4. Sub-regions of Special Importance for MPA Management Planning

On a larger geographic scale, three sub-regions are of outstanding conservation importance:

Gulf of Aqaba. This is the northern-most extent of extensive reef growth in the Indian Ocean, and one of the northern-most in the world. Some parts of the area experience cool-water upwelling from the deep central parts of the Gulf of Aqaba. As such, it may be expected that the area would support marginal coral communities of low diversity. However, the area supports diverse coral communities of high species diversity, abundance and cover, and includes species rare or absent from other parts of the Red Sea (e.g. *Caulastrea tumida* MATTHAI (1928), *Cantharellus doerderleini* (VON MARENZELLER, 1907). In some areas, the reefs are very narrow, forming 'contours' some 10 – 30 m wide along the coast adjacent to steep coastal mountains (e.g. N of the town of Maqna). The reefs generally were in good condition at time of survey, with low levels of cover of dead corals and low levels of injury to coral species. Reefs of the sub-region rated highly in terms of replenishment (species diversity, abundance and coral cover), and in terms of biodiversity conservation, with high representation of species otherwise uncommon or rare in the study region. There was little to no local human impact in most areas other than some coastal littering, and the sub-region provides an excellent opportunity for future MPA management planning.

Tiran Area. The mainland and islands bordered by Ash Shaykh Humaydh in the west, Al-Khuraybah in the north-east and Duba in the south supports a wide range of reef types, including mainland fringing reefs, platform and reticulate patch reefs, island and mainland fringing reefs. There is great variety in the range of exposure of different reef types, and some reefs appear to be growing in marginal conditions of temperature and sediment. Indeed, further research in the region may prove crucial in understanding the environmental limits of reef growth and roles of acclimation – adaptation of corals in marginal habitats.

Several of the highest scoring sites, in terms of replenishment (species diversity, abundance and coral cover), and reservoirs of biodiversity (representation of species otherwise uncommon or rare in the study region, Table 19), were present in the Tiran area. These reefs may be important as 'stepping stones' for dispersal of reef species into and out of the Gulf of Aqaba and Red Sea proper. The area has a high level of ecological integrity, with little local human impact. These findings support the earlier listing of the area as an Environmentally-Sensitive Area by NCWCD-IUCN. Notably, protection has already been afforded to some parts of the area, in the restriction of fishing activities (O. AL-KHUSHAIM, pers. comm.), and nearby Egyptian reefs of Ra's Muhammed are included in a Marine Protected Area. Future consideration may be given toward locating a future MPA in the area to coincide with that of Ra's Muhammed.

Al-Wajh Bank. The Bank and adjacent coastline to the north and south support the greatest range of reef types and other marine and coastal habitats in the study region. Reef types include those developed in open and closed Sharms, mainland fringing reefs, patch reefs, island fringing reefs and barrier reefs. The area has a high level of ecological integrity, with some local human impact from reef fishing and littering. Reefs rated very highly in terms of species diversity, abundance and coral cover, and in terms of representation of species otherwise uncommon or rare in the study region. This area supports most of the endemic species reported from the Red Sea and many of the undescribed species. These findings support the earlier listing of the area as an Environmentally-Sensitive Area by NCWCD-IUCN.

Its size, density and diversity of reef habitats, and likely high level of ecological 'connectedness' in terms of dispersal in ocean currents (both within the Bank and to other parts of the Red Sea), provide it with high priority in terms of conservation and future MPA designation and management planning. For these and other reasons the Al-Walh Bank was selected as the location for the Phase III (Model Sudy).

The other sub-regions, Duba - Al-Wajh, Umluj - Yanbu', Yanbu' - Rabigh, also supported reefs of high conservation significance.

Duba - Al-Wajh

This sub-region supported a variety of reef types, including mainland and island fringing reefs, fringing reefs developed in sharms, patch and barrier reefs. Apart from the towns of Duba and Al-Wajh and some smaller villages, the sub-region has little human habitation. Most of the survey reefs were in good condition, with little sign of local human impact or other disturbances. Of particular note was the fringing reef surrounding Jazirat Al-Naman to the S of Duba, and the series of coastal sharms - notably Sharm Jazzah. Within < 1 km distance, coral communities of this open sharm are subjected a wide range of physical exposures, with high wave energy habitats and associated assemblages on the outer edges and highly sheltered habitats and assemblages on the inner margin. Coral communities in this Sharm rated highly in terms of conservation of biodiversity (Table 18), and the surrounding coastal area (as with much of the entire region) is composed of highly preserved examples of geologically-uplifted fossil reef terraces.

Individual sites of special conservation value included:

- high coral cover - C24b (Marsa Hawwaz), C37b (Sharm Jazzah),
- high coral diversity - C34a (Jazirat Al-Naman), C37a (Sharm Jazzah),
- communities with uncommon and rare species - C37a (Sharm Jazzah).

Umluj – Yanbu'

Of particular note was the reef complex surrounding Jabal Hassan and patch reefs to the north (S of Al-Wajh Bank). Reefs in Sharm Al Hisay also scored highly on several conservation criteria, as did reefs subjected to coastal upwelling around Ra's Baridi. The Ra's Baridi reefs may be naturally buffered against the worst effects of bleaching by the cool-water upwelling, and thus may be key sites for replenishment.

Individual sites of special conservation value included:

- high coral cover - C41b (Ra's Baridi), C47b (Jazirat Malihah)
- high coral diversity - C44a and C45b (Sharm Al Hisay)
- replenishment - C19b and C41b (Ra's Baridi), C44b and C46b (Sharm Al Hisay),
- undescribed species - C12a (Sharm Shabaan), C14b (Jabal Hassan)

Yanbu' - Rabigh

Previous studies have described rich coral communities developed on a wide range of reef types in the vicinity of Yanbu' (SHEPPARD & SHEPPARD 1985, 1991). Present condition of the reef complexes around Yanbu' are not known, as no surveys were conducted there. However anecdotal reports by local divers described coral bleaching in the area, similar to the situation on reefs further south around Rabigh which had been badly affected by bleaching in the summer of 1998. Recovery of these reefs should be a high priority for future monitoring studies.

Individual sites of special conservation value included:

- high coral cover - C40a (Sharm Ar Rayis)
- high coral diversity - C40a (Sharm Ar Rayis)
- replenishment - C40b (Sharm Ar Rayis)
- communities with uncommon and rare species - C16b (Sharm Abu-Aduli).

5. Criteria for selection of Marine Protected Areas

The preceding analyses have identified key reefs and sub-regions for conservation, based on a range of criteria deemed important in the selection and design of marine protected areas (MPAs), including:

- conservation of 'high quality' examples of representative habitat-community types,
- conservation of representative species, including endemic, rare and endangered taxa,
- conservation of unique or special areas, habitats or species,
- conservation of sites likely to be important as reservoirs of biodiversity and replenishment.

Future planning of MPAs in the region should also give consideration to:

- the relation between proposed MPA boundaries and the full distribution ranges of endemic, rare and globally endangered taxa,
- the relation between population sizes of endemic, rare and globally endangered taxa within the proposed MPA and total population sizes,
- the relation between proposed MPA size and dispersal patterns for replenishment and future viability of populations of endemic, rare and globally endangered taxa,
- oceanographic currents, for maintenance and replenishment of populations, and restocking of harvested species,
- traditional, present and future human-use patterns,
- levels of 'ecologically sustainable development',
- operational budget, staffing requirements, public perceptions and degree of support.

Considerations of geographic and ecological scale

In the case of small MPAs, the proclaimed areas usually are managed in a similar manner to terrestrial 'National Parks' with no extractive or exploitative human usage, other than 'tourism' visitation rights. Within large MPAs by contrast, different areas may be allocated to different levels ('zones') of protection and use. This 'multiple-use' approach, as adopted in Saudi Arabia (CHILD & GRAINGER 1990), attempts to balance the need for protection of species and habitats with traditional and recent human uses of the areas. Traditional uses in the central-northern Red Sea include various forms of artisinal fishing and collecting whereas recent uses include commercial fisheries, small-scale tourism, port activities, desalination projects and land reclamation.

Specific recommendations regarding the sizes and boundaries of future MPAs, and related zoning plans, are beyond the scope of the present report. However, it is worth reiterating several important points for future consideration:

- the large size of the region, covering some 10,000 km^2,
- the near-continuous nature of the reef tract on the central-northern Red Sea coast of Saudi Arabia,
- the generally high ecological integrity of most reefs in the region,
- the generally low level of local human impact,
- the high level of homogeneity in terms of species composition within the region,
- the likelyhood of different levels of oceanographic and biological connectivity within the reef-tract (e.g. possibility of partial isolation of the Gulf of Aqaba).

Based on the above points, consideration may be given by NCWCD to declaring the entire region or several large sub-regions as multiple-use Marine Protected Area(s), rather than establishing many small MPAs (e.g. Table 5). In the former approach of one or several large MPAs, individual reefs and reef-complexes would be allocated to the various zones (CHILD & GRAINGER 1990), affording them different levels of protection and use. Based on the recommended zoning system of NCWCD-IUCN, reefs of high conservation value identified in the preceding analyses could be declared as Special Nature Reserves or Biological Reserves, within large multiple-use MPAs.

This approach would result in further amalgamation of the ~ 20 Environmentally-Sensitive Areas already identified by NCWCD (Table 5). Such an approach may have advantages in terms of development of management plans and staffing structure. This approach has been applied successfully in the Great Barrier Reef Marine Park (GBRMP), Australia, which covers some 350,000 km^2 and ~2,900 individual reefs. In the case of the GBRMP, one federal (Australian Commonwealth Government) management agency, the GBRMP Authority, is responsible for all management decisions (analogous to the role of NCWCD in Saudi Arabia), whilst day-to-day surveillance and enforcement of the GBRMP are conducted by the State (Queensland Government) Department of Environment and Heritage. A large portion of the funds for management and research in the GBRMP is generated by a 'user-pays' system. With expanding tourism opportunities and continuing reef fisheries in the present study region, such a system may prove useful in the future development of MPAs in the Red Sea. It may prove useful for key NCWCD personnel to liase with the GBRMP Authority on these matters.

6. Recommendations for future monitoring

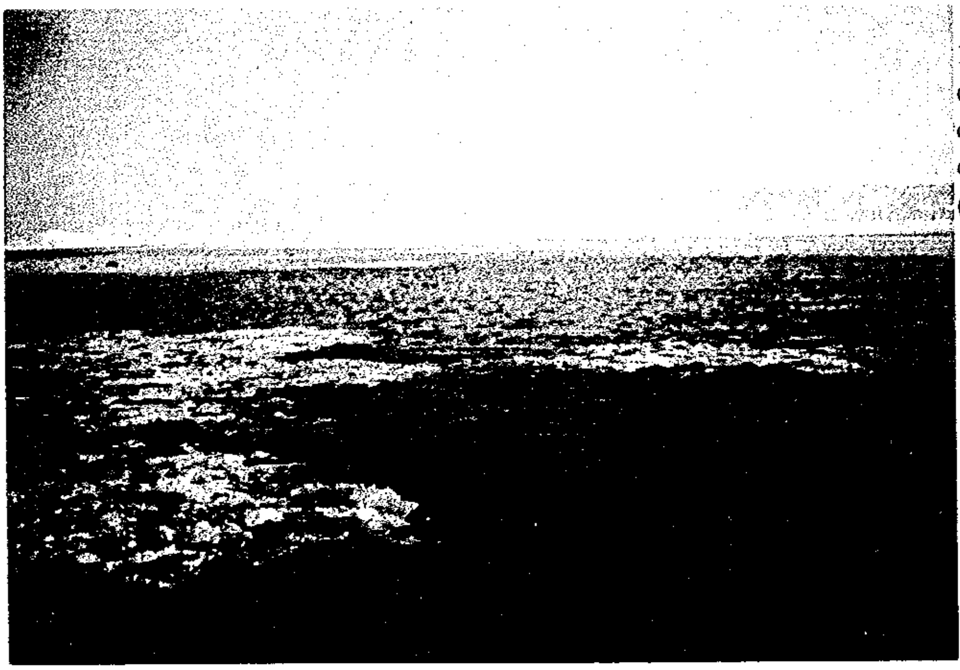
It is recommended that NCWCD develop a dedicated coral reef monitoring program. The scale of the reef tracts both in the Red Sea and Arabian Gulf are such that an adequate monitoring program would require a minimum of four dedicated full time personnel. Various monitoring programs, most linked with GCRMN, already exist in many Indo-Pacific countries, and consideration should be given by NCWCD to the Kingdom of Saudi Arabia (through NCWCD) becoming a member of both GCRMN and Reef Check. This would facilitate the continued development of coral reef research and monitoring within the Kingdom, essential adjuncts to future MPA management.

7. Recommendations for further research

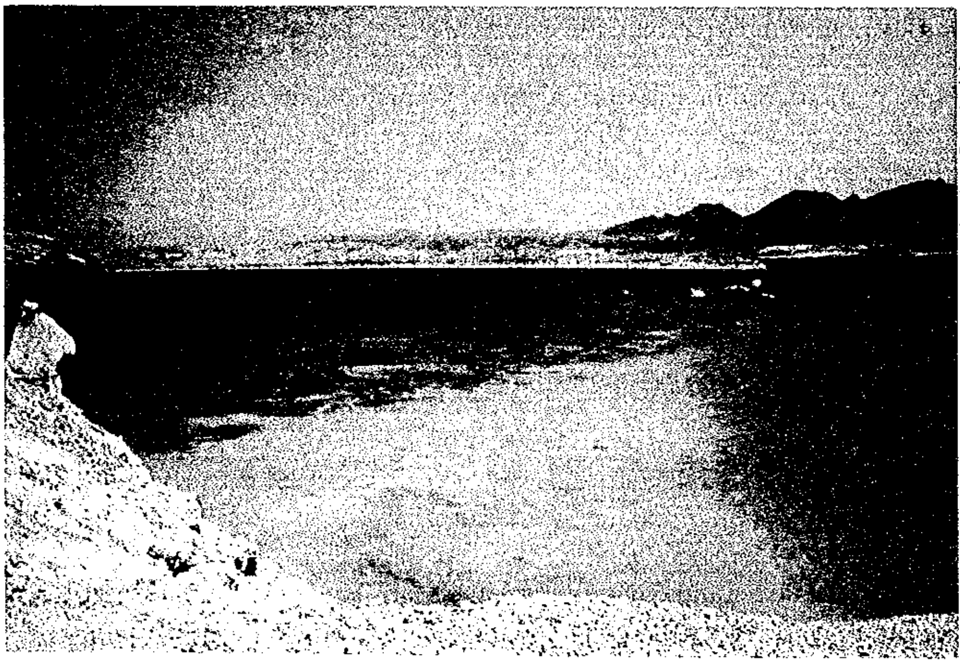
The present study has identified sites and sub-regions of special importance in terms of coral communities in the study region. However, large gaps remain in the understanding of these communities, particularly in relation to future management. Additional studies that would be useful for management include:

- Coral reproduction – timing,
- oceanographic connectivity within the region, in terms of determining likely 'source – sink' dispersal relationships for maintenance and replenishment of populations,
- coral recruitment and growth rates,
- recovery of coral cover and community structure following disturbance,
- genetics – linkages with other areas.

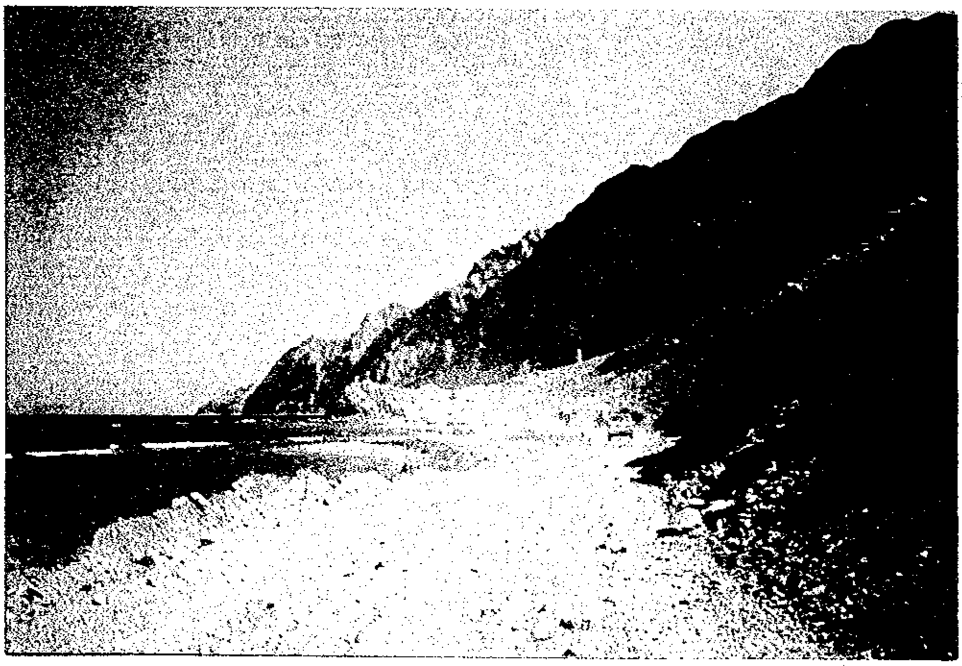
Photo. 1-1. Coral



1. Small patch reefs developed in sheltered conditions inside a coastal embayment (sharm).

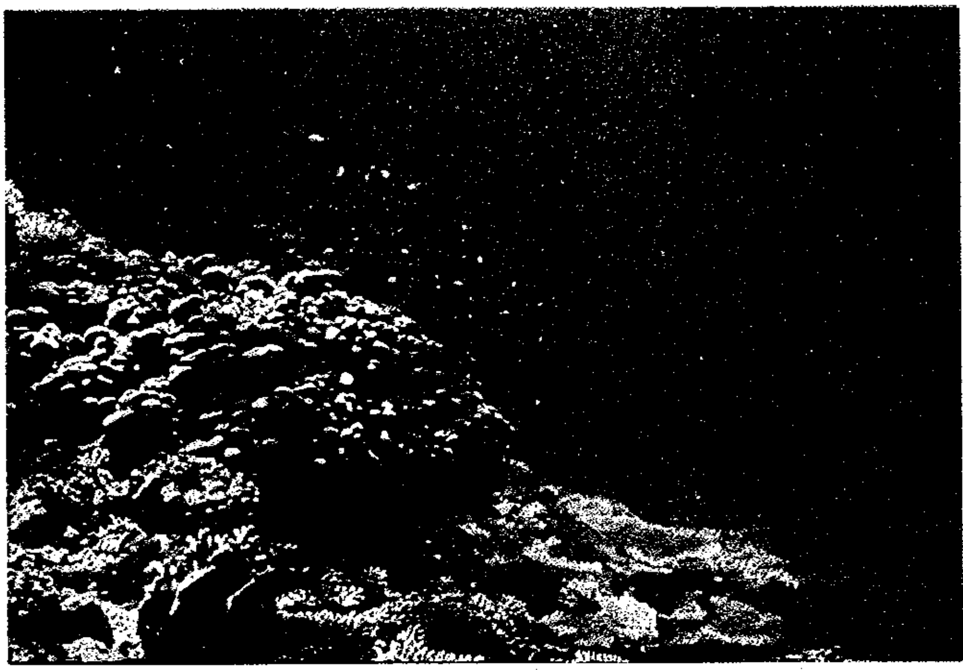


2. Fringing reef closing the entrance to a coastal sharm. Low species richness and coral cover characterize coral communities inside such closed sharms.

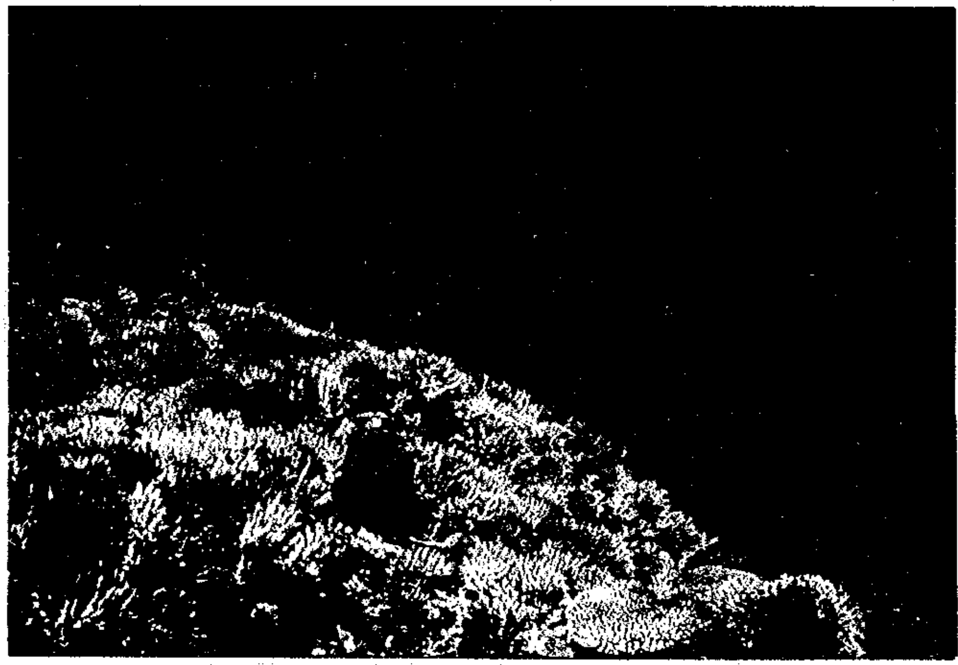


3. Narrow 'contour' reefs developed adjacent to coastal mountains in the Gulf of Aqabah.

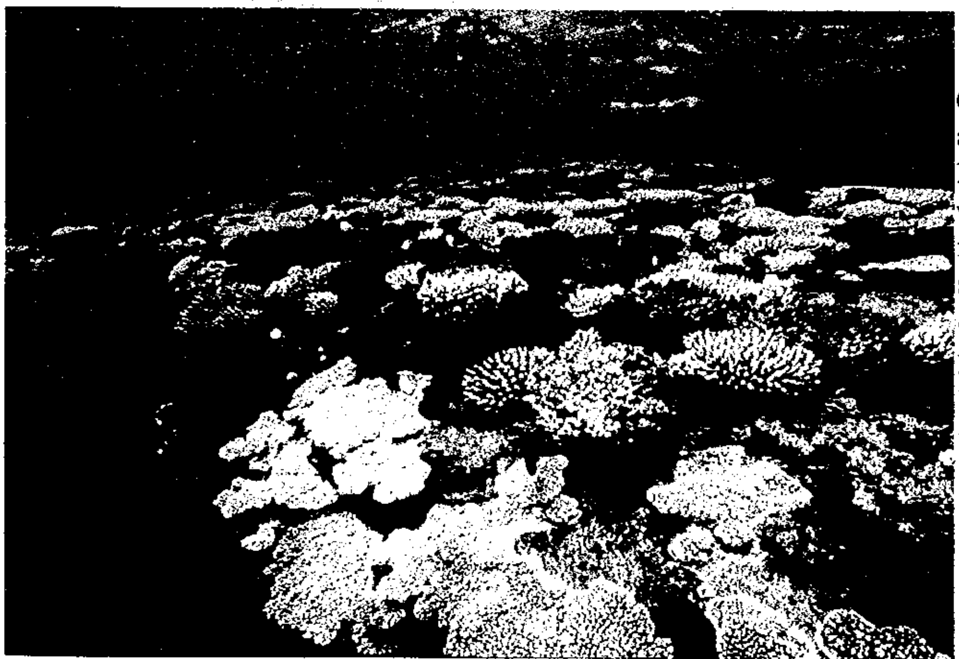
Photo. 1-2. Coral



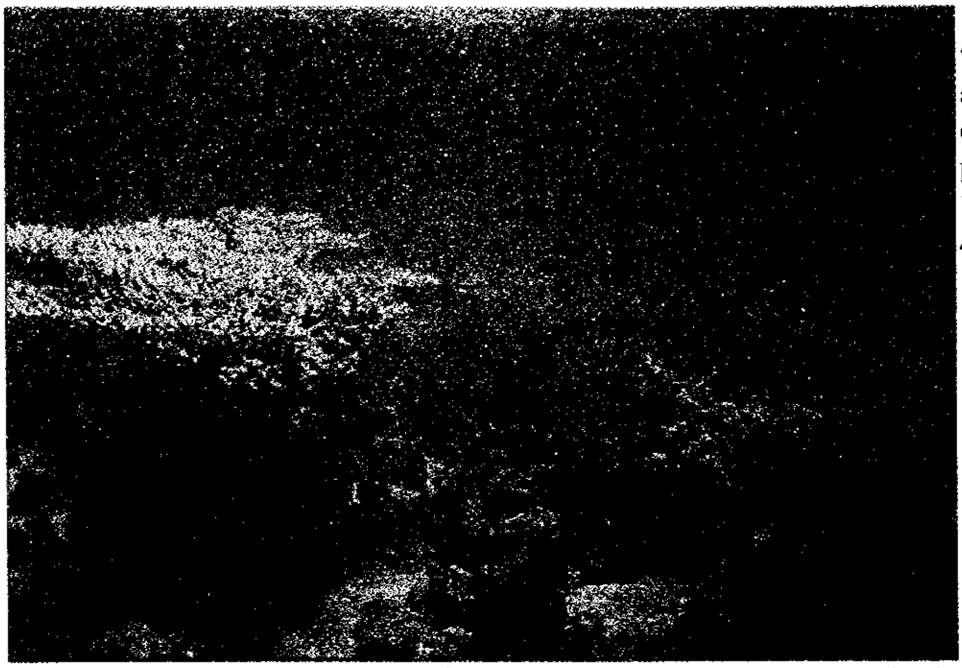
4.Coral community of a shallow reef slope exposed to strong wave energy, composed predominantly of massive ***Favia stelligera***, and digitate – stout branching and tabular species of Acropora.



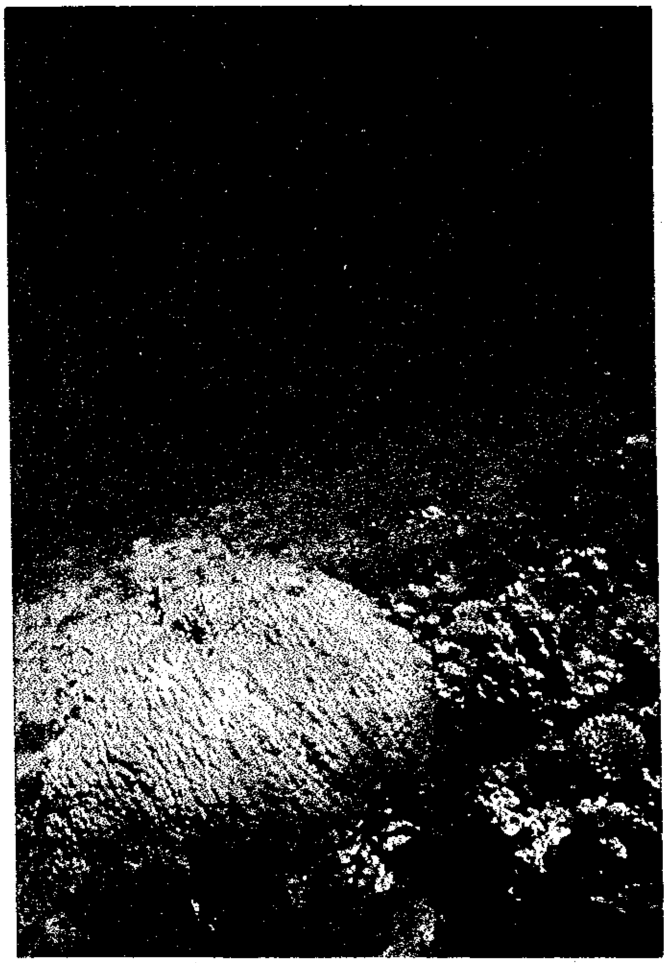
5. Coral community of a shallow reef slope exposed to moderate wave energy, composed predominantly of staghorn species of ***Acropora***.



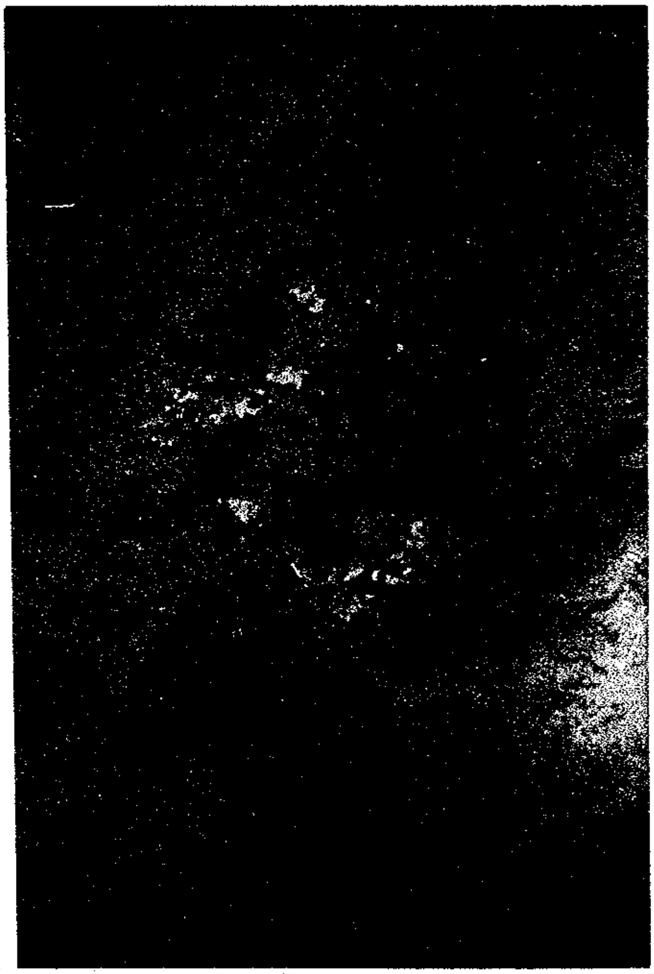
6. Coral bleaching on a shallow reef slope. Bleaching, the whitening of corals following expulsion of symbiotic micro-algae (zooxanthellae) and pigments, is a response to physiological stress, often caused by elevated sea temperatures.



7. Coral community of a sheltered reef slope, composed predominantly of large 'tree-like' colonies of *Acropora pharaonis*.



8. Coral community of a sheltered deep reef slope, composed predominantly of foliaceous species of ***Mycedium***, ***Echinopora*** and ***Leptoseris***.



9. Large massive species of ***Porites*** are characteristic components of sheltered Red Sea coral communities.

2.1.3. SEAGRASSES / ALGAE

2.1.3.1. Introduction

The transparency of waters in the Red Sea is very high owing to low precipitation and consequent low impacts from the land area. This makes it possible for seagrasses and algae to grow even in deep water. LIPKIN (1979) found the distribution of two species of seagrass, *Halophila stipulacea* and *Thalassodendron ciliatum* at depths of 70 m and 40 m respectively, though algae have not been reported in deep water.

Climatic and oceanographical conditions in the Red Sea in one of the hottest regions of the world put severe stresses on intertidal and shallow sublittoral biological communities (JONES et al., 1987). The strong sunshine heats up the surface water. It is difficult to imagine that the coastal shallow water with high temperature rapidly exchanges with cool offshore water . This is because the waves along the Red Sea coast of Saudi Arabia are low throughout the year and they seem not to generate strong currents on the reef flats in general. Thus, seagrasses and algae, a principal components of the intertidal and shallow sublittoral communities, are exposed to the severe physical environment, though the physical condition varies in places, such as wave action, current, turbidity of water and bottom sediment, since coral reefs have a wide variety of configuration of the physical features of habitats. This unique environment in the Red Sea has an effect on species diversity and biomass.

Besides the physical impact, seagrasses and algae receive the influence of grazing by herbivores which enter the seagrass/algal habitats mainly from offshore open areas. Breaking wave areas where wave action keeps them away are the exception. Significant seagrass grazers in the Red Sea are Dugong and Green Turtle (JONES et al. 1987), together with many herbivorous fishes.

Some authors have reported 11 species of seagrasses from the Red Sea (Table 20). A species list of seagrasses in the Indian Ocean (DEN HARTOG, 1970) shows that there is basically the same flora in the Indian Ocean and the Red Sea. PRICE et al. (1988) reported that *Halodule uninervis, Thalassia hemprichii, Cymodocea* spp. and *Enhalus acoroides* showed a significant increase in abundance towards the southern Red Sea, and conversely the abundance of *Halophila stipulacea, Syringodium isoetifolium* and *Thalassodendron ciliatum* increased significantly towards the northern Red Sea, the present Study Area.

Table 20. Seagrass species in the Red Sea reported in the available references.

Order	Family	Species	References
Helobiae	Hydrocharitaceae	*Enhalus acoroides*	LIPKIN (1975, 1977)
		Halophila decipiens	JACOB & DICK (1985)
		H. ovalis	LIPKIN (1975, 1977), MIGAHID (1989)
		H. ovata	ALEEM (1979)
		H. stiplacea	LIPKIN (1975, 1977), MIGAHID (1989)
		Thalassia hemprichii	LIPKIN (1975, 1977), MIGAHID (1989)
	Cymodoceaceae	*Cymodocea rotundata*	LIPKIN (1975, 1977), MIGAHID (1989)
		C. serrulata	LIPKIN (1975, 1977), MIGAHID (1989)
		Halodule uninervis	LIPKIN (1975, 1977)
		Syringodium isoetifolium	LIPKIN (1975, 1977)
		Thalassiodendron ciliatum	LIPKIN (1975, 1977), MIGAHID (1989)

Many seagrass species in the Red Sea have wide intraspecies variation in morphology due to severe stresses in the intertidal and shallow sublittotal zone. The common Red Sea species, *Halophila stipulacea*, has larger (120 mm by 10 mm), has greener leaves in the dimly-lit deeper water than in shallow water, where leaves may be only 30 mm by 5 mm (LIPKIN 1977, HULINGS 1979). Similarly, the leaves of *Halodule uninervis* in the shallow water are generally 0.5-1 mm in width but those in the deeper water are up to 3 mm wide and tend also to be longer (JONES et al. 1987). This indicates that light is probably the prime regulating factor on leaf form in this species (LIPKIN 1977).

The Study on algae in the Red Sea has a long history. It has been known that, in general, the algal species of the Red Sea belong to the circumtropical and subtropical marine flora occurring in the Indo-Pacific as well as the Mediterranean and Caribbean Seas (WALKER 1987). Some expeditions in the 19th century established a foundation of knowledge on the distribution of Red Sea algae. It helped PAPENFUSS (1968) to record 485 species of algae from the Red Sea, based on collected specimen from the entire Red Sea.

SILVA et al. (1996) published a catalogue of algae in the Indian Ocean including the Red Sea. They re-analysed the taxonomy of algae and pointed out many synonyms. Their suggestions are important and require special attention to identifying the species of algae to prepare a correct inventory which gives basic information for an appropriate environmental management.

2.1.3.2. Methods

The fieldwork was carried out during 31 May to 6 July and 27 September to 14 November 1998, covering 197 survey spots. At all survey spots, their positions were determined using a portable GPS (Appendix 7).

Surveys were conducted by snorkelling in the intertidal zone and by SCUBA diving in the subtidal zone, employing the quadrat method. At least two dried specimens of the collected samples for each species were made. The coverage of seagrasses and algal species were observed at each spot.

2.1.3.3. Results

The Study recorded 188 taxa in total; eight Seagrasses, 68 Chlorophyta, 30 Paeophyta and 82 Rhodophyta (Separate Volume 1). They include 11 species of algae reported newly to the Red Sea, that is, *Dudresnaya hawaiiensis*, *Gibsmithia hawaiiensis*, *Hypnea nidulans*, *Stypopodium hawaiiensis*, *Microdictyon japonicum*, *Caulerpa taxifolia*, *Prionitis* sp., *Acrosorium* sp., *Gelidiopsis* sp., one species of Kallymeniaceae, and one species of Rhodymeniaceae.

Geographical distribution of species number is summarised in Table 21. The fact that survey efforts were not paid evenly to six sub-areas seemed to have affected the species number of the relatively wide range observed in the sub-areas. Intensively studied sub-area revealed a large number of species.

Diving observation found key locations which showed high species diversity of seagrass or algae. Algae diversified their flora at patch reefs and fringing reefs where the rough wave action interfered with invasion of herbivorous fish. Many seagrass species occurred in inlets with an appropriate water movement which prevented the accumulation of silt particles. The species number in the Tiran area or Al-Wajh Bank where the number of spots was small would increase if such key locations had been surveyed more.

Table 21. Species number of seagrasses and algae.

	The Gulf of Aqaba	**Tiran**	**Duba / Al-Wajh**	**Al-Wajh Bank**	**Umluj/ Ra's al-Bardi**	**Yanbu'/ Jeddah**
No. of Site	3	2	7	5	6	4
No. of Spot	39	12	51	37	30	28
Seagrass species	4	2	7	5	7	5
Algae species	75	48	130	77	60	78

In general, the seagrass beds occured in the inner part of fringing reefs, lagoons in inner reefs, sharms and inlets. *Thalassodendron ciliatum* and *Halophila stiplacea* were common in the subtidal zone, and they made extensive seagrass beds. *Halodule uninervis* was common in the intertidal zone. *Syringodium isoetifolium* and *Talassia hemprichii* had bite marks due to grazing by Green Turtles.

Distribution pattern of the algal community is described briefly as follows.

Macro algal beds of *Sargassum* and *Cystoceira* developed in the southern part of the

Study Area. *Sargassum* were distributed on the reef flat which generated overtopping waves. *Cystoceira* grew on the shallow bottom within the reef flat. A lot of turf and small algae thrive on the reef edge. On the reef slope, the algal community was not abundant.

In the southern Al-Wajh Bank, there was found an aggregate of drifted algae, *Sargassum* sp. on the shallow sandy bottom, covering an area of several hectares. The water temperature within the aggregate was 24.5°C and it was 5°C lower than the surrounding water.

The algal flora of various habitats is summarized below.

— Reef slope

- Algal coverage was less than 5%.
- Number of algal species was 75.
- Seven newly recorded algal species for the Red Sea were found.
- Representative algal species were red algae, *Actinotrichia fragilis* and *Galaxaura obtusata*, brown algae, *Lobophora variegata* and green algae, *Codium arabicum*.

— Reef edge

- There was found the most diversified flora with high algal coverage.
- Number of algal species was 78.
- Six newly recorded algal species for the Red Sea were found.
- Representative species were red algae, *Rhodymenia* sp., *Laurencia intricata* and *Polyshiphonia* spp. and brown algae, *Sphacelaria* spp..

— Reef flat

- Crustose coralline algae dominated the area of low current velocity in the offshore area. Other principal species were red algae, *Rhodymenia* sp. and *Martensia elegans*, and brown algae, *Sphacelaria* spp.
- In the nearshore area, small algae dominated the area where current flow is slow,

while macro algae were common in the areas which received the flow generated by breaking water.

- Number of algal species reached 100.
- Offshore hard substrate on which algae might be able to grow had already been occupied by coral.
- *Sargassum* beds developed under a condition of rapid current flow on the reef flat.
- Cyanophcea covered the silty bottom.

— Reef patch

- Number of algal species reached 95.
- Representative species were red algae, *Dasya* sp. and brown algae, *Dictyota* sp., *Sargassum* sp. and *Turbinaria elatensis* and green algae, *Caulerpa lentillifera.*
- Submerged reef patches had poor flora. Emerged reef patches with rapid current flow have richer flora.
- Macro algae, *Turbinaria* and *Sargassum* formed beds in Al-Wajh Bank and off Masturah respectively.

— Sand bottom

- There were three species which utilized the seagrass bed, *Thalassodendron ciliatum,* as their substratum. Those were *Galaxaura* sp., *Rosenvingea intricata* and *Liagora* sp.
- A species of small green algae, *Halimeda cylindracea,* formed a colony on the sandy bottom in tide pools at the mouth of the Gulf of Aqaba and the coast of Rabigh.
- Three drifted *Sargassum* beds were observed in the adjacent area of Jazirat Suwayhil, southern part of Al-Wajh Bank.

2.1.3.4. Discussion

1. Seagrasses

In the Study Area, species composition of seagrasses showed little geographical difference. *Halodule uninervis* and *Halophila ovalis* were the principal species within the barrier reef, and occurred even in tide pools and shallow lagoons where they experienced the extremely high water temperature. *Syringodium isoetifolium, Cymodocea rotundata, C. serrata* and *Thalassia hemprichii* had smaller distribution areas in the north than in the south of the Study Area, presumably due to the lower water temperature. Some sharms and inlets provided many seagrass species with a suitable environment, if the water movement there is enough to sweep silt particles away. The open shore nourished *Thalassodendron ciliatum, Halophila ovalis* and *Cymodocea serrata.*

Though in the southern part of Al-Wajh Bank there was found only one species of seagrass, it was obvious through the aerial observation that there were many key locations for growth of many seagrass species in that area. The condition for a key location for seagrass is water movement which removes silt from bottom sediment and leaf surface. These locations were found in tidal pools, lagoons, sharms, inlets and the inner part of fringing reefs, which are most abundant in the southern part of Al-Wajh Bank, judging from the aerial photographs. Therefore, Al-Wajh Bank was recognised as an important candidate area for the Model Study.

2. Macro algae

Macro algae showed the geographical difference in formation of beds in the entire Study Area, though the entire algal flora did not differ in six sub-areas either. Macro algal beds developed more extensively in the southern half of the Study Area than in the northern half. In the southern area, reef flats extend widely, offering a large substrate for algae. Many reef patches provide macro algae with a suitable habitat which has strong current flow originated from waves and prevents herbivorous fish from invading the areas.

3. Water conditions and marine flora

Reef edges also break the waves and generate strong current flow behind them. Thus, as illustrated in Fig. 22, algal communities developed in the reef edges, as well as in reef patch areas. Although reef slopes are found next to the areas, they have already been utilised by coral and there is little room for algae to thrive.

In the Red Sea, the wind is generally so gentle that herbivorous fishes invade the reef flat area. This causes a low coverage of algae and dominance of hard crustose coralline algae on reef flats. The Study found that a principal factor for growth of rich seagrass/algal flora is the micro-scale topography of the sea bottom, which regulates the water movement. For seagrass communities, wave and current flow play an important role to eliminate silt particles from the bottom and the leaves. Sharms and inlets were typical areas providing such a condition. It also functioned for algal communities to keep herbivorous fish away from reef patches and reef edges.

Another key for the development of algal flora seems to be a cold water mass as observed in the southern Al-Wajh Bank. The low water temperature may be brought about by the evaporation heat from the aggregate of drifting *Sargassum*. This phenomenon may be specific to shallow areas in the Red Sea where precipitation is very low. In such a cold water mass, herbivorous fishes were not observed, probably due to the barrier of the temperature.

For the selection of the Model Area, it was thought reasonable to choose an area which has many such key locations to study abundant and diversified seagrass/algal communities. The Tiran area and Al-Wajh Bank were selected from this point of view, based on the result of aerial topographycal analysis.

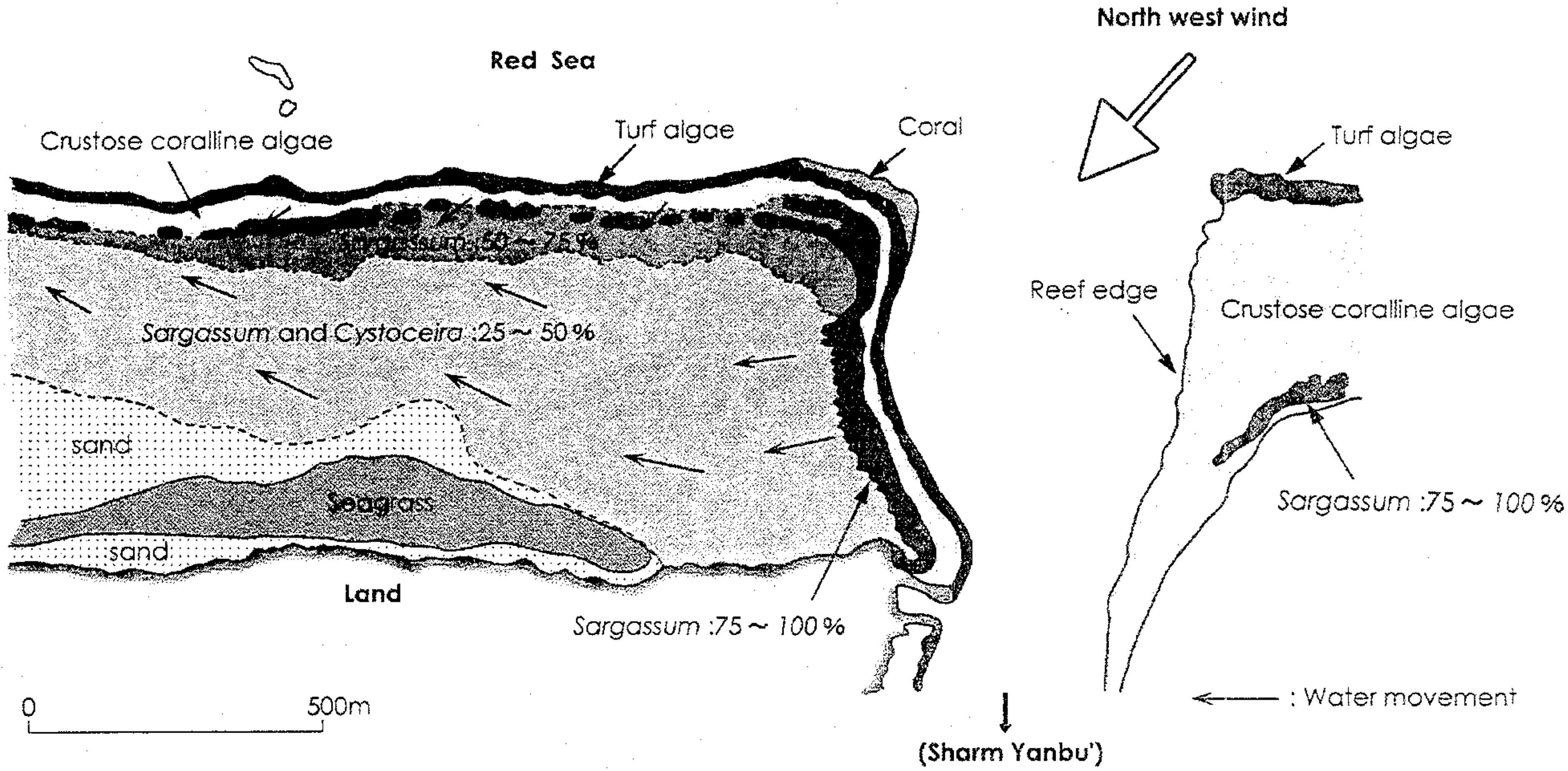


Fig. 22. Water conditions and marine flora.

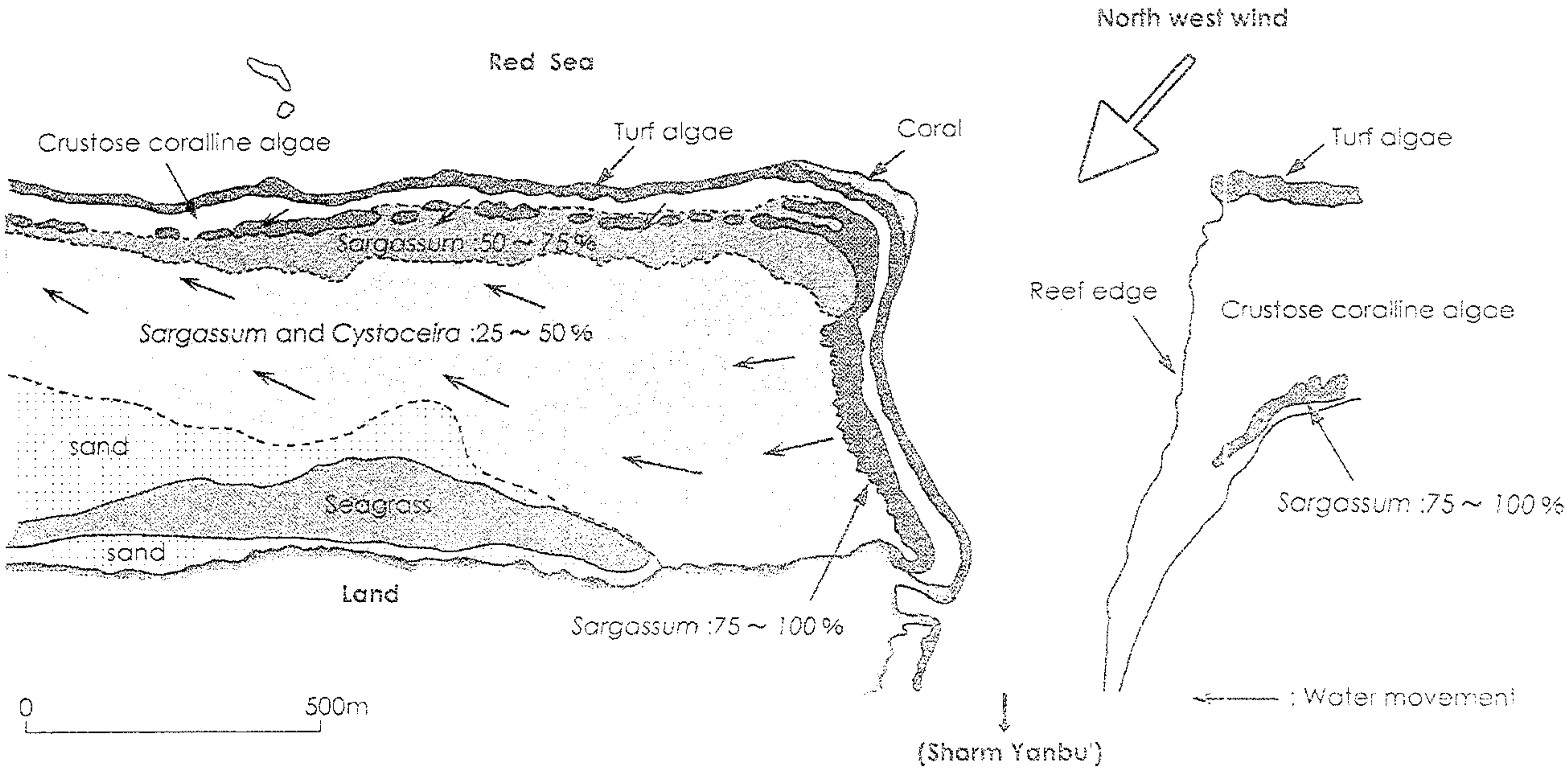
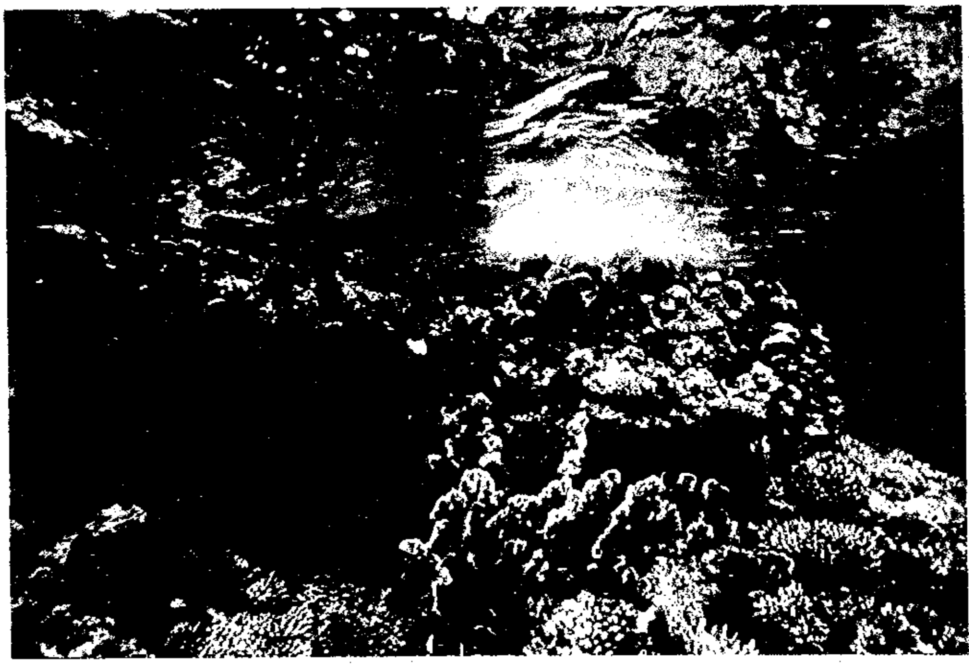


Fig. 22. Water conditions and marine flora.

Photo. 2-1. Seagrasses / Algae

1. Some algae grow on sand.

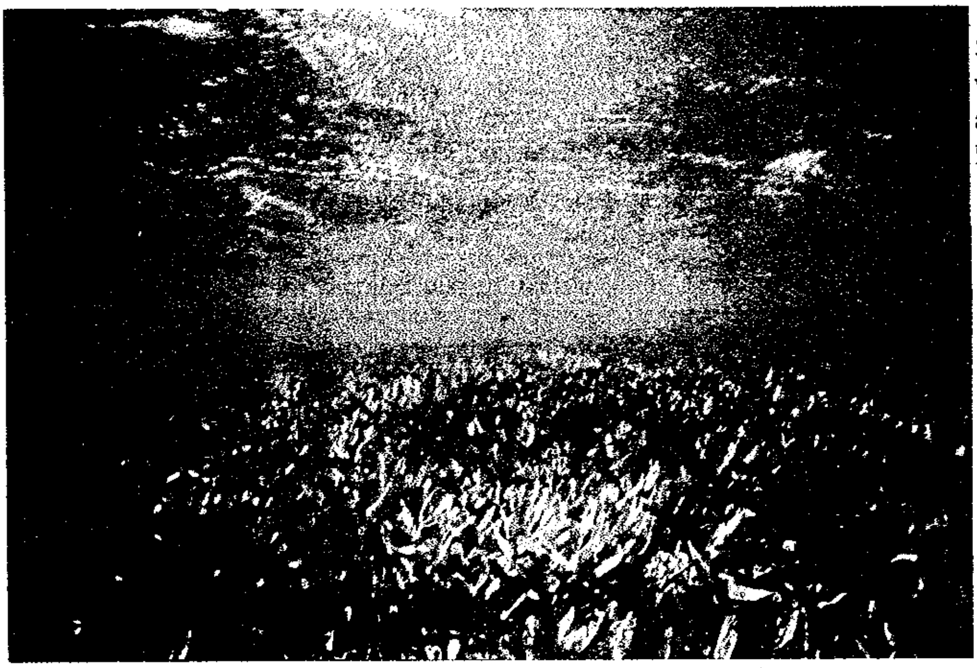
2. On a reef slope, some small algae often grow on recently dead corals.



3. Small and turf algae community is developed on an exposed reef edge.

Photo. 2-2. Seagrasses / Algae

4. Sargassum beds are sometimes developed on reef flats.



5. Seagrass beds are well developed on sand areas in a shallow lagoon or inner sharm.

2.1.4. FISHES

2.1.4.1. Introduction

The vast Indo-Pacific region stretches from the Red Sea and southern Africa to the islands of Polynesia, fully 2/3 of the way around the world. It contains the world's richest shorefish fauna, estimated at over 4,000 species in approximately 179 families. The Indian Ocean contains nearly all the families (162 families) and over half of the species of Indo-Pacific shorefishes (LIESKO & MYERS 1994).

The shorefish fauna of the Red Sea has been well studied and many scientists describe it as followings.

The Red Sea has a rich shorefish fauna of about 1,000 species, about 15% of which are endemic (LIESKO & MYERS 1994). It is known that the fishes of the Red Sea have much in common with those of the Indian Ocean, with its great tropical marine fauna stretching far into the vast Indo-Pacific (FOWLER 1956).

70% of the 508 species in 86 families are widespread in the tropical Indo-Pacific region and 17% of those species are found only in the Red Sea. About 30 species have invaded the Mediterranean and at least 5 presumed Mediterranean immigrant fish species have been found in the Red Sea since the opening of the Suez Canal (EDWARDS & HEAD 1987).

A Study on morphological differences between the fish fauna of the Red Sea and that of the Indian Ocean was made by KLUNZINGER (1870 and 71); 140 out of 520 (=27%) species seemed to be restricted to the Red Sea. MARSHALL (1952), who estimated that at least 10% of the Red Sea fish species are endemic, was the first scientist to discuss the phenomenon of endemism in the Red Sea fishes. (KLAUSEWITZ 1989)

Table 22 shows the rate of endemism suggested by different authors.

Table 22. Rate of endemism (KLAUSEWITZ 1989).

Family	Rate	Author
Branchiostegidae	25%	CLARK & BEN-TUVIA 1973
Labridae	14%	ORMOND & EDWARDS 1987
Pomacentridae	29%	ALLEN & RANDALL 1980
Pomacantidae	25%	AHL 1923
Chaetodontidae	50%	AHL 1923
Gobiidae	39%	GOREN 1979
Pseudochromidae	90%	LUBBOCK 1975, RANDALL 1983
Tripterygiidae	90%	CLARK 1979
All families	15%	CLARK & GOHAR 1953
	10%	RANDALL 1983
	17%	ORMOND & EDWARDS 1987

In this study, eight scientific documents were used to list the fishes in the Red Sea. These documents list a total of 127 families, 536 genera and 1354 species including 50 endemic species.

The Biological Inventory (Separate Volume 1) shows an inventory of the fish obtained from these documents. The taxonomical order of fish species and their scientific names are based on LIESKE & MYERS (1994), and NAKABO (1993) is used to refer to those fish names which are not shown in LIESKE & MYERS (1994).

2.1.4.2. Methods

The survey was basically undertaken through SCUBA and snorkel diving. The divers observed fish fauna for about 30 to 60 minutes at each spot. Survey depths were between 0 and 15 m below the water surface. Survey spots were selected in order to observe various habitats, such as seaward reef slope, patch reef and reef lagoon. The morphology of the survey spots is shown in Fig. 23.

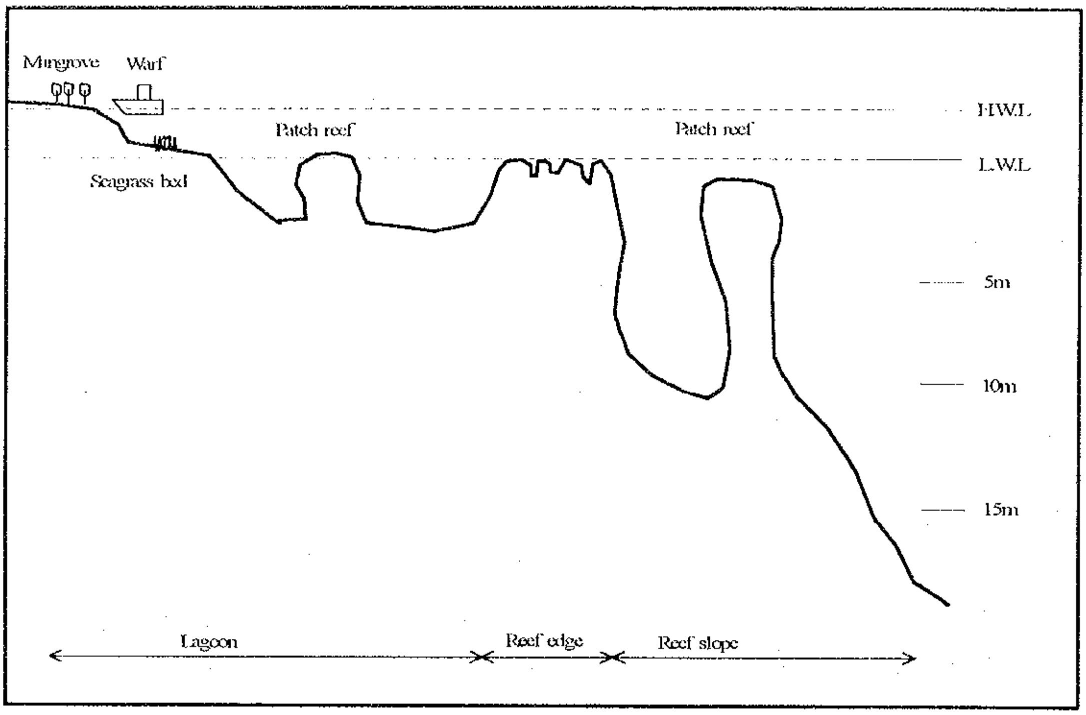


Fig 23. Topography of survey spot.

Species which were difficult to identify in the water were photographed using digital video cameras or digital still cameras, and were later identified in the laboratory. Sampling collections were also made whenever possible.

Gill nets, hand nets and throwing nets were used to collect samples. Angling was also undertaken for the same purpose. Samples were fixed with formalin-aqueous solution, and were identified in the laboratory.

2.1.4.3. Results

1. General description of the results

65 families, 175 genera and 378 species observed in the course of this field survey which was undertaken at 121 spots in 25 sites, are listed in the Fish Component of Volume II.

Locations of the survey spot, are shown in Appendix 8.

Table 23 shows a comparison of fish diversity between the Study Area and other coral areas in the world. Major taxa of fishes in the Red Sea are similar to those of the other coral sea areas in the world. The number of fish species is one of the highest in the world.

The number of fish species identified by the field surveys is less than half of the 127 families, 536 genera and 1354 species which have been previously reported. This is because the previous literature covers the entire Red Sea, and also because some of the nocturnal fishes might have been missed in this Study. LIESKE & MYERS (1996) have reported that 75% of the fishes are diurnal species and 10% live on or beneath sand, mud, or rubble.

Table 24 and Fig. 24 show the distribution of the top five families observed through the Study. The families Labridae (wrasses) and Pomacentridae (damsels) were observed at every site except for site 6 where only angling and hand net sampling were undertaken.

The five survey spots where the five biggest numbers of fish species were observed were F80 (114 spp.; Al-Quff, Site 7), F36 (91 spp.; Jazirat Muraykhah, Site 11), F78 (85 spp.; Ra's Shakh-humayd, Site 3), F71 (84spp.; Jazirat Murbat, Site 13) and F61 (72spp.; Khawr al-Majdha, Site 22).

The ten most frequently observed species are listed in Table 25 and are shown in Photo.3-1. These species were observed at every diving site. This may imply there is no strong locality effect on species distribution within the Study Area.

Table 23. Comparison of fish distribution worldwide.

Area	Place	Familes	Species	5 top families					Method
This Project		59	347	Labridae	Pomacentridae	Gobiidae	Apogonidae	Blenniidae	Observation,Collection
Red sea	Dahlak Arch.	40	128	Gobiidae	Blenniidae	Labridae	Pomacentridae	Scaridae	Observation
Okinawa	Sesoko Is.	80	597	Pomacentridae	Labridae	Gobiidae	Blenniidae	Chaetodontidae	Observation,Collectior
Australia	Great Barrier Ree:	46	323	Pomacentridae	Labridae	Chaetodontidae	Serranidae	Gobiidae	Blasting collection
Micronasia	Marshall Is.	56	233	Labridae	Pomacentridae	Muraenidae	Acanthuridae	Serranidae	Poison collection
Micronasia	Marshall Is.	34	178	Labridae	Pomacentridae	Chaetodontidae	Acanthuridae	Serranidae	Observation
Hawaii	Hawaii Is.	28	138	Labridae	Acanthuridae	Chaetodontidae	Pomacentridae	Holocentridae	Observation
Hawaii	Oahu Is.	35	112	Muraenidae	Labridae	Acanthuridae	Chaetodontidae	Mullidae	Poison collection
Polynesia	Thumotu Arch.	29	115	Labridae	Chaetodontidae	Gobiidae	Pomacentridae	Acanthuridae	Observation
Caribbean Sea	Virgin Is.	36	116	Serranidae	Pomacentridae	Scaridae	Haemulidae	Labridae	Observation

The source:Tetuo Kuwamura, 1987

Table 24. Composition of fish families.

Unit:Species

Family \ Site Nc	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Labridae	24	16	23	6	11	0	25	15	14	12	13	16	20	6	9	16	10	18	10	10	1	11	6	11	13
Pomacentridae	16	13	16	12	12	0	17	15	9	13	13	18	14	12	8	13	8	13	11	4	6	9	10	16	12
Gobiidae	1	1	2	4	0	0	7	1	1	4	3	4	9	6	11	5	3	5	3	2	2	6	1	7	5
Apogonidae	2	4	7	1	0	0	3	1	0	4	2	3	5	0	2	5	5	2	3	0	3	0	0	3	1
Blenniidae	4	2	5	3	2	3	7	2	2	7	2	3	7	2	5	4	1	5	3	3	2	4	0	5	4
Others	55	50	59	38	44	2	82	46	35	91	60	48	69	22	38	51	44	56	33	43	26	42	25	60	34
Total	102	86	112	64	69	5	141	80	61	131	93	92	124	48	73	94	71	99	63	62	40	72	42	102	69

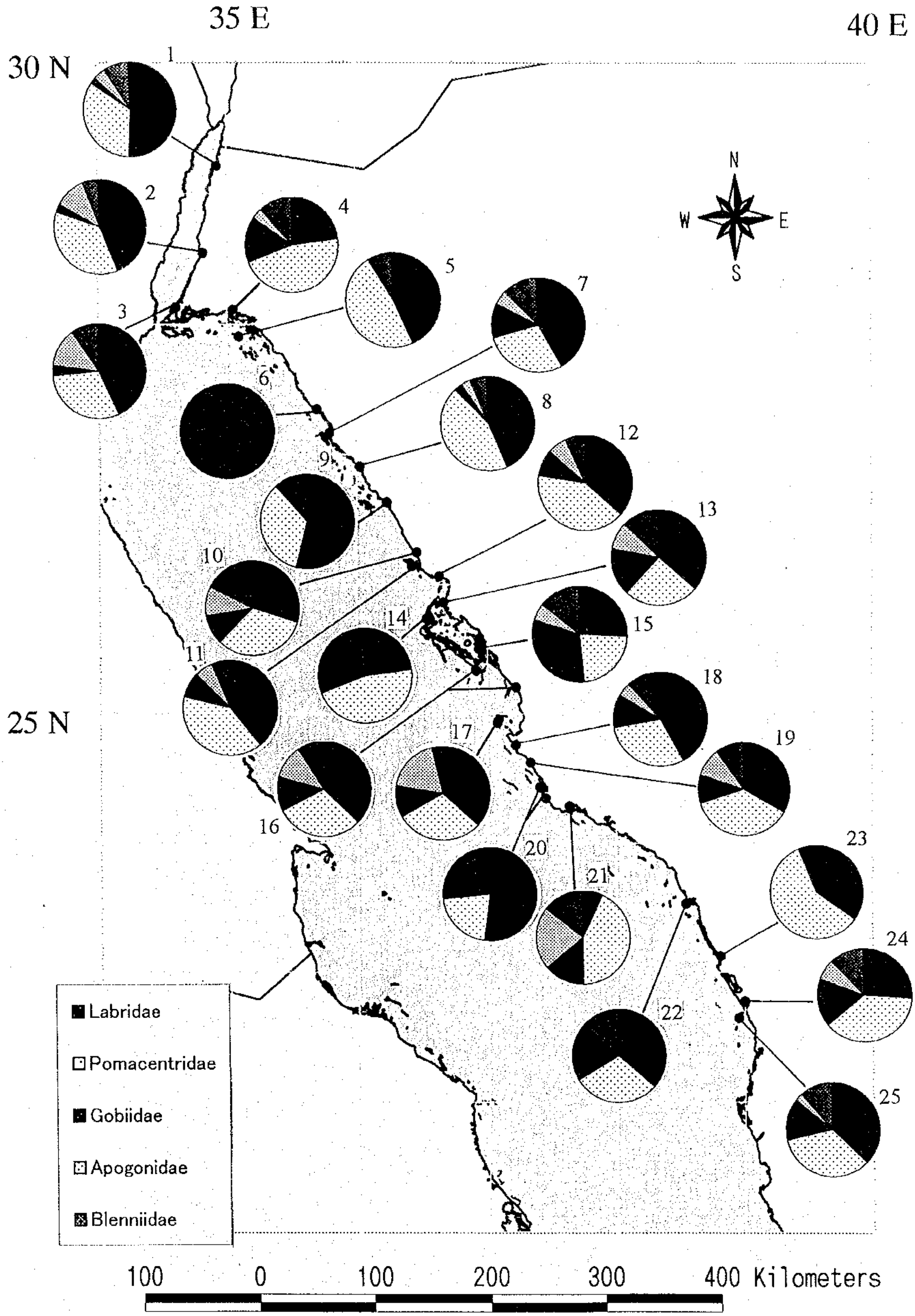


Fig. 24. Distribution of the top five families.

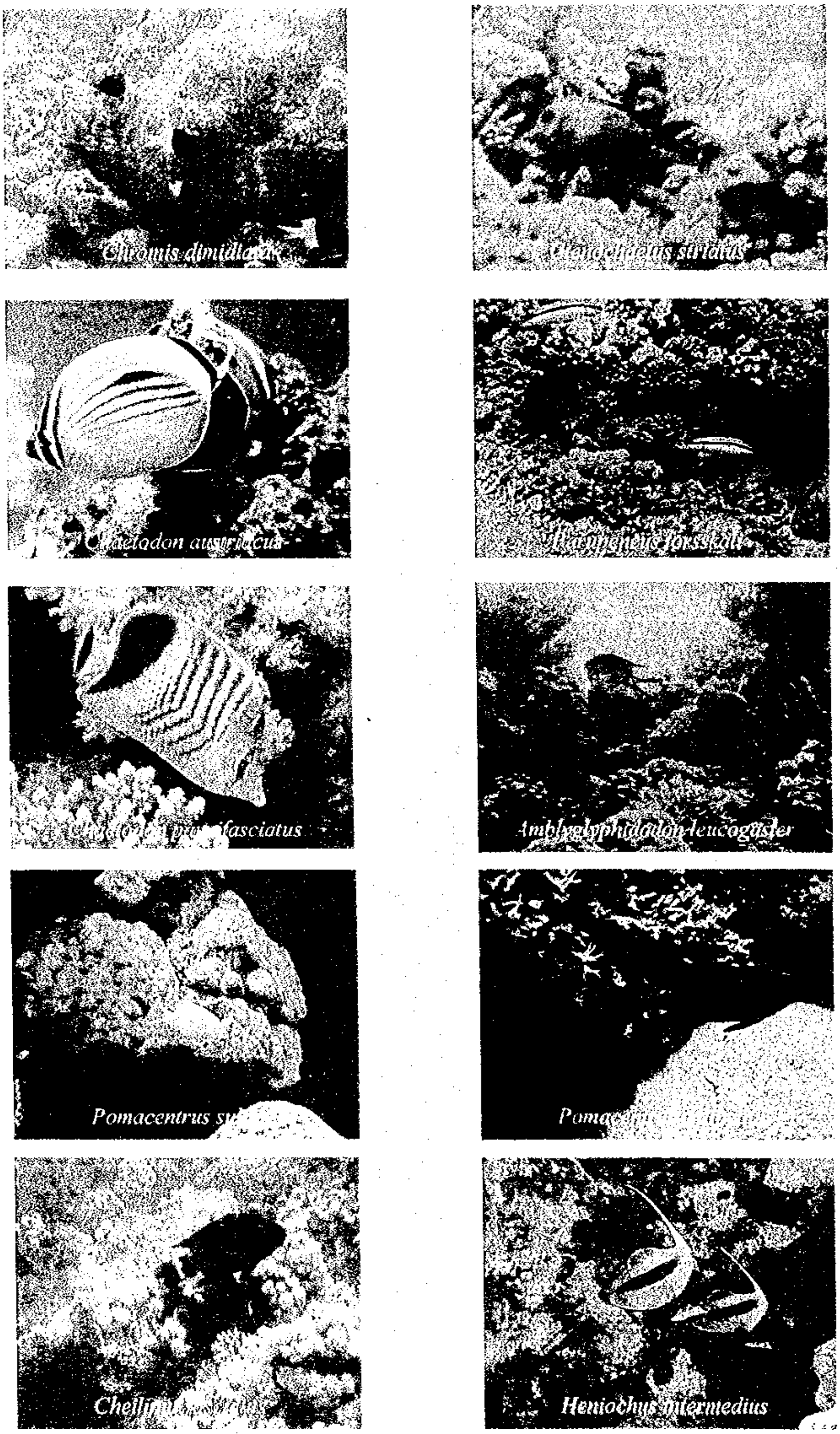


Photo. 3-1. Ten most frequently observed species in the Study Area.

Table 25. Ten most frequently observed species in the Study Area.

Family	Genus Species	English name
Pomacentridae	*Chromis dimidiata*	Twotone / Half and Half Chromis
Acanthuridae	*Ctenochaetus striatus*	Striped / Lined Bristletooth
Chaetodontidae	*Chaetodon austriacus*	Exquisite Butterflyfish
Mullidae	*Parupeneus forsskali*	Forsskal's / Dash and Dot Goatfish
Chaetodontidae	*Chaetodon paucifasciatus*	Red-backed / Crown Butterflyfish
Pomacentridae	*Amblyglyphidodon leucogaster*	Whitebelly Damsel
Pomacentridae	*Pomacentrus sulfureus*	Sulphur Damsel
Pomacentridae	*Pomacentrus trilineatus*	Threeline Damsel
Labridae	*Cheilinus fasciatus*	Redbanded / Redbreasted Wrasse
Chaetodontidae	*Heniochus intermedius*	Redsea Bannerfish

Among 50 endemic species in the list, 34 species were observed in the Study. The three most frequently observed endemic species are cited in Table 26 and are shown in Photo. 3-2. These species were also observed at every diving site.

Table 26. Three most frequently observed endemic species in the Study Area.

Family	Scientific name	English name
Chaetodontidae	*Chaetodon austriacus*	Exquisite Butterflyfish
Labridae	*Thalassoma klunzingeri*	Klunzinger's Wrasse
Chaetodontidae	*Heniochus intermedius*	Redsea Bannerfish

Fig. 25 shows the total number of species and endemic species at each survey site.

2. Shorefish fauna at each site

The northern part of the Red Sea has a much greater biomass than the southern part, presumably as a result of its comparatively moderate water temperature. Up-welling of cold water from the deep layer was observed at several sites such as the Gulf of Aqaba (Site 1, 2), Ra's al-Luqayq (Site 20) and Ra's Haramil (Site 10), where many kinds of fish were observed.

Water temperature and turbidity were comparatively high in the southern sections such as Rabigh and Yanbu'. The number of fish species was lower here than in other areas.

The east side of Jazirat Farshar (Site 4) showed very unique fauna, being enclosed

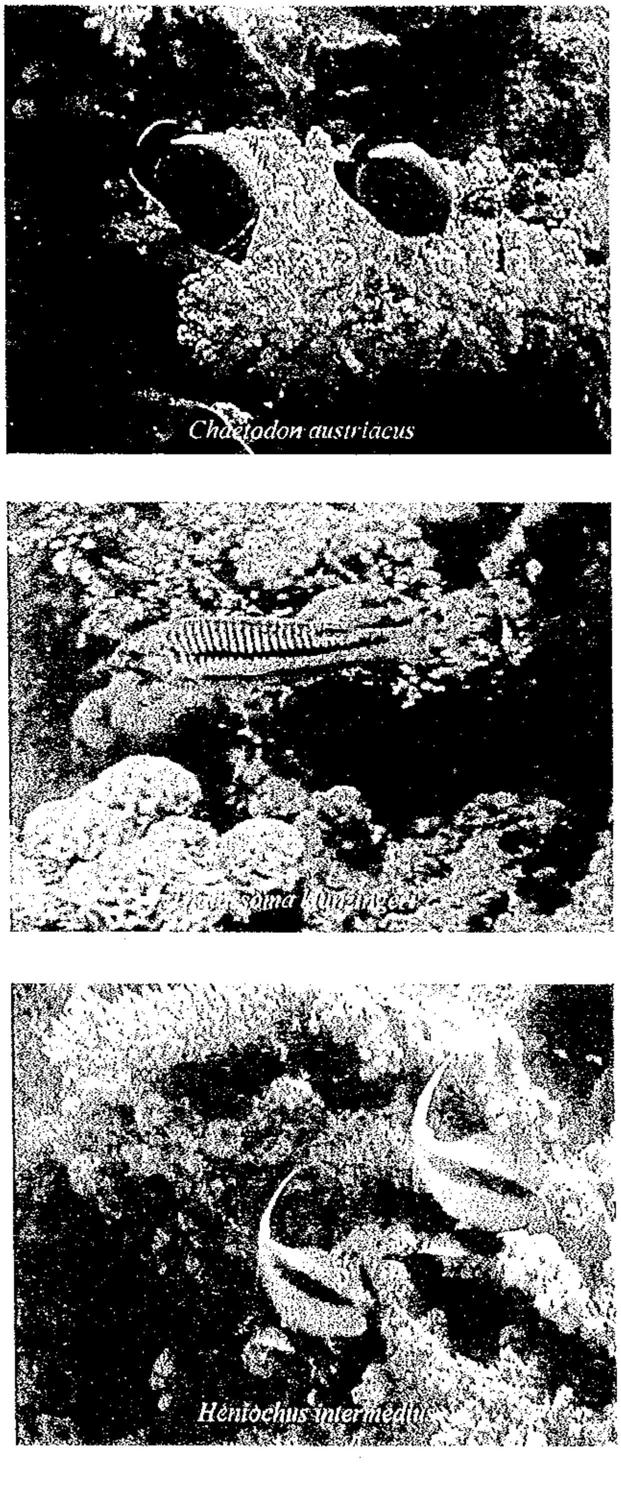


Photo. 3-2. Three most frequently observed endemic species in the Study Area.

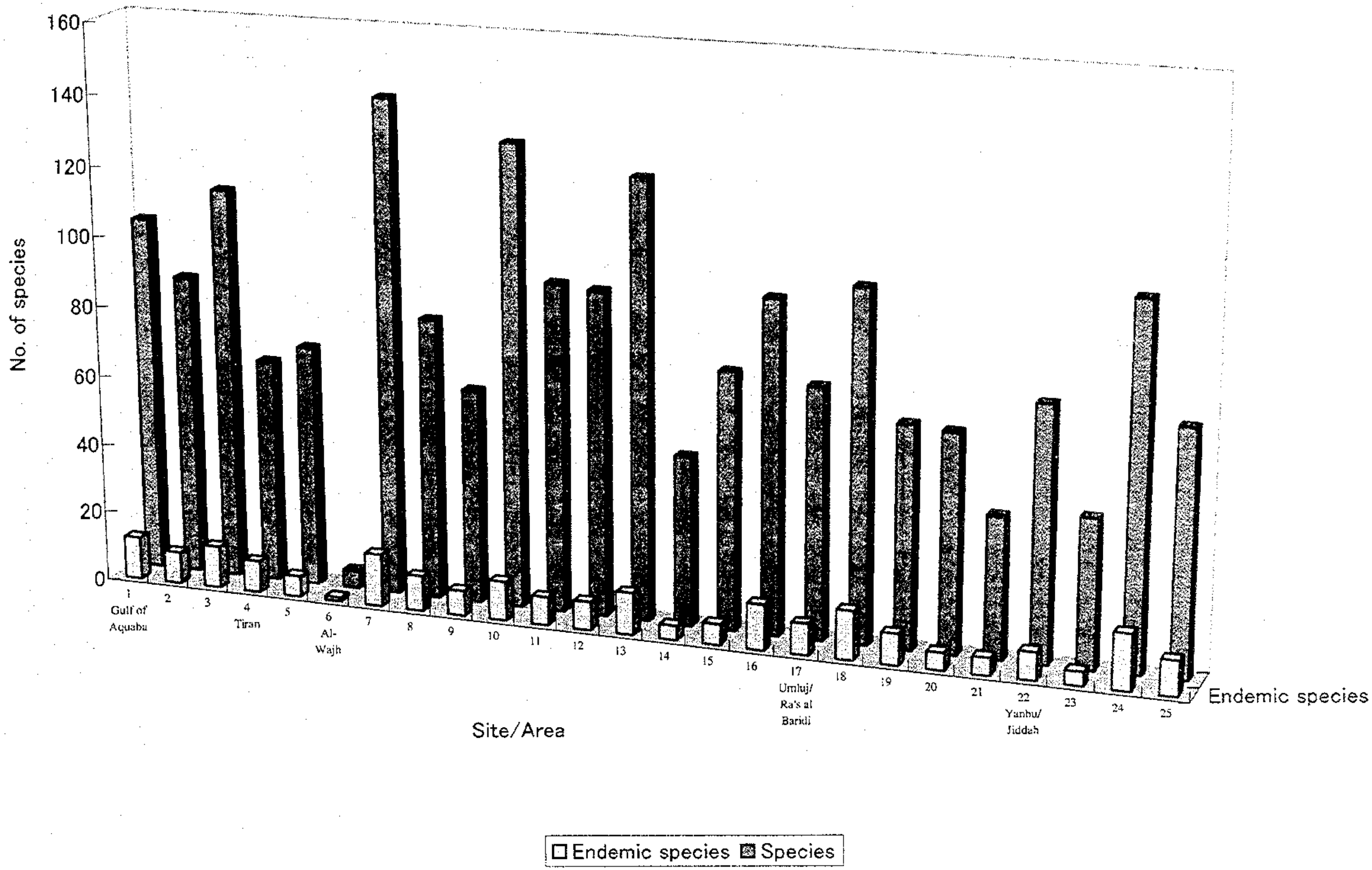


Fig. 25 Number of species and endemic species

and isolated from the outside water. Some fishes show different colour variation to those of other areas.

Al-Wajh Bank (Site 13, 15), located in the middle of the Study Area, has a lot of large shallow lagoons. As these lagoons are isolated from harsh conditions such as high waves, Al-Wajh Bank provides a good habitat for small fishes.

3. Collection of specimens

A total of 373 fish specimens were collected by gill nets, hand nets, throwing nets and fishing lines (271 for the Kingdom of Saudi Arabia and 102 for Japan)and fixed with formalin-aqueous solution. These are listed in Appendix 9.

4. Newly-recorded species

Five species shown in Table 27 are considered fish which have possibly never before been recorded in the Red Sea. Since specimens of most of them were collected, further study may be expected. Photographs of these species are shown in Photo.3-3.

2.4.1.4. Discussion

1. Habitats and species

44 survey spots at which diving or snorkeling was carried out in order to observe fishes are categorized into the two types shown below, taking into consideration the differences in physical conditions and human impact (accessibility) between the habitats.

- Inside habitat (16 spots); inner reef lagoon, shallow lagoon, sub-tidal lagoon, lagoon, inner patch reef, patch reef, patch coral in seagrass bed, inside of lagoon, inside of reef edge, inner bay.
- Outside habitat (28 spots); seaward reef slope, seaward reef edge, seaward sand slope, seaward slope, seaward patch reef, reef edge.

Table 27. Fish species thought to have been recorded in the Red Sea for the first time.

Family	Scientific name	English name	Location	Spot no.	Site no.	Specimen	Under water Photo.
Apogonidae	*Cheilodipterus percicus*	Percian Cardinalfish	Al Muracy	F70	13	x	x
			Jazirat Murbat	F71	13		
			Maqna	F76	2		
			Umluj	F113	17	x	
Caesionidae	*Pterocaesio* sp.	Fusilier	Al Humaydah	F75	1		x
			Ra's Shakh-humayd	F78	3		
			Al Quff	F80	7		
Gobiidae	*Paragobiodon* sp.	Goby	Jazirat Qumma'an	F103	15	x	
Muraenidae	*Gymnothorax pseudothyrsoideus*	Highfin Moray	Sharm al-Wajh	F97	10	x	
Ambassidae	*Ambassis* sp.	Glass Perch	Sharm al-Wajh	F83	10	x	

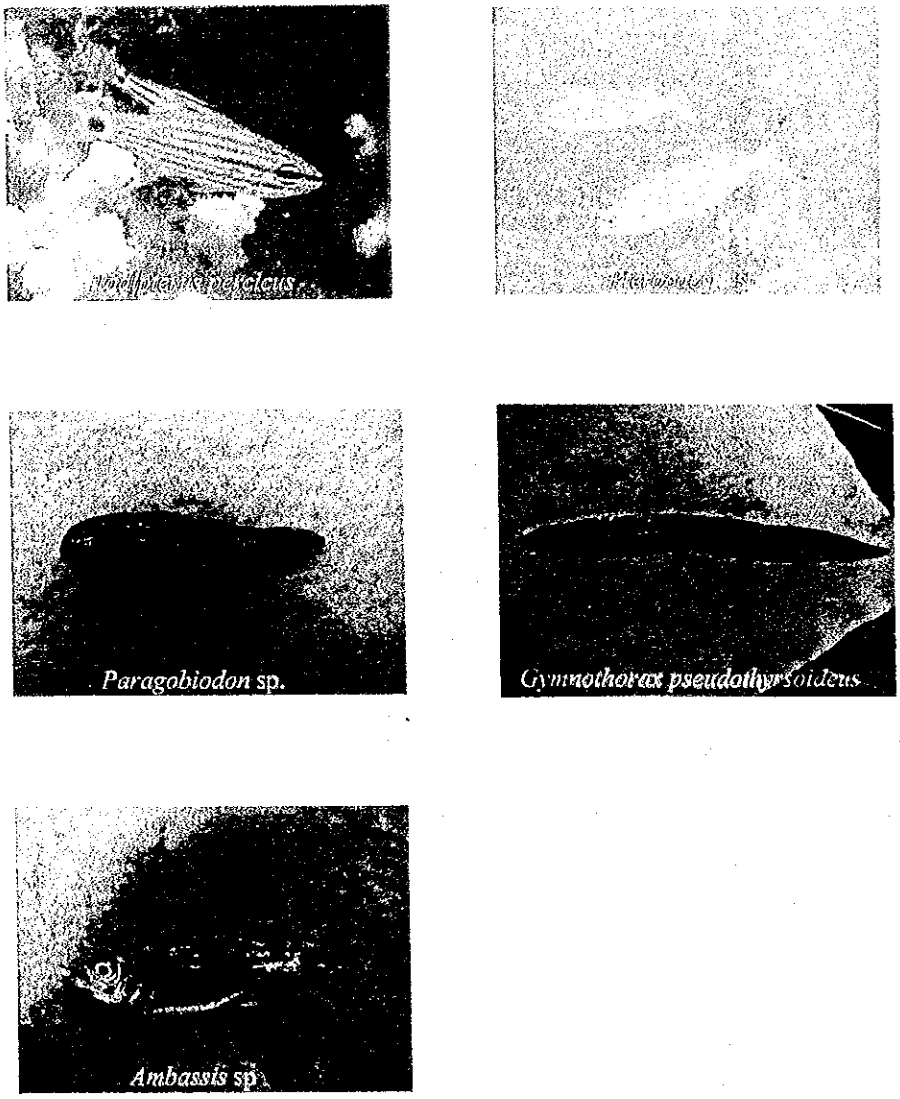


Photo. 3-3. Fish species thought to have been recorded in the Red Sea for the first time.

A comparison of fish fauna between the inside and the outside habitats is shown in Table 28. As the number of survey spots in the outside habitats was greater than that in the inside habitats, the outside habitats have a greater total abundance of fish and a greater total number of species compared to the inside habitats. The average number of species (number of species per one survey spot) do not show any big difference between the outside and inside habitats. Average fish abundance in the outside habitats is greater than in the inside habitats. The outside habitats also have a greater abundance per species compared to the inside habitats. This means that the outside habitats have a greater abundance compared to the inside habitats, although it does not seem to be any difference between them in species richness.

The composition of the fish species observed in the inside and outside habitats is shown in Table 29. There is no significant difference in predominant fish families between the inside and the outside habitats. The composition of the major 10 fish families in the inside and the outside habitats is shown in Table 30 and Fig. 26. The families Pomacentridae (damsels), Labridae (wrasses) and Gobiidae (gobies) are the most common ones in both habitats. Other major families are Acanthuridae (surgeonfishes), Chaetodentidae (butterflyfishes), Serranidae (groupers) and Blenniidae (blennies) in the inside habitats and Serranidae (groupers) and Blenniidae (blennies) in the outside habitats. The composition rates of Apogonidae (apogons) and Pomacentridae (damsels) in the inside habitats are a slightly greater than those in the outside, and the outside habitats had greater composition rates of Labridae (wrasses) and Serranidae (groupers) compared to the inside habitats.

Although feeding (eating) habits vary considerably depending on fish species or their living environments (EDWARDS & HEAD 1987), this composition may reflect feeding habits. That is, the inside habitats, characterized by rich seagrasses and algae, sustain herbivorous fish or plankton feeders such as Acanthuridae (surgeonfishes), Pomacentridae (damsels) and Apogonidae (apogons). Outside habitats, on the other hand, are home to many fish that serve

Table 28. Comparison of fish fauna in the inside and outside habitats.

	Inside	Outside
Species	174	284
Species/spot	10.9	10.1
Total abundance	653	1847
Averaged abundance	40.8	66.0
Index	3.75	6.50
No. of spot	16	28

Note: Index=Abundance/Species

Table 29. Fish species observed in the inside and outside habitats.

(Unit:species)

Fish families	Inside	Outside
Synodontidae	3	3
Fistulariidae	1	0
Syngnathidae	1	3
Holocentridae	7	5
Sphyraenidae	1	3
Serranidae	8	16
Pseudochromidae	6	5
Plesiopidae	0	0
Apogonidae	14	12
Gerreidae	0	1
Mullidae	4	5
Lutjanidae	4	7
Pomadasyidae	0	0
Nemipteridae	1	2
Lethrinidae	3	8
Chaetodontidae	10	11
Pomacanthidae	4	6
Pomacentridae	23	29
Labridae	20	36
Scaridae	6	13
Zanclidae	0	0
Acanthuridae	8	10
Siganidae	3	4
Gobiidae	10	19
Mugiloididae	0	0
Blenniidae	8	15
Scorpaenidae	4	4
Callionymidae	0	0
Soleidae	1	1
Balistidae	4	8
Monacanthidae	1	5
Tetradontidae	3	5
Diodontidae	0	1
Orthers	16	47

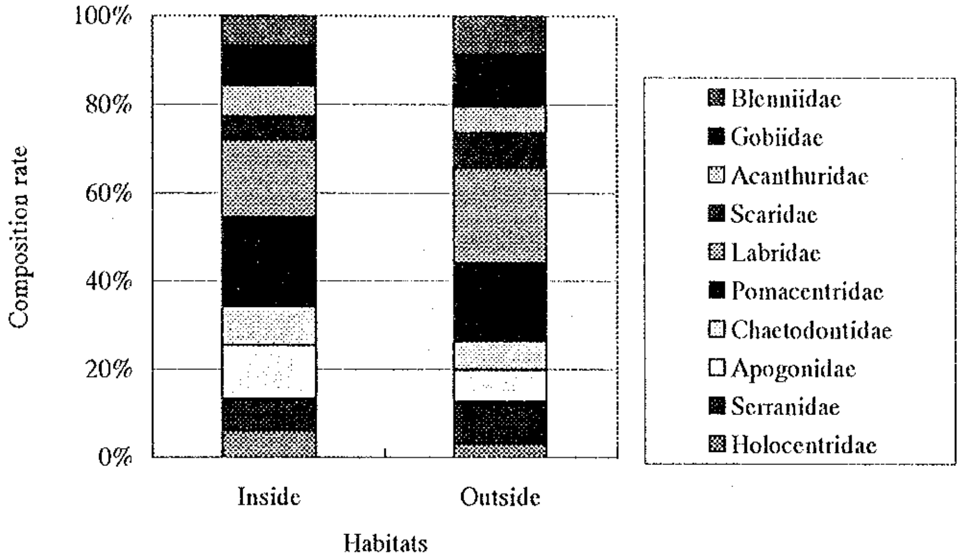


Fig. 26. Composition of major 10 fish families in the inside and outside habitats.

Table 30. Composition of major 10 fish families in the inside and the outside habitats.

Families	Inside	Outside
Holocentridae	7	5
Serranidae	8	16
Apogonidae	14	12
Chaetodontidae	10	11
Pomacentridae	23	29
Labridae	20	36
Scaridae	6	13
Acanthuridae	8	10
Gobiidae	10	19
Blenniidae	8	15
Orthers	60	118
Sum	174	284

as food for carnivorous fish, such as Serranidae (groupers) and Labridae (wrasses) (Table 31).

2. Selection of the Model Area

At the beginning of the Study, diversity, biomass and endemism were considered as the indices for selecting a model Study Area for Phase III. Indices were defined as follows.

- Diversity: the number of species
- Biomass; the biomass index (sum of abundance factors divided by sum of species number); and
- Endemism; the number of endemic species.

Although the abundance factor (0: no occurrence, 1: rare occurrence, 2: common occurrence, 3: dominant occurrence) does not exactly reflect the difference between gregarious fish and solitary living fish, the number is used as an expression of productivity. The difference in size of each area is not considered.

The Study Area was divided into six areas, namely the Gulf of Aqaba (Sites 1-3), Tiran (4-5), Duba / Al-Wajh (6-12), Al-Wajh Bank (13-16), Umluj / Ra's Baridi (17-21) and Yanbu' / Jeddah (22-25). A comparison of diversity, productivity index and endemism in these areas is shown in Table 32 and Fig. 27.

The Al-Wajh area had the greatest diversity, followed by Al-Wajh Bank, and then the Umjuj / Ra's Baridi area. The Gulf of Aqaba area had the greatest productivity, followed by the Al-Wajh area, and then the Umluj / Ra's Baridi area. The Al-Wajh area had the greatest level of endemism, followed by the Yanbu' / Jeddah area, and then Al-Wajh Bank.

Factors in consideration of the Model Study Area are shown in Table 33. From the results of the Study in Phase II, the wide area from the Al-Wajh area to the Umluj / Ra's Baridi area is considered a candidate for the Model Study Area for Phase III because of its high diversity, productivity and endemism. Al-Wajh Bank has many kinds of habitats such as

Table 31. Eating habit of coral reef fishes in Okinawa.

Fish families	Herbivorous	Omnivorous	Benthos feeder			Plankton feeder				
			Migration	Adhesion	Coral polyp	Bottom layer	Middle layer	Parasitic worm	Fish skin	Fish eater
Synodontidae										x
Fistulariidae										x
Syngnathidae						x				
Holocentridae			x							
Sphyraenidae										x
Serranidae			x							x
Pseudochromidae			x			x				
Plesiopidae			x							
Apogonidae			x			x				x
Gerreidae				x						
Mullidae			x	x						
Lutjanidae			x							
Pomadasyidae						x				
Nemipteridae				x						
Lethrinidae			x	x						
Chaetodontidae		x		x	x					
Pomacanthidae		x								
Pomacentridae	x	x			x		x			
Labridae		x	x	x	x	x		x		
Scaridae	x									
Zanclidae		x								
Acanthuridae	x									
Siganidae	x	x								
Gobiidae	x	x	x		x	x	x			
Mugiloididae		x	x							
Blenniidae	x	x			x				x	
Scorpaenidae			x							
Callionymidae						x				
Soleidae				x						
Balistidae		x		x						
Monacanthidae					x					
Tetradontidae					x					
Diodontidae			x							

The source:Tetuo Kuwamura, 1987.

Table 32. Comparison of diversity, productivity and endemism.

Area	Site	Species	Endemic species	Abundance	Index
Gulf of Aquaba	1,2,3	166	18	560	3.37
Tiran	4,5	111	12	174	1.57
Duba/Al-Wajh	6,7,8,9,10,11,12	264	26	879	3.33
Al-Wajh Bank	13,14,15,16	192	20	514	2.68
Umluj/Ra's Baridi	17,18,19,20,21	172	18	493	2.87
Yanbu'/Jeddah	22,23,24,25	156	21	402	2.58

Note: Index = Abundance / Species

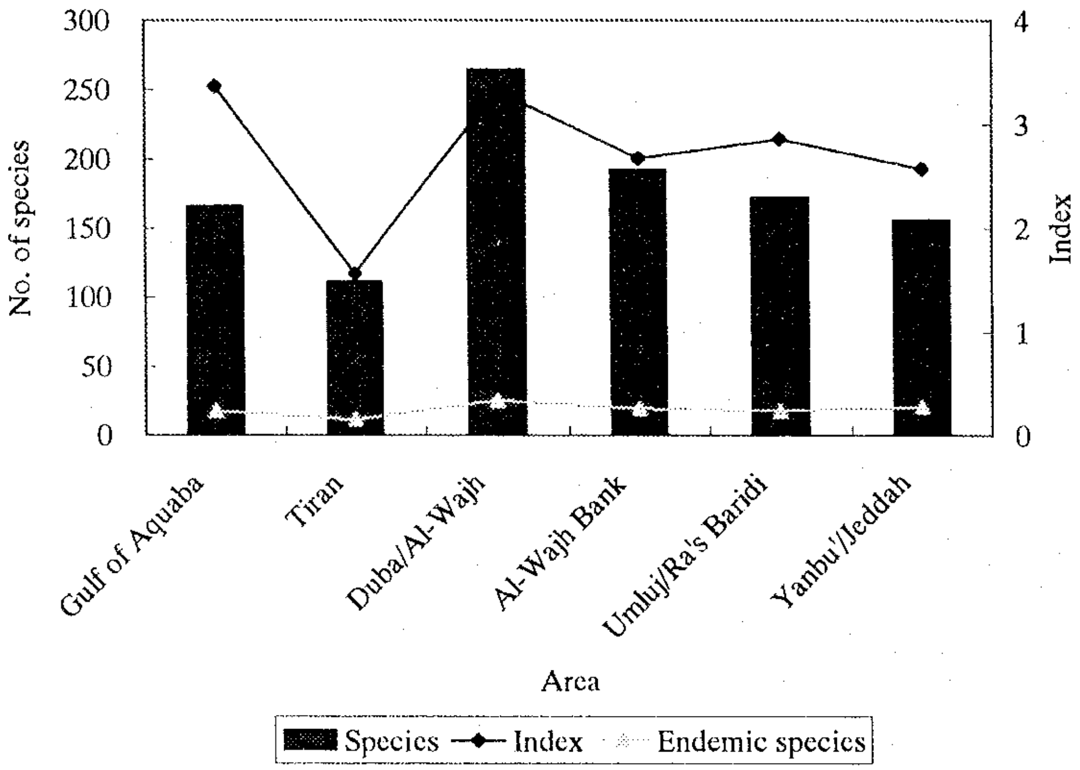


Fig. 27. Comparison of diversity, productivity and endemism.

seagrass bed, patch reef and outside reef, and it too is considered a good candidate for the Model Area.

Table 33. Factor in consideration of the Model Area.

Area	Diversity	Productivity	Endemism
Gulf of Aqaba		3	
Tiran			
Duba / Al-Wajh	3	2	3
Al-Wajh Bank	2		1
Umluj / Ra's Baridi	1	1	
Yanbu' / Jeddah			2

3: very good, 2: good, 1: not good, blank; there are not sufficient data for evaluation.

2.1.5. BENTHOS

2.1.5.1. Introduction

The group called "benthos" includes many phyla such as MOLLUSCA, CRUSTACEA and ECHINODERMATA. Almost all phyla were included in the list of benthos by VINE (1986) that was quoted to make a list of benthos of the Red Sea. However, this documentation does not provide descriptions adequate for identification of these species. Therefore, further documentation for each phylum is needed for the identification of species.

Species identification in Phase II was conducted using the following literature:

MOLLUSCA GASTOPODA; SHARABATI (1984)

MOLLUSCA BIVALVIA; OLIVER (1992)

CRUSTACEA; MIYAKE (1982, 1983)

Others; TERENCE et al. (1996) and others.

In the above literature, 279 families and 2,441 species of benthos in the Red Sea are listed.

2.1.5.2. Methods

A topographical cross-section typical of the Red Sea is shown in Fig.28.

The survey was conducted on foot in the supertidal zone, by mainly snorkeling and occasionally SCUBA diving in the intertidal zone, and by SCUBA diving in the subtidal zone.

In each tidal zone, survey spots were selected in order to survey various habitats, such as sand and mud bottoms, bedrock, seagrass bed, and patch coral. Time duration for the survey at each spot was about 30 to 60 minutes.

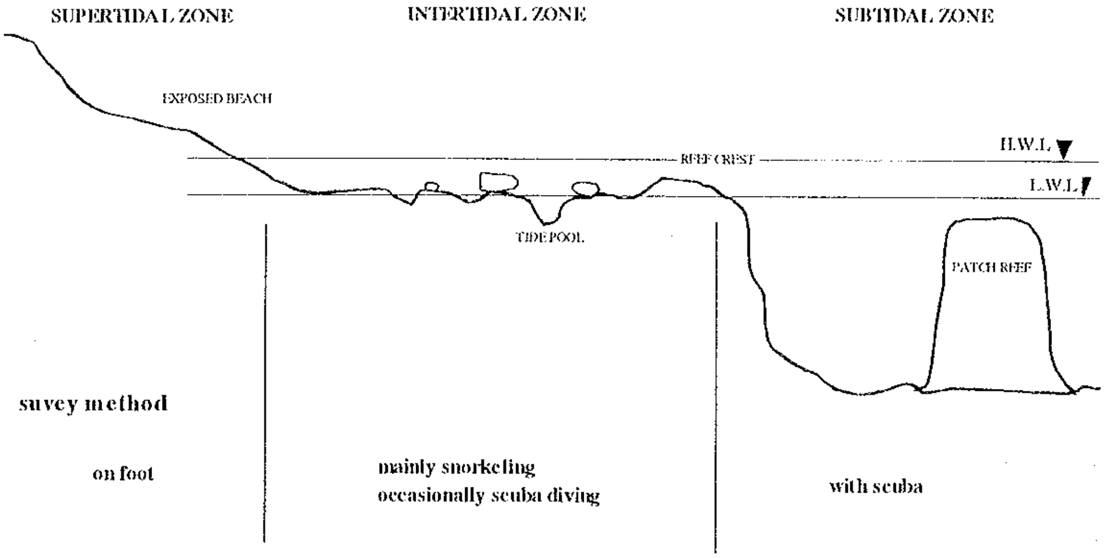


Fig. 28. Survey methods in each tidal zone.

Scientific names and the abundance of the benthos over about 1cm (megalobenthos) observed in each spot were recorded in the field. The abundance was classified into three categories;

abundance level 1 (rare): less than 10 individuals per 100 m^2

abundance level 2 (common): 10 ～ 100 individuals per 100 m^2

abundance level 3 (abundant): more than 100 individuals per 100 m^2

Species that could not be identified in the field were collected and identified in the laboratory. Photographs of benthos were taken using underwater camera, and samples, including empty shells, were collected whenever possible.

2.1.5.3. Results

The number of survey sites was 25 and the number of survey spots was 96 (Appendix 10).

In the field survey of Phase II, 123 families and 341 species, including empty shells, were identified (Table 34), and several unidentified or doubtful species were examined in detail. The phylum that showed the highest number of genenra and species was MOLLUSCA.

Table 34. Number of benthos families and species in Phase II.

Phylum	Family	Species
CNIDARIA	1	1
ANNELIDA	2	2
SIPUNCULA	1	1
MOLLUSCA	72	245
CRUSTACEA	20	50
ECHINODERMATA	24	40
CHORDATA	2	2
Total	123	341

The number of live benthos of all species observed at each site is shown in Table 35. The total number of species of live benthos was 285 (see also Appendix 11).

Sites yielding a high number of species were more prevalent in the northern sections of the Study Area, and the largest number of species was observed at Site 3 in the area of the Gulf of Aqaba (82 species, Fig.29).

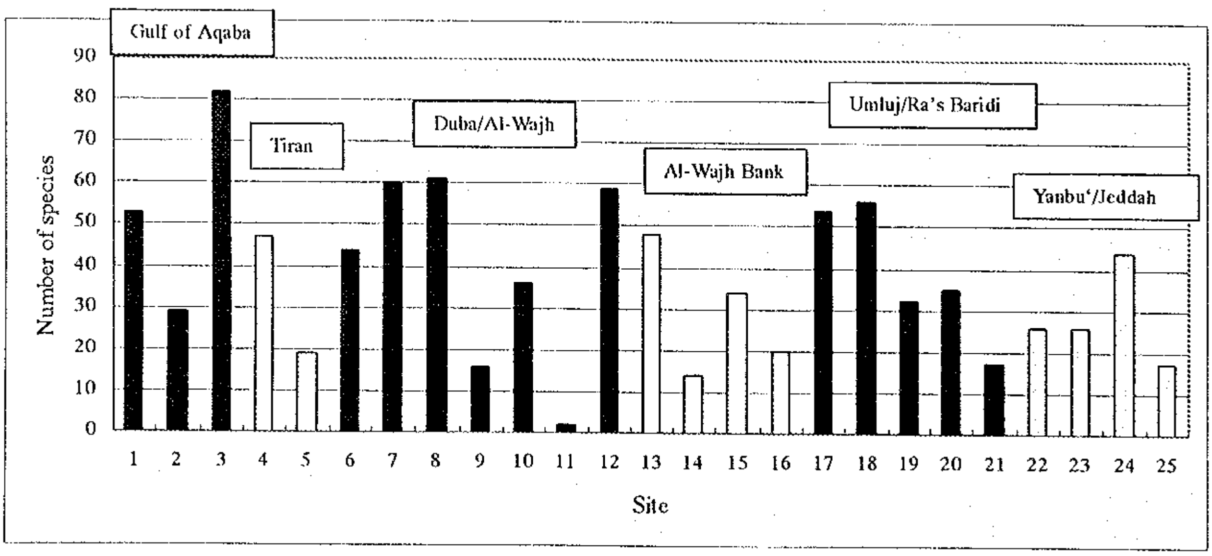


Fig. 29 The number of species in each site.

Species observed alive at ten or more sites were *Tridacna maxima* (21 sites), *Diadema setosum* (19 sites), *Echinometra mathaei* (17 sites), SERPULIDAE (16 sites), *Pedum spondyloideum* (14 sites), *Tectus dentatus* (13 sites), *Turbo radiatus* (12 sites), *Dendropoma maxima* (13 sites), *Coralliophila violacae* (12 sites) and *Conus arenatus* (12 sites). Almost all of these species inhabit the entire Study Area. There was no significant difference in the geographical distributions among these species (Table 35).

Table 35. Species of live benthos observed at ten or more sites.

No.	Scientific Name	English Name	Gulf of Aqaba			Tiran		Duba/Al-Wajh						
			site											
			1	2	3	4	5	6	7	8	9	10	11	12
1	*Tridacna maxima*	clam	x	x	x	x	x	x	x	x	x	x	x	x
2	*Diadema setosum*	diadematid	x	x	x	x	x	x	x	x			x	x
3	*Echinometra mathaei*	echinometrid	x	x	x	x	x	x	x	x	x			x
4	SERPULIDAE	calcareous tube-worm	x	x	x	x	x	x		x	x	x		
5	*Pedum spondyloideum*	scallop	x	x	x	x		x		x	x			
6	*Tectus dentatus*	topshell	x			x			x		x			x
7	*Dendropoma maxima*	worm shell	x			x		x	x		x	x		
8	*Turbo radiatus*	turban	x	x	x		x		x					
9	*Coralliophila violacea*	Violet Coral Shell	x		x			x	x	x	x	x		x
10	*Conus arenatus*	Sand Cone	x			x			x					x
11	*Chama* sp.	chama			x	x		x	x	x				x
12	DIOGENIDAE	spotted hermit crab							x	x		x		x
13	*Holothuria atra*	holothuriid	x		x	x		x		x	x			x
14	*Vasum turbinellus*	Pacific Top Vase	x					x	x	x		x		x
15	*Cerithium erythraeonense*	horn shell	x		x			x	x	x				x
16	*Strombus gibberulus albus*	conch shell								x	x	x		x
17	*Conus frigidus*	cone shell					x	x		x		x		x
18	*Calcines latens*	spotted hermit crab	x		x			x		x	x			x
		Total number of species	53	29	82	47	19	44	60	61	16	36	2	59

No.	Scientific Name	English Name	Al-Wajh / Umluj				Umluj/ Ra's Baridi					Yanbu'/Jeddah				Number of sites *
			site													
			13	14	15	16	17	18	19	20	21	22	23	24	25	
1	*Tridacna maxima*	clam	x	x	x	x	x	x	x				x	x		21
2	*Diadema setosum*	diadematid	x	x	x		x	x	x	x			x	x		19
3	*Echinometra mathaei*	echinometrid	x	x	x	x		x		x			x			17
4	SERPULIDAE	calcareous tube-worm		x	x	x	x	x					x	x		16
5	*Pedum spondyloideum*	scallop	x	x			x	x	x				x	x		14
6	*Tectus dentatus*	topshell	x		x	x	x	x		x		x		x		13
7	*Dendropoma maxima*	worm shell	x				x	x	x	x			x	x		13
8	*Turbo radiatus*	turban			x	x	x	x		x		x	x			12
9	*Coralliophila violacea*	Violet Coral Shell		x			x						x	x		12
10	*Conus arenatus*	Sand Cone			x	x	x		x		x	x	x	x		12
11	*Chama* sp.	chama			x		x	x	x	x			x			12
12	DIOGENIDAE	spotted hermit crab	x		x		x		x		x	x		x	x	12
13	*Holothuria atra*	holothuriid			x			x		x				x	x	12
14	*Vasum turbinellus*	Pacific Top Vase					x	x		x		x		x		11
15	*Cerithium erythraeonense*	horn shell	x				x	x			x					10
16	*Strombus gibberulus albus*	conch shell	x			x				x		x		x	x	10
17	*Conus frigidus*	cone shell					x	x		x		x		x		10
18	*Calcines latens*	spotted hermit crab	x			x	x							x		10
		Total number of species	48	14	34	20	54	56	32	35	17	26	26	44	17	285

Number of sites:Number of sites where the live species of benthos were observed.

In order to illustrate the biomass at each site, species with an abundance level 3 at each site are shown in Fig.30 and Table 36. Additionally, the sites where the bigger (in size) benthos, *Tridacna maxima, Diadema setosum* and *Lambis truncata sebae* were recorded at abundance level 2 are shown in the same table, because they play an important role in the ecosystem due to their large biomass per individual in terms of body weight.

The biomass of benthos was high in the Gulf of Aqaba and Duba /Al-Wajh areas. In contrast, the biomass was low in the Al-Wajh Bank and Yanbu' / Jeddah areas.

Large biomass species observed frequently were SERPULIDAE, *Dendropoma maxima*, *Echinometra mathaei*, *Nerita albicilla*, *Coralliophila violacea* and *Clibanarius strilatus*. These species were observed more frequently in the northern part of the Study Area. Even when the numbers of *Tridacna maxima*, *Diadema setosum* and *Lambis truncata sebae* were low in each spot, these fish represented a large biomass because of their physical size. *Tridacna maxima* and *Diadema setosum* were observed through the entire Study Area and *Lambis truncata sebae* was frequently seen in the middle of the Study Area.

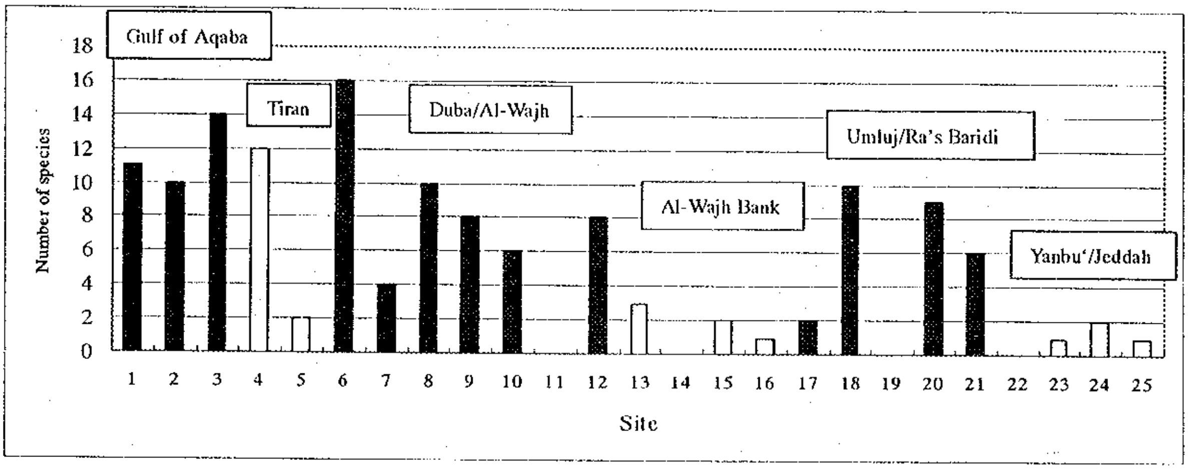


Fig. 30. Species number of benthos of abundance level 3 in each site.

Table 36. Species of abundance level 3 and their occurrence by site.

			Gulf of Aqaba			Tiran		Duba/Al-Wajh						
			site											
No.	Scientific Name	English name	1	2	3	4	5	6	7	8	9	10	11	12
1	SERPULIDAE	calcareous tube-worm	x	x	x	x	x	x		x	x	x		
2	Dendropoma maxima	worm shell	x			x			x		x	x		
3	Echinometra mathaei	echinometrid	x	x	x	x		x			x			
4	Nerita albicilla	slipper winkle			x					x				x
5	Coralliophila violacea	Violet Coral Shell	x					x		x	x	x		
6	Clibanarius striolatus	spotted hermit crab	x		x			x		x				x
7	Tetraclita sp.	barnacle		x	x			x						x
8	Scopimera cf.globosa	stalk-eyed crab								x				
9	Ophiocoma scolopendrina	ophiocomid			x			x						x
10	Planaxis sulcatus	cluster winkle	x					x						x
11	DIOGENIDAE	spotted hermit crab							x			x		
12	Strombus gibberulus albus	conch shell								x	x			
13	Thais savignyi	comb shell	x		x					x				
14	Pedum spondyloideum	scallop						x			x			
15	Chama sp.	chama				x		x						
16	Tridacna maxima	clam				x			x		x			
	(Tridacna maxima)	clam	+		+	+	+	+	+	+	+	+		
17	Diadema setosum	diadematid		x	x	x								
	(Diadema setosum)	diadematid	+	+	+	+	+		+	+				+
18	Holothuria atra	holothuriid				x					x			
	(Lambis truncata sebae)	Spider Conch							-	-	-			-
		Total number of species of abundance level 3	11	10	14	12	2	16	4	10	8	6	0	8

			Al-Wajh Bank				Umluj/Ra's Baridi					Yanbu'/Jeddah				Number of sites
			site													*
No.	Scientific Name	English name	13	14	15	16	17	18	19	20	21	22	23	24	25	
1	SERPULIDAE	calcareous tube-worm					x	x								11
2	Dendropoma maxima	worm shell								x				x		7
3	Echinometra mathaei	echinometrid			x											7
4	Nerita albicilla	slipper winkle						x		x	x					6
5	Coralliophila violacea	Violet Coral Shell												x		6
6	Clibanarius striolatus	spotted hermit crab								x						6
7	Tetraclita sp.	barnacle						x								5
8	Scopimera cf.globosa	stalk-eyed crab	x					x			x		x			5
9	Ophiocoma scolopendrina	ophiocomid						x		x						5
10	Planaxis sulcatus	cluster winkle						x								4
11	DIOGENIDAE	spotted hermit crab									x				x	4
12	Strombus gibberulus albus	conch shell								x						3
13	Thais savignyi	comb shell														3
14	Pedum spondyloideum	scallop					x									3
15	Chama sp.	chama						x								3
16	Tridacna maxima	clam														3
	(Tridacna maxima)	clam	+	+	+	+	+	+						+		(16)
17	Diadema setosum	diadematid														3
	(Diadema setosum)	diadematid		+	+		+	+	+				+	+		(15)
18	Holothuria atra	holothuriid								x						3
	(Lambis truncata sebae)	Spider Conch							-	-						(6)
		Total number of species of abundance level 3	3	0	2	1	2	10	0	9	6	0	1	2	1	

Number of sites*:Number of sites where the species was observed above abundance level 3.
+:Site where the species was observed above abundance lebel 2.
-:Site where the species was observed.