seashore with shallow water (V18: Duqm Sabq).

2). Desert shrub

Communities of *Tamarix* sp. (*T. nilotica*, *T. aphylla*) grew in various habitats from intensive saline sands to inland deserts, and sometimes forming circular sandy hillocks inside wadi. *Salvadora persica* formed dense shrubs 1 – 3.5m in height in the mouth of wadi connecting to inlets. *Acacia* sp. (*A. tortilis*, *A. ehrenbergiana*) was found mainly as open scattered shrubs on desert hills.

3). Succulent salt marsh

The dominant species of the succulent salt marshes were halophytes distributed in alluvial fans with sandy flats affected by salt through tidal change and salt spray along the seashore. *Halocnemun strobilaceum* communities were the most abundant and typical salt

marsh feature, usually occupying a narrow belt adjoining and parallel to the hightide shoreline. *Zygophyllum album* communities were distributed widely from alluvial sandy flat to inland sandy desert, irrespective of soil salinity and humidity.

4). Desert succulent half-shrub

Desert succulent half-shrubs dominated by *Salsola imbricata, Seidlizia rosmarinus* and *Haloxylon salicornicum* were distributed with low coverage in the inland-side area of alluvial fans.

5). Grassland salt marsh

Grassland salt marshes were distributed on alluvial sandy flats, and have grown the halophytes *Aeluropus lagopoides, Sporobolus spicatus* and *Juncus rigidus. Juncus rigidus* communities grew on alluvial sandy flats with high soil salinity near the seashore.

6). Reed

Phragmites australis and *Typha domingensis* communities were seen in specific habitats such as small water pools beside a steep coral cliff (V12: Marsa Hawwaz).

7). Desert grassland

Desert grasslands of *Panicum turgidum* formed communities accompanied by a few xerophytes on gentle slopes of sand deposits beside coral cliffs behind inlets.

8). Others

Other vegetation type consisted of dominant species such as *Phoenix dactylifera, Calotropis procera* and *Taverniera lappacea. Phoenix dactylifera,* including plantations, existed on alluvial sandy flats at elevations slightly higher than sea level. The presence of *Phoenix dactylifera* may indicate a high ground water level.

Table 59-1. Floristic composition of mangroves and desert shrubs.

		Mangrove								Desert shrub									Other	
Spot No.		M95	M35	M34	M58	M21	M65	M6	M72	M27	M9	M4	M38	M40	M54	M10	M73	M15	M28	M25
Date (1998)		10/17	5/31	5/31	6/15	5/28	6/16	5/25	6/18	5/29	5/25	5/24	6/7	6/7	6/14	5/25	6/18	5/26	5/29	5/29
Area (m^2)		25	25	25	100	25	100	25	25	25	100	25	100	900	100	100	400	400	25	400
Height of tree layer (m)		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	7
Coverage of tree layer (%)		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	20
Height of shrub layer (m)		3.5	3.5	2	4.5	2.3	5.5	1	2.5	3	4.5	2	·	1.2	3.5	3.5	2	1.5	2.5	2.5
Coverage of shrub layer (%)		80	80	80	90	70	85	55	90	80	65	20	·	30	85	35	5	10	12	15
Height of herb layer (m)		·	·	·	0.3	·	0.7	·	0.5	1	·	0.5	1	0.3	0.5	0.7	0.8	0.5	0.4	0.5
Coverage of herb layer (%)		·	·	·	<1	·	5	·	3	15	·	60	15	3	5	25	10	10	30	5
The number of species		1	2	1	1	1	1	1	2	2	1	5	2	4	2	7	7	1	5	9
Scientific name																				
Mangrove species																				
Rhizophora mucronata	S	5·5	3·3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Avicennia marina	S	·	2·2	5·5	5·5	4·4	4·4	4·4	5·5	·	·	·	·	·	·	·	·	·	·	·
	H	·	·	·	+	·	1·2	·	+·2	·	·	·	·	·	·	·	·	·	·	·
Desert shrub dominant species																				
Tamarix nilotica	S	·	·	·	·	·	·	·	·	5·5	4·4	2·3	·	1·2	·	·	·	·	·	+
	H	·	·	·	·	·	·	·	·	·	·	·	2·3	·	·	·	·	·	·	·
Tamarix aphylla	S	·	·	·	·	·	·	·	·	·	·	·	·	3·4	·	·	·	·	·	·
	H	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·
Salvadora persica	S	·	·	·	·	·	·	·	·	·	·	·	·	·	5·5	·	·	·	·	·
	H	·	·	·	·	·	·	·	·	·	·	·	·	·	1·2	·	·	·	·	·
Acacia tortilis	S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4·4	1·2	·	·	·
	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·2	·	·	·	+
Acacia ehrenbergiana	S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·2	·	·
Other dominant species																				
Calotropis procera	S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·3	·
	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·
Phoenix datylifera	T	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·3
	S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·2
Salt marsh speceis																				
Zygophyllum album	H	·	·	·	·	·	·	·	·	·	·	2·3	·	·	1·1	+	1·2	·	2·3	+·2
Aeluropus lagopoides	H	·	·	·	·	·	·	·	·	2·2	·	1·1	·	·	·	·	·	·	·	1·2
Suaeda monoica	S	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
	H	·	·	·	·	·	·	·	·	·	·	2·2	·	1·2	·	·	·	·	·	·
Lycium shawii	S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·2	·	·	·	·
	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·1	·	·	·	+
Sporobolus spicatus	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	+
Cressa cretica	H	·	·	·	·	·	·	·	·	·	·	2·2	·	·	·	·	·	·	·	·
Haloxylon salicornicum	H	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·
Limonium axillare	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·
Salsola imbricata	S	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·
	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·3	·	·	·	·
Zygophyllum simplex	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·2	·	·	·	·
Zygophyllum decumbens	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·1	·	·	·
Plain speceis																				
Panicum turgidum	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	1·2	+
Cyperus conglomeratus	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	+
Stipagrostis hirtigluma	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·
Dipterygium glaucum	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·2	·
Blepharis ciliaris	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·	·
Senna alexandrina	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·

Table 59-2. Floristic composition of succulent salt marshes and desert succulent half-shrubs.

		Succulent salt marsh																												Desert succulent half-shrub				
Spot No.		M66	M20	M39	M33	M42	M62	M79	M57	M60	M70	M64	M30	M63	M97	M16	M77	M74	M55	M53	M68	M83	M49	M76	M19	M3	M2	M43	M81	M86	M8	M44	M31	M59	M37
Date (1998)		6/16	5/28	6/7	5/31	6/8	6/16	6/20	6/15	6/15	6/17	6/16	5/30	6/16	10/18	5/26	6/19	6/18	6/14	6/14	6/17	6/21	6/13	6/19	5/28	5/24	5/24	6/8	6/20	6/21	5/25	6/8	5/30	6/15	6/7
Area (m^2)		100	25	100	25	100	100	100	100	100	100	100	64	25	25	25	100	100	100	25	100	100	100	100	25	25	25	100	100	25	100	25	25	100	100
Height of herb layer (m)		1	0.3	0.4	0.3	0.4	0.6	1.2	1	0.7	1.3	1	0.7	0.4	0.4	0.4	1.2	0.6	0.6	0.5	0.4	1.2	0.3	0.4	0.5	1.2	1	0.5	1.2	0.6	0.6	0.5	0.8	0.7	0.4
Coverage of herb layer (%)		70	85	35	70	40	35	15	60	40	70	60	35	20	20	20	13	15	10	15	35	12	35	10	50	60	20	5	15	30	35	15	70	15	15
The number of species		2	3	2	1	2	2	1	2	2	2	1	4	2	1	3	5	3	4	2	2	2	2	2	3	2	3	2	1	1	6	2	10	5	3
Scientific name																																			
Succulent salt marsh dominant species																																			
Halocnemum strobilaceum	H	4·5	4·4	4·4	4·4	3·4	3·4	2·3	4·4	1·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arthrocnemum macrostachyum	H	.	.	.	.	.	.	.	1·2	3·4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Atriplex farinosa	H	.	.	.	.	.	.	.	.	.	4·4	4·4	3·3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Halopeplis perfoliata	H	.	.	.	.	+	+	.	.	.	.	.	.	2·3	2·3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Zygophyllum album	H	.	.	.	.	.	.	.	.	.	+·2	.	.	.	.	3·4	2·2	2·3	2·3	2·3	3·4	2·3	+·2	+·2	.	.	.	.	.	.	+	.	.	.	.
Limonium axillare	H	.	2·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3·4	2·3	3·3	.	.	.	.	.	1·1	.	.	.	.
Suaeda monoica	H	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4·4	2·3	1·2	.	.	.	+	.	.	.
Nitraria retusa	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2·3	3·4	.	.	.	.	.
Desert succulent half-shrub dominant species																																			
Salsola imbricata	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3·4	2·3	2·3	1·2	.
Seidlitzia rosmarinus	H	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2·3	.
Haloxylon salicornicum	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2·3
Other salt marsh species																																			
Aeluropus lagopoides	H	.	1·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1·2	+	1·1	.	.	.	.	.	.	.	+
Cornulaca ehrenbergii	H	.	.	.	.	.	.	.	.	.	.	.	2·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tamarix nilotica	H	.	.	+·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Zygophyllum decumbens	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1·2	+·2	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Suaeda vermiculata	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	2·3	.	.	+·2	.	.	.	.	.	.	.
Cressa cretica	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+·2	.	.	.	+	.	.	.	.
Suaeda verna	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1·1	.	.	.	.
Lycium shawii	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1·1	.	.	.	.
Plain species																																			
Panicum turgidum	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+·2	1·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Indigofera articulata	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2·2	.	.
Fagonia bruguieri	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+·2	.	.	+·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stipagrostis hirtigluma	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Citrullus colocynthis	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+·2	.
Ochradenus baccatus	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Iphiona scabra	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2·3	.	.
Cyperus sp.	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+·2	.	.	.	.	.	.	.	.	.	.	.	.	.
Echium sp.	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+·2	.	.
Rhazya stricta	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Reseda muricata?	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Polycarpaea robbairea	H	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helitropium crispum	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
GRAMINEAE sp.	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Fagonia boveana	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Cyperus jeminicus	H	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cistanche phelypaea	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Hyoscyamus muticus	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+

Table 59-3. Floristic composition of grassland salt marshes, reed and desert grassland.

		Grassland salt marsh								Reed		Desert grassland					Other
Spot No.		M1	M26	M7	M12	M50	M24	M23	M85	M11	M89	M14	M17	M46	M51	M47	M69
Date (1998)		5/24	5/29	5/25	5/25	6/13	5/29	5/29	6/21	5/25	10/11	5/26	5/26	6/9	6/13	6/9	6/17
Area (m^2)		25	25	25	25	100	100	25	25	25	25	25	25	100	100	100	100
Height of herb layer (m)		0.4	0.3	1	0.6	0.3	0.3	1.5	1	1	2	0.9	0.8	1.2	1.2	1	0.4
Coverage of herb layer (%)		90	85	55	25	30	15	90	65	90	80	25	25	20	15	10	15
The number of species		3	1	4	2	2	1	2	2	1	2	4	3	7	8	8	7
Scientific name																	
Grassland salt marsh dominant species																	
Aeluropus lagopoides	H	5·5	5·5	3·4	3·4	3·4	·	1·2	·	·	·	·	·	·	·	·	·
Sporobolus spicatus	H	·	·	·	·	·	2·3	·	·	·	·	·	·	·	·	·	·
Juncus rigidus	H	·	·	·	·	·	·	5·5	4·4	·	·	·	·	·	·	·	·
Reed dominant species																	
Phragmites australis	H	·	·	·	·	·	·	·	·	5·5	1·1	·	·	·	·	·	·
Typha domingensis	H	·	·	·	·	·	·	·	·	·	5·5	·	·	·	·	·	·
Desert grassland dominant species																	
Panicum turgidum	H	·	·	·	·	·	·	·	·	·	·	2·3	2·3	2·3	2·3	1·2	·
Other dominant species																	
Taverniera lappacea	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2·3
Salt marsh dominant species																	
Zygophyllum album	H	·	·	·	·	+·2	·	·	+·2	·	·	1·2	1·1	+	·	·	+·2
Limonium axillare	H	·	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·
Salsola imbricata	H	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	+
Suaeda monoica	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·2
Tamarix nilotica	H	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Suaeda vermiculata	H	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Cressa cretica	H	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Plain species																	
Cyperus conglomeratus	H	·	·	·	·	·	·	·	·	·	·	+·2	·	+·2	·	+·2	+·2
Fagonia bruguieri	H	·	·	·	·	·	·	·	·	·	·	+	+·2	·	·	+	·
Indigofera articulata	H	·	·	·	·	·	·	·	·	·	·	·	·	1·2	1·2	·	·
Sphaerocoma aucheri	H	·	·	·	·	·	·	·	·	·	·	·	·	+	+·2	·	·
Dichanthium foveolatum	H	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	+·2	·
Heliotropium pterocarpum	H	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	·
Lasiurus scindicus	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1·1	·
Indigofera oblongifolia	H	·	·	·	·	·	·	·	·	·	·	·	·	·	+·2	·	·
Monsonia nivea	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Launaea mucronata ssp.*cassiniana*	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+
Farsetia ramosissima	H	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Senna italica	H	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Glossonema boveanum	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+
Deverra triradiata	H	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Citrullus lanatus	H	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Acacia tortilis	H	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·

Table 60. Vegetation types in the Study Area.

Vegetation Type	Dominant Species of Plant Community	Number of Species min~max (average)	Main Habitat and Soil
1. Mangrove thicket	*Avicennia marina*	1~2 (1.5)	Seashore with shallow water in alluvial fan, lagoon, off shore flat island (high salinity, wet sand and mud)
	Rhizophora mucronata	1~2 (1.2)	Creek with week wave action in offshore flat island (high salinity, wet sand and mud)
2. Desert shrub	*Tamarix nilotica*	1~5 (2.5)	Wadi, alluvial sandy flat near seashore (high salinity, dry – wet sand)
	Tamarix aphylla	4	
	Salvadora persica	2	Wadi adjoining to inlet (low salinity, dry sand)
	Acacia tortilis	7~7 (7)	Hill with gentle slope, wadi on inland side (low salinity, dry sand)
	Acacia ehrenbergiana	1	
3. Succulent salt marsh	*Halocnemum strobilaceum*	1~3 (1.9)	Alluvial sandy flat near shoreline, adjacent to high tide level (high salinity, wet – dry)
	Arthrocnemum macrostachyum	2	
	Atriplex farinosa	1~2 (1.5)	Sandy beach in alluvial fan (high salinity, dry deposit sand)
	Halopeplis perfoliata	1~4 (2.3)	Alluvial sandy flat (high salinity, dry sand)
	Zygophyllum album	2~5 (3)	Alluvial sandy flat (low – high salinity, wet – dry sand)
	Limonium axillare	2~3 (2.3)	Alluvial sandy flat, sand and rock of fossil coral (high salinity, wet – dry coarse sand and rock)
	Suaeda monoica	2~3 (2.3)	Alluvial sandy flat (high salinity, dry sand)
	Nitraria retusa	1~1 (1)	Alluvial sandy flat, sandy beach (high salinity, dry sand)
4. Desert succulent half-shrub	*Salsola imbricata*	2~10 (6)	Inland area of alluvial sandy flat in coastal zone (low salinity, dry sand)
	Seidlizia rosmarinus	5	
	Haloxylon salicornicum	3	
5. Grassland salt marsh	*Aeluropus lagopoides*	1~4 (2.4)	Alluvial sandy flat with slight elevation from sea level near seashore (high salinity, dry coarse sand)
	Sporobolus spicatus	1	
	Juncus rigidus	2~2 (2)	Alluvial sandy flat near seashore, sandy beach (high salinity, dry – wet sand)
6. Reed	*Phragmites australis*	1	Along seashore, water pool beside fossil coral cliff (high – low salinity, in the water)
	Typha domingensis	2	
7. Desert grassland	*Panicum turgidum*	3~8 (6)	Sand deposit with gentle slope beside fossil coral cliff behind inlet, and hill (low salinity, dry sand)
8. Others	*Phoenix dactylifera* (including plantations)	9	Alluvial sandy flat with high ground water level (low salinity, dry sand)
	Calotropis procera	5	Alluvial sandy flat (low salinity, dry sand)
	Taverniera lappacea	7	Small depression on the hill (low salinity, dry sand)

1-2. Vegetation maps

Vegetation maps and profiles of the sites representing 12 geomorphological types (see Table 57) are shown in Fig. 34. The features of each vegetation map of the sites are as follows.

1). Offshore islands (Fig. 34-1)

Coral flats on one offshore island (V19) were densely and almost entirely covered with mangrove thickets, but islands with steep slopes (V21) and fossil coral terraces (V10) were covered partly with some scattered salt marshes.

2). Alluvial fan (Fig. 34-2)

Alluvial sandy flats near sea level in elevation (V22) were covered partly with mangrove thickets and salt marsh. The vegetation of alluvial sandy flats with elevations slightly higher than sea level (V25) consisted of various vegetation types with a high plant coverage. On alluvial sandy flats with a gentle slope (V11), salt marshes and mangrove thickets were concentrated along the seashore in narrow belts.

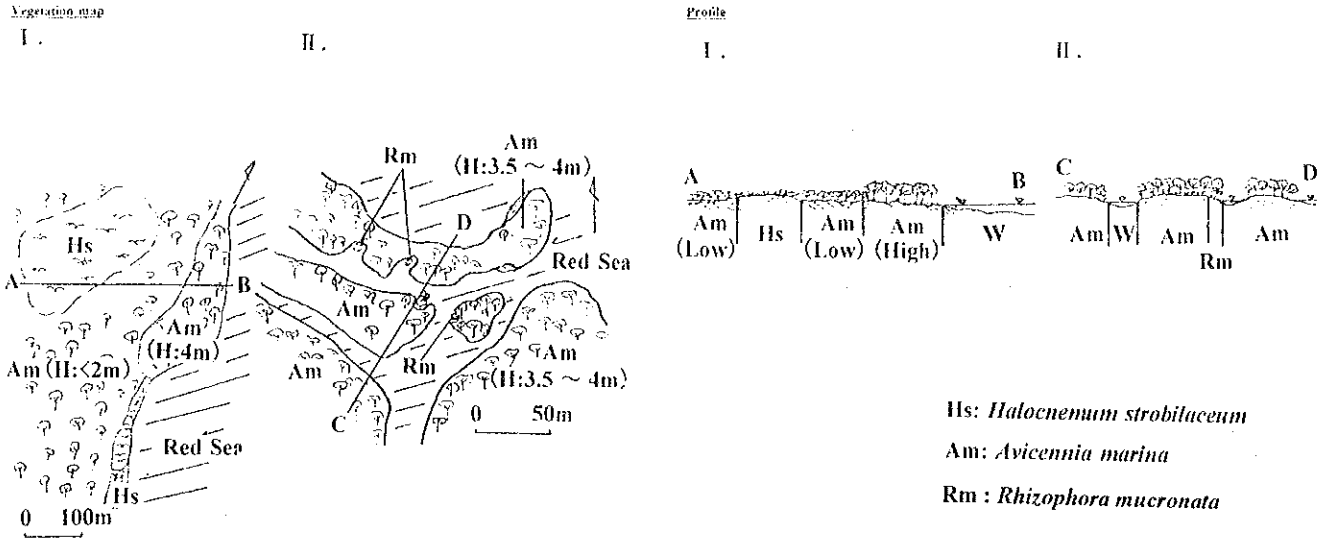
3). Inlet enclosed by terrace or hill (Fig. 34-3)

A few salt marshes and desert shrubs were distributed on the sandy flats in the inlet enclosed by fossil coral terraces (V8). Inlets with gentle slopes (V4) and steep slopes (V12) had a lower plant coverage than the previously mentioned site.

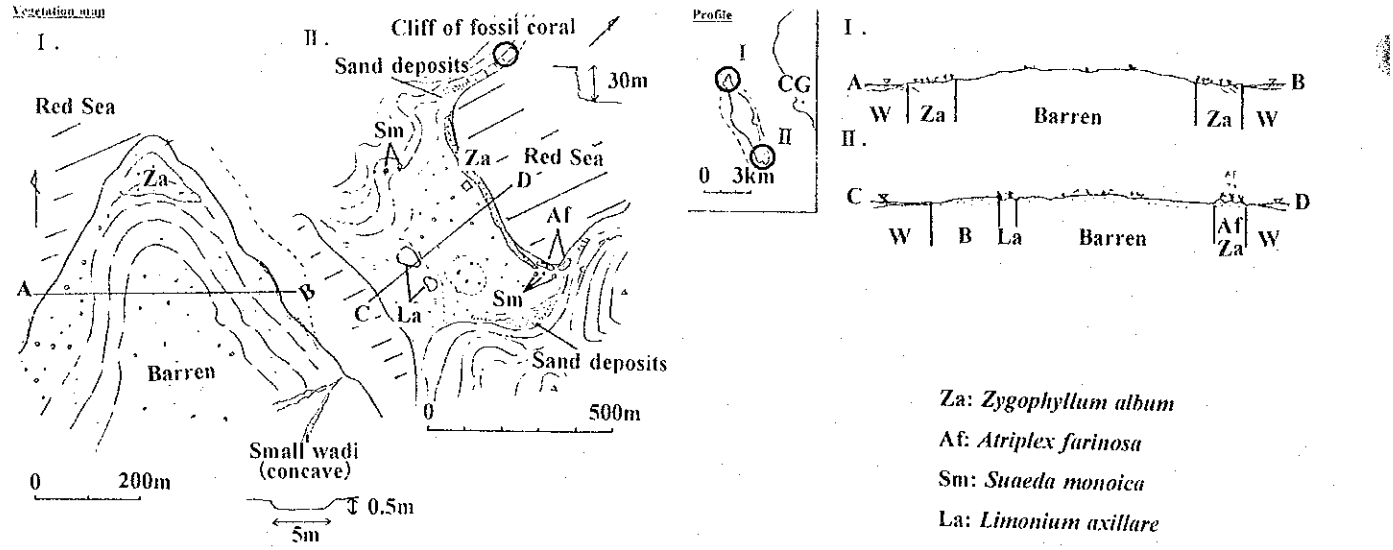
4). Mountain, wadi (Fig. 34-4)

There was almost no vegetation coverage in the mountainous site with steep rocky slopes (V3). A wide wadi with no slope (V16) was very rich in plant coverage, consisting of *Tamarix* sp. shrubs and salt marshes. In contrast, a small wadi with gentle slopes (V1) was barren with no vegetation.

Offshore flat island (V19 : Jazirat Shaybarah)



Offshore island with terrace of fossil coral rock (V10 : Jazirat an Numan)



Offshore island with steep slope (V21 : Jazirat Jabal Hassan)

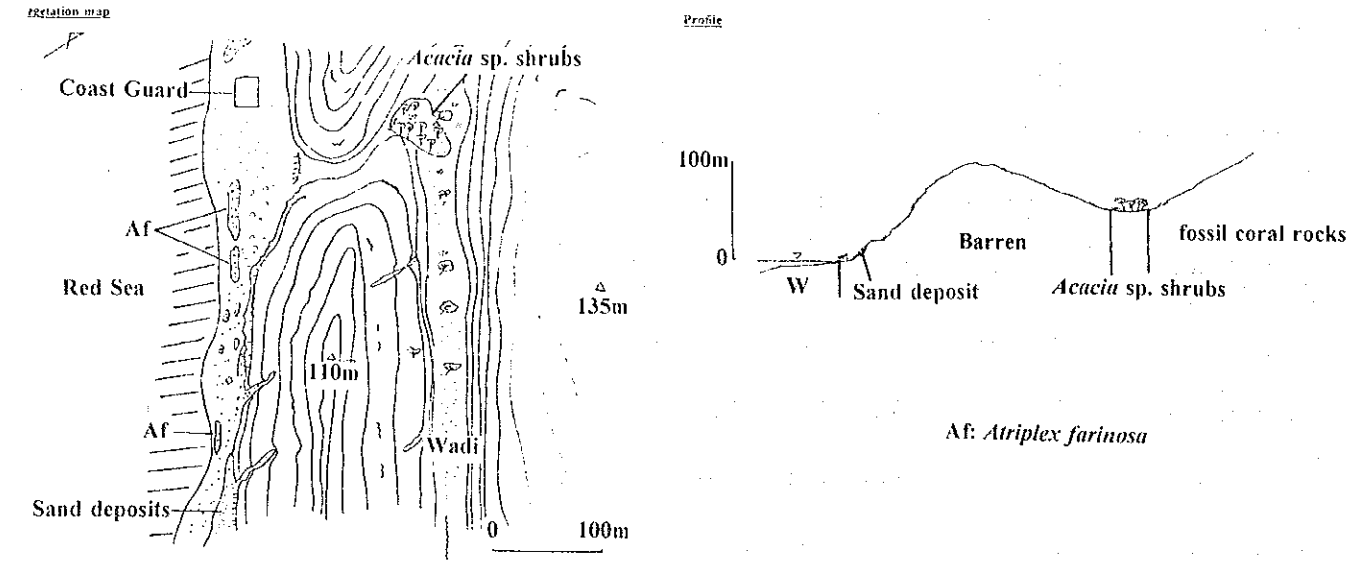
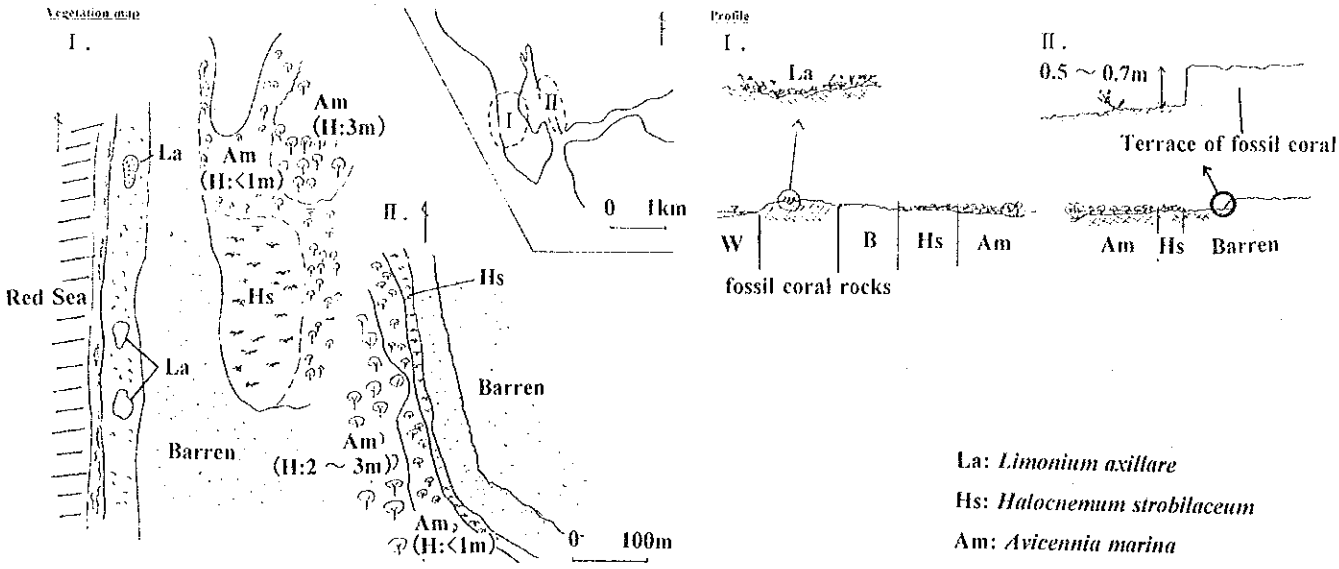
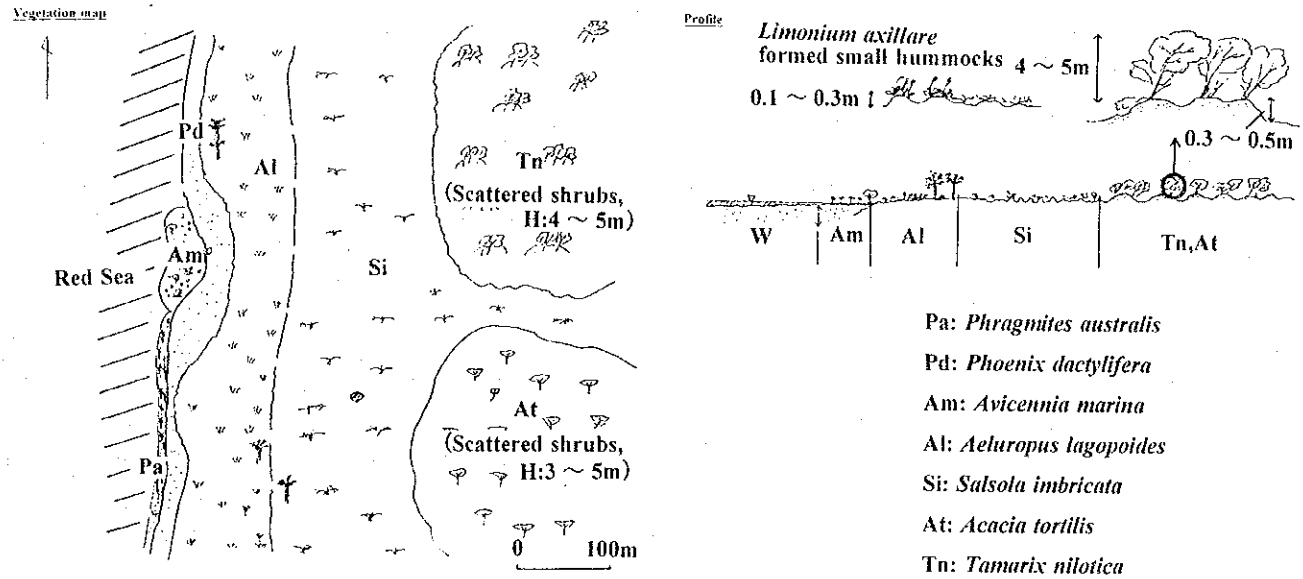


Fig. 34-1. Vegetation maps and profiles (offshore islands).

Alluvial fan with flat near sea level (V22 : Ash Shaban)



Alluvial fan with flat slightly higher than sea level (V25 : Masturah)



Alluvial fan with gentle slope (V11 : Zubaydah)

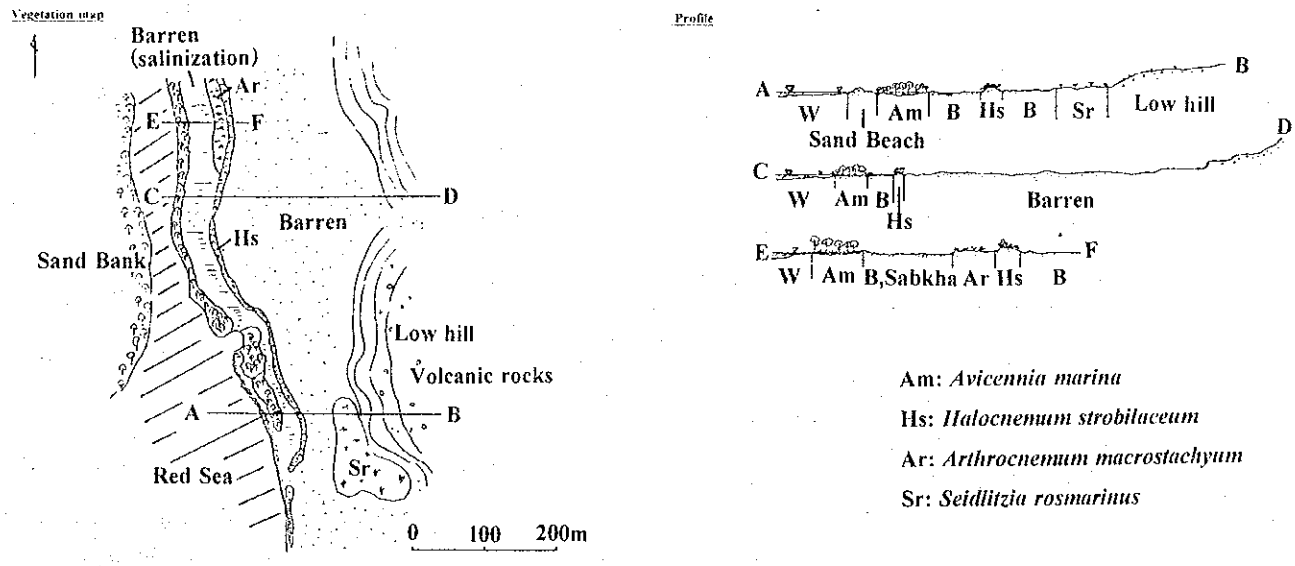
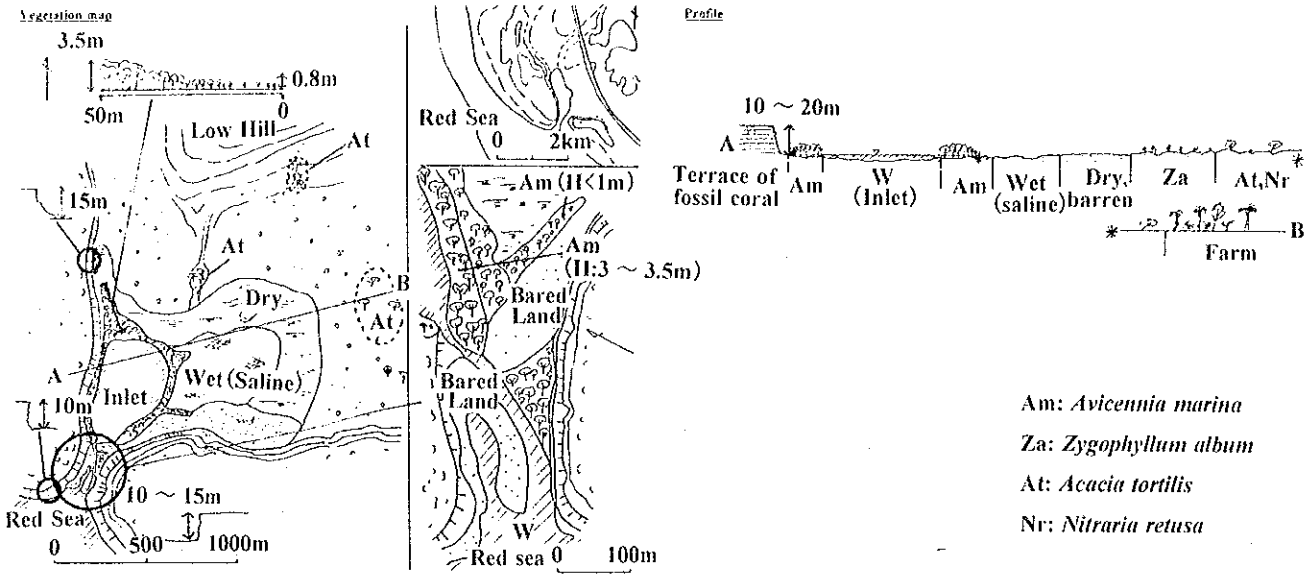
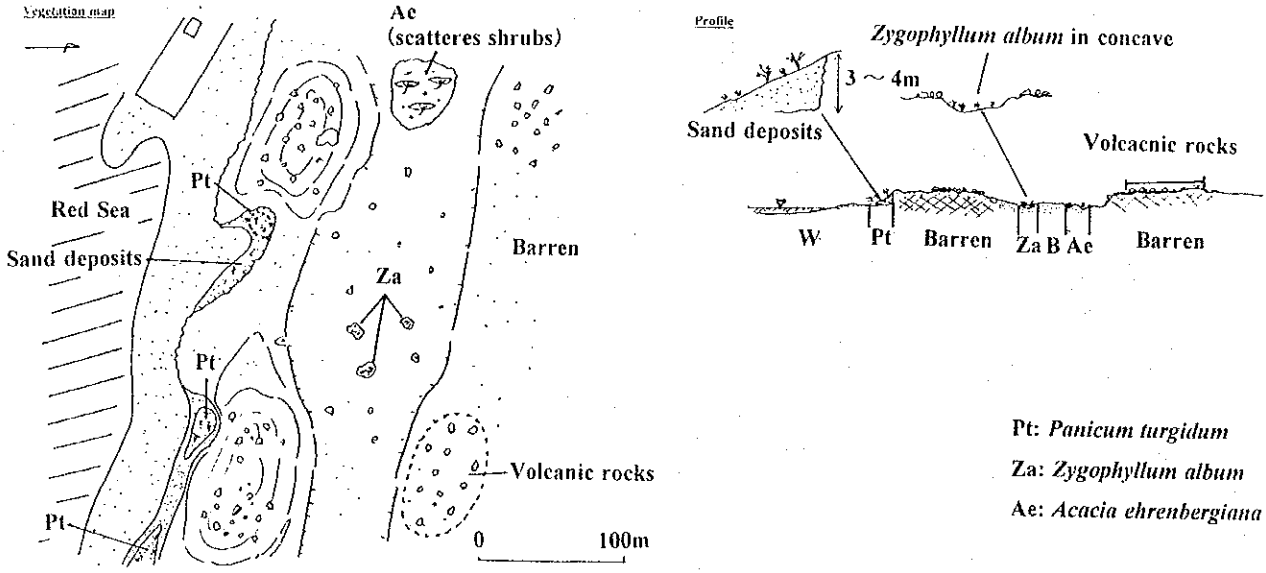


Fig. 34-2. Vegetation maps and profiles (alluvial fan).

Inlet enclosed by terrace of fossil coral with mouth of wadi (V8 : Rawd az-Ziyan)



Inlet enclosed by hill with gentle slope (V23 : Marsa al-Khawr)



Inlet enclosed by hill with steep slope (V12 : Marsa Hawwaz)

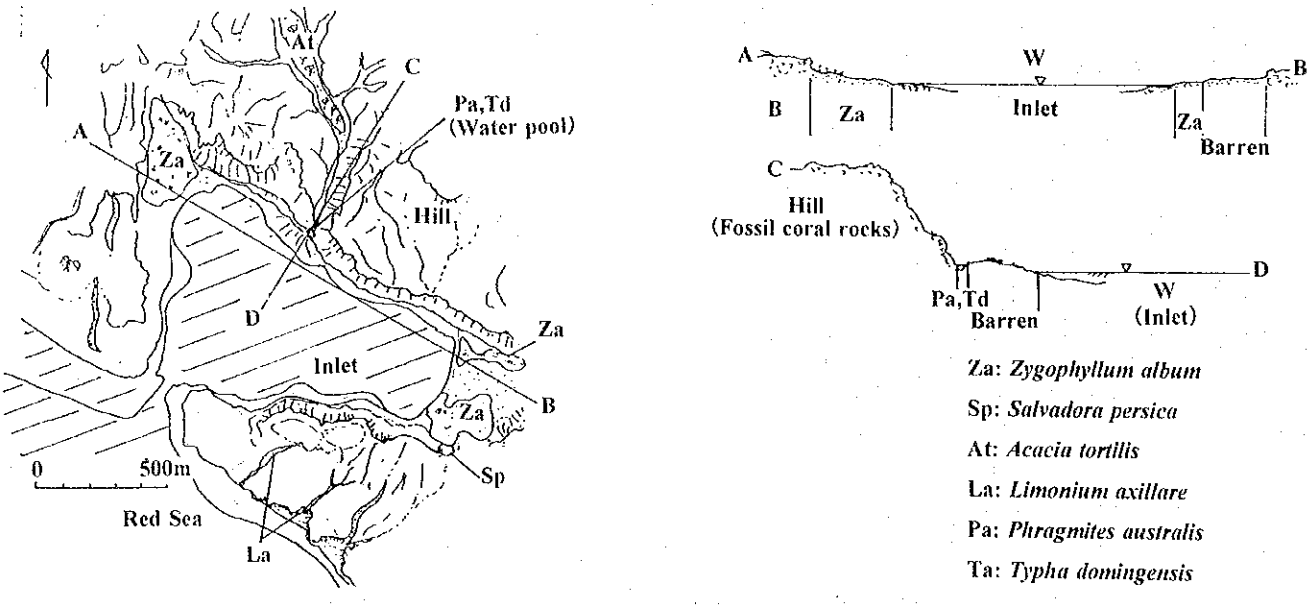
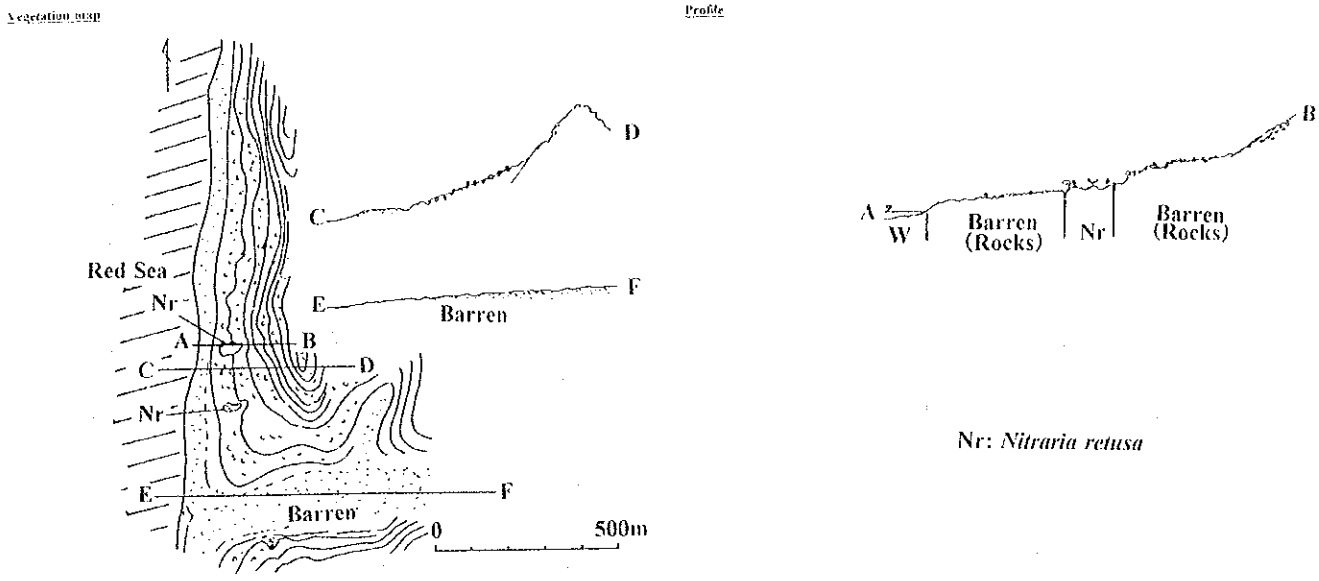
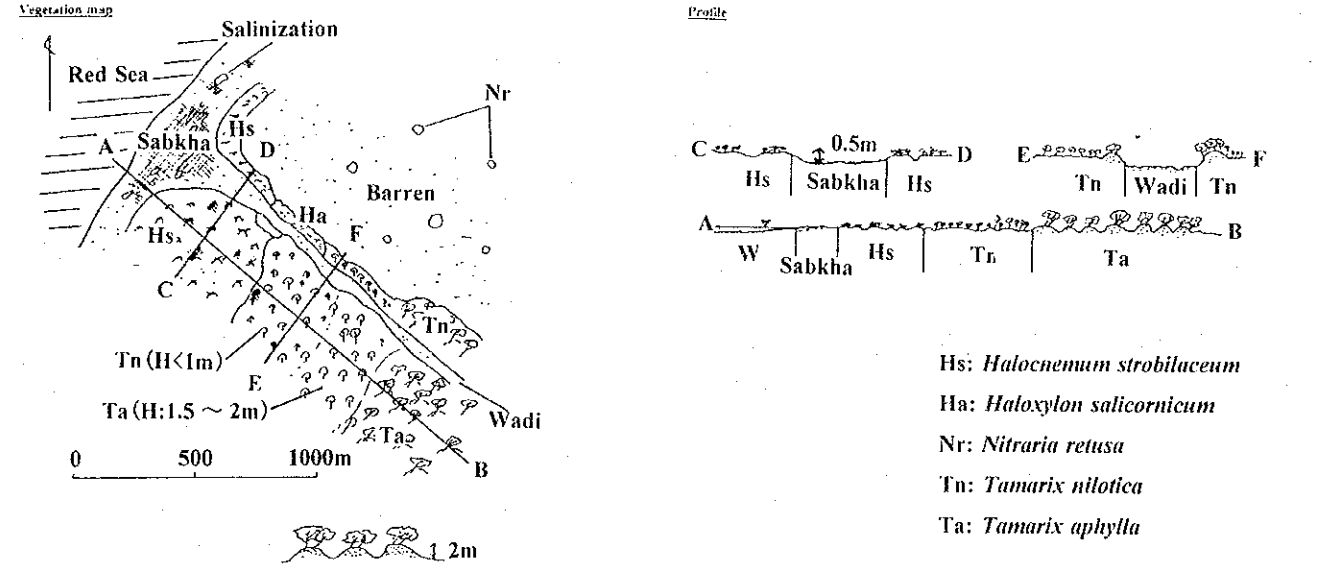


Fig. 34-3. Vegetation maps and profiles (inlets enclosed by terrace or hills).

Mountain with steep slope (V3 : Maqna)



Flat wadi (V16 : Wadi al-Hamd)



Wadi with gentle slope (V1 : Al-Durah)

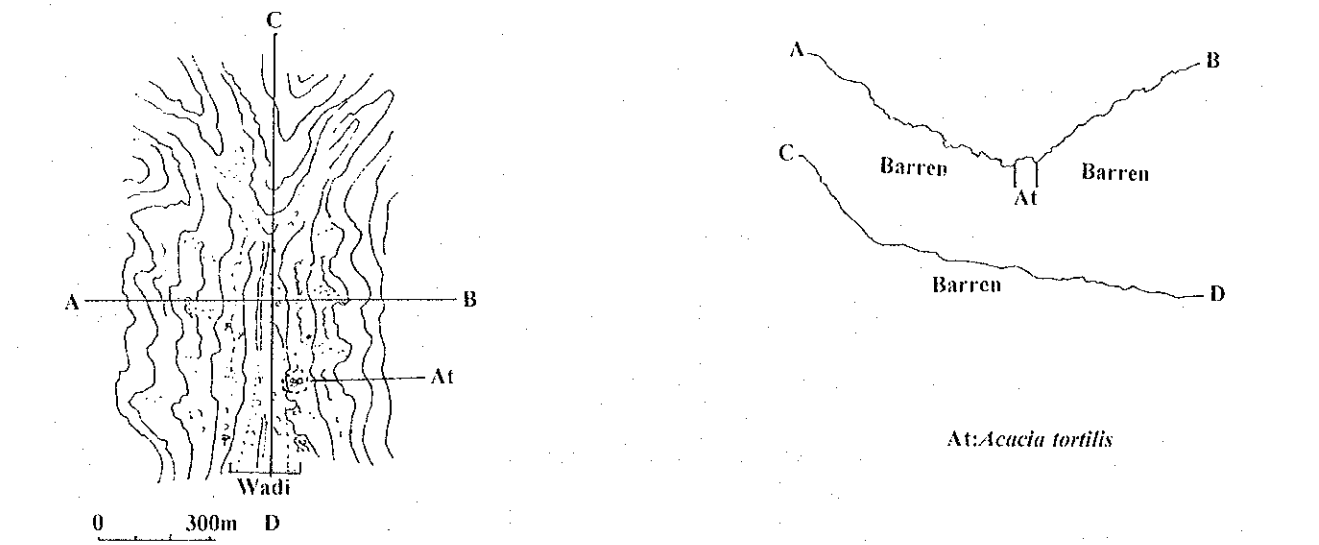


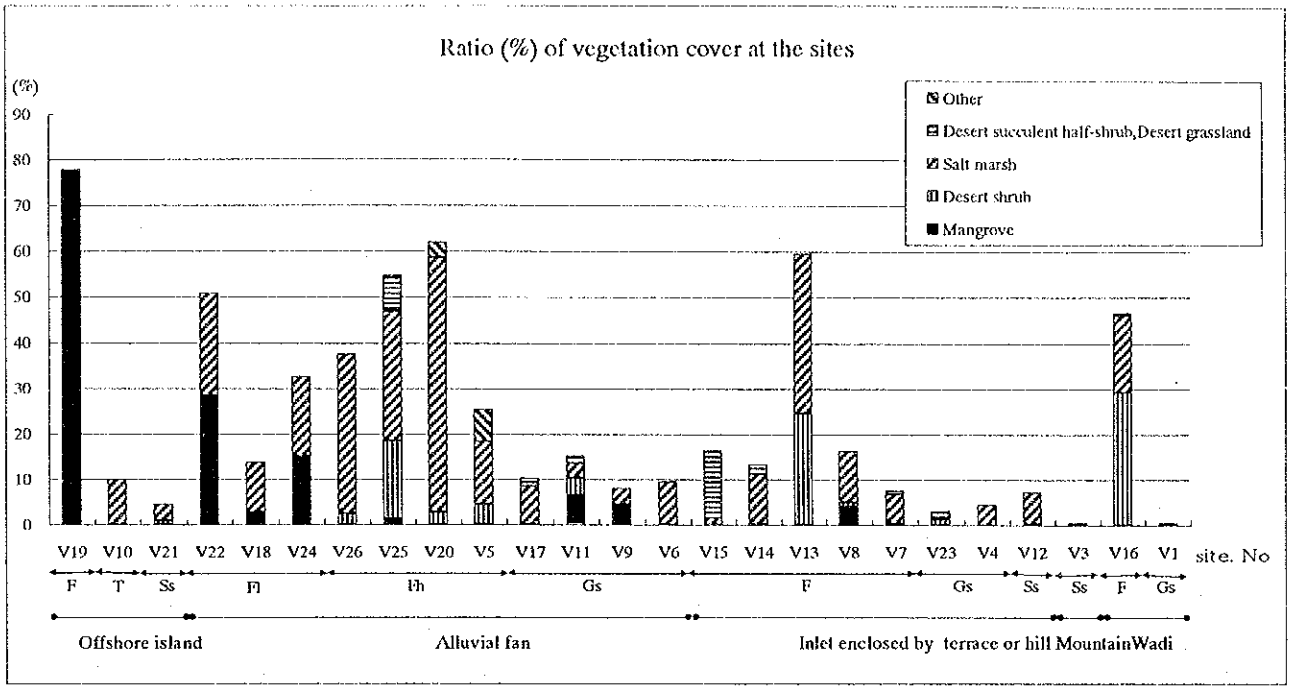
Fig. 34-4. Vegetation maps and profiles (mountains, wadi).

1-3. Vegetation cover

The vegetation cover of the Study Area is very low under the harsh climatic conditions. Additionally, grazing by livestock also influences the degree of plant coverage more or less in all inland sites, except for a conservation area (V24: Yanbu'). The ratios (%) of vegetation coverage at the sites (50 ha : 1,000 m x 500 m) are shown in Table 61 and Fig. 35. The site with the highest vegetation coverage (77.8%) was V19 on the offshore flat island, with its mangrove thickets. Sites with more than 50% vegetation coverage were V20, V22 and V25 (alluvial fan), and V13 (inlet with flats). On the other hand, the sites with the lowest vegetation coverage (0.5%) were V3 (mountain with steep slopes) and V1 (wadi with gentle slopes). On the whole, sites of alluvial fan with flats usually had a high vegetation coverage, and sites of alluvial fan with gentle slopes, and inlet enclosed by terraces or hills, had relatively low vegetation coverage.

1-4. Bio-geography of plant community

The geographical distribution of the community types of the Study Area is shown in Fig. 36. The Study Area covers about 1,000 km long from south to north, with several bio-geographic gradients or patterns. As for mangroves, *Avicennia marina* thickets were widely distributed southward from V8 (Rawd az-Ziyan), located about 8 km north of Duba. *Rhizophora mucronata* was found only in Jazirat Shaybarah (V19) and Duqm Sabq (V18), both in Al-Wajh Bank. *Zygophyllum album* communities were distributed widely from south to north in the Study Area. It was the most widespread plant. *Salvadora persica* and *Seidlitzia rosmarinus* communities were abundant in the area between Al-Wajh and Duba; on the other hand, *Sporobolus spicatus* and *Tamarix nilotica* communities were present in the southern part of the Study Area. These bio-geographical patterns may reflect not only the climatic factors but also the geomorphological features.



F:Flat, Fl:Flat(near sea level), Fh:Flat(slight high in elevation from sea level), T:Terrace of fossil coral, Ss:Steep slope, Gs:Gentle slope

Fig. 35. Ratio (%) of vegetation cover at the sites.

Table. 61. Ratio (%) of vegetation cover at the sites.

	Offshore island			Alluvial fan										Inlet enclosed by terrace or hill								Mountain	Wadi	
Geomorphological type	Flat	Terrace	Steep slope	Flat (sea level)			Flat (slight high)				Gentle slope				Flat					Gentle slope		Steep slope	Steep slope	Flat	Gentle slope
Site.No	V19	V10	V21	V22	V18	V24	V26	V25	V20	V5	V17	V11	V9	V6	V15	V14	V13	V8	V7	V23	V4	V12	V3	V16	V1
Vegetation type (%)																									
Mangrove	77.8			28.2	2.6	15.0		1.3				6.3	4.5					4.0							
Desert shrub			0.8				2.3	17.3	2.7	4.4		4.1				0.2	24.6	1.0	0.2	1.2		0.2		29.3	0.2
Salt marsh		10.0	3.7	22.7	11.1	17.5	35.2	28.4	56.0	13.9	8.5	3.2	3.6	9.4	1.5	11.1	34.9	11.3	6.6	0.6	4.4	7.0	0.5	16.7	0.2
Deset succulent half-shrub,Deset grassland								7.5			1.8	1.5			14.9	2.1			0.7	1.3				0.6	
Other								0.3	3.2	7.0															
Total of vegetation (%)	77.8	10.0	4.5	51.0	13.8	32.6	37.5	54.8	61.9	25.4	10.3	15.1	8.1	9.4	16.4	13.4	59.4	16.2	7.5	3.0	4.4	7.3	0.5	46.6	0.5
Average (%)				32.4			44.9				10.7				22.6					3.7		7.3			
		30.7					29.1													16.0			0.5	23.6	
Barren land (%)		73.7	81.8	41.0	59.0	32.4	62.5	43.4	37.8	73.3	89.7	82.4	80.2	90.6	82.6	86.6	40.6	82.6	81.8	95.0	95.6	79.4	99.5	53.4	99.5
Water (%)	22.2	16.3	13.7	8.0	27.2	35.0		1.8	0.3	1.4		2.5	11.8		1.0			1.1	10.6	1.9		13.4			

Fig. 36. Distribution of dominant species in the Study Area.

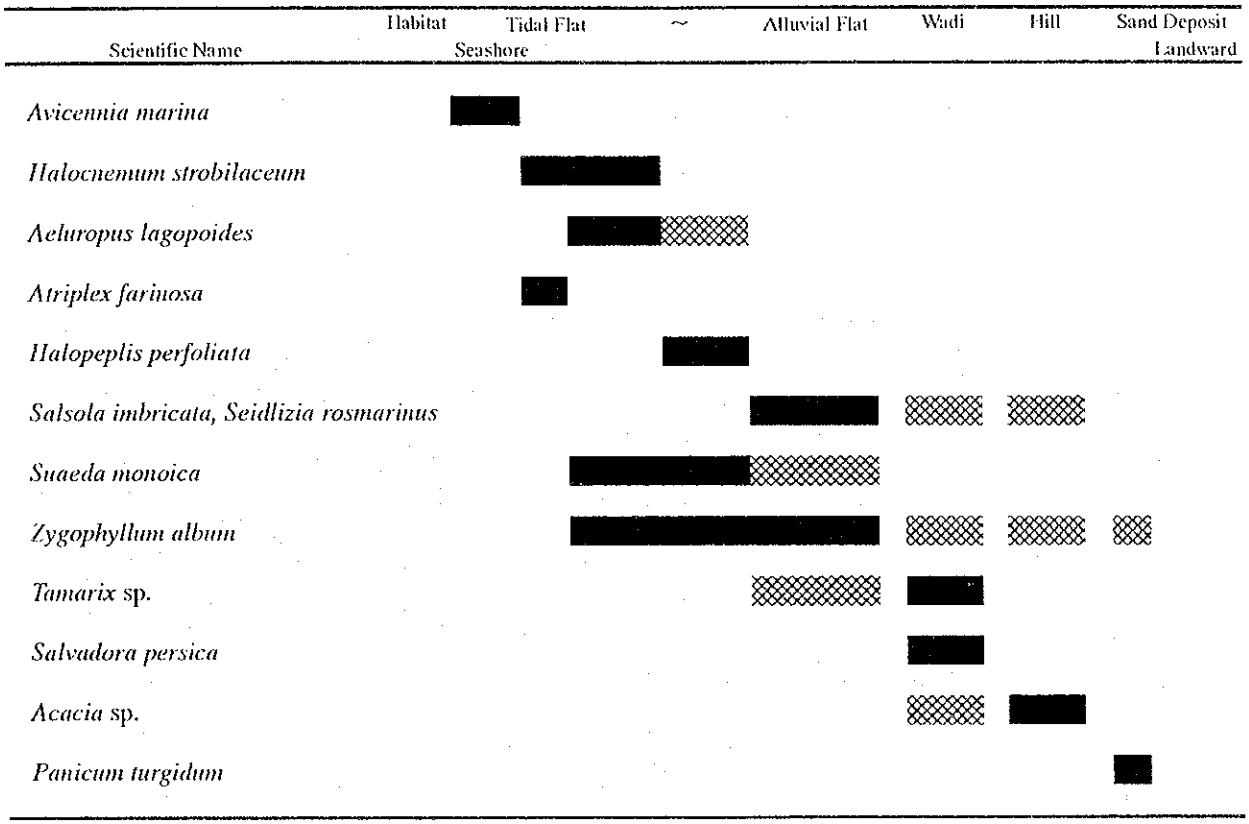
Site. No	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	1	
	South																						North			Frequency
Dominant species	Rabigh					Umluj							Al-Wajh						Duba						Haql	
Mangrove																										
Avicennia marina		--	--		--			--	--							--		--	--							8
Rhizophora mucronata								--	--																	2
Desert shrub																										
Tamarix nilotica	--	--					--				--										--					5
Tamarix aucheriana	--													--												2
Tamarix aphylla											--															1
Salvadora persica													--	--	--					--						4
Acacia tortilis		--		--			--						--	--	--	--		--	--	--	--	--		--	--	14
Acacia ehrenbergiana	--	--		--			--												--	--						6
Succulent salt marsh																										
Zygophyllum album	--	--		--		--	--	--	--			--	--	--	--	--	--	--	--	--	--	--	--	--	--	21
Halocnemum strobilaceum			--		--			--	--	--	--					--		--			--					9
Arthrocnemum macrostachyum		--														--		--	--		--				--	6
Atriplex farinosa						--								--		--	--	--								5
Nitraria retusa							--				--	--	--	--	--				--	--		--	--	--	--	12
Halopeplis perfoliata	--	--			--				--	--	--					--		--								8
Zygophyllum decumbens						--						--	--	--	--				--	--						7
Suaeda monoica	--	--								--	--					--	--	--								7
Limonium axillare		--			--	--				--		--	--		--		--			--						9
Desert succulent half-shrub																										
Salsola imbricata	--	--		--		--				--	--	--				--	--									9
Haloxylon salicornicum											--							--				--			--	4
Seidlitzia rosmarinus																--	--	--			--					4
Grassland salt marsh																										
Aeluropus lagopoides	--	--			--		--				--		--	--		--			--							9
Sporobolus spicatus	--	--					--																			3
Juncus rigidus							--															--				2
Reed																										
Phragmites australis		--													--											2
Typha domingensis															--											1
Desert grassland																										
Panicum turgidum	--	--					--			--		--	--	--	--	--		--	--	--	--					13
Other																										
Phoenix dactylifera		--					--															--				3
Cyperus conglomeratus				--		--	--			--		--	--				--		--	--	--					10

1-5. Zonation

Zonation is a characteristic feature of coastal vegetation. Zonation patterns of the dominant species in the Study Area are shown in Fig. 37. The forming of zonation was observed from seashore to inland at almost all sites. In salt marshes, this is especially very clear due to the tide action and gradient soil conditions such as salinity, humidity and water

level. Although the height pattern of *Avicennia marina* thickets was regular, it seems that the depth of the soil on the fossil coral rock and the edaphic gradient factor limited mangrove growth (height) (Fig. 6).

Fig. 37. Zonation patterns of the dominant species.



※Black: dominant, Shade: present

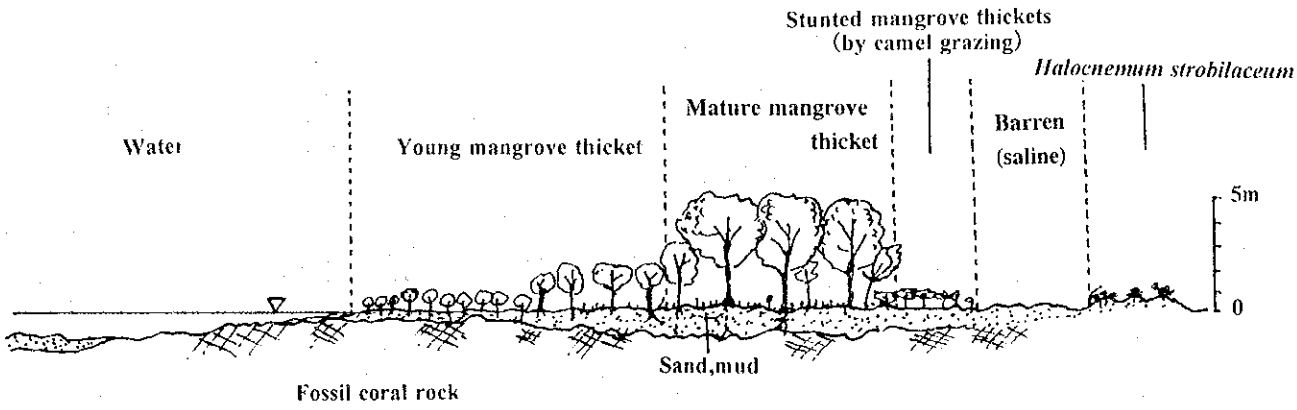
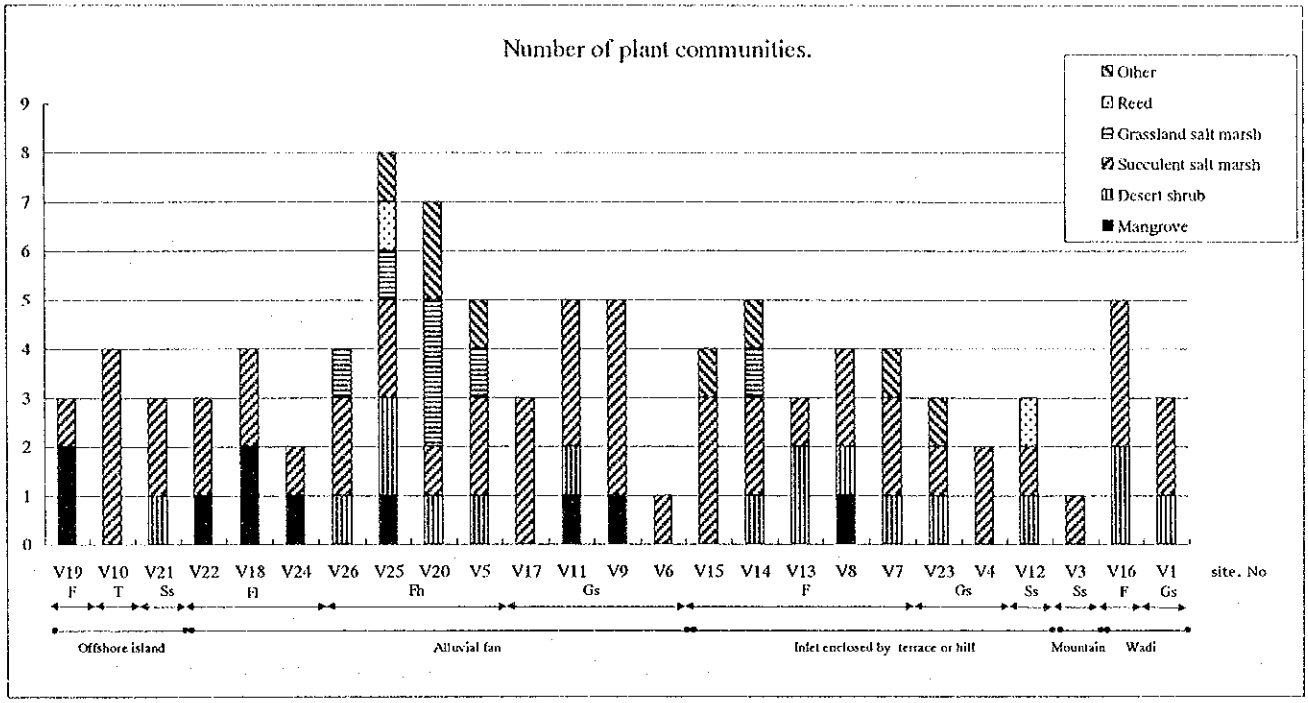


Fig. 38. Zonation pattern of mangrove thickets (*Avicennia marina*).

1-6.Presence of plant communities at the sites

The number of plant communities at the sites is shown in Table 62 and Fig. 39. The number of plant communities and their proportions varied from site to site. The minimum number of communities was only one in V6 and V3, and the maximum was eight in V25. There was almost no vegetation cover at the former two sites. In V6, *Halocnemum strobilaceum* covered only the mouth of a wide wadi because of the high salinity of its soil. In V3, there were only small patches of *Nitraria retusa* at the edge of a steep rocky slope. This may be due to frequent disturbances by active rock movements. On the other hand, various plant communities such as *Avicennia marina* thickets and *Acacia* sp. shrub were distributed in V25, which belongs to the type alluvial fan with an elevation slightly higher than sea level. It seems that underground water is abundant enough to support the growth of various plant communities. The average number of plant communities in each geomorphological type indicates that the alluvial fan is rich in plant diversity (an average of 4.3 communities); alluvial fans with flats slightly higher than sea level in particular have the richest variation of plant communities of all the sites (an average of 6.0 communities).



F:Flat, Fl:Flat(near sea level), Fh:Flat(slight elevation from sea level), T:Terrace of fossil coral, Ss:Steep slope, Gs:Gentle slope

Fig. 39. Number of plant communities in the sites.

Table. 62. Number of plant communities in the sites.

Geomorphological type	Offshore island			Alluvial fan										Inlet enclosed by terrace or hill									Mountain	Wadi	
	Flat	Terrace	Steep slope	Flat (sea level)			Flat (slight elevation)				Gentle slope				Flat					Gentle slope		Steep slope	Steep slope	Flat	Gentle slope
Site.No	V19	V10	V21	V22	V18	V24	V26	V25	V20	V5	V17	V11	V9	V6	V15	V14	V13	V8	V7	V23	V4	V12	V3	V16	V1
Vegetation type																									
Mangrove	2			1	2	1		1				1	1					1							
Desert shrub			1				1	2	1	1		1				1	2	1	1	1		1		2	1
Succulent salt marsh	1	4	2	2	2	1	2	2	1	2	3	3	4	1	3	2	1	2	2	1	2	1	1	3	2
Grassland salt marsh							1	1	3	1						1									
Reed								1														1			
Other								1	2	1					1	1			1	1					
Total	3	4	3	3	4	2	4	8	7	5	3	5	5	1	4	5	3	4	4	3	2	3	1	5	3
Average			-	3			6				3.5				4					2.5		3			
	3.3			4.3											3.5								1	4	

2. Flora

2-1. Flora of the Study Area

From the results of the preliminary survey and the inventory survey of 26 sites, 159 vascular plants (43 families) including two mangrove species were recorded (Separate Volume 1). The list of specimens collected is shown in Appendix 13.

The flora of the Study Area was mainly characterised by halophytes and xerophytes, due to the harsh climate and the soil conditions. Halophytes are plants characteristic of coastal areas as they have tolerance to high soil salinity influenced by tidal action. Halophytes in the Study Area were represented by CENOPODIACEAE (e.g. *Halocnemum strobilaceum, Halopeplis perfoliata, Arthrocnemum macrostachyum, Suaeda vermiculata, Salsola imbricata, Atriplex farinosa*), ZYGOPHYLLACEAE (e.g. *Zygophyllum album, Z. boulosii, Z. decumbens*) and GRAMINEAE (e.g. *Aeluropus lagopoides, Sporobolus spicatus, Phragmites australis*). These halophytes were abundant in frequency and number and formed salt marsh communities in the Study Area, though plant coverage was not so high.

Xerophytes in the Study Area represented by LEGUMINOSAE (e.g. *Acacia* sp., *Senna* sp., *Indigofera* sp.), CAPPARACEAE (e.g. *Cadaba* sp., *Capparis* sp., *Cleome* sp.) and EUPHORBIACEAE (e.g. *Chrozophora oblongifolia, Euphorbia* sp.), were not abundant or dominant except for scattered desert shrubs of *Acacia* sp. These xerophytes grew sometimes in sandy or rocky deserts areas as an accompanying species to desert shrubs and desert grasslands, but most xerophytes were present individually, adapting to microhabitats such as a drift beside a cliff, concaves and small depressions with slight differences in elevation.

Some plants were distinctive to particular sites. For example, *Cadaba glandulosa, Cornulaca ehrenbergii* and *Acacia orerfota* were recorded only on the mountainous island of site V21 (Jazirat Jabal Hassan). *Ziziphus spina-christi* and *Zilla spinosa* were present only at V1 (Al-Durah), the northernmost site in the Study Area. V2 (Taip esim) was a unique site

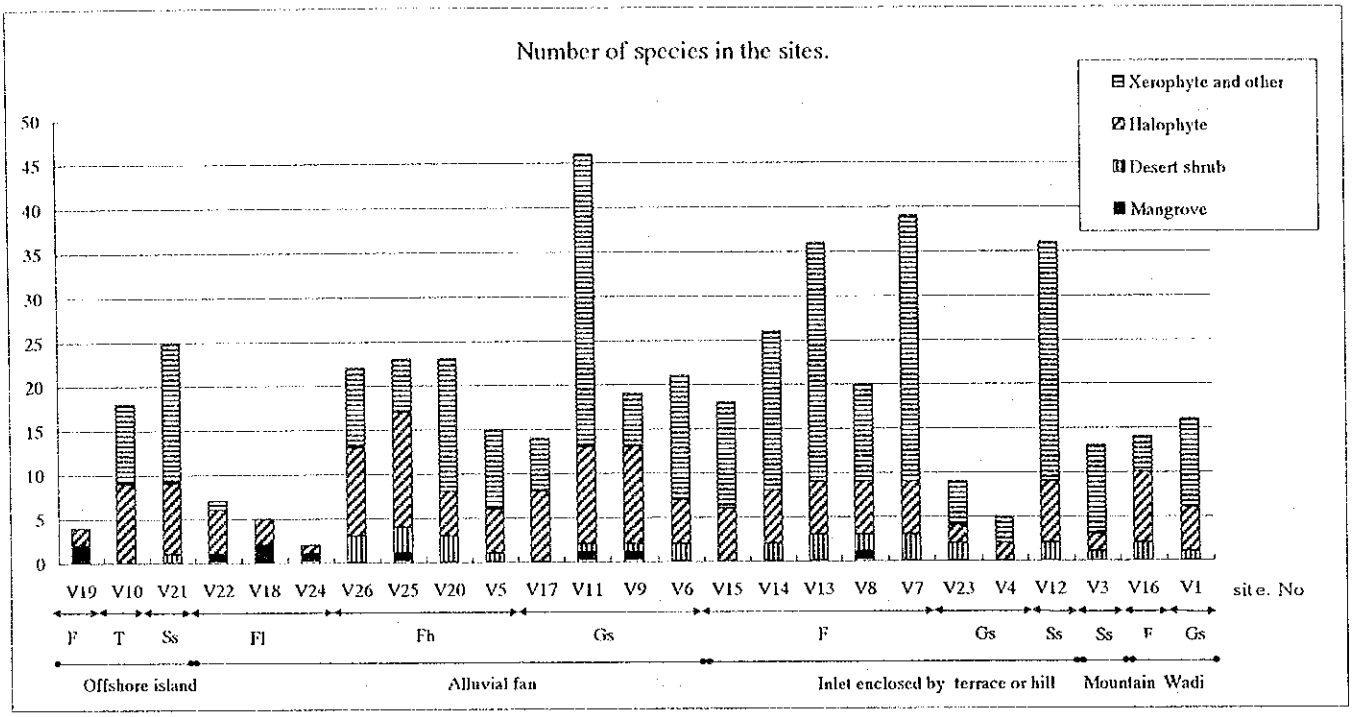
with a narrowbottomed gorge formed with vertical valley walls. There were a couple of rare plants in this site V2, such as *Solenostemma arghel, Bacopa monnieri, Hyoscyamus albus,* and *Blumea* sp. As mentioned above, the sites with characteristic and / or unique geomorphological features tend to have their own flora.

2-2. Number of species in the sites

The number of species in the sites arranged by geomorphological types is shown in Table 63 and Fig. 40. The number of species at each site varied from 2 (minimum) to 44 (maximum). There were only two species (*Avicennia marina, Halocnemum strobilaceum*) in V24 (Yanbu'), which is an alluvial sandy flat near sea level. Sites of alluvial fan or offshore island with sandy flats affected by inundation may not support various habitats. In these monotonic habitat sites (V18, V19, V22, V24), the number of species was usually less than seven, and the flora of these sites consisted entirely of mangroves and halophytes. Thus species diversity is usually low in sites dominated by *Halocnemum strobilaceum* and / or *Avicennia marina* which have a high salinity tolerance. On the other hand, at V11 (Zubaydah), there was a wide variety of habitats including alluvial flats at the mouth of the wadi, and low hills with many undulations. At this site 44 species in total were recorded. The second highest number of species was 39 species at V7 (Sharm al-Badu) which also supports heterogeneous habitats such as alluvial flats, coral fossil terrace and sand deposits beside a coral cliff. On the whole, the sites comprising an inlet enclosed by terrace and hill can support diverse species (23.6 species on average), and an alluvial fan with sea level flats does not have much diversity (4.7 species on average).This indicates that habitat variation is a very important factor for species diversity at each site.

2-3. Endemic and / or endangered plants

There were two published lists concerning endemic and / or endangered plants in



F:Flat, Fl:Flat(near sea level), Fh:Flat(slight elevation from sea level), T:Terrace of fossil coral, Ss:Steep slope, Gs:Gentle slope

Fig. 40. Number of species in the sites.

Table. 63. Number of species in the sites.

	Offshore island			Alluvial fan											Inlet enclosed by terrace or hill								Mountain	Wadi	
Geomorphological type	Flat	Terrace	Steep slope	Flat (sea level)			Flat (slight elevation)				Gentle slope				Flat					Gentle slope		Steep slope	Steep slope	Flat	Gentle slope
Site.No	V19	V10	V21	V22	V18	V24	V26	V25	V20	V5	V17	V11	V9	V6	V15	V14	V13	V8	V7	V23	V4	V12	V3	V16	V1
Plant group																									
Mangrove	2			1	2	1		1				1	1					1							
Desert shrub			1				3	3	3	1		1	1	2		2	3	2	3	2		2	1	2	1
Halophyte	2	9	8	5	3	1	10	13	5	6	8	11	11	5	6	6	6	6	6	2	2	7	2	8	5
Xerophyte and other		9	17	1			8	6	15	9	6	31	6	15	13	18	26	11	29	6	3	27	10	4	10
Total	4	18	26	7	5	2	21	23	23	16	14	44	19	22	19	26	35	20	38	10	5	36	13	14	16
Average				4.7			20.8				24.8				27.6					7.5		36			
		16.0					17.8													23.6			13		15

Saudi Arabia. According to COLLENETTE (1998), 156 out of 246 endemic species are endangered, and a further 500 non-endemic species are also endangered in Saudi Arabia. FARHAN (1998) also tentatively selects 103 endangered species. He regards these plants as some of the most endangered or rare species in Saudi Arabia.

Through the field survey, 12 endemic and/or endangered plants included in these lists were found in the Study Area. Of these, eight species, consisting of three endemic/not endangered and five non-endemic / endangered plants, were included in the COLLENETTE list. In addition to these plants, four species from FARHAN's list were found (Table 64).

Table 64. The distribution of the endemic and / or endangered plants in the Study Area.

				Site	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Frequ -ence
		Literature			Rabigh						Umluj					Al-Wajh						Duba							Haql		
No.	Scientific name	①	②																												
1	*Zygophyllum boulosii*	+															--								--					2
2	*Salvadora persica*		L													--	--	--					--							4
3	*Ziziphus spina-christi*	#																											--	1
4	*Sphaerocoma aucheri*	#													--	--	--	--	--	--	--	--	--							8
5	*Cornulaca ehrenbergii*	#								--																				1
6	*Acacia ehrenbergiana*		L	--	--		--				--												--	--						6
7	*Acacia oerfota*	+								--																				1
8	*Acacia tortilis*		L			--		--			--						--	--	--	--	--		--	--	--	--		--	--	--	15
9	*Taverniera lappacea*	#			--																	--		--							3
10	*Rhizophora mucronata*		V									--	--																		2
11	*Convolvulus asyrensis*	+																							--						1
12	*Hyoscyamus albus*	#	-																										--		1
	Number of species		8	4																											

①: COLLENETTE 1998. ②: FARHAN 1998.
+ : Endemic / not endangered, # : Non-endemic / endangered, L : Lower risk, V : Vulnerable.

1). Endemic / not endangered plants in COLLENETTE's list

Three endemic / not endangered plants (COLLENETTE 1998), - *Zygophyllum boulosii*, *Acacia oerfota* and *Convolvulus asyrensis* were recorded in two sites only. *Zygophyllum boulosii* was usually present adjacent to a *Zygophyllum album* community (V5,V13). *Acacia oerfota* formed shrubs at the bottom of small wadi on the mountainous island (V21). *Convolvulus asyrensis* was found at the small concave in V6 with low vegetation cover. These

three plants were found as a couple of individuals.

2). Non-endemic / endangered plants in COLLENETTE's list

Five non-endemic /endangered plants (COLLENETTE 1998) were recorded in the Study Area. *Ziziphus spina-christi, Hyoscyamus albus and Cornulaca ehrenbergii* were observed at particular sites (V1, V2, V21, respectively) namely a rocky wadi, sandy beach of a mountainous island and the bottom of a narrow valley. *Sphaerocoma aucheri* was found in eight sites located in the area from Duba to Al-Wajh. *Taverniera lappacea* was found in the small depressions of three sites (V7, V10, V26).

3). Lower risk plants in FARHAN's list

The three lower risk plants recorded in FARHAN's list (*Acacia tortilis, Acacia ehrenbergiana* and *Salvadora persica*) are relatively widespread in Saudi Arabia, where these shrub-like plants are threatened by wood cutting and camel grazing (Table 9). *A. tortilis* and *A. ehrenbergiana* were commonly the dominant species of open shrubs in desert wadis and on hills with gentle slopes in the Study Area. Most of them were grazed so intensively by camels that the shape was like an inverted umbrella. The other species at lower risk, *Salvadora persica*, grew in four sites between Duba and Al-Wajh. *S. persica* formed low and dense shrubs in wide wadis facing inlets, and it also was damaged by camel grazing at every site.

4). Vulnerable plants in FARHAN's list

The distribution of a vulnerable plant in FARHAN's list, *Rhizophora mucronata*, is limited to some offshore islands in Saudi Arabia (Table 65). It was recorded in only two sites in the Study Area.V19 (Jazirat Shaybarah) is one of the offshore coral flat islands in Al-Wajh Bank. V18 (Duqm Sabq) is an alluvial sandy flat facing Al-Wajh Bank located about 70 km north of Umluj town, and is the only place on the mainland where *R. mucronata* was recorded. *R. mucronata* formed small patches along creeks and on the inland sides in shallow water, and it was surrounded by *Avicennia marina*. The habitat of *R. mucronata* tend to have little wave

action and sea breezes.

Table 65. Summary of plants recorded in FARHAN's list (1998).

Scientific Name	Status in Saudi Arabia	Distribution	Species Value	Threat
Acacia tortilis Acacia ehrenbergiana (Leguminosae)	Lower risk (least concern)	All over the country except in sandy deserts	An important member of the desert ecosystems, especially in valley.	Wood cutting
Salvadora persica (Salvadoraceae)	Lower risk (least concern)	South western region, Quinfudah	Its roots and stems are widely used in Arabia and elsewhere as an effective tool for cleaning teeth. The bark is reported to be an effective agent for removing plaque from teeth.	The unsustainable collection of roots and stems by traders and the camel grazing pressure on only the Salvadora thickets in the Quinfudah area have a negative effect on its survival.
Rhizophora mucronata (Rhizophoraceae)	Vulnerable	Farasan and Dumsaq Islands	An important member of the coast line ecosystem. It supports both marine life and sea birds for breeding as and nesting.	Seafront earth filling, wood cutting

2.1.7.4. Discussion

The value of the sites for plants and vegetation was evaluated in order to select the Model Study Area. The evaluation was based on the results of the field survey from the following points of view: biological diversity (the number of species), endemism and / or endangered species and biomass (plant coverage). The surveyed sites are so varied and complicated that evaluation was conducted for each geomorphological type using three ranks: high, middle and low (very low). The results of the evaluation are shown in Table 66.

1. Biological diversity

From the point of view of biological diversity, two geomorphological types, offshore island with steep slopes and inlet enclosed by fossil coral terraces are considered to be of high value, because the number of species in such sites was usually high with more than 25 species. On the other hand, the geomorphological types influenced by tidal change such as the

offshore flat islands and alluvial fans with flats near sea level, are regarded as low value because of the low number of species.

2. Endemic and / or endangered species

In terms of endemism and / or endangered species, an inlet enclosed by fossil coral terraces with wadi is the richest geomorphological type, having endemic and /or endangered plants such as *Salvadora persica, Sphaerocoma aucheri* and *Acacia tortilis*. This geomorphological type is found in the area between Duba and Al-Wajh. Also offshore flat islands with the vulnerable species *R. mucronata* are considered of a high value.

3. Biomass and productivity

With regard to biomass and productivity, offshore flat islands occupied by mangrove thickets (*A. marina* and *R. mucronata*) are the most important habitat. Additionally wide flat wadis and some inlets enclosed by fossil coral terraces with wadi also support a high biomass with shrubs of *Salvadora persica*, *Acacia* sp. and *Tamarix* sp., though the plant coverage is not very high compared with mangrove thickets.

4. Total evaluation

As a whole, the offshore flat islands including mangroves and inlets enclosed by fossil coral terraces with wadi were evaluated as being very valuable areas for plants.

Table 66. Evaluation of the sites by three criteria.

Geomorphological type	Main landform	Number of sites	Diversity	Endemism	Biomass	Total Evaluation
Offshore island	Flat	1	Low	High	High	High
	Terrace	1	Middle	Low	Low	Low
	Steep slope	1	High	Low	Low	Middle
Alluvial fan	Flat (near sea level)	3	Low	Middle	Middle	Middle
	Flat (slight elevation)	4	Middle	Low	Middle	Middle
	Gentle slope	4	Middle	Middle	Low	Middle
Inlet enclosed by fossil coral terrace	Flat (mouth of wadi)	5	Middle	High	Middle	High
	Gentle slope	2	Low	Low	Low	Very low
	Steep slope	1	High	Low	Low	Middle
Mountain	Steep slope	1	Low	Low	Low	Very low
Wadi	Flat	1	Low	Low	High	Middle
	Gentle slope	1	Middle	Low	Low	Low

Note Diversity: species diversity, Endemism: endangered plants, Biomass: plant coverage, Total evaluation: High: including more than 2 categories in 'High', Middle: including at least 1 category in 'High', Low: including 2 categories in 'Low' and 1 category in 'Middle', Very low: 3 categories in 'Low'.

5. Selection of a Model Area

As for geomorphological type, the offshore flat islands with mangroves, and inlets enclosed by fossil coral terrace with wadi are evaluated as being very valuable areas for plants. The Study Area divided into six areas was evaluated according to the three criteria on the basis of these results. Thus, Duba / Al-Wajh and Al-Wajh / Umluj were given high value points overall (Table 67). As far as plants are concerned, these areas could be regarded as suitable areas in which to conduct the Model Study.

Table 67. Assessment of the Study Area.

Area / Criteria	Gulf of Aqaba	Tiran	Duba / Al-Wajh	Al-Wajh / Umluj	Umluj / Ra's Baridi	Yanbu' / Jeddah
Diversity	1	2	3	1	2	2
Endemic or endangered plants	1	1	3	3	1	1
Biomass	1	1	2	3	1	2

3: very good, 2: good, 1: bad.

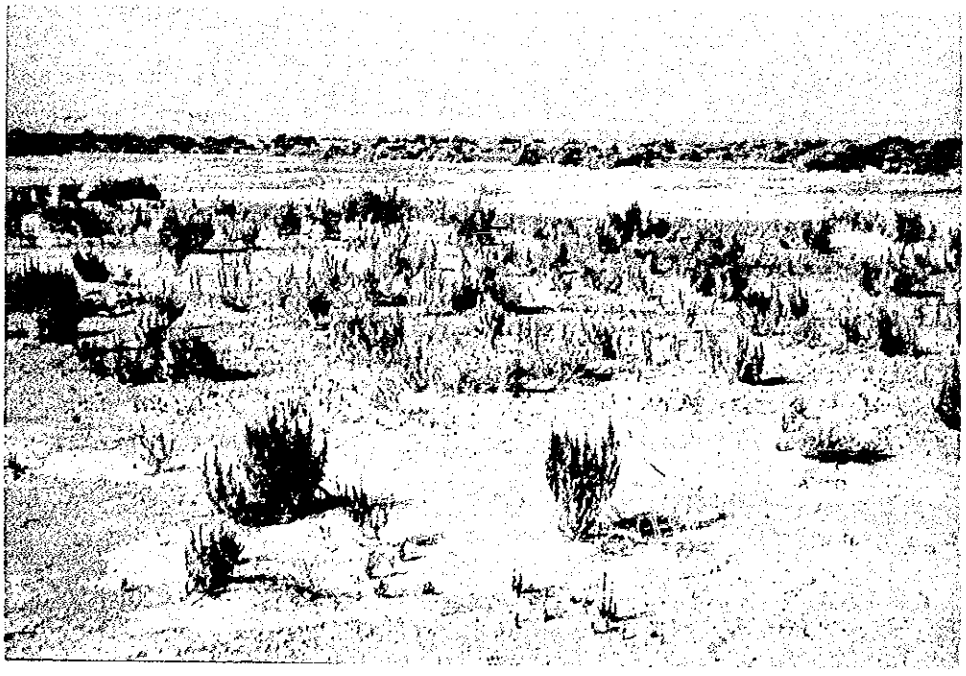
Photo. 5-1. Mangroves / Coastal Vegetation

1. *Zygophyllum album* is widespread in the coastal area under the wide range of soil conditions (Sharm 'Antar, 14 June 1998).

2. *Halocnemum strobilaceum* community of the salty flat in front of the mangrove forest Al-Quff, 16 June 1998).

3. *Atriplex farinosa* community (in the right side of the photograph; whitish green plant) on the sand beach, adjacent to *Halocnemum strobilceum* community (Al-Quff, 16 June 1998).

Photo. 5-2. Mangroves / Coastal Vegetation



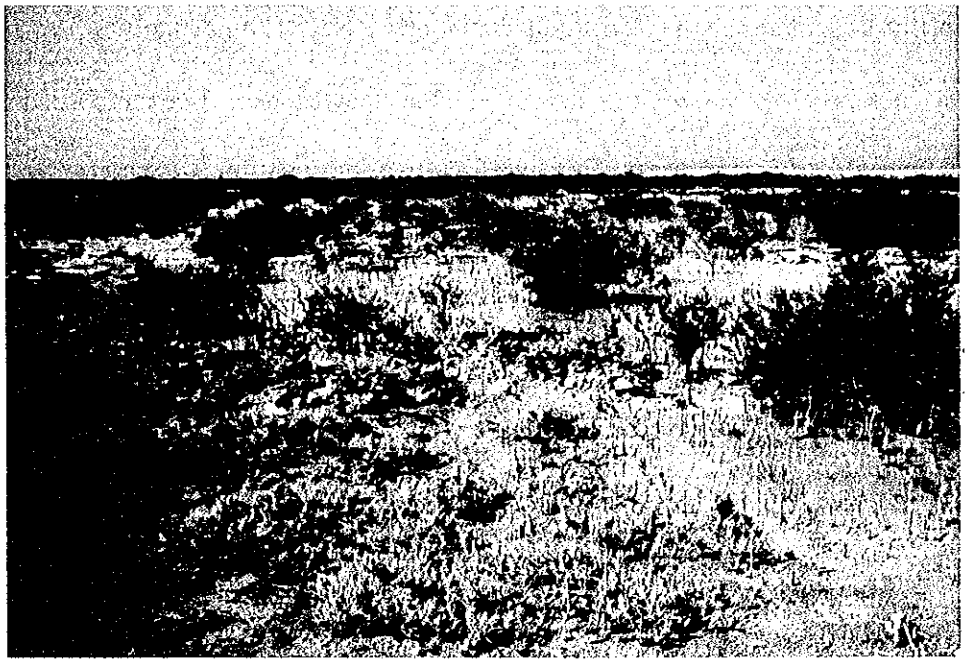
4. *Halopeplis perfoliata* community with low cover on the salty sand flat (Al-Q 16 June 1998).

5. *Panicum turgidum* community on the sand de beside the coral fossil cliff (Habban, 9 June 1998).

6. *Tamarix arabica* forming scattered shrub in the inlan area of the site (Wadi al-Ha 25 May 1998).

Photo. 5-3. Mangroves / Coastal Vegetation

7. *Juncus rigidus* community or the saline sandy beach (Sharma 21 June 1998).



8. *Avicennia marina* young shrub on the alluvial sandy flat adjacent to the *Halocnemum strobilaceum* community (Ash-shabban, 28 May 1998). The height of *Avicennia marina* ma be regulated by the depth of soils.

9. *Avicennia marina* mature forest on the tidal mud (Al-Quf 16 June 1998). The edge of the forest is damaged by grazing.

2.1.8. BIRDS

2.1.8.1. Introduction

The avifauna of Saudi Arabia includes elements of the Palearctic, Afrotropical and Indo-Malaysian regions (CHILD & GRAINGER 1990). In the northern part of the Red Sea coast area, the avifauna is dominated by Palearctic species, and a few Afrotropical species have been recorded (JENNINGS 1995).

The avifauna of Saudi Arabia has been studied for a long time but the harsh climate and poor accessibility to some areas have limited systematic study. The northern part of the Red Sea coast has not been systematically surveyed. 288 species have been recorded in Yanbu' including coastal and inland areas (BALDWIN & MEADOWS 1987). JENNINGS (1995) describes the coastal and mountainous areas of the northern part of the Red Sea as "Northern Tihama", says and that the bird species diversity "is very poor, even compared to the Northern Plains due, no doubt, to greater aridity and poorer vegetation". 81 species are listed as breeding species (all records except for the species which have negative evidence) in the Northern Tihama (JENNINGS 1995).

BALDWIN & MEADOWS (1987) classified the coastal habitats into the following two categories; 1. upper salt-marsh and 2. mangroves, flats and reefs. Of these habitats, mangroves are important for birds, providing safe feeding, nesting and roosting places for many of them (BALDWIN & MEADOWS 1987, LOBLEY).

The conditions for breeding and feeding in the area are very harsh, which makes it necessary for birds to migrate; and the Arabian peninsula is a crossroads for birds migrating between Eurasia, Africa and the Indian sub-continent (BALDWIN & MEADOWS 1987). Migration time is especially busy in March / April and September / October (LOBLEY).

A general description of sea birds in the Red Sea region is given and 46 species including 16 breeding species are listed by EVANS (1987). Sea bird colonies on the islands

were well surveyed during their breeding season by NCWCD (NEWTON *et al.* 1996) using aircraft. Since this Study focuses mainly on terrestrial bird species and the range of the Study Area extends from the water's edge out to one kilometre landward, seabird colonies and their breeding status were not a main target of the Study.

2.1.8.2. Methods

The Birds team coordinated its field survey work closely with the Mangrove / Coastal Vegetation team in order to understand the area's avifauna together with the vegetation on which the bird species depend heavily for their survival.

In the Preliminary Study of February 1998, observation surveys were conducted in order to record as many species as possible. In this survey, no route or site was set up due to a lack of time. The team mobilised a car to run through the whole study area and recorded all observed species. The whole study area was divided into five areas in order to show the rough distribution of the recorded bird species.

In the inventory survey (Phase II), one or two spots were selected at each site on the basis of their vegetation coverage. In the summer survey, at each spot (the area of a spot is approximately 500m x 1,000 m), a census was conducted for about 0.5 – 1.5 hours, and all species and their numbers were recorded. A census route was not set up beforehand, but the observers walked through each spot carefully so as not to overlap observation ranges or count the same individuals twice. All the species observed in and around a site were recorded (this is recorded as a 'spot' record) to create a site record. In the autumn survey, observation surveys were conducted in order to record as many species as possible. At each spot, no route was set up and observers walked around to observe as much as possible (Appendix 14).

The mist netting method was applied at one site in October 1998 in the morning and late afternoon for two days.

In the Model Study (Phase III), additional data was incorporated into the biological inventory.

Binoculars of 10 x 40 and 8 x 30, and a 24 x 60 telescope were used for the survey. In the autumn survey, mist nets were used to capture and ring birds. The bird list is based on the checklist in PORTER et al. (1996).

2.1.8.3. Results

1. General

In February 1998, 82 species were recorded in the Study Area. In May – June 1998, 64 species were recorded at 21 sites, and five other species were recorded outside the sites. In October 1998, 86 species were recorded at 10 sites, and three species were recorded outside the sites. Although the number of individual species observed in the spots were recorded, the information is still not sufficient to indicate their abundance accurately, and the numbers in this report should be used with care. Mist netting was used at one site in October. All captured birds were ringed and released. Six species (eight individuals) were captured and recorded.

As a result of the field survey of Phase II and the Preliminary Study, 134 species were recorded in the Study Area.

In Phase III, an inventory study was also conducted in the Model Area (Al-Wajh Bank). 43 species including six unidentified species were recorded in February 1999, and 34 species including three unidentified species were recorded in June 1999. Red-rumped Swallow *Hirundo daurica* was added to the biological inventory, and 135 species were identified during the whole Study period.

The following sections describe the results of the Preliminary Study and Phase II. The data from Phase III are slightly different from other data in their nature, and they will be described in 2.2.9.

2. Areas, Sites and species

In February it seemed that more species were observed in the northern section than in the southern section of the Study Area (Table 68). However, it is important to note that not enough time was allocated to conduct surveys in the southern part because of the tight schedule.

Distribution of wintering birds seems to differ between the northern and southern sections. Great Black-headed Gull *Larus ichithyaetus*, Yellow-legged Gull *L. cachinnans*, Desert Lark *Ammomanes deserti*, and Blackstart *Cercomela melanura* were often observed in the northern section (a, b, c), but were not observed in the other sections. Crab Plover *Dromas ardeola* and Black Kite *Milvus migrans* were observed in the southernmost area (e) but were not observed in other sections. Although the differences in climatic conditions and geographical features could be the reason, further studies will be required to reach a conclusion and to provide clear distribution patterns of wintering birds in the Study Area.

Table 68. Areas and species.

No.	Area name	Start		End		Number of species
		Latitude (N)	Longitude (E)	Latitude (N)	Longitude (E)	
a	Maqna to Zubaydah	28° 22′ 18″	34° 43′ 44″	26° 54′ 14″	36° 02′ 05″	47
b	Sharm 'Antar to Wadi Marakh	26° 36′ 01″	36° 15′ 26″	25° 16′ 27″	37° 08′ 56″	43
c	Wadi Marakh to Sharm Hisay	25° 16′ 27″	37° 08′ 56″	24° 37′ 40″	37° 20′ 00″	50
d	Ra's al-Mukharraf to Masturah	24° 16′ 27″	37° 31′ 31″	23° 04′ 07″	38° 48′ 44″	35
e	Rabigh to Tuwal	22° 46′ 22″	38° 58′ 41″	22° 17′ 24″	39° 05′ 44″	32

In May – June and October, a total of 24 sites were surveyed, seven of them being surveyed in both seasons (Table 69: three sites were surveyed in Phase III). The sites which were surveyed in both seasons (site 4, 8, 10, 11, 21, 26 and 27) had more species than the

other sites. This is because many migratory species were recorded in October (see 5. *Seasonality*).

Table 69. Sites and species.

Site number	Site name	Latitude (N)	Longitude (E)	Number of species
1	Al-Durah	29° 20′ 26″	34° 57′ 07″	19
2	Maqna	28° 22′ 18″	34° 43′ 44″	3
3	Ash Shaykh Humayd	28° 06′ 00″	34° 35′ 41″	7
*4	Sharma	28° 02′ 37″	35° 13′ 46″	24
5	Ash Sharma	28° 01′ 27″	35° 12′ 09″	9
6	Sharm al-Badu	27° 35′ 24″	35° 32′ 22″	10
7	Rawd az-Ziyan	27° 25′ 49″	35° 36′ 09″	18
*8	Al-Quff	27° 08′ 11″	35° 47′ 39″	30
9	Jazirat an Numan	27° 07′ 58″	35° 45′ 09″	11
*10	Zubaydah	26° 54′ 14″	36° 02′ 05″	35
*11	Sharm 'Antar	26° 36′ 01″	36° 15′ 26″	38
12	Sharm Haramil	26° 22′ 27″	36° 22′ 21″	7
13	Habban	26° 03′ 40″	36° 35′ 43″	5
14	Wadi al-Hamd	25° 57′ 33″	36° 43′ 31″	5
15	Al-Muraysi	25° 50′ 26″	36° 41′ 06″	5
16	Duqm Sabq	25° 36′ 11″	36° 57′ 53″	16
20	Jazirat Shaybarah	25° 24′ 52″	36° 53′ 25″	8
*21	Duqum	25° 07′ 18″	37° 15′ 46″	34
22	Jazirat Jabal Hassan	24° 57′ 11″	37° 06′ 04″	10
23	Ash Shabaan	24° 47′ 38″	37° 10′ 29″	11
24	Marsa al-Khawr	24° 17′ 20″	37° 38′ 06″	9
25	Yanbu'	23° 55′ 38″	38° 17′ 43″	15
*26	Masturah	23° 04′ 07″	38° 48′ 44″	45
*27	Rabigh	22° 46′ 22″	38° 58′ 41″	14

Note: Site numbers with asterisks indicate that the sites were surveyed in both seasons.
Site 17 (Duqm Sabq – 2), 18 (Jazirat Qumma'an) and 18 (Qara'ir) were surveyed in Phase III.

Table 70 shows vegetation coverage and the number of species at each site in May – June. The number of species at each site does not correlate with the vegetation coverage.

Abundance of species may depend on the composition of vegetation at a site rather than its coverage (see *7. Habitats and their species*).

Table 70. Vegetation coverage and species abundance.

Site number	Site name	Vegetation cover (%)	Number of species
2	Maqna	0	3
3	Ash Shaykh Humayd	4	7
4	Sharma	25	11
5	Ash Sharma	9	9
6	Sharm al-Badu	8	10
7	Rawd az-Ziyan	16	18
8	Al-Quff	8	20
9	Jazirat an Numan	10	11
10	Zubaydah	15	17
11	Sharm 'Antar	59	11
12	Sharm Haramil	13	7
13	Habban	16	5
14	Wadi al-Hamd	47	5
15	Al Muraysi	10	5
20	Jazirat Shaybarah	78	8
21	Duqum	62	22
22	Jazirat Jabal Hassan	4	10
23	Ash Shabaan	51	11
24	Marsa al-Khawr	3	9
26	Masturah	55	19
27	Rabigh	38	6

Note: Data on the vegetation coverage was provided by the Mangrove / Coastal Vegetation team.

3. Most commonly - seen species

The number of sites and areas where each species was recorded were counted in order to identify the most commonly seen species in the Study Area (Table 71). The Crested Lark *Galerida cristata* was the most commonly seen species throughout the three seasons and

the entire Study Area.

In February, or species such as Striated Heron *Butorides striatus*, Lesser Sand Plover *Charadrius mongolus*, Grey Plover *Pluvialis squatarola*, Sanderling *Calidris alba*, Redshank *Tringa totanus*, Great Black-headed Gull *Larus ichthyaetus*, Slender-billed Gull *L. genei*, Yellow-legged Gull *L. cachinnans*, Swift Tern *Sterna bergii*, African Rock Martin *Ptyonoprogne fuligula*, and Desert Wheatear *Oenan deserti* were also often recorded in the Study Area.

Table 71. Most commonly seen species in the Study Area.

English name	Scientific name	Number of sites and areas where species was recorded
Crested Lark	*Galerida cristata*	25
Western Reef Heron	*Egretta gularis*	20
Kentish Plover	*Charadrius alexandrinus*	20
Sooty Gull	*Larus hemprichii*	19
Hoopoe Lark	*Alaemon alaudipes*	18
Great Grey Shrike	*Lanius excubitor*	18
Brown-necked Raven	*Corvus ruficollis*	18
Osprey	*Pandion haliaetus*	16
Yellow-vented Bulbul	*Pycnonotus xanthopygos*	16
CaspiAntarn	*Sterna caspia*	15
Crab Plover	*Dromas ardeola*	14
Graceful Prinia	*Prinia gracilis*	14
Curlew	*Numenius arquata*	13
Laughing Dove	*Streptopelia senegalensis*	13
Barn Swallow	*Hirundo rustica*	13
Blackstart	*Cercomela melanura*	12
House Sparrow	*Passer domesticus*	12
Grey Heron	*Ardea cinerea*	11
White-eyed Gull	*Larus leucophthalmus*	11
Rock Dove	*Columba livia*	11
Collared Dove	*Streptopelia decaocto*	11
Greater Sand Plover	*Charadrius leschenaultii*	10
Turnstone	*Arenaria interpres*	10
Lesser Crested Tern	*Sterna bengalensis*	10
Desert Lark	*Ammomanes deserti*	10

4. Species of interest

4-1. Breeding species

Breeding categories are based on ABA Breeding Evidence Code (JENNINGS 1995).

There were only two species for which breeding was confirmed; Kentish Plover *Charadrius alexandrinus* and Sooty Gull *Larus hemprechii*. Downy young of Kentish Plover were recorded at several sites, and a nest with a Sooty Gull egg was observed on Jazirat an Naman.

The following species were categorised as "probable breeding"; Osprey *Pandion haliaetus*, Little Green Bee-eater *Merops orientalis*, Hoopoe Lark *Alaemon alaudipes*, Crested Lark *Galerida cristata*, African Rock Martin *Ptyonoprogne fuligula*, Yellow-vented Bulbul *Pycnonotus xanthopygos*, White-crowned Black Wheatear *Oenanthe leucopyga*, Graceful Prinia *Prinia gracilis*, and House Sparrow *Passer domesticus*.

The following species were categorised as "possible breeding"; Collared Dove *Streptopelia decaocto*, Laughing Dove *S. senegalensis*, African Reed Warbler *Acrocephalus baeticatus*, and Clamorous Reed Warbler *A. stentores*.

The survey was conducted from the middle of May to the end of June, and this could be the reason only two breeding species were confirmed.

4-2. Wintering species

The following 20 species were recorded only in February 1998. However, some of them are residents and happened to be observed only in February. The names with asterisks (15 species) are thought to be only wintering in the Study Area.

*Steppe Eagle *Aquila nipalensis*, Black-winged Stilt *Himantopus himantopus*, Cream-coloured Courser *Cursorius cursor*, *Lesser Sand Plover *Charadrius mongolus*, *Caspian Plover *C. Asiaticus*, *Sanderling *Calidris alba*, *Curlew Sandpiper *C. ferruginea*, *Bar-tailed Godwit *Limosa lapponica*, *Great Black-headed Gull *Larus ichithyaetus*, *Black-

headed Gull *L. ridibundus*, *Lesser Black-backed Gull *L. fuscus*, *Yellow-legged Gull *L. cachinnans*, *Armenian Gull *L. armenicus*, Sooty Tern *Sterna fuscata*, Ring-necked Parakeet *Psittacula krameri*, *Lesser Short-toed Lark *Calandrella rufescens*, *Tawny Pipit *Anthus campestris*, *Isabelline Wheatear *Oenanthe isabellina*, *Mourning Wheatear *O. lugens*, Fan-tailed Raven *Corvus rhipidurus*.

4-3. Globally threatened species

In Saudi Arabia, one species is categorised as "critical", nine as "vulnerable" and eight as "near-threatened" (COLLAR et al. 1994). White-eyed Gull *Larus leucophthalmus* (vulnerable) and Pallid Harrier *Circus macrourus* (near-threatened) were recorded in the Study Area.

White-eyed Gull was recorded throughout the study period. In winter, it was recorded in four areas, excluding the southernmost area (Rabigh to Tuwal). In summer and autumn it was recorded at six out of 24 sites.

Pallid Harrier was recorded in winter (one record) and in autumn. In winter it was recorded in the southernmost area (Rabigh to Tuwal). In autumn it was recorded at two sites, namely Al-Quff and Duqm Sabq, and these birds were apparently on their migration south. The species was not recorded in summer.

4-4. Regionally threatened or declining species

32 species which are threatened or declining throughout all or large parts of their range in the Middle East are listed in EVANS (1994). Among them, the following two species were recorded in the Study Area (Table 72).

Table 72. Regionally threatened or declining species recorded in the Study Area.

English name	Scientific name	Areas and sites where the species was recorded
Goliath Heron	*Ardea goliath*	b 10 and one more spot
Sooty Falcon	*Falco concolor*	8, 9, 22, 23

At each of the above-mentioned sites and areas, one individual of Goliath Heron was always observed

At Site 9 (Jazirat an Naman) and 22 (Jazirat Jabal Hassan), several individual Sooty Falcons were recorded. Both sites are on an off-shore island with high cliffs. At 8 (Al-Quff) and 23 (Ash Shabaan), one or two individuals were observed. 8 is located close to 9, and 23 is located close to B19.

4-5. Species restricted wholly or largely to the Middle East

62 species which have relatively small total world ranges with important populations in the Middle East are listed in EVANS (1994). Among them, the following 10 species were recorded in the Study Area (Table 73).

Table 73. Species restricted wholly or largely to the Middle East recorded in the Study Area.

English name	Scientific name	Areas and sites where the species was recorded
Sand Partridge	*Ammoperdix heyi*	a 11
Crab Plover	*Dromas ardeola*	e 5, 8, 10, 13, 15, 16, 20, 21, 23, 26
White-eyed Gull	*Larus leucophthalmus*	a, b, c, d 2, 3, 4, 6, 21, 22
Sooty Gull	*Larus hemprichii*	a, b, c, d, e 6, 7, 8, 9, 10, 12, 13, 20, 21, 22, 23, 26
White-cheeked Tern	*Sterna repressa*	3, 5, 9, 21, 24, 26
Saunders' Tern	*Sterna saundersi*	5
Yellow-vented Bulbul	*Pycnonotus xanthopygos*	a, c, e 4, 6, 7, 10, 11, 21, 26, 27
Upcher's Warbler	*Hippolais languida*	1, 4, 26
Menetries' Warbler	*Sylvia mystacea*	26
Arabian Babbler	*Turdoides squamiceps*	e 10, 11, 26, 27

5. Seasonality

The following seven sites (Table 74) were surveyed in May – June and in October. 13 to 30% of the species recorded at sites are considered to be migratory species, including

wintering species, in the Study Area. At the present moment, it is very difficult to determine which species are purely migratory, and a further study will be required to determine the status of migratory species in the Study Area.

Table 74. Sites, seasons and species.

Site number	Site name	Number of species		Percentage of the same species observed during both seasons
		May – June	*October*	
4	Sharma	11	19	80%
8	Al-Quff	20	20	75%
10	Zubaydah	17	26	81%
11	Sharm 'Antar	11	34	84%
21	Duqum	22	26	70%
26	Masturah	19	37	80%
27	Rabigh	6	10	87%

However, the following 27 species at least can be considered from observation to be on migration south in October 1998.

Honey Buzzard *Pernis apivorus*, Black Kite *Milvus migrans*, Marsh Harrier *Circus aeruginosus*, Hen Harrier *C. cyaneus*, Pallid Harrier *C. macourus*, Sparrow Hawk *Accipiter nisus*, Common Buzzard *Buteo buteo*, Kestrel *Falco tinunculus*, Quail *Coturnix coturnix*, Common Crane *Grus grus*, Lapwing *Vanellus vanellus*, Common Kingfisher *Alcedo atthis*, Blue-cheeked Bee-eater *Merops superciliosus*, European Bee-eater *M. apiaster*, Barn Swallow *Hirundo rustica*, Black Redstart *Phoenicurus ochruros*, Common Redstart *P. phoenicurus*, Whinchat *Saxicola rubetra*, Olivaceous Warbler *Hippolais pallida*, Upcher's Warbler *H. languida*, Menetries's Warbler *Sylvia mystacea*, Lesser Whitethroat *S. curruca*, Garden Warbler *S. borin*, Blackcap *S. atricapilla*, Chiffchaff *Phylloscops collybita*, Willow Warbler *P. trochilus*, Spotted Flycatcher *Muscicapa striata*, and Red-backed Shrike *Lanius collurio*.

6. Mist netting

Mist netting was conducted at Site 8 (Sharm 'Antar) on 10 and 11 October. Two 12 m long mist nets were set up separately among the shrubs in early morning and late afternoon. All rings were provided by NCWCD.

Eight individuals of six species were caught and ringed. Details are shown in Table 75.

Table 75. Ringing record in October 1998 at Sharm 'Antar.

Date	Species	Ring number	Sex	Tail (cm)	Wing (cm)	Head (cm)	Fat
10 Oct.	Arabian Babbler	E009501	?	13.1	10.6	5.0	1
10 Oct.	Black Redstart	A10401	♀	5.6	7.7	2.9	3
10 Oct.	Red-backed Shrike	C006401	?	7.6	9.2	3.6	3
10 Oct.	Yellow-vented Bulbul	D005751	?	8.7	9.1	3.7	2
10 Oct.	Yellow-vented Bulbul	D005752	?	9.6	10.2	3.9	2
11 Oct.	Garden Warbler	A10402	?	5.5	3.7	2.9	3
11 Oct.	Laughing Dove	E009502	?	10.9	13.3	3.7	3
11 Oct.	Yellow-vented Bulbul	D005753	?	9.5	9.9	3.7	2

7. Habitats and species

24 sites were categorised into the following six habitats (Table 76). The habitat types are different from the ones in the Mangroves / Coastal Vegetation section (2.1.7.). Since birds in the Study Area are not associated with a specific habitat except for the mangroves, it is not necessary for this section to categorise the habitats into more specific ally as in the Mangroves / Coastal Vegetation section.

Table 76. Habitat types and sites.

Habitat Type	Site Number	Average No. of Species
Wadi	1, 6, 11, 14, 26, 27	16.8
Mangroves	20, 25	11.5
Mangroves and arid area	8, 10, 16, 23	18.3
Mangroves, wadi and farm	7	18.0
Arid area	2, 3, 5, 9, 12, 13, 15, 22, 24	7.3
Farm and palm trees	4, 21	17.0

Wadi: This habitat type includes both large and small wadis. For example, Site 1 (Al-Durah) has a medium scale wadi with a width of about 200 m, and 26 (Masturah) is located at the mouth of a large wadi. The habitat usually has relatively rich vegetation cover and diverse plant species compared with other habitats, and provides birds with places for breeding, resting and feeding.

Mangroves: This habitat is usually only found on islands in Al-Wajh Bank. It consists of two species of mangrove: *Avicennia marina* and *Rhizophora mucronata*. Site 25 (Yanbu') is located in the middle of an oil industrial area with little habitat left for birds on the landward, and therefore the habitat is categorised as "mangroves". The habitat has rich vegetation coverage and gives birds places for breeding, resting and feeding.

Mangroves and arid area: This habitat has mangrove forests at the seaside and its landward area is arid. The arid area has very little vegetation coverage and very few species of plants, and as such very few bird species are found there. In mangrove forests, species richness and diversity depend on the scale of the forests. There is a relatively large-scale mangrove forest in Site 8 (Al-Quff) which had diversified avifauna. 23 (Ash Shabaan) has a small forest because of its substrata and the forest does not hold diversified avifauna.

Mangroves, wadi and farm: Site 7 (Rawd az-Ziyan) is the only site which has this habitat. It is a diversified habitat possessing a diversified avifauna.

Arid area: The only vegetation in this habitat usually consists of salt marsh plants. These plants are found sparsely and cannot support diversified avifauna at all.

Farm and palm trees: Sites 4 (Sharma) and 21 (Duqum) have this type of habitat which has a farm (or farms) and palm trees. The habitat contains relatively rich avifauna but this type ofhabitat is not often found in the Study Area.

The detailed plant composition of each site is covered in greater detail in the Mangroves / Coastal Vegetation section.

2.1.8.4. Discussion

In Phase III, a Model Study is to be conducted in order to supply basic information on the conservation and appropriate management of the natural environment in the Study Area, and its biological diversity. A model area is to be selected in which the model study will be carried out. Five criteria are used in selecting the model area, and the following three are considered important for avifauna in the area and they are used to summarise the results.

1. Species diversity

Each season has a different species composition in the Study Area. 82 species in winter (February), 64 species in summer (May – June) and 86 species in autumn (October) were recorded. The climate is very harsh in the summer and so many terrestrial species do not breed in the Study Area. The area seems to be more important for migratory and wintering species.

There were no big differences among sites. Species diversity at each site depends more on the site's habitat and its vegetation coverage rather than its location in the Study Area. Wadis and mangroves are the key elements of habitat with high species diversity.

Large wadis have many physically small habitats and relatively rich vegetation coverage and they can support a high number of species compared to the other habitat types,

and even small wadis, because of their vegetation coverage, can also support a relatively high number of species.

As BALDWIN & MEADOWS (1987), and LOBLEY mentioned, mangroves are an important habitat for birds in the area, supporting a high number of bird species. However, some small (immature) mangrove thickets in the Study Area do not seem to have many species because of their poor forest structure. Mature mangrove thickets like the one at Al-Quff seems to support many species and individuals. Analysis of the aerial photographs shows that there are extensive mangrove thickets on some of the islands in Al-Wajh Bank, and it is expected that they may support many bird species.

2. Abundance

The abundance of each species is relatively low throughout the Study Area and during each season. Although sea birds generally have a high number of individuals, their numbers were not counted in this Study.

Since the number of individuals of each species is usually very low in each site (one or two), the number of individuals at each site is roughly correlated with the number of species. In other words, a site with a high number of species has a high number of individuals. However, Site 24 in summer is the only exception. It has a low number of species but with a high number of individuals.

In summer, Sites 7, 8, 10, 21, 26 and 27 had a higher number of individuals than other sites. The Habitat types of these sites are "wadi", "mangroves and arid area", "mangroves, wadi and farm" and "farm and palm trees".

In autumn, 10 out of the 24 sites were surveyed, and all these sites except Site 27 had a high number of individuals. Habitats of these sites are the same as the ones surveyed in summer.

3. Threatened and endemic species

EVANS (1994) selects Al-Wajh Bank and Madinat Yanbu' al-Sinaiyah as the important bird areas in Saudi Arabia. This is because they hold the following important species.

- Globally threatened species: White-eyed Gull *Larus leucophthalmus* (Al-Wajh Bank)
- Regionally threatened or declining species: Sooty Falcon *Falco concolor* (Al-Wajh Bank), Goliath Heron *Ardea goliath* (Yanbu')
- Species restricted wholly or largely to the Middle East: Crab Plover *Dromas ardeola* (Al-Wajh Bank and Yanbu'), Sooty Gull *Larus hemprichii* (Al-Wajh Bank), White-eyed Gull *L. leucophthalmus* (Al-Wajh Bank), White-cheeked Tern *Sterna repressa* (Al-Wajh Bank and Yanbu'), Saunders' Little Tern *S. saundersi* (Yanbu')

Several Pallid Harrier *Circus macrourus* (globally near-threatened species) individuals were observed at B8 (Al-Quff) and B16 (Duqm Sabq which is in Al-Wajh Bank) in October 1998. The habitat type of both sites was categorised as "mangroves and arid area" and the species seemed to be resting in the mangrove forests.

4. Seabirds

Although seabirds are not criteria for selecting the Model Area and are not a main target of this Study, it is worthwhile to mention them in the conclusion. NEWTON et al. (1987) recommends a more comprehensive study of seabirds in Al-Wajh Bank in conjunction with other research efforts covering other taxa and conservation interests.

On the basis of the above-mentioned criteria, the Study Area was assessed and the

results are shown in Table 77.

Table 77. Assessment of the Study Area.

Criteria / Area	Gulf of Aqaba	Tiran	Duba / Al-Wajh	Al-Wajh Bank	Umluj / Ra's al- Bardi	Yanbu' / Jeddah
Diversity	1	1	3	2	1	1
Endemic or endangered species	1	1	1	2	1	1
Biomass	1	1	2	n/i	n/i	1

3: very good, 2: good, 1 bad. n/i: not enough information

Photo. 6-1. Birds

1. Mist nets set up in a wadi at Sharm 'Antar.

2. Mr. Al-Salamah, the Saudi counterpart for the Birds survey, removed a bird from the net.

3. Yellow-vented Bulbul *Pycnonotus xanthopygos* was ringed and measured.

2.2. MODEL AREA

2.2.1. INTRODUCTION

A Model Area is selected as a representative and an important ecosystem in the entire Study Area. It is considered as a candidate for a marine protected area.

The purpose of the Model Study is to conduct a detailed biological study in order to understand the ecosystem of the area, to set up a framework for the monitoring of the ecosystem and to add as much information as possible to the inventory which was prepared in Phase II.

2.2.2. SELECTION OF THE MODEL AREA

2.2.2.1. Criteria

The biological criteria for the selection of the Model Area are as follows.

- Species diversity: an area which has high biological diversity. An area which has a long list of species recorded in this study is a candidate for a Model Area.
- Biomass: an area which has a high degree of biomass (an area which has many recorded individuals or is densely covered by, for example, corals). Since these areas can support many biological resources, they are important for other taxa as well as human beings.
- Threatened species and endemism: an area which contains threatened and / or endemic species. There are several species which are globally threatened and / or distributed only in or around the Red Sea, and these species have been recorded in some areas in the Study Area. These areas are important habitats for the species and are of special interest from the point of view of conservation.
- Wide range of habitats: an area which has a wide range of habitats. Such an area can

support many species of fauna and flora. These criteria were examined through aerial photograph analysis.

The social criterion in selecting the Model Area is as follows.

- Low human impact: an area which does not receive a great deal of impact from human activities. It is important to know which kind of human activities have an impact on an area, and to what extent, in order to manage the biological resources in tandem with the local people.

The Study Team had discussions with NCWCD on the management of marine protected areas in the Red Sea. The following criteria are considered important in terms of future management of marine protected areas in the Study Area.

- A large area: There are arguments regarding adequacy in the selection and design of protected areas (IUCN 1998). Different objectives require different designs. At the present moment, there is no precise information on which area is the most important, and there is a strong intention on the part of NCWCD to protect the ecosystems of the Red Sea. For a marine protected area in the Red Sea, having a very large area, covering as much of the ecosystem as possible, is considered to be a very important point.
- Existence of aerial photographs: Identification of ecosystems through aerial photographs is a very useful and important tool for the management of a protected area.
- Political and social regulations: Even if the protection of an area is very important, often it is the case that political or social circumstances do not allow for the establishment or management of a protected area.

The Study has been and will be conducted with limited time and resources, it is very important to consider appropriate logistics in order that field surveys may be carried out smoothly and efficiently. The following criterion is considered to be an important addition to

the above-mentioned criteria.

- Easy access to the area

2.2.2.2. Candidates for the Model Area, and the selection process

The Study Area was divided into the following areas for the purpose of assessing the environment.

i The Gulf of Aqaba

ii Tiran

iii Duba / Al-Wajh

iv Al-Wajh Bank

v Umluj / Ra's Baridi

vi Yanbu' / Jeddah

1. Assessment of each area

In each part of the Study (biological, habitat and social environment), the above-mentioned areas were assessed by each member. The overall assessment is summarised in the following table.

Table 78. Overall assessment of the Study Area by three categories.

	Gulf of Aqaba	Tiran	Duba / Al-Wajh	Al-Wajh Bank	Umluj / Ra's al-Bardi	Yanbu' / Jeddah
Biological	2	4	4	5	4	1
Habitat	*	3	2	5	3	1
Human impact	5	*	4	3	2	1

5: excellent, 4: very good, 3: good, 2: not good, 1: bad, *: not enough information

For "Human Impact" 5: very low, 4: low, 3: intermediate, 2: high, 1: very high

It is very important to note that the assessment is only for comparing these areas and does not imply the absolute value of the areas by any means.

Assessment of the areas in terms of management of a protected area is shown in Table 79.

Table 79. Overall assessment in terms of protected area management.

	Gulf of Aqaba	Tiran	Duba / Al-Wajh	Al-Wajh Bank	Umluj / Ra's al-Bardi	Yanbu' / Jeddah
Large area	1	5	3	5	2	1
Aerial photographs	no	yes	yes	yes	yes	yes / no
Political & social regulations	yes	yes	no	no	yes	yes

5: excellent, 4: very good, 3: good, 2: not good, 1: bad, *: not enough information

The Government of Saudi Arabia and JICA jointly took aerial photographs of the Study Area, but photographs could not be taken of the Gulf of Aqaba and Tiran Island as this is not allowed for national security reasons. With regard to the area of Tiran – Al-Khuraybah, photographs and videos were taken by the Study members from the NCWCD aricraft in the course of the study.

In terms of the logistics of the Study, the field office in Al-Wajh has all the equipment and the vehicles are stationed there. From the field office, Al-Wajh Bank is the best area for the Model Study.

2. Overall assessments

The Gulf of Aqaba is very rich in coral species, but in other aspects (seagrasses / algae, fishes, benthos, marine mammals / marine turtles, mangrove / coastal vegetation and

birds) it is not identified as a very important area. This area has very strict regulations which may prohibit the establishment of a protected area in the future. The area is very far from the field office in Al-Wajh and it would be rather difficult to carry out the Model Study efficiently.

The area around Tiran Island is rich in all taxa except mangrove and birds. It is also a sensitive area because of national security. It would not be easy to carry out the Model Study efficiently within the time limits.

The area Duba / Al-Wajh has intermediate status for allconsiderations.

Al-Wajh Bank is rich in all taxa and contains all habitat types which appear in the Study Area. The southern part of Al-Wajh Bank is richer in coral species and it is an important location for mangrove. Al-Wajh Bank is already a candidate to become a marine protected area of the NCWCD.

The area Umluj / Ra's al-Bardi has intermediate status for all considerations.

The area from Yanbu' to Jeddah is rather poor in all taxa, but some species of algae have the largest biomass in the Study Area. The consideration in this area is that wide-scale development has been undertaken and the resulting damage to the biological resources is marked compared to other areas.

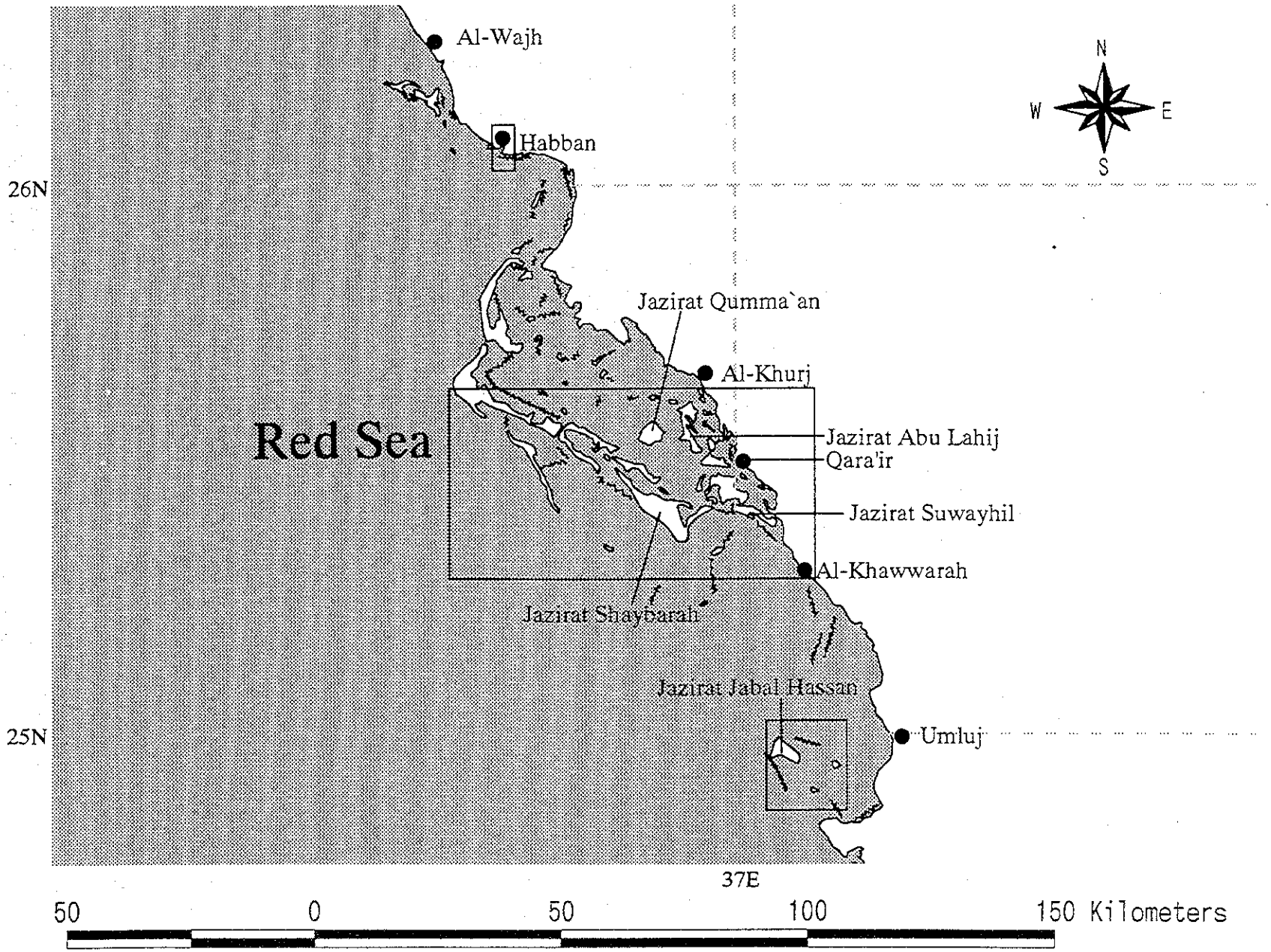
Consideration of all of these assessmentsmakes Al-Wajh Bank the best candidate site for conducting the Model Study in Phase III.

2.2.2.3. Model Area

1. Methodology

Taking all these criteria into consideration, a couple of candidate sites for the Model Study were reviewed. On the basis of discussions between NCWCD and the Study Team, Al-Wajh Bank was selected as the Model Area (Fig. 41).

Fig. 41. Map of the Model Area.



Since the Model Area is too large to conduct a detailed biological study, a "cross bank transect" survey will be carried out. An area containing as many habitats as possible will be selected as a "cross bank". The area which contains the cross bank is the southern part of Al-Wajh Bank, the Bank Transect Area. In this cross bank, each team will conduct their survey in the most appropriate way to achieve the purposes of Phase III. Any important habitats nor found in the cross bank, will be surveyed separately.

2. Location of the Model Area

A Model Area is selected as an important ecosystem representative of the entire Study Area.

The southern part of Al-Wajh Bank was selected as the Bank Transect Area, and each team (coral, algae / seagrasses, fishes, benthos, marine mammals / marine turtles, mangrove / coastal vegetation and birds) is to select appropriate points at which to conduct their surveys. Each survey point is to be selected on the basis of the aerial photographs and the habitat maps. In the field, each team is to co-ordinate its surveys in order to cover as many habitats as possible. The Bank Transect Area does not include any major coastal sharms or offshore islands surrounded completely by deep waters. For this reason, an area from Sharm Habban to Sharm Muraybirah (north of Al-Wajh Bank) and Jazirat Jabal Hassan (west of Umluj) were also surveyed in Phase III.

In order to cover as large an area as possible for the establishment of a marine protected area in Al-Wajh Bank, detailed habitat maps covering the entire area from Al-Wajh to Sharm Hisay are proposed.

3. Physical / geomorphological features

Al-Wajh Bank is situated in the north-eastern part of the Red Sea coast of the Kingdom of Saudi Arabia, extending up to 50 km offshore from the mainland coast, between the towns of Al-Wajh in the north and Umluj in the south. Al-Wajh Bank covers an area of up

to 1,000 km², bordered by longitudes 36°30' - 37°00' E and latitudes 25°20' – 25°50' N.

On its seaward (western) side, Al-Wajh Bank is enclosed to a greater or lesser degree by barrier reefs. The present living reefs have developed during the past 6,000 years of the Holocene high sea levels, on topographic highs formed by earlier reef structures. These earlier reefs flourished at various times during the past several million years, in previous interglacial periods of high sea level. The present living reefs, a thin veneer of coral growth on the earlier structures, presently exhibit vigorous growth in waters of high clarity (underwater visibility > 30 m).

Seaward of the barrier reef system, the sea bed drops away sharply, to depths in excess of 500 m in places. Several channels pass between the barrier reefs (e.g. between Jazirat Umm Rumah and Jazirat Birrim), providing narrow (< 500 m wide) oceanographic connections driven by strong tidal currents between the inside and outside areas of the Bank. Tides in the Bank and the Red Sea generally are usually < 1 m in amplitude, but because of the narrowness of the openings between the Bank and the open Red Sea, strong tidal currents are generated at the reef passes and channels.

To leeward (eastward) of the barrier reefs the Bank is relatively shallow, ranging up to 40m deep in places, but generally < 20 m in depth. The southern part of the Bank is shallower than the northern part, and supports large areas of seagrass beds, tidal flats and mangroves. The bottom sediments of the Bank consist of a mixture of carbonate reef-derived sands mostly offshore, and siliceous terrestrial-derived silts inshore.

The Bank has six main islands, mostly composed of coral fossil rock and carbonate sands. The islands are developed across the entire width of the Bank, from just inside the outer barrier reefs (e.g. Jazirat Birrim), midway across the Bank (e.g. Jazirat Qumma'an) to near the mainland coast (e.g. Jazirat Suwayhil). The islands generally have little topographic complexity, with maximum heights of less than 5 m above sea level. Some parts of the islands

are submerged during high tides, producing wide sand flats. Some of the sub-tidal flats support extensive algal or seagrass beds, notably in the southern part of the Bank.

Major islands in the Model Area include Shaybarah, Qumma'an, Abu Lahij and Suwayhil. Some of these islands support extensive mangrove thickets, composed generally of *Avicennia marina*, but also accompanied by *Rhizophora mucronata* in certain localities, e.g. Jazirat Qumma'an, where a tidal creek provides an ideal habitat for the development of a rich mangrove ecosystem.

Most of these islands are fringed by coral reefs, with reef slopes extending from sea level to a depth of up to 15m in most areas. Inside the Bank, reefs generally are developed well offshore from the islands, usually separated by large expanses of subtidal sand flat. Most of these reefs are relatively narrow, being less than 100 m in width. In addition, numerous sub-tidal patch reefs are developed, many of which are relatively small (< 5 km^2) in area and surround sub-surface sand banks. There are also many smaller coral patches scattered throughout the Bank.

Winds blow from the north-west throughout most of the year. These winds may drive coastal upwelling, bringing cool nutrient-rich waters close to the surface in certain areas. Winds usually increase in intensity throughout the day, gusting to > 30 knots at times during the afternoon, before decreasing during the night. Mornings may be calm or have slight land breezes. The strong northwesterly winds generate waves of > 2 m on the exposed seaward fronts of the barrier reefs. By contrast, inside this protective barrier waves are usually less than 0.5 m in height. These differences in wave energy influence the distribution of sediments.

Temperatures of the shallow (< 20 m depth) waters within the Bank are influenced by seasonal changes in air temperature, averaging 22-23° C in winter and 28-30° C in summer.

The mainland coast adjacent to the Bank comprises an alluvial sandy plain

interspersed with occasional small wadis created mainly during the Pleistocene. To the north and south of the Bank, wadis extend into coastal sharms. These sharms often support rich coral growth and extensive reef development on their outer margins (e.g. Sharm Habban south of Al-Wajh town). Within the bank itself, sharms are largely or completely absent, whereas shallow tidal flats are widespread along the seashore, usually extending for less than 1 km seaward.

The abundance of fine sands and silts in these shallow inshore waters, and regular resuspension of these sediments by wind-driven waves, limits coral growth to a few hardy species, and there is minimal mainland fringing reef development. Although mangroves and salt marshes are found in some lagoons and tidal mud flats, there is little vegetation cover in most of the mainland coastal area of the Bank.

4. Characteristics of ecosystems

Analysis of the aerial photos defined 17 main habitat types within Al-Wajh Bank, including those dominated by corals, seagrasses, small algae (including turf algae), macro-algae, mangroves (two species) and salt marshes. In particular, extensive areas of coral reefs, sand flats, seagrass beds and sand islands are developed in the Model Area, and support associated communities of benthos, fishes, dugongs, marine turtles and sea birds.

A variety of coral reef types, developed under different environmental regimes, is found within the Model Area. These include outer barrier reefs developed in relatively high energy conditions on the seaward edge of the Bank, reefs fringing the offshore islands, and sub-tidal patch reefs, often surrounding submerged sand banks. These latter reefs are developed in moderate to low energy conditions. The coral reef habitats are noted for their high diversity of coral species and associated biota. Reefs in the Model Area contain several of the coral species endemic to the Red Sea. These reefs are presently used to a greater or lesser degree as fisheies by people from the adjacent mainland.

Huge inter-tidal sand flats are widespread on the mainland coast and islands of the Model Area, providing habitats for soft-sediment benthos and for the development of mangroves and salt marshes. These habitats support a rich diversity of fish species and other benthos, with primary production by algae, seagrasses, mangroves and salt marshes utilised by herbivorous fishes, and turtles and dugongs as primary consumers. The herbivorous fishes and other benthos subsequently are fed upon by carnivorous fishes and sea birds.

The distribution of mangroves and salt marshes is closely related to the geo-morphological features, particularly differences in elevation and soil conditions. Two mangrove species are recorded in the Model Area. *Rhizophora mucronata* is rare, with plants distributed only along the tidal creeks of a few islands, notably Jazirat Qumma'an, Jazirat Shaybarah and Jazirat Umm Rumah. By contrast *Avicennia marina* forms extensive thickets on the tidal flats. These mangroves play an important role in the marine ecosystems of the Model Area. They provide nesting sites and feeding grounds for birds and insects, and also contribute primary production to the marine biota. Nutrients from within the mangrove thickets become available through leaf fall, and are utilised by primary producers such as algae and seagrass.