2.2.6. BENTHOS

2.2.6.1 Methods

The monitoring survey method should be easy and standardised so that monitoring can be carried out by anybody. For this purpose, selection of monitor species should meet the following requirements;

- species that occur commonly in the Red Sea;
- species that can easily be found and identified; and
- species typical for each habitat, such as tidal zone and bottom type.

Prior to the survey, 17 monitor species were selected (Table 96).

Table 96. Species monitored in the benthos survey.

Phylum	Scientific name	English name
CRUSTACEA	*Scopimera* cf.*globosa*	stalk-eyed crab
CRUSTACEA	*Macrophthalmus* cf.*convexus*	stalk-eyed crab
CRUSTACEA	*Uca* cf.*lactea perplexa*	fiddler crab
CRUSTACEA	*Uca* cf.*tetragnon*	fiddler crab
ECHINODERMATA	*Diadema setosum*	sea urchin
ECHINODERMATA	*Echinometra mathaei*	sea urchin
ECHINODERMATA	*Ophiocoma scolopendrina*	ophiocomid
MOLLUSCA	*Tridacna maxima*	clam
MOLLUSCA	*Dendropoma maxima*	worm shell
MOLLUSCA	*Conus arenatus*	Sand Cone
MOLLUSCA	*Cellana eucosmia*	limpet
MOLLUSCA	*Acanthopleura haddoni*	chiton
MOLLUSCA	*Nerita polita*	slipper winkle
MOLLUSCA	*Pinctada margaritifera*	Black-lip Pearl Shell
MOLLUSCA	*Pedum spondyloideum*	scallop
MOLLUSCA	*Coralliophila violacea*	Violet Coral Shell
MOLLUSCA	*Lambis truncata sebae*	Spider Conch

Sites for the benthos survey were selected using the habitat maps. In each site survey spots with various microhabitats, such as tidal zones or bottom types, were selected using aerial photographs of the site or by observation in the field.

The latitude and longitude of the spots were determined by GPS, or the distance to

the spot from the closest location already determined was recorded, the direction obtained by compass.

A quadrat (3 m x 3 m) was set up on the typical bottom of a survey spot, and an overview of the bottom conditions such as mud, sand, bedrock, hard coral or seagrass, was recorded. Numbers of each monitor species found in the quadrat were counted. However, in the case of stalk-eyed crabs *Scopimera* cf.*globosa, Macrophthalmus* cf.*convexus* and *Uca* species, only nest holes were counted, because the crabs hide in their holes when observers approach.

Of these species, the body size of the clam *Tridacna maxima*, Black-lip Pearl Shell *Pinctada margaritifera* and Spider Conch *Lambis truncata sebae* were measured and recorded. This is because these are caught for consumption and monitoring information is needed. Other abundant or especially interesting species, were also recorded even if they were not selected for monitoring.

In principle, surveys of three quadrats per spot were conducted and the average number of species observed was calculated.

2.2.6.2. Results

The locations and habitat types of the survey sites and spots in the benthos survey are shown in Fig. 55 and Appendix 20. There were 17 survey sites and 48 survey spots. It was found that various microhabitats existed at each survey site.

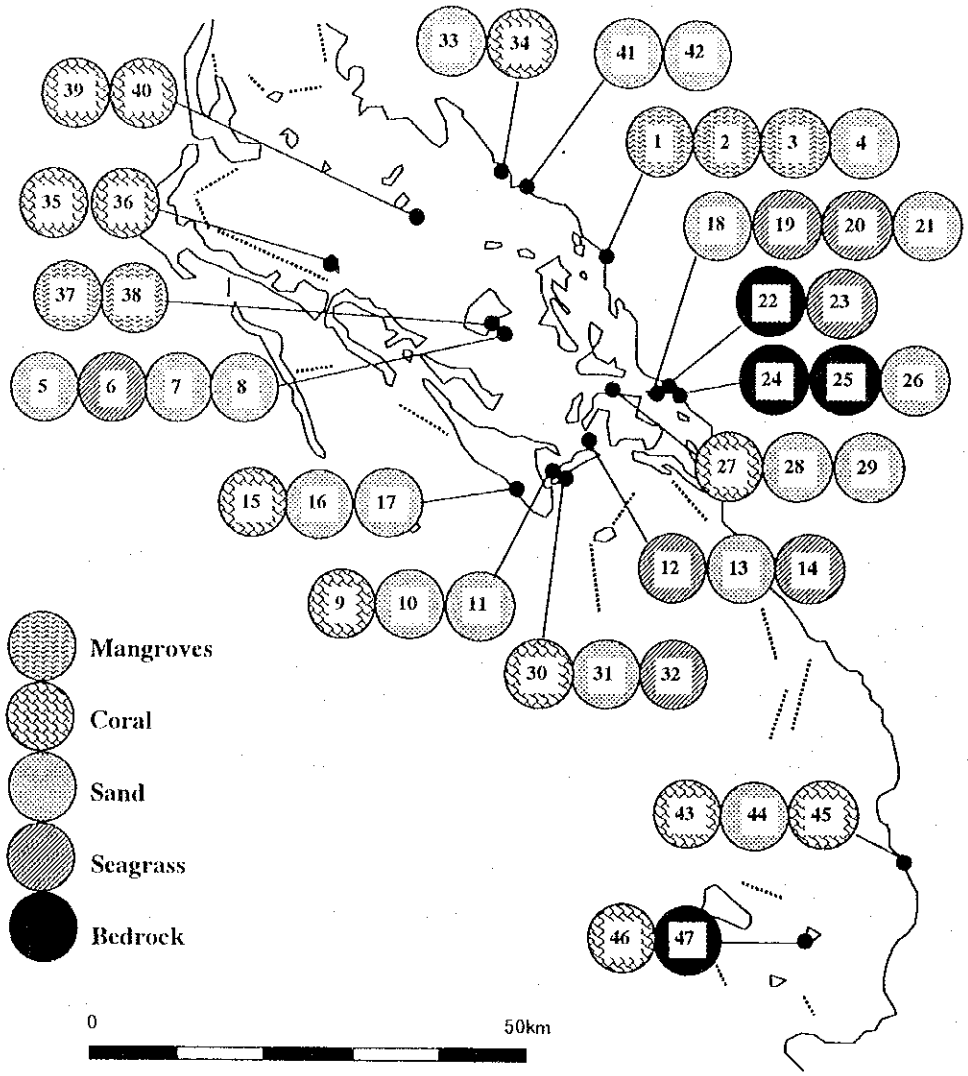


Fig. 55. Locations and habitat types of survey sites and spots in the benthos surveys.

An outline of the survey sites follows (also see Appendix 20).

(1) South of Dugm Sabq

This site was an area that included mangrove thickets. There was a narrow tidal flat near the coast and mangrove thickets about 10 m wide were approximately 50 m offshore. A shallow area with a compound bottom of sand and hard substrata extended offshore, and there were very shallow lagoons with sandy bottoms at the spot site.

There were many *Macrophthalmus* cf.*convexus* and *Uca* species in the tidal flat. Around the mangrove thickets there was a mud and soft bottom with many unidentified nest holes; however, no benthos was observed. In the shallow lagoon, *Strombus tricornis* was observed.

(2) South of Jazirat Qumma'an

Mangrove thickets were widespread on Jazirat Qumma'an; the bottom around them was not muddy but sandy. The sea around the island was very shallow (less than 5m in depth) for a distance of hundreds of meters from the shore, and scattered with small patches of seagrass and small patch reefs. There were steep cliffs offshore, with a height of over 10 m.

The nest holes of *Scopimera* cf.*globosa* were distributed in a belt 50cm wide along the beach of the island. *Strombus fasciatus* was abundant over a wide area of the sandy bottom.

(3) Offshore east of Jazirat Shaybarah

This site was in a shallow patch reef area offshore to the east of Jazirat Shaybarah. The depth at the patch reef was about 1 m and at the sandy bottom around the patch reef, less than 3 m.

Tridacna maxima, *Echinometra mathaei*, and *Pinctada margaritifera* were observed on the patch reef. Sandy bottoms at a depth of 2 or 3 m were covered in blue algae, and *Chicoreus virgineus* was observed. On the sandy bottom of a very shallow area less than 1 m in depth, small algae were scattered but no benthos was observed.

(4) Offshore west of Jazirat Suwayhil

This site was a shallow offshore area west of Jazirat Suwayhil. Seagrass beds were well formed on a sandy bottom. The relatively deeper sandy bottom was covered in scattered patches of blue-green algae.

Strombus tricornis was observed in patches of seagrass and *Holothuria* genus (a sea

cucumber) was observed on a sandy bottom and in patches of seagrass.

(5) West coast of Jazirat Shaybarah

This was a shallow reef flat on the west coast of Jazirat Shaybarah. The inner flat was bedrock with a thin accumulation of sand, and the outer reef flat was bedrock. On the edges of the outer reef flat were cliffs and deep lagoons.

Colonies of small algae and of sargassums were on the inner flat. *Conus arenatus*, *Conus vexillum*, *Strombus tricornis*, *Strombus fasciatus* and *Strombus gibberulus albus* were observed there. *Tridacna maxima*, *Echinometra mathaei*, *Dendropoma maxima*, *Heterocentrous mammillatus* and *Tectus dentatus* were observed on the bedrock in the outer flat reef. The lagoon water was clouded by suspended mud, so that no observations were made.

(6) Offshore south of Qara'ir

This was a very shallow area to the south of Qara'ir. A sandy bottom was studded with colonies of small algae and seagrass and colonies of drifted sargassum.

Strombus tricornis and *Murex tribulus* were observed on the sandy bottom. *Strombus tricornis* and *Chicoreus virgineus* were observed among the colonies of small algae, seagrass and drifted sargassum.

(7) Coast of Duqm Abu 'Awashiz

This site was a very shallow area in the front of a sandy beach to the south of Qara'ir. Close to the coast was bedrock with a thin accumulation of sand; many *Brachidontes variabilis* clung to it. There was a seagrass bed offshore where *Chicoreus virgineus* was observed.

(8) Coast of Wadi Hayran

The landward side of the coast was bedrock with a very sharp rugged surface. The intertidal bottom was bedrock with a thin accumulation of sand and was very shallow (less

than 50 cm in depth). The bedrock ended suddenly some ten meters offshore where the water became a little deeper and the bottom changed to sand and mud.

Nelita albicilla and *Planaxis sulcatus* were observed among sharp folds of the bedrock. On the sand and mud bottom, there was a scattering of small seagrasses only, and *Chicoreus virgineus* and *Strombus tricornis* were observed.

(9) North of Jazirat Suwayhil

This site was north of Jazirat Suwayhil. Mangroves grew in a narrow belt along the beach. The sea bottom around the island was bedrock with a thin accumulation of sand and there were mixed colonies of small algae, sargassum and seagrass. Offshore were a sandy bottom and patch reefs.

Ophiocoma scolopendrina and *Strombus tricornis* were observed in the colonies of algae, sargassum and seagrass. *Murex tribulus* and *Strombus tricornis* were observed on the sandy bottom. Many *Diadema setosum* were seen on the patch reef surveyed; in addition *Tridacna maxima, Echinometra mathaei* and *Holothuria* sp. were observed.

(10) Offshore south-east of Jazirat Shaybarah

This site was a patch reef area offshore to the south-east of Jazirat Shaybarah. The sea bottom around the patch reefs was sand and mud and there was a seagrass bed.

Tridacna maxima, Lambis truncata sebae and *Strombus tricornis* were observed on the patch reef surveyed. Sabellidae were found on the sand and mud bottom with no seagrass; however, no benthos was observed in the seagrass bed.

(11) Al-Khurj

This site was in a shallow patch reef area just north of Al-Khurj coast guard station. The depth at the patch reefs was less than 1 m and there was a fine sandy bottom around the patch reefs. There was a seagrass bed at a depth of more than 3 m.

There were many *Diadema setosum* and *Echinometra mathaei* on the patch reef

surveyed, and in addition some *Tridacna maxima* were observed. Many *Strombus fasciatus* were observed on the sandy bottom around the patch reefs.

(12) Sandbar near the Shunbuzah channel

This site was a shallow and flat sandbar less than 1 m deep near the Shunbuzah channel at the outer reef in the middle of Al-Wajh Bank. The edge of the sandbar that faced the channel was a well developed coral reef to a depth of 5 m from the top of the edge. The other side was a shallow sand bottom on which many patch reefs were scattered.

Tridacna maxima and *Echinometra mathaei* were found on the reef surveyed, in addition to a small number of *Coralliophila violacea* and *Pedum spondyloideum*.

(13) Creek south of Jazirat Qumma'an

This site was a creek south of Jazirat Qumma'an. Thickets of mangrove *Avicennia marina* grew in a narrow belt along the creek.

Large numbers of *Diadema setosum* were observed on the sea bottom near the mouth of the creek but there were fewer in the creek.

The wet muddy bottom around the thickets was almost completely covered by *Certhium* sp. and many Scopimera cf.globosa nest holes were observed on dry sandy beaches higher up the creek. *Metopogropsus messor* was observed among the roots of the mangroves, and *Planaxis sulcatus* and *Littorina scabra* were found on the aerial roots of the mangroves.

(14) Bank to the south of Jazirat Al-'Ishsh

This site was a bank to the south of Jazirat Al-'Ishsh, offshore west of Khurj. The top part of the bank was a sandy flat at a depth of 8 m with a scattering of many small patch reefs . The south edge of the bank was a reef slope.

Tridacna maxima and *Diadema setosum* were observed on the patch reefs and the reef slope, and *Conus arenatus* was observed on the sandy bottom.

(15) Harbour in front of Al-Khurj coast guard station

At this site, there were a sandy beach and a large tidal flat where nest holes of *Scopimera* cf.*globosa* were observed in large numbers.

Many *Strombus fasciatus* were observed on the shallow sandy bottom at a depth of less than 1 m. Many *Diadema setosum* were observed on the sea bottom where the water was deeper than 1 m.

(16) Umluj

The site was a stretch of coast in front of the Umluj coast guard station. The intertidal bottom was a shallow flat bedrock covered with turf algae and small algae. The bedrock formed a vertical wall of coral reef about 3 m in height 20 - 30 m offshore from the shoreline. From the bottom of this wall, there was a gentle slope of sand scattered with many small patch reefs to a depth of about 15 m, and there was a steep slope of coral reef past this slope.

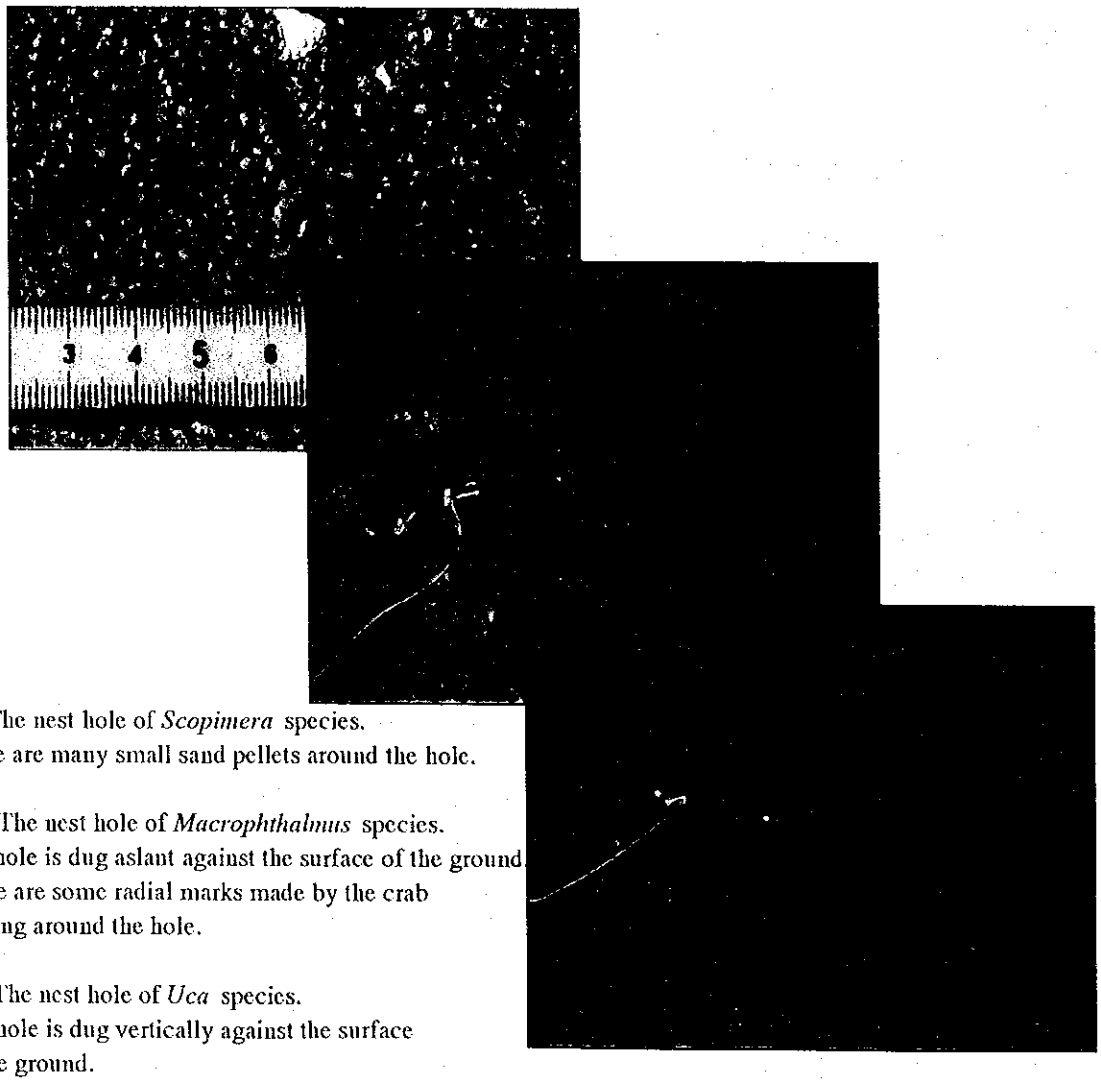
Tridacna maxima and many *Diadema setosum* were observed at the wall. *Tridacna maxima* should a high proportion of young shells less than 10 cm long. Many *Pedum spondyloideum* and *Coralliophila violacea* were observed in or on the corals. One individual of *Acanthaster planci* (Crown-of-Thorns Sea-star) was found at the foot of a small coral at a depth of 6 m.

(17) North-west of Jazirat Umm Sahar

This site was a patch reef area north-west of Jazirat Umm Sahar. There were a sandy bottom where a few seagrasses grew and a flat bottom of hardstrate covered with small algae around the patch reefs.

Tridacna maxima and *Lambis truncata sebae* were observed on the patch reefs surveyed. Although there was almost no benthos observed on the flat hard bottom, *Terebra maculata* and *Terebra crenulata* were found in the sand.

An example of a survey by a quadrat method.
The researcher is counting the number of
nest holes of fiddler crabs etc. on a tidal flat.



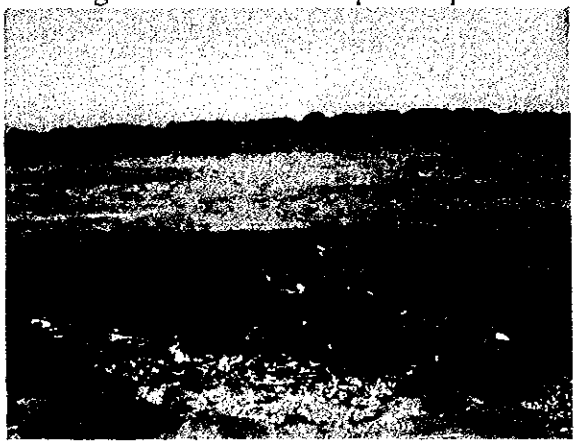
Upper: The nest hole of *Scopimera* species.
There are many small sand pellets around the hole.

Middle: The nest hole of *Macrophthalmus* species.
The hole is dug aslant against the surface of the ground.
There are some radial marks made by the crab
moving around the hole.

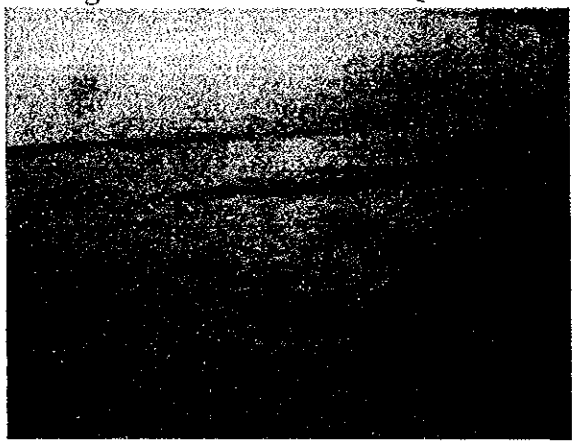
Lower: The nest hole of *Uca* species.
The hole is dug vertically against the surface
of the ground.
There are some sand pellets around the hole.

Photo. 8-1. Nest holes of crabs observed on a tidal flat.

a. Mangrove thickets of Duqm Sabq



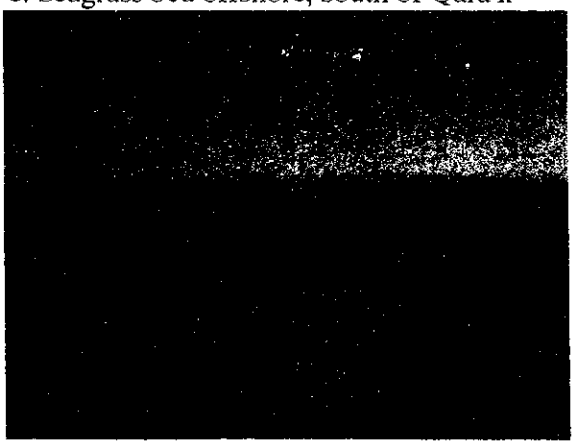
b. Seagrass bed south of Jazirat Qumma'an



c. Patch reef in east of Jazirat Shaybarah

d. Reef flat at west coast of Jazirat Shaybarah

e. Seagrass bed offshore, south of Qara'ir



f. Coast of Duqm Abu 'Awashiz

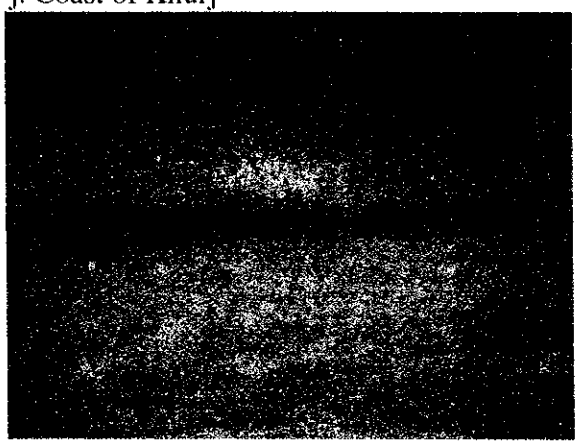
Photo. 8-2. Locations of survey sites of benthos in the Model Area (1).

g. Coast of Wadi Hayran

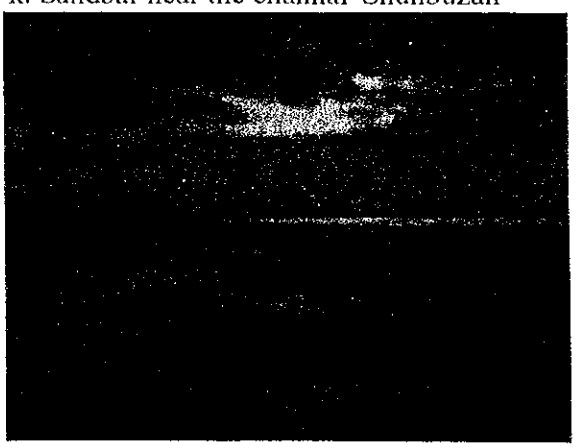
h. Patch reef north of Jazirat Suwayhil

i. Seagrass bed offshore, south-east of Jazirat Shaybarah

j. Coast of Khurj



k. Sandbar near the channal 'Shunbuzah'



l. Creek south of Jazirat Qumma'an

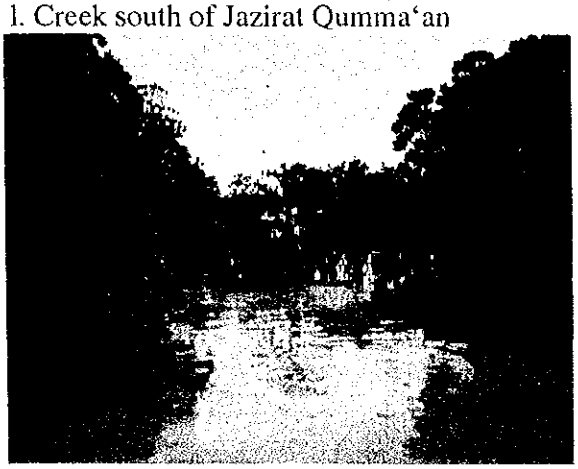
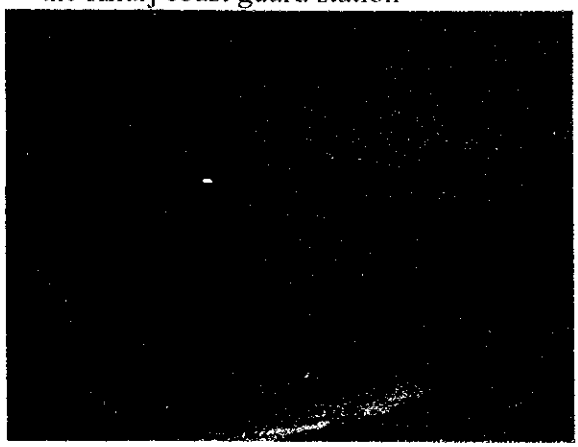


Photo. 8-3. Locations of survey sites of benthos in the Model Area (2).

m. Reef slope in bank south of Jazirat al 'Ishsh

n. Harbor in front of the Khurj coast guard station



o. Reef crest in fornt of the Umluj coast guard station

p. Patch reef north-west of Jazirat Umm Sahar

Photo. 8-4. Locations of survey sites of benthos in the Model Area (3).

2.2.6.3. Discussion and conclusions

1. Habitats and species

Each spot is classified into the following habitat types; mangroves, bedrock, seagrass bed, sand, coral. The species observed in each habitat are discussed.

1-1. Mangroves

Scopimera species were observed in the supertidal zone in mangrove areas, and *Macrophthalmus* species and *Uca* species were observed in the intertidal zone. *Littorina scabra* and *Planaxis sulcatus* were observed on the aerial roots of *Avicennia marina,* above the water. *Metopogropsus messor* was observed among the prop roots of *Rhizophora mucronata. Diadema setosum* were observed in large numbers on the sea bottom around the mangrove thickets (Table 97).

Table 97. Species in the mangrove habitats.

Species name	Spot name Depth(m)	Bt37 0	Bt1 0	Bt2 <1	Bt3 <1	Bt38 1
holes of *Scopimera* species	stalk-eyed crab	c				
holes of *Macrophthalmus* species	stalk-eyed crab		35.5			
holes of *Uca* species	fiddler crab		80			
Diadema setosum	sea urchin					+
Littorina scabra	periwinkle	+				
Planaxis sulcatus	cluster winkle	+				
Metopogropsus messor	shore-crab	+				

1-2. Bedrock

The number of bedrock habitats along the mainland in the Bank-transect area is small. Most of them are covered in sand, and the number of species observed there was fewer than in bedrock habitats in other areas of the Red Sea.

Brachidontes variabilis, Planaxis sulcatus, and *Nerita albicilla* were observed (Table 98).

Table 98. Species in the bedrock habitat.

Species name	Spot name / Depth(m)	Bt24 0	Bt22 <1	Bt25 <1	Bt47 9
Brachidontes variabilis	mussel		cc		
Planaxis sulcatus	cluster winkle	9.0			
Nerita albicilla	slipper winkle	2.3			
Conus pennaceus	cone shell				0.3

1-3. Seagrass bed

In areas where seagrass grew densely, few benthos were observed. Almost all benthos observed were distributed in an area with little seagrass and around the seagrass bed.

Holothuria sp., *Strombus tricornis* and *Chicoreus virgineus* were observed, and occasionally dense gatherings of *Strombus fasciatusis* were observed on a shallow bottom around the seagrass bed (Table 99).

Table 99. Species in the seagrass bed habitat.

Species name	Spot name / Depth(m)	Bt12 4	Bt14 1	Bt20 3	Bt23 <1	Bt32 5	Bt6 1	Bt19 <1
Holothuria sp.	sea cucumber	0.3	2.0					
Strombus tricornis	conch shell	0.3		0.3				1.0
Cerithium erythraeonense	horn shell	0.3						
Glycymeris pectunculus	Comb Dog Cockle		0.5					
Chicoreus virgineus	comb shell				0.3			0.3
Strombus fasciatus	Lineated Conch						67.3	
Strombus mutabilis	conch shell							0.3

1-4. Sand

Sandy beach and sandy bottom are the most common type of habitat on the coast of Al-Wajh Bank. Many *Scopimera species* were present in sandy beaches high in the intertidal zone. *Strombus fasciatus* was observed from the intertidal to the subtidal zones with over 30 individuals / 9 m^2 in some spots. *Strombus tricornis* was widely observed in the subtidal zone at a density of almost less than one individual / 9 m^2. Large groups of over 30 *Diadema setosum* were observed occasionally on the shallow sea bottom with gentle waves Table 100).

Table 100. Species in the sand habitat.

Species name	Spot name / depth(m)	Bt8 0	Bt29 <1	Bt4 <1	Bt44 4	Bt16 1	Bt18 1	Bt21 2	Bt28 1	Bt26 2
holes of *Scopimera* species	stalk-eyed crab	6.3								
Ophiocoma scolopendrina	ophiocomid		0.7							
Strombus tricornis	conch shell		2.0	0.7	0.7	0.5	0.3	0.3	0.3	0.3
Coralliophila violacea	Violet Coral Shell				r					
Strombus gibberulus albus	conch shell					2.3				
Conus vexillum	cone shell					0.3				
Strombus fasciatus	Lineated Conch					1.0				
Conus arenatus	Sand Cone					0.3				
Rhinoclavis kochi	horn shell						1.7			
Murex tribulus	comb shell							0.3	0.7	
Chicoreus virgineus	comb shell									0.3
Holothuria sp.	sea cucumber									
Diadema setosum	sea cucumber									
Volema pyrum	crown Conch									
Tridacna maxima	clam									
Echinometra mathaei	sea urchin									
Vasum turbinellus	Pacific Top Vase									
Actinopyga mauritiana	sea cucumber									
Vasum turbinellus	Pacific Top Vase									
Conus frigidus	cone shell									
SABELLIDAE	fan-worm									

Species name	Spot name / depth(m)	Bt7 7	Bt33 1	Bt41 <1	Bt5 4	Bt42 1	Bt17 1	Bt13 5	Bt10 2	Bt31 4	Bt11 <1
holes of *Scopimera* species	stalk-eyed crab										
Ophiocoma scolopendrina	ophiocomid										
Strombus tricornis	conch shell										
Coralliophila violacea	Violet Coral Shell										
Strombus gibberulus albus	conch shell										
Conus vexillum	cone shell										
Strombus fasciatus	Lineated Conch	42.0	33.0	31.0	3.3						
Conus arenatus	Sand Cone			1.0	0.3	0.3	0.3				
Rhinoclavis kochi	horn shell		0.3					3.0			
Murex tribulus	comb shell										
Chicoreus virgineus	comb shell					0.3			1.7		
Holothuria sp.	holothuriid		0.7		0.7			0.3			
Diadema setosum	diadematid			0.7		35.0					
Volema pyrum	crown Conch			0.3							
Tridacna maxima	clam				0.3						
Echinometra mathaei	echinometrid										
Vasum turbinellus	Pacific Top Vase					0.3					
Actinopyga mauritiana	holothuriid					0.3					
Vasum turbinellus	Pacific Top Vase						0.3				
Conus frigidus	cone shell						0.3				
SABELLIDAE	fan-worm				0.3					3.0	

1-5. Coral

The habitat is developed outside the outer reef, along coasts with strong wave action, and around islands or banks with a strong current.

The most common species in this habitat were *Tridacna maxima*, *Diadema setosum* and *Echinometra mathaei*. *Tridacna maxima* were present in many spots in the Bank-transect Area. The density was over 8 individuals / 9 m^2 at a spot (Bt48) outside Al-Wajh Bank, but less than 4 individuals / 9 m^2 at the spots inside Al-Wajh Bank. *Diadema setosum* was observed in shallow spots with gentle waves and in deep spots, in greater numbers in the shallow spots than in the deep. *Echinometra mathaei* was observed in the shallow spots and in greater numbers at spots with strong wave action., *Pedum spondyloideum* and *Coralliophila violacea* were also observed frequently, but their numbers were low (Table 101).

Table 101. Species in the coral habitat.

	Spot name	Bt34	Bt48	Bt45	Bt27	Bt15	Bt35	Bt46	Bt36	Bt9	Bt30	Bt39	Bt43	Bt40
Species name	Depth(m)	<1	4	2	3	1	3	3	<1	1	4	15	17	8
Tridacna maxima	clam	4.0	8.3	3.7	3.3	2.7	2.3	2.0	1.3	0.7	0.7	0.3	0.3	
Diadema setosum	sea urchin	35.7	2.0	21.3	26.3		2.0					2.7	2.0	2.3
Echinometra mathaei	sea urchin	39.0	1.7		1.0	20.0	5.3		9.7	0.3				
SERPULIDAE	calcareous tube-worm	c		c			r					+	r	c
Tectus dentatus	topshell	1.3		0.7										
Holothuria sp.	sea cucumber	0.3			0.7									
Isognomon isognomon	toothed Pearl shell	c												
Drupella cornus	comb shell	r												
Culcita novaeguineae	pin-cushion starfish	0.3												
Chama sp.	chama	+												
Pedum spondyloideum	scallop		r	+			r					+	+	
Coralliophila violacea	Violet Coral Shell		r	+			r	r					r	
Dendropoma maxima	worm shell			0.3		68.7			0.3			r		
Strombus tricornis	conch shell										0.7			
Tectus dentatus	topshell					2.0								
Trochus maculatus	topshell					0.3								
Heterocentrous mammillatus	echinometrid					1.7								
Lambis truncata sebae	spider Conch							0.3			0.3			
Drupa ricinus hadari	comb shell							r						
Drupella cornus	comb shell							r						
Conus pennaceus	cone shell							0.3						
Fromia sp.	starfish								0.3	0.3		0.3		
Pinctada margaritifera	Black-lip Pearl Shell									0.3				
Conus arenatus	Sand Cone											0.3		
Tectus virgatus	topshell											0.3		
Morula cf.*chrysostoma*	comb shell													r
Actinopyga mauritiana	holothuriid													0.3

2. The dominant species and their distribution in the Bank-transect Area

In the previous chapter, the habitats and their characteristic species in the Bank-transect Area were discussed. Some species were observed in only one habitat and other species were observed in several habitats. The distributions of the dominant species in the Bank-transect Area are discussed in this chapter.

2-1. *Scopimera* sp., *Macrophthalmus* sp. and *Uca* sp.

These species are the typical species found in a sandy or muddy tidal flat. They filter organic matter contained in the sand and mud of the surface of the tidal flat and eat it. In other words, they are resolving a sewage stocked in the tidal flat; therefore, they play a very important role in the purification of the tidal flat.

Scopimera sp. was observed not only on sandy bottoms but also on complex bottoms of sand and pebbles, from exposed beaches near the water front to the upper tidal zone throughout the whole area. The presence of this species can be known usually only by the small sand pellets that are scattered around its nest holes. These are made only when the tide has ebbed and the bottom has been exposed. Full attention should therefore be paid to tides in a survey of this species.

Macrophthalmus sp. and *Uca* sp. were observed on the sandy tidal flats around the mangrove thickets of Duqm Sabq, but were not observed at the mangrove area on Jazirat Qumma'an. There were some differences in the properties of the soil of Duqm Sabq and of that of Jazirat Qumma'an in colour, salinity and particle size (see details in 2.2.8. Mangrove / Coastal Vegetation). Apart from Duqm Sabq *Macrophthalmus* sp. and *Uca* sp. were observed only at Marsa Zubaydah and Masturah. Therefore, it is thought that these species are rare and important in the Study Area.

2-2. Tridacna maxima

The distribution and the range of shell length of *Tridacna maxima* in the Model Area

are shown in Fig. 56.

Tridacna maxima lives mainly in areas with waves such as the outer reef, or an area with a strong current such as a canal. *Tridacna maxima* was observed throughout the whole area. It can live even in a sandy habitat, if there are small rocks. However, as mentioned above, there were fewer individuals inside Al-Wajh Bank than outside Al-Wajh Bank. In addition, although the length of its shell may reach 350 mm, the maximum size in the Al-Wajh Bank was 260 mm.

The Tridacna species is host to Zooxanthellae such as *Gymnodinium* sp. which provide nutrients through photosynthesis. The species can therefore be basically self-sufficient in food, and has physiological and ecological properties suited to the oligotrophic sea water of a tropical area. When environmental conditions such as light intensity, temperature or salinity deteriorate, the Zooxanthellae leave the *Tridacna* species. If the Zooxanthellae are absent for too long, the *Tridacna* species will die. Al-Wajh Bank is an enclosed environment, and it can be thought that muddy sea water and silt are not very suitable for *Tridacna* species, because they need enough light for photosynthesis to take place.

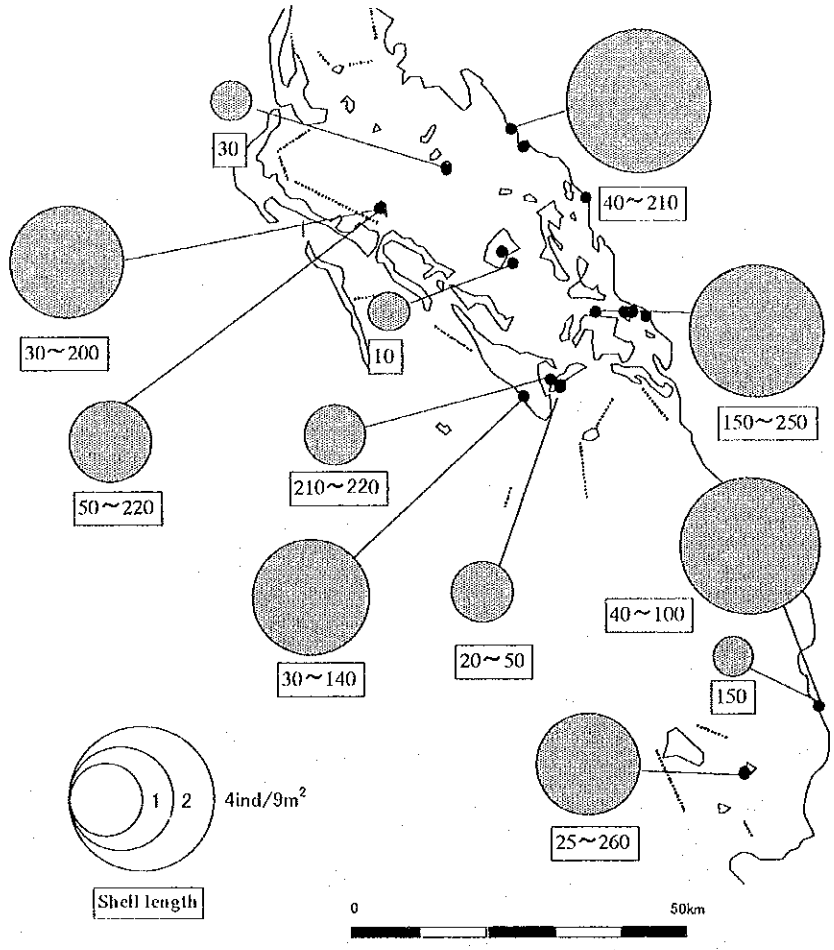


Fig. 56. Distribution and range of shell length *Tridacna maxima*.

2-3. *Diadema setosum* and *Echinometra mathaei*

The distributions of *Diadema setosum* and *Echinometra mathaei* are shown in Fig. 57. *Diadema setosum* were found not only in coral habitats but also on shallow sandy bottoms near coral reefs and around thickets of mangrove. The highest density of *Diadema setosum* recorded was 36 individuals / 9 m^2.

Echinometra mathaei was observed mainly on shallow coral reefs or reef flats and the highest density recorded was 39 individuals / 9m^2. The actual density is probably higher than this because this species often hides under rocks or in deep rock crevices.

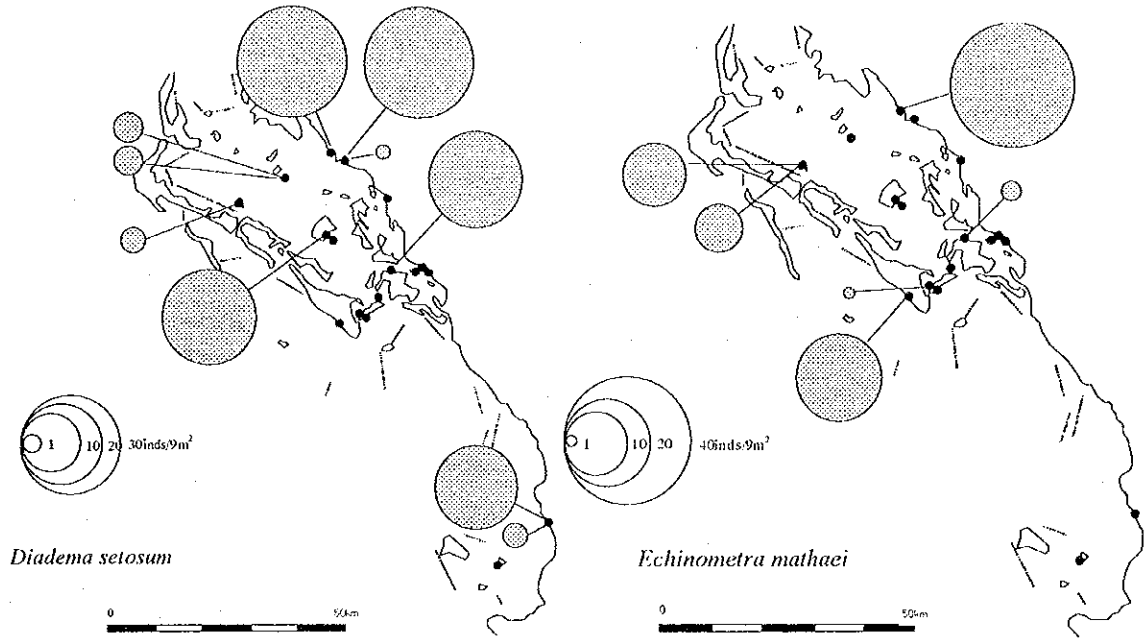


Fig. 57. Distribution of *Diadema setosum* and *Echinometra mathaei*.

Diadema setosum was observed mainly in areas with gentle waves, while *Echinometra mathaei* was observed even in areas with high waves or strong currents. At one patch reef, the number of *Echinometra mathaei* was greater on the side facing the waves, while the number of *Diadema setosum* was greater on the side sheltered from the waves. It is thought that *Diadema setosum* eats sediments on the bottom and *Echinometra mathaei* grazes on small organic matter such as microalgae on the rocks.

2-4. *Strombus fasciatus* and *Strombus tricornis*

The distributions of *Strombus fasciatus* and *Strombus tricornis* are shown in Fig. 58.

Strombus fasciatus is a species endemic to the Red Sea and *Strombus tricornis* is endemic to the Red Sea and the Gulf of Aden.

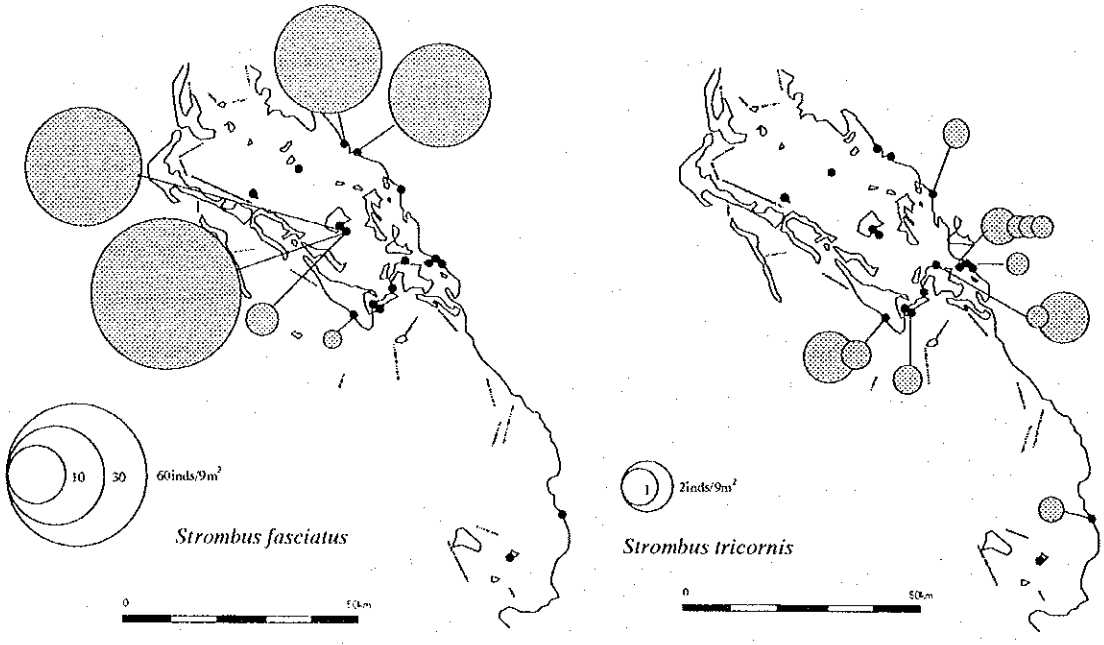


Fig. 58. Distribution of *Strombus fasciatus* and *Strombus tricornis*.

Strombus fasciatus was found on shallow sandy bottoms around seagrass beds, at a high density of 30 to 70 individuals / 9 m^2.

Strombus tricornis was observed on sandy bottoms and seagrass beds. The density was less than one individual / 9 m^2.

3. The characteristics of benthos and their habitats in the Model Area

The species of benthos which were observed in the Bank-transect Area could be found anywhere in the Study Area.

The most characteristic habitat in the Model Area is the mangrove habitat and the most important mangrove site is the one at Duqm Sabq. The reasons are that *Macrophthalmus* species and *Uca* species, which are important for the tidal-flats ecosystem, can be observed at

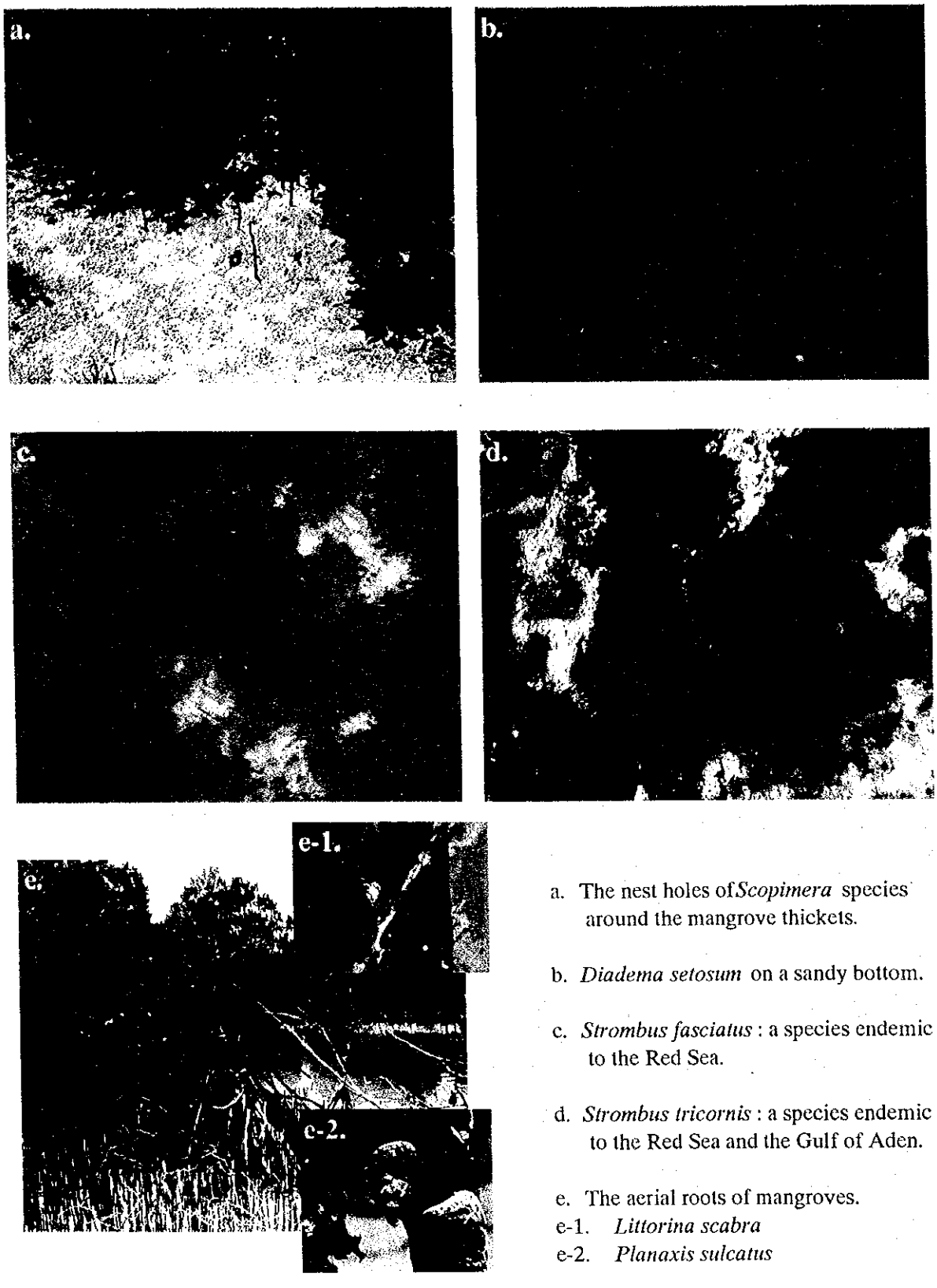
this site, and sites where these species can be observed are limited in the Study Area.

Since the intertidal zone has a complex bottom of sand and bedrock or patch reef, the number and abundance of benthos are usually high in other survey sites in the Study Area. However, the number and abundance of benthos in the intertidal zone of the Model Area were lower than other sites outside Al-Wajh Bank. This is because almost all the bottoms of the intertidal zone in the Model Area are covered with sand or silt. For example, the number and body size of *Tridacna maxima* observed at a coral reef in Al-Wajh Bank were smaller than at other sites outside the bank.

The characteristics of the benthos fauna in the Model Area are summarised as follows;

1. The number of species is low;
2. The abundance of each species is low; and
3. The body size of *Tridacna maxima* is smaller than in other areas.

Al-Wajh Bank is a relatively closed environment, and there is not a good exchange of sea water between the inside and the outside; the sea water of the Model Area is therefore muddy. An environment like this is suitable for macrobenthos which live beneath the sand or the silt, rather than for the megalo benthos that is the main subject of this study. It is assumed that macrobenthos such as Polychaeta or Amphipoda are important as secondary produce or food for benthosfeeding fish in Al-Wajh Bank. A survey on macrobenthos could provide an accurate understanding of the ecosystem of the Model Area in the future.



a. The nest holes of *Scopimera* species around the mangrove thickets.

b. *Diadema setosum* on a sandy bottom.

c. *Strombus fasciatus* : a species endemic to the Red Sea.

d. *Strombus tricornis* : a species endemic to the Red Sea and the Gulf of Aden.

e. The aerial roots of mangroves.
e-1. *Littorina scabra*
e-2. *Planaxis sulcatus*

Photo. 8-5. Habitats and species in the Model Area.

2.2.7. MARINE TURTLES / MARINE MAMMALS

2.2.7.1. Marine Mammals

1. Methods

Dugong, which has been surveyed intensively by MEPA, is the key marine mammal in terms of the establishment of a protected area because of its dependency on the local habitats. An aerial transect survey on Dugong for the whole of Al-Wajh Bank aiming to evaluate the status of the Dugong population was carried out.

1-1. Aerial transect survey

The aerial transect survey was conducted in the Model Area to acquire more detailed information on the status of Dugong and other marine mammal species. The basic method of the survey followed the methodology of MEPA in July and August 1987.

A four-seat fixed and high-wing aircraft was used for the aerial survey. The aircraft was equipped with a Radar Altimeter. Transects were marked by a simple tape on the wing shaft. This marker delineated the outside edge of the search area, and the bottom of the aircraft window marked the inside edge. The aircraft flew at an altitude of 500-ft (152.4m) above ground level at 110 – 120 kts (198–216 km/h). The transect width was calculated to be about 200 m on each side, making a transect survey width of about 400m at each transect. Parallel transects were flown at 5 minute intervals, or 2.5 minute intervals in areas where the existence of extensive seagrass beds was suggested by aerial photo analysis.

To minimise differences on both sides due to the reflection of the sea surface, transects were oriented only in an east-west direction. The survey team consisted of right and left observers in the rear seats and a co-ordinator in the co-pilot seat. The left and right observers were changed each day. The observers filled in the data sheet when they sighted Dugongs and other marine mammals. UTC, GPS position, direction, speed of aircraft and

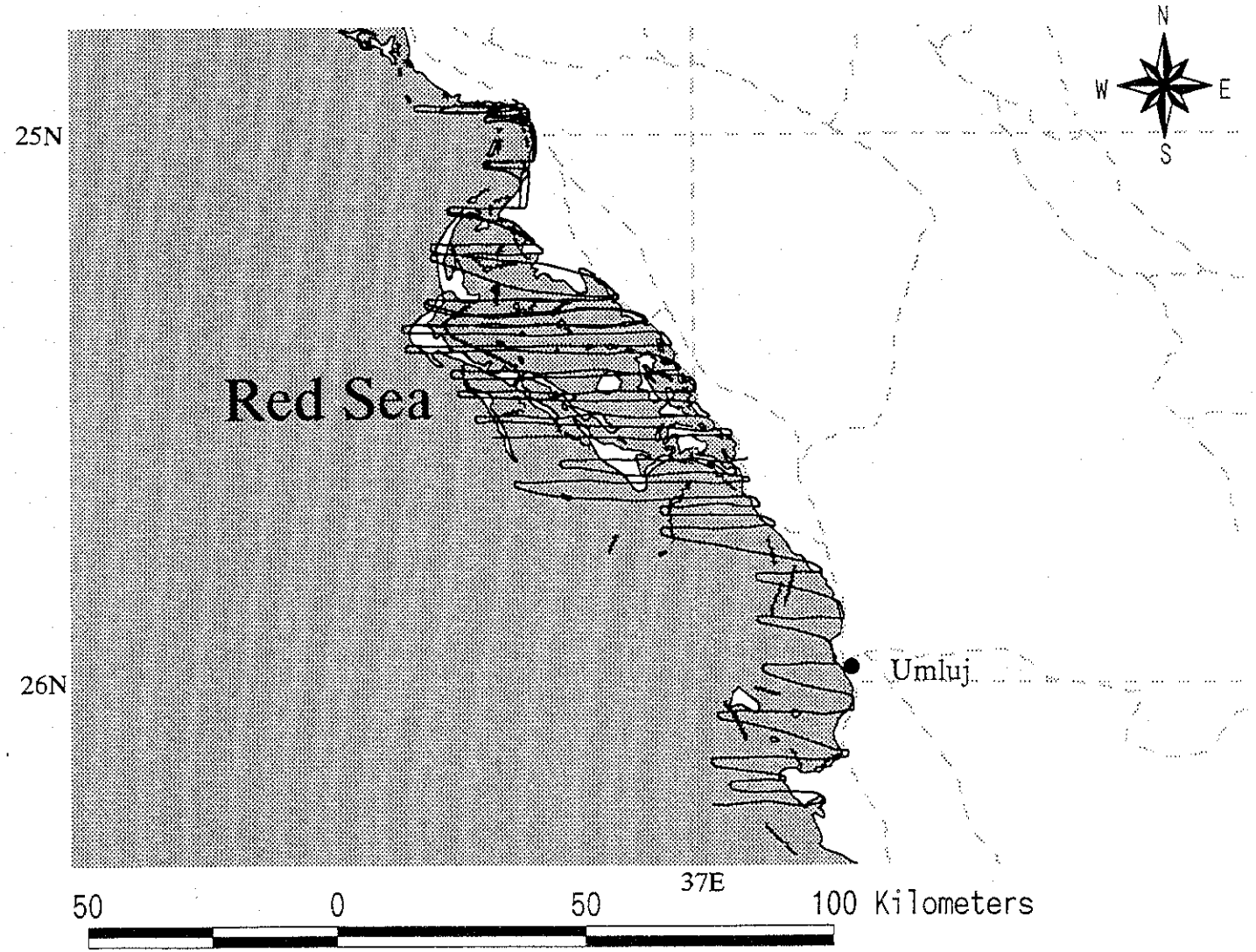
satellite data quality were recorded into a personal computer each second. Thus, the exact locations of the sightings were determined by collation of the time recorded.

A practice survey was conducted on the first day since the observers were still new to this kind of survey. 23 transects covering the whole of Al-Wajh Bank were flown on the following two days, 15 and 16 February 1999. Fig. 59 shows the flight paths for the aerial survey, including the first day practice.

1-2. Boat survey of the primary habitats

Following the aerial survey, a boat survey of the primary Dugong habitats where frequent sighting were recorded by the previous and present aerial surveys, was conducted. Adjacent seagrass beds near to Al-Habban and Qara'ir coast guard stations and east of Shaybarah island were selected from the draft habitat map for the boat survey.

Fig. 59. Flight paths of the aerial survey conducted from 14 to 16 February, 1999.



2. Results

The Dugong sighting locations in the aerial survey are shown in Figure 9. On transect 7, Dugong sighted the most frequently (8 dugongs) during the practice survey on the first day. The sightings made on the following two days are summarised in Table 102.

Table 102. Dugong sightings in the aerial transect survey 14-15 February 1999.

Transect No.	Date	Time (UTC)	Latitude	Longitude	ObL	ObR	Co	Dg	Out of Transect
T1	2/15/99	4:51:10	260202	364019		AK		1	
T2		4:51:52	260150	363857			TT	1	
T5		5:18:11	254702	363557		AK		1	
T7		5:58:11	253916	365058		AK		1	
T7		6:03:21	253905	363928		AK		1	Out
T8		6:27:52	253659	365338	MM			3	
T9		6:58:20	253411	365546	MM			1	
T10		7:36:25	253203	363459	MM			1	
T10		7:27:10	253159	365455		AK		1	
T10		7:26:24	253157	365636			TT	1	
T10		7:28:20	253205	365223		AK		3	
T12		8:25:10	252647	365407	MM			2	
T12		8:27:32	252700	364915	MM			1	
	2/16/99	5:01:27	252237	370515	AK			1	Out
T14		5:03:51	252152	370246	AK			1	Out
T15		5:31:20	251926	370431	AK			2	
T15		5:34:17	251923	365927	AK			1	
T15		5:30:35	251919	370545		MM		1	
T16		5:46:25	251653	370205			TT	1	Out
T18		6:07:56	250700	371539	AK			1	
T18		6:10:35	250659	371048			TT	1	
Total sighitings in Aerial Transect Survey, February 1999.								23	

ObL: Left Observer, ObR: Right Observer, Co: Coordinator, Dg: Number of Dugong
AK: Akira Kishi, MM: Mustafa Al-Merghani, TT: Toshinori Tsubouchi

The number of Dugong sightings is similar to that made in the previous survey by MEPA though the sampling intensity is slightly different. The sampling intensity of the present survey is 6.87% (survey area: 3547.6km^2, sampling area: 243.9 km^2). The comparative

sighting ratio which was used to estimate the Dugong population in the previous survey by MEPA seemed in applicable because of the significant difference between the co-ordinator and the observers. The difference was mainly due to the wing shaft and position. Thus, assuming the sampling of the aerial transect was done in a random manner, the population suggested from the aerial transect survey is over 335 (23:sighted animals / 6.87%: sampling intensity).

Only 2 out of 43 total sightings during the 3-day survey were of calves (Fig. 60). The calf ratio in the survey was found to be 4.7%.

2-1. Other sightings

Sightings of dolphin, were also recorded during the aerial transect survey and the results are shown in Table 103. The sightings were quite limited though the survey covered a quite wide area. The calf ratio was found to be 16 %.

Table 103. Sightings of other marine mammals in the aerial transect survey 14 – 15 February 1999.

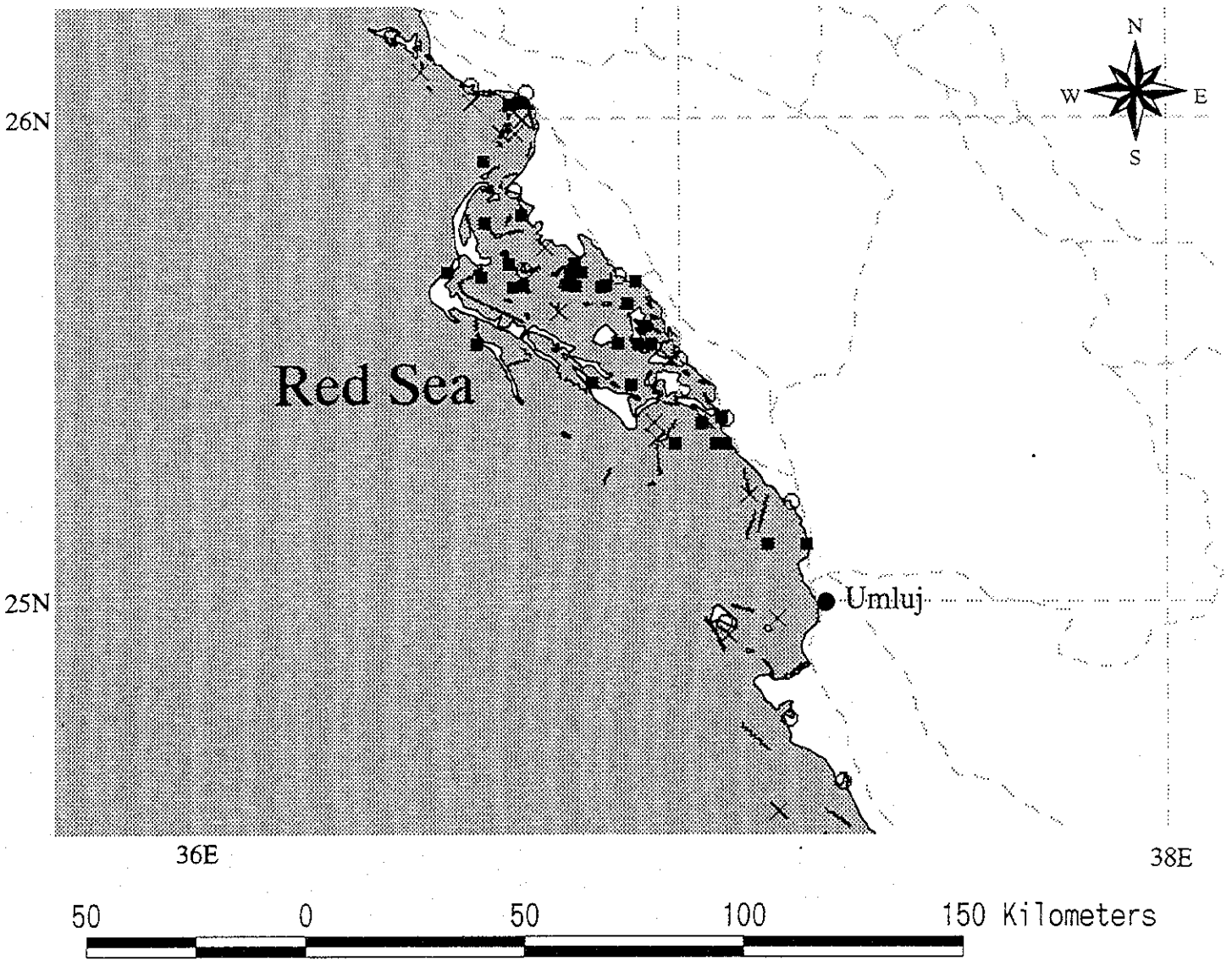
Date	Time (UTC)	Latitude	Longitude	ObL	ObR	Co	DP	s	c
2/14/99	5:38:31	254200	363857	AK			5	5	2
2/15/99	5:23:18	254448	363618		AK		1	1	
	7:00:09	353441	365141		AK		2	2	1
	6:02:21	253912	364135	MM			5	5	
	6:51:05	253610	364902	MM			4	4	
	7:00:35	253423	365045			TT	2	2	1
2/16/99	4:59:21	252308	380053	AK			1	1	
	5:46:37	251655	370143	AK			1	1	
	6:12:01	250719	370808	AK			1	1	
	6:38:21	245511	374701	AK			1	1	
	6:42:05	245239	371525	AK			2	2	
Total sightings							25		4

ObL: Left Observer, ObR: Right Observer, Co: Coordinator

AK: Akira Kishi, MM: Mustafa Al-Marghaini, TT: Toshinori Tsubouchi

s: surface, c: calf

Fig. 60. Locations of Dugong sighting in the present and previous aerial transect survey in Al-Wajh Bank. The total number of Dugong sighted was 43 in three days.



Sighting of marine turtles were also recorded during the aerial transect survey and the results are shown in Table 104.

Table 104. Sightings of marine turtles in the aerial transect survey 14 – 15 February 1999.

TR	Date	Time(UTC)	Latitude	Longitude	ObL	ObR	Turtle	Species
	2/15/99	8:24:12	252647	365605	AK		2	
		8:28:18	252646	365553		AK	1	
		4:48:28	260228	363925	MM		2	cm
T6					MM		1	ei
		6:35:38	253658	363630	MM		1	ei
	2/16/99	5:02:45	255453	364117		MM	1	ei
		5:34:35	254208	364642		MM	1	ei

TR: Transect Number, ObL: Left Observer, ObR: Right Observer

cm: *Chelonia mydas*, ei: *Eretmochelys inbricata*

AK: Akira Kishi, MM: Mustafa Al-Merghani

No Dugong were sighted during the 3-day boat survey of the primary habitats. Many fishermen stated during the questionnaire / interview survey that their Dugong sightings were inside or near sharms. In front of Ghawash coast guard station where fishermen indicated frequent Dugong sightings, the seagrass beds grow in an area which is protected from waves by patch reef at a certain. Five species of seagrass were found but only *S. isoetifolium* (Photos 9-1-1) was apparently grazed intensively by Dugong. Table 105 summarises the findings of the boat survey.

Table 105. Findings of the boat survey of the primary Dugong habitats.

Spot	Date	Location	Latitude	Longitude	Finding
MM1	21-Feb-99	East of Shaybarah island	252350	365420	Blue green algae covering on silt surface.
MM2		Same as above	252222	365341	Blue green algae covering on silt surface.
MM3		Same as above	252355	365454	Patch reef surrounded by white silt with a few sea grasses.
MM4	22-Feb-99	Al-Habban CGS	260411	363439	Dugong grazing pattern was found on seagrass beds of *Cymodocea rotundata*
MM5		Ghawash CGS	260241	364115	No grazing found on the seagrass beds of *Cymodcea rotundata*.
MM6		Ghawash CGS	260233	364114	Grazing found on almost all *Sylingodium isoetifolium*.
MM7	23-Feb-99	South west of Al-Khurj CGS			no seagrass bed
MM8		Same as above	252533	365722	No grazing found on the seagrass beds.

3. Discussion and conclusions

3-1. Population and reproduction of Dugong

1). Population

The population of Dugong in Al-Wajh Bank was estimated to be 759±246.9 by MEPA in 1987 (PREEN 1987). The area surveyed in the present study is quite similar to the area covered by the MEPA survey. Due to differences in equipment, the aircraft used, survey season and observers, though methodology basically followed the previous survey, we were not able to come up with similar population figure. However, the population is estimated at over 335 in Al-Wajh Bank, with little human exploitation

The sightings of Dugong were mainly associated with seagrass habitats in the Arabian Gulf where extensive seagrass habitats were widely distributed. The behaviour and sighting frequency of Dugong seems to be related to the seagrass habitats. Though limited and scattered seagrass habitats have been confirmed in Al-Wajh Bank, the area has relatively extensive and accumulated seagrass habitats comparated with other areas in the Study Area.

Therefore, a significant Dugong population is concentrated in Al-Wajh Bank.

2). Reproduction

The low calf ratio in Al-Wajh Bank was noted by the previous survey (PREEN 1987). In Hervey Bay, Australia, a 22 % calf ratio was reported in 1988, 1992 (PREEN 1995). The question of whether this significant difference in the calf ratio is indicative of the reproduction condition, a high calf mortality rate or bias by the survey method, needs to be carefully studied for conservation management. If this rate actually indicates the natural reproductive condition in the area, it means that the Dugong population in Al-Wajh Bank is very sensitive to any habitat loss or modification especially of the seagrass beds, and to human activities.

3-2. Population of marine mammals

It was quite difficult to identify species in the aerial transect survey. Only the Indo-Pacific Humpback Dolphin *Sousa chinensis* has been confirmed in the Model area. Little information on marine mammals in the Red Sea was available. Of the species recorded in the Red Sea, Indo-Pacific Humpback Dolphin and Red Sea Bottle-Nosed Dolphin (there is still a lot of dispute regarding this classification) have a relatively restricted distribution. The two species inhabit inshore areas, which means they are relatively vulnerable to habitat loss. Al-Wajh Bank apparently provides significant habitats for inshore species of marine mammals. Thus, studies are still needed to understand the population and habitat dependency of species for conservation management.

3-3. Issues related to conservation management

High sensitivity of Dugong population

Immediately after the mass destruction of seagrass beds in Australia in 1993, the ratio of calves, which are much more vulnerable than adults was found to be 2.8% (PREEN 1995). If the calf ratio in the Model area indicates the natural mortality rate, the survival of Dugong so far could be attributed to the lack of human impact. It could be said the unspoiled environment

of the Model Area is the greatest factor attributing to their survival in the harsh environment.

Human activities such as net fishing, oil spills or accidents and other events which can cause habitat loss need to be carefully managed for the sake of the conservation of the sensitive population of Dugong in the Model area.

2.2.7.2. Marine Turtles

1. Methods

In order to obtain more data on the status of marine turtles, especially Hawksbill Turtle *E. imbricata* in the Model Area, two major nesting islands, Jazirat Jabal Hassan and Jazirat al-Waqqadi, were selected for Model Study. Surveys of nesting beaches, and nesting females and nest examinations were carried out especially for Hawksbill Turtle whose peak nesting activity is reported to be in May and June (MUSTAFA per. comm.)

Fig. 61 and 62 show the survey sites of Jazirat Jabal Hassan and Jazirat al-Waqqadi. Jazirat Jabal Libnah and Jazirat Malihah were also included in the Jazirat Jabal Hassan area since a couple of turtle tracks were found in the previous aerial survey. Seven beaches in Jazirat Jabal Hassan, Jazirat Jabal Libnah and Jazirat Malihah were surveyed for nesting activities in this stage. All around Jazirat al-Waqqadi was surveyed, since the Hawksbill Turtle' nested took place all around the island.

Firstly, new tracks and nests on the beaches were counted to ascertain the status of nesting activity in this season. Then, the most used beach in each area was selected for the capture of nesting females. Beach 3 of Jazirat Jabal Hassan and the south-west and the north-western beaches of Jazirat al-Waqqadi were selected for the survey. During the nesting female survey, some of the new nests were examined to obtain reproduction data.

Fig. 61. Marine turtle survey sites in Jazirat Jabal Hassan, Jazirat Jabal Libnah and Jazirat Malihah.

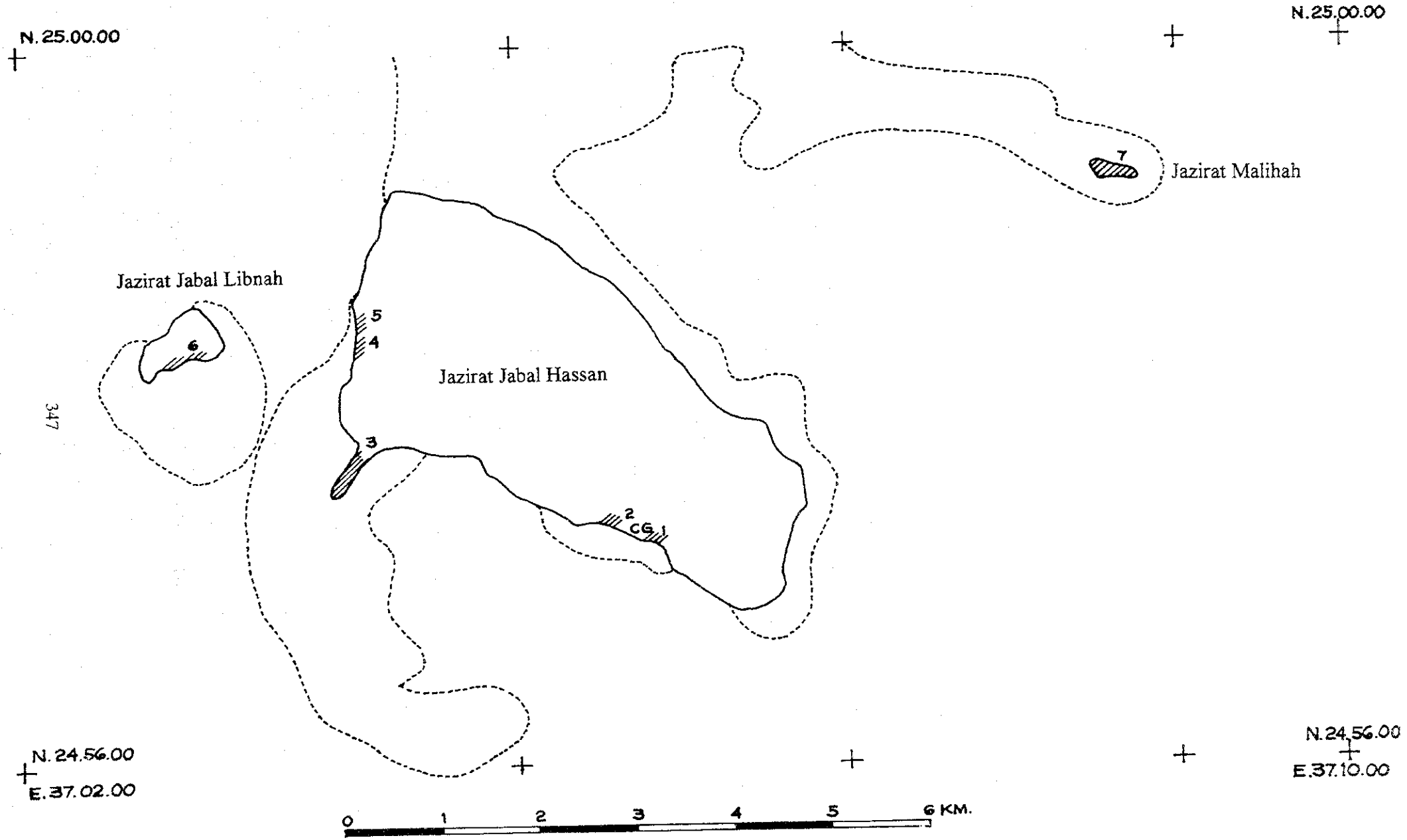
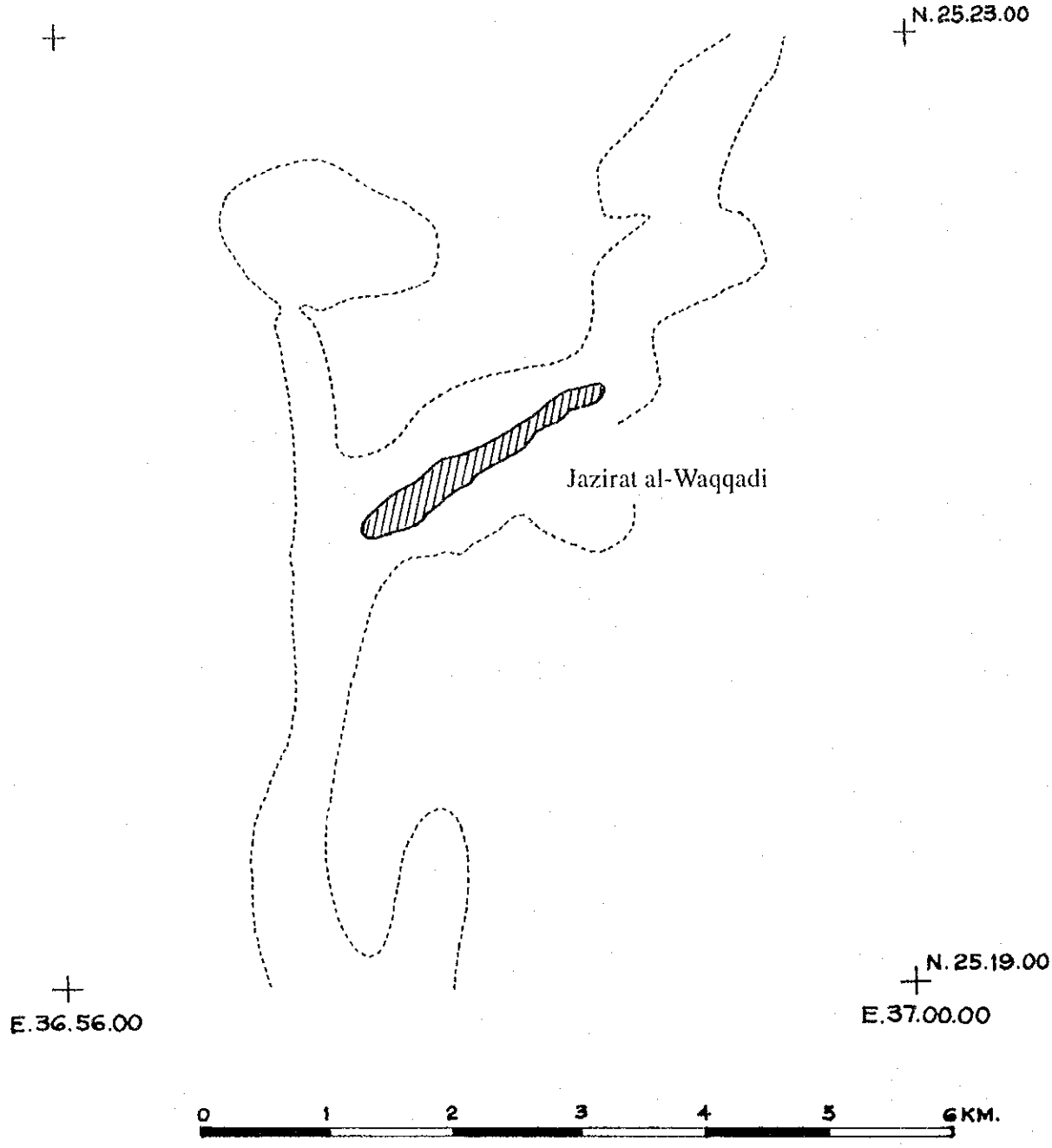


Fig. 62. Marine turtle survey sites in Jazirat al-Waqqadi.



2. Results

2-1. Nesting Activity

The tracks and the nest counted on the beaches in the Jazirat Jabal Hassan area are summarised in Table 106. Although the survey was conducted late in the Hawksbill Turtle nesting season, 15 Green Turtle tracks and two Green Turtle nests were found. One Green Turtle female laid eggs during the survey on the west side of Beach 3. In addition to the findings, during retrieval of the data loggers set at Ra's Baridi, 13 new Green Turtle tracks were found on the beach.

Table 106. Number of tracks and nests found of the beaches on Jazirat Jabal Hassan, Jazirat Jabal Libnah and Jazirat Malihah.

Beach No.	Hawksbill Turtle		Green Turtle	
	Track	Nest	Track	Nest
1	0	0	0	0
2	0	0	0	0
3	14	?	7	1
4	0	0	3	1
5	8	1	5	0
6	3	0	0	0
7	2	1	0	0

On Jazirat al-Waqqadi, where over 44 tracks and 39 nests were counted in the previous survey, 38 tracks and 15 nests were found on the island in this season. All of the tracks and nests were of Hawksbill Turtles.

2-2. Examination of Hawksbill Turtle nests

The results from the Hawksbill Turtle nest examination are shown in Table 107. The average clutch size of the four Hawksbill Turtle nests was 56.5±13.1, and their yolkless eggs

numbered 31.8±24.5. The distance of the nests from the sea at high tide was between 3.5 – 6.7 m. All nests were located within 3 m of the nearest vegetation and directly exposed to the sun. The clutch size is significantly smaller than those found in the Seychelles in the Indian Ocean, and many yolkless eggs were found in all nests, which are characteristic of the Hawksbill Turtle reproductive condition in the Model Area.

Table 107. Results of Hawksbill Turtle nest examination.

No.	Location	Beach No.	Date Examined	Normal Eggs	Fertile Eggs	Yolkless Eggs	Status
1	Jaziart Jabal Malihah	7	15-Jun-99	61	59	25	C 2 week old
2	Jazirat al-Waqadi	NW	20-Jun-99	73		18	C 1 week old
3	Jazirat al-Waqadi	NW	20-Jun-99	45		16	C 1 week old
4	Jazirat al-Waqadi	NW	21-Jun-99	47		68	C4 days old (Photo. 9)

NW: North West Beach

Morphometric data obtained from the nesting females are shown in Table 108. No Hawksbill Turtle nesting femalse could be found on Beach 3 on Jazirat Jabal Hassan, and two Green Turtle nesting females were found although their peak nesting season is reported by NCWCD surveys to be September and October.

In Jazirat al-Waqqadi, only one Hawksbill Turtle nesting female was captured during the night survey. The morphometric data of this female is shown in Table 108. The straight carapace length was 660 mm and body weight was 30 kg, comparatively small for a nesting female.

Table 108. Nesting female turtles examined.

Species	Tag.*	Date	SCL (mm)	CCL (mm)	SCW (mm)	CCW (mm)	BW (kg)	Location	Status
C. mydas	13164(e) 17164(a)	14/6/99	991	1085	747	945		Jabal Hassan beach 3	Nesting, laid eggs.
E. imbricata	13185(e) 17165(a)	20/6/99	660	690	505	605	30	N/W beach of al-Waqqadi island.	Nesting (aborted).

*: (e) English Tag, (a): Arabic Tag
SCL: straight carapace length, CCL: curved carapace length, SCW: straight carapace width, CCW: curved carapace length, BW: body weight

2-3. Sightings of marine turtles during the survey

Marine turtles sighted during the survey are listed in Table 109. Although the coral reef habitat, a primary habitat for the Hawksbill Turtle, covers quite an extensive area in Al-Wajh Bank, sightings of the turtles were very limited. Only one juvenile Hawksbill Turtle, which usually resides in shallow areas of coral reef ,was sighted during the survey. All sightings of Green Turtle including non-recorded sightings were estimated at sub-adult to adult size.

Table 109. Sightings of marine turtles during the survey.

Species	N	By	Date / Time Sighted		Location and Estimated Size
Hawksbill Turtle	1	Y.H.	8/June/99	12:00	West of Shunbuzah channel, about 70 cm (adult).
Green Turtle	1	T.T.	14/June/99	8:01	Between CG to beach 3 at Jabal Hassan, about 80 cm (sub-adult – adult).
Green Turtle	1	T.T., M.M.	14/June/99	8:52	Between beach 3 of Jabal Hassan and Libnah island, about 80 cm (sub-adult – adult).
Hawksbill Turtle	1	T.T., M.M.	14/June/99	9:14	Between beach 3 of Jabal Hassan and Libnah, about 40 cm (juvenile).

M.M.: Mustafa Merghani, Y.H.: Yoichi Harada, T.T.: Toshinori Tsubouchi

3. Discussions and conclusions

3-1. Population and reproduction of Hawksbill Turtles in the Model Area

1). Population

In spite of the extensive coral reef coverage in the Model Area, sightings of Hawksbill Turtle, especially juveniles, in the survey, were quite limited. This would indicate that there are only a few resident juvenile Hawksbill Turtles in the area. The marine survey in the Model Area suggests a limited distribution and abundance of sponges, which are known to be suitable food for Hawksbill Turtles. Therefore, this low number of sightings during the survey would be explained by population limitation due to the low food availability, i.e. availability of sponges in the area.

2). Nesting season

The peak nesting season was reported to be from May to June for Hawksbill Turtle in the northern part of the Red Sea. Many tracks of Hawksbill Turtle were found in Jazirat al-Waqqadi in May 1998 and June 1999. It was confirmed that significant nesting activities take place in the May – June season. The temperature of the nesting beaches could not be compare on the three major nesting beaches due to defects in the devices. However, it is speculated that the Green Turtle nesting season would be from April to July and from late August to October at Ra's Baridi. It needs to be confirmed whether significant nesting activities by Hawksbill Turtle take place from September to October.

3). Reproductive conditions

The examination of the Hawksbill Turtle nests revealed the characteristic small clutch size and large percentage of yolkless eggs, which has also been reported previously (ROSS 1987). The large percentage of yolkless eggs has been explained by the protection of lower eggs from direct solar exposure and the smaller clutch size was suggested to be caused by thermal stresses (FRAZIER 1987). It has been suggested that the lower fertility rate of Hawksbill Turtle on the Omani coast is the result of physiological stress from the upwelling of the cold water (ROSS 1981). Reproduction of Hawksbill Turtle in the Model Area is some what less than half what it is in the Seychelles in the Indian Ocean, where the average clutch

size is over 150 eggs. These reproduction characteristics indicate the very high sensitivity of the turtle to any habitat loss or modification, exploitation, oil spill accidents or other human activities.

4). Exploitation

The exploitation of marine turtles by humans does take place but it is of quite minor consequence in the Model Area.

3-2. Population and reproduction of Green Turtles in the Model Area

1). Population

From the monitoring survey of the nesting of Green Turtles in Ra's Baridi, Al-Wajh Bank, where a significant Dugong population was indicated by MEPA, was thought to have Green Turtle population since both species depend on seagrass habitats. However, seagrass habitats were found to be quite restricted in Al Wajh Bank, being mostly found in open sharms or areas moderately surrounded by patchy reefs. The silty areas are mostly covered in blue-green algae, which Green Turtle does not feed on. Sightings of Green Turtle were mainly of sub-adult to adult size, with very few juvenile. The findings suggest that there are only a few resident Green Turtles in the Model Area.

2). Nesting season

The peak nesting season for Green Turtle at Ra's Baridi was reported by NCWCD to be from late August to October. Quite a few new Green Turtle tracks were found on Jabal Hassan and Ra's Baridi in June 1999. It is suggested from the nesting beach temperature at Ra's Baridi that there is nesting activity from April to June when almost the same range of temperature is available.

3-3. Issues relevant to conservation management

1). Key factors for the survival of the Hawksbill Turtle in the Red Sea

Nesting females of Hawksbill Turtle in the Red Sea are reported to be significantly smaller than those in the Arabian Gulf. This suggests that the reproductive conditions of the turtle in the Model Area are not in optimum condition compared to other areas of the world. The same findings on their reproductive status are also reported in other parts of the Red Sea. It seems that the northern part of the Red Sea supports a resident and nesting population of Hawksbill Turtle though the habitats provide marginal or sub-optimum conditions for them. The factors key to their survival need to be studied carefully for conservation management in the area.

2). Peak nesting season and migration of Green Turtle

The nesting activity at Ra's Baridi has been surveyed intensively by NCWCD, concentrated in September and early October. Two nesting females and a number of Green Turtle tracks were found in the present survey, which might indicate a not small nesting activity taking place in June. In order to develop effective programmes for monitoring the turtles in the Model Area, it is essential to know the peak nesting season.

Green Turtle nesting females in Ra's Baridi are reported to be bigger than those in the Arabian Gulf, though Hawksbill Turtle is reported by NCWCD to be smaller. The sighting of Green Turtle juveniles in the survey is very limited throughout the Study. This might mean the nesting females are migrating for long distances. Therefore, it is important for the development of conservation management programmes, to know where the nesting population of the Model Area migrates from, and the conditions of the resident population in the Model Area

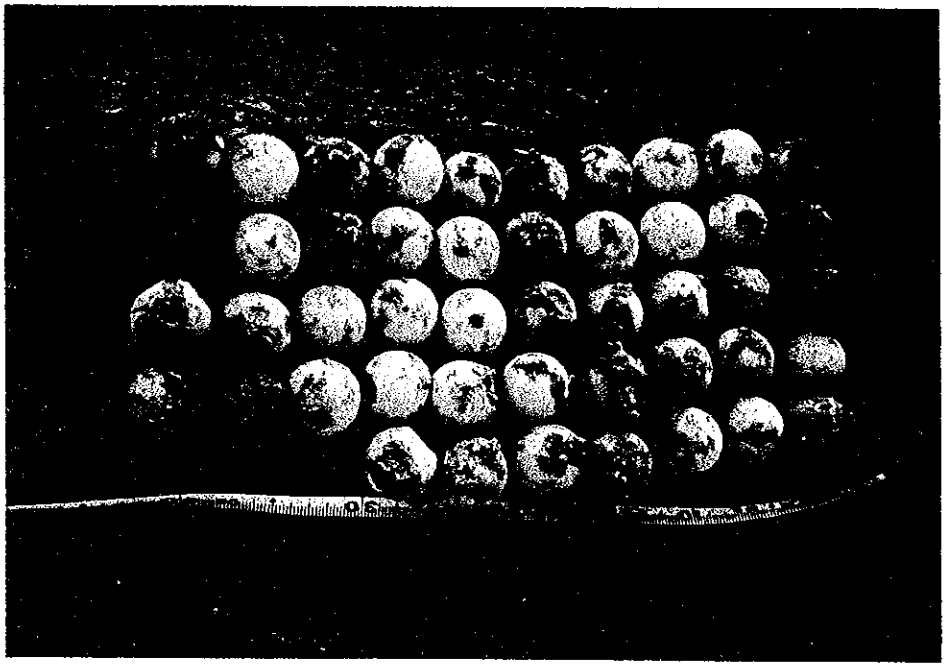
3). Food resources (seagrass and sponges); their reproduction and fragility

Sponges (*Chondrilla nucula, Chondrosia collectrix, Erylus ministrongylus* and

Geodia gibberosa) and seagrass (*Thalasia spp.*) are the main food for Hawksbill and Green Turtles respectively. The distributions and abundance of these foods are the key factors for the survival of the turtles. However, the present Study suggests that these foods are not so significant in terms of distribution or abundance, in the Model Area. To develop an effective conservation management programme for marine turtles, the abundance and reproductive factors of food resources in the Model Area need to be evaluated.

Photo. 9 – 1. Marine Mammals / Marine Turtles

1. *S. isoetifolium* apparently grazed by Dugong in the seagrass beds in front of Ghawash Coast Guard Station.



2. Normal eggs of Hawksbill Turtle nest (no.4) examined on north-west beach in Jazirat al-Waqqadi. Only 47 normal eggs were found.

Photo. 9 – 2. Marine Mammals / Marine Turtles

3. Yolkless eggs of Hawksbill Turtle nest (no.4) examined on north-west beach in Jazirat al-Waqqadi. 68 yolkless eggs (59%) were found.

4. A female Hawksbill Turtle captured and examined in Jazirat al-Waqqadi on 20 June 1999. Note relatively small size (SCL:660mm, Body Weight 30 kg)

2.2.8. MANGROVES / COASTAL VEGETATION

2.2.8.1. Methods

The purpose of the mangrove / coastal vegetation survey in the Model Area is not only to obtain fundamental data concerning the community structure and the soil – vegetation relationship, but also to establish the framework for the vegetation monitoring. The survey focused mainly on the mangrove vegetation because of its high biomass and the rarity of *R. mucronata*. To this purpose, the following surveys were conducted; quadrat census survey, soil survey and vegetation mapping. The details of each method are as follows ;

1. Quadrat census survey

In order to set up monitoring points for vegetation, six typical transect lines which had various plant communities (especially mangrove and salt marsh) were selected in the Model Area, using the aerial photographs and the habitat maps. Four lines (TD1, 2, 3, 4) were set around Duqm Sabq located about 100 km south of Al-Wajh, and two lines (TQ1, 2) on Jazirat Qumma'an, an offshore island located about 10 km off the coast of Duqm Sabq (Fig.63). Each transect line had a length of less than 1 km from the shoreline to inland. The location of the transects is shown in Fig. 63.

On each transect line, two to five quadrat census surveys were carried out in February 1999 for each vegetation type including mangroves. The mangrove communities of all sites in the Model Area were relatively young. In addition to these, one mature *Avicennia marina* community (site 18) at Al-Quff, outside the Model Area, 100 km north of Al-Wajh was added in order to provide comparative data on community structure and soil conditions. Totally, the number of sites (quadrats) was 18, including eight in mangroves (Table 110 and Appendix 21).

To set a permanent quadrat, each corner was marked by staking a PVC pipe into the ground. The size of each quadrat was decided according to the coverage and density of the

plant community. Each quadrat had an area between 5 m x 5 m and 10 m x 20 m.

In the mangrove sites, the items determined for each individual were the scientific name, location, height, DBH (diameter of stem at breast height, approximately 1.3 m above the ground), D_{10} (diameter at stem base, approximately 10 cm above the ground), branch spread, flowering, and number of seedlings. Crown projection and profile charts were also sketched at each site. At typical mangrove sites (St. 1, 2, 7, 15, 18), for the purpose of long-term monitoring numbered PVC tags were attached to the stems of all mangrove individuals with more than 1cm DBH. With regard to the sites of salt marshes and desert vegetation, the following items at least were recorded; scientific name, location, height, branch spread. Additionally, geomorphological features and soil conditions of the sites were recorded. All vascular plants appearing in the sites were recorded, and added to the inventory.

Table 110. Summary of the tree census and soil surveys in the Model Area.

	Mangrove		Salt marsh and other (dominant)
Dominant*1	Rm	Am	
Place Transect			
Duqm Sabq			
TD1	-	-	Site 13 (Za), 14 (Za)
TD2	Site1*2(+Am)	-	Site 10 (Hs), 11 (Hp), 12 (Za)
TD3	-	***Site.15****2	Site 16 (Arm+Hs)
TD4	-	-	Site 17 (Hp), 20*3(no vegetation)
Jazirat Qumma'an			
TQ1	***Site 2****2	Site 3, 4, 6	Site 5 (Arm)
TQ2	-	Site.7*2, 8	Site 9 (Hs+Arm), 21*3 (Arm)
Al-Quaff			
-	-	Site 18*2,19*3	-
Measured items in			
Tree census survey	Scientific name, location, height, DBH, D_{10}, branch spread, flowering, seedling.		Scientific name, location, height, branch spread, flowering.
Soil survey	Eh, salinity, pH, temperature, soil colour (at the sites).		EC(salinity), pH, temperature, particle size (at the field office).
Total number of sites	2	8	11

*1. Rm : *Rhizophora mucronata*, Am : *Avicennia marina*. Za : *Zygophyllum album*, Hs : *Halocnemum strobilaceum*, Hp : *Halopeplis perfoliata*, Arm : *Arthrocnemum macrostachyum*,
*2. Numbered tags were attached to trees. *3 : Soil survey was carried out on site.

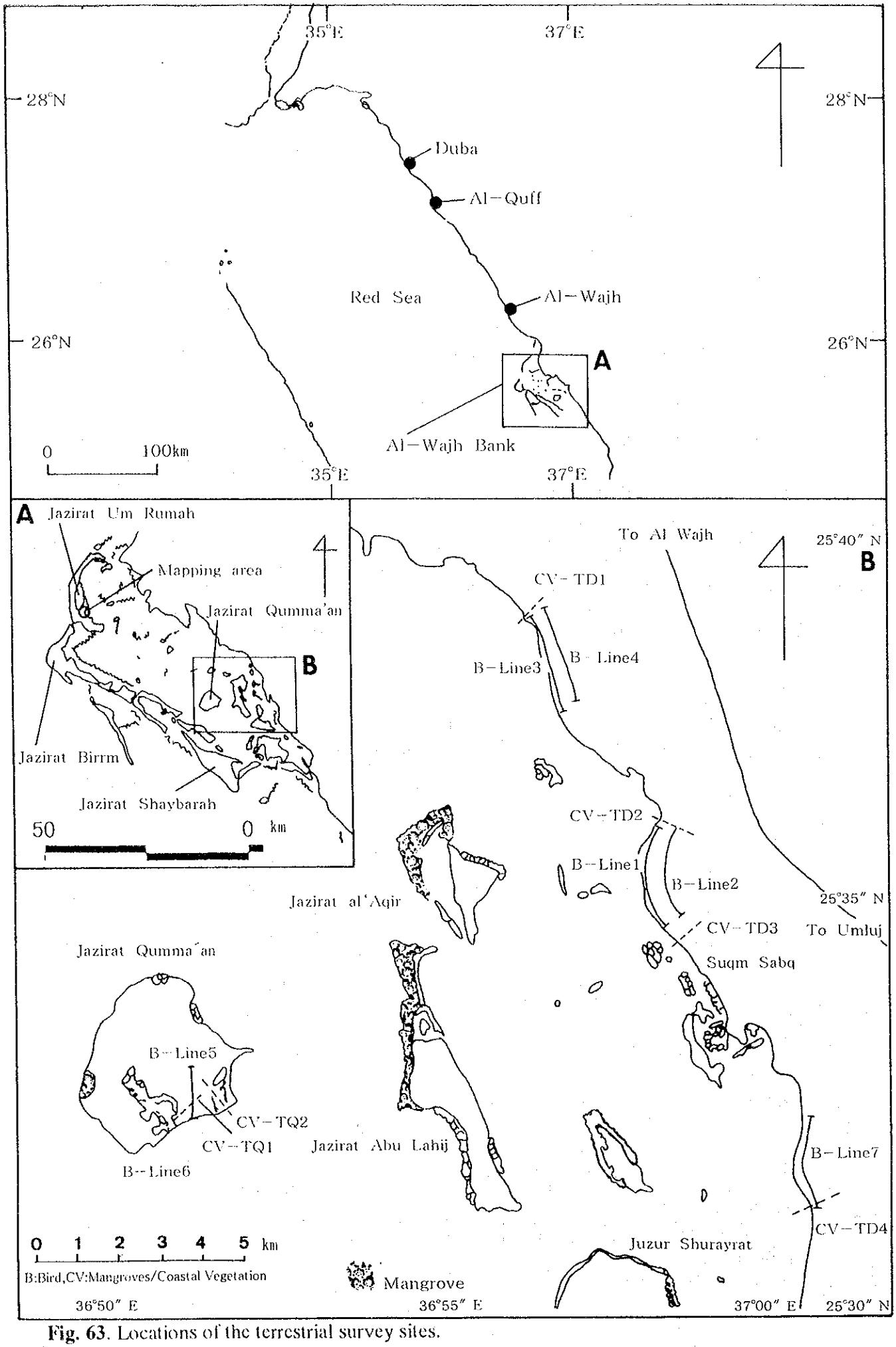


Fig. 63. Locations of the terrestrial survey sites.

2. Soil survey

2-1. Soil in mangrove areas

Soil characteristics are one of the most important environmental factors affecting mangrove productivity and structure (ENGLISH et al. 1997). In order to understand the relationship between mangrove vegetation and soil conditions, soil surveys were conducted in the same sites as of the tree census survey (Table 110). The soil surveys were conducted in summer because of the low tide. In winter, even when the tide is low, the soils are still under water. Items measured in the soil survey were Eh (redox potential), salinity, pH, temperature, soil colour, soil type and site drainage conditions. All these items were measured or recorded at each site.

At each quadrat site, three typical points were selected and dug to expose the soil profile. At each point, the soil conditions at depths of 10 cm and 40 cm were measured with least three replicates to stabilise the measured values. Eh was measured using a portable Eh meter (Takemura ORP-meter), inserting the electrode into the soil wall directly as soon as possible after digging. As for salinity and pH, soil water squeezed through gauze from the soil sample was measured at the sites, using a portable salinity meter (Sekisui SS-31A) or a refractometer, and a pH meter (Horiba Twin pH) respectively. Soil colour was identified according to standard soil colour charts.

2-2. Soil in salt marshes and desert vegetation

Soil in salt marshes and desert vegetation was also surveyed, using a different method from that used in mangrove, areas because, of the absence of the covering sea water. Soil samples at depths of 10 cm and 40 cm were collected in salt marshes and desert vegetation at the same sites as in the quadrat survey. The number of the sampling sites was 11, including two sites with no quadrat census survey (Table 110). After soil samples were transported to the field office in Al-Wajh, EC (electrical conductivity), salinity and pH were

measured in a soil / water suspension. The suspension was prepared one hour before measurement after shaking a sample mixture of one part air-dried soil and five parts water (by volume) for 10 minutes. EC, salinity and pH were measured using a conductivity meter (Horiba Twin Cond) and the pH meter (Horiba Twin pH) respectively.

Further, air-dried soil samples were divided using sieves into the following four major particle size groups; gravel (greater than 2 mm), coarse sand (0.5 – 2 mm), fine sand (0.05 – 0.5 mm) and mud (silt and clay : less than 0.05 mm). After division, the proportion of the particles within the soil was calculated according to the weight of each particle group.

3. Mapping of vegetation

Detailed vegetation maps of two parts of the Model Area (around Duqm Sabq and Jazirat Qumma'an) including transect lines and the eastern part of Jazirat Umm Rumah and Al-Quff, were drawn using the aerial photographs and results of the field surveys. The purpose of making the maps is to understand the distribution of the vegetation including transect lines and to obtain accurate data on the distribution of *R. mucronata.*

In advance of the field survey, rough vegetation maps were prepared on the scale of 1:10,000. Dominant species were confirmed in the field survey and their boundaries were mapped. Basically, legends were decided according to the dominant species; however mangroves were divided not only by dominant species (*R. mucronata* and *Avicennia marina*) but also according to their height and density.