2.2.8.2. Results

1. Quadrat census survey

1-1. Vegetation profile

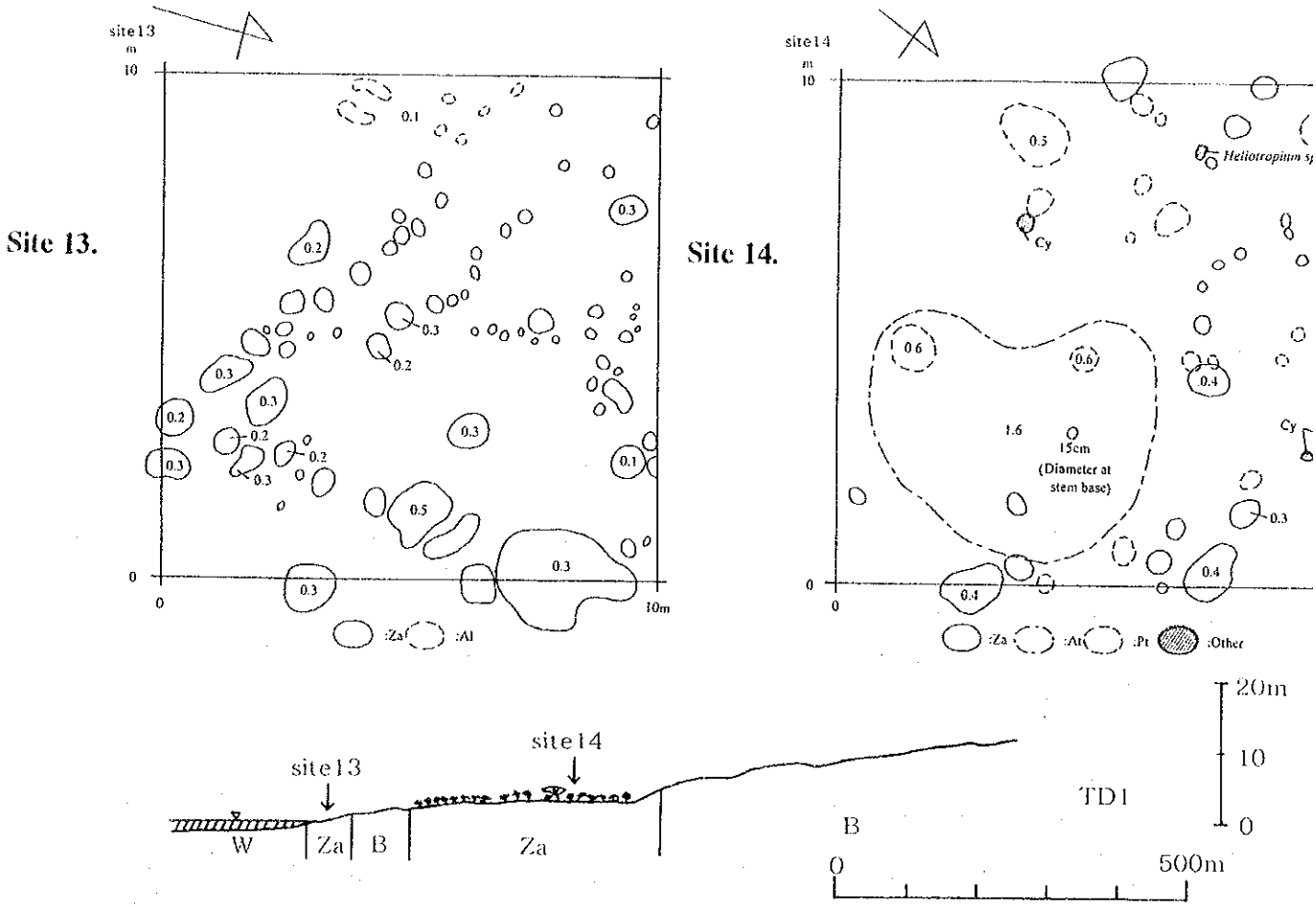
As a result of quadrat census surveys on the six transect lines, the distribution of plant communities was compiled in vegetation profiles. Plant distribution in quadrats excepting mangroves and schematic vegetation profiles on each transect are shown in Fig.64 - 66. A summary of the vegetation profiles is shown in Table 111.

The zonation pattern of the vegetation was very clear on each transect line, though the vegetation cover was very low in the surveyed area. A common zonation pattern from the seashore inland was as follows; mangrove thickets were distributed in lagoons or tidal creeks with shallow water; behind the mangroves, the salt marshes consisted of *Halocnemum strobilaceum* and *Arthrocnemum macrostachyum* forming a dense sub-shrub community in a narrow belt (5 – 50m in width) parallel to the shoreline. *Halopeplis perfoliata* formed a community with low coverage in alluvial sandy flats behind the salt marshes, and it is replaced gradually by a *Zygophyllum album* community away from the shoreline.

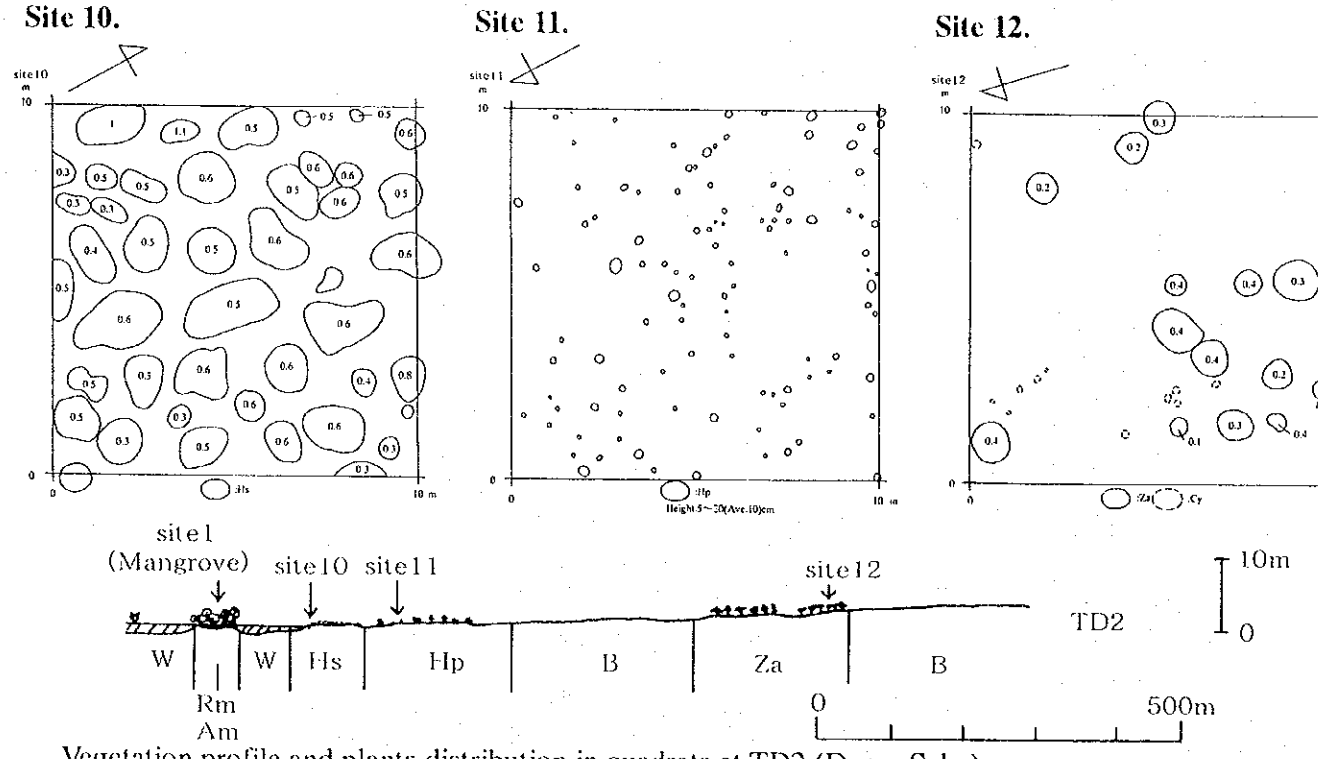
Table 111. Summary of vegetation distribution on the transect lines.

Transect (Place)	Vegetation distribution Seashore inland	Comments
TD1 (Duqm Sabq)	-------Za------- -------B------	Little vegetation cover in this area except in wadis. Za is distributed densely in the bottom small wadis Za forms communities at the end of wadis, facing the shoreline. Soil of wad consists mainly of coarse sands.
TD2 (Duqm Sabq)	Am-Rm-W--Hs—Hp--B-Za--B	Rm coexists with Am in lagoons with shallow water. Hs forms a salt marsh as a narrow be parallel to the shoreline. Hp is distributed on a wet and soft saline sandy area behind the sa marsh. In some parts inland, Za is scattered with low coverage.
TD3 (Duqm Sabq)	Am--W—Arm-Hs-- --B-----Hs-	Am forms thickets along the seashore with shallow water. A couple of Rm seedlings found the Am thickets. Some Am facing landward are damaged by camel grazing. Along th shoreline, Arm and Hs exist in a dense narrow belt.
TD4 (Duqm Sabq)	--W—Hp-- ---------B----------	Hp forms a sparse community near the seashore. There is almost no vegetation except I community in this area. The soils of this area are mainly coarse sands; salt crusts are found some parts of this area.
TQ1 (Jazirat Qumma'an)	C---Rm---Am---Arm---Hs--B--	Rm is distributed only along tidal creeks. Am forms thickets in tidal mud of the inner islan Sprouting is found in all Am individuals, so branches of Am grow horizontally from stum Arm is widespread in lower flats, adjacent to the Am thickets. Hs forms circular patches at t edge of mud flats, which are higher than the habitat of Arm in elevation.
TQ2 (Jazirat Qumma'an)	Am----B---Am---Hs--- --B---	Am forms thickets along the seashore. Aerial roots are covered by drift sands on the si behind the Am thickets facing the shoreline. Am in the inner tidal mud are distributed in sm circular patches. Hs communities are found from the edge of tidal inner mud to dry flat.

Rm: *Rhizophora mucronata*, Am: *Avicennia marina*, Hs: *Halocnemum strobilaceum*, Arm: *Arthrocnemum macrostachyum*, Hp: *Halopeplis perfoliata*, Za : *Zygophyllum album*. W: Water, C: Creek, B: Barren (less than 5 % vegetation coverage).



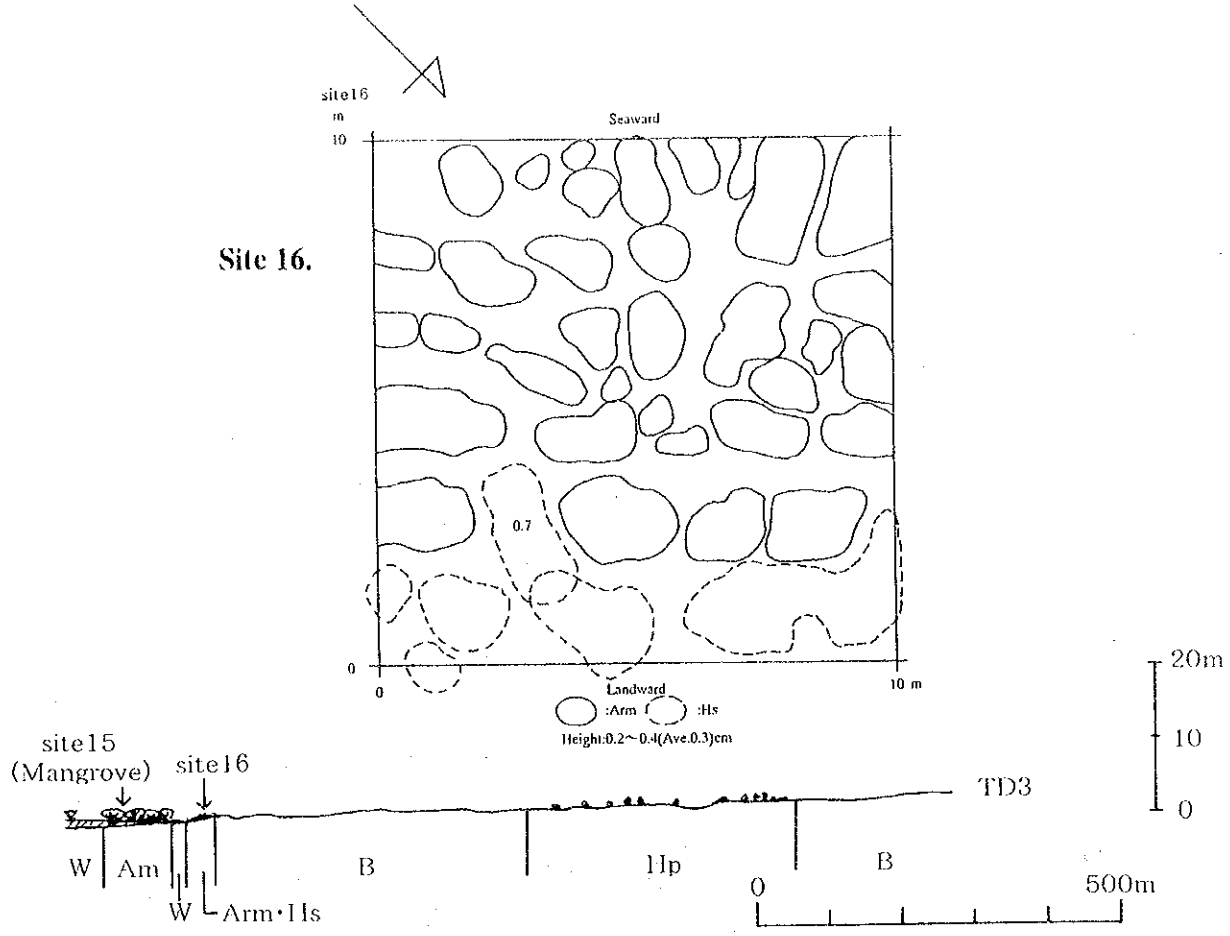
Vegetation profile and plants distribution in quadrats at TD1 (Duqm Sabq).



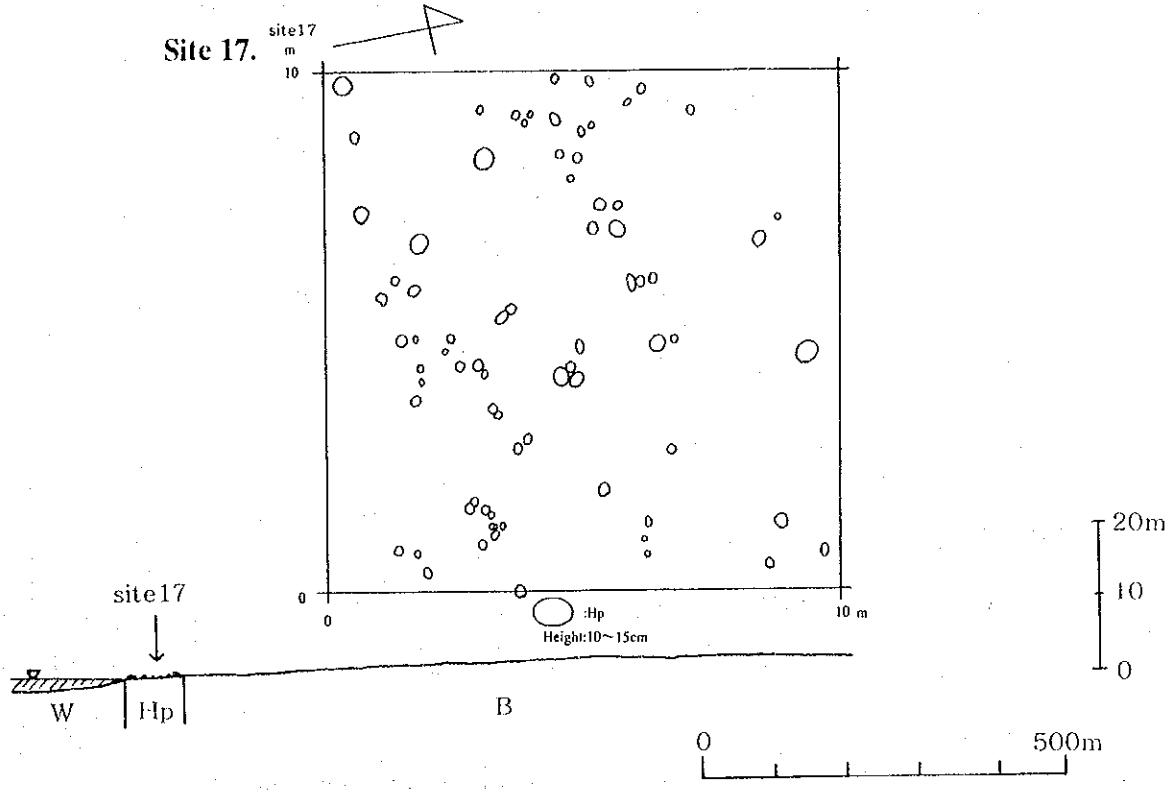
Vegetation profile and plants distribution in quadrats at TD2 (Duqm Sabq).

※ Figures in quadrats indicate the height of plants.
Rm : *Rhizophora mucronata*, Am : *Avicennia marina*, Hs : *Halocnemum strobilaceum*, Hp : *Halopeplis perfoliata*, Za : *Zygophyllum album*. Al : *Aeluropus lagopoides*, Pt : *Panicum turgidum*, Cy : *Cyperus* sp, W : Water, C : Creek, B : Barren (less than 5 % vegetation coverage).

Fig. 64. Schematic vegetation profiles and plant distribution in quadrats (northern Duqm Sabq).



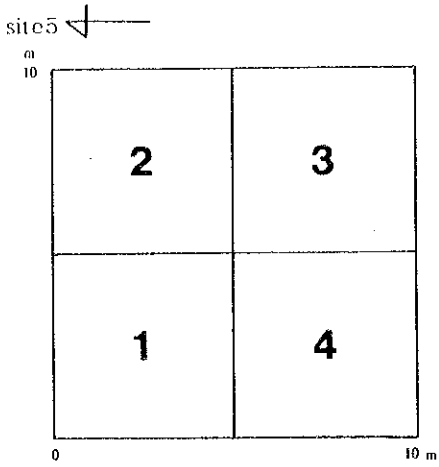
Vegetation profile and plants distribution in quadrats at TD3 (Duqm Sabq).



Vegetation profile and plant distribution in quadrats at TD4 (Duqm Sabq).

※ Figures in quadrats indicate the height of plants.
Am : *Avicennia marina*, Hs : *Halocnemum strobilaceum*, Arm : *Arthrocnemum macrostachyum*,
Hp : *Halopeplis perfoliata*, W : Water, C : Creek, B : Barren (less than 5 % vegetation coverage).

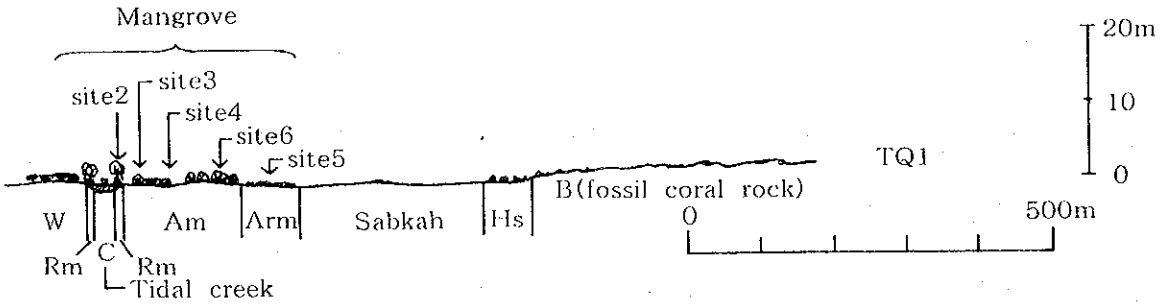
Fig. 65. Schematic vegetation profiles and plant distribution in quadrats (southern Duqm Sabq).



Site 5.

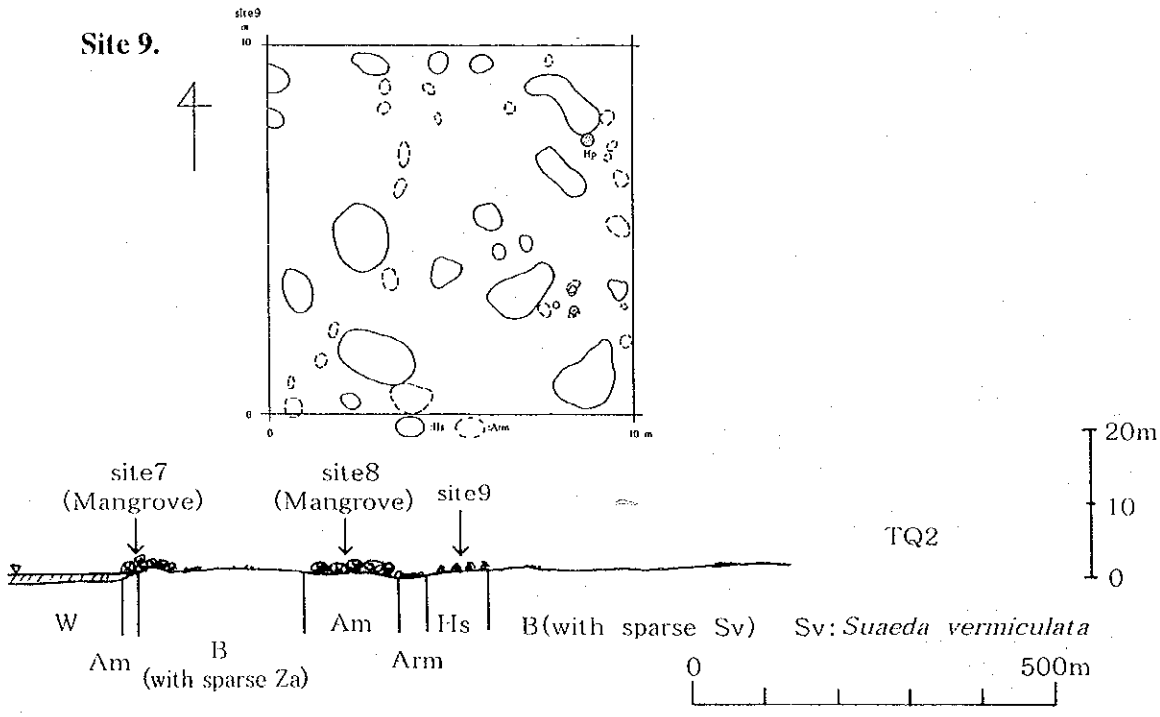
Site 5. *Arthrocnemun macrostachyum* community

Block	1	2	3	4
Number of individuals	45	47	37	55
Branch spread size (cm) (mean diameter)	38	28	20	23
Mean height (cm)	35	35	35	35
Coverage (%)	70	70	70	70



Vegetation profile and plants distribution in quadrats at TQ1 (Jazirat Qumma'an).

Site 9.



Vegetation profile and plant distribution in quadrats at TQ2 (Jazirat Qumma'an).

※ Figures in quadrat indicate the height of plants.
Rm : *Rhizophora mucronata*, Am : *Avicennia marina*, Hs : *Halocnemum strobilaceum*, Hp : *Halopeplis perfoliata*, Za : *Zygophyllum album*. Sv : *Suaeda vermiculata*, W : Water, C : Creek, B : Barren (less than 5 % vegetation coverage).

Fig. 66. Schematic vegetation profiles and plant distribution in quadrats (Jazirat Qumma'an).

1-2. Community structure of salt marshes and desert vegetation

The plant distribution in salt marshes and desert vegetation in the sites had patterns peculiar to the dominant species. It seems that the dominant species is distributed in peculiar habitat, and it has own community structure of coverage, density, population size and height. The dominant species in the surveyed sites were *Arthrocnemum macrostachyum, Halocnemum strobilaceum, Halopeplis perfoliata* and *Zygophyllum album*. The features of each community structure are described below.

The salt marshes of *A. macrostachyum* occurred in (submerged) areas covered by sea water when the tide is high (site 5, 16). *H. strobilaceum* formed a community adjacent to the *A. macrostachyum* community (site 7, 10). The habitat of *A. macrostachyum* was slightly lower in elevation than that of *H. strobilaceum* in elevation. Both dominant species usually formed circular dwarf patches 30 – 60 cm in height, and coverage in the sites was usually higher than 70 % (Fig. 64 - 66). The traces of camels were clearly apparent as narrow stripes in site 16.

The dominant species of site 11 and 17 was *H. perfoliata*. It was distributed on wet and saline sandy areas not covered by seawater, behind salt marshes. The coverage of *H. perfoliata* was very low, less than 5 %. Individuals of *H. perfoliata* were small, less than 20 cm in height, and extent foliage diameters were 10 – 30 cm, in sites 11 and 17 (Fig. 64-5).

Z. album formed circular patches were distributed from the seashore to the inland desert in sites 12, 13 and 14. The circular patches of *Z. album* varied from 10 cm to 100 cm in diameter, but coverage in the sites was usually low, less than 15 % (Fig. 64). An *Acacia tortilis* tree 2 m in height grew in site 14 with the *Z. album*.

1-3. Mangrove types

A summary of the mangrove quadrat census surveys is shown in Table 112. Mangroves in the surveyed area varied in community structure such as density, height and growing form. Mangroves including the mature mangrove of Al-Quff are categorised into the following six types, according to the dominant species, habitat and community structure;

1. *R. mucronata* community mixed with *A. marina* in a lagoon of the mainland coast (site 1)
2. *R. mucronata* community along the tidal creek on an offshore flat island (site 2)
3. *A. marina* community fringing the shoreline on an offshore flat island (site 7)
4. *A. marina* dwarf community in a lagoon of the mainland coast (site 15)
5. *A. marina* dwarf community an inner tidal mud on an offshore flat island (site 3, 4, 6, 8)
6. *A. marina* mature community of Al-Quff (site 18)

Table 112. Summary of mangrove quadrat census surveys.

Location	Transect	Quadrat	Date (1999)	Dominant species*1	Distance from shoreline (m)	Area (m^2)	Height (m)	Habitat
Duqm Sabq	TD2	Site.1*2	Feb.14-16	Rm, Am	110 (seaward)	200	2.5 – 4	Lagoon, shallow water along seashore
	TD3	Site.15*2	Feb.23	Am	60 (seaward)	100	2 – 2.5	Lagoon, shallow water along seashore
Jazirat Qumma'an	TQ1	Site.2*2	Feb.17	Rm	0	25	2.5 - 3.9	Along tidal creek
		Site.3	Feb.17	Am	10(from creek)	50	1 – 1.5	Beside tidal creek, adjacent to Site.2
		Site.4	Feb.17	Am	25(from creek)	50	0.5 - 1.2	Beside tidal creek, adjuacent to Site.3
		Site.6	Feb.17	Am	120(from creek)	100	0.6 - 1.9	Tidal mud inner island, adjacent to salt marsh
	TQ2	Site.7*2	Feb.18	Am	0	50	1.5 – 3	Along seashore
		Site.8	Feb.18	Am	300 (landward)	50	2.5 – 3	Tidal mud inner island, adjacent to salt marsh
Al-Quff	-	Site.18	June.12	Am	10 (landward)	100	4 – 5.5	Lagoon, mouth of wide wadi

* 1. Rm : *Rhizophora mucronata*, Am : *Avicennia marina*. *2 :Numbered tags were attached to trees.

1-4. Mangrove tree census

1). Duqm Sabq

Two mangrove quadrats in sites 1 and 15 were set up along the seashore at Duqm Sabq. The results from the sites are shown in Table 113. Crown projection diagrams and profile charts of the sites in Duqm Sabq are shown in Fig. 67.

R. mucronata community mixed with _A. marina_ in lagoon of mainland coast (site 1)

Site 1, *R. mucronata* community mixed with *A. marina*; the site is a shallow open lagoon located in a wide, open bay. This site is very important because it is the only mainland site in which *R. mucronata* is found. The maximum height of *R. mucronata* and *A. marina* individuals in site 1 were 3.3 m with 6.5 cm DBH and 3.7 m with 6.5 cm DBH, respectively. There were 84 stems (/ 200 m^2) more than 1 m in height, consisting of 57 *R. mucronata* and 27 *A. marina* in site 1. Most *R. mucronata* were less than 3 m in height, with less than 4 cm DBH. The coverage of the landward sub-quadrat (10 m x 10 m) was 70%, and of the seaward, 40%. Individuals of *R. mucronata*, including seedlings, were found to be more abundant in the landward rather than the seaward area which is directly affected by wave action. A couple of *A. marina* seedlings were found in the site. No sign of grazing was found.

Table 113. Number of mangrove stems in quadrats at Duqm Sabq (site 1 and 15).

Site 1. *R. mucronata* community mixed with *A. marina* — Surveyed area : 200m²

	DBH (cm)									Total	D_{10} (cm)					Total
	~2	~4	~6	~8	~10	~12	~14	~16	~18		~5	~10	~15	~20	~25	
Height (m)																
~5																
				(1)						(1)					(1)	(1)
~4		3	2							5	3		2			5
		(1)	(3)							(4)		(3)		(1)		(4)
~3	9	17	1							27	24	3				27
	(1)	(14)	(1)	(2)						(18)	(1)	(7)	(7)	(1)	(2)	(18)
~2	23	2								25	25					25
	(2)	(2)								(4)	(2)		(2)			(4)
Total	32	22	3							57	52	3	2			57
	(3)	(17)	(4)	(3)						(27)	(3)	(10)	(9)	(2)	(3)	(27)

※ ( ) indicates number of stems of *A. marina*

Site15. *A. marina* dwarf community. — Surveyed area : 100m²

	DBH (cm)									Total	D_{10} (cm)					Total
	~2	~4	~6	~8	~10	~12	~14	~16	~18		~5	~10	~15	~20	~25	
Height (m)																
~3	3	1								4		1	2		1	4
~2	7	4								11	2	2	5	2		11
Total	10	5								15	2	3	7	2	1	15

A. marina dwarf community in lagoon of mainland coast (site 15)

A. marina thickets around site 15 at Duqm Sabq were distributed in a lagoon with shallow water. The height of *A. marina* was 2 - 2.5 m, and D_{10} (the diameter of stem base) was mainly 10 – 23 cm. The number of stems was 15 (/ 100m²), 11 of which were less than 2 m in height. The coverage of the site was 60%. Sprouting was observed at stems and / or stumps of almost all *A. marina*, and the branches extended horizontally. Water depth around site 15 was relatively shallow at 20 – 30 cm, with the consequence of that some *A. marina* in the landward area were damaged by camel grazing. There were many *A. marina* seedlings less than 1 m in height in the quadrat. Although a couple of *R. mucronata* seedlings were found around site 15, there was no mature individual . Many seeds and a few flowering *A. marina* were observed in February.

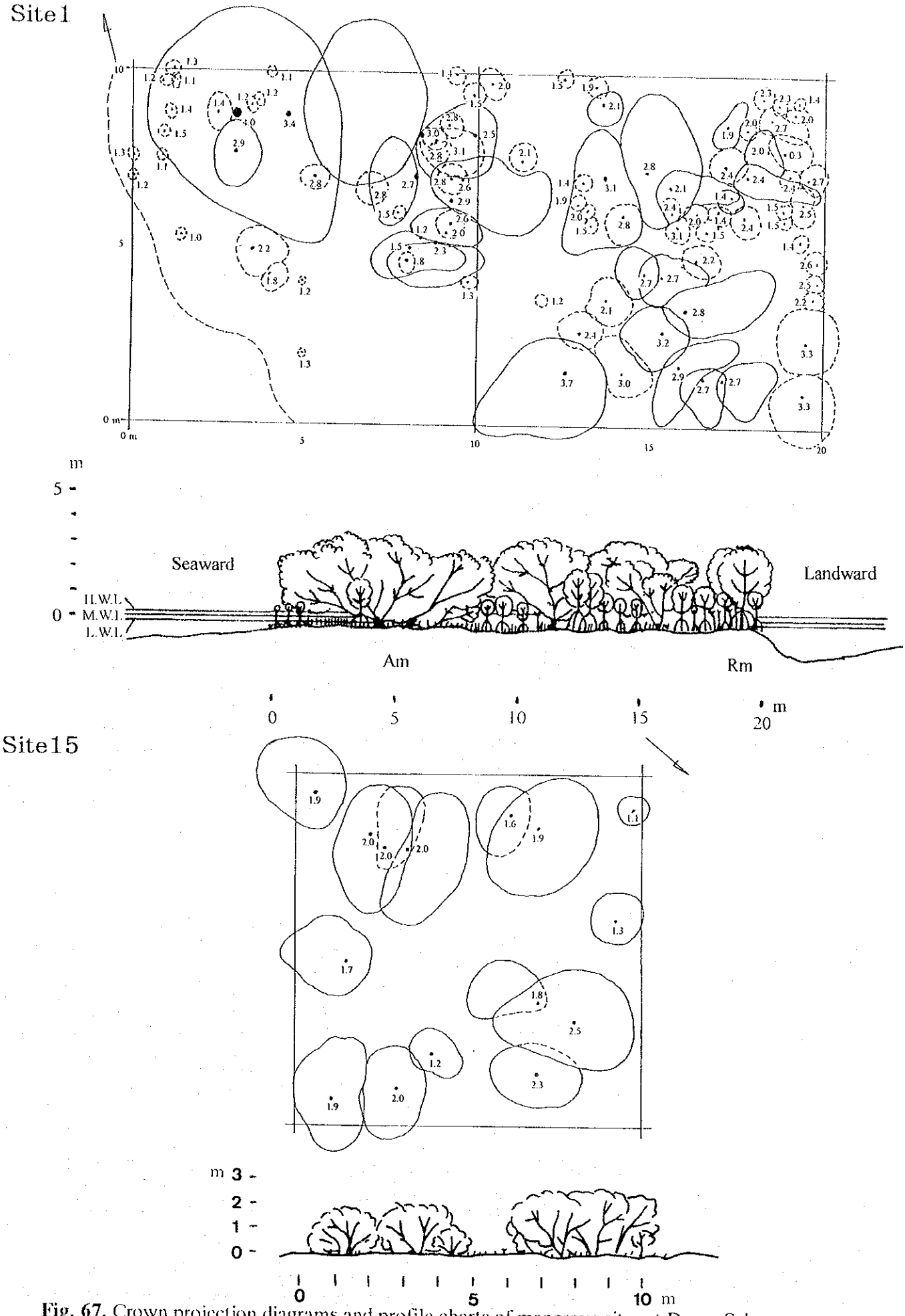


Fig. 67. Crown projection diagrams and profile charts of mangrove sites at Duqm Sabq.

2). Jazirat Qumma'an

Six mangrove quadrats on two transect lines, including two quadrats with numbered tags, were surveyed on Jazirat Qumma'an. The results of the quadrat census surveys are shown in Table 114. Crown projection diagrams and profile charts are shown in Fig. 68. Mangroves in Jazirat Qumma'an were categorised into the following three types according to the dominant species and habitats; *R. mucronata* community in tidal creek, *A. marina* community facing the seashore and *A. marina* in inner tidal mud.

***R. mucronata* community along the tidal creek on offshore flat island (Site 2).**

R. mucronata in Jazirat Qumma'an (site 2, TQ1) was distributed only along the tidal creek from the seashore to the inner tidal mud flat; the crown width was about 5 m and the length of the winding creek was over 1 km. The maximum height of *R. mucronata* individuals in site 2 was 3.9 m with 7 cm DBH. The number of stems was 14 (/ 25m²), half of which were less than 3 m in height and with less than 4 cm DBH. Though the coverage was high at 70 %, it should be noted that *R. mucronata* with branches spreading landward were noticeably withered.

Table 114. Number of mangrove stems in quadrats at Jazirat Qumma'an (site 2 and 7).

Site 2. *R. mucronata* community along the tidal creek. Surveyed area : 25m²

	DBH (cm)									Total	D_{10} (cm)					Total
	~2	~4	~6	~8	~10	~12	~14	~16	~18		~5	~10	~15	~20	~25	
Height (m)																
~4		1	1	4		1				7	2	5				7
~3		7								7	5	2				7
Total		8	1	4		1				14	7	7				14

Site 7. *A. marina* community fringing shoreline Surveyed area : 50m²

	DBH (cm)									Total	D_{10} (cm)					Total
	~2	~4	~6	~8	~10	~12	~14	~16	~18		~5	~10	~15	~20	~25	
Height (m)																
~3		5	2							7	1	5	1			7
~2	8	1	1							10	9		1			10
Total	8	6	3							17	10	5	2			17

A. marina community fringing shoreline on offshore flat island (site 7)

The habitat of site 7 (TQ2) was sandy tidal flats facing the sea. This mangrove type developed on the shoreline fringing the offshore island. An *A. marina* thicket at site 7 was 1.5 – 3 m in height, and its branches grew seaward from stumps. The coverage was 80%. The number of stems was 17 (/ 50m²), 10 of which were less than 2 m in height, and eight had a DBH of less than 2 cm. Aerial roots on the landward side without inundation were covered with sandy sediment, and litter was accumulated on the sand in this site.

A. marina dwarf community inner tidal mud on offshore flat island (site 3, 4, 6, 8)

A. marina in the inner tidal mud of Jazirat Qumma'an (site 3, 4, 6 and 8) formed thickets of the dwarf mangrove community type. Sites 3 and 4 were adjacent to site 2, the tidal creek. Thus varied in height from 0.5 to 3 m, and the density and coverage were various. The heights and structures of this community seems to be restricted by humidity, salinity and the depth of the soil. These edaphic factors are assumed to be closely related to the relationship between ground level and tidal changes. The most characteristic features in these thickets were sprouting from stumps and the horizontal growth of the branches. There were no signs of grazing, and the marks of cutting were not conspicuous.

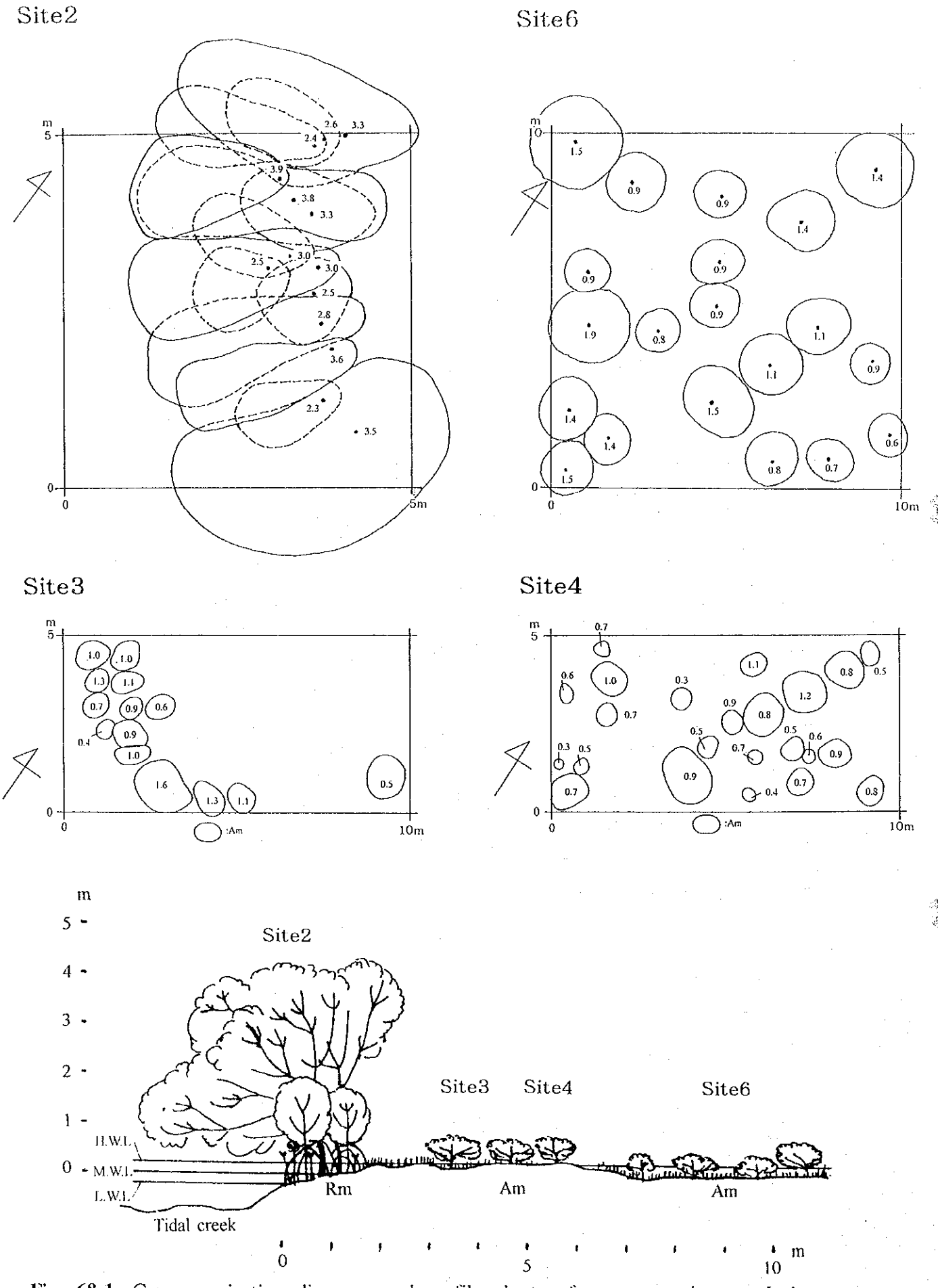
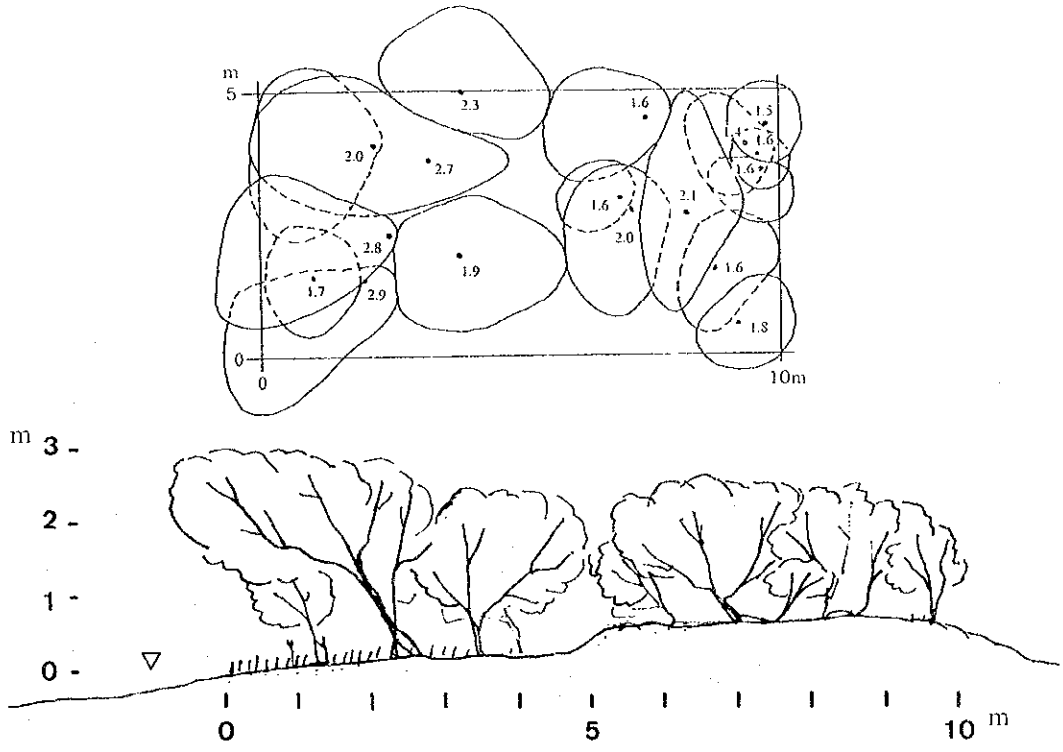


Fig. 68-1. Crown projection diagrams and profile charts of mangrove sites on Jazirat Qumma'an.

Site7



Site8

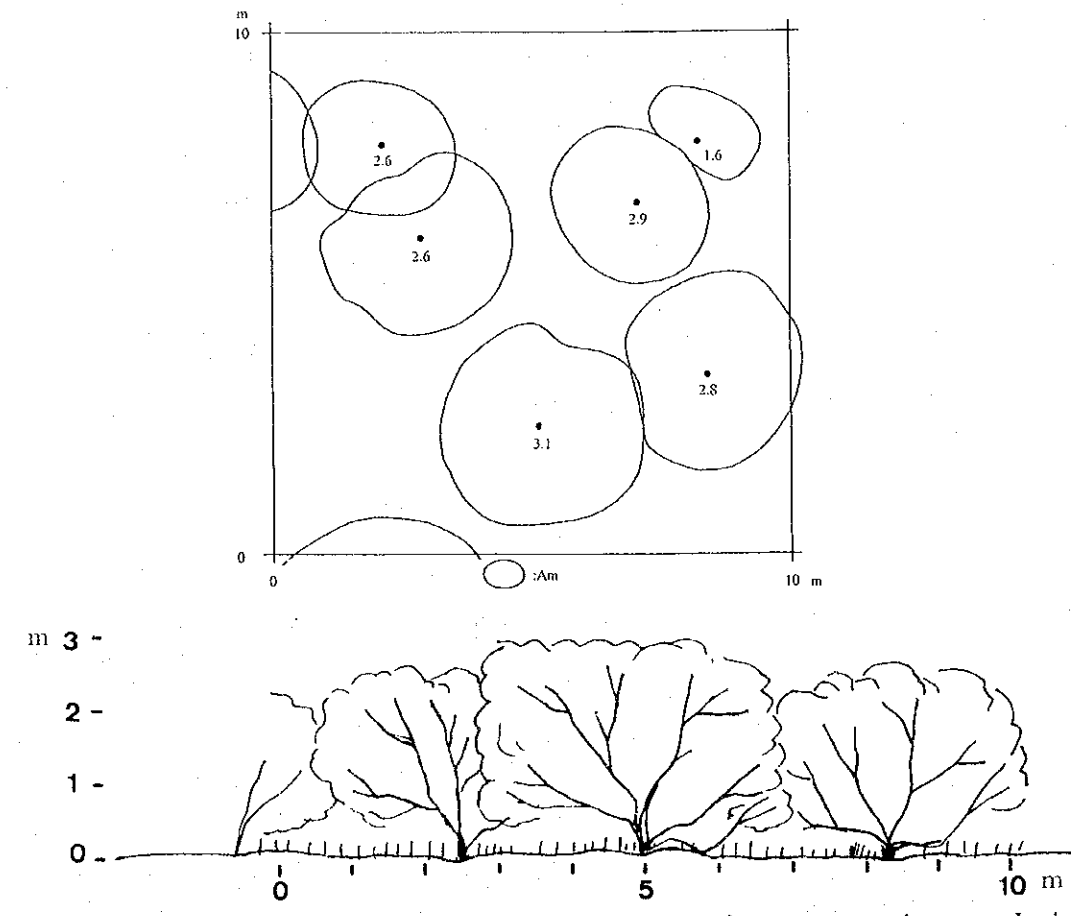


Fig. 68-2. Crown projection diagrams and profile charts of mangrove sites on Jazirat Qumma'an.

3). Al-Quff

The results of the quadrat census survey at Al-Quff are shown in Table 115. The crown projection diagram and profile chart are shown in Fig. 69. This mature mangrove survey site was set up for comparison with the community structure of the mangrove sites of Al-Wajh Bank .

A. *marina* mature community (site 18)

The site was set up on the mature mangrove community at Al-Quff, which is located at the mouth of a wide wadi. The community structure of the landward part of site 18 quadrat was quite different from its seaward part. In the landward part, only four *A. marina* stems 4 – 4.4 m in height and 10 cm in DBH were found, and not only their branches and leaves at lower level but also their aerial roots were grazed intensively by camels. In contrast, there were 24 stems in the seaward part, and their heights and DBH varied between 1.6 - 5.2 m and 1 –16 cm respectively. In this part, seedlings were also abundant and grazing damage was very low. The shrub layer less than 1.5 m in height was densely developed. There was a total of 28 stems (/ 100m²) in the site quadrat. There were several decayed stumps in the muddy area between the *A. marina* community included in site 18 and the salt marshes, located 10 – 15 m from the landward edge of the quadrat. This suggests that a larger *A. marina* community existed here in the past.

Table 115. Number of mangrove stems in the quadrats at Al-Quff (site 18).

Site 18. *A. marina* mature community. Surveyed area : 100m²

	DBH (cm)									Total	D_{10} (cm)					Total
	~2	~4	~6	~8	~10	~12	~14	~16	~18		~5	~10	~15	~20	~25	
Height (m)																
~6		1				1				2			1	1		2
~5		3	2		1	4	1		1	12	1	3	5	2	1	12
~4		4	2	1						7	2	4	1			7
~3	2	2				1				5	1	3		1		5
~2	1	1								2	1	1				2
Total	3	11	4	1	1	6	1		1	28	5	11	7	4	1	28

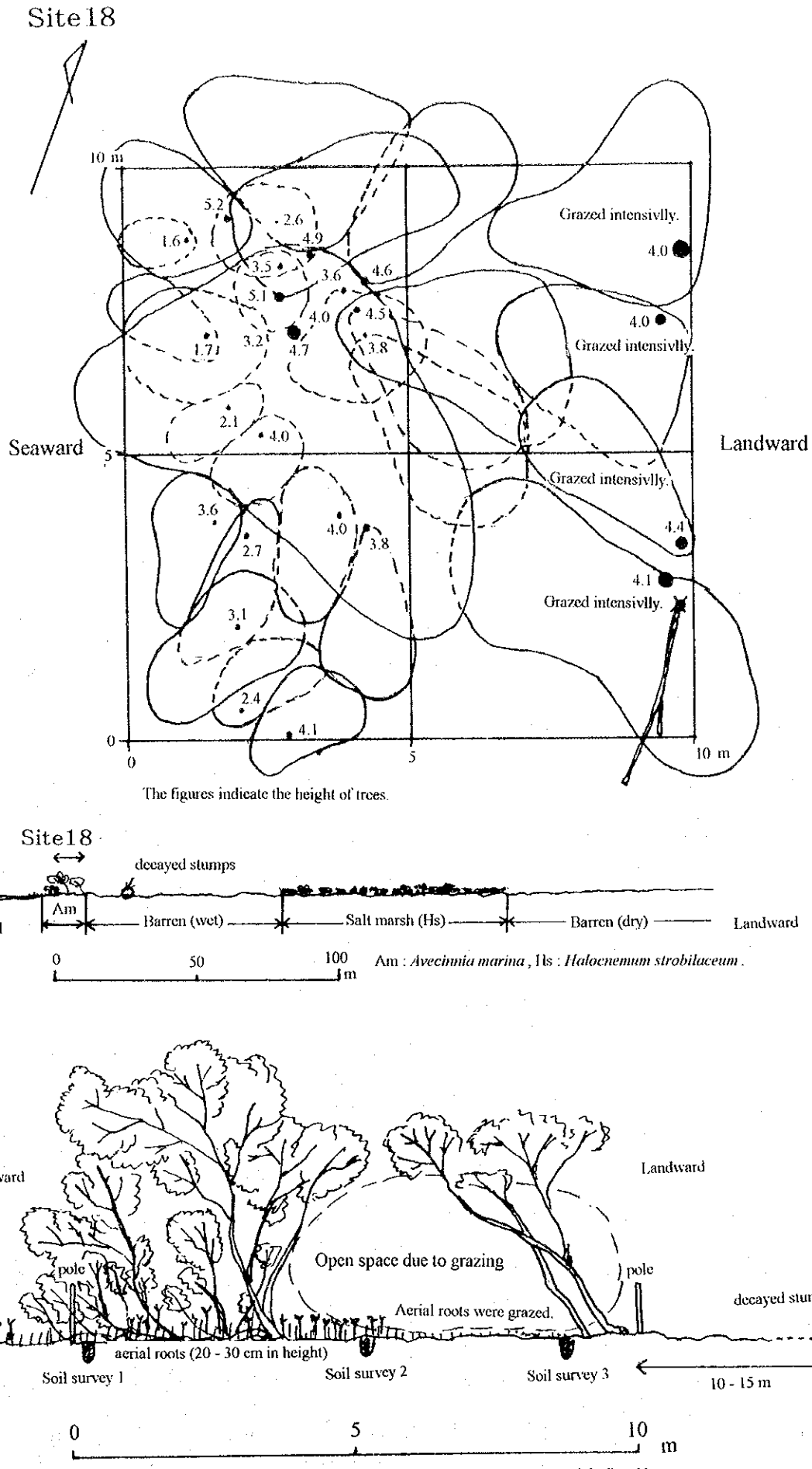


Fig. 69. Crown projection diagram and profile chart of mangrove site at Al-Quff.

1-5. Density and basal area at mangrove sites

The indicative values of the density and basal area were calculated in order to compare the community structure of the sites. A summary of the indicative values is shown in Table 116.

***R. mucronata* community (site 1, 2)**

The *R. mucronata* communities at sites 1 and 2 were denser in stems than the *A. marina* communities. Density at sites 1 and 2 was 42 and 56 stems / 100 m^2, respectively. Site 2 also had the highest value in total basal area at breast height at 2527.4 cm^2. In site 2, the tidal creek, the location of roots and stems of *R. mucronata* was limited to a narrow range with about 1 m wide at the creek brink. This restricted habitat gave a high value in not only density but also total basal area at breast height. However, the value of the total basal area at stem base was the lowest in site 2,. because stems of *R. mucronata* at ground take the place of prop roots, as the plant grows.

The mean diameter at stem base in site 1 including *A. marina*, was 6.9 cm, more than two times greater than the mean DBH of 2.6 cm.

***A. marina* community (site 7, 15, 18)**

Although the mean diameter at stem base at site 7 was the lowest at 5.2 cm, density was the highest of the three sites of *A. marina* at 34 stems / 100 m^2. Total basal area at breast height and at stem base were 802.7 cm^2 and 1867.7 cm^2 respectively.

Site 15 had the lowest density of the five sites, at 15 stems / 100 m^2 . The lowest value of total basal area at breast height, 333.2 cm^2 was also in site 15. However, the mean diameter at stem base was the biggest in site 15 at 10.3 cm.

Site 18 had the highest value in total basal area at stem base among the five sites, with 2606.9 cm^2 . The highest mean height and mean DBH were also in site 18, with 3.6 m and 5.6 cm respectively.

Table 116. Summary of the indicative values in five sites with numbered tags.

Site.	Dominant species	Quadrat size (m^2)	Number of individual	Density ($/100m^2$)	Mean height (m)	Mean DBH (cm)	Mean diameter at stem base (cm)	Total basal area at breast height (cm^2)		Total basal area at stem base (cm^2)	
								Actual data	Calculated for $100m^2$	Actual data	Calculated for $100m^2$
Site 1	Rm	200	57	28.5	2.1	1.9	3.3	418.6	209.3	580.1	290.1
	Am		27	13.5	2.6	3.3	10.6	1326.7	663.4	3790.6	1895.3
	Am, Rm		84	42	2.4	2.6	6.9	1745.4	872.7	4370.7	2185.36
Site 2	Rm	25	14	56	3.0	5.0	5.1	631.9	2527.4	326.7	1306.9
Site 7	Am	50	17	34	1.9	2.3	5.2	401.3	802.7	933.8	1867.7
Site 15	Am	100	15	15	1.8	1.6	10.3	333.2	333.2	1528.4	1528.4
Site 18	Am	100	28	28	3.6	5.6	9.5	1361.5	1361.5	2606.9	2606.9

Rm : *Rhizophora mucronata*, Am : *Avicennia marina*.

1-6. Growth form of *R. mucronata* and *A. marina* at the sites

In order to compare the growth form of *R. mucronata* and *A. marina* at the sites, the correlation of the height, DBH (diameter at breast height), D_{10} (diameter at stem base) and crown size (branch spread) was examined as follows;

Height - DBH and height - D_{10}

The correlation of height – DBH and height - D_{10} at the sites is shown in Fig. 70-1. Site 15 was a dwarf *A. marina* thicket 1 – 2.5 m in height. D_{10} varied from 2 cm to 23 cm, but DBH was limited to less than 3 cm in Site 15. The stems of *A. marina* were remarkably sprouted, in site 15 extending horizontally from stumps. The stunted growth form of *A. marina* mentioned above is caused by the sprouting. This tendency was also observed in site 7. Site 18 was a mature *A. marina* thicket ranging from 1.6 – 5.3 m in height. D_{10} and DBH also varied in site 18. The mature *A. marina* community contains individuals of various size. In a comparing *R. mucronata* with *A. marina*, the D_{10} of *A. marina* usually varied irrespective of height, but the range for *R. mucronata* was limited in correspondence to the DBH. *R. mucronata* stands erect without sprouting. For this reason, DBH and D_{10} are not so different.in *R. mucronata*.

DBH - D_{10}

The correlation between DBH and D_{10} at the sites is shown in Fig. 70-2. In the case of *R. mucronata*, DBH was almost equal to D_{10} in sites 1 and 2. The D_{10} of *A. marina* however tended to be greater than its DBH. In site 15 where there was conspicuous sprouting of *A. marina* , the D_{10} was more than five times the DBH. The sprouting of *A. marina* causes this correlation, though the pattern was different in the other sites.

Crown size and height

The correlation between crown size and height at the sites is shown in Fig. 71. The crown size increased in proportion to height, but the ratio differed between the sites. The crowns of *A. marina* tended to be much bigger than those of *R. mucronata* because of *A. marina* sprouting.

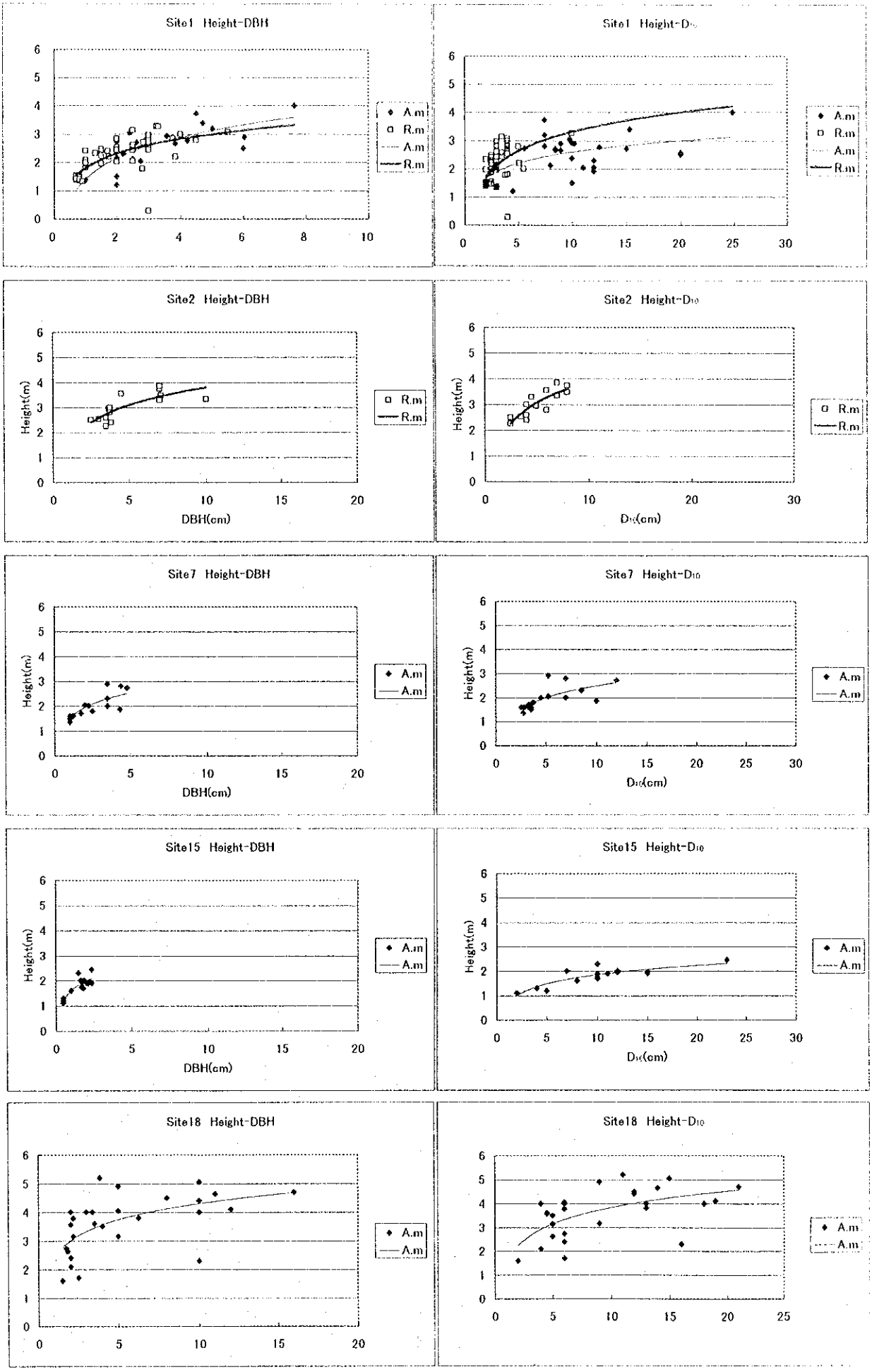


Fig. 70-1. Correlation of height – DBH, and height – D_{10}.

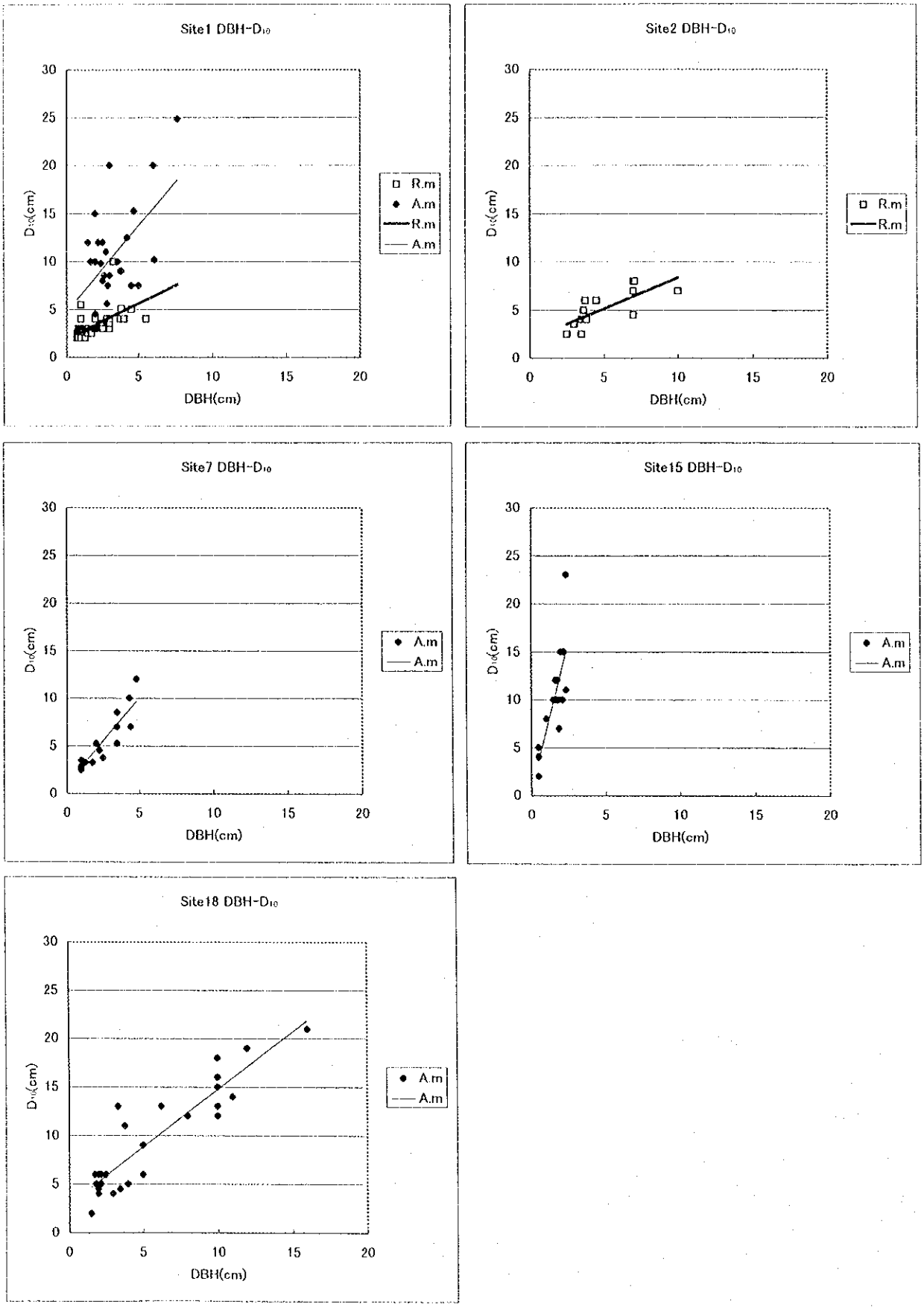
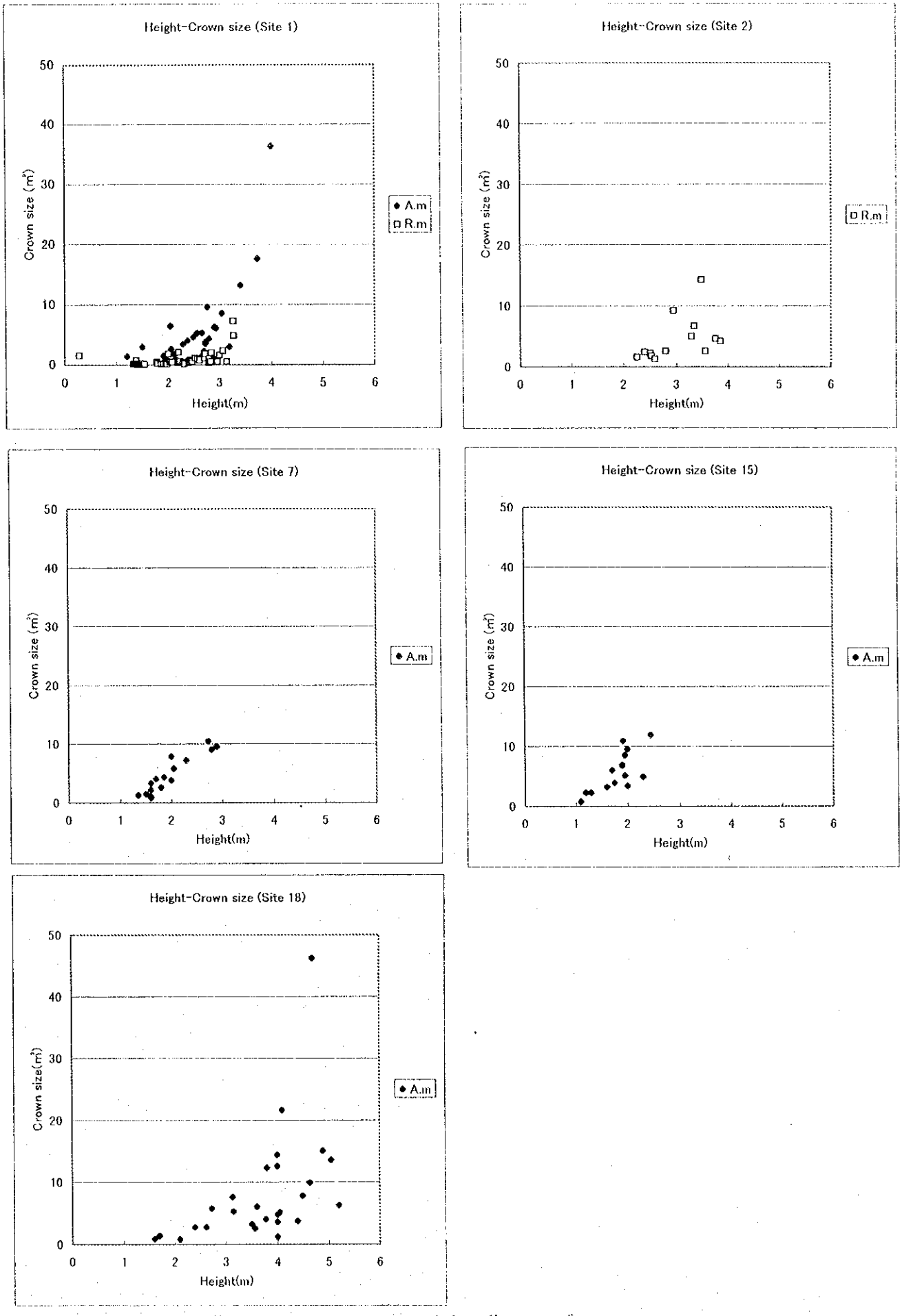


Fig. 70-2. Correlation of DBH - D_{10}.



Note: Crown size is given as the product of the long and short diameters of crown.

Fig. 71. Correlation between height and crown size at each site.

2. Soil survey

2-1. Soil conditions in the mangrove sites

A summary of the soil survey in the mangrove sites is shown in Table 117.

Though there was no clear difference between *R. mucronata* sites and *A. marina* sites with regard to Eh (redox potential), Eh seemed to indicate the degree of mangrove development in the sites. The soils of site 7 and site 8 in Qumma'an, dwarf *A. marina* communities 3 m in height had aerobic conditions with an Eh of more than 300 mV. Other mangrove sites tended to have anaerobic soil with Eh ranging from minus 137 to 84 mV. There was a strong smell of H_2S when sites with anaerobic soils were dug. The site with the most anaerobic soil was site 18, where *A. marina* has been developed very well to 5 m in height.

As for differences in soil depth, soil at a depth of 40 cm tended to show more aerobic conditions than at a depth of 10 cm except in site 15, where there were hard sands from below 35 cm.

The soils of the surveyed sites were alkaline, with pH ranging from 7.2 to 7.9. Almost all sites had a salinity (at 10 cm depth) of less than 4.7%. The salinity of site 8 however, located in the tidal mud of inner Jazirat Qumma'an, was exceptionally high at 9.4%. It is assumed tha evaporation caused higher salinity of stagnant water there.

Table 117. Summary of the soil surveys in the mangrove sites.

Place.		Duqm Sabq		Jazirat Qumma'an			Al-Quff	
No.		1	2	3	4	5	6	7
Site No.		TD2-site 1	TD3-site 15	TQ1-site 2	TQ2-site 7	TQ2-site 8	site 18	site19*2
Date (1999)		Jun.5	Jun.6	Jun.8	Jun.14	Jun.14	Jun.13	Jun.14
Dominant*1		Rm + Am	Am	Rm	Am	Am	Am	Am
Height (m)		2.5 - 4	2 - 2.5	2.5 – 3.9	1.5 – 3	2.5 - 3	1.6 - 5.1	1 – 2
	Depth(cm)							
Soil type	10	Mud, sand	Mud, sand	Mud, sand	Sand	Mud, sand	Mud	Sand, mud
	40	Mud, sand	Sand	Mud, sand	Sand	Mud, sand	Mud	Sand, mud
Eh(mV)	10	-66.0	-37.1	-37.9	379.3	329.3	-74.9	84.0
	40	-93.8	65.1	-86.8	384.3	177.7	-137.1	44.0
pH	10cm	7.4	7.5	7.5	7.9	7.3	7.4	7.2
	40cm	7.3	7.3	7.3	7.7	7.3	-	-
Salinity(%)	10cm	3.8	2.9	4.7	3.1	9.4	4.0	4.1
	40cm	3.5	3.1	4.2	3.2	-	-	-

* 1. Rm : *Rhizophora mucronata*, Am : *Avicennia marina*. *2. Soil survey only was carried out in the site.

2-2. Soil conditions in salt marshes and desert vegetation

A Summary of the soil survey in salt marshes and desert vegetation is shown in Table 118. The soils of these sites were generally alkaline with a pH ranging from 8.2 to 9.6. The salinity (in a 1 : 5 soil / water suspension) ranged from 0.0 to 1.3%. Each vegetation type had its own salinity range. For example, the salinity of the *Halopeplis perfoliata* communities was relatively high at 0.73 – 1.3% (at 10 cm depth), whereas *Zygophyllum album* formed communities on the low saline sands with 0.01 – 0.05% salinity (at 10 cm depth). Usually, the upper part (t 10 cm depth) tended to show higher salinity than the deeper part (t 40 cm depth).

The proportion of mud (silt and clay) was relatively high with more than 20% in the salt marsh sites of Jazirat Qumma'an. The desert soils of Duqm Sabq had a high proportion of fine sand and low proportion of mud (less than 6.8%).

Table 118. Summary of the soil surveys in the salt marshes and desert vegetation.

Place.	Duqm Sabq														Jazirat Qumma'an					
Transect No.	TD1				TD2						TD3		TD4		TQ1		TQ2			
No.	1		2		3		4		5		6		7		8		9		10		11	
Site (dominant)	St.13(Za+Al)		St.14(Za+At)		St.10(Hs)		St.11(Hp)		St.12(Za)		St.16(Arm+Hs)		St.17(Hp)		No vegetation		St.5(Arm)		St.9(HS+Arm)		St.21(Arm)	
Sampling / measure date(1999)	Jun.9 / Jun. 10		Jun.9 / Jun. 10		Jun.5 / Jun. 10		Jun.5 / Jun. 10		Jun.6 / Jun. 10		Jun.9 / Jun. 10		Jun.9 / Jun. 10		Jun.14 / Jun.15		Jun.8 / Jun. 10		Jun.14 / Jun.15		Jun.14 / Jun.15	
Depth(cm)	10cm	40cm	10cm	40cm	10cm	40cm	10cm	40cm	10cm	40cm	10cm	40cm	10cm	40cm	10cm	40cm	10cm	40cm	10cm	40cm	10cm	40cm
Chemical condition																						
Temp(℃)	30.1	30.3	31	30	29	29	28.1	28.6	29.1	29	28.5	28.4	31	29.7	28.3	28.3	28.7	29	28	28	28	23.8
EC(mS/cm)	9.8	5.3	0.2	0.1	11	7.1	13.5	14.3	1.02	0.4	13.8	13.5	-	10.2	8.3	6.1	14.2	16	12	11	16	8.6
Salinity(%)	0.51	0.28	0	0	0.6	0.4	0.73	0.78	0.05	0	0.75	0.74	1.3	0.53	0.44	0.32	0.77	0.9	0.6	0.6	0.9	0.46
pH	8.7	8.4	9.4	9.6	9	9.1	8.3	8.4	8.4	8.9	8.6	8.6	8.7	8.9	8.2	8.9	8.5	8.7	8.5	8.8	8.7	9
Soil color	2.5Y6/3 Dull yellow	2.5Y6/4 Dull yellow	2.5Y6/4 Dull yellow	2.5Y6/4 Dull yellow	2.5Y4/4 olive brown	2.5Y6/4 yellow ish brown	2.5Y6/6 bright yellowish brown	2.5Y5/4 yellowi sh brown	10YR6/6 Bright yellowish brown	10YR5/6 Yello wish brown	7.5Y5/2 grayish olive	5Y6/3 olive yellow	2.5Y6/4 Dull yellow	2.5Y7/3 Light yellow	2.5Y7/4 light yellow	2.5Y6/4 dull yellow	7.5Y7/1 light gray	7.5Y8/1 light gray	10YR6/4 dull yellow orange	2.5Y7/3 light yellow	5Y7/3 light yellow	2.5Y7/3 light yellow
moisture	slight wet	slight wet	dry	dry	wet	wet	slight wet	wet	dry	dry	wet	wet	slight wet	slight wet	dry	slight wet	Wet	Wet	slight wet	slight wet	slight wet	wet
Particle size (%)																						
Gravel	0	1.8	1.7	11	3.8	2.5	4.1	3.2	1.4	5.5	2	2	2	5.5	7.5	28.4	1.9	1.9	1.7	7.4	13	21.8
Coarse sand	1.7	2.7	8.5	23	3.8	2.5	41.5	6.4	21.9	31	2	5.9	19	18.5	30.2	38.8	7.4	11	17	9.3	26	14.6
Fine sand	98.3	94.6	86	65	77	83	53.6	81.6	69.9	60	82	78.4	77	70.4	56.6	32.8	57.4	72	53	61	28	40
Mud (Silt, Clay)	0	0.9	3.4	1.4	15	13	0.8	8.8	6.8	3.6	14	13.7	1.9	5.6	5.7	0	33.3	15	29	22	34	23.6
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

*Gravel : >2mm, Coarse sand : 0.5-2mm, Fine sand : 0.05-0.5mm, Mud (Silt + Cray) : <0.05mm

*Za : *Zygophyllum album*, Al : *Aeluropus logopoides*, At : *Acacia tortilis*, Hs : *Halocnemum strobilaceum*, Hp : *Halopeplis perfoliata*, Arm : *Arthrocnemum macrostach*

3. Vegetation maps

3.1. Duqm Sabq

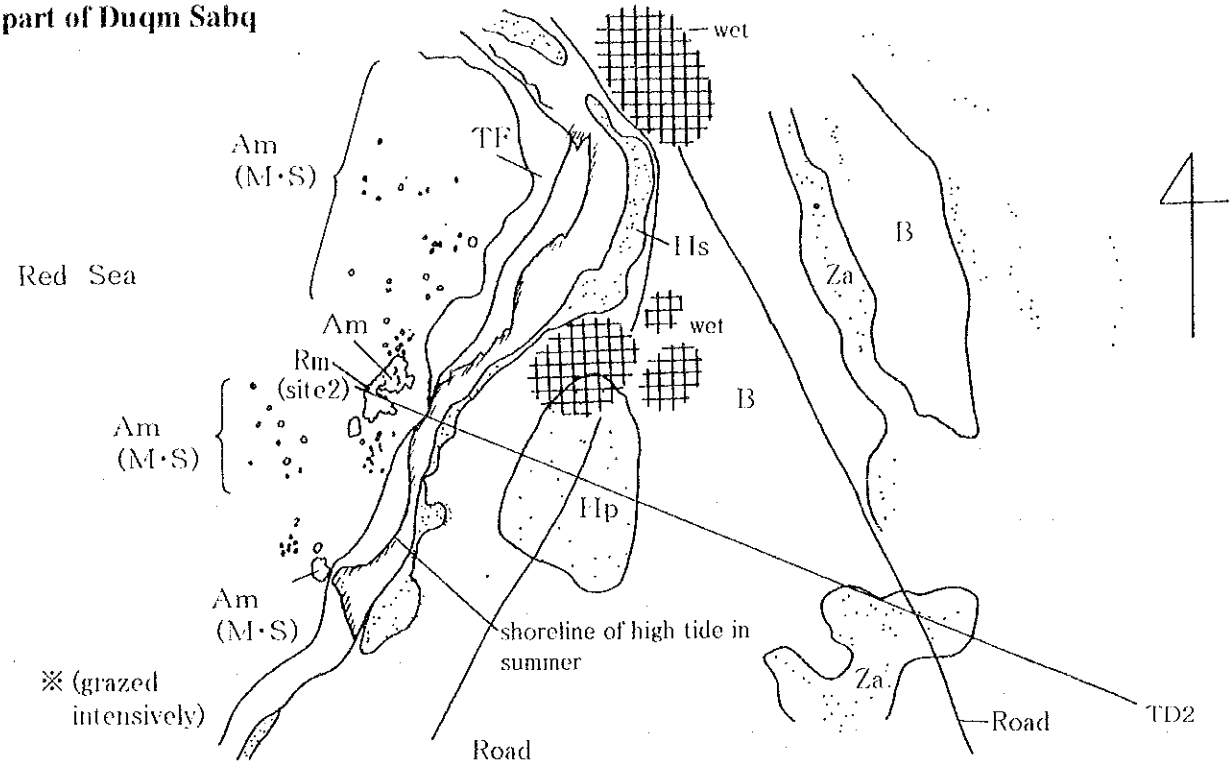
The vegetation maps of Duqm Sabq are shown in Fig. 72. In the northern part of Duqm Sabq, *R. mucronata* and *A. marina* grew in shallow water, 10 – 50 m distance from the shoreline. Withered mangrove trees grazed by camels were found in some parts of this group near the shoreline. Only *A. marina* individuals with less than 2 m high grew scattered in the tidal flat 250 m seaward from the shoreline. Salt marshes of *Halocnemum strobilaceum* were distributed in a narrow belt along the shoreline. There was scanty vegetation cover of *Halopeplis perfoliata* and *Zygophyllum album* on the inland side.

The pattern of vegetation distribution in the southern part of Duqm Sabq was similar to that in the northern part, though there was no *R. mucronata* community. *A. marina* formed dwarf shrubs less than 2 m in height along the shoreline. In total, the vegetation of Duqm Sabq had a relatively monotonic structure and the biomass was also not so high.

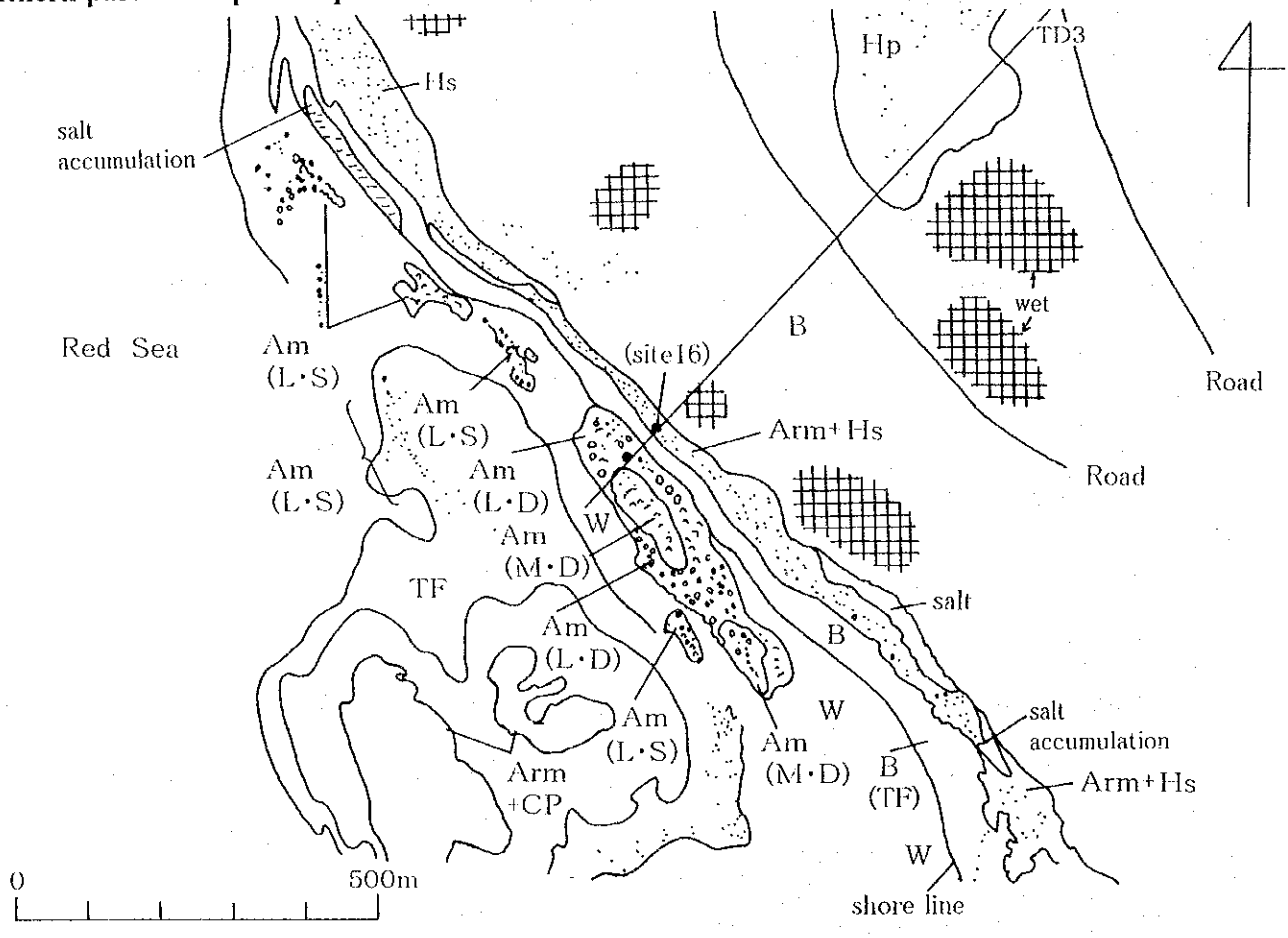
3.2. Jazirat Qumma'an

The vegetation map of the southern part of Jazirat Qumma'an is shown in Fig. 73. *R. mucronata* grew along the tidal creek, running from north-west to south-east in the southern part of Jazirat Qumma'an. The inner tidal mud areas adjacent to the tidal creek and submerged by seawater at high tide, were covered in *A. marina* thickets, *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum* and Cyanophycea mats. *Halopeplis perfoliata* and *Suaeda vermiculata* grew in inland sandy desert areas not covered by seawater. The slight difference in elevation from sea level may be the cause of this distribution of plant communities. In total, this area contained various habitats, but the biomass was not so high because of the dwarf and sparse mangrove communities.

Northern part of Duqm Sabq



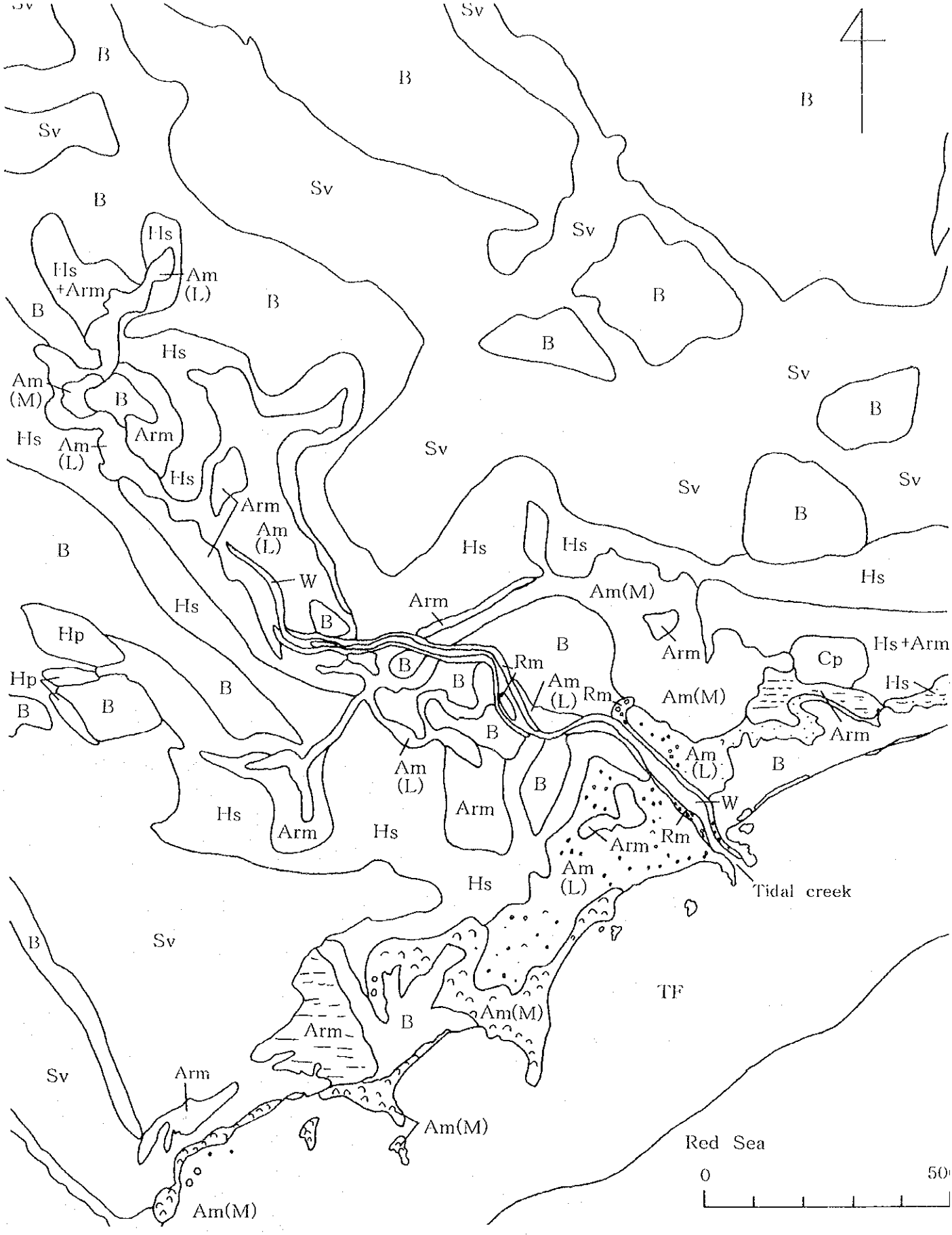
Southern part of Duqm Sabq



Legend (Duqm Sabq)

<Mangroves> Rm : *Rhizophora mucronata* (2 – 3m in height), Am (M·D) : *Avicennia marina* (2 – 3 m, >50% coverage), Am (M·S) : *A. marina* (2 – 3 m, <50%), Am (L·D) : *A. marina* (< 2m, >50%), Am (L·S) : *A.marina* (<2m, <50%)
<Salt marshes> Hs : *Halocnemum strobilaceum*, Arm : *Arthrocnemum macrostachyum*, Hp : *Halopeplis perfoliata*
<Others> TF : Tidal flat, Cp: Cyanophyceae (blue-green algae), B : Barren land (< 5 %), W : Water

Fig. 72. Vegetation maps of Duqm Sabq.



Legend (Southern part of Jazirat Qumma'an)

<Mangroves> Rm : *R. mucronata* (3 – 4m in height), Am (M) : *A. marina* (2 – 3 m),Am (L) : *Avicennia marina* (<2m)

<Salt marshes> Hs : *Halocnemum strobilaceum*, Arm : *Arthrocnemum macrostachyum*, Hp : *Halopeplis perfoliata*
Sv : *Suaeda vermiculata*

<Others> TF : Tidal flat, Cp: Cyanophyceae (blue-green algae), B : Barren land (I< 5 %), W : Water (Tidal creek)

Fig. 73. Vegetation map of the southern part of Jazirat Qumma'an.

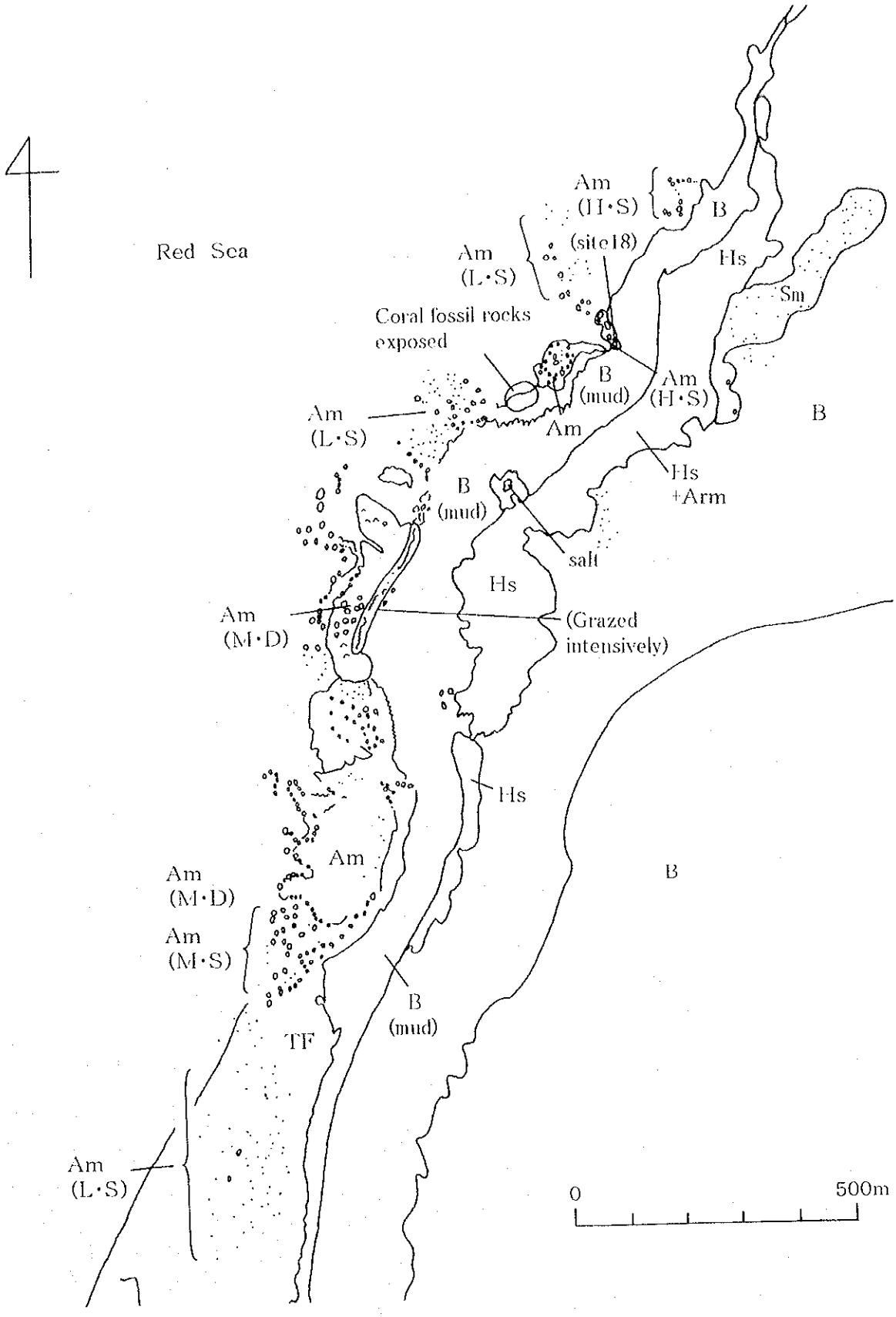
3.3 Al-Quff

The vegetation map of Al-Quff is shown in Fig.74. Al-Quff was the site with the most extensive *A. marina* community in the coastal zone of the Study Area. *A. marina* communities of various heights 2 - 6 m grew in mosaic along the seashore. There were also salt marshes 50 – 150 m in width parallel to the shoreline. The inland-side edges of some *A. marina* communities were damaged intensively by camel grazing. Camels can reach the *A. marina* because the water is shallow even at high tide. In total, the vegetation structure at Al-Quff was heterogeneous compared with the other areas. The biomass of this area also seems to be high because of the mature *A. marina* community 4 – 6 m in height.

3.4 Jazirat Umm Rumah.

The vegetation map of the eastern part of Jazirat Umm Rumah is shown in Fig.75. *R. mucronata* communities grew mainly in three areas on the east side of Jazirat Umm Rumah. *R. mucronata* was found not only along the tidal creeks but also along the shorelines. The shorelines in this area were protected from wave action by *A. marina* communities forming a lagoon. The height and DBH of *R. mucronata* were 3 – 4 m and about 5 – 8 cm respectively.

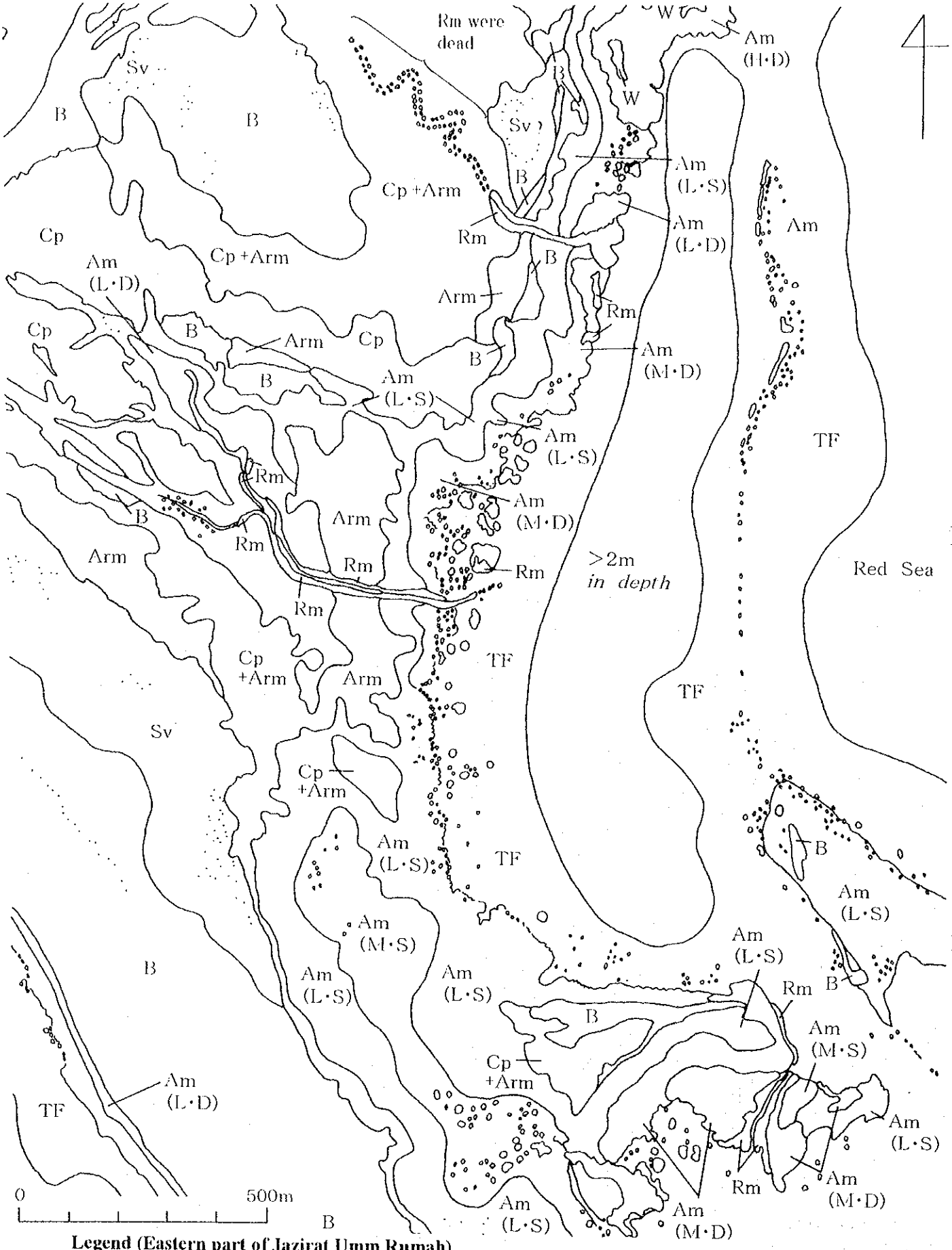
A *R. mucronata* community in the upper part of the northern tidal creek about 300 m from the mouth was dead.



Legend (Al-Quff)

<Mangroves> Am (H·S) : *Avicennia marina* (4 – 5 m in height, <50% coverage), Am (M·D) : *A. marina* (2 – 3 m, >50%), Am (M·S) : *A. marina* (2 – 3 m,< 50%), Am (L·D) : *A. marina* (< 2m, >50%), Am (L·S) : *A. marina* (<2m, 50%)
<Salt marshes> Hs : *Halocnemum strobilaceum*, Arm : *Arthrocnemum macrostachyum*, Sm : *Suaeda monoica*
<Others> TF : Tidal flat, B : Barren land (less than 5 % coverage), W : Water

Fig. 74. Vegetation map of Al-Quff.



Legend (Eastern part of Jazirat Umm Rumah)

<Mangroves> Rm : *R. mucronata* (3 – 4m in height), Am (M·D) : *Avicennia marina* (2 – 3 m, more than 50% coverage), Am (M·S) : *A. marina* (2 – 3 m, <50%), Am (L·D) : *A. marina* (<2m, >50%), Am (L·S) : *A. marina* (<2m, <50%)
<Salt marshes> Hs : *Halocnemum strobilaceum*, Arm : *Arthrocnemum macrostachyum*, Hp : *Halopeplis perfoliata*
<Others> TF : Tidal flat, Cp: Cyanophyceae (blue-green algae), B : Barren land (< 5 %), W : Water (Tidal creek)

Fig. 75. Vegetation map of the eastern part of Jazirat Umm Rumah.

2.2.8.3. Discussion and conclusions

1. Mangrove distribution in Al-Wajh Bank

The field survey and analysis of the habitat maps show that mangrove distributions in Al-Wajh Bank tend to concentrate in the eastern and / or southern parts of offshore islands located in the outer barrier reef, such as Jazirat Umm Rumah, Jazirat Birrim and Jazirat Shaybarah. Jazirat Qumma'an is located in the centre of Al-Wajh Bank and its mangroves are distributed in its south-eastern area. This tendency is conspicuous in the distribution of *R. mucronata* communities.

North–west winds prevail in Al-Wajh Bank throughout the seasons, and the north–west parts of offshore islands are hit directly by strong winds and waves. The downwind side, less affected by winds and waves is considered a more favourable habitat for mangrove growth and re-establishment.

2. *R. mucronata* distribution

It is clear that *R. mucronata* communities were established on the three islands of Jazirat Umm Rumah, Jazirat Qumma'an and Jazirat Shaybarah. . Of the three islands, Jazirat Umm Rumah has the largest *R. mucronata* community. It is also remarkable that the northern tidal creek on Jazirat Umm Rumah (around 25°44'00''N) is the northernmost point of *R. mucronata* distribution in Arabian regions. The northern limit was considered to be the Sonmiani forest in Pakistan at latitude 25°30'N, and at 23° N on the Egyptian Red Sea coast (AL-WETAID et al. 1998).

3. Total destruction of *R. mucronata* community on Umm Rumah

All *R. mucronata* individuals along the upper tidal creek on Jazirat Umm Rumah were dead. Sedimental sands have almost closed the tidal creek there, causing higher salinity in stagnant water, which might have caused the death of the community. Though this phenomenon occurs naturally, the status of *R. mucronata* communities needs to be

monitored in order to protect the *R. mucronata* population from extinction, because the distribution of the *R. mucronata* in Al-Wajh Bank is limited to particular places, and *R. mucronata* is very sensitive to environmental changes.

4. The influence of grazing on mangroves

There was of course no sign of grazing by livestock on the offshore islands of Al-Wajh Bank. On the mainland side of Duqm Sabq and Al-Quff, marks of grazing by livestock were clearly evident in and around the surveyed sites.

The mangrove trees of sites 1 and 15 in Duqm Sabq were not damaged by grazing at all because both of the sites are located in seaward areas covered by seawater even at low tide. On the other hand, the mangroves in the landward areas not covered by seawater and / or with shallow water even at high tide were grazed by camels to a greater or lesser degree.

The mature *A. marina* groups of site 18 in Al-Quff were grazed intensively in the landward area. The landward edge of the mangroves in Al-Quff was almost completely withered away. The damaged mangrove area was located parallel to the shoreline, in a narrow belt.

These observations indicate that the depth of seawater can be considered as the most important factor for limiting camel access to the mangroves.

5. The age of mangroves affected by cutting

There was no direct human impact on the mangroves, such as destruction due to a large scale development and coastal land reclamation in the Model Area. However, the marks of tree cutting in the past were found in and around some mangrove sites.

The marks of tree cutting were found clearly on *A. marina* stumps with sprouting in some places on the mainland coast. On the offshore islands of Al-Wajh Bank, the evidence of cuttings in *A. marina* individuals was not found in the field surveys. *A. marina* communities in Al-Wajh Bank were usually dwarf, their height were usually low (less than 3 m). *A. marina*

naturally displays stump sprouting, irrespective of whether of not there has been cutting. Its branches and stems extend horizontally from the stump, so the plant looks stunted regardless of its age. It is difficult to know the age of an *A. marina* mangrove in Al-Wajh Bank from to its height.

There were no marks of tree cutting on *R. mucronata* individuals. The height of *R. mucronata* communities in Jazirat Qumma'an and Jazirat Umm Rumah averaged 3 – 4 m. *R. mucronata* does not sprout naturally, and its stems and branches grow upward. It is reported that there are mature *R. mucronata* forests 7 – 9 m high in Farasan islands, southern part of the Red Sea (AL-WETAID et al. 1998). Considering the facts mentioned above, it is assumed that *R. mucronata* communities in Al-Wajh Bank are still in mature.

Traditionally, mangroves were used for not only firewood but also timbers for building huts and boats in Arabian regions, and *R. mucronata* is preferred to *A. marina* (ORMOND et al. 1986). After the discovery of the oil fields, the use of mangroves is supposed to have reduced gradually. Considering both the change in life style of local people and the present state of the mangroves as mentioned above, it is assumed that the age of mangroves is closely connected with the mangrove utilisation in the past.

6. Succession

In the case of site 1 at Duqm Sabq, *R. mucronata* coexisted with *A. marina*. The former individuals seemed to be younger than the latter because of their small sizes in height, D_{10} and DBH. *R. mucronata* were found mainly at the landward edge, less affected by wave and wind. From these facts, the following hypothetical regaarding the process of mangrove formation in this site can be assumed.

Initially *A. marina* germinated as the pioneer species and settled in a lagoon with shallow water, and their stems and roots accumulated sands and mud as they grew in the site. After the formation of *A. marina* thickets, floating viviparous seeds of *R. mucronata* reached the site

from the offshore island with *R. mucronata* community. It settled the site and started growing under the protection from winds and wave by *A. marina*. *R. mucronata* seedlings were abundant around the prop roots in site 1, though a couple of *A. marina* seedlings were also found. This fact suggests that the regeneration of *R. mucronata* is more active than *A. marina* in the site. From the viewpoint of the dynamics of mangrove community, it is recommended to continue monitoring this site.

7. Soil – vegetation relationship

The tree census and the soil surveys, clasified some aspects of the soil-vegetation relationship such as redox potential and salinity of the soils in some typical mangrove and other vegetation sites. For instance the redox potential, indicating decomposition by microbes, increased in correspondance with the mangrove development.

Since the soil conditions are changed so much by seasonal and daily tidal movements, the information obtained by this survey is not sufficient for an understanding of the soil conditions of the sites. A more detailed survey of the mangrove soils will be needed in the future.

8. Evaluation of the areas in Al-Wajh Bank

The vegetation of the offshore islands of the Al-Wajh Bank is not so rich in terms of biodiversity. This is because hyper-saline conditions are created by the monotonous flat topography. Biomass and productivity are relatively high in comparison with mainland because of the widespread distribution of mangrove .

Of all the offshore islands two, Jazirat Qumma'an and Jazirat Umm Rumah, which have tidal creeks with *R. mucronata* are considered as the most valuable. The habitat requirements of *R. mucronata* cover such a narrow ecological range that it is more sensitive than *A. marina*.

Jazirat Shaybarah should also be evaluated highly because of the large distribution of

A. marina communities. A small population of *R. mucronata* also grows on this island.

Duqm Sabq on the mainland has a *R. mucronata* community mixed with *A. marina*, though it is small. In terms of both the unique *R. mucronata* distribution on the mainland coast and its peculiar status in succession, this site is considered an important site for monitoring.

9. Recommendations

The Model Study has shown the present situation of mangroves / coastal vegetation in Al-Wajh Bank, but there is still not sufficient information to understand the vegetation structure, dynamics and function. A more detailed and deeper study based on the results of the Model Study will be needed in the future. The recommendations concerning the mangroves / coastal vegetation are as follows ;

9-1. Re-survey of the permanent quadrats

Permanent quadrats of the different vegetation types including mangroves were set up in Al-Wajh Bank, and data concerning community structure were obtained in the study. For the purpose of understanding changes in the community structure, a follow-up survey should be conducted in the future,using the same methods for instance after five years. Comparison of the data in different periods may clarify the mechanism of vegetation dynamics and / or succession.

9-2. Survey of tidal flooding / inundation

The field surveys indicated that tidal flooding / inundation is considered as one of the most important factors affecting mangrove germination, formation, zonation and distribution. It is recommended that the frequency and duration of tidal flooding in the mangrove sites be investigated in detail.

9-3. Survey of grazing pressure

Obviously grazing pressure is one of the strongest factors affecting the vegetation. In order to understand how the Model Area could support the vegetation wthout grazing pressure,

it is recommended to set several quadrats surrounded with fence to protect it from livestock invasion in the Model Area to monitor grazing pressure. A comparison between the vegetation coverage and number of individuals in the quadrat with those of neighbouring unprotected sites, will clarify the capacity to support the vegetation.

9-4. Social survey regarding mangrove use in the past and the present

A knowledge of the state of the vegetation and human activities in the past is important for an understanding of the present situation. For that reason, in addition to the monitoring, detailed social surveys in terms of mangrove utilisation will also be needed in the future.

9-5. Using the aerial photographs taken in the past

As the case of the Al-Quff mangrove site with decayed stumps shows, it seems that the vegetation has been changing. It is recommended that the aerial photographs taken both in the past and the present are compared and analyzed in order to understand the changes in the vegetation. This would provide fundamental data for understanding vegetation dynamics.

2.2.9. BIRDS

2.2.9.1. Methods

The Birds team co-ordinated its field survey work closely with the Mangroves / Coastal Vegetation team in order to understand the status of the avifauna together with the vegetation on which the bird species depend heavily for their survival.

Three survey sites were selected using aerial photographs and the habitat maps; two on the mainland and the other on an island. Site selection was also carried out in close collaboration with the Mangroves / Coastal Vegetation team. The criteria for selecting the areas were as follows;

- an area which represents one of the major habitats in the Model Area; and
- an area with easy access, where a permanent monitoring line can be set up.

At the sites, census lines were set up: lines about 2.5 km long on the mainland and lines about 1.2 km long on the island. Lines were set up in different habitats in the sites.

The study was conducted in two different seasons: February 1999 and June 1999.

A census was conducted at least three times (on different day) on each line, and all species and their numbers were recorded. In each census, the observers walked along the line at the same speed as far as possible. A 50 m wide strip on both sides of the lines was included in the counting (i.e. a 100 m belt for the census) and the observers walked along the line carefully so as not to count the same individual twice.

The following three areas were selected as the survey sites; Duqm Sabq, Jazirat Qumma'an and Qara'ir. Four lines (Line 1 – Line 4) were set up at Duqm Sabq, two lines (Line 5 – Line 6) at Jazirat Qumma'an and one line (Line 7) at Qara'ir (Appendix 22).

In February, Line 1 – Line 4 were surveyed four times on different days. Lines 5 and

6 were surveyed three times on two days (i.e. two surveys were conducted on the same day). This was because the island is difficult of access and only two visits were made. Line 7 was surveyed twice on two days.

In June, all lines were surveyed three times. Line 5 and 6 were surveyed on two days (i.e. two surveys were conducted on the same day).

The surveys were conducted in the morning on the mainland, and on the island the survey was conducted soon after landing (late morning to early afternoon). An attempt was made to conduct the survey at the same time each day on each line . In consideration of the light conditions for census, the starting point of each line was set at the southern end of the line and the survey proceeded northwards.

The vegetation type of each site was surveyed by the Mangroves / Coastal Vegetation team. The details are given in Section 2.2.8 Mangroves / Coastal Vegetation.

In June 1999, Al-Quff, about 100 km north of Al-Wajh, was visited for one day to conduct a line transect survey in order to compare the avifauna in mangrove thickets other than the ones in Duqm Sabq and on Jazirat Qumma'an. This site is outside the Model Area.

Binoculars of 10 x 40 and 8 x 30 were used for the survey. The bird list is based on the checklist in PORTER et al. (1996).

2.2.9.2. Results

1. Habitat description of the survey sites

Habitats and number of recorded species on each line are summarised in Table 119.

Table 119. Survey sites, lines, habitats and numbers of recorded bird species.

Survey site	Line	Habitat	No. of recorded species	
			February	June
Duqm Sabq	Line 1	The line is located along the shoreline. It is topographically flat. At the starting point, there is a mangrove thicket (mainly *Avicennia marina*), and at the end of the line, there is also a mangrove thicket (mainly *Avicennia marina*). The vegetation type along the line is a salt marsh with *Arthrocnemum macrostachyum* and *Halocnemum strobilaceum*.	30 spp.	15 spp.
	Line 2	The line is located about 500 m from inland Line 1. It is topographically flat. The vegetation cover is very low and it is dominated by *Halopeplis perfoliata* and *Zygophyllum album*.	6 spp.	2 spp.
	Line 3	The line is located along the shoreline. It is topographically flat and there are small sand dunes. The vegetation cover is low and is dominated by *Zygophyllum album*. The soil is mainly sandy.	25 spp.	7 spp.
	Line 4	The line is located about 500 m inland from Line 3. Topographical features are more complex than on Line 2. Several small wadis are developed in the area. The vegetation is dominated by *Zygophyllum album*.	10 spp.	0 spp.
Jazirat Qumma'an	Line 5	The line is located on the island. It extends inland from the shoreline. It is topographically flat. There are mangrove thickets (*Avicennia marina*), salt marsh and dry land.	4 spp.	5 spp.
	Line 6	The line is located on the island. It runs along and through mangrove thickets (*Rhizophora mucronata* and *Avicennia marina*).	7 spp.	7 spp.
Qara'ir	Line 7	The line is located along the shoreline. It is topographically flat. The vegetation cover is very poor and there are a few small patches of *Halopeplis perfoliata*. The soil is mainly sandy.	18 spp.	8 spp.

According to the aerial photographs and the previous field surveys, the vegetation type of the area containing Lines 1 – 2 (except for mangrove thickets *Avicennia marina* and *Rhizophora mucronata*) is typical of the predominant vegetation cover in the Model Area. The vegetation is dominated by *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum*, *Halopeplis perfoliata* and *Zygophyllum album*. These are distributed from the shoreline inland, forming zones according to the effects of the sea (mainly salination). In the same site, the habitat on Line 1 is different from that on Line 2.

The vegetation type of the area containing Lines 3 - 4 is not typical. Small wadis, which are a rare topographical feature in the Model Area, are developed, and vegetation coverage is high. The vegetation is dominated by *Zygophyllum album*. In the same site, the habitats on Line 3 and Line 4 are different.

The vegetation type of Lines 5 – 6 may be typical of other islands in the Model Area.

The vegetation type of Line 7 is the one which dominates in the Model Area.

At Al-Quff, a line (about 2.5 km long) was set up along the shore. It is topographically flat. Mangrove thickets continue along the line. Some parts are very well developed and their structure is more complex than in Duqm Sabq or on Jazirat Qumma'an. Salt marsh vegetation is also well developed.

2. Species and habitats

The composition of bird species and number of individuals on each line were different. This is believed to be a result of the differences in habitat, and is also affected by season. Species and their numbers on each line in the two seasons are shown in Table 120.

2-1. February (winter)

The species composition on Line 1 is similar to that on Line 3. On Lines 1 and 3, more shorebirds and gulls (e.g. Dunlin *Calidris alpina* and Slender-billed Gull *Larus genei*)

Table 120. Lines and species.

	English name	Scientific name	Mean number of individuals													
			Line 1		Line 2		Line 3		Line 4		Line 5		Line 6		Line 7	
			February	June	February	June	February	June	February	June	February	June	February	June	February	June
1	Western Reef Heron	*Egretta gularis*	1.0	1.3			0.8	0.7			0.3		0.3		1.5	0.3
2	Goliath Heron	*Ardea goliath*	0.5	0.3												
3	Spoonbill	*Platalea leucorodia*		1.3												
4	Osprey	*Pandion haliaetus*		0.7		1.3		0.3				1.3	0.3			2.3
5	Oystercatcher	*Haematopus ostralegus*	0.3				3.5								0.5	
6	Crab Plover	*Dromas ardeola*	0.3	16.7				24.7				0.7		2.7		23.0
7	Ringed Plover	*Charadrius hiaticula*					0.3									
8	Kentish Plover	*Charadrius alexandrinus*	3.8	0.7			10.8	1.7					1.3		15.5	4.3
9	Lesser Sand Plover	*Charadrius mongolus*	0.8				0.3								5.0	
10	Greater Sand Plover	*Charadrius leschenaultii*	4.0				7.8								7.5	
11	Plover sp.	*Charadrius* sp.	0.3				6.8									
12	Grey Plover	*Pluvialis squatarola*	2.5				6.8								6.5	
13	Little Stint	*Calidris minuta*													0.5	
14	Dunlin	*Calidris alpina*	18.3				16.3								39.5	
15	Bar-tailed Godwit	*Limosa lapponica*	1.5				6.5								4.0	
16	Whimbrel	*Numenius phaeopus*												0.3		
17	Curlew	*Numenius arquata*	2.0				3.5		1.3				0.3		1.5	
18	Redshank	*Tringa totanus*	3.5								2.0		1.0	0.7	2.5	
19	Greenshank	*Tringa nebularia*	1.8				0.8								2.0	0.7
20	Green Sandpiper	*Tringa ochropus*					0.5								3.0	
21	Terek Sandpiper	*Xenus cinereus*	3.5												0.5	1.3
22	Turnstone	*Arenaria interpres*	15.8				7.3								4.5	
23	Sooty Gull	*Larus hemprichii*	0.8	6.0			1.0	2.7							0.5	1.0
24	White-eyed Gull	*Larus leucophthalmus*						0.7				0.7				
25	Slender-billed Gull	*Larus genei*	2.8	0.7			1.5								0.5	
26	Yellow-legged Gull	*Larus cachinnans*					0.5									
27	Gull sp.	*Larus* sp.	0.3	0.3												
28	Gull-billed Tern	*Gelochelidon nilotica*		0.7												
29	Caspian Tern	*Sterna caspia*	0.5	0.3												
30	Rock Dove	*Columba livia*		7.0												
31	Common Kingfisher	*Alcedo atthis*												0.3		
32	Desert Lark	*Ammomanes deserti*		1.0	0.3				4.3							
33	Hoopoe Lark	*Alaemon alaudipes*	0.3		2.0		3.5		7.8							
34	Crested Lark	*Galerida cristata*	5.8	5.0					0.3							
35	Lark sp.	*Calandrella sp.*													3.5	
36	Sand Martin	*Riparia riparia*	0.3													
37	Barn Swallow	*Hirundo rustica*	1.3				0.5									0.3
38	Red-rumped Swallow	*Hirundo daurica*			0.5				0.3							
39	White Wagtail	*Motacilla alba*	0.3		0.3		0.5									
40	Wagtail sp.	*Motacilla sp.*					0.3									
41	Tawny Pipit	*Anthus campestris*					2.5		3.3							
42	Desert Wheatear	*Oenanthe deserti*	1.8		0.8		2.5		4.5		0.3					
43	Graceful Prinia	*Prinia gracilis*	2.0	1.3					0.8		0.7		0.3	1.0		
44	Scrub Warbler	*Scotocerca inquieta*			0.8				0.8			0.3				
45	Warbler sp.	*Acrocephalus sp.*										0.3	4.0	5.3		
46	Warbler sp.	*Sylvia* sp.	1.0													
47	Chiffchaff	*Phylloscopus collybita*	0.3				0.3		0.3							
48	Brown-necked Raven	*Corvus ruficollis*	0.3				0.5	1.0								
		Total number of species	30	15	6	1	25	7	10	0	4	5	7	6	18	8

were observed than terrestrial birds. However, different terrestrial birds were observed on Line 1 and Line 3. For example, *Sylvia* sp. was recorded on Line 1 but not on Line 3, and Tawny Pipit *Anthus campestris* was observed on Line 3 but not on Line 1.

The species compositions on Lines 2 and 4 are similar but the numbers of certain species are different. For example, the number of individuals of Hoopoe Lark *Alaemon alaudipes* observed on Line 2 is much lower than that observed on Line 4.

The avifauna on the island was poor. Mangrove thickets (Line 6) did not seem to hold many birds. *Acrocephalus* spp. and a few other species were recorded. Very few species were recorded on other line (Line 5) on the island. No sea bird colony was observed.

Only one terrestrial species (a lark) was observed on Line 7. Commonly seen species in other sites (e.g. Crested Lark *Galerida cristata*) were not recorded. Other species observed included herons, shorebirds and gulls.

2-2. June (summer)

The number of bird species is very low and on Line 4 no bird was observed during the survey (3 days). Climatic conditions are believed to be the major reason.

With regarding to the number of individuals, Crab Plover *Dromas ardeola* was the only exception. About 20 – 30 individuals were usually counted on the lines on the mainland (Line 1, 3 and 7).

Generally, very few terrestrial birds were observed. Crested Lark *Galerida cristata* and Graceful Prinia *Prinia gracilis* were observed as in February, but their numbers were lower than in February.

Few shorebirds (e.g. Dunlin *Calidris alpina*) were observed, both in numbers of species and individuals. Shorebirds winter in this area and go back to their breeding sites in the north in summer, and only few individuals remain in this area. The exceptions are Crab Plover and Kentish Plover *Charadrius alexandrinus*, which breed in the area.

The species compositions of Lines 1, 3 and 7 were similar. These lines are all on the shoreline of the mainland, and thus has a similar composition of marine species (e.g. Crab Plover). On Lines 3 and 7, Brown-necked Raven *Corvus ruficollis* (Line 3) and Barn Swallow *Hirundo rustica* (Line 7) were the only terrestrial birds observed.

Lines 2 and 4 are located about 500 m inland on the mainland. Only Osprey *Pandion haliaetus* and White-eyed Gull *Larus leucophthlmus* flew over Line 2, and no bird was observed on Line 4.

Lines 5 and 6 are on an island. On Line 5, few birds were observed. On Line 6 which is along mangrove thickets, a warbler sp. was heard. Since its full song was never heard, it is difficult to identify the species. The voice was low and loud, and it may have been Clamorous Warbler *Acrocephalus stentoreus*. A small reed warbler-like bird was also observed and this may have been African Reed Warbler *A. baeticatus*.

Al-Quff, which is outside the Model Area, was surveyed in order to compare avifauna in different mangrove thickets, and 12 species were recorded. The main difference between the avifauna in Duqm Sabq and that in Al-Quff was doves. In Al-Quff, two species of doves were observed and the numbers of their individuals were high; Collared Dove *Streptopelia decaocto* (30 individuals in one hour) and Laughing Dove *S. senegalensis* (4 in one hour). In Duqm Sabq, none were observed.

3. Inventory

With regard to the inventory, in February 43 species including six unidentified species were recorded, and in June 34 species including three unidentified species were recorded. Red-rumped Swallow *Hirundo daurica* is new to the inventory.

2.2.9.3. Discussion and conclusions

1. Species and habitats

Both in February and June, the species composition and number of individuals were different in different habitats.

On the mainland, the lines along the shorelines had more bird species and individuals than the lines inland. This could be explained by the following;

1. on lines along the shoreline, there are many shorebirds and gulls especially in winter; and
2. salt marsh vegetation is generally developed along the shoreline, providing terrestrial birds with their habitats.

Although the vegetation type on Line 7, which dominates in the Model Area, is poor, the species number is relatively high because of reason 1 above.

On the lines inland on the mainland, namely Lines 2 and 4, few bird species or individuals were observed. This is mainly because of the poor vegetation cover and severe climatic conditions. Especially in summer, the conditions on the two lines are very harsh. It should be noted that, although Line 4 has better vegetation coverage than Line 2, no bird was observed there in June.

On the island, the vegetation coverage becomes poorer towards the centre. On Line 5, almost all observed species were counted close to the shoreline, where a salt marsh and mangrove thickets are developed.

1-1. Arid area

This habitat is the dominant one in the Model Area and it is a typical habitat in "Northern Tihama" where the bird species diversity is very poor (JENNINGS 1995). In both seasons, there were very few birds observed in the habitat. On Line 2, one species (Osprey *Pandion haliaetus*) was observed in summer but it is thought that it was merely flying over

the site. The inland area of Line 7 belongs to this habitat and there were few species observed here.

1-2. Salt marshes

This habitat is developed narrowly along the shoreline on Line 1. This habitat is not well developed in the Model Area but it is often seen in the Study Area generally. It provides terrestrial birds with a breeding, wintering and resting habitat. Generally there were few species, but a relatively high number of individuals was observed.

This habitat is not discussed in the section Inventory Survey. This is because it is a microhabitat and is discussed as part of the larger habitats.

1-3. Wadis

The area in which Line 4 was set up is the only place where wadis are observed in the Model Area. Although the wadis are small, the difference from other habitats . regarding species composition and their abundance in winter is obvious. In early summer, the species composition and their abundance are expected to be different because of their specific vegetation coverage.

Wadis in the mountainous area of the southern part of the Red Sea are described as a very important habitat (NEWTON et al. 1994, FELEMBAN 1996). Although these wadis are on a much bigger scale, the wadi is a very important area in the Model Area since it is only found in Duqm Sabq in the Model Area. It is also noted that Duqm Sabq itself is located in the mouth of a large flat wadi. Wadi is a habitat to be studied in more detail in the future.

1-4. Mangroves

There are two types of mangrove thicket in the Model Area; one in Duqm Sabq and one on islands. The mangrove in Duqm Sabq consists mainly of *Avicennia marina* and the one on the islands there is a mixture of *A. marina* and *Rhizophora mucronata*.

On the basis of the Inventory Survey, these mangrove thicket were expected to

support many bird species and individuals. However, it seems that they apparently do not support them as expected.

In the Inventory Survey, the mangrove thickets in Al-Quff showed that they supported many bird species and individuals. In June 1999, a one day trip was made to conduct a line transect survey in Al-Quff and two species of dove with relatively many individuals were observed as in the Inventory Survey.

The Mangroves / Coastal Vegetation team conducted a comprehensive survey of mangroves in Duqm Sabq, Jazirat Qumma'an, Jazirat Umm Rumah (not visited by the Birds team) and Al-Quff. According to their findings, mangrove thickets in Al-Quff are more developed and have a more complex structure than those in any other sites, which indicates that the mangroves in Al-Quff are mature and the others are still in the young stage. This may explain why the avifauna of mangroves in Duqm Sabq and Jazirat Qumma'an is less complex than that in Al-Quff.

Mangroves cover the biggest area in the Study Area and it is very important to monitor the relationship between the mangroves and their avifauna.

Due to logistical problems and time constraint, the survey of mangroves and their bird species were not well conducted in the Study. There are detailed vegetation maps of these three sites in the Model Area, and it is important that a detailed study of these sites be conducted in order to understand this habitat and its bird species.

2. Species and season

In the Model Area (maybe also in the entire Study Area), there are two important factors which determine the species composition and numbers. One is habitat as already mentioned, and the other factor is season.

The two field surveys in the Model Area show that the seasonal difference is very clear. There are many wintering shorebirds and gulls in February, and few of these birds are

observed in June.

In the Model Area, vegetation cover is very low and it is generally very difficult to find breeding species such as Collared Dove and Little Green Bee-eater *Merops orientalis*. It is, however, necessary to question whether June is the right time to observe breeding species, especially terrestrial ones. There were some logistical problems concerning this point which the Study could not overcome. It is too early to say that there are few breeding species in the Model Area, and further work will be required. However, it is noted that in the entire Study Area the conditions for breeding are not suitable for many bird species (BALDWIN & MEADOWS 1987, JENNINGS 1995), and many numbers of breeding species, especially terrestrial ones, may not be recorded in future studies.

In order to understand the seasonal differences, it is strongly recommended that surveys should be conducted on the lines in autumn. This is because the results of the Inventory Survey indicate that the mangroves provide migratory birds with resting places.

3. Conditions for monitoring survey

In order to conduct monitoring surveys, all conditions apart from season need to be the same each time. Since the Study was conducted under many restrictions; e.g. logistical constraints Japanese members and social conditions of Saudi counterparts, all these conditions were not met. For example, tide conditions were not the same each time. It will be necessary to give careful consideration to this issue in future monitoring surveys.

2.2.10. ECOLOGICAL TRANSECT OF THE MODEL STUDY AREA

In the Model Study Area, many habitats were found along the ashore - offshore transect in harmony with the physical environment. Typical ecological features are summarized as follows (see Fig. 76).

Coastal land area

Coastal vegetation composed of trees such as *Acacia*, and *Tamarix* is found in the upper area. In the lower part, saltmarsh, sabkha covered with Cyanophyceae and mangroves form their own habitats on the sandy tidal flats form by wave action. Many crabs are found on the tidal flat, and they play an important role in water quality improvement through feeding on sedimented organic matter.

Zone A

Nearshore reefs washed by relatively high waves resulted from the long fetch store hardly any silt because the wave action disturbs the bottom sediment and takes fine particles away. Such physical condition, allows little seabottom flora, including Cyanophyceae, seagrasses or macro algae, to develop. Turf / small algae which thrive on the very shallow hard substrate are usually the only significant flora in this zone. Poor flora consequently results in a sparse distribution of fish. Reef patches and other coral reef areas in this zone, however, are sometimes inhabited by some benthic animals, such as crabs, sea urchins and giant clams together with small fishes.

Zone B

A transect of the nearshore area in this zone shows a basin with depth of 5 – 10 m or more, where rapid flow occurs in the shallow layer so as to wash the silt particles away, allowing the growth of seagrass beds and the aggregation of drifted sargasso. The silt particle sedimentation from the upper layer settles in the sea bed at depths below 5 m or so. Therefore, no seagrass or algae other than Cyanophyceae thrive there. The biomass of benthos is abundant on the deep Cyanophycea mat and on the shallow sandy area surrounding the dense

seagrass beds. Fish appear less abundant there than in the coral reef areas.

The area immediatly offshore from the above is characterized by reef patches and tidal creeks. There appears to be a rapid water current which does not allow a high abundance of epibenthic fauna. Thus, the ecosystem here is symbolized not by the food chain of plant – benthos – reef-associated fish, but by the migration of large predatory fish, such as scads, feeding on smaller fish.

Zone C

The nearshore area in this zone sometimes forms a very shallow flat seabottom made up of coral reef. Macro algae thrive here because waves and rapid water currents prevent herbivorous fish from invading the seaweed bed to graze. Similarly to Zone B, in deep areas this zone often has basins the of which of which is covered with Cyanophyceae. These make a mat on the silt and fine sand originating from the coral reef. The shallower seabottom in basins which receive the effect of waves from the open ocean, has seagrass beds and coral reef, the development of which is aided by the wave action shaking silt off the leaves. The offshore area in this zone has a sandy and silty seabottom where saltmarsh and mangroves grow.

Zone D

The outer barrier reef is characterized by turf/small algae on the top and a steep drop-off with healthy coral reef. Turf/small algae can survive around the top of the reef edge in spite of the high abundance of herbivorous fish just outside the reef. This is because the strong wave action keeps them away. Some filter feeders, including large schools of sardine observed there, may feed on the small algae coming off the hard substrate because of the strong wave action. The coral reef on the steep slope has highest live coral coverage in the area because there is no disturbance by siltation, and the reef supports a rueg reef-associated fish community.

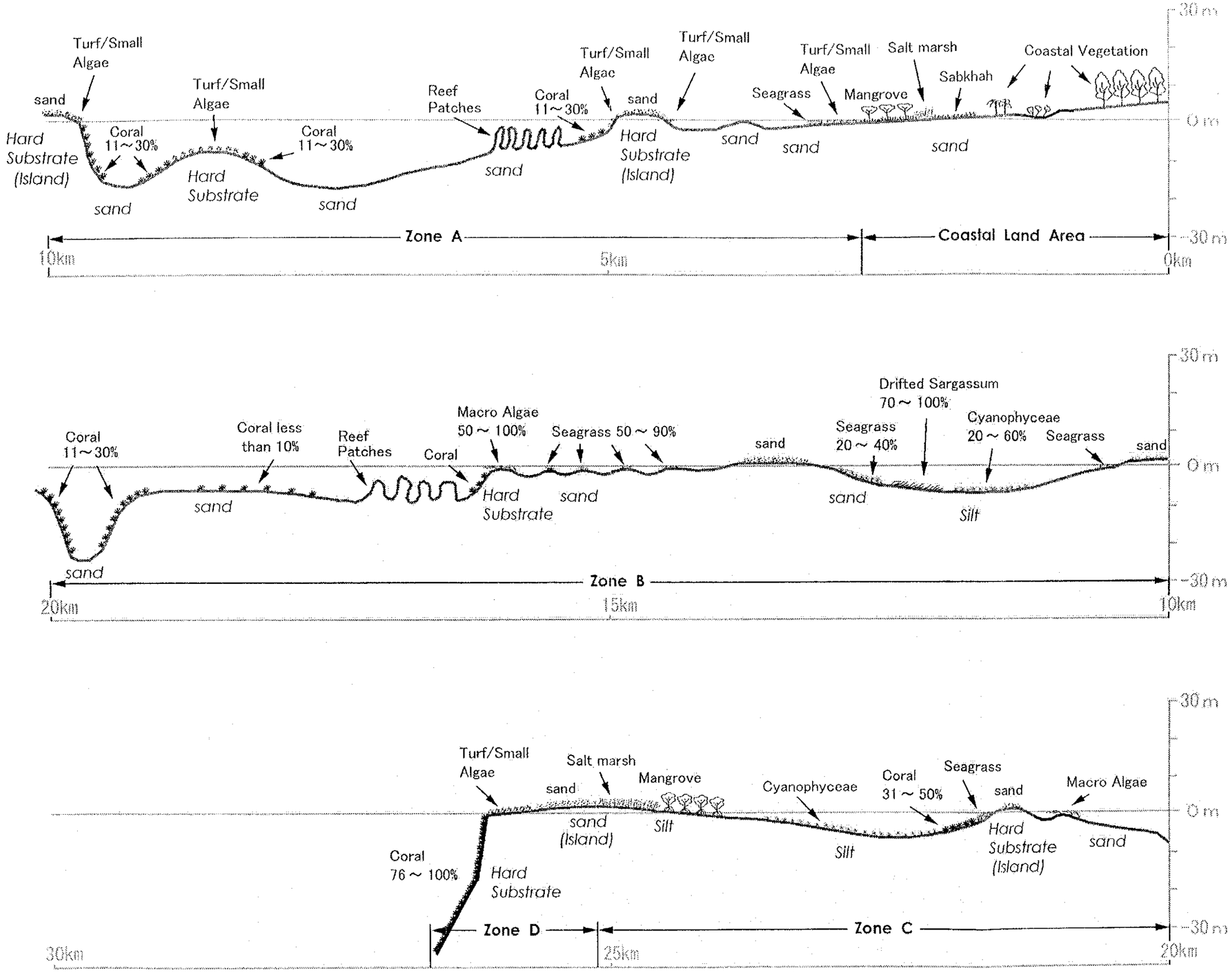


Fig. 76. Ecological transection of the Model Area.

3. SOCIAL ENVIRONMENT

3.1. INTRODUCTION

Socio-economic surveys were conducted to determine the present extent and future potential impact of human activities on the coastal biological environment. The northern coast of the Red Sea belongs to an arid zone, where the annual rainfall is no more than 40 mm. The coastal region has a milder and more humid climate in comparison with the inland region due to the existence of the Red Sea. Almost all local people in the Study Area are Muslims. They subsisted traditionally on grazing, fishing and agriculture in wadis. Grazing plays an important role in providing protein for people living in the arid zone with meager vegetation. The local people continue to engage in these traditional occupations in this extremely dry and sparsely populated region. The livelihood of traditional society was dependent on the available natural environmental resources. However, the recent influx of oil wealth has been radically changing the traditional ways of life (McKINNON 1990). Previous socio-economic studies in the northern Red Sea region had not been comprehensive enough to point out effects from these recent changes.

3.2. METHODS

The socio-economic surveys consisted of three phases, a preliminary survey (Phase I), a comprehensive survey of the northern coast of the Red Sea (Phase II) and an in-depth survey of the Model Area (Phase III). The preliminary survey was conducted in February, 1998, to gain an understanding of the general condition of the Study Area. The comprehensive survey was conducted in May-June and October of 1998. The in-depth survey of the Model Area was conducted in February-March and June of 1999.

3.2.1. METHODS OF THE COMPREHENSIVE SURVEY IN THE STUDY AREA

The Comprehensive Survey focuses on three subject areas; 1) general information, 2) grazing and 3) fishing, to determine the impact of the human activities on the natural biological environment in the Study Area. General information consists of a) population, b) large scale development projects including oil plants, power plants, desalination plants and cement factories, c) waste disposal sites. Two survey methods were employed for this study; 1) collection of information from government offices, and 2) interviews with local people. Table 121 shows the subjects covered by the survey, the methods used and the sources of information for each subject .

3.2.2. METHODS OF THE IN-DEPTH SURVEY IN THE MODEL AREA

The in-depth socio-economic survey focuses on two subject areas, grazing and fishing, to determine the impact of human activities on the biological environment of the Model Area. Three survey methods were employed for the in-depth socio-economic study; 1) interviews with local people, 2) collection of information from government offices and 3) visits to local markets. Table 122 shows the subjects covered by the survey, the methods used and the sources of information for each subject.

3.3. RESULTS

3.3.1. STUDY AREA

The Study Area stretches over approximately 1,000 km from Haql to Jeddah. Six cities, Haql, Duba, Al-Wajh, Umluj, Yanbu' and Masturah, were selected as survey sites. A survey team visited two or three villages in each site. On the basis of population distribution, two distinct regions were defined in the study area. The northern region is sparsely populated, and accounts for two thirds of the Study Area, while the southern region is relatively densely

Table 121. Subjects, survey methods, and information sources in Phase II.

Subject	Survey method	Information sources
Population	Interview	Municipality, state government
Proportion of foreigners	Data collection	Hospital Patients classified Saudi and non-Saudi
Desalination plants	do	The Saline Water Conversion Cooperative
Power plants	do	The Saudi Consolidated Electric Company
Oil plants	do	The Ministry of Industry and Electricity
Domestic waste water	Interview	Municipality
Hot waste water	Data collection	The Saline Water Conversion Cooperative
do	do	The Saudi Consolidated Electric Company
Grazing	Interview	Bedouins and foreign workers
Wadi agriculture	do	Saudi owners and foreign workers
Fishing	do	Saudi and non-Saudi fishermen
do	Data collection	Coast guard centres
do	Interview	Fish markets, fish businessmen
do	do	Fishery Service Station (Duba, Umluj, Yanbu')

Table 122. Subject, survey method, information sources and main items in Phase III.

Subject	Survey method	Information sources	Main items
Grazing	Data collection	Local office	No. of animals in the area
	Interview	do	Impact on grasses, bushes and trees
	do	do	Ways of conserving range-land
	do	Local marcket	Marcket prices, age, weight of animals
	do	Bedouins	Nomadic areas
	do	do	Management of animal husbandry
	do	do	Modernization of management
	do	Foreign worker	Working situations, nomadic areas
Fishing	Data Collection	Coast Guard Centres	No. of fishermen, boats by ports
	do	do	Fishing trips of fishermen
	Interview	Fisheries Service Station	Data of fishing catch
	do	Local office	Technique of fish conservation
	do	Fish Markets	Trends in fish distribution
	do	Saudi fishermen	Conditions of concession, fishing management
	do	Foreign fishermen	Conditions of concession

populated and accounts for one third of the Study Area.

3.3.1.1. General Information

1. Population

1-1. Population distribution and density

According to the census conducted in 1992, the population of Saudi Arabia was estimated to be 16.9 million, and the country's territory covered over 2.25 million square km of land. The population density was 7.5 persons per square km. The size of the Study Area was nearly 1,000 km along the coastline of the Red Sea. Two-thirds of the coastline, a 676 km section, was in the sparsely populated northern region that comes under the Tabuk administrative region (estimated 3.2 persons/km^2, 486,134 persons in 1992). The remaining one third of the coastline, a 349 km section, was in the densely populated southern region between Yanbu' and Jeddah. This section comes under the Madinah (including Yanbu', 1,084,947 persons in 1992) and the Makkah (including Jeddah, 4,467,670 persons in1992) administrative regions, and is one of the most densely populated areas in Saudi Arabia (Table 123).

The uneven distribution of population in the region is confirmed by a comparison of the population densities of the survey sites. Table 123 shows population densities of the survey sites in the Study Area; the densities of four survey sites in the Tabuk region were relatively low, i.e., 3.4 persons per square km in Haql, 2.5 in Duba, 2.2 in Al-Wajh, and 2.8 in Umluj. In contrast, the population densities of two survey sites in the southern region were considerably higher, i.e., 42.4 persons per square km in Yanbu', and 208.2 in Masturah. (Since boundaries of political units, such as districts and administrative regions are not clearly delineated in this country, areas of districts or administrative regions can not be determined, and thus exact data on population densities are not available.)

Table 123. Estimated population of the Study Area.

Survey site	Haql	Duba	Al-Wajh	Umluj	Yanbu'	Masturah
Population (persons)	19,323	39,100	32,644	44,091	172,086	5,207
Area (km^2)	5,643	15,750	15,000	16,000	4,250	25
Density persons/km^2	3.4	2.5	2.2	2.8	40.5	208.3
Percentage of foreigners (1)	17.1	19.1	13.3	11.5	22.2	14.6

1. Masturah is one district of Rabigh city.
2.Percentage of foreigners (1) come from the rate of non-Saudi in public hospital in 1997.
3.The data for Yanbu' is from the population census of 1992.

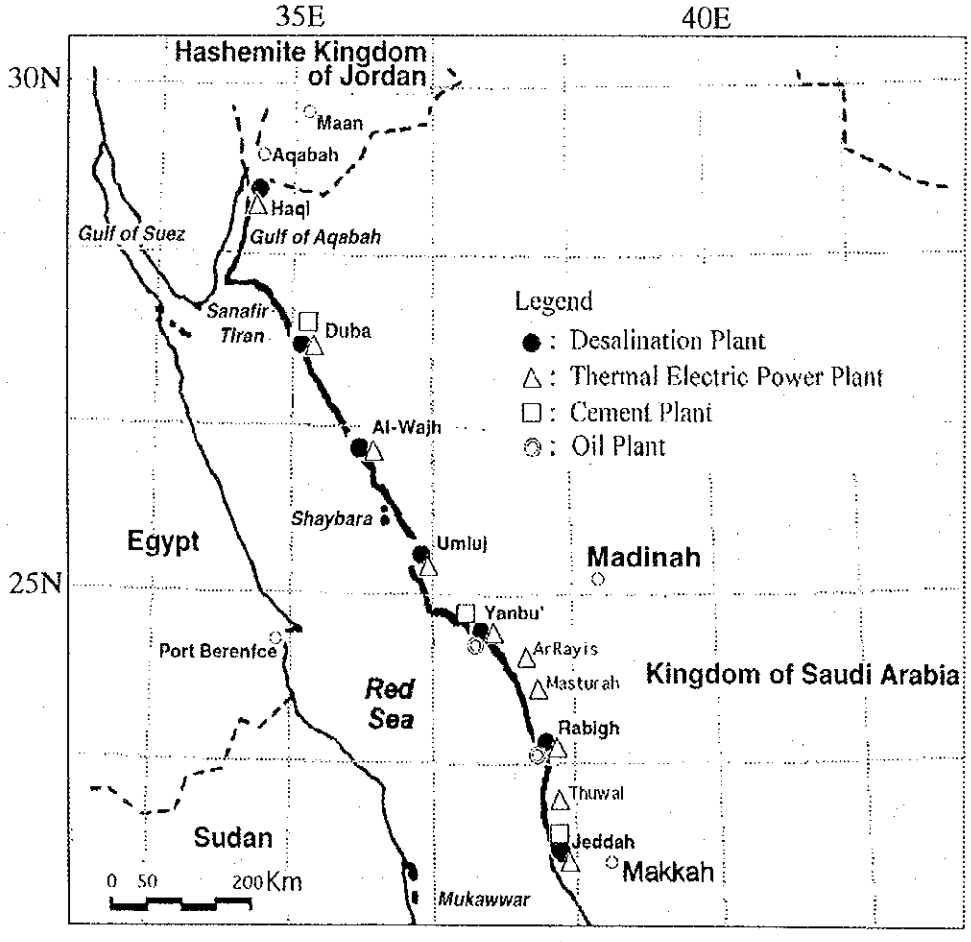


Fig 77. Distribution of large industrial plants in the Study Area.
Source: Saline Water Conv. Corp. *Annual Report 1996.*

JCCME/JEPIC. 1998. *Survey on Electric Power Generation in Saudi Arabia.*

1-2. Proportion of foreigners

The percentage of foreigners to the entire population of the country was 27.4% in 1992 (Table 124), and 31.0% in 1995. Of the foreign nationals, 70 % were male. According to the census conducted in 1992, the percentage of foreigners in all the densely populated administrative regions was also high. For example, foreigners accounted for 37.8% of the population in Makkah, 31.8% in Riyadh, 26.2% in Eastern, and 22.8% in Madinah. The reason migrant foreigners are concentrated in large cities is that of jobs are available there in manufacturing, construction, oil and service industries. In contrast, the percentage of foreigners in rural areas is significantly low.

The percentages of foreigners given in Table 123 were estimated based on the proportion of non-Saudi patients in public hospitals in 1997, except the percentage for Yanbu'. The percentage of foreigners in the northern region was 17.1% in the Haql area, 19.1% in the Duba area, 13.3% in the Al-Wajh area and 11.5% in the Umluj area. There are only traditional primary industries in these rural areas. The percentage of foreigners on the other hand, was as high as 22.2 %, in the Yanbu' area, and 14.6% in the Masturah area. The southern region from Yanbu' to Jeddah contains a higher percentage of foreigners.

2. Large scale development projects in the Study Area

There are a number of large plants, such as oil plants, power plants, desalination plants and cement factories, along the coast of the Red Sea (Fig. 77). High demand for electricity and water in the large cities can be satisfied only by large power and desalination plants. Table 125 shows the distribution and sizes of desalination plants.

The desalination plants in Jeddah and Yanbu' are especially large. Jeddah is the second largest city in Saudi Arabia, and the most commercially developed city, with a population of 2.5 million. The desalination plants in Jeddah supply water not only to Jeddah but also to Makkah (population 0.63 million). Similarly, the plants in Yanbu' (population 0.17

Table 124. Population by nationality and administrative area (1992).

Administrative area	Total	Saudi	non-Saudi	% non-Saudi
Makka	4,467,670	2,781,075	1,686,595	37.8
Riyadh	3,834,986	2,613,915	1,221,071	31.8
Eastern	2,575,820	1,902,108	673,712	26.2
Madinah	1,084,947	837,695	247,252	22.8
Northern	229,060	178,610	50,450	22.0
Najran	300,994	240,581	60,413	20.1
Qaseem	750,979	610,566	140,413	18.7
Tabuk	486,134	401,917	84,217	17.3
Jawf	268,228	223,406	44,822	16.7
Hail	411,284	346,177	65,107	15.8
Jizan	865,961	733,968	131,993	15.2
Aseer	1,340,168	1,150,089	190,079	14.2
Baha	332,157	289,946	42,211	12.7
Total	16,948,388	12,310,053	4,638,335	27.4

Souce : Ministry of Planning. Statistical Yearbook.1996.

1. Jeddah belongs to the administrative area of Makka,
   Yanbu' belongs to that of Madinah.

Table 125. Production capacity of the saline water conversion corporation plants (1996).

Plant		Daily of Water	
Location	Establishment	Cubic meter	Rate(%)
Haql	1980	3,784	0.2
Duba	1969	3,784	0.2
Al-Wajh	1969~1989	2,803	0.1
Umluj	1986	3,784	0.2
Yanbu'	1981	92,944	4.8
Rabigh	1982	1,978	0.1
Jeddah	1970~1994	402,154	20.7
Western others		282,539	14.6
Western sub total		793,770	40.9
Eastern sub total		1,145,094	59.1
S.W.C.C. Total		1,938,864	100.0

Source : Saline Water Conv. Corp. 1996. *Annual Report.*

million) supply water to Madinah (population 0.61 million).

The government has been developing major oil plants and modernizing harbor facilities in Yanbu'. Table 126 shows the present and future status of the development project in the new industrial city of Yanbu', which has been directly overseen by the Royal Commission for Jubail and Yanbu'. The current population of the new industrial city is approximately 60,000. There were 45 plants and factories operating in 1998. Six plants of primary industries, four oil refineries, one liquefied natural gas fractionation and one petrochemical plant, accounted for 58% of all employees and 89% of all capital costs in the new industrial city. The large plants are concentrated in the southern part of the Study Area (Fig. 77). Bedause of the hot waste water discharged from the plants and harbor facilities, the water quality along the coast from Jeddah to Yanbu' is expected to be much more polluted than in other parts of the Study Area.

3. Waste disposal sites

All the municipal offices have sections in charge of waste management, and use disposal sites located in the desert area. In the case of the Al-Wajh area, the waste management section of the municipality uses a hillside near Habban as an open waste disposal site. Low and simple soil banks enclose the disposal site. Many Bedouins that had used the hillside as rangeland have been criticizing the municipality. In Yanbu', there is one disposal site for auto scraps, where piles of auto scrap were abandoned.

3.3.1.2. Grazing

1. Suitability of land resources for range and crops

Grazing is an essential means of storing and providing animal protein for people living in arid zones with meager vegetation. The main grazing plants on which sheep and

Table 126. Industrial development status of Yanbu' (1998).

Classification	Status	Plant /Factory	Employee persons	Area ha	Capital cost SR million
Primary industries	In operation	6	5,020	2,043	29,600
	Under construction	3	895	161	10,400
	In design	1	250	39	1,750
	Proposed	5	no data	no data	no data
Secondary industries	In operation	9	1,182	124	2,775
	Under construction	4	367	196	1,880
	In design	2	251	48	955
	Proposed	14	no data	no data	no data
Light manufacture & support industries	In operation	30	2,433	127	819
	Under construction	4	212	47	161
	In design	1	32	1	50
	Proposed	0	no data	no data	no data
Overall	In operation	45	8,635	2,293	33,194
	Under construction	11	1,474	404	12,441
	In design	4	533	88	2,755
	Proposed	19	no data	no data	no data

Source : The Royal Commission for Jubal and Yanbu'. 1998. *Industrial Development Status Report*

Table 127. Suitability for grazing of land types along the northern part of the Red Sea coast.

Landforms	Suitability	Distance (km)	(%)
Af : Alluvial fans	Suit.	104.6	10.2
Ap : Alluvial plain	S	20.8	2.0
Cp : Coastal plain	S	301.8	29.4
Fs : Footslopes	S	13.0	1.3
Gl : Alluvial fans and footslopes	S	7.6	0.7
Wadi	S	10.0	1.0
Sub Total		457.8	44.7
As : Active slopes	Non Suit.	13.3	1.3
B : Beach and wet coastal sands	N	318.5	31.1
Hl : Hills and rock outcrops	N	2.8	0.3
Mn : Mountains	N	73.1	7.1
Pg : Gypseous pediplain	N	20.0	2.0
Tf : Tidal flats	N	125.8	12.3
Town	N	13.8	1.3
Sub Total		567.1	55.3
Total		1024.9	100.0

Source : The Ministry Agriculture and Water. 1995.*Land use in Saudi Arabia.*

goats feed in the dry season are small shrubs and perennial grasses such as *Panicum* spp., which are found on stable sand sheets. Grazing plants favored by camels are the same grasses and small shrubs that are eaten by sheep. In addition, camels also feed on the larger woody plants.

Table 127 shows the suitability for gazing of particular landforms in the Study Area. For example, "Beach and wet coastal sand" that is unsuitable for grazing accounts for 31.1 % of the coastline of the Study Area. "Tidal flat" accounts for 12.3 % of it. Land that is suitable for grazing accounts for 44.7 % of the coastline of the Study Area (Department of Land Resources, 1995).

There are wadis where underground water flows. Farmers practice agriculture irrigated by wells in wadis. Wadis comprise 1.0% of the entire coastline of the Study Area that is suitable for agriculture.

2. Demand for livestock

The demand for livestock in Saudi Arabia has been increasing over the past 30 years. Fig. 78 shows that in 1993 the average intake of animal protein jumped to 2.5 times the 1970 level. 55% of the livestock slaughtered under the supervision of the municipalities came from the domestic market, and the rest was imported (Table 128). The Saudis prefer domestic animal meat to imported. The high demand for domestic meat supports the grazing industry in this country. Grazing is still an important traditional industry in the rural areas.

3. Types of grazing

There are two types of grazing, nomadic grazing and stationary grazing combined with wadi agriculture. Table 129 shows the results of interviews with people who practice nomadic grazing, while Table 130 shows the results of interviews with people who practice

Table 128. Livestock slaughtered in Saudi Arabia under the supervision of the municipalities. by region and type(1996), and estimated number (1995).

Unit : Head, %

Region	Type	Goats	Sheep	Cows	Camels	Sub Total
The number of livestock slaughtered	Domestic	538,727	798,146	36,794	131,381	1,505,048
		70.0	45.3	53.6	89.0	54.8
	Imported	230,882	962,726	31,815	16,206	1,241,629
		30.0	54.7	46.4	11.0	45.2
	Sub Total	769,609	1,760,872	68,609	147,587	2,746,677
		100.0	100.0	100.0	100.0	100.0
		28.0	64.1	2.5	5.4	100.0
The estimated number of living livestock		4,373,137	7,752,990	249,323	421,700	12,797,150
		34.2	60.6	1.9	3.3	100.0

Source : Ministry of Municipal and Rural Affairs, Minstry of Agriculture and Water

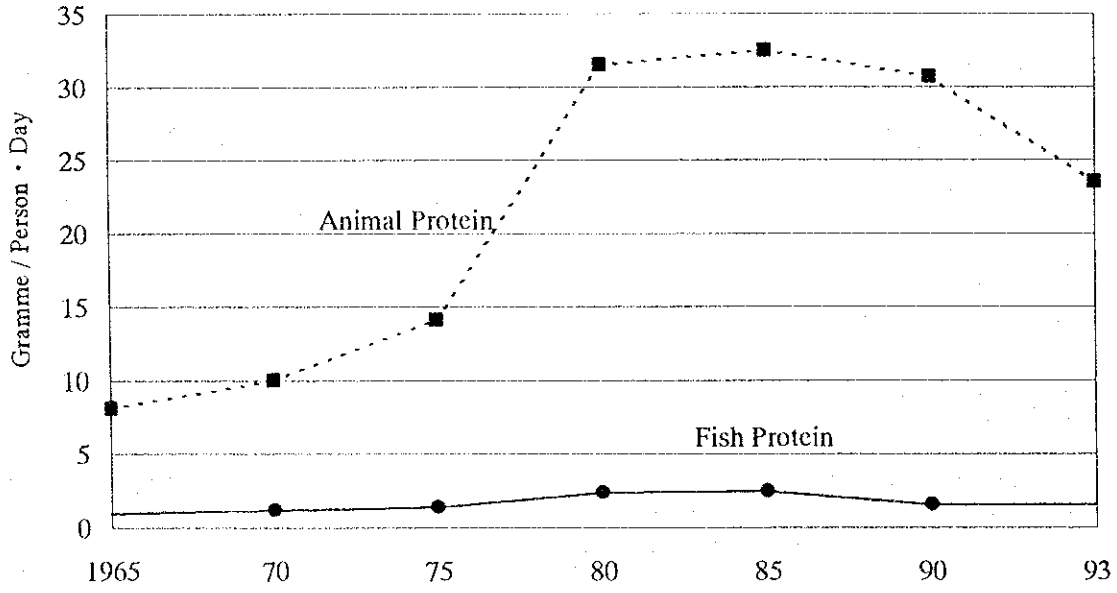


Fig. 78. Daily protein intake from animals and fish

Source: FAO Fisheries Circular No.821 Revision 3.Fish and fishery products.
World apparent consumption statistics based on food balance sheet (1961-1993)

agriculture combined with stationary grazing.

3-1. Nomadic grazing

Eleven groups of nomads were interviewed, and classified into three types. Four families were practicing full-scale grazing, while six families were practicing small-scale grazing. One group of Bedouin was classified into neither type (Table 129).

The criterion for the scale of operation was based on the number of livestock. An owner of 100 sheep can sell eight to ten sheep every month to earn 3,600 to 5,500 S.R.(=Saudi riyal). For example, Dr. Saleh Alsoghair studied the monthly income of Bedouin by interviewing 338 families in the Dilam area of the central district of Saudi Arabia in 1994. The resulting average monthly income of a family was 6,390 S.R (ALSOGHAIR 1995). The above figure included the monthly income of all the family members. A family that practices a full-scale operation with 100 sheep can earn at least one half of the average monthly earning from the livestock operation.

A typical full-scale family operation tends 100 to 200 head of sheep/goats and 20 to 40 head of camels. One camel is worth five times more than a sheep. Sheep and goats are usually seen grazing in a compact flock accompanied by a shepherd. Sheep and goats range within a radius of about 5 km from the camp where they are based. Camels range within a radius of about 12 km from their base, covering a distance of 22 to 27 km a day.

General characteristics of full-scale nomadic Bedouin are as follows:

a) they keep 100 head of sheep and 20 camels or more,

b) they can afford to hire foreign migrant workers, and

c) their families live in camps, but some family members are engaged in cash earning jobs.

Table 129. Types of nomadic people dependent on grazing.

Type	Saudi-owner Regular job	Foreign worker	Sheep	Camel	Location	Latitude (N)	Longitude (E)
Full-scale	no data	1 S.	200	100	South of Al-Wajh	260208	364252
	No	no data	200	20	Masturah	230652	385035
	Soldier	1 S.	100	30	Al-Demigau	263654	361410
	Military officer	1 E.	50	20	Suburbs of Al-Wajh	261249	363249
Small-scale	No	No	50	5	Suburbs of Haql	290545	350349
	No	No	60	0	Suburbs of Umluj	250300	371822
	No	No	50	0	Suburbs of Al-Wajh	261249	363252
	Officer	No	12	4	Suburbs of Haql	290545	350349
	No	No	20	0	Suburbs of Haql	290545	350349
	No	No	15	0	Suburbs of Haql	290545	350349
Other	Racecamel trainer	1 S.	0	6	Suburbs of Al-Wajh	261251	363133

1. Nationality of foreign workers; E. = Egyptian and S. = Sudanese

Table 130. Types of stationary grazing combined with wadi agriculture(Phase II).

Types		Saudi-owner Regular job	Foreign worker	Farm ha	Well No.	Sheep head	Camel head	Date palms	Fodder Grass	Other Fr./Ve.	Location	Latitude (N)	Longitude (E)
Many kinds of products	Good water quality	Yes	1B. 2E.	9.0 ha	4	50	0	145	No	Fr./Ve.	Umluj	250611	371451
		Yes	2I. 3E.	5.0 ha	1	100	0	50	No	Fr./Ve.	Yanbu'	240921	380834
		Yes	1B.	4.0 ha	2	40	0	80	No	Fr.	Umluj	250333	371644
		no data	1E.	1.4 ha	2	115	0	130	Yes	Fr.	Umluj	250406	371639
		no data	no data	1.1 ha	2	40	0	100	Yes	Fr.	Umluj	250406	371639
		Yes	1B.	6.0 ha	1	50	0	55	No	Ve.	Al-Wajh	261511	363113
Few kinds of products	Brackish water	no data	1P. 1S.	25.0 ha	1	200	60	200	Yes	(Corn)	Masturah	230450	385200
		Yes	2B.	25.0 ha	1	0	0	250	Yes	No	Masturah	230457	385158
		Yes	1E.	2.0 ha	1	200	20	50	No	No	Bi'r al Qusayr	255526	365045
		No	1E.	1.0 ha	1	100	0	0	Yes	No	Bi'r al Qusayr	255706	364526
Well	No	No	No	0.4 ha	No	20	0	10	No	No	Yanbu'	240927	380835

1. Nationality of foreign workers: B.= Bangladeshi, E.= Egyptian, I.= Indian, P.= Pakistani, S. = Sudanese: number is number of workers.
2. 'Other Fr./Ve.' means that there are some kinds of cultivated fruit trees and/or vegetables.

General characteristics of people who practice smaller-scale grazing are as follows:

a) they usually keep as few as 20 to 50 sheep and few camels,

b) they employ no foreign migrant workers,

c) they live in houses with sheep and goats in the suburbs of towns, and

d) some of them are engaged in cash earning jobs.

Families that practice small scale grazing are not nomadic. They live in houses in the suburbs of towns, and are engaged in grazing on lands surrounding their houses.

3-2. Stationary grazing combined with wadi agriculture

Compared with nomadic grazing, stationary grazing combined with wadi agriculture has relatively less impact on the biological environment. Table 130 shows that a typical form of wadi agriculture is a combination of sheep tending and date palm cultivation. Many wadi farmers manage to grow fodder grass, which is not seen with nomadic grazing. Nevertheless, grazing concentrated on lands surrounding the farms will inevitably have an impact on the natural vegetation. Wells, irrigation and earth banks are the essential facilities of wadi agriculture. Earth banks protect irrigated farms from grazing animals.

The two products, sheep and date palms, can be raised using the brackish water of arid zones. Fodder grass can also be grown with brackish water. Depending on the quality and quantity of available water, wadi farmers can grow additional crops. Supported by a good water well, a farmer can grow a variety of crops, vegetables and fruits, whereas a farmer who must depend on a limited amount of water of poor quality, called 'brackish water,' can grow few additional crops. Table 130 shows that six families were growing a variety of crops using water of high quality, three families were growing a limited number of crops using brackish water, and one family which did not own a well was growing date palms and tending sheep using only purchased water.

3.3.1.3 Fishing

There are 88 fishing ports along the 1,800 kilometer coastline of the Red Sea. The Coast Guard oversees all fishing ports and fishing boats.

1. Traditional fishing in the Red Sea

Table 131 shows the number of fishermen and fishery workers recorded in 1996. Over 11,000 people were engaged in fishing in the Red Sea, while about 9,000 people fished around the Arabian Gulf. Just over 30% of traditional fishermen in the Red Sea area own their own boats and practice small-scale fisheries operations. The table also shows that there are around 6,000 non-Saudi fishery workers in both the Red Sea and Arabian Gulf.

Extended coral reefs are found along most of the coast of the Red Sea. Traditional fishing gear includes hand held lines and gill nets. The use of hand-held lines on small boats is especially suitable for coral coastlines. The average number of fishermen per boat is two, and the boats are usually between 6 meters and 9 meters long. Major groups of fish caught in the Red Sea by traditional fishing methods are groupers, emperors, scads, snappers, rabbitfishes and parrotfishes.

2. Participation by foreign fishermen

Most fishermen who are actually working out in the sea in today's Saudi Arabia are foreign migrant workers. It is a common practice for a Saudi boat owner and non-Saudi fisherman employee to share their income evenly. This practice of income sharing greatly encourages foreign fishermen. A non-Saudi fisherman can earn between 1,500 and 2,000 SR, which is a quite high income for a non-Saudi. The majority of foreign fishermen are from Egypt, India and Bangladesh.

Table 131. Number of fishermen and fishery workers,by category (1996).

Unit:Person, %

						Total		Red Sea		Arabian Gulf	
Total			Boat	Fishing	Saudi	20,326	100.0	11,301	100.0	9,025	100.0
Fishermen	Sub total		owing		citizen	6,111	30.1	4,212	37.3	1,899	21.0
	Investor	fishermen	○	×	○	38	0.2	28	0.2	10	0.1
	Traditional	fishermen	○	○	○	5,095	25.1	3,444	30.5	1,651	18.3
	On-foot	fishermen	×	○	○	724	3.6	621	5.5	103	1.1
	Temporary	fishermen	×	○	○	254	1.2	119	1.1	135	1.5
Fishery workers	Sub total					14,215	69.9	7,089	62.7	7,126	79.0
	Saudi	worker	×	○	○	2,209	10.9	1,029	9.1	1,180	13.1
	Non-Saudi	worker	×	○	×	12,006	59.1	6,060	53.6	5,946	65.9

Source: SAKURAI,T. 1998. *Fisheries of Saudi Arabia.*

1 Actually many traditonal fishermen, who employ workers, engage themselves only in managing the fishing business.

2 Temporary fishermen are younger than 18 years old.

3 ○ Yes, × No

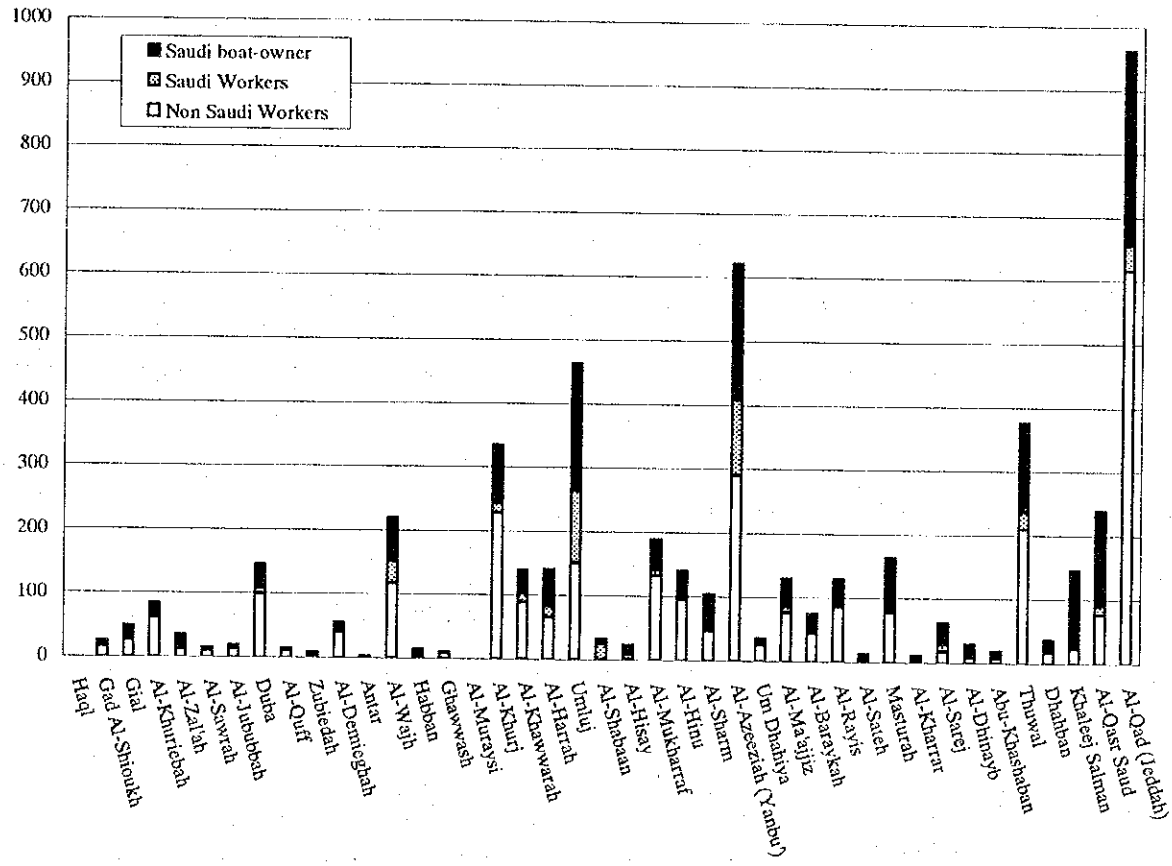


Fig. 79. Number of fishermen by category at each port (1996).

3. Fishing pressure in the Study Area

The number of fishermen can indicate fishing pressure. Fig. 79 shows the number of fishermen stationed at each fishing port in the Study Area. Al-Azeezizh is the port for Yanbu' and Al-Gad is located near Jeddah. In the southern region, the number of fishermen is much higher than in the northern region, thus the fishing pressure is considered higher in the south. In particular, increasing numbers of fishery workers and boats near large cities in the south, may intensify the pressure on fisheries resources.

3.3.1.4. Assessment of the Study Area

Table 132 summarizes the impact of human activities on the natural environment of the Study Area. In the northern region of the Study Area, from the Gulf of Aqabah to Umluj, the population density is very low, while the southern region from Yanbu' (42.4/ km2) to Jeddah, in contrast, is one of the most densely populated regions in Saudi Arabia. The uneven distribution of the population affects the environmental impacts of human activities in many different aspects.

Table 132. Impact of human population and activities.

Impact	Subject	Location					
		Gulf of Aqaba	Tiran	Duba / Al-Wajh	Al-Wajh Bank	Umluj / Ra's Baridi	Yanbu' / Jeddah
Population		1	0	1	1	1	2
Activities							
Development	Desalination	1	0	1	1	1	3
	Power Plant	1	0	1	1	1	2
	Oil Plant	0	0	0	0	0	2
Grazing	Rangeland	1	0	2	2	2	2
	No. of Animals	1	0	2	2	2	3
Fishing	No. of Boats	1	0	1	1	2	3
	No. of Fishermen	1	0	1	2	2	3

*1. Degree of impact : 3: high, 2: medium, 1: low 1, 0: no data.

Large-scale development projects are prominent in the more densely populated southern region. The desalination plants and power plants in Yanbu' and Jeddah supply water to other large cities such as Makkah and Madinah. Therefore, the degree of impact from these plants in the area of Yanbu' and Jeddah is significantly high.

Two typical traditional occupations in the Study Area, nomadic grazing and fishing, seem to be causing an excess impact on natural resources, i.e., over-grazing and over-fishing. The vegetation situation in the rangeland and the number of animals indicates the impact of grazing. According to the results of a terrestrial vegetation survey, the vegetation overall is affected significantly by grazing. Fishing pressure was indicated by the number of fishermen and boats. As the number of fishery workers and boats increases in the southern region of the Study Area, from Umluj / Ra's Baridi to Yanbu' / Jeddah, the pressure on fisheries resources will be more intensified. Furthermore, the southern region hosts a number of large scale development projects. Therefore, it is not advisable to plan a marine protected area in the southern section.

3.3.3. MODEL AREA

Al-Wajh Bank was selected as the Model Area on the basis of the results of the Phase II study. The two traditional industries, grazing and fishing, were studied to determine the impact of human activities on the natural coastal environment. The coastal area between the towns of Al-Wajh and Umluj was selected as the study field for an in-depth socio-economic survey.

3.3.3.1. Grazing

1. Main grazing sites in the model survey area

To determine impact of the grazing impacts by camels, a strip along the coastline ten

kilometres wide inland was proposed as the survey field. The length of the coastline between the towns of Al-Wajh and Umluj is 165 km. There is a considerable proportion of fertile rangeland between Al-Khruj and Umluj. Bi'ral-Qusayr is a small village, and stationary grazing with wadi agriculture is practiced there. Main grazing sites in the survey area are as follows:

・Bi'r al-Qusayr (25° 55' 26" N, 036° 50' 45" E)

Bi'r al-Qusayr is located 45 km south from Al-Wajh, and five km inland from the coast. There is a very small settlement which consists of only four households. The families grow a few products using brackish water. Fodder grass cultivation and camel grazing are characteristics of grazing base camps in this remote area.

・South of Duqm Sabq (25° 32' 20" N, 037° 00' 15" E)

This is located 15 km south-east from the fishing port of Al-Khurj. There are mangrove thickets in the sea since the grazing pressure by camels on mangroves is too strong for them to grow on the coast. The social survey team met a herd of forty camels with a Sudanese herdsman there.

・Abar Umm Nitash (25° 28' 35" N, 037° 10' 12" E)

There are over ten Bedouin camps on hill-slopes beside the highway, located 55 km north of Umluj. Some of the Bedouins practice full-scale camel grazing.

・Al-Harrah (25° 14' 17" N, 037° 14' 01" E)

This is a large settlement with about 200 Bedouin households, located 25 kilometres north of Umluj. Most of the people are engaged in small-scale sheep grazing, besides their cash-earning jobs. The wide scattered forest of acacia trees has been conserved by the local community and the local government. "Hima" is a traditional system in this society for the conservation of the commons and rangeland.

・Northern and southern suburbs of Umluj (25° 03' 00" N - 24° 52' 14" N, 037° 18' 22" E - 037° 19' 55" E)

There is a concentration of small-scale Bedouin hoders in the suburbs of Umluj, as observed in the town of Al-Wajh.

2. Changes in Bedouins'life style

Nomadic grazing is practiced by Bedouins or people of Bedouin descent. There are three important grazing sites in the model survey area, Abar Umm Nitash, Al-Harrah and Umluj. Table 133 describes the current status of the families which were interviewed in this study. Out of the eleven families that were practicing grazing, five families were in "full-scale" operations, and six were in "small-scale" operations. The small-scale Bedouins were based in the towns of Umluj and Al-Harrah. In contrast, some full-scale Bedouin families were based in Abar Umm Nitash, which is a remote area located 55 kilometres north of Umluj. Their campsites were scattered over the hillside.

The characteristics of these eleven groups of Bedouins are described below:

a) Just as it was found in the comprehensive survey that families of small-scale Bedouin hoders were settled in the suburbs of towns and lived in houses, the families of full-scale Bedouin hoders also had settled down. Even though they were living in tents away from towns, the families had not moved for over 20 years.

b) Four out of five heads of families of full-scale Bedouin hoders were engaged in regular cash earning jobs in towns. Some of them were settled by highways in houses for the convenience of the long commute by automobile to the towns for work and for children's schooling. Their activities have become more and more dependant on automobiles.

c) Four out of the eleven families of Bedouins lived in houses, not tents. Even families of full-scale Bedouin horders, who stay on remote rangelands, have changed their life style to settle

Table 133. Types of grazing (Phase III).

Type	Saudi-owner Regular job	Sheep	Camel	Living in Tent /House	Location	Latitude (N)	Longitude (E)
Full-scale	Petrol station	300	15	House	Abar Umm Nitash	252835	371012
	Officer	65	45	Tent	Abar Umm Nitash	252825	371220
	C.G. soldier	80	18	Tent	Abar Umm Nitash	253003	370929
	IMARA officer	40	20	House	Al-Harrah	251417	371401
	No	100	3	Tent	South of Umluj	245215	371947
Small- scale	Desali. plant staff	30	12	House	Al-Harrah	251417	371401
	No	40	3	Tent	Abar Umm Nitash	253000	370930
	C.G. soldier	50	0	House	South of Umluj	245711	371650
	No	50	0	Tent	Al-Harrah	251351	371835
	No	20	2	Tent	Abar Umm Nitash	252741	371126
	No	10	0	Tent	South of Umluj	245214	371955

1. The boarder between the two scales is 100 sheep.
2. One camel is evaluated as 5 sheep.

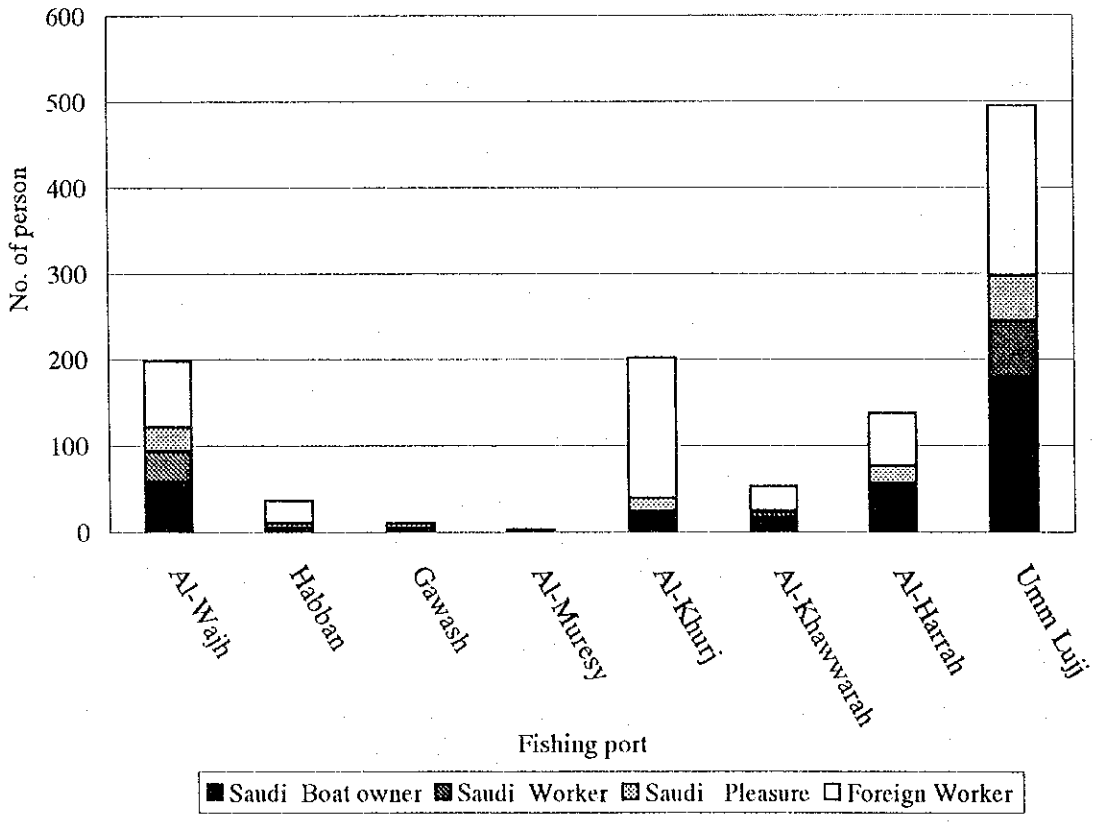


Fig. 80. Number of fishermen by port and their categories by nationality.

down and be engaged in regular cash earning jobs.

d) Technical modernization in grazing practices is observed in the following areas: 1) motorization in every aspect of daily life, 2) transportation of water by water-tank lorry, and 3) utilization of purchased fodder grass and barley to feed animals.

Despite the changing practices in grazing with the shift toward more purchasing of fodder, the impact of grazing on natural vegetation will continue to be a serious concern. Although their scale of operations is small, a number of herders settled in the suburbs of towns will significantly modify the surrounding vegetation, while large-scale grazing operations in remote areas will affect the coastal biological environment including the mangrove forests. Stationary grazing practices with wadi agriculture were not observed in the Model Area as a significant part of its economy. Changes in the life styles of the people in the survey area started taking place 30 years ago when the highways and desalination plants were constructed.

3. Animal market

The high demand for domestic meat supports the grazing industry in this country. Every local town has a permanent animal market, which is usually located in a suburb of the town. The animal markets of Al-Wajh and Umluj are always busy. In the town of Umluj nearly 1,000 livestock are kept. Bedouins sell their livestock directly to consumers or to market middlemen. 40 middlemen belong to the market. About 300 livestock are traded daily. The price of a sheep is 450 to 550 SR. A large amount of firewood and charcoal is also traded in the market.

3.3.3.2. Fishing

1. Coastal fishing ports

There are eight fishing ports along the 165 kilometer coastline. The coast guard oversees all fishing ports. Generally traditional fishermen use small boats and hand held lines in the sea around the coral reefs. According to the latest report by the Umluj Fish Service Station (December 1998), more than 100 fishermen were working out of the ports of Umluj, Al-Harrah, Al-Khurj and Al-Wajh, while the numbers of foreign fishery workers at the same four ports were 61 in Al-Harrah, 77 in Al-Wajh, 163 in Al-Khurj, and 197 in Umluj (Fig. 80). Foreign migrant workers already account for significant proportion in the fishing industry in the Model Area.

2. Two types of fishing practices

Twenty Saudi boat owners, five from Al-Wajh, twelve from Umluj and three from Yanbu', were interviewed at six fishing ports, four at the Al-Wajh Port, one at Al-Muraysi, five at Al-Khruj, two at Al-Khawwarah, five at Al-Harrah and three at Umluj (Table 134).

There are two types of fishing practices. A "self-employed" independent fisherman practices traditional small fishing with one boat, fishing daily alone or with another worker to sell fish at the local markets in Al-Wajh and Umluj. A "fishing business owner" owns two or three boats, hiring foreign workers. They sell fish to the markets in large cities such as Jeddah, Yanbu' and Madinah where fish prices are considerably higher.

Out of the twenty Saudi boat owners interviewed, eight were self-employed and twelve were fishing business owners, shown as 'employer' in Table 14. Although both types of fishing operations similarly used on small boats, the difference between their scales of operation is significant. Self-employed fishermen living in Al-Wajh or Umluj can earn enough to live on by selling fish at a local fish market. They are content to spend their lives as

Table 134. Interview data on fishing, by type (Phase III).

Type	Saudi owner Address	No. of boats	Fishing workers	Fishing day per 1time	Fishing port Location	Selling Market
Employer = Fish businessman	Umluj	4	5 E. 5 I.	4 day	Al-Khurj	no data
	Yanbu'	3	6 B.	4 day	Al-Harrah	Y.
	Yanbu'	3	6 B.	no data	Al-Harrah	Y. M.
	Umluj	2	2 B. 3E.	no data	Al-Khurj	no data
	Al-Wajh	2	2 B. 2E.	4 day	Al-Khurj	Y.
	Umluj	2	2 B. 2E.	4 day	Al-Khurj	Y. M. J.
	Umluj	2	4 Saudi(family)	5 day	Al-Khawwarah	Y. M. J.
	Yanbu'	2	3 P.	4-6 day	Al-Harrah	Y. M. J.
	Umluj	1	3 B.	4 day	Al-Harrah	Y. M.
	Umluj	1	1 I. 1 Saudi.	1 day	Al-Khurj	Y. M. J.
	Umluj	1	2 Saudi	5 day	Al-Khawwarah	Y. M.
	Umluj	1	2 Saudi	1 day	Al-Muraysi	Y. U.
Self-employed	Al-Wajh	1	No (brother)	1 day	Al-Wajh	W.
	Al-Wajh	1	No (son)	1 day	Al-Wajh	W.
	Al-Wajh	1	No (son)	1 day	Al-Wajh	W.
	Al-Wajh	1	No	1 day	Al-Wajh	W.
	Umluj	1	No	3 days	Al-Harrah	U.
	Umluj	1	No	1 day	Umluj	U.
	Umluj	1	No	1 day	Umluj	U.
	Umluj	1	No	(3 days)	Umluj	U.

1. Nationality of foreign workers: B.= Bangladeshi, E.= Egyptian, I.= Indian, P.= Pakistani. Number indicates number of workers.
2. Selling Market: J.= Jeddah, M.=Madinah, U. = Umluj, Y.=Yanbu', W.=Al-Wajh
3. Under fishing workers,( ) indicates the hiring of family members as a temporary worker.

Table 135. Address, fishing port and selling market of Saudi owners.

Saudi owner address	No.	%	Interviewed fishing port	No.	%	Selling market	No.	%
Total	20	100	Total	20	100	Total	30	100
Al-Wajh	5	25	Al-Wajh	4	20	Al-Wajh	4	13
			Al-Muraysi	1	5			
			Al-Khurj	5	25			
			Al-Khawwarah	2	10			
			Al-Harrah	5	25			
Umluj	12	60	Umluj	3	15	Umluj	5	17
Yanbu'	3	15				Yanbu'	10	33
						Madinah	7	23
						Jeddah	4	13

1. Numbers for selling markets include duplicate responses.

traditional fishermen.

Table 134 and 135 show responses to the question of where they sell their catch, and includes duplicate responses. Out of the twenty Saudi boat owners, eight "self-employed" owners (four residents of Al-Wajh and four residents of Umluj) sell fish only at the local markets of Al-Wajh and Umluj.

In contrast, the twenty-one responses by "fishing business owners" indicated that ten sold to Yanbu'(0.17 million people), seven to Madinah(0.61 million people) and four to Jeddah (2.5 million people). They go to the fishing ports of Al-Wajh Bank, sparsely populated areas with no coast guard stations, to catch larger amounts of fish. They hire foreign migrant fishermen, and bring the fish to large cities in their pickup-vans with ice. Saudi owners bring and sell the fish themselves, thus they are called "fish-businessmen."

The fishing ports at Al-Wajh Bank are important bases for the "fish-businessmen." Some of them sell not only their own catch but also the catches of others, catch charging 10 % of the sales as a commission. The growing for demand fish in large cities is encouraging these "fishing business owners" to rapidly expand their fishing operations.

3. Fishermen interviews

Al-Khurj is the only fishing port located inside the Al-Wajh Bank, and Al-Khawwarah and Al-Harrah are e fishing ports located outside the Al-Wajh Bank. Although there are almost no settlements near these three fishing ports, these ports are important for fishing. Interview surveys were conducted at the Al-Khruj fishing port, and the interviewed fishermen listed the following islands and their surrounding areas as good fishing grounds: Jazirat Umm Rumah, Jazirat Birrim, Juzur Safa'ih, Jazirat Qumma'an, Jazirat al-'Ishsh.

Similarly, interviews with fishermen were conducted at the Al-Harrah and the Al-Khawwarah fishing ports. Good fishing grounds listed by the fishermen were Jazirat al-

Waeqdi, Jazirat Shaybarah, Jazirat ar-Rudaym, and Jazirat al-A'la, all of which are located in the southern part of the Al-Wajh Bank. These fishermen fish outside the Al-Wajh Bank. The coral reefs of the Al-Wajh Bank provide good fishing grounds for fishermen. More information will be needed since fishermen sometimes did not understand the maps which we showed to them.

3.4. DISCUSSION AND CONCLUSIONS

3.4.1. LARGE SCALE DEVELOPMENT

Generally, population is the most basic indicator of human impact on natural environmental resources. The northern coastal region of the Red Sea from the Gulf of Aqabah to Umluj is sparsely populated. In contrast, the southern region between Yanbu' and Jeddah is one of the most densely populated regions in Saudi Arabia. The uneven distribution of the population affects the environmental impact of human activities in many different ways.

There are a number of large industrial plants, such as oil plants, harbor facilities, power plants, desalination plants and cement factories, along the coast of the Red Sea. The desalination plants in the northern region mainly provide the local residents with fresh water and electricity, but the desalination plants in Yanbu' supply water not only to Yanbu' but also to Madinah. Similarly the plants in Jeddah supply water to Makkah. The impact from the operations of these large plants in the area of Yanbu' to Jeddah is significant. However, the impact of development projects on the natural biological environment along the coast of the northern Red Sea, from the Gulf of Aqabah to Umluj, is limited since the region is sparsely populated, and there is no large concentration of operations.

3.4.2. STATIONARY GRAZING WITH WADI AGRICULTURE

Almost all wadi farmers tend not camels but sheep. They manage small scale

irrigation systems which depend on the quality and quantity of the water wells. Their main products are sheep and dates and, the second main product is fodder grass. A half of the interviewed farmers were cultivating fodder grass for sheep. In this case, sheep are fed with cultivated fodder grass and are kept from grazing on land around the wadi farms. Therefore, the grazing impact on coastal natural vegetation of sheep raised by wadi farmers is very limited.

3.4.3. GRAZING

Nomadic grazing has been exploiting the environment. In the case of the mangroves along the northern coast of the Red Sea, they have been seriously damaged by camels. There are very few mangrove stands left on the seashore and most of the remaining mangroves are in shallow water or on islands. Over-grazing is still a serious problem in the survey areas. Nomadic people used to move around all over the country, which thinned out the impact from grazing.

However, the changing life style of full-scale nomadic herders, who have become more or less settled, can be a serious environmental concern since it could cause overgrazing in the areas surrounding their settlements. Although some grazers have started feeding their animals with purchased grass and barley, many animals still feed on grass in the area surrounding camps and the suburbs of towns, especially along the coast.

There is a considerable expansion of fertile rangeland around Al-Harrah. Most of the local people at Al-Harrah (about 200 households) have cash earning jobs in adition to selling animal products from the grazing of sheep and camels. There are many acacia trees there, indicating rich soil. Camels feed on acacia trees, and feeding camels with acacia can be a sustainable use of the trees. The traditional practice of setting grazing land aside as "hima" should be re-evaluated and implemented by local communities to avoid major impact from

grazing. Stationary grazing combined with wadi agriculture seems to create no serious environmental problems at the present time.

3.4.4. COASTAL FISHING

Fishing practices in the coral Red Sea are still very much traditional, with hand-held lines and gill nets. Fishing has been well monitored by the Coast Guard Centres. However, there are serious concerns about excess utilization of the fisheries resources. The growing demand for fish in large cities, such as Jeddah, Makkah, Yanbu' and Madinah, has been encouraging fishing businesses to expand their operations. While impact on fisheries resources from the traditional fishing practices is relatively limited, the modern fishing businesses carry out more indiscriminate and intensive operations. If the trend of expanding fishing businesses continues, the resulting over-fishing may become a serious threat to the marine natural resources in the Model Area.

3.4.5. CONCLUSIONS

The traditional industries are necessary for local areas. It may be due to sustainability that the traditional industries may have continued till today. All traditional industries have accepted by modernization and a change in the life style of local residents. It is hoped that the modernized and economically expanded traditional industries will be able to recover a system of sustainability.

The Model Area and almost all the northern part of the Study Area is sparsely populated, and human impact on the biological environment has been limited. The impact of large-scale developments on the natural biological environment along the coast of the northern Red Sea, from the Gulf of Aqabah to Umluj, seemed very limited. Two possible cases of human-induced impact on the natural resources are identified in the Model Area. One

is the impact of grazing and the other is that of intensive fishing. With regard to the grazing, stationary grazing with wadi agriculture seems to create no serious environmental problems at present.

Nomadic grazing has been exploiting the biological environment. Nomadic people used to move around all over the country, but as their life style has changed, they are becoming more stationary in feeding their animals. The "forest of trees" at Al-Harrah has been controlled as a "hima" by local government and the community leaders. This traditional system of conservation should be studied to implement management of a protected area in this particular social and cultural environment of the Model Area. The growing demand for fish in large cities, such as Jeddah, Makkah, Yanbu' and Madinah, has been encouraging fishing businesses to expand their operations.

While the impact on fisheries resources from traditional fishing practices is relatively limited, the modern fishing businesses carry out more indiscriminate and intensive operations. If the trend of expanding fishing businesses continues, the resulting over-fishing may become a serious threat to the marine natural resources in the Model Area.

In order to conserve the coastal biological environment and to implement sustainable practices in traditional industries in local areas, therefore, the following recommendations are made:

1) the changing life style of the Bedouins should be continually monitored;
2) the practice of the 'hima' system should be studied in order to sustain the grazing industry;
3) operations of fishing businesses and the marketing/distribution systems should be monitored; and
4) marine protected areas should be established in consideration of sustaining the traditional fishing practices.

Photo. 10. Social Environment

1 .Overfishing may become the biggest human induced impact to the marine natural resources in the Model Area. Appropriate measures need to be planed.

2. Grazing needs to be controlled under the local social conditions. "Hima" is considered to be one of those the systems.