

THE STATUS OF CORAL REEFS IN YEMEN - 2000

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Executive Summary

The Republic of Yemen lies in the south-western corner of the Arabian Peninsula, and includes the Socotra archipelago. The coastline is about 2200 km long, roughly one third of which is in the Red Sea and the remaining two thirds is in the Gulf of Aden. Only about 25 % of the Red Sea coastline supports coral reefs. The best developed reefs occur offshore, in the vicinity of the large number of islands which characterise the Yemeni Red Sea. Only 5 % of the Gulf of Aden coast supports fringing coral communities or reefs. There is extensive coral growth around the Socotra archipelago. True coral reefs developed on biogenic calcium carbonate are most widely developed in the Red Sea, fringing the mainland coast and offshore islands. The southern Red Sea reefs have a markedly different geomorphology to those of the northern and central Red Sea, with comparatively limited reef development, resulting from differences in bathymetry, topography, turbidity and sea temperature. The Gulf of Aden and Socotra have even less Holocene reef development than the southern Red Sea, mostly supporting coral communities developed directly on non-reef substrates or relict reef deposits.

Several major projects have recently assessed the distribution, composition and status of living marine resources around much of the Yemen coastline, focusing on the Red Sea coast, the Gulf of Aden and Socotra archipelago. Coral reef survey methods have included remote sensing using satellite imagery for Socotra, rapid ecological and impact assessments in the Red Sea, Gulf of Aden and Socotra, and more detailed biodiversity studies in the Red Sea and Socotra.

In excess of 250 species of reef building corals and 600 species of reef-associated fishes have been identified on Yemen reefs and coral communities. In particular, coral and fish communities of the Socotra archipelago are extremely diverse. A total of ca. 176 species of stony corals are presently known for the Yemen Red Sea, with richness at individual sites ranging from 1 to 76 spp. At least 19 new records have been identified for the southern Red Sea and further coral specimens await identification. Diversity is lower along the mainland Gulf of Aden coast, which is thought to support some 100 coral species but remains relatively poorly studied. In contrast, the Socotra archipelago supports a diverse fauna of ca. 240 stony coral species, placing it among the richest sites in the western Indian Ocean (Table I).

In the Red Sea, live coral cover was generally higher (ca.10 %) in the south than at most of the northern and central areas, and there were more large colonies at the southern part of Saba Island in the Zubayr group, and Mayun Island in the straits of Bab Al Mandab. Submerged patch reefs were the most dominant in terms of cover and abundance, and were found west of Al Hodeidah, South of Ras Isa peninsula and scattered in the southern Farasan

Islands in the inter island waters. Red algal reefs and associated coral communities occurred in the shallow coastal waters from the Saudi Arabian border south to the Ras Isa peninsula and around many nearshore islands.

In the Gulf of Aden there are at least six discrete areas where coral communities are developed, from the entrance to the Red Sea to Aden in the west, and from Belhaf to Al Mukalla in the east. Coral communities grow as a veneer over a rocky substrate of inorganic origin, usually discernible between colonies. Coral diversity is higher to the west of Al Mukalla where there are approximately 40 genera. In the north-east Gulf of Aden, coral communities are also found at the islands offshore from Bir Ali. These communities are of moderate diversity (100 spp. Scleractinia) and wide ranging coral cover (< 10 to > 75 %). The Bir Ali area supports the most concentrated distribution of coral communities known from the northern Gulf of Aden, with large coral patches developed offshore from the village and coral communities fringing the offshore islands.

Around the Socotra archipelago, coral communities are distributed patchily around the islands, with most extensive development on the north coasts. Trident Bay, on the SW side of Abd Al Khuri, was exceptional for a south coast location in terms of the cover and species richness of the coral assemblage and sizes of individual coral colonies. here is great variety in coral community structure around the archipelago. Individual sites are characterized by low to high coral diversity (13 - 81 spp. Scleractinia) and coral cover (from < 1 to > 75 %). Most coral communities are small and on the north coasts, where coral cover and diversity are higher than in macroalgal dominated south coast locations.

Cover of stony corals, dead corals, soft corals and algae were all highly variable among different sites within the Red Sea, Gulf of Aden and Socotra archipelago. Ratios of live : dead coral cover at individual sites were related largely to the differential effects of recent disturbance, notably coral bleaching in 1998. The northern Red Sea had low average live coral cover (17 %), high average dead coral cover (34 %) and high macroalgae cover (20 %). The northern and central Yemen coast and nearshore islands had very low live coral cover (3 %) and very high dead standing coral cover (averaging 34 %). Macro algae cover was also high (avg. 34 %). In the Gulf of Aden and Socotra archipelago, some sites supported high live coral cover (> 50 %). Examples include the islands offshore from Bir Ali and N coasts of the Socotra archipelago. On Socotra, north-facing sites generally had higher cover than their more exposed south-facing counterparts, the latter being more exposed to the SW Monsoon. Around the Socotra archipelago, cover of stony corals ranged from < 1 % to > 75 %, and in large patches (ca. 1,000 m²) attained ca. 100 %. Overall, living stony coral cover averaged ca. 20 % , with highest cover (ca. 35 %) on the Brothers (Samha, Darsa and Sabunyah Rocks). Stony coral cover was much higher on the north coasts (ca. 25 %) than on the south coasts (ca. 5 %).

Bleaching effects in 1998 were patchily distributed around the Socotra archipelago and NE Gulf of Aden. At worst affected sites more than half species were injured and about half of the live coral cover was killed. Pocilloporids, table and branching *Acropora* spp. and fire corals *Millepora* sp. were worst-affected, and changes occurred in species composition and relative abundance. On the north coast of Socotra, SSTs were > 31° C in May - June 1998, followed by rapid cooling (< 24 °C) in July 1998. Warming occurred in June in the NE Gulf of Aden.

Only in recent years has the protection of coral reefs been addressed. A fledgling tourism industry poses little threat to reefs in the form of anchor and flipper damage as compared with neighbouring countries. Coastal development, the petroleum industry and maritime shipping, on the other hand, pose a significant risk to reefs in the form of untreated sewage, land filling, and hydrocarbon pollution, among others. Fishing is a traditional profession for thousands of Yemenis. Fishermen operate from bases and landing sites spread along the mainland coastline and from a number of islands. Total annual catches vary between 90,000 and 95,000 mt and more than 90 % of the total fish production is landed by artisanal fishermen. Reef-based fisheries, for the most part, are underdeveloped and at a subsistence level.

There is one protected area and six proposed protected areas in Yemen. Establishment of marine protected areas is a relatively new process in Yemen, with funding and technical input from IUCN, the Global Environment Facility and PERSGA. The Socotra archipelago occupies some 362,500 km² and is home to diverse terrestrial plant and animal life with a high degree of endemism. Socotra is the main island, the others being Abd al-Khuri, Samha and Darsa. There are also smaller rock islets, Kal-faraon and Sabouniya. The Republic of Yemen is a party to international conventions, agreements and treaties which have implications on the marine environment. Similarly, a number of national instruments exist at various government levels which directly or indirectly concern coral reefs. One of the major gaps in coral reef conservation is the lack of funding to establish and implement regulations in marine protected areas. These will also need strict enforcement, and further research to acquire baseline information.

1. Introduction

The Republic of Yemen lies in the south-western corner of the Arabian Peninsula, and includes the Socotra archipelago. The coastline has a length of about 2200 km, roughly one third of which is in the Red Sea and the remaining two thirds is in the Gulf of Aden (Fig. 1).

Along the Red Sea, the climate is dry with an average annual rainfall of 100 - 200 mm and a humidity of about 60 %. No perennial surface streams discharge into the Red Sea. However, flash floods are a wide-spread feature following torrential rains. The Gulf of Aden is dominated by the Indian Ocean monsoon system. The highest annual rainfall occurs after flash floods between January and March (NE monsoon). Between May and September the SW monsoon generates winds in a north-easterly direction (SW Monsoon), and the relatively warm surface water of the Gulf of Aden is blown offshore and replaced by cooler, nutrient-rich water from deeper layers, limiting coral growth.

True coral reefs developed on biogenic calcium carbonate are most widely developed in the Red Sea, fringing the mainland coast and offshore islands. The southern Red Sea reefs have a markedly different geomorphology to those of the northern and central Red Sea, with comparatively limited reef development, resulting from differences in bathymetry, topography, turbidity and sea temperature. The Gulf of Aden and Socotra have even less Holocene reef development than the southern Red Sea, mostly supporting coral communities developed directly on non-reef substrates or relict reef deposits.

Yemen reefs and coral communities are developed in some of the most extreme environments known for corals, ranging from high sea temperatures, minimal tidal movement and relatively

calm sea conditions in the southern Red Sea, to seasonal cool water upwelling and large oceanic waves in parts of the Gulf of Aden and Arabian Sea. Areas exposed to the upwelling share a unique mix of tropical and temperate species, and highly productive fisheries.

Along Yemen's Red Sea coast, the seasonal influx of waters through the Straits of Bab al-Mandab results in relatively lower surface salinities and higher nutrients levels. About 75 % of the coastline consists of soft sediments and more than half of the shores are covered by sabkhas and salt marshes. The scarcity of hard substrates and the high turbidity along the wide and shallow continental shelf create unfavourable conditions for coral growth, and only about 25 % of the mainland coastline supports coral reefs. South of Al-Khaukha nearshore reefs are more extensive and diverse than further north. The best developed reefs occur offshore, mainly in the vicinity of the large number of islands which characterise the Yemeni Red Sea (IUCN 1987, Sheppard & Wells 1987, Sheppard et al. 1992).

Along the Gulf of Aden coast, which has a length of about 1400 km and a continental shelf area of 20,225 km², the southern extent is characterised by rocky cliffs that normally terminate in shallow water alternating with stretches of sandy beaches. Coral growth is limited by seasonally low temperatures as a result of the upwellings, and large expanses of unfavourable sandy substrate. Only 5 % of the coast is known to support fringing coral communities or reefs. Corals have been reported from Perim Island, near Aden (Khor Umairah, Little Aden), Ghuraira and Shuqra. More extensive areas of coral growth occur further east, towards Al Mukallā, particularly at Belhaf and Burum, and a group of six small islands lying off Bir Ali (Watt 1996, DeVantier & Hariri in press).



Fig. 1: Map of the Republic of Yemen indicating coastlines along the Red Sea and Gulf of Aden, inclusive of the Socotra archipelago.

The Socotra archipelago has long been isolated from the mainland, surrounded by deep waters, in places exceeding 3,000 m depth. It lies 400 km south of the Arabian peninsula and is highly exposed to the monsoon climate of the Indian Ocean. Annual rainfall is around 200 mm, mainly falling in June, November and December. Average air temperature ranges from 17 °C in January to 37 °C in July. Most of the coast consists of cliffs or sandy beaches with occasional gravel shorelines. Corals are widespread throughout the archipelago, with cover varying from less than 5 % to 80 % (UNDP/GEF 1996). Most of the coastal and marine areas surrounding these islands are still in a pristine state and in 1996, the Government of Yemen declared Socotra a special natural area in need of protection.

Major economic resources are port-related activities, fisheries, maritime traffic and oil and gas exploitation, and coastal and marine tourism play a minor role. Fish production is an important component of the GDP, with bases and landing sites spread along the mainland coastline and from a number of Islands. In the Red Sea, the continental shelf comprises are rich fishing grounds for finfish and prawn trawlers.

2. Methods

i. Geographical Scope

The coral reefs of Yemen are mainly found along the Red Sea coast, Socotra archipelago and some sites in the Gulf of Aden. Coral growth of the Red Sea coast is found both as coral reefs and coral communities on a variety of substrates. There are two principal reef types: (1) fringing reefs of the southern Red Sea coast and some offshore islands, and (2) semi-submerged patch reefs are found west of Al-Hodeidah and south of the Ras Isa peninsula. Coral reefs off the northern Gulf of Aden are limited by cold intense seasonal upwelling.

Several major projects have recently assessed the distribution, composition and status of living marine resources around much of the Yemen coastline, focusing on the Red Sea coast (Turak & Brodie 1999), Gulf of Aden (Watt 1996) and Socotra archipelago (Cheung et al. in press). Additional studies at key sites along the Gulf of Aden and Red Sea have been undertaken by members of the Arabian Seas Expedition (J. Kemp, U. Zajonz pers. comm.) and as part of smaller projects (e.g. assessment of coral bleaching in NE Gulf of Aden; DeVantier and Hariri in press).

ii. Coral Survey Techniques

Methods have ranged from remote sensing using satellite imagery (Socotra), rapid ecological and impact assessments (Red Sea, Gulf of Aden and Socotra), to more detailed biodiversity studies (Red Sea and Socotra). Most recently these studies have culminated in the initiation of long-term monitoring programs at selected sites in the Red Sea and Socotra archipelago.

Remote Sensing - Distribution and composition of coastal and marine biotopes around Socotra were assessed using Landsat images, combined with extensive ground-truthing. These data have been used to provide unsupervised and supervised biotope classifications of the coastal and marine habitats of Socotra (J. Turner & R. Klaus pers. comm.). In combination with biodiversity data (see later) the biotope classifications were used in planning the zone boundaries of the recently proclaimed Socotra multiple use marine protected area.

Rapid Ecological Assessment - The broad distribution of different coastal and marine habitat types, including coral reefs and coral communities, along the Yemen Red Sea, Gulf of Aden and Socotra coastlines has been documented using several rapid assessment methods (MacAlister Elliot & Partners 1995, Watt 1996, Turak & Brodie 1999, DeVantier et al. in press a-c). These and ongoing studies have begun to fill the previous large gaps in knowledge of Yemen coastal and marine habitats (Sheppard & Sheppard 1991).

The biological resources, resource uses and impacts along the 1,365 km coastline of southern Yemen were assessed at 91 geographically discrete sites (MacAlister Elliot & Partners 1995, Watt 1996). The sites were selected every 15 km along the shoreline, from West to East, on 1:100,000 scale topographical maps. Sites were physically located using GPS (WGS 84 map datum; EC/MFW 1995). Each sample comprised a 500 m × 500 m quadrat bisecting the beach, covering the immediate terrestrial, supratidal, intertidal and immediate subtidal zones. Within the quadrat, the abundance or magnitude of biological resources and resource uses / impacts were estimated and recorded semi-quantitatively. The abundance of biological resources were scored using a ranked 0 - 6 scale and scores were based on estimates of the relative abundance within each quadrat.

A rapid assessment was also made of the coastal and marine environments of the Socotra archipelago in 1995 (MacAlister Elliot & Partners 1996, Kemp 1998). The subtidal appraisal, conducted on snorkel or SCUBA, included general observations of benthic cover and more detailed assessments of coral and fish biodiversity (Kemp 1998). A nine point habitat code was used to classify sublittoral habitats, with observations of the dominant biota, providing an overview of the distribution and composition of coral and fish communities.

Further rapid assessments of coral reef status (levels of reef development, benthic cover and various environmental attributes) of the Socotra archipelago (DeVantier et al. in press a, in prep.) and the Yemen Red Sea (Turak & Brodie 1999) have been undertaken since 1995. The surveys were conducted at 51 sites along the Red Sea coast and offshore islands and 65 sites around the coasts of Socotra and adjacent islands. In meandering SCUBA swims of 30 - 45 min. duration, ecological and substratum attributes were assigned to standard ranked cover categories, based on an assessment integrated over the length of the swim (see DeVantier et al. 1998 for detail).

The sites were classified into one of four categories based on the amount of biogenic reef development:

- 1) Coral communities developed on rock, sand or rubble;
- 2) Incipient reefs, with some calcium carbonate accretion but no reef flat;
- 3) Reefs with moderate flats (< 50 m wide); and
- 4) Reefs with extensive flats (> 50 m wide).

The sites were also classified into one of four categories based on the degree of exposure to wave energy, where:

- 1) Sheltered;
- 2) Semi-sheltered;
- 3) Semi-exposed;
- 4) Exposed.

Sea temperatures were recorded in °C with a thermometer mounted on a SCUBA regulator (accuracy +/- 0.5 °C). The depths of the sites (maximum and minimum), average angle of reef slope to the horizontal, and underwater visibility were also recorded. The presence of any unique or outstanding biological features, such as particularly large corals or unusual community compositions, bleached corals (partial or total loss of pigments on living corals), coral predators, other cause(s) of coral mortality and rank abundance of echinoid bioeroders were also recorded.

Biodiversity Assessment - Taxonomic inventories of some key elements of reef fauna and flora have been undertaken in the Red Sea (corals: Turak & Brodie 1999; fish: Brodie et al. 1999), Gulf of Aden (corals: DeVantier & Hariri in press; fish: Arabian Seas Expedition, J. Kemp pers. comm.), and Socotra archipelago (fish: Kemp 1998, F. Krupp, U. Zajonz pers. comm.; corals: DeVantier et al. in prep.; crustaceans, molluscs and other fauna and algae, various authors in GEF-UNDP Socotra Biodiversity Project Progress Reports).

For corals, bio-inventories of the Socotra and Red Sea fauna were undertaken during SCUBA swim searches at each site. Each species was identified to species level whenever possible, and to genus and growth-form for taxonomically difficult species. Stony corals that could not be readily identified in the field were photographed, collected and bleached for detailed study. The bleached coralla are stored as a permanent reference collection as part of the GEF-UNDP Socotra Biodiversity Project.

At the end of each swim search, the bio-inventory list was reviewed, and each taxon was categorized in terms of its relative abundance in the community using six ordinal ranks. For each coral taxon, a visual estimate of the total amount of injury (dead surface area) was made and the approximate proportion of colonies of each taxon in each of three size classes was estimated.

Reef fish composition and abundance in the Red Sea, Gulf of Aden and Socotra archipelago have been assessed using both quantitative (belt transects, collecting stations) and semi-quantitative (visual census) field methods (Kemp 1998, pers. comm., Brodie et al. 1999, U. Zajonz pers. comm.).

For quantitative assessments, numbers and/or log abundance estimates and/or sizes of fishes were made in single or replicated belt transects of known volume (e.g. 50 m length, 5 m width, 5 m height above sea bed). In Socotra, fish surveys were undertaken jointly with the coral surveys, allowing combined community analyses. Fish species composition around the Socotra archipelago was also assessed at point sampling stations, where the fish narcotizing agent Rotenone was used to collect fishes (U. Zajonz pers. comm.).

For semi-quantitative assessments, fish species lists and abundance estimates were compiled at point census stations or during SCUBA swims, using standard rapid assessment methods (see English et al. 1997).

iii. Sea Surface Temperature Studies - Red Sea

As part of the GEF-UNDP Yemen Red Sea Project, a sea temperature monitoring program was established in 1998. The program is presently monitoring sea surface temperature using submerged temperature loggers (Dataflow 392 loggers). These have been deployed at Mayun island near the entrance to the Red Sea, and a further two loggers were deployed near Al

Luhayyah in the north, recording temperature every 30 min. (Rouphael et al. 1999, M. Al Safani pers. comm.).

iv. Benthos and Fish Monitoring - Socotra Archipelago

A long-term monitoring program was established around the Socotra archipelago in 2000. Recent assessment found surprisingly diverse reef coral and associated fish communities, and selection of monitoring sites was based on initial surveys of benthos and fish conducted in 1999. The 11 monitoring sites that were selected are distributed widely around the archipelago, with seven sites on Socotra Island, and one site each on four of the smaller outer islands of Abd Al Khuri, Samha, Darsa and Kal Faraon. The sites were located in a variety of benthic community types, ranging from those dominated by mono-specific coral stands to those supporting diverse coral assemblages to those dominated by macroalgae with sparse corals. These communities had been affected to greater or lesser degree in 1998 by the global coral bleaching event. Several of the sites had experienced major bleaching-induced declines in cover and shifts in community composition in 1998 whereas others had been little- or unaffected, and represented near-pristine reef habitats in terms of cover and community structure.

Field methods followed Global Coral Reef Monitoring Network (GCRMN) standards, employing sets of replicated line intercept transects (5 x 20 m length for benthos) and belt transects (3 x 50 m length, 5 m width and height for fish). The special nature of coral habitats around the Socotra archipelago, with little true reef development and often small coral patches with little or no reef slope, required modification of the GCRMN protocol. The lack of reef slope precluded establishment of two sets of transects (at two depths) per site, rather each site was at a single depth range (3 - 5 m or 8 - 11 m). Further, transects were aligned roughly parallel to each other approximately 15 m distance apart.

3. Status of Coral Reefs - Benthos and Fish

i. Summary

In excess of 250 species of reef building corals (Sheppard & Sheppard 1991, Sheppard 1997, Turak & Brodie 1999, DeVantier et al. in press) and > 600 species of reef-associated fishes (Kemp 1998, Brodie et al. 1999, Zajonz pers. comm.) have been identified on Yemen reefs and coral communities. In particular, coral and fish communities of the Socotra archipelago are surprisingly diverse, given that there is little reef development. The islands lie at a crossroads among different faunal provinces and sub-provinces, and the coral and fish faunas show biogeographic affinities with Arabia, east Africa and the greater Indian and Indo Pacific regions.

Some of Yemen's reefs have been adversely affected by various disturbances over the past decade, causing major declines in living coral cover and shifts in community composition at worst affected sites in the northern part of the Red Sea (Turak & Brodie 1999) north-east Gulf of Aden (DeVantier & Hariri in press) and north coast of Socotra (DeVantier et al. in press b). Bleaching has adversely affected reefs and coral communities in all three areas, most recently during 1998. Other more localised disturbances include predation by the crown-of-thorns seastar and gastropod snails, sedimentation, storm damage and flood run-off. Although these disturbances have had adverse impacts in some locations, particularly in the Red Sea, other Yemeni reefs, particularly in more exposed clear water areas of the southern

Red Sea and outer islands of the Socotra group, remain in good to excellent condition, with little or no local human impact.

In Socotra, preliminary results indicate that there had been little change in coral cover or community composition from 1999 to 2000, other than an apparent increase in coral recruitment at sites badly impacted by bleaching in 1998. The rapid growth of coral recruits suggests that very small juvenile corals survived the 1998 bleaching-induced mortality. Some recent (post-bleaching) coral mortality had occurred at several sites, possibly caused by flood run-off during intense rains of December 1999. Most outer island sites were in good - excellent condition, and presently have low levels of human use. These sites give the Socotra islands international importance as a coral reef monitoring centre, as such sites are becoming rare in many coral reef-bearing countries, where human impacts are causing loss of valued reef attributes.

The islands are presently undergoing rapid development and are receiving increasing national and international attention as a tourism destination and as an export source of fish and coral. Thus the recent proclamation of a large multiple-use marine protected area around the Socotra archipelago by the Government of Yemen is both timely and well conceived. The monitoring sites will prove important in assessing effectiveness of the zoning plan and other management practices. Following on-site training, the Yemen national team hold sufficient expertise to continue monitoring, providing funding is available. With completion of the present GEF-UNDP project in 2001, it is crucial that financial support for management is continued. If not, there is a real possibility that the unique living marine resources of the area will be rapidly depleted.

ii. Coral Diversity

Yemen reefs support > 250 species in 60 genera and 14 families of scleractinian stony corals (Sheppard & Sheppard 1991, Sheppard 1997, Turak & Brodie 1998, DeVantier & AbdalAziz unpubl.), the high richness reflecting the wide range of habitat types, oceanographic and environmental conditions.

A total of ca. 176 species of stony corals are presently known to occur in the Yemen Red Sea (Turak & Brodie 1998). Richness at individual sites ranged from 1 to 76 spp. Of 51 Red Sea bio-inventory sites almost 50 % of sites had more than 40 coral species and 12 % of sites had over 50 species, similar to counts at reefs in the central and northern Red Sea (DeVantier et al. in press c). Turak & Brodie (1999) identified at least 19 new distribution records for the southern Red Sea, based on the list compiled by Sheppard & Sheppard (1991), and further coral specimens await identification.

Diversity is lower along the mainland Gulf of Aden coast, which is thought to support some 100 coral species (Sheppard & Sheppard 1991, DeVantier & Hariri in press), but remains relatively poorly studied. By contrast, the Socotra archipelago supports a diverse fauna of ca. 240 stony coral species, placing it among the richest sites in the western Indian Ocean (Table I). The high diversity is related to the co-occurrence of a composite coral fauna from different biogeographic provinces and sub-provinces, including species with wide Indo Pacific ranges, species from the Indian Ocean, species previously known only from E. Africa, Arabia or the Red Sea (DeVantier et al. in press) and undescribed species (Veron in press).

A high degree of similarity in stony coral richness and composition between the Red Sea and Socotra archipelago exists at family and generic levels, whereas the Gulf of Aden is relatively depauperate at generic and species levels (Table I). At individual sites in the Red Sea, Gulf of Aden and Socotra, coral richness ranges from < 5 spp. to > 70 spp. Low diversity sites include those composed of large monospecific coral stands (covering 1,000s of m²), sites on coralline algal reefs, or sites where environmental characteristics are suitable only for tolerant corals (Sheppard & Sheppard 1991, Turak & Brodie 1999). Sparse coral assemblages (with several notable diverse exceptions) are common along the exposed southern coastlines of the Socotra archipelago, where monsoonal upwelling and high biomass of macroalgae and other benthos tend to limit coral growth. High diversity assemblages are more commonly found in areas of moderate water movement and clarity, notably on the offshore islands of the Red Sea (Turak & Brodie 1999), north-east Gulf of Aden and protected northern coasts of outer islands of the Socotra island group.

Table I: Species diversity of reef-building stony corals from the Yemen Red Sea (Turak & Brodie 1999), NE Gulf of Aden (DeVantier & Hariri in press) and Socotra archipelago (DeVantier & AbdalAziz unpubl.).

<i>Taxonomic level</i>	<i>Red Sea</i>	<i>NE Gulf of Aden</i>	<i>Socotra islands</i>
Family	14	14	14
Genus	56	38	56
Species	176	100	240

iii. Reef distribution and coral communities

Red Sea Coastal and Island Fringing Reefs - Live coral cover was generally higher (ca.10 %) in the south than at most of the northern and central areas, and there were more large colonies (up to 3 - 4 m diameter) at the southern part of Saba Island in the Zubayr group, and Mayun Island in the straits of Bab Al Mandab. There was a long fringing reef from just north of Al Khawthah down the coast to opposite Mayun island. This reef continued in patches around the rocky headland on the Gulf of Aden coast. The width varied from less < 100 m up to > 1 km enclosing a shallow lagoon (0.2 - 1.5 m depth). The seaward margin typically dropped to around 3 m except south of Al Mulbah, where there was a healthy patch of *Platygyra* colonies on a sandy bottom at 5 - 6 m. *Acropora* spp. were more evident than farther north and formed stands of branching colonies. *Porites* spp. and *Stylophora pistillata* colonies were found at all sites. Other common species were *Montipora* spp., *Acropora valida* and *A. humilis*, *Porites nodifera*, *Pavona cactus*, *Galaxea ascicularis*, *Acanthastrea echinata*, *Hydnophora* spp., *Favia fava*, *Goniastrea retiformis*, *Platygyra daedelea*, *Leptastrea purpurea* and *Echinopora gemmecea* (Turak & Brodie 1999).

Fringing reefs around the islands were in the form of extensive patches with gradual slopes and intermittent sand areas. Some of the coral patches and ridges were formed by coral rubble accumulations from storm activities. These rubble ridges were often covered with thick mats of *Dictyota* sp. In addition to *Stylophora pistillata* and *Porites* spp., *Psammocora contigua* was very common on one reef. Most *Acropora* corals were dead, including numerous tabular colonies.

Mayun island, at the mouth of the straits of Bab al Mandab and subject to the effects of periodic nutrient-rich cold water upwelling from the Indian Ocean, had distinct coral reef formations. The island is of volcanic origin with reef growth on basal volcanic rock. On the northern side, extensive reef flats with diverse and healthy coral growth have developed. The eastern and western sides support predominantly monospecific *Stylophora* communities, and bays on the southern side have healthy growth of corals dominated by large *Porites* colonies up to 4 - 5 m in diameter. The corals survived the 1997/1998 bleaching event.

Red Sea Submerged Patch Reefs - In terms of surface and volume, these reefs may be the most dominant. Large patches are found west of Al Hodeidah, South of Ras Isa peninsula and scattered in the southern Farasan Islands in the inter island waters. The shallower parts generally are 6 - 8 m deep, although some reefs in the southern Farasan group grow to just below sea surface. Several large patches appeared not even to be marked on current hydrographic charts. The dominant corals are *Porites* spp..

Red Algal Reefs and Associated Coral Communities - Red algal reefs occur in the shallow coastal waters from the Saudi Arabian border south to the Ras Isa peninsula and around many nearshore islands, in waters < 6 m (typically 2 - 4 m depth). On these reefs coral growth ranges from a few small colonies of some hardy species to extensive coral communities with high substrate cover. These reefs are essentially built by red coralline algae of the genera *Porolithon* and *Lithothamnium*, and support limited coral reef development. They are generally found in semi sheltered, low energy environments with high temperature, salinity and sedimentation levels. The more tolerant corals to these conditions are the Pocilloporidae, *Porites* spp. (massive growth forms) and *Siderastrea savignyana*. Coral colonies on these reefs do not attain large sizes, reaching a maximum of around 50 cm diameter. In addition to corals, fleshy macroalgae are also associated with the coralline algal reefs. The main species are *Caulerpa* sp., *Sargassum* sp. and *Padina* sp. At times dense *Sargassum* mats, which may have fronds growing more than 2 m in length can totally obscure the underlying coralline red algal growth.

Coral Communities on Volcanic Rock - Offshore islands of the Hanish and Zubayr groups and At Tair island support some areas of extensive coral development and a high diversity of scleractinian corals. *Porites* species were the dominant coral. Similar diversity of hard coral species was also found in coral communities on mid water pinnacles of volcanic origin, such as Six Foot Rocks south of Tiqfash Island and Avocet Rock south of Hodeidah. These pinnacles, rising from 40 - 60 m, support rich and abundant fish fauna. The highest recorded coral species diversity (76 species, Brodie et al. 1999) was at a community on Six Foot Rocks, and was comparable to diversity levels in other areas of the Red Sea.

Around At Tair and islands of the Zubayr group, small coral colonies of massive growth form, mostly *Porites*, grew unattached to the flat volcanic rock. Other common corals were massive *Coniastrea retiformis*, encrusting *Acropora*, *Montipora* and *Leptastrea* and *Cyphastrea* species. Under the volcanic ash cliffs of At Tair island, where fine sediments predominated, very large *Siderastrea savignyana* colonies were developed, reaching several meters in diameter and typically partially buried in shifting sediments.

Coral Growth on Relic Reef Formations - Virtually all the corals in this area had suffered mortality from a recent wide spread mortality event. The extent of coral or coral reef growth could not be established, since most of the dead coral was covered with algal growth.

Previous surveys reported luxurious branching and foliaceous coral growth in these shallow coastal areas. However, the dominant pattern of size distribution of corals, including dead ones, suggest that there may not have been long periods of sustained coral growth. Dead coral surfaces were covered by fleshy macro algae such as *Sargassum*, *Padina* and *Dictyota* spp. In addition, the long spine black sea urchin *Diadema setosum* was common in the area and particularly prevalent on reef edges around Tiqfash, Uqban, Fasht Islands and offshore from Al Luhayyah. Most of the live coral appeared to be of growing remnants from the latest wide spread mortality.

Although the Yemen Red Sea reefs have proven surprisingly diverse in species composition, the main structural elements are massive corals in the genus *Porites*. These are by far the most common genus of reef-building coral in Red Sea waters of Yemen and the main reef framework builder of contemporary coral reefs in this region. The other two most common corals were *Stylophora pistillata* and *Platygyra daedelea*, both species found in a wide range of habitats.

Gulf of Aden - Until recently, descriptions of coral communities from the northern coast of the Gulf of Aden were sparse (Sheppard & Sheppard 1991). More recent surveys have demonstrated that there are at least six discrete areas where coral communities are developed along the Gulf of Aden coast - concentrated from the entrance to the Red Sea to Aden in the west, and from Belhaf to Al Mukalla in the east. Coral diversity is higher to the west of Al Mukalla where there are approximately 40 genera (Table I). East of this point growth is limited to isolated colonies of a few genera, principally the more hardy or massive forms such as *Stylophora*, *Porites* and various faviids, a finding echoed by studies in southern Oman (Barratt 1984). Low sea water temperatures associated with upwelling and competition for light from algae probably limit growth while grazing by urchins and herbivorous fish are important in determining larval settlement rates.

Generally, coral communities in the Yemeni Gulf of Aden grow as a veneer over a rocky substrate of inorganic origin, usually discernible between colonies. Thus these are coral communities rather than true reefs. Cold water upwelling and the limited distribution of available habitat are the two principal factors which limit coral diversity and growth in the area, although other factors such as turbidity and scouring also may be important. Along the north-west Gulf of Aden coast, key sites include:

Khor Umairah: This is a semi-enclosed lagoon cut off from the sea by a large spit and an ideal habitat for seagrasses (Hirth et al. 1973). Large coral areas occur in the lagoon, where the sheltered conditions in the lagoon favour coral growth by reducing wave energy.

Crater, Aden: The coral fauna at this site forms a veneer over steeply sloping volcanic rocks and boulders down to 8 m depth where a gently sloping sandy bottom prevents further colonisation. Live coral cover is high on average (30 - 50 %) although it reaches 100 % in places. Massive growth forms of *Porites* colonies dominate, and at least 20 other genera were also present, including large colonies of *Lobophyllia*, *Galaxea*, the solitary coral *Fungia* and *Turbinaria* in deeper water. Rosen (1971) reports a total of 32 genera for the Aden area.

Shuara: The area is relatively diverse and supports two examples of a larger reef complex in the area. The corals at site Shuara itself showed evidence of forming a true fringing reef (typical reef profile with reef flat, reef crest and slope; the development of a massive, wave-

resistant structure composed of biogenic carbonate). Live coral cover ranged from < 5 % on the reef flat, to 30 - 40 % at the sample site 20 km east of Shuara. Both sites were dominated by *Stylophora* and *Porites*, with a range of other genera in lower abundances, with Faviids and Acroporiids being well represented.

Further to the east, in the north-east Gulf of Aden, coral communities are developed from Belhaf to Al Mukalla and including the islands offshore from Bir Ali. These coral communities are of moderate diversity (ca. 100 spp. Scleractinia) and low - high coral cover (< 10 to > 75 %, DeVantier & Hariri in press).

Community structure of individual sites ranges from monospecific coral stands (including *Pocillopora damicornis*, *Stylophora pistillata*, *Goniastrea retiformis*, *Porites* spp., Kemp and Benzoni 1999, DeVantier & Hariri in press) to moderately diverse assemblages of tabular and branching acroporids, massive and encrusting faviids, mussids and poritids. Despite the general lack of reef development, the area supports some large corals estimated to be centuries old.

Belhaf: The area around Belhaf is volcanic with extensive lava fields leading to the coast in places and providing a suitable substrate for coral colonisation. Conditions are favourable for reef formation, and have resulted in the growth of a mature fringing reef, dominated by *Porites* colonies and occasional large *Acropora* tables, staghorn beds and foliose *Montipora* stands. This site was particularly badly affected by coral bleaching in 1998, with major reduction in living coral cover (DeVantier & Hariri in press).

Bir Ali and Offshore Islands: The Bir Ali area supports the most concentrated distribution of coral communities known from the northern Gulf of Aden, with large coral patches developed offshore from the village and coral communities fringing the offshore islands. Community structure at individual sites varies from large monospecific stands of pocilloporids, faviids and poritids to moderately diverse assemblages (ca. 50 spp. Scleractinia). Coral and fish communities on the islands offshore from Bir Ali are particularly well developed, share interesting biogeographic affinities and may be important in maintaining gene flow along the Gulf of Aden coast.

Broum: Coral growth forms only a veneer over the volcanic outcrop and boulders in the shallow sublittoral, although at this site the more fragile foliaceous and branching forms of *Montipora* dominate the live coral cover, with *Porites* and other massives also contributing significantly. Wave energy significantly influences the composition of coral assemblages along this stretch of coast.

Al Mukalla: The area supports both shallow (1 - 10 m) and deep water (15 - 25 m) coral communities, mostly developed directly on terrigenous rock. Shallow water assemblages were composed of massive poritids, faviids and mussids, and tabular *Acropora* spp., with cover of live coral approaching 50 % at several locations. These assemblages were adversely affected by bleaching in June 1998, with loss of ca. ½ live coral cover at worst affected sites. Deeper assemblages, composed predominantly of encrusting and massive faviids, mussids and siderastreids, were less affected by the bleaching event, with living coral cover remaining at ca. 10 %.

Ras Fartak and Ras Fantas: The area around Ras Fartak and Ras Fantas is influenced by seasonal upwelling. The sublittoral epifauna is dominated by ascidians, sponges and large populations of urchins. Small encrusting coral colonies covered 1 - 5 % of the substrate, composed mainly of Faviids, *Porites* and *Stylophora* species and small branching colonies of *Acropora*.

Socotra Archipelago - Coral communities are distributed patchily around the islands, with most extensive development on the N coasts. The S coasts are more strongly dominated by macroalgae, although some sites supported assemblages of stony and soft corals interspersed among macroalgae, turf and coralline algae and/or barrel-foliose sponges (e.g. Socotra: Qataninh, Qaara, Bidholan; Abd Al Khuri: Bandar Salih, E. Ras Lubaynah ‘Trident Bay’; and SW Samha). Trident Bay, SW Abd Al Khuri, was exceptional for a south coast location in terms of the cover and species richness of the coral assemblage and sizes of individual coral colonies.

The communities were developed from low tide level to > 20 m depth, with most occurring on gentle slopes (< 10° to the horizontal), and usually surrounded by sand or merging into sand on their deeper extent. With some exceptions on the N coasts, the communities were of small aerial extent (1 - 5 ha). Most communities occurred in semi-sheltered environments, although distributed over the full range of exposures, from sheltered to highly exposed (S coasts).

There was little to no recent (Holocene) reef development at most sites around the archipelago, with ca. 2/3 of sites classified as incipient reefs with some accretion, and ca. 1/3 as coral communities developed directly on rock, sand or rubble (mostly on the S coasts). Some communities were growing on relict ‘spur and groove’ structures that probably represent earlier (pre-Holocene) periods of reef development.

There is great variety in coral community structure around the Socotra archipelago. Individual sites are characterized by low to high coral diversity (13 - 81 spp. Scleractinia, average 44 spp.) and coral cover (< 1 to > 75 %, average 22 %). Most coral communities are small (1 - 5 ha) and developed on the north coasts, where coral cover and diversity are higher than in macroalgal dominated south coast locations (N coasts average: 27 % coral cover, 46 spp., S coasts average: 5 %, 35 spp.).

The outer islands (Abd Al Khuri, Samha, Dahsa and Kal Farun) were on average more diverse than Socotra for both corals and fish. As with the Gulf of Aden, some corals attained great size and are centuries old, although there is little recent biogenic reef accretion. The lack of Holocene reef development is likely to be related to recurrent mass mortality from intense monsoonal upwelling or ENSO events, competition with macroalgae, episodic burial under sediments, high rates of bioerosion and the recent initiation of reef growth late in the Holocene. Some communities, notably on the N coast of Socotra Island and north-east Gulf of Aden, were adversely affected by elevated sea temperatures (> 31° C) in May - July 1998, causing mass coral bleaching and mortality, and resulting in major reductions in cover and shifts in community composition at worst-affected sites (DeVantier & Hariri in press, DeVantier et al. in press b). Other sites, particularly on the outer islands of Socotra group, were little affected, exhibiting high living cover and little damage. These communities also support other reef-associated species of high conservation value and/or economic importance.

The following account is summarised from DeVantier et al. (in press a, in prep.). Coral communities showed great variety in composition, dominance and cover, being variously composed of massive (poritids, faviids, oculinids and mussids), tabular (*Acropora* spp.), branching (*Acropora* spp. and pocilloporids), foliose (mostly *Turbinaria* and *Montipora* spp.), encrusting (*Montipora* spp., faviids, merulinids and pectiniids) and ‘mushroom’ (fungiids) growth-forms. The hydrozoan ‘fire corals’ *Millepora* spp. were also important components of some biotopes. Several coral biotopes were composed of large monotypic or low diversity stands of massive, submassive, tabular, encrusting and/or foliose (R. Klaus pers. comm.) or branching corals. Others were composed of more diverse coral assemblages of a variety of growth forms, often developed in close proximity to the former monotypic areas. Field observations suggested that the coral communities were structured by ca. 19 inter-grading coral - algal assemblages (Table II).

Table II: Grading of coral community coral - algal assemblages.

<i>ID</i>	<i>Description</i>
1	Monotypic massive Porites spp. (W coast Socotra, Kal Farun),
2	Monotypic massive Galaxea astreata (N coast Socotra),
3	Monotypic massive Goniopora stokesi (N coast Socotra),
4	Monotypic sub-massive Pavona maldivensis (N coast Socotra),
5	Monotypic branching Stylophora kuehlmanni (N coast Socotra, R. Klaus pers. comm.),
6	Monotypic table Acropora clathrata and / or Acropora downingi (N coast Dahsa),
7	Monotypic staghorn Acropora muricata (formerly A. formosa N coast Samha),
8	Monotypic foliose-encrusting Montipora cf. circumvallata (W coast Abd Al Khuri, R. Klaus pers. comm),
9	Monotypic fire-corals Millepora spp. (N coast Socotra),
10	Massive Goniastrea retiformis - branching Acropora palifera (N coast Socotra),
11	Mixed massive assemblages of faviids, mussids, poritids, agaric13iids (N coasts Socotra, Samha, Dahsa),
12	Massive poritids, faviids - table and branching Acropora (N coasts Socotra, Samha, Dahsa),
13	Encrusting - foliose agariciids, pectiniids, faviids, dendrophylliids (N coast Socotra),
14	Mixed stony - soft corals (N coast Abd Al Khuri),
15	Hydrozoan ‘fire corals’ with other massive corals, notably Porites spp. (N coast Socotra),
16	Soft corals Sarcophyton, Sinularia, Cladiella, Litophyton, Xenia spp. (N coast Abd Al Khuri),
17	Mixed assemblages of frondose macroalgae, hard and soft corals (S coast Socotra),
18	Diverse frondose macroalgae and/or sponges with sparse corals (S coast Socotra, Abd Al Khuri, Samha),
19	Rhodoliths of crustose coralline algae with sparse corals (Kal Farun).

These assemblages formed six major benthic community types (Table III) defined from multivariate analysis of all sessile taxa including algae. The following section provides a brief descriptive overview of the coral communities and coral community types (see Table III for descriptions) that are known to occur in the marine National Parks and Nature Sanctuaries of the recently proclaimed Socotra marine protected area.

Table III: Classification of benthic community types.

<i>Type</i>	<i>Description</i>
A	Low - moderate diversity assemblages of massive, submassive or branching corals, mostly on N coasts.
B	Low - high diversity macroalgae, low - moderate coral diversity, mostly on S coasts.
C	Moderate diversity coral assemblages composed predominantly by tabular <i>Acropora clathrata</i> and <i>A. downingi</i> , mostly on N coasts of Samha and Darsa.
D	Moderate - high diversity coral assemblages composed predominantly by massive <i>Porites</i> spp. and/or <i>Millepora</i> spp., mostly on N coasts.
E	High diversity assemblages of stony and soft corals, mostly on N coasts.
F	Moderate - high diversity shallow water assemblages composed predominantly by acroporids, N coasts.

Socotra Island, Ras Momi National Park, Qallus Nature Sanctuary: Coral community type: B. The Qallus Nature Sanctuary is composed of a sublittoral area of terrigenous rock located approximately 1 km off the extreme eastern tip of Socotra Island. From its shallowest point (ca. 6 m depth), the area shelves into deeper (> 20 m depth) waters, with development of sand-filled surge channels one - two m deeper than the surrounding rock pavement. There is no biogenic accretion, with the very sparse corals developed directly on the basement terrigenous rock. The area supports extensive and diverse algal communities, composed of macro-, encrusting coralline and turfing taxa, and covering most of the available substrate (ca. 90 % benthic cover). Similar algal-dominated benthic communities occur along the adjacent coastline.

Scattered amongst the macroalgae is a sparse cover of stony and soft corals (< 1 % benthic cover) of low diversity (ca. 15 wave-tolerant species), mostly developed as small encrusting / stout branching colonies nestled in protected crevices. These include the siderastreids *Anomastrea irregularis*, *Siderastrea savignyana*, *Psammocora haimeana* and *Coscinaraea columna*, the pocilloporids *Pocillopora verrucosa* and *Stylophora pistillata*, the acroporids *Acropora appressa* and *Montipora* n. sp. (Veron in press), and faviids *Leptastrea*, *Favites* and *Goniastrea* spp.

NE Socotra (Halleh - Delysha) National Park - Coral community type: F. The National Park coastline adjacent to Roosh around Dubihil - Siqua supports extensive shallow coral communities (0.5 - 8 m depth), including some of the best examples of shallow Holocene biogenic accretion around the archipelago. High mortality of shallow-water acroporids occurred following the 1998 bleaching event. Massive and encrusting corals were less affected. Recruitment by acroporids was occurring in 2000. This area was selected as a Subtidal Monitoring Site.

Roosh Nature Sanctuary - Coral community type: D. The Roosh Nature Sanctuary is located seawards of the eastern fish landing site of the Siqua district on the NE coast of Socotra Island. The Nature Sanctuary covers a subtidal (ca. 9 - 15 m depth) area formed from extensive growth of various forms of stony and fire corals, developed on a terrigenous basement. From its shallowest point at ca. 9 m depth, the coral community shelves gently into deeper waters (> 15 m) with sandy substrate. This area was selected as a Subtidal Monitoring Site.

The coral community is one of few around the archipelago composed predominantly by the stony hydrozoan 'fire corals' *Millepora* spp. (mostly *M. cf. platyphylla* and *M. cf. exaesa*). This area was selected to accommodate Subtidal Monitoring Site # 11. In addition to the predominant fire corals *Millepora* spp., large massive colonies of *Porites* spp., and a diverse range of other massive and encrusting coral species are present. Coral cover in patches is ca. 50 %, dominated by the fire corals. There is little macro-algal development, although encrusting corallines and to a lesser extent turfing algal species are common. Some of the massive *Porites* colonies are of considerable size (ca. 3 m diam. and 2 m ht) and are likely to be over a century old. These provide a high degree of topographic relief and shelter sites for a diverse range of fishes.

Some coral species were adversely affected by the bleaching event of May 1998, notably the previously common *Acropora palifera* and branching pocilloporids, the dead skeletons of which remain standing *in situ*. Shallower coastal coral communities were worse affected, with high mortality of staghorn and table *Acropora* spp.

Di Timri Nature Sanctuary - Coral community types: A, B, C. The Nature Sanctuary extends seawards from the coastline near the village of Di Timri in the west of the Siqua district on the NE coast of Socotra Island. The Nature Sanctuary covers an inter-tidal and subtidal area, the latter incorporating a small 'trench' of terrigenous rock to ca. 70 m depth. The trench is aligned approximately perpendicular to the coastline, and may represent the sublittoral continuation of a ravine extending down the adjacent coastal mountains. On its seaward (north-eastern) side the trench is defined by a near vertical rock wall extending from ca. 25 m to > 60 m depth. There is little biogenic accretion, with corals and other sessile benthos mostly growing attached directly to the terrigenous basement rock. Near-shore, coral communities are developed on fossil limestone 'spur and groove' structures, with some recent (Holocene) biogenic accretion in the better-developed communities.

The area is one of few known around the archipelago that has such steep sublittoral topography in the form of an abrupt near-vertical rock wall, and deep water relatively close to the coastline. This habitat supports a suite of sessile and vagile species otherwise uncommon or rare, including several coral species recorded only from this Sanctuary. The near-vertical trench wall (ca. 25 - 60 m depth) supports a mixed coral assemblage composed predominantly of small encrusting colonies of the agariciids (*Leptoseris*, *Pavona* and *Pachyseris* spp.), pectiniids (*Echinophyllia* and *Mycedium* spp.), the astrocoeniid *Stylocoeniella guentheri*. Various ahermatypes (*Cyathelia*, *Tubastraea*, *Dendrophyllia*, *Balanophyllia* spp.) are also present, most of which are uncommon or rare at other sites. Less steep areas support massive and encrusting faviids (*Echinopora*, *Favia*, *Favites*, *Goniastrea* spp.) and mussids (*Lobophyllia* and *Symphyllia* spp.) and branching pocilloporids *Stylophora danae* and *S. kuelhmanni*. Coral cover is low to moderate (< 30 %). There is little macro-algal development, although encrusting corallines and to a lesser extent turfing species are present on the basement rock surfaces.

Shallower near-shore areas, particularly adjacent to the headlands, support similar coral and associated communities to those of Dubihil - Siqua (see above 2.1).

Di Hamri Nature Sanctuary - Coral community types: A, D, E, F. The Di Hamri Nature Sanctuary is located around the twin-peaked headland of Rhiy di Hamri, to the west of Khor Qaria and to the east of Khor Delysha on the NE coast of Socotra Island. The Nature

Sanctuary extends approximately 2 km seawards of the headland, from adjacent to the fish landing site on the inner western side of the headland, from the intertidal zone to > 20 m depth. The Sanctuary incorporates a wide variety of inter-tidal and subtidal communities, related to the different hydrographic conditions, exposures and depth regimes around the headland. The Sanctuary encloses one of the largest areas of shallow biogenic accretion in the entire archipelago, with an extensive 'reef flat' developed on the basement igneous rock on the western side of the headland.

The sublittoral extension of the tip of the headland and adjacent deep offshore patches of hard substrate are formed by terrigenous rock, with little biogenic accretion, with most corals and other sessile benthos attached directly to the basement rock. The eastern side of the headland has large sandy patches, with an area of large massive corals, mostly *Porites* spp. developed immediately adjacent to the coastline.

Shallow water coral assemblages were badly affected by the May 1998 bleaching event. To monitor status of recovery of these assemblages, the Sanctuary was selected to accommodate subtidal monitoring sites.

As noted above, the area supports representative examples of a wide variety of coral assemblages, among the most varied of any of the Nature Sanctuaries which include:

- shallow-water (1 - 2 m) assemblages dominated by large expanses of staghorn *Acropora* spp. and digitate *Montipora spongiosa* and *M. cf. digitata* covering 100s of m² on the sheltered part of the western reef flat, the *Acropora* spp. being mostly dead from the 1998 bleaching event,
- slightly deeper (2 - 6 m) assemblages dominated by large massive corals, mostly the faviids *Goniastrea retiformis* and *Platygyra daedalea* and poritid *Porites*, with a diverse mix of smaller massive and encrusting taxa and mostly dead columnar colonies of *Acropora palifera*, developed on the more exposed part of the western reef flat and extending to ca. 6 - 8 m depth,
- large massive corals, mostly *Porites* spp., developed in shallow waters (< 6 m) off the eastern side of the headland,
- deeper (8 - 20 m) assemblages composed of a diverse mix of massive and encrusting corals (faviids, mussids, poritids, pectiniids) developed on terrigenous basement rock.

N Socotra Ras Dillio-Qadama National Park, Qatalni-Alama Nature Sanctuary - Coral community type: A. The area supports rich macro-algal communities nearshore, dominated by phaeophytes. Further offshore, coral communities structured predominantly by monospecific stands of massive corals are developed:

- a deep (ca. 20 m) community of the massive poritid *Goniopora stokesi*, occurs as 'meadows' growing among otherwise sandy sediments
- a dense aggregation of large (ca. 1 - 3 m diam.) massive colonies of the oculinid *Galaxea astreata*, with a mix of other corals developed on dead surfaces of the main framework builder.

In the case of the 'meadows' of *Goniopora stokesi*, these arise from a unique mode of asexual reproduction, the production of small colonies as 'polyp balls' that ultimately are detached from the parent, forming new colonies. This ability facilitates the spreading of this species

into predominantly sandy areas other unsuitable for recruitment by corals reliant on settlement by planula larvae. Similar meadows are also developed in the Qadama - Medina Nature Sanctuary. Because of their deep (ca. 20 m) occurrence, the full extent and distribution of the meadows around the archipelago are unknown at present.

In the case of the *Galaxea astreata* patch, similar assemblages are developed in the Hawlaf area, in the immediate vicinity of the Port (ST-380, -700), and thus are likely to be subject to increasing levels of disturbance with future expansion of port activities. Thus the protection of this community type here is well justified.

Further inshore, diverse patches of macroalgae with sparse corals, mostly massive and encrusting spp. are developed.

Qadama - Medina Nature Sanctuary - Coral community types: A, C, D, E. The area supports a wide variety of benthic communities from algal-covered cobbles (western side of Ras Qadama) to large (ca. 500 - 1,000 m²) monospecific stands of a variety of coral species to the most diverse coral assemblage recorded from Socotra Island. In the case of the monospecific stand of the submassive agariciid coral *Pavona maldivensis*, which covers ca. 500 m², this is the largest presently known anywhere (J.E.N. Veron pers. comm.), this species usually forming small encrusting - sub-massive colonies < 50 cm diam. There is another large mono-specific stand in the area, composed by the pocilloporid *Stylophora kuehlmanni* (R. Klaus pers. comm.). The mono-specific stands and highly diverse assemblages occur adjacent to each other, sometimes < 200 m apart.

The Nature Sanctuary supports a variety of deep-water (> 15 m) coral assemblages:

- monospecific coral beds of the massive poritid *Goniopora stokesi*,
- monospecific coral beds of the sub-massive agariciid *Pavona maldivensis*, with other species developed on dead surfaces of the *Pavona* 'super-colony',
- monospecific coral beds of the branching pocilloporid *Stylophora kuehlmanni*, with a low diversity of other species co-occurring (R. Klaus pers. obs.),
- highly diverse mixed coral assemblages (> 70 spp. Scleractinia), the best example of which has large old coral colonies and high cover (30 - 50 %).

Qalansya lagoon & Sabonia National Parks - The National Parks provide a buffer zone surrounding Nature Sanctuaries centred on the Qalansya (Didhua) lagoon and offshore rock stack of Sabonia.

Sabonia Nature Sanctuary - The Nature Sanctuary extends for one nautical mile around the rock stack, encircled by the larger National Park extending to three nautical miles. The stack rises steeply from the surrounding ocean on all sides, with water depths of 20 m or deeper within 100 m of the rocks. A coral community of small aerial extent is developed directly on the basement rock next to the channel between the islands. There is little biogenic accretion.

Coral community type: D. The coral community is composed predominantly of large massive colonies of *Porites* spp., with a mix of other taxa of stout growth forms (mostly encrusting, massive and sub-massive) developed on dead surfaces and in crevices on the basement rock. Although of small aerial extent (ca. 1,000 m²), the coral community supports the largest population of the Red Sea 'endemic' coral *Stylophora wellsi* known from the Socotra

archipelago. This species, otherwise recorded from only a few colonies on Darsa, is common on Sabonia and is likely to form a viable population there.

West Socotra (Ras Bidoh - Shuab - Neet) National Park - This is a mostly land-based and coastal National Park, extending offshore into a sandy bay adjacent to the Shuab mangrove system, and circling the ‘Sunset’ shipwreck. There are narrow (ca. 30 m width) coral communities developed adjacent to the coastal cliffs of Ras Bidoh.

Coral community type: A, B. Coral communities of the W coast (Ras Bidoh) are composed of moderate diversity encrusting and massive taxa, mostly in the families Faviidae, Mussidae and Siderastreaeidae. Benthic communities of the SW tip of Socotra Island (Ras Shuab - Net) are dominated by macroalgae with only sparse corals.

SW Socotra (Qatanin - Qaara) National Park - The National Park covers the coastal and marine area adjacent to the spectacular headland of Ras Qatanin, the sandy beach (Sebriho) and fossil reef platform at the western end of the Noged.

Ras Qatanin Nature Sanctuary - To the west of Ras Qatanin headland, a small bay and wadi are developed, providing winter (NE Monsoon) shelter for fishermen who use the bay as an anchorage. The sublittoral is composed of terrigenous cobbles - boulders, with a dense cover of macroalgae and a sparse cover of stony and soft corals. The general lack of biogenic accretion notwithstanding, several of the corals, massive colonies of *Porites* spp., have attained large size (ca. 2 m diam.) and are likely to be at least a century old. This is an excellent example of the mixed assemblage of macroalgae, stony and soft corals that occurs at several sites along the south coasts of the Socotra archipelago. Although coral cover is low (< 10 %), there is a surprisingly diverse array of taxa, including the Oman - Gulf-of-Aden endemic mussid *Acanthastrea maxima* and rare mussid *Symphyllia hassi*. This area was selected as subtidal monitoring site.

Coral community type: B. The sublittoral is dominated by a mix of macro- (predominantly *Padina* sp.), coralline and turfing algae, with sparse colonies of stony and soft corals developed among the algae on patches of hard substrate, notably on raised boulders and large massive corals (*Porites* spp.). The stony corals are represented by mostly small (< 50 cm diam.) encrusting - massive colonies in the families Faviidae, Mussidae, Pectiniidae and Poritidae adapted to the harsh physical conditions imposed by the SW Monsoon.

Muthaz - Zaraghin Nature Sanctuary - The coastline is formed predominantly by a fossil (probably Pleistocene) coral reef some 1 - 3 m above high tide level, and interspersed by small sandy beaches. The near-shore sublittoral similarly appears formed by fossil limestone ‘spur-and-groove’ structures supporting a diverse mix of algae, stony and soft corals. Further offshore, the sublittoral topography is less rugose, being a predominantly level - gently sloping surface of terrigenous hard substrate interspersed with sandy patches. The spur and groove structures support a mixed assemblage of macroalgae, stony and soft corals, some of which are rare or absent from N coast localities.

Coral community type: B. The near-shore sublittoral is dominated by a mix of macro-, coralline and turfing algae, interspersed with colonies of stony and soft corals developed among the algae, mostly on the tops and sides of the ‘spur’ structures. As with Ras Qatanin, the stony corals are represented by mostly small (< 50 cm diam.) encrusting - massive

colonies in the families Faviidae, Mussidae, Pectiniidae and Poritidae adapted to the harsh physical conditions imposed by the SW Monsoon. Large colonies of the soft corals *Lobophyton*, *Sarcophyton* and *Sinularia* spp. are also present.

Central S Socotra (Maharaf - Bidhola) National Park, Qashor Nature Sanctuary - The near-shore sublittoral does exhibit some fossil limestone 'spur-and-groove' structures, though apparently less well developed than those further to the west. There is little or no recent biogenic accretion, as the fossil limestone structures support a diverse mix of algae (predominantly the phaeophytes *Padina* and *Sargassum* spp.), with sparse stony and soft corals. Further offshore, the sublittoral topography is less rugose, being a predominantly level to gently sloping surface of terrigenous hard substrate supporting algae, sponges and sparse corals, interspersed with sandy patches.

The Brothers (Samha & Darsa) National Parks - Samha: The entire coast and offshore waters extending three nautical miles are included as National Park, with three enclosed areas of high protection Nature Sanctuaries on the NE, central N and W coasts.

NE Samha (Khaisa Halelibino) Nature Sanctuary - The Nature Sanctuary and National Park encompass a small headland and adjacent coral community located offshore from a sandy bay. The coral community, developed in waters ranging from ca. 6 - 20 m depth, is of roughly oblong shape, several hundred m in length and < 100 m in width, covering several ha in total area.

This is one of the most structurally diverse coral communities known from the entire Socotra archipelago. Apparently unaffected by the mass bleaching event of May 1998, the coral community was in excellent condition in 1999 and 2000, with high cover of stony and soft corals (ca. 50 %), dominated by tabular and staghorn *Acropora* spp. Interspersed among the *Acropora* spp. are a diverse array of corals of other growth forms, from massive and encrusting to mushroom and foliose. The assemblage also supports a species-rich reef-associated fish assemblage. This site is likely to be a crucial location for maintenance and replenishment of populations. Because of its pristine condition, the Sanctuary will be a crucial data source for monitoring the status of coral and fish communities, a primary reason for its selection as a subtidal monitoring site.

Coral community type: C. As noted above, the Sanctuary supports a diverse coral community structured predominantly in terms of cover by thickets of staghorn *Acropora* and large tabular *Acropora* spp. Some of the staghorn thickets cover ca. 100m² and the tables are also of large size (ca. 3 m diam.). Interspersed among the *Acropora* thickets are several particularly large and uninjured colonies of massive corals in the genera *Porites*, *Lobophyllia*, *Platygyra*, *Leptoria* and *Astreopora*, among a diverse assemblage of corals of other growth forms. Some of these colonies are likely to be over a century old. The community also supports an undescribed coral species in the genus *Favites*.

NW Samha (Khaisa al Sheikh) Nature Sanctuary - Offshore, the sublittoral is steep, descending to > 50 m within several hundred m of the coast. To the east of the headland, a narrow fringing coral community is developed. To the west, in the bay formed behind the headland by the wadi, the sublittoral is less steeply sloping, and coral patches are interspersed among sandy areas.

Coral community types: A, D. To the east of the headland a diverse mixed coral assemblage is developed, with massive poritids and faviids the predominant taxa. This assemblage supports the largest population of branching and submassive *Porites* n. sp. (Veron in press) known from the Socotra archipelago. To the east of the headland, a large monospecific stand of *Acropora muricata* (formerly *A. formosa*) is developed, covering some 1,000 m², the largest individual stand of this species known from the archipelago.

W Samha (Khaisa Migiriha) Nature Sanctuary - The sublittoral of the north-western end of Samha is composed of a mix of terrigenous boulders and pavement, 'spur and groove' structures (relict fossil reef) and sand patches. The sublittoral of the SW side is composed of terrigenous cobbles / boulders covered mostly by macroalgae, with little or no biogenic accretion. Very powerful currents converge off the western end of the island, producing standing waves, whirlpools and white water on otherwise calm days. The Sanctuary encompasses a great range of biotopes and benthic communities within a small area, from those dominated by macroalgae with sparse corals, to those dominated by large massive corals, to more diverse coral and fish assemblages. These are developed in relation to the strong current flow and differences in hydrographic regime on the northern and southern sides of the western tip of the island.

Coral community types: A, D. The north-western tip of Samha supports various coral communities. These include monospecific stands of large massive corals (*Porites* spp.) developed very near to the tip of the island, in an area subject to extremely strong current flow (ca. 3-5 kn.). Further from the tip of the island, in an area of less intense current flow, a more diverse coral assemblage is developed on large terrigenous boulders and relict limestone 'spur and groove' structures.

The south-western side of the island supports a benthic community developed on terrigenous (mostly igneous) cobbles and boulders, dominated by large frondose macroalgae with a moderately to diverse coral assemblage (ca. 30 spp. Scleractinia). The coral assemblage is composed predominantly by encrusting and massive species in the families Faviidae and Mussidae.

Darsa National Park and Nature Sanctuary - The entire coast and offshore waters extending one nautical mile are included as Nature Sanctuary, encircled (buffered) by the larger National Park extending to three nautical miles around the island.

Offshore on the northern side of the island, a shallow subtidal platform (< 10 m depth) extends for a considerable distance offshore. This platform is formed of a mix of terrigenous rock, limestones and sand areas, with coral communities exhibiting some biogenic accretion distributed patchily. The southern side of the island is formed by a coastal cliff plunging steeply into the sea, to a depth of ca. 20 m, onto a more level platform of terrigenous basement rock.

Coral community types: A, C, D, E, F. The sublittoral of the north coast has a variety of coral communities from assemblages dominated by large massive corals to more diverse assemblages of staghorn and table *Acropora*, encrusting, foliose and massive species and soft corals. The latter community was selected as a subtidal monitoring site.

Abd Al Khuri - The entire coastline of Abd Al Khuri and coastal waters extending three nautical miles offshore are zoned as National Park, enclosing the four Nature Sanctuaries on its eastern and western ends and northern coast.

Anjara Bay Nature Sanctuary - On the eastern end of Abd Al Khuri, a sandy beach is developed at the head of a deep bay situated between two near-parallel headlands several km apart. On the southern side of the bay, the headland is steep-sided, descending near-vertically to the intertidal. Here, in the sheltered lee of the SW Monsoon, a narrow coral community (< 50 m width) is developed for several hundred m along the base of the cliff. The community is developed mostly on terrigenous rock, with some recent biogenic accretion. On the northern side of the bay, the headland is less steep and high than its southern counterpart and more exposed to the SW Monsoon. Here sublittoral rocky areas support macroalgae with only sparse corals developed directly on the basement rock. The coral and associated fish community on the southern side of the bay is an excellent example of a diverse benthic assemblage. The coral community is in good condition, although some recent mortality (between the 1999 and 2000 surveys) had occurred to the staghorn *Acropora* thickets, possibly related to flooding and run-off from the adjacent headland in December 1999. These features, and the lack of local human impact, contributed to its selection as a sublittoral monitoring site.

Coral community types: B, E. The coral communities are composed of a species-rich mix of staghorn and tabular *Acropora* spp., and a variety of encrusting, massive and foliose taxa, similar in gross form to that at NE Samha.

Bir Al Agooz Nature Sanctuary - Situated on the north-east coast of Abd Al Khuri and bordered on its western extent by the headland of Ras Turum, this wide, open bay is fringed by a long sandy - rocky beach backed by coastal plain fronting the central mountains. The sublittoral topography mostly slopes gently for a considerable distance (ca. 1 km) offshore, where water depths approach 20 m. The substrate is composed of sand patches, terrigenous (igneous) basement rock and areas of biogenic accretion, the latter with well-developed coral communities.

Coral community types: A, E. The Nature Sanctuary supports extensive and diverse coral patches from ca. 4 m - 20 m depth. Shallow communities are dominated by tabular *Acropora* and branching spp., whereas deeper areas support encrusting and massive faviids, mussids, agariciids and pectiniids. Areas of the intertidal and shallow sublittoral (< 3 m deep) support macroalgal beds of high biomass, composed predominantly by phaeophytes.

Badt Eissa Nature Sanctuary - Further to the west of Bir Al Agooz, on the western side of Ras Turum headland, the coastline features several small sandy bays interspersed among rocky points. Here the main village and fish landing site of Badt Eissa is established. The sublittoral topography is formed of large sand patches, terrigenous rock areas, some relict 'spur and groove' structures with little recent biogenic accretion. Next to the western side of the headland of Ras Turum a narrow coral community is developed, with most corals developed directly on the terrigenous basement rock. Similar coral communities and large frondose macroalgal beds fringe other sublittoral areas adjacent to the rocky points. Further offshore, the sublittoral terrain slopes gently to ca. 20 m depth, being mostly sandy with patches of hard substrate of terrigenous or biogenic origin. These support diverse coral communities dominated by a high cover of soft corals. The Sanctuary supports the best

example known from the archipelago of a diverse, high cover coral assemblage dominated by soft corals.

Coral community types: B, E. The Sanctuary supports a wide variety of coral assemblages, from communities composed predominantly by:

- tabular colonies of *Acropora* spp.
- large massive corals (mostly faviids and poritids),
- diverse massive, encrusting and foliose taxa,
- large frondose macroalgae, particularly phaeophytes, with only sparse hard and soft corals,
- soft corals, notably in the genera *Sarcophyton*, *Sinularia*, *Lobophyton*, *Cladiella* and *Xenia*.

The latter community type is particularly well developed on patches of hard substrate (aerial extent ca. 1 ha) from 10 - 15 m depth, located several hundred m offshore.

Kal Farun Nature Sanctuary - The rock stack of Kal Farun is situated to the north of Abd Al Khuri. The Nature Sanctuary extends for one nautical mile around the rock stack, encircled by the larger National Park extending to three nautical miles. The two steep-sided rocks, separated by a narrow channel (ca. 6 m width and 2 m depth), are located near the centre of a larger, relatively level undersea 'plateau' several km² in area and mostly at ca. 20 m depth. The plateau is composed of hard terrigenous substrate covered by various forms of macroalgae, notably patches of cobble-sized rhodolyths formed by crustose coralline algae. There is only very sparse coral growth and little biogenic accretion other than by the rhodolyths over most of the 'plateau'. Close to the rock stacks in shallower waters (4 - 12 m depth), small patches (< 1 ha) of biogenic accretion are developed, in the form of coral communities composed predominantly by large massive corals.

The coral communities, although of small aerial extent (< 1 ha) are in excellent condition, with diverse fish assemblages, particularly in the reef-associated species. The near-pristine condition of the coral community, and its species composition were both important considerations in the selection of the Nature Sanctuary as a subtidal monitoring site.

Coral community type: D. On the SE - E side of the rock stacks, from ca. 4 - 15 m depth, a small coral community is developed, of roughly oblong shape ca. 200 m in length and < 50 m wide. The community is formed predominantly by densely-packed large massive corals in the genus *Porites*, with a diverse mix of other stony and soft corals developed among the massive corals and on dead colony surfaces. The corallimorpharian *Discosoma* sp. and soft corals in the family Xenidae were important colonisers of the dead *Porites* colony surfaces. On the opposite side of the rock stacks, a more diverse coral community, structured mostly by massive and encrusting corals in the Faviidae, Mussidae and Poritidae is developed, with large colonies interspersed among a bed of rhodolyths.

Khaisa Ten Naum Nature Sanctuary - Located on the western end of Abd Al Khuri, where the central mountains diminish in height to low hills bordered on their northern side by a series of long sandy beaches interspersed among small rocky points. The sublittoral topography slopes relatively gently for a considerable distance offshore (ca. 500 m), being composed of large sandy areas interspersed with patches of hard substrate, the latter

supporting coral assemblages. The extreme western tip of the island holds a wide shallow bay (ca. 500 m width at its mouth and mostly > 10 m depth). The coastline to the south is formed of large boulders and a low cliff line broken by two very small ‘bays’, and is fully exposed to the brunt of the SW Monsoon wind and waves. The sublittoral here is initially steep, dropping to > 15 m before leveling off to a more gently-sloping expanse of hard substrate. The bays each support diverse coral assemblages with a surprising degree of biogenic accretion, given the exposed location. The large western bay hosts a small village and fish landing site occupied during the calm NE Monsoon season.

The Sanctuary hosts the most diverse coral fauna known from the entire Socotra archipelago, including a suite of species recorded only from this location, and distributed in a wide variety of community types developed in relation to their degree of exposure to the SW Monsoon.

Coral community types: C, E, F. The Sanctuary supports great variety in coral communities, including those structured predominantly by:

- large tabular and staghorn *Acropora* spp., with a diverse mix of massive, encrusting and foliose corals,
- high diversity assemblages of large massive and encrusting corals, including faviids, mussids, pectiniids, agariciids, dendrophyllids, siderastreids and poritids,
- small massive and encrusting corals, mostly faviids, growing on igneous basement rock,
- large massive corals (poritids, oculinids and faviids) with tabular and branching *Acopora* spp.
- large monospecific beds of foliose and encrusting *Montipora* sp. (R. Klaus pers. comm.).

All major coral community types are well represented in the Socotra marine protected area.

iv. Coral Cover

Cover of stony corals, dead corals, soft corals and algae were all highly variable among different sites within the Red Sea, Gulf of Aden and Socotra archipelago. Ratios of live : dead coral cover at individual sites ranged from strongly positive to negative, related largely to the differential effects of recent disturbance, notably coral bleaching in 1998.

Red Sea - In the northern area of the Yemen Red Sea, extensive coral mortality over the past decade, probably caused by elevated sea temperatures and predation by crown-of-thorns seastars, had resulted in major reductions in living coral cover on some reefs (Turak & Brodie 1999). Reefs of the southern Red Sea, and those fringing offshore islands, were less disturbed, supporting higher living coral cover.

When surveyed in the mid-1990s, semi-protected island reefs in the northern Red Sea had low average live coral cover (17 %), high average dead coral cover (34 %) and high macroalgae cover (20 %). These reefs had relatively high average species richness (44 sp.). The northern and central Yemen coast and nearshore islands, from north of Al Khawkhah to Midi near the border with Saudi Arabia had very low live coral cover (3 %) and very high dead standing coral cover (averaging 34 %). Macro algae cover was also high (avg. 34 %) with *Sargassum*, *Turbinaria*, *Padina* and *Dictyota* spp. being dominant. These communities were also characterized by very low coral species richness (average 9 sp.).

Clear water communities facing the open sea: Zubayr group, At Tair in the north and Mayun Island in the south - had the highest live coral cover (29 %) and lowest dead coral cover (14 %) in the Yemeni Red Sea. Macroalgae cover was also among the lowest, while coral species diversity was high (46 sp.) with some of the largest colonies encountered in the surveys. Deep water pinnacles and submerged patch reefs had high overall coral cover (avg. 52 %), with similar levels of live (24 %) and dead coral (28 %). Outbreaks of the crown-of-thorns starfish *Acanthaster planci* may have caused this extensive mortality. The most common distinguishing characteristic of these sites was high coral species richness (56 spp.) including 76 species at one site.

Most exposed reefs with algal crests and monospecific stands of coral also had high cover of dead coral, often in the form of mounds or ridges of branching coral rubble but also dead massive and tabular *Acropora* colonies. Reefs in this group had a very high percentage of total coral cover (averaging over 50 %), although it was mostly dead standing coral (avg. 44 %) at time of survey. Southern fringing reefs (south of Yakhtul to Dhubab) also had higher average cover of dead corals (23 %) than live corals (15 %) and substantial cover of macroalgae (avg. 14 %).

Thus for many coral communities of the Yemen Red Sea, disturbances over the past decade (probably predation and bleaching) have caused major coral death, with ratios of live : dead coral being negative for five of the six major coral community types present (Turak & Brodie 1999).

Gulf of Aden and Socotra - The lack of major biogenic reef accretion in the Gulf of Aden and Socotra archipelago notwithstanding, some sites support high live coral cover (> 50 %, and large sizes of individual coral colonies). Examples include the islands offshore from Bir Ali and N coasts of the Socotra archipelago. These sites have high regional significance, as communities with high coral cover (whether forming true reefs or not) are known to occur only very rarely in the Arabian Sea (Sheppard & Sheppard 1991, Sheppard et al. 1992, Watt 1996). On Socotra, north-facing sites generally had higher cover than their more exposed south-facing counterparts, the latter being more exposed to the SW Monsoon.

Around the Socotra archipelago, cover of stony corals (including the reef-building hydrozoan 'fire coral' *Millepora*) ranged from < 1 % to > 75 %, and in large patches (ca. 1,000 m²) attained ca. 100 %. When assessed over all sites, living stony coral cover averaged ca. 20 %, with highest cover (ca. 35 %) on the Brothers (Samha, Darsa and including Sabunyah Rocks). Stony coral cover was much higher on the north coasts (ca. 25 %) than on the south coasts (ca. 5 %).

Sites of high stony coral cover (> 50 %) included Medina (NW Socotra - large monospecific beds of *Pavona maldivensis* and *Goniopora stokesi*), Ras Anjara Bay (E Abd Al Khuri: tabular and staghorn *Acropora* spp., massive and encrusting faviids, poritids, mussids), N Samha (large monospecific beds of staghorn *Acropora muricata*), NE Samha (tabular and staghorn *Acropora* spp., massive and encrusting faviids, poritids, mussids). Other notable locations were Diham-Qubbah and Hawlaf Port (Socotra), and the small outer island rock stacks of Kal Farun and Sabunyah Rocks, all with living coral cover (ca. 50 %), composed predominantly by large (1 - 4 m diam.) massive corals of the genera *Porites* or *Galaxea*.

All the above sites remained largely unaffected by the mass coral bleaching event that caused major reductions in live cover at other sites in May-June 1998 (see later). Most south coast sites had stony coral cover of < 10 %, being dominated by macroalgae, with the notable exception of SW Abd Al Khuri, where cover of both living and dead corals each was ca. 20 %, composed predominantly by massive corals, some of which had dead colony surfaces consistent with injury during the 1998 bleaching event.

Previous coral surveys reported that most sites were in good - excellent condition (MacAlister Elliott and partners 1996, see also Kemp 1998), although high cover of dead *Acropora* spp. (ca. 50 %) was reported from one site on the NE coast of Socotra. No cause of the mortality was identified. Coral mortality following bleaching in 1998, particularly among tabular and staghorn *Acropora*, foliose *Montipora*, fire corals and soft corals, caused reductions in average coral cover from ca. 50 % to ca. 20 % at some locations in the north-east Gulf of Aden and Socotra. Following the 1998 bleaching event, overall dead coral cover around the Socotra archipelago averaged 8 %, with little variability among islands. Cover of dead corals was lowest at the Brothers (ca. 5 %) and on the S coasts (reflecting the generally low coral cover there).

v. Special Characteristics of Yemeni Reefs

One of the important features of most Yemeni Red Sea coral reefs is the very limited or complete lack of an intertidal zone. The main tidal movements in the Red Sea are diurnal tides of limited magnitude, seasonal tides of more significance and at times most importantly, sea level fluctuations due to strong persistent onshore winds (Edwards 1987). Most reefs in the Yemeni Red Sea either do not have an intertidal reef flat development or they are devoid of live corals.

From the shallow coastal waters of southern Saudi Arabia, Sheppard (1985) described a reef formation built essentially of crustose red algae and named them Algal Reefs. Such formations also occur along the north coast of Yemen, and south to Al Urj. Algal reefs also occur in the shallow nearshore waters north of Hodeidah. They are often covered by dense macro algal growth and also may be surrounded by seagrass beds. Associated biota is usually poor and may include some sea urchins and a variety of algae species. Fish diversity and abundance were generally low.

Coral communities of the Socotra archipelago and north-east Gulf of Aden are notable for the occasional co-occurrence of large monospecific coral stands immediately adjacent to diverse coral assemblages, developed in similar environmental conditions: depth, light, sea temperature, sediment type.

5. Status of Coral Reef Fisheries

i. Summary

Fishing is a traditional profession for thousands of Yemenis. These fishermen operate from bases and landing sites spread along the mainland coastline and from a number of islands. Total annual catches vary between 90,000 and 95,000 mt and more than 90 % of the total fish production is landed by artisanal fishermen. Most of the landings come from trawling in the

Red Sea and the pelagics fishery in the Gulf of Aden. Reef-based fisheries, for the most part, are underdeveloped and at a subsistence level.

ii. Fishery Distribution

Coral reef fisheries are based primarily in the Red Sea and around the Socotra archipelago. The trawlable grounds of the Red Sea are about 6,200 km² of which 550 km² are shrimp fishery areas (Sanders & Kedidi 1981). Coral reef-based fisheries are mostly artisanal in nature and are distributed along the entire coast. There are five main landing centres along the Red Sea coast: Midi, Khoba, Hodaida and Khaukha, and Mokha. Reef-based fisheries in the gulf of Aden are minor, with the majority of the fishing industry targeting pelagics. On Socotra, reef-based fishing activities take place along the entire coastline, but only one processing plant exists to market catches on a commercial scale. Other catches are predominantly at a subsistence level.

iii. Fishery Composition and Trends

In the Red Sea, most of the fisheries data dates back to the 1970s and early 1980s and focusing on demersal fishes and shrimps. Sanders & Morgan (1989) estimated the standing stocks in the Yemeni Red Sea at roughly 23,000 - 32,000 mt. No more recent data on stocks are available. Statistics are generally unreliable because catches are auctioned and sold as individual fishes for large species, or in bundles for small size fish, without being weighed. Furthermore, there are no accurate figures on the fishing effort.

In the Gulf of Aden several surveys provided valuable resource information on demersal and pelagic stocks, but little on artisanal fisheries. Among the exploitable stocks pelagics are more abundant than demersal resources. Large pelagics include tunas, Spanish mackerels, sharks, jacks and marlins. Data on the distribution of demersal stocks and their densities are given in Edwards et al. (1984). Catches of the Spanish mackerel *Scomberomorus commerson* amount to about 1,000 mt annually; horse mackerels (*Trachurus* and *Decapterus* sp.) ranged between 5,000 to 8,000 mt annually during the 1980s. There has been a slow but gradual decline in catches of pelagic species following a peak in 1989, and demersal fish stocks have been declining sharply since 1987. Sharks (mostly Carcharinidae and Sphyrnidae) are also fished, using trolling and surface longlining. During the 1980s annual catches were in the order of 7,000 mt.

There is an artisanal fishery for spiny lobsters (*Panulirus* spp.) in Hadhramut and Mahra and around the Socotra archipelago. Catches were about 200 mt between 1972 and 1983, rose to a peak of 1,150 mt in 1987 and dropped to around 600 to 700 mt 1991. Only 5 % came from Socotra. Management measures since 1970 restricted the lobster fishing season to between October and April, limited tail lengths to > 7 cm and catching female with eggs was forbidden. Since 1983 fishermen have encouraged to use lobster traps which have now totally replaced nets.

Resource surveys in the 1960s and 1970s reported rich fishery resources in the waters surrounding the Socotra archipelago. Kesteven et al. (1981) estimated biomass for demersal resources at 55,000 - 116,000 mt and for pelagics at 112,000 - 224,000 mt with yield estimates of 10,000 - 20,000 mt and 39,000 - 78,000 respectively. Fish, turtles and lobsters are important resources in the archipelago and abalone is a resource of potential future exploitation. More recent information is provided in UNDP/GEF (1996).

6. Threats to Coral Reef Biodiversity

i. Summary

Coral reefs have not ranked highly on the protection agenda in Yemen. Development of urban centers and industry carry a higher priority, and only in recent years has the protection of coral reefs been addressed. A fledgling tourism industry poses little threat to reefs in the form of anchor and flipper damage as compared with neighbouring countries. Coastal development, the petroleum industry and maritime shipping, on the other hand, pose a significant risk to reefs in the form of untreated sewage, land filling, and hydrocarbon pollution, among others.

ii. Coastal Development

Coastal cities and towns are expanding at accelerating rates, and unplanned settlements around cities such as Hodaïda may result in a loss coral reefs. The proposed development of Aden Port and Aden Free Zone are expected to have a major impact on the environment. Reclamation for port development and expansion and for construction of industrial areas is already underway in Aden where lagoons and intertidal areas are being reclaimed. In Socotra, harbour and airport development are planned. Unless appropriate environmental precautions are taken, this development is likely to cause considerable local impacts.

iii. Tourism

Reef-based tourism is still in its infancy and impacts on the reefs by visitors is low. This might soon become an important issue in the Gulf of Aden where corals are already under stressful conditions and particularly sensitive to disturbance.

iv. Shipping and Navigation

Yemeni waters are major shipping routes. About 16,000 ships pass through the Strait of Bab al-Mandab each year and many call at Yemen's main ports (Table IV; Aden Port Development 1996). Ships are known to dump their wastes and dirty ballast water in the Yemeni waters. Dirty ballast waters result in the formation of tar balls which have been found throughout the coastline of the Gulf of Aden (EC/MFW 1995) and some parts of the Red Sea coast (Rushdi et al. 1991). Additionally, solid waste from ship-based sources may be found on beaches. The potential threat of a major accident is significant, and may result in major habitat destruction and oil pollution. Main ports lack reception facilities and there is limited oil spill contingency planning.

Table IV: Number of ships calling at Yemeni ports and volume of oil cargo in mt (Source: PERSGA 1997).

<i>Port</i>	<i>1994</i>		<i>1995</i>		<i>First half 1996</i>	
	<i># of ships</i>	<i>Oil cargo</i>	<i># of ships</i>	<i>Oil cargo</i>	<i># of ships</i>	<i>Oil cargo</i>
Aden	878	2,548,563	1164	4,201,809	696	4,112,120
Hodaïda	523	1,350,524	583	1,326,711	392	108,807
Al-Mokha	84	263,447	97	230,254	159	19,304
Mukalla	224	229,100	186	248,404	183	116,084
Ras Isa	83	7,639,899	84	7,411,011	46	3,543,541

v. Shark Fishery

Catches of sharks from the Red Sea increased in 1993 (a peak of 6,537 mt) and dropped gradually to 3,556 mt in 1996. Sharks are mainly caught for their fins which are exported and fetch high prices on international markets. There are no signs (as yet) of declines in shark stocks in the Gulf of Aden.

vi. Oil Pollution

Threats to Yemen's reefs include those from oil and related industries, shipping and harbour activities, ballast water discharge, fishing, urban development and sewage discharge, litter, catchment pollution and sedimentation, chemical pollution, tourism, coastal industries, coral predators and global climate change (PERSGA 1997, Brodie & Turak 1999). Threats to biodiversity range from local (e.g. coral collecting), regional (bleaching) to global (e.g. future changes in ocean alkalinity from increasing atmospheric carbon dioxide affecting coral growth and reef building through failure of calcification). A 409,000 DWT floating storage and offloading vessel is moored 4.8 nautical miles offshore Ras Isa on Al-Salif peninsula. This ship is supplied with crude oil by a pipeline from the shore, which is then transferred to crude oil tankers. Oil spill risks associated with these procedures are considered significant. Over 200 tarballs per 10 m transect were recorded at Bandar east of Aden (Rushdi et al. 1991). Current daily bunker supplies in the Port of Aden are around 40,000 mt. Poor maintenance has resulted in low level, but locally significant leaks from bunkering facilities into the port. One bunker barge sank in 1995, causing considerable localized oil pollution in the Tawahi area (Aden Port Development 1996), and a thick layer of oil covering the intertidal and lower supralittoral zones of the area is still evident.

vii. Bleaching

Bleaching has caused extensive recent coral mortality on many Yemeni reefs, including those in the northern nearshore area of the Red Sea (since 1990), in the southern Red Sea (within the last 2 - 4 years), Socotra archipelago and north east Gulf of Aden (1998). A number of Red Sea sites with near total mortality had been reported as having healthy coral growth in the 1980s (IUCN 1987).

Bleaching effects in 1998 were patchily distributed around the Socotra archipelago and NE Gulf of Aden. At worst affected sites > ½ species were injured and about half of the live coral cover was killed. Species were affected differentially. Pocilloporids, table and branching *Acropora* spp. and fire corals *Millepora* sp. were worst-affected, and changes occurred in species composition and relative abundance.

The bleaching followed a period of elevated sea surface temperatures of > 1 °C above mean monthly averages (as derived from NOAA 'hotspot' satellite imagery). On the N coast of Socotra, SSTs were warmer than 31° C in May - June 1998, followed by rapid cooling (< 24 °C) in July 1998 (DeVantier et al. in press b). Warming occurred in June in the NE Gulf of Aden.

viii. Crown-of-Thorns Starfish - Offshore Red Sea Reefs

Recent extensive coral mortality on offshore Red Sea reefs was similar in appearance to that following crown-of-thorns starfish outbreaks. Nearly all the acroporid corals, the preferred food of *A. planici*, were dead, including large (4 - 5 m diameter) colonies, and some starfish remained feeding in the area. Small scale starfish outbreaks have also been reported previously from other parts of the Red Sea, and it is believed that the present level of damage

is comparable to that caused by *A. planici* in Sudan in the late 1960s (Ormond & Campbell 1971).

ix. Drupella Mortality

The coral-feeding snails *Drupella* was present at most Red Sea and Socotra sites with a varying degree of abundance, most commonly on compact branching forms of *Acropora*, tabular *Acropora* and pocilloporids, in order of preference. Generally damage was at a sub-lethal level, with most infected corals showing partial mortality ranging from 10 % to 70 % of the colony.

x. Bio-Erosion by Sea Urchins and Parrotfish

The urchins *Echinometra* and *Diadema* spp. occur in moderate - high abundance (> 10 m²) at some sites, and with the grazing parrot fishes (Scaridae) and boring sponges, are major contributors to bio-erosion of the reef substrate. Bio-erosion was particularly noticeable at sites badly affected by the 1998 bleaching event.

xi. Coral Breakage by Storm Waves

Coral assemblages at some sites around Socotra had been affected by storm waves, where large tabular colonies of *Acropora clathrata* had been overturned or toppled and some branching corals had been fragmented. Dead corals that had been killed by the 1998 bleaching or other agents, where the skeletons had been weakened by bio-erosion, were particularly susceptible to breakage.

xii. Coral Diseases

Little is presently known of the distribution and effects of coral diseases in Yemeni waters. In the northern Red Sea, several diseases have been identified as killing or injuring corals. In the Socotra archipelago, diseased corals were uncommon or absent from most sites, although 'white band' disease was causing injury to tabular colonies of *Acropora clathrata*, a species badly affected by the 1998 bleaching event.

xiii. Coral Collecting for Lime, Building Materials

Coral collecting (evidenced by coastal piles of coral boulders) occurs at many locations around the Socotra archipelago. However, most collecting is of dead corals that had been deposited on beaches by storms. At present there is little evidence of subtidal collecting of live corals on any of the islands. However, increasing export demand may engender live coral collecting in the future.

xiv. Changes in ocean chemistry

Increasing atmospheric carbon dioxide is expected to alter the alkalinity of the world's oceans over the next century, making it increasingly difficult for corals and other carbonate secreting organisms to grow. Present predictions are that calcification rates may slow by as much as 2/3 over the next 50 years, with catastrophic effects on reef growth and marine biodiversity in general (Kleypas et al. 1999).

xv. Overfishing

Overfishing of reef-associated species has the potential to produce cascading secondary effects in the ecosystem. A recent pertinent example is from the Caribbean Sea, where chronic overfishing, a mass die-off of herbivorous sea urchins and several major tropical storms have produced major shifts in ecosystem function, manifested as massive loss of reef-

building corals and concomitant increase in macroalgae. Outbreaks of crown-of-thorns starfish are also hypothesized to be caused by overfishing of reef-associated fish predators in the families Lethrinidae, Balistidae and Tetrododontidae (Ormond et al. 1990).

xvi. Aquarium Trade

At present two companies are licensed to collect coral reef fishes for the aquarium trade, for which there are no catch records. More licenses are expected to be issued in the future. Fish collecting for the aquarium trade should be monitored carefully to prevent damage to the reef habitat and decline in reef associated fauna.

xvii. Industrial and Urban Development

Waste waters of the main coastal cities and industries are discharged directly into the sea. Only about 30 - 40 % of large coastal cities are served by public sewage networks. In Aden raw organic matter is discharged directly into the sea. Problems of bacterial contamination are apparent (EU & MFW 1995). In Mukalla and the smaller towns, sewage is directly discharged into the sea without any treatment. Power stations at Mokha, Ras Katheeb and Hiswa (Aden) discharge saline high-temperature water directly into the sea causing temperature increase in surrounding waters.

7. Marine Protected Areas (MPAs) and Level of Management

i. Summary

There is one protected area and six proposed protected areas in Yemen. Establishment of marine protected areas is a relatively new process in Yemen, with funding and technical input from IUCN, the Global Environment Facility and PERSGA.

ii. MPAs Declared

Socotra Islands: The archipelago occupies some 362,500 km² and is home to diverse terrestrial plant and animal life with a high degree of endemism. Socotra (12°30'N 54°00'E) is the main island, the others being Abd al-Khuri, Samha and Darsa. There are also smaller rock islets, Kal-faraon and Sabouniya. They are all fringed by diverse and largely pristine marine habitats and biota, including well-developed coral communities. Funding and logistical support is provided through the GEF-Socotra biodiversity project.

iii. *de facto* and Planned MPAs

Belhaf and Bir Ali Area: This is a coastal stretch and group of high aspect islands with extensive fringing coral reefs and rich fishing areas (14°00'N 48°10'E). The area is also an important seabird and marine turtle nesting site, and contains a salt water crater with fringing mangroves.

Ras Isa / Kamaran Island: located at 15°16'N 42°44'E, the headland / island complex contains coral reefs with diverse associated fauna which are threatened by chronic pollution from the nearby oil terminal, and reef fisheries for the aquarium trade.

Khor Umaira: Mixed seagrass and coral reef habitat, the area is a semi-enclosed lagoon that supports marine turtle feeding (12°40'N 44°10'E). No coral reefs.

Ras Sharma: Important (regional and possibly global) nesting site for marine turtles (13°00'N 43°40'E). No coral reefs.

Dhobba: Considered as it is a marine turtle nesting site (14°45'N 49°40'E). No coral reefs.

Bab al-Mandab and Perim Island: Contains extensive seagrass beds and mangrove stands, and is an important waterway feeding the Red Sea (12°30'N 43°30'E). No coral reefs.

8. Current and Potential Climate Change Impacts

The coral reefs are mainly found in the Red Sea, the Socotra archipelago and some sites in the Gulf of Aden. Most coral communities near shore islands suffered mortality from a recent widespread event, and the pattern of mortality was consistent with severe bleaching. Extensive coral bleaching with high mortality rates was observed near the islands of Socotra in May - June 1998. Bleaching was patchily distributed and highly variable in intensity. Intense bleaching occurred in some coral communities on the north coasts of Socotra and Abd Al Khuri, where greater than half total coral cover was bleached or recently dead (20 - 40 % absolute cover). Bleaching occurred to 20 m depth, but was usually most intense in depths of less than 5 m, where at worst-affected sites more than 75 % of all coral species had been affected, causing shifts in relative abundance and community composition. High mortality occurred in the most susceptible taxa, particularly tabular and staghorn colonies of *Acropora*, branching pocilloporids and the hydrozoan fire corals *Millepora* spp. Corals on the south coasts and the islands of Samha and Darsa were only partially affected.

9. Current Monitoring and Management Capacity to Conserve Coral Reef Resources

i. Monitoring Capacity

The Department of Oceanography, University of Sana'a, which was established in the late 1970s, has more than 10 staff members specialized in marine ecology, chemistry, geology and fish biology. Its main responsibilities are teaching, research and advising the government on marine issues. It has a capacity for and is carrying out research and training in the fields of coastal surveys, pollution monitoring and analysis. The University of Aden also has several departments which are involved in research and training in the marine sciences. In 1996, this university organised the first international symposium on Socotra Island. The are colleges in Hodaïda and Mukalla.

The Marine Science and Resources Research Centre (MSRRC) in Aden is the advisory body for the MFW. The centre advises the ministry on aspects of fish stock assessment and management, data on fish landing, fishing seasons etc. It consists of Fisheries, Oceanography and Benthos departments, and has a newly established small pollution control centre at Al-Buriekah (Little Aden), an experimental mariculture station and a small laboratory in Mukalla. The MSRRC operates a 37 m research vessel which is currently in need of maintenance. The centre receives some technical assistance from the Fourth Fisheries Development Project and has collaborated with IV Fisheries to execute a coastal habitat survey of the Gulf of Aden.

ii. Management Capacity

A number of governmental agencies have responsibility for the coastal and marine areas. There is no authority solely in charge of the management of the coastal zone in Yemen.

Environment Protection Council (EPC): The EPC was established in 1990 by Prime Ministerial Decree 94/1990. The Technical Secretariat (TS) co-ordinates and monitors planning, implementation, environmental protection and natural conservation policy. Implementation at field level is under the responsibility of the line ministries. There are three departments under the TS: Environment Protection, Planning and Data, and Administration and Financial Affairs. The EPC is the official government agency in charge of development and implementation of the general national policy planning for environmental protection and control.

Ministry of Fish Wealth (MFW): The MFW regulates fishing, issues licenses, supervises processing and marketing of fish and fisheries products for local consumption and export. Imports and/or manufacturing of fishing gear and other relevant equipment must be in accordance with specifications of the MFW. The ministry is responsible for the management and development of Yemen's fish resources. The MFW, through the department of monitoring and surveillance, is responsible for the enforcement of laws and regulations concerning marine resources.

Public Corporation for Maritime Affairs (PCMA): This is the main governmental body concerned with maritime safety and marine pollution control. It also plays an important role in developing a legislative framework to protect the marine environment.

Maritime Training Centre: Was established in Aden in 1989. It conducts training courses in port operations and maritime transport, maritime safety and pollution control. It offers courses on MARPOL Convention and oil spill response. It currently receives assistance from UNDP.

General Tourism Authority (GTA): The GTA is responsible for tourism activities throughout the country including eco-tourism. Permission for building tourist villages along the coast or Yemeni islands are issued by the GTA. In 1995, the GTA issued a set of regulations and guidelines for tourists while snorkelling or/and diving.

10. Government Legislation, Strategies and Policy Pertinent to Reef Conservation

i. Summary

The Republic of Yemen is a party to international conventions, agreements and treaties which have implications on the marine environment. Similarly, a number of national instruments exist at various government levels which directly or indirectly concern coral reefs.

ii. International Agreements

Treaties or conventions that were signed by ex-YAR and ex-PDRY Yemen are still in force according to the unification decree. Yemen is party to the Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal (1996); the Convention on Biological Diversity (1996); the Montreal Protocol on Substances that Deplete the Ozone Layer (1996); the Protocol Concerning Regional Cooperation in Combating Pollution by Oil

and other Harmful Substances in Cases of Emergency (1992); The Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (1982); the United Nations Convention on the Law of the Sea (1987); the United Nations Framework Convention on Climate Change (1996); and the Vienna Convention for the Protection of the Ozone Layer (1996).

Yemen has signed, but not yet ratified the MARPOL Convention due to lack of funds to purchase the necessary port waste reception facilities. At present Yemen co-operates with Djibouti and Somalia in combating oil spills. Oil pollution control equipment for the Gulf of Aden area (Yemen, Somalia and Djibouti) have been stored at the MEMAC in Djibouti. Yemen and Djibouti are currently negotiating a bilateral agreement regarding the use of such facilities.

iii. National Legislation

In recent years Yemen has established a number of significant instruments, laws and regulations which concern coral reefs (see also Table V):

Prime Ministerial Decree No. 4 (1996): Established Socotra as a protected area and developed a High Committee for Development of Socotra headed by the Deputy Prime Minister and Minister of Planning and Development.

Law No. 11 (1993): Established in 1993 for the protection of sea from pollution. Is mainly concerned with pollution by oil and pollution from passing ships. The law determines procedures for prosecuting, penalizing and requesting compensation from ships that violate the law. It gives the Public Corporation for Maritime Affairs the legislative power to deal with oil pollution at sea. In its article No. 35, the law prohibits any form of discharge of pollutants of any kind and from any source into the sea without prior treatment.

Table V: National Laws and Regulations related to Coastal and Marine Environments and Resources.

<i>Law, Ordinance, Regulation</i>	<i>Year</i>	<i>Government Agency concerned</i>
Presidential Resolution on the Territorial Sea, Adjacent Waters, the Exclusive Economic Zone and the Continental Shelf (Law No. 37)	1991	Ministry of Defense, MFW
Presidential Resolution on Fishing, Exploitation and Protection of Living Aquatic Resources (Law No. 42)	1991	Ministry of Fish Wealth
Free Zone Law (Law No. 4)	1993	Free Zone Authority
Protection of the Marine Environment from Pollution (Presidential Decree No. 11)	1993	Public Corporation for Maritime Affairs
The Maritime Law for the Republic of Yemen (Presidential Decree No. 5)	1995	Public Corporation for Maritime Affairs
Environment Protection Law	1995	Environment Protection Council
Ministerial Decree for Specifications of Fishing Vessels and Gear (No. 101)	1995	Ministry of Fish Wealth
Prime Ministerial Decree No. 4 of 1996 establishing Socotra as a protected area	1996	Ministry of Planning and Development

Law No. 4, Article 10(d) (1993): Prohibits any activities or practices carried out in contradiction with special directives regarding the protection of the environment.

Fisheries Law No. 42 (1991): This is the main legal framework for organization, exploitation and protection of fishing and aquatic resources. This law deals with the protection of fisheries resources and regulation of fishing activities. The law prohibits the use of destructive fishing methods such as poisons, chemicals, etc. The law also indicates means of limiting and/or dealing with pollution.

Law No. 37 (1991): Defines the territorial waters and the exclusive economic zones of 200 nautical miles, the boundaries of the islands. It also regulates free passage in the Strait of Bab al-Mandab. It emphasizes on the prohibition of dumping any wastes into these zones.

11. Analysis of Gaps in Capacity and Requirements for Improved Conservation

i. Summary

One of the major gaps in the process of coral reef conservation is the lack of funding to establish and implement regulations in marine protected areas. These will also need strict enforcement, and further research to acquire baseline information. There is a general lack of funding for marine research activities, and most research is currently funded through GEF, World Bank or UNDP projects. Specifically, the Republic of Yemen needs to address the following issues:

ii. Research

Research needs to be carried out in order to update baseline environmental conditions, and follow-up monitoring should refer to these baselines to detect changes in environmental quality.

iii. Networking

There is a need to integrate current research into global initiatives such as ICRI and GCRMP, and regionally among PERSGA members.

iv. Planning and Coastal Development

Direct use and indirect development activities that affect reef systems need to be carefully evaluated in the design stages, and be subject to continued monitoring through the implementation stages.

vi. Community Education

There is a need to develop community education programmes that highlight the role of communities in reef ecology, including degradation.

vii. Legislation

Yemen needs to take further steps in the establishment of marine protected areas, and monitor the implementation of legislation concerning these areas with regard to coastal development, fisheries and tourism.

viii: Funding and Expertise

A larger proportion of funds allocated to protected areas and environmental research needs to be appropriated for marine conservation efforts. With the EPC for instance, this would also require the expansion of the marine research and conservation activities, which is currently staffed by only one person with limited research funds and equipment.

12. Recommendations to Improve the Conservation of Coral Reef Resources

i. Summary

ii. Legislation

There is a need for developing rules, regulations and human resources to implement the existing Maritime Law and the Law for the Protection of the Marine Environment from Pollution. This should take place contiguously with the development and implementation of environmental assessment procedures and guidelines, including those which develop and implement a protected area law.

iii. Institutional strengthening

Strengthen the institutional capacity of the Environmental Protection Council to co-ordinate and monitor activities affecting the marine environment. Strengthen the capacity of the Public Corporation for Maritime Affairs to enable it to carry out its duties in the fields of protecting the marine environment from pollution, safety of shipping, including Port and Flag State duties. Strengthen institutional capacity for enforcement of environmental and fisheries regulations.

iv. Environmental management

Develop and implement a master plan for conservation and sustainable development of the Socotra archipelago. Prepare and implement a coastal zone management plan. Strengthen the capacity of GTA, GIA and the Free Zone Authority for environmental management. Develop and establish a system of marine protected areas with effectively implemented management plans.

v. Habitat conservation

Design and conduct inventory surveys, habitat mapping and sensitivity analyses of the entire coastline including distribution of rare and endangered species.

vi. Petroleum development and transport

Develop and implement an oil spill contingency plan.

vii. Industrial development

Establish a framework for development and operation of the Aden Free Zone in an environmentally sound manner. Develop and implement a port reception facilities plan.

viii. Urban development

Upgrade the wastewater collection and treatment in coastal areas, including Aden, Hodaida and Mukalla. Upgrade solid waste management and disposal in coastal areas, including Aden, Hodaida and Mukalla.

ix. Applied research

Develop a database for biological resources and environmental information and establishment of a monitoring programme to support operations and enforcement activities. Develop training programmes for marine resource surveys, monitoring and management, and

GIS applications. Design and implement a programme to evaluate potential impacts from agricultural chemicals on the Tihama coastal zone.

x. Environmental education and Participation

Conduct public awareness and environmental education programmes for all levels of the coastal population. Promote the broad-based participation of NGO's.

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Appendix III - Fish species observed on the reefs in the Yemen Red Sea

ACANTHURIDAE	<i>Triacnodon obesus</i>	<i>Halichoeres zeylonicus</i>
<i>Acanthurus gahhm</i>	CHAETODONTIDAE	<i>Halichoeres hortulanus</i>
<i>Acanthurus mata</i>	<i>Chaetodon auriga</i>	<i>Halichoeres marginatus</i>
<i>Acanthurus nigricans</i>	<i>Chaetodon austriacus</i>	<i>Halichoeres nebulosus</i>
<i>Acanthurus nigrofuscus</i>	<i>Chaetodon fasciatus</i>	<i>Halichoeres scapularis</i>
<i>Acanthurus sohal</i>	<i>Chaetodon larvatus</i>	<i>Hemigymnus fasciatus</i>
<i>Ctenochaetus striatus</i>	<i>Chaetodon lineolatus</i>	<i>Hemigymnus melapterus</i>
<i>Naso hexacanthus</i>	<i>Chaetodon melapterus</i>	<i>Hologymnosus annulatus</i>
<i>Naso aturatus</i>	<i>Chaetodon mesoleucos</i>	<i>Labroides dimidiatus</i>
<i>Naso unicornis</i>	<i>Chaetodon semilarvatus</i>	<i>Labroides quadrilineatus</i>
<i>Zebrasoma desjardini</i>	<i>Heniochus intermedius</i>	<i>Oxycheilinius digrammus</i>
<i>Zebrasoma xanthurum</i>	CIRRHITIDAE	<i>Stethajulis albivittata</i>
APOGONIDAE	<i>Cirrhitichthys oxycephalus</i>	<i>Stethojulis interrupta</i>
<i>Apogon annularis</i>	DASYATIDIDAE	<i>Thalassoma hardwicke</i>
<i>Apogon cyanosoma</i>	<i>Taeniura lymna</i>	<i>Thalassoma lunare</i>
<i>Apogon tueniatus</i>	DIODONTIDAE	<i>Thalassoma purpureum</i>
<i>Cheilodipterus quinquelineatus</i>	<i>Diodon histrix</i>	<i>Thalassoma klunzinger</i>
<i>Cheilodipterus macrodon</i>	EPHIPPIDAE	LETHRINIDAE
<i>Siphamia versicolor</i>	<i>Platax teira</i>	<i>Lethrinus harak</i>
BALISTIDAE	<i>Platax orbicularis</i>	<i>Lethrinus lentjan</i>
<i>Balistapus undulatus</i>	GINGLYMOSTOMATIDAE	<i>Lethrinus mahsena</i>
<i>Balistoides viridescens</i>	<i>Nebrius ferrugineus</i>	<i>Lethrinus microdon</i>
<i>Melichthys indicus</i>	GOBIIDAE	<i>Lethrinus nebulosus</i>
<i>Odonus niger</i>	<i>Amblygobius hectori</i>	<i>Lethrinus olivaceus</i>
<i>Pseudobalistes fuscus</i>	<i>Cryptocentris sp</i>	<i>Monotaxis grandoculus</i>
<i>Rhinecanthus assasi</i>	<i>Ctenogobiops sp</i>	LUTJANIDAE
<i>Suffiamen chrysopterus</i>	HAEMULIDAE	<i>Lutjanus bengalensis</i>
BLENNIIDAE	<i>Diagramma pictum</i>	<i>Lutjanus bohar</i>
<i>Atrosalarus fuscus</i>	<i>Plectorhinchus flavomaculatus</i>	<i>Lutjanus coeruleolineatus</i>
<i>Ecsenius midas</i>	<i>Plectorhinchus gaterinus</i>	<i>Lutjanus ehrenbergi</i>
<i>Meiacanthus nigrolineatus</i>	<i>Plectorhinchus gibbosus</i>	<i>Lutjanus fulviflamma</i>
<i>Plagiotremus rhinorhynchus</i>	<i>Plectorhinchus obscurus</i>	<i>Lutjanus kasmiri</i>
<i>Plagiotremus tapienosoma</i>	<i>Plectorhinchus schotaf</i>	<i>Lutjanus monostigma</i>
<i>Plagiotremus townsendi</i>	HOLOCENTRIDAE	<i>Lutjanus sanguineus</i>
BOTHIDAE	<i>Adioryx ruber</i>	<i>Lutjanus sp</i>
<i>Bothus pantherinus</i>	<i>Myripristis murdjan</i>	<i>Macolor niger</i>
CAESIONIDAE	<i>Myripristis xanthacrus</i>	<i>Paracaesio sordidus</i>
<i>Caesio caerulea</i>	<i>Neoniphon sammara</i>	MONODACTYLIDAE
<i>Caesio lunaris</i>	<i>Sargocentron caudimaculatum</i>	<i>Monodactylus argenteus</i>
<i>Caesio striata</i>	<i>Sargocentron inodai</i>	MUGILIDAE
<i>Pterocaesio chrysozoma</i>	<i>Sargocentron spiniferum</i>	<i>Crenimugil crenilabis</i>
CARANGIDAE	KYPHOSIDAE	MULLIDAE
<i>Carangoides bajad</i>	<i>Kyphosus cinerascens</i>	<i>Mulloidichthys flavolineatus</i>
<i>Carangoides fulvogunatus</i>	LABRIDAE	<i>Mulloidichthys vanicolensis</i>
<i>Carangoides plagiotaenia</i>	<i>Anampses lineatus</i>	<i>Parapeneus cyclostomus</i>
<i>Caranx ignobilis</i>	<i>Bodianus azillaris</i>	<i>Parapeneus forsskali</i>
<i>Caranx melampygus</i>	<i>Chelinius fasciatus</i>	<i>Parupeneus cinnabarinus</i>
<i>Caranx sexfasciatus</i>	<i>Chelinius lumulatus</i>	MURAENIIDAE
<i>Gnathanodon speciosus</i>	<i>Chelinius undulatus</i>	<i>Gymnothorax flavimarginatus</i>
<i>Scomberoides commersonianus</i>	<i>Coris africana</i>	<i>Strophidon sathete</i>
<i>Trachinotus bailloni</i>	<i>Coris caudimacula</i>	MYLIOBATIDAE
CARCHARHINIDAE	<i>Epibulus insidiator</i>	<i>Aetobatus narinari</i>
<i>Carcharhinus amblyrhynchos</i>	<i>Gomphosus coeruleus</i>	

NEMIPTERIDAE	<i>Daseyllus trimaculatus</i>	<i>Epinephelus chlorostigmata</i>
<i>Scolopsis ghanam</i>	<i>Pomacentrus albicaudatus</i>	<i>Epinephelus fasciatus</i>
OSTRACIIDAE	<i>Pomacentrus aquilus</i>	<i>Epinephelus fuscoguttatus</i>
<i>Lactoria cornuta</i>	<i>Pomacentrus arabicus</i>	<i>Epinephelus lanceolatus</i>
<i>Ostracion cubicus</i>	<i>Pomacentrus sulfureus</i>	<i>Epinephelus malabaricus</i>
<i>Ostracion cyanurus</i>	<i>Pomacentrus trichourous</i>	<i>Eptnephelus marcrodon</i>
PEMPNERIDAE	<i>Pomacentrus trilineatus</i>	<i>Epinephelus summana</i>
<i>Pempheris oualensis</i>	<i>Neoglyphidodon melas</i>	<i>Plectropomus pessulferus marisrubri</i>
<i>Pempheris vanicolensis</i>	<i>Stegastes nigricans</i>	<i>Variola loati</i>
PINGUIPEDIDAE	<i>Pseudochromis flavivertex</i>	SIGANIDAE
<i>Parapercis hexophthalma</i>	SCARIDAE	<i>Siganus argenteus</i>
PLESIOPIDAE	<i>Hipposcaris harid</i>	<i>Siganus luridus</i>
<i>Plesiops nigricans</i>	<i>Scarus collana</i>	<i>Siganus stellatus</i>
PLOTODIDAE	<i>Scarus scaber</i>	<i>Siganus sutor</i>
<i>Plotosus lineatus</i>	<i>Scarus ferrugineus</i>	<i>Siganus rivulatus</i>
POMACANTHIDAE	<i>Scarus frenatus</i>	SPARIDAE
<i>Apolemichthys xanthurus</i>	<i>Scarus ghobban</i>	<i>Acanthopagrus bifasciatus</i>
<i>Pomacanthus asfur</i>	<i>Scarus niger</i>	<i>Diplodus noct</i>
<i>Pomacanthus maculosus</i>	<i>Scarus psittacus</i>	<i>Rhabdosargus sarba</i>
<i>Pygoplites diacanthus</i>	<i>Scarus sordidus</i>	SPHYRAENIDAE
POMACENTRIDAE	<i>Scarus strongylocephalus</i>	<i>Sphyrarna barracuda</i>
<i>Abudefduf saxatilis</i>	SCOMBRIDAE	<i>Sphyrarna jello</i>
<i>Abudefduf sexfasciatus</i>	<i>Grammatorcynus bilinaeatus</i>	<i>Sphyrarna qenie</i>
<i>Abudefduf sordidus</i>	<i>Restrelliger kanagurta</i>	<i>Sphyaena putnamiae</i>
<i>Abudefduf vaigiensis</i>	SCORPAENIIDAE	SYNODONTIDAE
<i>Amblyglyphidodon leucogaster</i>	<i>Pterois miles</i>	<i>Synodus dermatogenys</i>
<i>Amphiprion bicinctus</i>	<i>Pterois radiata</i>	TRERAPONIIDAE
<i>Chromis dimidiata</i>	<i>Scorpaenopsis oxycephala</i>	<i>Terapon jarbua</i>
<i>Chromis pembae</i>	SERRANIIDAE	TETRAODONTIDAE
<i>Chromis trialpha</i>	<i>Aethaloperca rogaa</i>	<i>Arothron diadematus</i>
<i>Chromis viridus</i>	<i>Cephalopholis argus</i>	<i>Arothron hispidus</i>
<i>Chrysiptera leucopoma</i>	<i>Cephalopholis hemistiktos</i>	<i>Canthigaster margaritata</i>
<i>Chrysiptera unimaculata</i>	<i>Cephalopholis miniata</i>	
<i>Dascyllus aruanus</i>	<i>Cephalopholis sexmaculata</i>	
<i>Dascyllus marginatus</i>	<i>Epinephelus areolatus</i>	

Source: Brodie et al. (1998).

Appendix IV: Coral Reef Community Types and Composition in the Yemeni Red Sea

Reef Type	# Sites	TC (%)	HC (%)	DC (%)	MA (%)	SC (%)	# Sp	Depth (m)	Temp (°C)	Main Species	Common Species
SE Corners	5	51	17	34	20	2	44	4	32	<i>Pavona cactus</i> <i>Ginastrea</i> sp.	Foliose <i>Echinophora</i> sp.
Clear Water	12	43	29	14	7	2	46	3.5	30	<i>Acropora pentagona</i> <i>Pocillophora damicornis</i>	<i>Galaxesa fascicularis</i> <i>Seriatopora caliendrum</i> Tabular <i>Acropora</i> sp. <i>Lobophyllia</i> sp.
Pinnacles	4	52	24	28	7	3	56	9.5	30	<i>Porites</i> sp. <i>Siderastrea savignyana</i>	<i>Faviidae</i> <i>Montipora</i> sp. <i>Pavona</i> sp. <i>Leptastrea purpurea</i>
Low Density Mono-specific	13	37	3	34	35	1	9	2	32	<i>Platygyra daedelea</i> <i>Goniastrea retiformis</i>	<i>Fungia fongites</i> <i>Goniastrea retiformis</i>
	10	51	7	44	21	1	27	3	32	<i>Montipora monasteriata</i>	Encrusting <i>Faviidae</i> <i>Favia fava</i> <i>Porites nodifera</i>
South Fringing	7	38	11	23	14	1	26	2.5	30	<i>Echinophora geminecea</i>	Foliose <i>Echinophora</i> sp. <i>Montipora</i> sp. Branching <i>Acropora</i> sp. <i>Porites nodifera</i>

Note: TC = Total Substrate Cover; HC = Hard Coral (live); DC = Dead Coral; MA = Macro Algae; SC = Soft Coral; # Sp. = Number of Species.

Source: Tourak & Brodie (1998).

Appendix V - Acknowledgements

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