The Present Status of the Red Sea Coral Reefs between Haql and Yanbu, Saudi Aarabia

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Abstract. The coral reefs statuses of the Saudi Arabia Red Sea and Gulf of Aqaba coasts have not been assessed since 1990. A comprehensive field survey, funded by King Abdulaziz City for Science and Technology, was carried out to check the present status of the coral reefs along the northern Red Sea and Gulf of Aqaba coasts. The coral reefs and reef-associated communities were investigated in situ in the field and the results were compared with the previous studies. The study revealed that most reefs in the study area (from Haql to Yanbu) are in good to excellent condition in terms of the ratio of live to dead coral cover. There was little to no direct human impact (e.g. destructive fishing, anchor damage, coral mining or pollution) on the great majority of reefs, other than reefs in urban areas subject to land reclamation, urban run-off and pollution or littering. Most damaged reefs occur in the immediate vicinity of the major coastal cities and towns especially off AlQof, AlWajh and Yanbu. At most sites outside these areas, levels of injury and death of corals were low. No evidence of mass bleaching or other forms of major coral mortality were found during surveys. Most reefs appeared to be in good condition.
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1. Introduction

The Red Sea is one of the most important repositories of marine biodiversity in the world. Its relative isolation has given rise to an extraordinary range of ecosystems, biological diversity and endemism, particularly among reef fishes and reef-associated organisms. The coral reefs of the Red Sea are comprised of over 200 species of *Scleractinia* corals, representing the highest diversity in any section of the Indian Ocean. The warm water and absence of fresh water run-off provide suitable conditions for coral reef formation adjacent to the coastline. In the northern Red Sea the coast is fringed by an almost continuous band of coral reef, which physically protects the shoreline. Further south the shelf becomes much broader and shallower and the fringing reefs gradually disappear and are replaced with shallow, muddy shorelines. Coral reefs become more numerous in the offshore parts of this coast. Although many reef areas in the Red Sea are still in a pristine state, threats are increasing rapidly and reefs are being damaged by coastal development and other human activities (DeVantier and Pilcher, 2000). Major threats include: land-filling and dredging for coastal expansion; destructive fishing methods; damage by the recreational SCUBA diving industry, shipping and maritime activities, sewage and other pollution discharges; lack of public awareness, and insufficient implementation of legal instruments that affect reef conservation.

Several research studies have been carried out in Saudi Arabian waters, spanning much of the eastern Red Sea (Mergner, 1984, Sheppard *et al.,* 1992). The first major broad-scale surveys of coastal and marine habitat types and biodiversity of the Red Sea coast were undertaken (Ormond *et al.,* 1984a-c), which identified ~70 key sites for conservation, and also recommended establishment of five larger multiple-use marine protected areas (MPAs) in the Gulf of Aqaba, the Tiran Island chain, AlWajh Bank, the Outer Farasan Bank and part of the Farasan Islands. Reef types and composition of the coral fauna of the Saudi Arabian Red Sea were assessed in the early-mid 1980s (Sheppard & Sheppard, 1985, 1991, and Antonius *et al.,* 1990), producing a comprehensive coral species inventory for the Saudi Arabian Red Sea. Subsequently, a monitoring program was conducted during 1987-1988, investigating coral reef health and surrounding water quality along the Saudi Arabian Red Sea coast (Awad, 2000). In 1997, the distribution and composition of coastal and marine habitats of the central-northern Red Sea, from north of Jeddah to Haql in the Gulf of Aqaba were assessed in a 2 years study conducted jointly by the National Commission for Wildlife Conservation and Development (NCWCD) and Japanese International Co-operation Agency (JICA). This study produced detailed site bio-inventories for corals, fish, other benthos, algae, sea-grasses, coastal vegetation and birds, and assessed the distribution and abundance of marine mammals and turtles. Combined with socio-economic assessments of patterns of human use and detailed habitat mapping prepared from aerial photos

and satellite images, the data were used to define key reefs and larger reef areas of high conservation significance for MPA planning (NCWCD-JICA, 2000, and DeVantier and Pilcher, 2000). Further south in the Farasan Islands Marine Protected Area (FIMPA), abundances of live coral, dead coral, and coral-feeding crown-of-thorns starfish *Acanthaster planci* and snails *Drupella spp.* were assessed in 1999 (Al-Yami & Rouphael, 2000). Since 1990 no detailed *in situ* studies have been carried out to investigate the status of coral reefs along the Saudi Red Sea coast. Therefore, the present study is initiated –as part of Triple-Phase project funded by King Abdulaziz City for Science and Technology in Ryiadh- to reveal the present status of coral reefs and reef-associated communities in northern Saudi Red Sea coast between Haql and Yanbu.

The study area

Saudi Arabia's Red Sea coastline extends about 1800 km from Jordan to Yemen. The width of the continental shelf is less than 1 km in the Gulf of Aqaba and several tens of kilometers in the Farasan Bank. The climate is extremely arid and much of the biological productivity is confined to a narrow coastal strip, where coral reefs, mangroves and seagrass communities predominate. Average rainfall is less than 70 mm/year along the broad coastal Tihama plains of the Red Sea. Inland, above the coastal escarpment, it may exceed 200 mm/year (DeVantier and Pilcher, 2000).

The study area (Fig. 1) lies between latitudes 34° 56'N (Haql city) and 37° 56'N (Yanbu city) along the Saudi Arabian Red Sea coast. It comprises two distinctive zones each one has its unique characteristics, Gulf of Aqaba and the northern Red Sea proper. Generally, the study area exhibits markedly different bio-physical conditions where the coast and islands support a variety of coastal and marine habitats, related largely to oceanographic regime, degree of exposure, and topographic features, particularly the distribution of suitable topography for development of coral reefs, mangrove stands and seagrass beds. The area has a complex tectonic history of uplift and subsidence, related to the rift development of the Red Sea from the movements of the Arabian and African tectonic plates. The present series of living coral reefs are the latest in a chronological sequence of raised (uplifted) and submerged reefs that have developed at various times over the past several hundred millenia. In many cases the present reefs are developed on earlier reef structures. Detailed descriptions of the geology, physical environment, climate, hydrology, oceanography and habitats of the Red Sea are given by Fishelson (1971), Ormond *et al.* (1984a), Edwards and Head (1987), Crossland *et al.*, 1987, IUCN/UNEP 1988, Sheppard and Sheppard (1985, 1991), Behairy *et al.* (1992) and Sheppard *et al.* (1992).

2. Material and Methods

In the framework of the scientific research project entitled "Coastal Resource Mapping, Yanbu-Haql, Red Sea Coastal Zone, Saudi Arabia" (Project APR-28-163 funded by King Abdulaziz City for Science and Technology KACST), the coral reefs and reef-associated communities were investigated at 31 locations along the coast of Tabuk Governorate. The location names and positions are shown in Fig. (1).

The presence of fish, coral reefs, marine invertebrates and vegetation at each location were recorded as follows:

Coral reefs

The survey methods chosen originated from a variety of methods (Phinn and Neil, 1998, McMahon *et al.,* 2002, Ford *et al.,* 2003, Joyce, 2003, Joyce *et al.,* 2004, and Mumby *et al.,* 2004) and conforming to the Reef Check Organization (RCO) protocol www.reefcheck.org (Hodgson *et al.,* 2004). The transect line method recommended by the RCO was used in the coral reefs field survey at 5 m and 10 m depths. For the transect line, a standard 100 m measuring tape was extended at each surveyed depth. The transect is then divided into four 20m-segments that are separated by 5 m belt zones. The grid consisted of 40 half meter grid cells in a five by five grid constructed from thin ropes. The grid was positioned, so that its diagonal was parallel to the transect line and the grid centre point placed on the 10 m mark of the transect line.

Percentage benthic cover was determined from *in situ* assessment. Percent cover of different corals cover types for the transect was calculated by counting the occurrences of a coral cover class on the transect line (Greig-Smith, 1983 and Hodgson *et al.,* 2004). The bottom constituents were classified basing on the RCO recommendations into Hard Corals (HC), Soft Corals (SC), Recently Killed Corals (RKC), Algae (NIA), Sponges (SP), Rocks (RC), Rubbles (RB), Sands (SD), Silts (SI), and Others (OT).

Fish, invertebrates and vegetation

A standard 100 m measuring tape was used to lay a transect belt of 100 long and 7 m wide between the depths of 4 m and 11 m. Inside the belt, the fish and invertebrates species were recorded and classified *in situ*.

3. Results

Corals

The coral communities of the study area are represented by 76 species of reef-building stony corals of the *Scleractinia*. They are composed predominantly, both in terms of composition and cover, by the families *Acroporidae*, *Faviidae* and *Poritidae*. A diverse mix of soft corals (*Alcyonarea*),

hydrozoan fire corals (*Anthomedusae*), gorgonians (*Gorgonacea*), black corals (*Antipatharia*), octacorals (*Pennatulacea*), sea anemones (*Zoantharia*), horn corals (*Melithaeidae*), hydroids, (*Hydroida*) and *Zoanthiniaria* are also present. The field investigation showed that, at 5 m depth, living cover of reef-building corals at individual reefs ranged from 8% (Beer AlMashi and Umluj) to 80%, (10 km south of Dubah) whereas soft corals ranged from 1% (10 km south of Dubah) to 54% cover (Yanbu cement factory) (Table 1).

Table 1. The percentages of the different components of coral reef ecosystem in the study area between Haql and Yanbu cities.

Site	Name	HC %	SC %	RKC %	NIA %	SP %	RC %	RB %	SD %	SI %	OT %	IV Sp.	Algae Sp.	Fish Sp.
1	Haql	19	2	0	0	0	21	0	58	0	0	11	2	103
2	AlHomaydah	43	8	3	0	0	44	0	2	0	0	14	2	124
3	Beer AlMashi	8	6	0	0	0	10	0	76	0	0	9	1	116
4	Sowayhal	NA												72
5	Meqna	60	14	0	0	1	1	0	24	0	0	14	2	150
6	Qeyal	NA												62
7	AlSorah	NA												37
8	AlBayedah	46	13	0	13	0	8	0	20	0	0	7	2	110
9	New Dubah Corniche	28	15	0	0	0	1	0	56	0	0	6	2	116
10	10 km south of Dubah	80	1	4	0	1	13	0	1	0	0	9	2	124
11	AlQof	28	18	6	0	0	42	0	6	0	0	10	2	131
12	Zobaydah-AlQof	35	17	3	0	1	39	2	3	0	0	11	1	94
13	Zobaydah	65	19	0	0	0	16	0	0	0	0	11	1	140
14	AlDomeghah	63	29	0	0	0	6	0	2	0	0	10	3	120
15	AlDomeghah-Haramel	53	23	0	0	0	12	0	12	0	0	11	3	106
16	Haramel	46	9	0	0	0	23	0	22	0	0	8	2	94
17	North of Wajh	55	23	3	0	0	19	0	0	0	0	10	7	99
18	AlWajh Desalination Plant	63	13	5	0	0	19	0	0	0	0	12	1	132
19	South of Ghawash	45	10	5	2	1	36	0	1	0	0	6	2	90
20	South of AlMeraisi	NA												22
21	South of AlKhorj	NA												12
22	AlKhowara	NA												8
23	AlNosbah	NA												76
24	Umluj	8	4	3	3	0	44	1	37	0	0	10	7	67
25	AlShabaan	59	15	3	0	1	22	0	0	0	0	15	4	124
26	Alhasi	32	40	0	0	0	6	1	17	0	4	10	4	99
27	AlMikharef	NA												61
28	Yanbu Cement Factory north	37	54	4	0	0	5	0	0	0	0	11	1	144
29	Yanbu Cement Factory sourth	NA										16	2	62
30	Yanbu north	53	31	1	0	0	4	0	11	0	0	12	4	123
31	Yanbu Creek	16	18	1	4	1	39	0	21	0	0	14	4	111
	Min.	8	1	0	0	0	1	0	0	0	0	6	1	8
	Max.	80	54	6	13	1	44	2	76	0	4	16	7	150
	Avg.	43	17	2	1	0	20	0	17	0	0	11	3	94

Fish

The field investigations showed that fish community of the study area is represented by 338 species from 62 families (Table 1). The minimum occurrence of fish families was found at AlKhowara (8 fish species from 3 families) while the maximum occurrence was found at Meqna (150 species from 33 families); the overall areal average is 94 species. Of the 62 fish families recorded in the area the most abundant fish family is *Pomacentridae* (30 species) followed by family *Labridae* (24 species) whereas 35 families are represented by one or two species. The most abundant fish species were *Chromis viridis, Pomacentrus aquilus, Plectroglyphidodon lacrymatus* (recorded at 21 sites), *Labroides dimidiatus, Chaetodon fasciatus, Heniochus intermedius* (recorded at 22 sites), *Parupeneus forsskali, Dascyllus aruanus, Chromis dimidiate, Thalassoma*

Klunzingeri (recorded at 23 sites), *Dascyllus trimaculatus, Chaetodon auriga* (recorded at 24 sites) and *Amblyglyphidodon leucogaste, Amblyglyphidodon flavilatus, Larabicus quadrilineatus* (recorded at 25 sites).

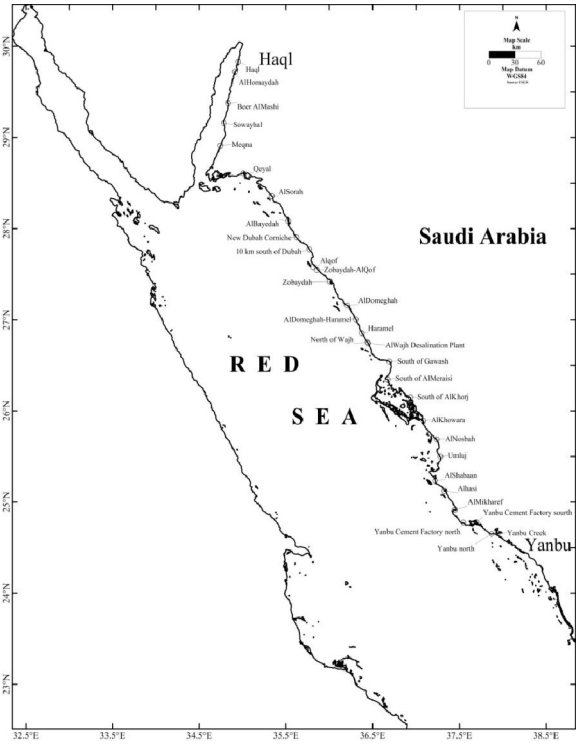

Fig. 1: The area of study and the locations of *in situ* reef check.

Invertebrates

The reef-associated invertebrates (sponges, crustaceans, polychaetes, mollusks and echinoderms) in the study area are relatively few. The occurrence of the invertebrates is minimum at sites 9 and 19 (6 species) and maximum at site 29 (16 species) with an overall areal average of 11 species (Table 1). The areal occurrence of reef-associated invertebrates showed more or less homogenous distribution pattern where 74% of the area hosts from 10 to 16 per site of reef-associated invertebrates species, and 26% hosts 6 to 9 species.

Algae

The four types of marine algae (Red, brown, green and blue-green) are present in the study area. The total number of algae species ranged between 1 (occurred at 22% of the area and 7 species (occurred at 6% of the area) with 70% of the area is occupied by 1 to 3 algal species (Table 1). Red algae are present at 9 locations, brown algae at 18 locations, green algae at 25 locations and blue-green algae at 8 locations. The relative abundance of algae is in the order green>brown>Red≈Blue-green.

Sea grasses

Seagrasses in the study area are scarce. A zone of continuous occurrence of seagrasses beds is located between Ghawash and AlNosbah. Isolated seagrasses beds are found at Sowayhal, AlSorah, 10 km south of Dubah and between Zobaydah and AlQof. Only four species of seagrasses occur in the area these are *Halophila stipulacea, Thalassia hemperichii,* and *Syringodium isoetifolium*, *Cymodocea sp.*

4. Discussion

Reef Distribution

The central-northern area from Haql in the Gulf of Aqaba to Yanbu supports a near-continuous coral reef tract composed of a wide range of reef types. The area supports relatively complex reef geomorphology, being comprised of mainland and island fringing reefs, various forms of patch reef, coral pinnacles and 'ribbon' barrier reefs (Ormond *et al.,* 1984a) provided a comprehensive review of the geomorphology and distribution of these reef types). Mainland fringing reefs are distributed along much of the study area coastline, and are often developed in the entrances and sides of sharms, a characteristic reef-form largely restricted to the Red Sea. Extensive mainland fringing reefs occur around Ras Baridi (60 km north of Yanbu), Umluj, AlWajh-Duba and in the Gulf of Aqaba, the latter often being narrow (<30 m width), developed as 'contours' on the relatively steep sub-littoral topography (Fishelson, 1980). Island fringing reefs are commonly developed in the Tiran area and from Duba - AlWajh Bank - Umluj.

Circular/elongate patch reefs are also widespread in offshore waters (< 50 m depth). Some patch reefs support sand-coral islands (cays), while others are submerged and resemble coral carpets as also described by Riegl & Piller, 1999. Both forms are common in the AlWajh Bank and south from Umluj. 'Reticulate' patch reefs, composed of interconnected networks of reef matrix separated by sand, and forming intricate reticulate patterns, are particularly well developed in shallow waters (< 10 m depth) of the Tiran area and southern AlWajh Bank. Pinnacles (individual corals and coral 'bommies' surrounded by sand) are present in shallow waters (< 10 m depth), particularly in the Al-Wajh Bank and Tiran areas (DeVantier and Pilcher, 2000).

Most reefs of the study area, at 5 m and 10 m depths, were in good to excellent condition. The percentages of living to dead corals ranged between 73% and 100%, with 86% of the surveyed locations lying in the range from 90% to 100%. The lowest percentages were found at

Umluj (73%) and AlQof (82%).In the Red Sea, Angelo *et al.* (2012) found that increased growth is the underlying physiological process associated with disease, wounding and stress-related colour changes in reef-building corals. There was little to no direct human impact (e.g. destructive fishing, anchor damage, coral mining or pollution) on the great majority of reefs, other than reefs in urban areas subject to land reclamation, urban run-off or littering. Coral communities on some reefs (ca. 10 % of those surveyed) thad also been adversely affected to greater or lesser extent by coral bleaching or predation. Bleaching was patchily distributed and highly variable in intensity, being most intense on reefs near Umluj. Predation by echinoderms and snails had no noticeable effect on coral cover or community composition on most reefs, where starfish and snail populations were at very low levels.

High cover of living corals was associated with reefs of relatively high exposure to wave energy and high water clarity. High coral cover was usually present on the shallow reef slopes of exposed fringing, patch and barrier reefs. With some important exceptions, reefs in low wave energy environments and reefs with low water clarity usually had lower living coral cover than their shallow, more exposed counterparts.

Species diversity of *Scleractinia* stony corals at individual sites in the study area ranged from 6–44 spp. (regional average = 25 spp.). Notably, there was only minor variability in species composition among the assemblages, with the entire region exhibiting a high degree of homogeneity in terms of coral community composition, both latitudinally and longitudinally. However, Riegl *et al.,* 2012 pointed to potentially increasing community homogenization and decline in average size of coral colonies throughout the Red Sea, after having remained constant from 1988 to 1997. These are phenomena that have also been observed in other peripheral seas. Reefs with moderate to high species diversity and abundance and living coral cover were widely distributed, with no clear latitudinal or longitudinal trends. Such reefs have high significance for replenishment, because of their potential as sources of large numbers of propagules of coral and of other reef-associated taxa.

Conservation Value

The area from Yanbu (northern Red Sea) to Haql (Gulf of Aqaba) is one of the most important coral reef areas for marine protected areas management on a global scale. Most of the region is presently unaffected by local human impact, other than in the vicinity of coastal cities and towns such as Umluj and Yanbu where reef fishing, land reclamation, urban run-off and coastal littering has occurred. Major additional threats include ship wrecks and oil spills and global impacts from future climate change (bleaching and reduction in reef-building capacity from projected changes in ocean alkalinity). Reefs in some areas of the region appear to be naturally buffered against the worst effects of coral bleaching, because of the prevalence of cool water upwelling. Reefs of high conservation value in terms of representativeness-uniqueness and 'quality' (i.e. high species diversity, high coral cover, and importance as reservoirs of biodiversity and replenishment) are widely distributed, from the Gulf of Aqaba and Tiran areas in the north, Duba-AlWajh, the AlWajh Bank, Umluj-Ras Baridi, and Yanbu. The following sub-regions are of special conservation importance:

- The Gulf of Aqaba: For the high levels of coral cover and species diversity, including species that are rare or apparently absent from other parts of the region (e.g. *Cantharellus doerderleini, Caulastrea tumida*). The high diversity is particularly significant given the restricted reef area, cool sea temperatures, and given that the Gulf of Aqaba is at the north western-most extent of reef development in the entire Indo-Pacific region.
- The Tiran Area: Extending from the mainland coast north of Duba to the entrance to the Gulf of Aqaba, for the wide variety of different biotopes and reef types, forming unique reef complexes with high zoogeographic significance. These reef complexes support a high species diversity including Red Sea endemic corals.
- The AlWajh Bank: For the greatest range of reef types (and other marine and coastal habitats) in the region. As with the Tiran area, reefs of the Al-Wajh Bank support Red Sea endemic corals, undescribed coral species and species with apparently restricted distributions. Its size and diversity of reef habitats, and likely high level of ecological connectedness in terms of larval dispersal in ocean currents, both within the Bank and to other parts of the Red Sea, afford it great conservation significance.

Coral Diversity

Red Sea: 111 coral species were identified in the study area (Sheppard & Sheppard (1985) identified 116), the most distinctive being those from exposed locations dominated by species of *Acropora* and those from sheltered locations dominated by species of Porites (Antonius *et al.,* 1990). Reefs around Yanbu were notable in supporting both a higher coral diversity and number of assemblage types than had previously been reported from the Red Sea (MEPA/IUCN 1987,

Sheppard & Sheppard (1991) and Sheppard (1997).

Some surveys have expanded this list substantially, with approximately 260 species of reef-building *Scleractinia* that were reported to occur in Saudi Arabian Red Sea waters (Veron 2000). Several additional species had been described from the Red Sea in the 19th century, but had either been synonymised or lost from recent species lists (e.g. the branching *Acropora variolosa* (Klunzinger, 1879), *Favites vasta* (Klunzinger, 1879) and *Echinopora forskaliana* (Milne Edwards and Haime, 1849) (Wallace, 1999, Veron, 2000). A further 16 species synonymised by Sheppard & Sheppard (1991) are considered as valid species in the Red Sea (Veron, 2000, DeVantier and Pilcher, 2000).

Coral Cover

There is considerable variability in cover of stony and soft corals in response to reef-specific characteristics and disturbance histories, and species-specific tolerances to stress, particularly exposure, levels of sedimentation, turbidity and illumination. Living cover of stony corals ranged from 8 % to 80 %, with an average of ca. 45 %. Approximately 45 % of sites had high living stony coral cover (>50 %), particularly at 5m shallow reef slopes, where large mono- and multi-specific stands of *Acropora*, *Porites* and *Millepora* were often conspicuous. At 10 m shallow reef slopes living cover of stony corals ranged from 18 % to 74 %, with an average of ca. 42 %. About 33 % of sites had high living stony coral cover (>50 %). Compared with the surveys conducted in 1998-99 in the central-northern Red Sea, where living cover of stony corals ranged from < 10 % to > 75 %, having an average of ca. 35 % (DeVantier and Pilcher, 2000) and 17 % of sites had high living stony coral cover (>50 %). It seems that the living stony corals cover is increased relatively showing some signs of improvements.

Dead standing corals was relatively minor components of cover (< 6 % at 5 m depth and < 5 % at 10 m depth) at most sites (averages ca. 2 % and 1 %, relatively). Highest levels of dead coral (4 % to 6 %) occurred off AlQof (site 11) Alwajh Desalination Plant (site 18) and Yanbu Cement factory site 28). Cantin *et al.* (2010) found that Three-dimensional computed tomography analyses of the massive coral *Diploastrea heliopora* in the Red Sea reveal that skeletal growth of apparently healthy colonies has declined by 30% since 1998. Cover of soft corals in the study area, at 5 m depth, ranged from 1 % to 55 % (average ca. 17 %). At 10 m soft corals cover ranged from 2 % to 64 % with an average of 22 %.

In 1997 cover of soft corals in the central-northern Red Sea ranged up to 50 %, but usually was < 30 % (average ca. 9 %). Large beds of *Xenia spp*. and stands of *Sinularia cf. capitalis* covering 100 m^2, were a characteristic feature of some area, the latter species forming large tree- like colonies to 2 m height and contributing substantially to reef accretion (Reinicke, 1997, Schuhmacher, 1997).

Although some reefs with high living coral cover occurred in sheltered habitats, particularly subsurface patch reefs of the Al-Wajh Bank, high cover of stony corals, soft corals and crustose coralline algae were all commonest on shallow reefs of high exposure with steep slopes and high water clarity.

Damage and Coral Mortality

Overall, most reefs (ca. 91 %) of the study area were in good to excellent condition in terms of the ratio of live to dead coral cover. In 1998-99 (DeVantier and Pilcher, 2000) reported a value of 90 % for the healthy condition of corals reefs in the central Northern Red sea. There was little to no direct human impact (e.g. destructive fishing, anchor damage, coral mining or pollution) on the great majority of reefs, other than reefs in urban areas subject to land reclamation, urban run-off and pollution or littering. Most damaged reefs occur in the immediate vicinity of the major coastal cities and towns especially off AlQof, AlWajh and Yanbu.

At most sites outside these areas, levels of injury and death of corals were low (< 6 % cover of dead corals).

No evidence of mass bleaching or other forms of major coral mortality were found during surveys. Most reefs appeared to be in good condition.

Predation by echinderms had no noticeable effect on coral cover or community composition on most reefs in the study area, where starfish and snail populations were at very low levels. Unlike the study area, starfish and snails were implicated in coral mortality in the southern Saudi Red Sea and Farasan Islands (Rouphael & Al Yami, 1999).

Fish Communities

An overall number of 338 species from 62 families were recorded in the study area. The areal occurrence ranged from 8 species at AlKhowara (site 22) to 150 species at Meqna (site 5). The most common family was *Pomacentridae* from which 32 fish species where recorded while the least common families were *Rhinobatidae, Torpedinidae, Centriscidae* and *Antennariidae* (only 1 species of each was recorded). Previous studies documented species composition and abundance of reef fishes in the Red Sea. Recent diversity estimates vary greatly. Randall (1983) lists 325 species, although this was not a comprehensive systematic account, rather a pictorial account of common taxa. Ormond & Edwards (1987) record 508 species, substantially

less than Botros (1971) with 776 species, Dor (1984) with 1,000 species or Goren and Dor (1994) with 1248 species. Differences among these various estimates are in part due to distinctions in the definition of 'reef fish', with the more conservative estimates being based on a stricter interpretation of the definition. Although many Red Sea reef fishes have distribution ranges that extend outside the Red Sea, to the Gulf of Aden, Arabian Sea and greater Indian Ocean and Indo-Pacific regions, others are presently considered 'endemic' to the Red Sea (Klauswitz, 1989). Levels of endemism vary among different groups of fishes, being particularly notable in the *Chaetodontidae*. These endemics and other Arabian and western Indian Ocean species give a characteristic structure to Red Sea reef fish assemblages in comparison with their central Indo-Pacific and eastern Pacific counterparts. Major threats to diversity and abundance of fishes in the Red Sea include increasing fishing pressure, and development pressures near coastal towns and cities (Krupp & Almarri, 2000).

5. Conclusion

The present study revealed that most reefs (ca. 91 %) of the study area (from Haql to Yanbu) were in good to excellent condition in terms of the ratio of live to dead coral cover. There was little to no direct human impact (e.g. destructive fishing, anchor damage, coral mining or pollution) on the great majority of reefs, other than reefs in urban areas subject to land reclamation, urban run-off and pollution or littering. Most damaged reefs occur in the immediate vicinity of the major coastal cities and towns especially off AlQof, AlWajh and Yanbu. At most sites outside these areas, levels of injury and death of corals were low (< 6 % cover of dead corals). No evidence of mass bleaching or other forms of major coral mortality were found during surveys. Most reefs appeared to be in good condition.

Local threats to Saudi Arabia's coral reefs originate primarily through industrial development and maritime transport. With these are associated risks of oil spills, land-filling, pollutant discharges, effluents from desalination activities and a number of other major impacts. Most acute damage to reefs is localised and restricted to offshore islands (in the Gulf) and around major urban areas (in the Red Sea). The local threats include:

1. Oil Pollution
2. Industrial Development
3. Maritime Transportation
4. Commercial and Residential Development
5. Land-filling
6. Dredging
7. Water Pollution
8. Desalination
9. Recreation and Tourism Activities
10. Bleaching (as a result of increase in seawater temperature)
11. Changes in seawater chemistry

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