

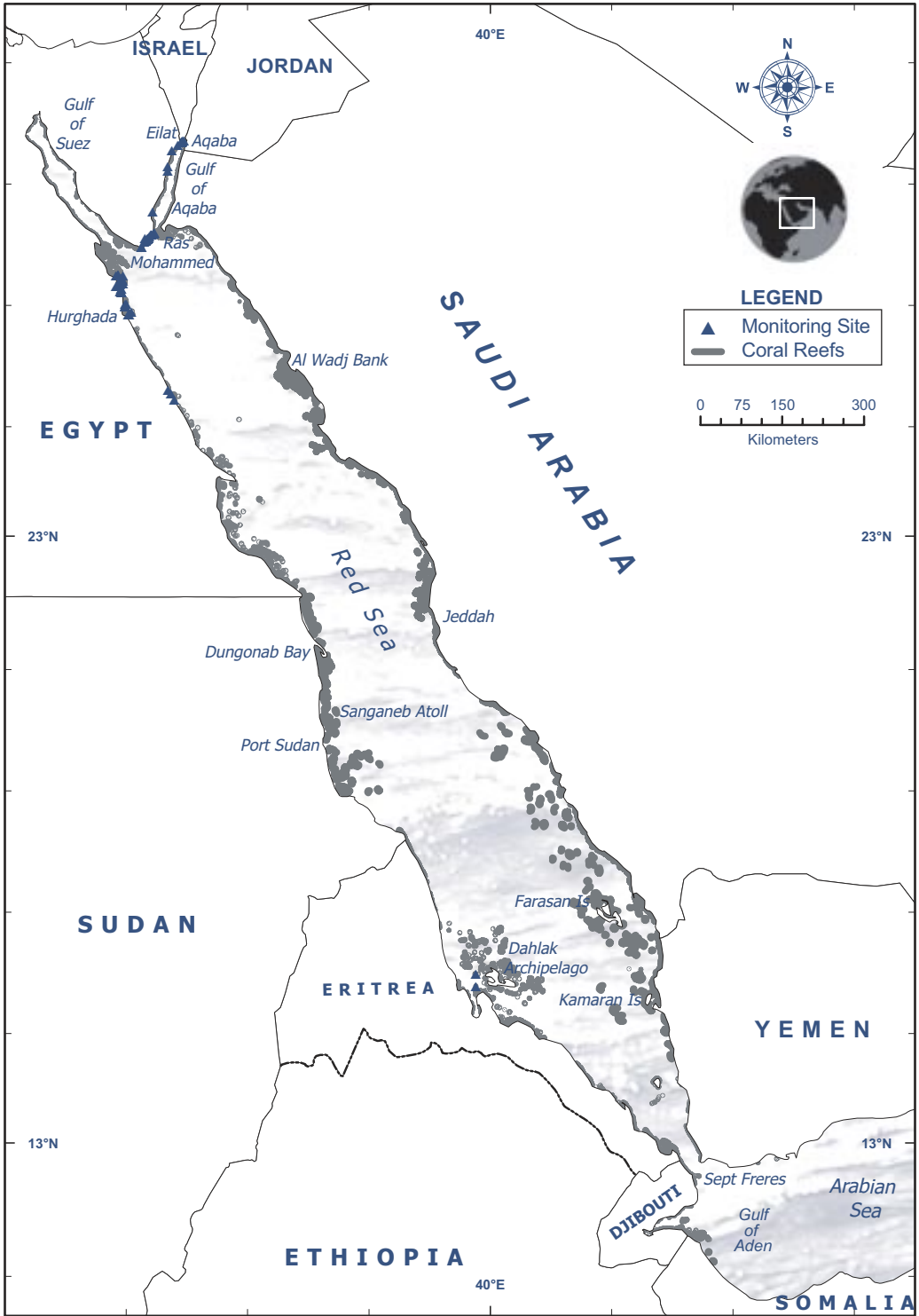
4. STATUS OF CORAL REEFS IN THE RED SEA AND GULF OF ADEN IN 2004

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ABSTRACT

The status of coral reefs and coral communities in the Red Sea and Gulf of Aden is generally good, with coral cover averaging 20-50%. This includes decreases and increases in live coral cover since 2002. The 1998 bleaching event caused major damage on parts of the southern Red Sea and Gulf of Aden, but caused no damage in the northern Red Sea; in some areas the recovery has been strong, and weak in others. Recent outbreaks of the crown-of-thorns starfish (COTS) have occurred in Egypt, Saudi Arabia, Djibouti and western Somalia, along with some local bleaching. Threats to coral reefs differ in the region, but are increasing with the increasing rate of coastal development. The major local threats include land fills, dredging, sedimentation, sewage discharge and effluents from desalination plants, mostly around towns, cities and tourist development sites. There is local reef damage around major tourism areas, caused by people and boat anchors, along with other threats. Fish populations are declining in some areas, because of increased demand for and fishing pressure on food and ornamental species. Destructive fishing practices such as trawling in fragile habitats is increasing. There has been an influx of illegal fishing vessels seeking to meet demands of the export market and more affluent and growing populations locally. The other major threats are from pollution and shipping accidents, and future bleaching. Monitoring these reefs is becoming increasingly important, as climate change and warmer waters near the limits for coral growth.

Most countries have enacted national legislation for coral reef conservation, and signed multinational agreements with assistance from the Regional Organisation for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA). However, these laws are either poorly implemented or enforced and often are ignored completely. The main need is to enforce national and international laws, develop public awareness programs and adopt sustainable management strategies. This will require long-term strategies for capacity building. PERSGA developed a Strategic Action Program in 1998 and a Regional Action Plan in 2003 for reef



Map courtesy of The WorldFish Center

conservation. The plan aims to reduce impacts with: Integrated Coastal Management; Education and Awareness; Marine Protected Areas; Ecologically Sustainable Reef Fisheries; Shipping and Marine Pollution control; and Research, Monitoring and Economic Valuation. Several major new MPAs are being developed in Djibouti, Eritrea, Saudi Arabia, Sudan and Yemen. Management of existing MPAs in a number of countries, including Egypt and Yemen, has improved, with support from the Global Environment Facility and bilateral donors. A UNDP/GEF Coastal, Marine and Island Biodiversity Project is starting in Eritrea.

100 years ago: Following the opening of the Suez Canal in 1869, the region was a major international shipping route with occasional shipwrecks and related oil spills. There were invasions of alien species but damage from human activities was minimal. There were some artisanal fishers but fishing pressure was low and fish stocks were largely unexploited. The reefs were predominantly healthy.

In 1994: Most reefs were in good condition, with sustainable levels of fishing and low levels of human damage, except near towns, cities and tourist sites. Some reefs were affected by COTS outbreaks in the 1970s, and bleaching in the early 1990s.

In 2004: Urban growth, coastal land reclamation and fisheries are expanding, and COTS outbreaks are continuing. Tourism continues to expand in some countries, but not others. There has been strong recovery of some reefs badly damaged by the 1998 bleaching event, but others have shown no recovery. There has been some success in establishing MPAs, but there is no effective regional MPA network, and most of the declared MPAs have ineffective management.

Predictions for 2014: Pressures will increase from: major development for mass tourism and industrialisation; over-exploitation and destructive fishing in poorly managed fisheries; COTS outbreaks; and bleaching events. Over-exploitation of fish throughout much of the region will pose a more serious threat, unless regulations are strengthened and enforcement improved. Further large-scale bleaching events, like that of 1998, may prove catastrophic to stressed coral reefs in the Gulf of Aden and southern Red Sea. These impacts will probably lead to decreases in the health and extent of reefs, reduce their renewable goods and services, and lower natural recovery. However many reefs in the region will remain healthy, particularly those remote from development or with strong currents or cool upwellings.

INTRODUCTION

This report summarises recent research and management in countries of the Red Sea and Gulf of Aden, including the Arab League nations of Djibouti, Egypt, Jordan, Saudi Arabia, Somalia (north coast), Sudan, and Yemen, and the non-affiliated Eritrea.

GEOGRAPHICAL SETTING AND REEF COVERAGE

The Red Sea is 2,270 km long from 30°N in the Gulf of Suez to 13°N at Bab el-Mandab where it joins the Gulf of Aden. It is a maximum of 350 km wide and 2,920 m deep and surrounded by extremely arid coastlines. The southern entrance at the Straits of Perim is only 130 m deep, which restricts water exchange between the Red Sea and the Gulf of Aden. The land surrounding the Red Sea is hot and dry with minimal freshwater inflows, and high rates of evaporation. The input of surface waters from the Gulf of Aden must compensate for evaporation losses. As a result the salinity varies along the Red Sea from 36.5ppt at the southern entrance, to more than 41ppt

in the northern Gulf of Aqaba in summer. Water temperatures and nutrient concentrations decrease in surface waters towards the northern end, where the water is generally clearer.

All major reef types occur in the region, including barrier reefs and extensive fringing reefs and patch reefs bordering the coasts and islands of Djibouti, Egypt, Eritrea, Jordan, Saudi Arabia, Sudan, and Yemen. There is one atoll, Sanganeb, and pinnacle reefs in the Central and Southern Red Sea. Coral reef development is limited by cold seasonal upwelling in the Gulf of Aden off Djibouti, Northern Somalia and Yemen. Many fringing reefs in clearer water have high coral cover close inshore and around islands away from the shore.

The Red Sea has high biodiversity, including approximately 300 reef-building coral species and over 1400 fish species. The biological diversity of other animals and plants associated with coral reefs is also high. There are many endemic species making this region a globally significant repository of biodiversity. The reefs and associated seagrass beds also support endangered turtles and dugong.

Coral distribution is patchy and true reefs are generally not well developed in the Gulf of Aden, although there are mixed coral-dominated communities with moderately diverse hard and soft coral fauna of some 150 species, plus many sponges and macro-algae. The Socotra Archipelago at the entrance to the Gulf of Aden has diverse reef communities, including 250 reef-building coral species, more than 700 fish species and 120 species of algae. More details are summarised in Chapter 2 in 'Status of the Coral Reefs of the World: 2002' and the 'World Atlas of Coral Reefs'.

REEF STATUS AND MANAGEMENT

Regional Level

Reef health is considered to be predominantly good, with 20% – 50% live coral cover at many locations, a generally positive ratio of live to dead coral cover, and high diversity and healthy stocks of key indicator species. The major regional stress during the last decade was coral bleaching in 1998, particularly in the southern Red Sea and Gulf of Aden; although this was highly patchy not affecting Egypt, northern Saudi Arabia, and Jordan. COTS outbreaks have also occurred in some countries. Progress has been made in coral reef monitoring, and many surveys are conducted using GCRMN – Reef Check protocols, consistent with recommendations of the 'Standard Survey Methods for Key Habitats and Key Species in the Red Sea and Gulf of Aden'. However, there is a lack of capacity to design, implement and support monitoring and management programs. Much more capacity is needed and major challenges remain to achieve effective coordination and implementation of national surveys, monitoring activities and reporting. Little new information has been received since 2002 for several countries.

Reef fish stocks are coming under increasing pressure, with rising national and international demand for food and ornamental aquarium species. Increasing activities in some parts contravene CITES regulations with the export of endangered turtles and of corals. Edible sea cucumbers are currently fished in most countries of the Red Sea for export to SE Asia. This industry is new to the region and harvesting is increasing rapidly. There is poor enforcement of existing regulations, and often conflicting policies and objectives about fisheries among different government departments. Moreover there is insufficient data to develop sound management policy. Aquaculture development is increasing in the region, and large shrimp farms are being developed in many countries, including Saudi Arabia, Sudan and Eritrea.

A Regional Action Plan for the Conservation of Reefs in the Red Sea and Gulf of Aden was developed in 2003, with 6 major components aimed at ameliorating predicted damage to reefs:

- i. **Integrated coastal management (ICM):** Implement ICM in all participating countries, supported by appropriate legislation, land use planning, participatory approaches, socio-economic and environmental impact assessment, monitoring and enforcement. Poorly planned and regulated coastal developments for tourism and urban expansion have caused the greatest local impacts and pose significant future threats in most countries.
- ii. **Marine protected areas (MPAs):** Establish a biologically interconnected network of MPAs, deemed crucial to the long-term maintenance of reef ecosystems and viability of populations of endemic, rare, threatened or endangered and harvested species. Most countries have already taken important steps toward developing MPAs, although considerable differences in management capacity exist, and capacity-building remains a priority. A series of demonstration MPA sites throughout the region have been proposed and/or established and site specific management plans are now written for some areas. The list of proposed demonstration sites includes (from north to south): Aqaba Marine National Park (Jordan); Ras Mohammed National Park (Egypt); Giftun Islands and Straits of Gubal (Egypt); Dungonab Bay and Mukawwar Island (Sudan); Sanganeb Atoll (Sudan); Farasan Islands Marine Park (Saudi Arabia); Iles des Sept Freres (Djibouti); Aibat and Saad ad-Din (NE Somalia); Belhaf – Bir Ali (Yemen); and Socotra Group of Islands (Yemen). Other MPAs will join these sites as capacity develops.
- iii. **Ecologically sustainable reef fisheries:** Implement accurate stock assessment and monitoring, effective regulation of fishing effort (e.g. through licensing) and ‘no-take’ zones in MPAs, with seasonal closures to protect spawning stocks, surveillance and enforcement. Recent examples include establishment of ‘no-take’ zones in MPAs in Egypt, Saudi Arabia, Sudan and Yemen. Reef fisheries, and other demersal fisheries which deliberately or inadvertently affect reefs, are expanding in most countries as national and international demand continues to grow, other than some MPAs, this growth remains largely unregulated or enforced.
- iv. **Shipping and marine pollution:** Implement obligations under regional and international conventions, including adoption of Port State Control, improved navigation systems and oil spill response capacities, surveillance and enforcement. The region is one of the major global thoroughfares for international maritime traffic, placing reefs at high risk of groundings, spills, pollution and introduction of alien species in ballast waters.
- v. **Research, monitoring and economic valuation:** Implement standard methods of biophysical and socio-economic survey and monitoring, including GCRMN – Reef Check protocols, to support ICM, MPAs, fisheries and shipping components. Biophysical monitoring is continuing in key locations, including in Egypt and the Socotra Islands (Yemen), and currently being established in various coastal and island locations of the Yemen Red Sea and NE Gulf of Aden.
- vi. **Education and awareness:** Increase government and public awareness of the various values and renewable goods and services of reefs through networks, the mass media, schools, universities and local communities. Recent initiatives for capacity-building include assessments of training and equipment needs and development of training program outlines in public awareness and eco-tourism in Djibouti, Egypt, Saudi Arabia, Northern Somalia, Sudan and Yemen.

Eritrea is not included in PERSGA, and is implementing its own plans through a UNDP-GEF Project based in Massawa (see below).

Three areas were recently recommended with the highest global priority for inclusion on the World Heritage Register for their outstanding tropical marine biodiversity: parts of the northern Red Sea and Gulf of Aqaba (including areas of Saudi Arabia and Egypt); parts of the Southern Red Sea 'Complex' (including areas of Saudi Arabia, Yemen, Djibouti, Eritrea); and the Socotra Archipelago (Yemen). Socotra is a UNESCO 'Man and Biosphere Reserve'. Parts of Southern Egypt, central Sudan and the Gulf of Aden coast of Yemen (Bir Ali area) were also recommended for World Heritage listing.

The following information has been summarised from the 'Country Reports' produced by PERSGA in the framework of the Strategic Action Program for the Red Sea and Gulf of Aden, and updated from various sources, including survey and monitoring data and management plans from 2002 - 2004.

Djibouti

There is discontinuous coral growth along the 370 km coastline of Djibouti with the total coral reef area being 12 km². There are fringing reefs around the Sept Frères Island group, within the Gulf of Tadjoura (a narrow 800 m deep trench), and around the vast fossil reef plateau of the Isles de Maskali and Moucha, at the entrance to the gulf north of Djibouti town. Corals grow between 1 m and 45 m depth, but the relatively high turbidity limits coral growth to the upper 15 – 25 m. These reefs vary in status, from very poor to good, with coral cover often well over 50% and up to 90% in the best areas. In the Gulf of Tadjoura, coral cover ranged from 12% south of Maskali to over 60% off Sable Blanc with an average of 36%. Cover has not changed much since surveys in 2000, however, several sites off Maskali Island were deteriorating. Some coral reefs are completely covered in algae, and reef flats covered in rubble from eroding table corals. These losses have been caused by the combination of coral bleaching and large numbers of COTS.

There is minimal coral disease recorded, mainly white band disease and black band disease, although coral eating snails *Drupella* sp. and *Coralliophila* sp. were present. There have been COTS outbreaks in the Gulf of Tadjourah and Isles des Sept Frères during 1998 – 2000, but no signs of recent bleaching events. Coral mortality at Iles des Sept Frères is attributed to the 1998 bleaching event. Coral cover in 2002 was: up to 90% at Kadda Dabali; 32-66% at Grande Ile, Tolka Ile Basse; 44% at Horod Le Rhale Ile de l'Est; 47% (range 13 - 64%) at Rhounda Komaytoug Ile du Sud, up to 60% at Hamra Ile de l'Ouest; and 25% (range 10 - 55%) at Khor Angar.

Djibouti's reefs are under threat from domestic tourism, sewage discharges, shipping and associated spills and pollution, with pressure particularly high around the capital city. Shipping is an important commercial sector in Djibouti, which is the major harbour for Ethiopia. Anchor, boating and tourism damage is increasing, with little increase in environmental awareness. International tourism is just developing and damage is limited. The low level of fishing is mostly for subsistence and there is limited exploitation of tropical fish for live export, but aquarium fish collecting is increasing. Djibouti is developing several MPAs including Moucha, Maskali ('Moucha Territorial Park' and the 'Integral Park of South Maskali) and Sept Frères/Ras Siyyan and Godoria. Maskali and nearby Moucha Island, in the Gulf of Tadjourah, were included in the first MPA declared in the Red Sea and Gulf of Aden in the early 1970s, however there is no effective

management. In 2004, PERSCA published a management plan for the Isles des Sept Frères/Ras Siyyan and Godoria Marine Protected Area, but management has not been implemented.

Egypt

There are a wide range of reefs including mainland and island fringing reefs, coral pinnacles and patch reefs along the 1800 km Egyptian Red Sea coast. These reefs sustain major international tourism operations, semi-subsistence harvesting, fishing and aquaculture. Tourism contributes significantly to the economy through tourist charges and spending. Coral reefs range widely in condition and cover, with up to 85% living coral cover at the best sites. Coral cover was significantly higher in the Red Sea than in the Gulf of Aqaba, ranging from 16-67% at 5 m depth, with an average of 45% in the Red Sea, and 35% in the Gulf of Aqaba. The 1998 global bleaching event had little effect in Egypt, but coral cover in some areas has declined by more than 30% due to coastal development, COTS outbreaks, illegal anchoring, scuba diving, snorkelling and reef walking. Coral cover at 2 sites in the Gulf of Aqaba decreased from 37% to 13% between 1997 and 2002, most probably due to COTS outbreaks.

Tourism activity is intense with some reef sites receiving over 75,000 divers per year. Commercial fishing is widespread and remains largely unregulated. The consequences of fishing are unknown except for the reduced biomass and mean length of target species. Butterflyfish and sweetlips decreased markedly in abundance in the Gulf of Aqaba and Red Sea from 1997 to 2002. The abundance of groupers and parrotfish remained stable in the Gulf of Aqaba, but decreased in the Red Sea. There is better enforcement of no-take zones and fishing prohibitions in South Sinai than in the Red Sea.

Reefs are threatened by oil pollution and solid waste discharged from vessels. Most human damage is around major tourist development sites (e.g. Hurghada, Safaga, Sharm El Sheikh), at reefs lacking mooring buoys and where tourist boats used to anchor on the leeward sides of reefs. Inter-tidal reefs have been damaged by inappropriate development. Some hotels were built on reclaimed land, although most reef flat disturbance has ceased since the laws have been enforced. Dredging for harbour and artificial lagoon construction for hotels, although illegal, continues. Seagrass beds are particularly vulnerable to disturbance by anchors and chains, while mangroves have been damaged by camel grazing and wood harvesting.

The Egyptian Environmental Affairs Agency (EEAA), the Egyptian Environmental Policy Programs (EEPP), and international donors, are strengthening protection of the reefs and other marine habitats. The Wadi El Gemal Hamata Protected Area (PA) was declared in 2003 to protect coral reefs, mangroves, seagrass meadows and terrestrial habitats south of Marsa Alam. A management plan was completed and a ranger station established at its northern boundary. This MPA complements those on the Sinai Peninsula and the Red Sea islands off Hurghada. More than 100 moorings have been placed at high use reefs between Hurghada and Ras Banas since 2002, and the number of EEAA rangers has doubled. The EEPP recently reviewed Egypt's environmental impact assessment procedures, developed environmental awareness guidelines for tourists and completed a strategic conservation plan for the Red Sea between Marsa Alam and Ras Banas. They are attempting to control the type and quality of tourism development, to encourage ecotourism and to increase public awareness of the importance of environmental protection. Several NGOs are active in the region, and the cooperation between the Provinces, the EEAA and the NGOs has steadily improved. A snorkelling and diving tax was recently imposed by the Red Sea Governorate, with a substantial proportion allocated for environmental protection.

The legal framework for the protection of coral reefs is excellent and is implemented in several areas. There is, however, an urgent need for better enforcement and improvements in tourism developments to cope with the increasing pressures, if the coral reefs are to continue to provide income for the country. Important research on coral reefs by local and international scientists continues to be fostered and is assisting MPA managers develop no-take zones, control Bedouin fishing, and limit diving and reef walking.

Jordan

The coral reefs on the short coastline (27 km) in the northern Gulf of Aqaba are in fairly good condition, with up to 80% living coral cover at the best sites. These cooler water reefs in the northern Gulf of Aqaba were not affected by the 1998 warming, however, the pressures from urban, industrial, port, and tourism developments are higher than anywhere else in the region. These pressures result in visible deterioration of coral reefs. Other threats include pollution and shipping, especially phosphate loading, COTS outbreaks and diseases from aquaculture. The Aqaba Coral Reef Protected Area at the Marine Station is the only MPA. Jordan recently revised its legal and regulatory framework, and implemented other measures to conserve the coral reefs, including establishing artificial reefs for divers.

Saudi Arabia

The coral reefs along the 1800 km Red Sea coastline are generally in good condition, with high living coral cover, often exceeding 50%, and healthy stocks of key fish and invertebrate species (except near major cities). Few areas have been surveyed, but the best reefs in 2002, were on the Wajh Bank (average 40% cover at 5 m). Jeddah reefs had 20% cover at 5 m, and the reefs off Farasan Island had 28% at 5 m. Jeddah reefs are influenced by the growing city of 2.2 million people and problems of urban and industrial development including pollution, domestic and industrial sewage dumping, construction, dredging for the construction of marinas, siltation and effluents from desalination plants. A further problem is the increase in local and foreign tourism, boating and diving, and their direct and indirect impacts on the coral reefs. By comparison, the regions of Wajh and Farasan Islands have relatively low human impacts.

Fishing pressure is low to medium in most Saudi Arabian waters, however, it is high in the more remote areas, which are not as well patrolled by the coast guard. Destructive fishing methods are sometimes used to drive fish into the nets at these remote sites. Spear-fishing is illegal in Saudi Arabia, although it is often carried out with the use of scuba, and this may explain the lack of large groupers and other target species in some areas, particularly around towns. There is also some collecting of ornamental reef fishes for the aquarium trade.

The major recent disturbance was the bleaching in 1998, which resulted in localised losses of coral cover and diversity on some reefs, particularly in the south. Damage was patchy elsewhere, and most northern reefs were virtually unaffected. Isolated COTS outbreaks have occurred, but most northern reefs remain in good condition. Recent management initiatives by the National Commission for Wildlife Conservation and Development include the designation of the Wajh Bank and the Gulf of Aqaba as MPAs and the development of master and management plans for these areas.

The proposed Ra's Suwayhil Protected Area has outstanding biological diversity and incorporates nearly 80% of the eastern coastline of the Gulf of Aqaba. Most of the coastline and hinterland remains in a near natural state with no urban and industrial development. The proposed Ra's

Qisbah Marine Protected Area, to the east of the Strait of Tiran, has coral reefs, seagrass beds, intertidal sand flats, and has large densities of dugong. New species of hard corals from the area have been described recently, and there is little commercial and recreational fishing. The Wajh Bank also has healthy diverse reefs, large seagrass beds, and probably the largest population of dugong in the eastern Red Sea. These northern parks will complement those of Egypt and Jordan, and conserve a significant portion of the northern Red Sea coral reefs in MPAs, while further south, the Farasan Islands MPA, will complement those proposed by Sudan, Yemen and Eritrea.

Somalia (Gulf of Aden coast)

There is 1,300 km of coastline on the Gulf of Aden from Ras Casey to the border of Djibouti, with large shallow sandy areas and a few seagrass beds. Coral growth is limited because of a lack of suitable bottom substrates and unfavourable currents. A seasonal upwelling in the Gulf of Aden encourages the growth of macro-algae on most hard substrates on northern Somalia. Corals grow in sheltered bays, but there are few true reefs. However there are extensive areas of coral-dominated communities. The largest and most diverse communities occur near Saad ad-Din Island, and near Karin, in the Maydh area, between Buruc and Bosaso and west of Xabo. Elsewhere there are isolated coral colonies and small coral patches. Coral species diversity is comparatively low and large areas are covered by one species of coral, sometimes with live coral cover of 80%.

These shallow water coral communities and associated reef fish are in near original condition, with minimal damage from recent bleaching events. Reef fisheries are minimal, except near the border area with Djibouti, however uncontrolled lobster fishing is a growing concern along the entire coast. Sharks, lobsters, and more recently sea cucumbers have been heavily harvested along this remote coastline. There was a COTS outbreak in an unknown proportion of reefs in western Somalia in the late 1990s resulting in considerable loss of living corals. Near Djibouti there is a trade in corals, other marine curios and turtle meat for sale in Djibouti. The fishers from Somalia, Djibouti and Yemen operate without any constraints, fisheries management, or enforcement. There are virtually no stresses from the land as the area is sparsely populated, and there is almost no central government presence in the area (Puntland and Somaliland).

The Aibat, Saad ad-Din and Saba Wanak Islands near Saylac were recently surveyed by PERSGA, and the area was declared as Somaliland's first MPA in 2003. The following year Somaliland declared several other MPAs including Daloh Forest Reserve and Maydh Island, a seabird breeding site of international significance. There are no management plans.

The main threats are uncontrolled fisheries, and the international shipping traffic in the Gulf of Aden. Somalia has limited ability to implement legislation and meet national and international obligations. There is a severe lack of effective institutions, funding and trained staff.

Sudan

The 750 km Sudanese coast has fringing and barrier reefs and the oceanic Sanganeb Atoll, which is an MPA of global importance. The reefs range in condition from some sites with more than 70% live coral cover to 15% in other areas. In 2002, the average live coral cover was 44% at 5 m and 34% at 10m (range 15% and 57%). The populations of some key indicator fish groups were average to low compared to the other regions of the Red Sea in 2002, although size of fish was generally larger.

The coral reefs in Dungonab Bay, Sanganeb Atoll, Wingate Reef, Shaab Rumi and Suakin are well studied as they are important for tourism, and Donganab Bay and Sanganeb Atoll have been declared as MPAs with management plans that have not been implemented. The reefs near Port Sudan and Port Basheir are also monitored to assess the damage from industrial activity. Corals are widespread and generally healthy inside Dungonab Bay, and outside the Bay there are extensive fringing and patch reefs, and barrier reefs to more than 30 km offshore. Sanganeb, about 30 km from Port Sudan, is the only atoll in the Red Sea, although it is small at 6.5 km by 1.5 km. Coral cover on the back reef and reef flat varies from 10-30%, while on the outer reef wall cover is 40-70% before a vertical drop to a debris slope. Fringing reefs near Port Basheir remain healthy with 35% cover in the back reef, 51% on the flat and 48% on the slope. Corals at Towartit Reef are less diverse than at Basheir and have lower cover (27% in 2002).

Damage from the 1998 bleaching event is still evident along the coast of Sudan. Corals in the Dongonab Bay showed patchy mortality; in some areas it was 90% from 0 – 15m depth, while other areas were almost entirely unaffected. Coral recovery has been patchy: some areas show high levels of recruitment and growth; but many others show no recovery. The offshore reefs were barely affected in 1998, and remain in very good condition (e.g. Merlot Reef, Abington, Sanganeb Atoll and Shaab Rumi). Outbreaks of COTS caused extensive damage to corals in the 1970s and 1980s, particularly inside Dungonab Bay, but in 2002-03, there were few COTS and minimal coral disease. Similarly, damage by *Drupella* is slight on these reefs.

Construction of an oil pipeline, refinery and marine terminal at Port Bashair, 24 km south of Port Sudan, has increased shipping traffic. These ships have to navigate through breaks in the fringing reefs which poses an accident risk to reefs. Coastal and urban development at Suakin Harbour and north of Port Sudan has damaged the corals, especially as a result of increased sedimentation; 2 km² of reef was reclaimed near Port Sudan. Shrimp farms, salt pans, and industrial development around Port Sudan have the potential to damage nearshore reefs. Tourism threats are mainly from boat anchors and breakage by divers, but this is not a serious problem, because there are few tourists. Tourism is growing in Sudan and some early regulation may reduce the type of damage that has occurred elsewhere in the Red Sea. There is low public and government awareness of the need for coral reef conservation, and enforcement of the legal framework is poor.

Yemen

The coastline of Yemen is 2,200 km long, with two thirds in the Gulf of Aden. The Red Sea and Gulf of Aden are markedly different environments and the reef types reflect these differences. The Red Sea coral reefs are mainly coastal and island fringing reefs, with some patch reefs and coral pinnacles; the reefs cover approximately 25% of the coastline. Reefs fringe the limestone islands (e.g. the Kamaran group or the southern Farasans), and the volcanic oceanic islands in clearer water (e.g. the Hunaish, Zuqar and Zubairy groups). There are more than 100 islands in the Yemen Red Sea and only a few have been assessed. Coral growth is generally reduced due to the shallow muddy nature of the shelf; unlike the central and northern Red Sea. There are strong seasonal southerly winds, which stir up the sediments, reduce water visibility and stress the corals. In addition, these shallow waters experience comparatively high water temperatures which further stresses the corals. The reefs are more like reef flats without true crests and slopes. The condition of Yemen Red Sea reefs varies widely. Many were badly damaged in the 1990s by bleaching, COTS outbreaks and trawling, with coral cover losses of up to 90%.

Living coral cover averaged 53% in 2002, with a maximum of 70%. Monitoring of 10 Red Sea sites in 2004 showed a range of healthy live coral cover from 28% to 63%. In other areas, coral cover ranged from 5% to 85% at sites with mixed macro-algae and coral communities. There has been good recovery since 1998, with higher coral cover and species diversity around the Tigfash and Kamaran island reefs in 2004, e.g. at Uqban Kebir island in 1998 there was 43% coral cover at 4 m, and 52% with a doubling of *Acropora* spp. cover in 2004. At Uqban Seghir island, there was extensive mortality around 1998, but in 2004, cover was more than 60%, dominated by *Stylophora* spp. There was still evidence of damage from the 1998 bleaching and COTS and *Drupella* outbreaks at some sites, with large piles of rubble. COTS have re-occurred in high numbers in some areas of the Hunaish Islands in 2004.

Information about coral communities along the Gulf of Aden coast is still sparse. Coral growth is limited by cold-water up-welling during the summer SW monsoons. Thus coral distribution is patchy and the reefs are not well developed, e.g. fringing reefs cover only 5% of the coast. The coral communities also contain large populations of soft corals, sponges and macro-algae, which are diverse and abundant. There are important seagrass areas and biodiversity 'hotspots' near Bir Ali-Belhaf. Hard coral cover previously ranged from 15% in Mukalla to 69% in Belhaf, however this declined dramatically after the 1998 bleaching event. Many areas in the north-eastern Gulf of Aden suffered particularly badly in 1998 with coral mortality of almost 100% in monospecific coral communities. There are few signs of recovery.

The Socotra Group of Islands at the entrance of the Gulf of Aden have rich marine biodiversity and many endemic species. These islands are biogeographic 'crossroads' between the adjacent larger regions. This high biodiversity was the reason the islands were high priority targets for MPAs in 1998-2000 as part of the UNDP-GEF 'Socotra Biodiversity Project'. They are studied well now, with 250 hard coral species, over 120 species of macro-algae, and 730 species of reef fishes. Coral growth on Socotra is affected by cool water upwelling during the south-west summer monsoons, and corals form small, discrete communities, rather than true reef structures. The corals were affected by the 1998 bleaching event, but there has been considerable recovery of surviving corals and new recruits, such that average coral cover is around 30% (Box p 148).

Artisanal fishing is the main source of income for many coastal people on the coasts of Yemen, with high fishing effort that is beyond sustainable levels for many target species, particularly in the Red Sea. The abundance of some of these species has steadily declined; the export sea cucumber fishery has expanded rapidly, and industrial and artisanal trawlers for cuttlefish, shrimp and fish are damaging the reefs. Destructive methods are used to collect aquarium fish around the Kamaran Island Group. Ship groundings have caused some damage. A ship smashed 1,500 m of reef on Zugar Island in 2001; and another in 2004 caused 2,350 m of damage to the coral reef in Mayun (Perim) Island. No cleanup or restoration was carried out and anti-fouling paints probably still remain on the reefs. Tourism has declined recently.

There have been some major management initiatives, including the continuing MPA program on the Socotra Islands (UNDP with national and multilateral support), implementing a reef monitoring program in the Red Sea, and MPA planning along the Red Sea (UNDP-GEF) and Gulf of Aden coasts (Belhaf – Burum and Sharma – Jethmun areas; World Bank-GEF). Integrated Coastal Management and Sustainable Fisheries projects are currently being drafted for both the Gulf of Aden and Red Sea coasts by various agencies and are expected to improve

MONITORING CORAL RECOVERY ON SOCOTRA, YEMEN AFTER THE 1998 BLEACHING EVENT

There was patchy coral mortality during the 1998 bleaching event around the Socotra Islands, Gulf of Aden, Yemen. Some sites, particularly on the main Island of Socotra, were badly affected, with more than half the coral cover lost, while other sites on the outer islands were barely affected. These islands and the marine communities were designated as protected areas, and a long-term coral monitoring program was established, as outlined in Status of Coral Reefs of the World: 2000. Recent monitoring is showing that average coral cover around Socotra Island increased from 25% in 2000 to 32% in 2001, and remained steady at 31% in 2003. There were some coral losses at one shallow site near the seaport. Hard coral cover increased at 5 of the 6 monitoring sites, indicating considerable recovery of the Socotra corals damaged by bleaching in 1998. There was some localised bleaching at the seaport between 2001 and 2003 with a major loss of mostly branching *Acropora*, probably due to elevated sea surface temperatures in May 2001, and water pollution from development of the port and a road. There was no sign of damage from 1998 on the outer islands and no major changes to coral cover have occurred since; 40% coral cover in 2000 and 43% in 2002. The monitoring program has demonstrated that the coral communities of Socotra have recovered strongly and consistently since 1998, particularly in the Nature Sanctuary protected zones of the MPA on Socotra Island. There is one exception, the shallow site near sea port in the General Use Zone. These coral communities near the port require particular management focus, and continued monitoring will be valuable to assess any future effects of climate change. From: Malek A. Abdulaziz, Yemen Environmental Protection Authority and Socotra Conservation and Development Program, malek_asaad@yahoo.com, John Turner and Lyndon DeVantier.

the conservation and management of Yemen's vital coastal and marine resources, and the coral reefs in particular.

Eritrea

The biodiversity of Eritrea's coral reefs is of global significance. The prolonged disturbances ended in 1993 after 3 decades during which there were very low levels of human damage to the reefs. The coral reefs generally remain in very good condition, despite a moderate growth in tourism, some coastal development, and significant growth of commercial fisheries since independence. Coral cover ranges from 20-50% at most sites in the west of the Dahlak Archipelago, the islands near the port cities of Massawa in the north and Assab in the south. Cover occasionally approaches 100% at some sites. The coral eating mollusc *Drupella* usually occurs in high densities on many reefs, however COTS and coral diseases are comparatively rare. Development of commercial fisheries is now a high priority, including an aquarium fish trade that was discontinued in the late 1990s. Artisanal fisheries target pearl oysters, *Trochus*, *Strombus*, finfish, marine turtles and sea cucumbers.

The majority of the coastline is sparsely populated, with Massawa and Assab the two main population centres. Only 4 of the 350 offshore islands are inhabited, hence human stresses remain relatively low. Land reclamation, sedimentation, and resort developments in Massawa and on nearby islands may have damaged the adjacent coral reefs. There are signs of anchor and

diver damage on the few reefs visited by tourists, but curio collection is minimal. Eritrea has ratified several international conventions, including the Jakarta Mandate, the Convention on Biological Diversity, and CITES, but this has not translated into legal protection for the coral reefs. National environmental legislation has been drafted, but is unlikely to be implemented in the near future.

The Ministry of Fisheries is responsible for the conservation of marine biodiversity and for implementing a US\$5 million GEF funded biodiversity conservation project to conserve the coastal, marine and island ecosystems. The project includes a monitoring program for coral reefs and invasive species, and there are plans to establish 3 MPAs near Massawa and Assab, and a Coastal Zone Management framework. The Marine Biology Department of the University of Asmara in Eritrea will be responsible for rapid national marine biodiversity surveys and there are plans to develop a species conservation program for the turtle and dugong populations.

CONCLUSIONS

100 years ago: The region was already receiving significant scientific attention, with many widespread Indo-Pacific reef species described. The Red Sea was already a major international shipping route, following the opening of the Suez Canal in 1869, with occasional shipwrecks and related oil spills. The Red Sea and Gulf of Aden have been trade routes for thousands of years and the reefs have supported artisanal fishers. There were no notable invasions of alien species through the Suez Canal, and damage from human activities was negligible.

In 1994: Most of the reefs were in good condition, with sustainable, although increasing, levels of fishing and other human pressures, except around the towns. Urban and tourism developments had caused major local damage to adjacent reefs. Some reefs in Egypt, Sudan and Yemen had been affected by COTS outbreaks, and minor bouts of coral bleaching in the early 1990s. Ship groundings in Egypt, Yemen and elsewhere had caused local damage. Reef and pelagic fisheries were expanding to supply increasing local, and export demands. There were few coral reef management activities in the region in 1994. The major national and regional environmental management initiatives started in the late 1990s, with PERSGA, in partnership with the Global Environment Facility (GEF), the United Nations Development Program (UNDP), the United Nations Environment Program (UNEP) and the World Bank.

In 2004: Urban growth, coastal land reclamation and fisheries are expanding, and COTS outbreaks are continuing. Tourism is expanding in some countries, but not in others. There has been strong recovery of some reefs badly damaged by the 1998 bleaching event, but others have shown no recovery. There have been notable successes in establishing MPAs, yet major challenges remain in developing an effective regional MPA network and managing some existing MPAs. Major gaps remain in survey and monitoring capacity, as well as most aspects of reef management.

Predictions for 2014: Increases in local and regional threats will degrade coral reef resources and reduce reef resilience. There will be increasing pressures from major coastal and port development, expanding fisheries, shipping and pollution, COTS outbreaks and climate change. These will cause reef deterioration, with reduced coral cover and lower fish stocks and biodiversity. As coastal development increases, there will be more damage to reefs around the larger ports and major tourist resorts. There is a serious and growing threat of major over-

exploitation of fisheries throughout the region, and both the regulations and enforcement mechanisms need to be urgently improved in most countries. Any repeat of the large-scale bleaching event of 1998 will prove catastrophic to reef communities in marginal conditions in the Gulf of Aden and southern Red Sea. It is highly likely that the combination of these impacts will lead to decreases in the health and extent of reefs, their renewable goods and services, and a loss in regional resilience. However, it is also expected that many healthy reefs will remain in the region, particularly those remote from development, and where local currents and upwellings moderate sea temperature fluctuations. These conditions will favour healthy reef growth, possibly the healthiest reefs in the world. Human populations in large parts of these desert areas will not expand therefore human pressure on coastal resources is expected to remain low.

RECOMMENDATIONS

Most countries have laws for coral reef conservation, but the scope of the laws and the degree of implementation differs widely in the region. Stronger enforcement of national and international laws is needed in every country of the region, along with campaigns to raise public awareness of coral reef issues and the need to adopt sustainable management strategies. The priority actions needed to minimize the predicted damage to reefs have been identified in the Regional Action Plan coordinated by PERSGA in 2003. Steps have been taken to implement action, including the recent development of standard survey and monitoring methods, and improved management of some MPAs. However, there is insufficient capacity for effective reef management, or monitoring in most countries. The lack of capacity is an important regional issue, and major long-term programs of capacity building are urgently required.

REVIEWERS

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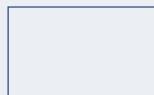
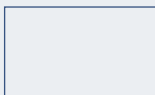
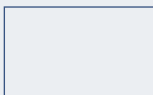
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SOCOTRA GROUP OF ISLANDS, REPUBLIC OF YEMEN - MAB SITE

The Yemeni Socotra Islands, located at the entrance to the Gulf of Aden, were recognized as a UNESCO Man and Biosphere Reserve in 2003 and have been recommended for inclusion on the World Heritage Register, for which a nomination is currently being prepared. The islands, Socotra, The Brothers (Samha and Darsa) and Abd al Kuri and small islets, host outstanding levels of terrestrial endemism, and are important nesting sites for at least 10 species of seabird. The marine communities are also diverse, with some 250 species of reef-building corals, 730 species of coastal fishes and 120 species of algae, and are characterised by a unique “cocktail” mix of species representative of several marine biogeographic realms that merge here: the Red Sea and Arabian Sea, East Africa and the western Indian Ocean and the broader Indo-Pacific. For the time being at least, a small number of these species are known only from these islands, like many of their terrestrial counterparts.

These biological features, both terrestrial and marine, have sustained the islands’ human inhabitants for millennia, as the Socotrans have maintained a unique cultural identity, living sustainably off their land and seas. In 1997, the year that the Government of Yemen declared the islands a special natural area that required protection, the GEF invested five million dollars US in a United Nations Development Program (UNDP) implemented project titled ‘Conservation and Sustainable Use of the Biodiversity of the Socotra Archipelago’. With strong Government support, terrestrial and marine protected areas were established in September 2000, with a ‘Conservation Zoning Plan’ defining the various activities that are permitted and forbidden in different areas. The Yemen Environmental Protection Authority (EPA) has responsibility to implement the Plan. The local communities have actively participated in the process, with an increasing future focus on co-management. Yet significant challenges remain, with inappropriate development and harvest pressures continuing to build, and the Islands are therefore being carefully monitored and steered towards ecological and socio-economic sustainability.

Ecological monitoring: A long-term monitoring program has been in place since 2000 (Box p 148) established as part of the UNDP-GEF Socotra Biodiversity Project.

Socio-economic monitoring: A socio-economic monitoring program for fisheries was also established as part of the UNDP-GEF Socotra Biodiversity Project.

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Coral reefs are 5% of the natural resources.

Ecological Monitoring is effective.

Socio-economic Monitoring is effective.

Contributed by Lyndon DeVantier and Catherine Cheung

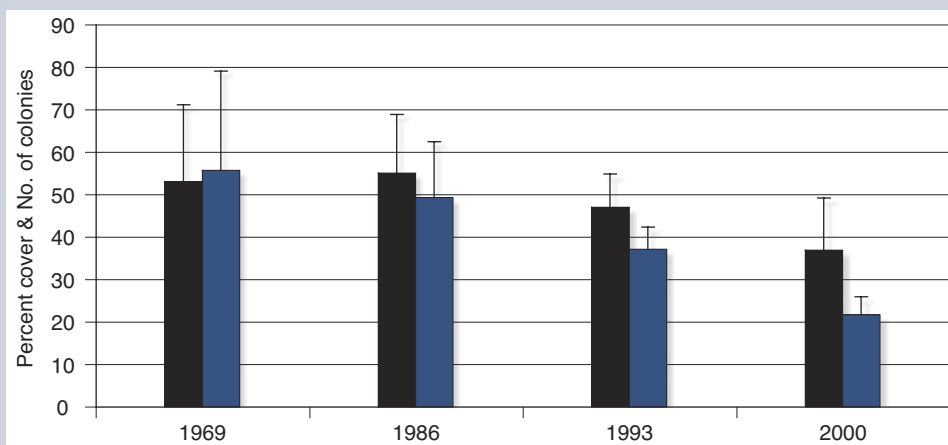
THE CORAL REEFS OF EILAT, ISRAEL OR HOW TO KILL A CORAL REEF

The rapid growth of the city of Eilat, Israel, put increasing human pressures on the nearby reefs. There were 20,000 people in 1980, 40,000 in 1990, 54,000 in 1995, and 65,000 in 2000. The first signs of the damage to the reefs of Eilat (northern Gulf of Eilat/Aqaba, Red Sea) were in the 1980s and early 1990s, probably due to a combination of anthropogenic disturbances such as urban sewage, phosphate dust, groundwater inputs, sedimentation, tourist diving activities and port-ballast water. Many of these harmful activities were minimised by strict environmental enforcement, however the sewage from Eilat continued to flow into the sea until 1995, when a sewage treatment plant was built. The coral cover and colony abundance at the 'Japanese Gardens' in the Eilat Coral Nature Reserve (3-7 m depth) decreased by 33% and 56%, respectively between 1986 to 2000. These falls occurred when the levels of nutrients released from anthropogenic sources into the northern Gulf of Eilat/Aqaba showed a dramatic increase: in 1980 the total annual nitrogen release was 5×10^6 mol Nitrogen; and phosphate release was 0.24×10^6 mol Phosphorous. These quantities doubled in 1990, with the increase in population, but stopped in 1995 after the sewage was diverted away from the Gulf. The increased nutrients were considered to be the main cause for the decline in the corals. However, about this time, a new threat emerged; intensive net-pen fish farming started at the northern end of Gulf, and these have continued to grow exponentially. These fish farms use large fish cages, 12 m in diameter and 10 m deep, packed with gilthead sea bream *Sparus aurata*. The annual fish yield was 200 tons in 1991; it increased to 700 tons in 1995; and grew to a massive 2400 tons in 2000. All the waste food and fish faeces which falls through the cages either accumulates on the sea floor, or is carried by the currents through the northern Gulf.

These fish cages became the major anthropogenic source of nutrient enrichment releasing 18×10^6 mol/year N and 2×10^6 mol/year P. It is estimated that about 68% of the nitrogen and 27% of the phosphorus fed to the fish ends up back in the water as dissolved excreted products. In addition, 10% of N and 44% of P are dispersed as solids; hence, the annual amount of nutrients released into the surrounding water is 240 tons of N and 40 tons of P. It has been further shown that the particulate matter from the fish farms reaches the coral reefs 8 km further south. Indeed, much of the nutrient matter from the fish farms was carried further south and accumulated on the sea floor at 500 m.

These added nutrients set up a chain reaction: the nutrient enrichment stimulated phytoplankton blooms; the excess phytoplankton stimulated zooplankton production; and these are eaten by fish and the excess nutrients are passed up the food chain and distributed over the northern Gulf. The waste products of this stimulated chain reaction are deposited on the reefs and particularly into the deep waters of the Gulf. The surplus of nutrients have accumulated in these deep waters; but during winter, the cold surface waters sink and mixes with the deeper waters (i.e. vertical mixing) and effectively 'pumps' the nutrient-rich waters to the surface, resulting in 'macro-algal blooms' with the algae growing over and smothering the corals.

The deterioration of corals in Eilat occurred in two major phases. Between 1986-1994, all of Eilat's sewage flowed into the sea; and from 1995-present, the fish farms became the major anthropogenic source of nutrient enrichment in the northern Gulf. The sewage caused the major decreases of 14.7% in coral living cover and 24.6% in coral abundance. The fish farms grew exponentially from 1993 and contributed most of the additional nutrients, thereby causing a further decrease of 21.6% in coral cover and 41.9% in coral abundance. There has been further deterioration of corals of the northern Gulf in the last 4 years, since these measures were taken, due to diseases affecting the corals. Hence, the fish farms "replaced" Eilat's sewage as the major anthropogenic source polluting nutrients (equivalent to an urban sewage of a city counting 70,000 people) responsible for the continued deterioration of the reefs after 1995 to date. Today, the coral reefs of Eilat are severely damaged and exist in a critical state of health. From: Yossi Loya, Department of Zoology, Tel Aviv University, Israel Yosiloya@post.tau.ac.il. (Reference: Y. Loya (2004). The coral reefs of Eilat- past, present and future: Three decades of coral community structure studies. In: Coral Reef Health and Disease; Rosenberg and Loya (Eds). Springer-Verlag; Berlin, Heidelberg, New York. pp. 1-34).



Nutrient pollution from urban sewage and fish farm wastes have resulted in a steady loss of coral cover and coral colonies in the 'Echinopora zone', (3-7 m depth) at the Eilat Coral Nature Reserve. The bars on the left are average live coral cover (%) and the bars on the right are average number of coral colonies along permanent 10 m line transects (\pm SD = standard deviations; n = number of transects).