5. Coral Reef Status in the ROPME Sea Area: Arabian/Persian Gulf, Gulf of Oman and Arabian Sea

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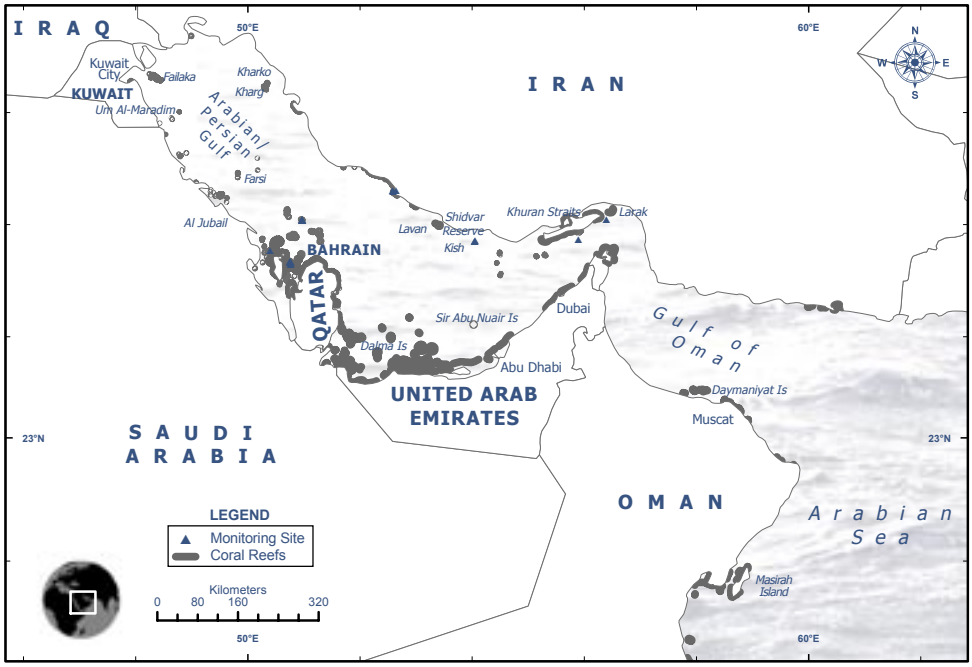
Abstract

This report summarises the status of coral reefs in the ROPME Sea Area which includes Bahrain, Iran, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates (UAE); there are no coral reefs in Iraq. The region can be split into three parts according to the local marine climate, which strongly influences the nature of the coral communities: the Persian/Arabian Gulf (hereafter called 'the Gulf'); the Gulf of Oman; and the Arabian Sea.

The Gulf region was amongst the worst affected by coral bleaching events in 1996, 1998 and 2002, which reduced live coral cover in many shallow areas to less than 1%. There has been very little recovery, except in a few areas close to deeper water and away from additional human impacts. Coastal engineering, land reclamation and dredging are causing significant environmental damage along the mainland coast, particularly in UAE and Bahrain, while offshore islands are protected either actively (as MPAs) or passively (as military or industrial zones). Any future coral reef conservation effort must be concentrated on these islands in order to be effective.

Coral communities in the Gulf of Oman and Arabian Sea remain in good condition, due in part to the mitigating effects of the summer monsoon upwelling that cools summer seawater temperatures. Coral cover in the Gulf of Oman is typically 30-40% at depths of 4-12 m, but live cover decreases very rapidly in deeper water. This range is consistent with earlier results and suggests that the condition of corals in the Gulf of Oman has not changed significantly in the past 10 years, although there is considerable temporal variability of live cover at some sites due to crown-of-thorns starfish (COTS) outbreaks and periodic recruitment episodes. Unlike the Gulf, coastal industrial development in coral rich areas in Oman does not generally involve large-scale land reclamation or dredging, although the discharge of cooling water is a concern in one area. Fishing remains the major human threat to coral communities in this area.

100 Years ago: Reefs were almost certainly healthy. They were simple reefs, dominated by *Acropora* (staghorn) corals to about 4-5 m depth, then by massive corals (*Porites*, faviids) from



Map courtesy of The WorldFish Center

5 m to about 10 m. Their diversity was lower than in the Indian Ocean due to natural causes including limited recruitment since the last ice age (Holocene), severe annual variation of temperature, and extreme salinity.

In 1994: Corals remained in similar condition in most areas. However, nearshore substantial construction, landfill, and oil and civil development removed much coastal habitat. This applied to seagrass areas as much as to reefs, though the sedimentation particularly affected the nearshore reefs. There were few activities to conserve and manage coral reef resources. The Jubail Wildlife Sanctuary was the first MPA and it was established after the 1992 Gulf War.

In 2004: Coral bleaching events in 1996 and 1998 had a profound effect on these reefs. The entire shallow water staghorn zones were killed in many areas. In 2004, many of these areas have been reduced to rubble, with no sign of recovery, and the mobile rubble may be impeding new recruitment. Some sites do show some recovery, especially in deeper water where there is significant recruitment of faviid species that were previously relatively minor components of the reefs. Consequently there appears to be a shift in the species that are dominating the Gulf reefs. Levels of estimated reef destruction range widely within the region, from a low of 1% in Oman to a high of 97% in Bahrain. There is rising awareness of coral reef conservation issues, but the region lags well behind much of the rest of the world.

Predictions for 2014: The shallow *Acropora* reefs are unlikely to recover because forecasts for sea surface temperatures (SST) indicate that future temperatures will be unfavourable for coral growth. Deeper reefs will increase their coral cover, probably with a shift in the dominant species. As has happened in the past, continuing landfill arising from development will add stresses to nearshore reefs, causing further degradation.

Introduction

This chapter summarises the status of coral reefs in countries bordering the Regional Organisation for the Protection of the Marine Environment (ROPME) Sea Area (Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates). There are no corals in Iraq. This is an update of the corresponding chapter in Status of Coral Reefs of the World: 2002 report.

Three basic marine climates occur in the ROPME Sea area. Extremes of temperature and salinity characterise the Gulf and constrain the development of coral reefs. Seawater temperatures can exceed 34ºC in summer and be less than 15ºC in winter; this is the world's greatest annual temperature range for corals. Salinity in the Gulf is also very high, generally greater than 45 ppt, while in the shallow waters between Bahrain and Qatar, salinity often exceeds 50 ppt. In terms of temperature and salinity, the few corals in the gulf of Salwah and the reefs of the western coast of the UAE probably face more 'extreme' conditions of higher and lower temperatures than those of other areas (e.g. Kuwait). Conversely, the reefs of Kuwait are exposed to a very heavy load of particles due to the shallow water environment and input from the Shatt Al-Arab. These conditions do not affect the reefs of Saudi Arabia or the Western UAE.

Temperatures in the Gulf of Oman are moderate in comparison to the Gulf. Typical winter temperatures fall to 22-23ºC, while summer temperature is characterised by a highly fluctuating regime caused by the rise and fall of a shallow, but strong thermocline. Summer temperatures range between 23-31ºC, and often cover this range within a day. Salinity is a constant 36.5 ppt. The southern seaboard of the Arabian Peninsula experiences a strong and persistent upwelling during the summer monsoon season. Water temperatures can drop to 16ºC but are more typically around 18-20ºC, and reach their annual maximum of about 30ºC just before the monsoon starts. The northern Arabian Sea is eutrophic for 5-6 months of the year, due to the nutrients carried in by the upwelling, resulting in the development of seaweed beds and algal blooms. Salinity is typically 34 – 35 ppt.

The pattern of coral diversity and reef building reflect these different marine climates. Coral diversity and reef building potential in the Gulf is low (less than 40 species) as a result of the extremes in water temperature and salinity that are close to the physiological tolerance limits of many species. Recent work has identified 107 reef-building coral species in the Gulf of Oman, while the species count for the Arabian Sea sector of ROPME is likely to be slightly higher as the influence of the wider Indian Ocean becomes increasingly important along the gradient towards East Africa. In both the Gulf of Oman and the Arabian Sea, reef building potential remains low due to high rates of bioerosion fuelled by primary production from the Arabian upwelling system. The ROPME coral fauna is a sub-set of the Indo-Pacific fauna, mixed with regional endemics, with faviids particularly well represented and acroporiids and fungiids significantly under-represented. At least 10 Southern Arabian endemic species are now known, including two endemic genera *Parasimplastrea* and *Calathiscus* and the taxonomic position of several other species has yet to be confirmed.

Status of Coral Reefs

Kingdom of Bahrain

Coral reefs in Bahrain are mainly distributed around the northern and eastern coastlines. Reefs are of special environmental and economic importance, but their growth, structure and distribution are limited to a few areas by extreme temperatures, salinity and high sediment loads. The reefs include: Fasht Al Adhom; west Fasht Al Dibal; Khwar Fasht; north Jabari; Fasht Al Jarim; Samahij; and Abul Thama. Live coral cover at all sites around Bahrain is very low following widespread mortality in 1996 and 1998. Recovery over the past 6-8 years has been very slow, hindered by an accumulation of silt resulting from extensive landfill. The only significant population of living coral in Bahrain surrounds Abul Thama, a small raised area surrounded by 40 m deep water, about 72 km north of the main island.

Islamic Republic of Iran

The coastline of Iran is approximately 2000 km along The Gulf and the Gulf of Oman. Corals are mostly restricted to the offshore islands on the Gulf coast of Iran that are often protected passively by military bases. This also restricts access to these islands for scientific work, such that many of the important coral areas in Iran remain un-surveyed. Much of the Iranian coast in the Gulf of Oman is sedimentary and exposed, therefore unsuitable for coral growth, although important areas of corals probably exist in the more sheltered bays such as Chah Bahar. There is a need for surveys on this coast to describe coral distribution and composition.

Of the known coral rich areas, Farur (19 ha), Farurgan (2.5 ha), Sirri (16 ha), Lavan (18 ha), Hendourabi (20 ha), Kish (62 ha) and Larak (16 ha) islands have been surveyed in the past 10 years, and Kish Island is now a Reef Check site. *Tubastraea* spp., *Heteropsammia* sp., *Dendronephthya, Sarcophyton, Antipathes* sp. and the gorgonian *Subergorgia suberosa* have been reported from these islands for the first time. It is likely that more detailed work will reveal some better-developed reefs in the Gulf because of the deeper water, slightly lower temperatures and more stable salinities found nearer the Straits of Hormuz.

Other reef sites are known, but have not been surveyed, e.g. the islands of Khark (181 ha), Kharko (266 ha), Nay Band (181 ha), Shidvar (13 ha), Hormuz (59 ha), Hengam (36 ha), Tonb-e-Bozorg and Tonb-e-Koochak (21 ha), Queshm Island and Aboomusa (11 ha). The best-developed reefs are in Kharg, Farur, Farurgan and Larak Islands. Surveys in the 1970s and 1980s indicated live coral cover ranges from 9% on Kish Island, to 30% on Nay Band Bay, with hard coral extending from 3 m to 15 m depths.

State of Kuwait

The most northerly reefs in the Gulf lie around the southern islands, particularly the islands of Kubbar, Qaru and Um Al-Maradim, where they occur in extreme oceanographic conditions with relatively high sediment loading. In this extreme environment, species diversity is relatively low (35 species). Overall the zooxanthellate coral fauna includes 29 species, and the others are not usually considered as 'reef builders'. Coral communities occur as platforms, patches or fringing coral assemblages and the most important and dominant reef builders are *Porites harrisoni, Acropora arabensis* and *A. downingi*. Considerable new research has taken place in Kuwait recently, resulting from surveys connected with the claims for compensation following the Gulf War. The distribution and composition of the coral communities and the fish life they support were reviewed recently.

Sultanate of Oman

Major coral growth occurs in four regions along the varied shores of the 1700 km coastline: the Musandam Peninsula; the Capital Area coast, including the Daymaniyat Islands; the Gulf of Masirah; and the Dhofar coast from the Al Hallaniyat Islands to Mirbat. Although the coral communities are relatively diverse, Oman's reefs are only marginally developed, especially along the Arabian Sea coast. The exception is the country's only true reef which is south of the Barr al Hickman peninsula in the Gulf of Masirah with large areas of monospecific stands of foliose *Montipora* sp. Elsewhere *Porites* is the most important reef builder, and extensive monospecific carpets of *Pocillopora* and *Acropora* are common features. Reef development appears to be limited by high rates of bioerosion, which are facilitated by the productive waters, and frequent lesions made by grazing predators (e.g. COTS and parrotfish).

Recently, 107 species of reef building corals were recorded in the Gulf of Oman, and an additional 20 species probably occur on Oman's Arabian Sea coast. About 15% of these corals are regionally endemic and about 10% are new species, which are being described. These results confirm earlier reports that Oman's coral fauna is unusual because some families are strongly under-represented (Acroporidae and Fungidae) while other families are over represented (e.g. Favidae, Poritidae).

Coral cover in the Gulf of Oman is typically 30-40% at depths of 4-12 m, but live cover decreases very rapidly in deeper waters. This range is consistent with earlier results and suggests that the condition of corals in the Gulf of Oman has not changed significantly in the past 10 years, although there is considerable temporal variability of live cover at some sites due to COTS outbreaks and periodic recruitment episodes. During the summer, upwelling of cool water is at its greatest in central and southern parts of Oman, apparently limiting the incidence of warm water bleaching.

There are often rapid changes in these dynamic communities. Cover at Qibliyah Island in 2002 was moderate in shallow areas (10 m depth), with about 25-30% live cover of the *Acropora* and *Porites* community, and 30-40% cover of dead, intact *Acropora* tables, suggesting significant mortality had occurred within 12-18 months, probably due to a COTS outbreak. A repeat of the 1998 survey in 2003 near Sur showed an average increase in coral cover of about 5% (from 10% to 15%) caused largely by widespread recruitment of *Acropora* species. Frequent disturbances and pulsed recruitment characterise the coral community dynamics throughout the region. Recruitment rates in the Gulf of Oman and the Arabian Sea are about a third of those in the Central Indian Ocean, with the most abundant juvenile corals in Oman being faviids, while the success of recruitment of *Acropora* appears to pulse strongly every few years.

Damage from the 1998 bleaching event in Oman was slight, with some mortality affecting shallow communities in Dhofar. Since then a number of minor and localised bleaching events were reported in 2000, 2002 and 2004 (Muscat Area), but none resulted in significant mortality. However, the frequency of bleaching indicates that corals are living close to their lethal limits during summer, particularly in Musandam where average summer temperatures frequently reach 32ºC.

State of Qatar

Conditions for coral growth are best on the northern and eastern coasts of Qatar, while the western coast is subject to extremes of temperature and salinity. The coral fauna found in Qatar

is similar to that in UAE, with 18 species recorded, although this figure would probably rise with further study. The best coral growth in Qatari territorial waters is on the offshore islands, including Halul Island where strong *Acropora* regeneration has occurred recently. This island, however, contains the main oil and gas marine terminal of Qatar Petroleum and is subject to significant human impacts including dredging for harbour construction and marine outfalls. There has been very high coral mortality in the past 10 years from bleaching and human impacts, particularly affecting the shallow coral communities on the mainland coast, from Fasht al Dibal to Khor Al Oudeid. For example, several hectares of shallow (1-4 m) *Acropora* beds, with *Porites* mounds east of Doha suffered nearly 100% mortality in 1998. Prior to 1998, heavy siltation from construction of a breakwater and land reclamation for the new Doha International Airport severely stressed these communities. At other sites near the mainland, there is about 10% live cover of *Porites* or *Cyphastrea* remaining.

Despite the severe degradation of shallow communities, coral reefs in deeper water have some live coral cover, presumably because of reduced mortality from thermal stress. The new data from Qatar are from seabed surveys for environmental impact assessments or engineering works. Much of the seabed surrounding the oil and gas rigs in the eastern sector of the Qatari exclusive economic zone (EEZ) is a flat limestone cap rock with an occasional veneer of sediment. Coral communities can grow where this platform rises slightly, and are usually dominated by faviids and siderastreids. Although the live cover of these communities is low (5% or less) they may provide brood stock for future recovery of shallow communities.

Kingdom of Saudi Arabia

Corals on The Gulf mainland are mostly limited to small pinnacles or outcrops, and patch reefs between Ras Al-Mishab Saffaniyah and Abu Ali, and between Abu Ali and Ras Tanura. The most developed and most diverse reefs are around 6 offshore islands, particularly Jana and Karan. However, like most Gulf sites, bleaching devastated the corals. For example, around Karan Island, live cover on the reef slope was 33% in 1992, but dropped to 23% in 1994 and to 1% in 1999 after mass coral mortality in 1996 and 1998 when temperatures exceeded 34ºC. Coral communities in the lagoons did not decline in cover, presumably because they are acclimatised to more extreme temperatures. Corals at Abu Ali suffered a similar fate with mortality of about 99%, and only small patches of coral tissue on the regionally endemic *Porites harrisoni* survive. No colonies of the extensive *Acropora* communities recorded in 1994 on the eastern tip of the peninsula were found alive in 1999.

United Arab Emirates

The coastline of the UAE extends 650 km along the southern shore of the Gulf and for 90 km along the Gulf of Oman to the east. However, the total coral reef area, which occurs as shoals and around the numerous offshore islands, is about 1,190 km^2 because the entire EEZ is less than 20 m deep. Many similarities exist between Dubai's coral communities and those of other parts of the Gulf particularly Qatar, Bahrain, Saudi Arabia and Iran. Notable absences from the UAE fauna include *Montipora*, *Pocillopora*, *Goniopora*, all fungiids, agariciids, and oculinids, alcyonaceans, as well as hydrozoans, although many of these taxa are found elsewhere in the Gulf and on other high-latitude reefs in the Arabian region. In general, coral cover, and recovery, was better towards the east than in the west.

Excellent coral growth occurs around Sir Abu Nuair Island (Sharjah Emirate) with probably the best *Acropora* stand in the southeastern Gulf. These corals were severely bleached in 2002

but recovered, probably because they have a degree of acclimation. The *Acropora* bleached much less than the faviids and poritids; a complete reversal from the situation in 1996.

A large MPA, which includes the islands of Bazm al Gharbi and Murawwa, has been declared and managed by the Environmental Resource and Wildlife Development Administration, with the support of private landowners. This area contained some of the densest coral growth in the Gulf before the bleaching in 1996 and in 1998. The area is well managed and has high potential to recover at least partially. Dalma Island off western Abu Dhabi had rocky outcrops and platforms covered with a veneer of corals in 1996, with large areas of *Acropora* and an under-storey of *Porites, Platygyra* and *Favia* spp at depths of 1-4 m. Greater depths were often dominated by large *Porites* colonies and an under-storey of *Acropora*. *Porites*-dominated reefs are also particularly well developed at Bu Tini shoals in Abu Dhabi, where *Acropora* has survived recent bleaching events in pockets protected by *Porites* bommies.

The highest cover and diversity of corals along the mainland coast of Dubai is in the Jebel Ali Wildlife Sanctuary. The Sanctuary has a wide diversity of habitats (lagoons, seagrass beds and coral communities) that are all close together and have strong ecological links. The area was hit hard by bleaching in 1996 and 1998 but recovery is strong, probably due to the availability of new recruits from deeper water. Until recently, this was the only stretch of the Dubai coastline free of industrial development, dredging and land reclamation, however, management of the sanctuary has now been provided to the Palm Island Development Corporation. They are reclaiming huge shallow areas for real estate development as part of the damaging Palm Island and Palm II developments. These mega-projects involve massive scale dredging and reclamation, and are expected to have very negative impacts on the entire coastal ecology of Dubai.

Threats to Reefs

Temperature, Bleaching and Upwelling

Bleaching during 1996 and 1998 devastated coral areas throughout the Gulf, reduced live coral cover to less than 1% in some areas, and may have resulted in local extinctions of certain species. Recovery has been patchy, with rapid recovery and apparent acclimation of more susceptible species in places, while in other areas there is little or no recovery. These latter sites frequently experience other stresses, which in the Gulf are most likely to be sedimentation from dredging and land reclamation, or industrial pollution from cooling water discharges.

The current recovery is limited and involves different species to those, which dominated previously. Recovery in some locations indicates the capacity of the system to gain new recruits from unidentified sources, presumably corals growing in waters deeper than about 10m. However, faviid corals rather than *Acropora* and *Porites* now dominate many of the affected coral areas. This may represent a stage in the ecological succession or a permanent phase shift towards species capable of withstanding higher temperatures. It is predicted that higher temperatures will occur in the Gulf in future. A minor bleaching event occurred in Musandam in August 2003 while seawater temperatures were being monitored. This showed that the critical threshold for bleaching in the Straits of Hormuz is close to 32.5ºC, as a nearby site did not bleach at lower temperatures. In the northern Persian Gulf islands of Iran, bleaching has occurred annually, although with varying intensity.

The contrast in the patterns of bleaching between the Gulf and the Gulf of Oman and Arabian Sea is very striking. There is a strong thermocline in summer in the Gulf of Oman that separates

heated upper water from cooler water arriving with the monsoon upwelling. Thus there is a rapidly fluctuating thermal environment, which protects corals from bleaching. Should the monsoon that induces the formation and movement of this protective thermocline fail or weaken, bleaching can result. This was the case in early 1989 and in 2000, 2002 and 2004. In each case, there was localised bleaching that was not severe enough to cause mortality. Upwelling in the Arabian Sea during the summer months also provides a more secure thermal refuge for corals.

Crown-of-thorns Starfish (COTS)
The persistent presence of COTS, coupled with the occasional population outbreak, are key factors influencing the dynamics and community structure of coral communities in much of the region, particularly in the Gulf of Oman and Arabian Sea. COTS numbers are probably influenced by the timing and strength of upwellings that control larval and juvenile survival rates, as well as prey availability (which appears to be limiting in Dhofar). Low-level COTS infestations in the Muscat area resulted in localised changes to community structure from 2003 – 2004. For example, the coral community at Kalbuh near Muscat was dominated by *Acropora* in 1996, but has not returned to its original structure by 2004 following a COTS infestation in 1997. COTS have also been reported in the Gulf where they appear to have a far smaller influence on reef formation and community structure than in the Gulf of Oman.

Disease
Little is known about the incidence of coral disease, and the effect it may have on coral community structure in the region. An apparently new disease to the region, Yellow Band Disease, has recently been reported from the Gulf, and at two sites in the Gulf of Oman; the Daymaniyat Islands and at Qalhat. Instead of exposing white skeleton, corals attacked by the disease retain a characteristic yellow colouration in the skeleton. Black Band and White Band Diseases have also been reported in UAE, and observed in the Gulf of Oman. Cancerous growths and hyperplasms are common in Omani waters and have been reported from the Straits of Hormuz, Gulf of Oman and Arabian Sea areas.

Bioerosion
Erosion of live corals and dead coral skeletons severely limits the accumulation of a limestone framework and therefore the formation of true reefs within the region, although it does not seem to have a significant effect on the diversity or distribution of corals. In Musandam, cliff erosion by the date mussel *Lithophaga* destabilises substrates and induces rock falls, which may limit reef development in some places.

The principal agents of bioerosion include boring algae and sponges, *Lithophaga*, and the echinoids *Diadema* sp. and *Echinometra mathaei*. *Diadema* forms the densest accumulations, massing on talus areas around the bases of live coral colonies, while in Kuwait high densities of *E. mathaei* are a feature of reef flats. In the Gulf of Oman and the Arabian Sea, the standing stock of urchins is probably higher than in other reef areas because of the high primary production rates of algal turf. Furthermore greater densities of filter feeding internal borers are supported by the greater abundance of phytoplankton and bacteria found in upwelled water. Indeed, in Oman it is common to find healthy colonies of *Platygyra* that are completely hollow because their skeletons have been completely eroded, leaving a thin shell of carbonate and living tissue.

The high incidence of bioerosion weakens corals and makes them more susceptible to physical damage from storms or anchor strikes. In Oman, 35-40% of *Acropora* colonies at Qalhat in the Gulf of Oman were either not attached firmly to the seabed or upside-down.

CORAL BLEACHING AND DISEASE IN THE NORTHERN PERSIAN GULF

Coral bleaching has been studied on the Iranian side of the Persian Gulf at Kish, Farur and Hendourabi islands on permanent transects at shallow (3 - 6 m) and intermediate (6 - 12 m) depths. In 1999, 30% of shallow corals were bleached around Kish Island, especially massive *Favia spp.* and sub-massive *Porites* species with typically 70% of each colony showing surface bleaching. In 2000, there was bleaching of 10% of shallow and 5% intermediate depth corals of Farur Island with about 50% of each colony affected. There was simultaneous, but less serious, bleaching in Nay Band Bay (5% shallow and 1% intermediate corals), with 70% and 50 -70% of each colony was affected, respectively. No bleaching was observed on Kish Island in 2001, but in 2002, there was minor bleaching of 1% of shallow corals around Kish and Larak islands with 40% and 30% of each colony affected, respectively. In 2003, 1% of the corals in Nay Band Bay at both depths were bleached (10% of shallow and 70% of deeper coral colony area affected). Therefore it appears that the incidence of coral bleaching declined between 1999 and 2003 in the northern Persian Gulf. Most of the bleached corals were in shallow water (1 – 30%), with 10-70% bleaching on each colony. Corals in deeper water were less affected (1-5%)..

The incidence of coral bleaching and disease on corals reefs in the northern Persian Gulf, Iran appears to be decreasing in recent years. Bleaching is more likely to affect shallow (3-6 m) water corals whereas the Yellow-Band Disease affects corals more in intermediate (6-12 m) depths.

Study area	Year of survey	% of coral bleached		% of colony bleached		Disease (type/%)	
		3-6 m	6-12 m	3-6 m	6-12 m	3-6 m	6-12 m
Kish Island	1999	30	0	70	0	0	0
	2001	0	0	0	0	0	YBD<1
	2002	1	0	40	0	0	YBD<1
Nay Band Bay	2000	5	1	70	50-70	0	0
	2003	1	1	10	70	0	0
Larak Island	2002	1	0	30	0	0	0
Farur Island	2000	10	5	50	50	0	YBD<5

The first incidence of Yellow-Band Disease (YBD) on corals in the northern Persian Gulf was around Farur Island in 2000. Less than 5% of corals were diseased at 6 -12 m. There was a low incidence (less than 1%) at intermediate depths (6 -12 m) around Kish Island in 2001 and 2002. The affected species were *Porites sp., Favia pallida,* and *Platygyra daedalea*. This disease was previously reported from the Southern Persian Gulf and Gulf of Oman. Thus it appears that intermediate depth corals (6-12 m) are the most susceptible to YBD in the northern Persian Gulf. From: Mohammad Reza Shokri, University of Newcastle, Australia, Mohammad.Shokri@studentmail.newcastle.edu.au

Human Impacts

Dredging and Landfill

Land reclamation and dredging in the Gulf have altered the coastal ecology in such widespread and fundamental ways that little of the original coastline remains around the major cities and industrial areas. The impact extends beyond the shoreline because turbidity and suspended sediments are dispersed from the dredge or reclamation sites. In addition, coastal currents are diverted by coastal engineering, altering the movement of sediment which accumulates. Landfill around Bahrain, Saudi Arabia and UAE have been particularly damaging to the coastal ecology, while alterations to the coast of Kuwait, Iran and Oman have been more localised. In Kuwait, major disturbance to the reef at Umm Al-Maradem has been caused by the Coast Guard base and harbour construction.

Three very large land reclamation projects have started in UAE in the past 2 years: Palm Island; Palm II; and the World Island. These real estate developments are fundamentally changing the ecology of Dubai's coastline. Large areas (several km^2) of seabed are filled, there are impacts from dredging sites, and there are changes to current patterns along the coastline. Palm II is being built over the Jebal Ali Marine Sanctuary where corals occur in one of the few MPAs in UAE. These projects are particularly destructive and there has been minimal environmental management attempted to mitigate the negative impacts. Maintenance dredging and expansion of Jebal Ali Port also releases large volumes of suspended sediments into the coastal environment, further damaging the rich coral areas to the east and west.

In Bahrain, land reclamation on the northern and eastern coasts have increased the urban area by 11 km^2 in less than 10 years, while also damaging valuable shallow coastal resources, including coral reefs. Large amounts of sediment were dispersed directly towards coral areas around the Muharraq dredging area, with about 182,000 m^2 of reef area lost between 1985 and 1992. There are now proposals to reclaim part of major coral reef areas at Fasht Al Adhom, and construct a causeway linking Bahrain with Qatar, further damaging reefs and disrupting currents in the Gulf of Salwah. Despite government regulations controlling impacts from land reclamation, there is little enforcement and many projects are completed without formal government approval. About 10 suction dredgers routinely operate in Bahrain's waters, including specialised cutter dredges capable of working in areas of weak rock, such as coral reefs. Extensive new housing developments are planned for areas currently offshore.

Elsewhere in the region, dredging for navigation, port and harbour construction, road-building and reclamation also occur but on smaller scales. For example, the reclamation of Khasab mud flats in Musandam was completed during construction of a large port complex which was intended to encourage tourism, but these have disturbed nearby coral communities and destroyed a significant seagrass bed.

Fishing

Damage to coral communities from nearshore gillnet fishing goes largely unreported in the region but is noted as a concern in Oman's Coral Reef Management Plan (1996) and National Biodiversity Strategy and Action Plan (2000). The main issue near reefs in Oman is the loss or abandonment of gillnets which entangle and damage the corals, and reduce tourism potential. Periodically the Ministry of Environment combine with dive clubs to remove fishing nets,

traps, and anchors from popular dive sites. Fishing debris is the most common category of waste on beaches of the Gulf of Oman, indicating that there is a larger impact underwater. In the UAE, abandoned fish traps continue 'ghost fishing' for weeks before the trap corrodes and becomes ineffective.

Recreational Activities

Some areas attract significant numbers of recreational divers, bringing with them the risk of anchor damage, especially in heavily used sites. Many of the most popular areas now have permanent mooring buoys e.g. areas in Kuwait, Daymaniyat Islands, Fahal Island, Bandar Jissah and Bandar Khayran in Oman. However, there are still reports of divers damaging corals in isolated areas e.g. Kish Island, Iran. Currently, diver pressure is within the carrying capacity at most sites, although tourism is being promoted throughout the region. Therefore, it is important to ensure that protective measures match rising tourist numbers.

Oil and Industrial Pollution

More than half of the world's ocean-transported crude oil passes through the Strait of Hormuz, and a major new pipeline is being planned for transporting gas from Qatar via UAE to Oman for export. The major sources of marine oil pollution are: tank washings; discharge of oily bilge water; operational spills during loading and unloading; leaks associated with offshore drilling and oil production; major oil spills; and war. Oil pollution can affect the long-term vitality of corals and other reef organisms by affecting their reproductive cycle and early life stages. Coral larvae float to where they are susceptible to the effects of floating oil. The abundant supply of gas from Qatar, UAE and Oman is driving rapid industrial development, often near coral rich areas, e.g. at Qalhat in Oman where gas and fertilizer industries are developing and expanding. New waste oil reception in Fujeirah in UAE has reduced the volume of tanker washings at sea, which may have reduced the volume of tarballs found on Gulf of Oman beaches. Offshore oil and gas exploration and production is continuing in Qatar, UAE and Oman, thereby providing additional risk of damage to coral areas. Exploratory drilling in the Straits of Hormuz failed to find significant gas reserves, but further exploration is currently underway in and around the Gulf of Masirah in Oman.

Cooling water discharges from desalination and power plants are generally 10ºC or more above the ambient temperatures and contain anti-fouling (chlorate) and anti-scaling chemicals. These thermal discharges near coral reefs add to the risk of bleaching, while chlorinated compounds contaminate the food chain and affect growth and reproductive output. The boom in industrial development, power production and desalination in the region, will increase the volume of heated water discharged into an already overheated system. Coral rich areas at risk from thermal discharges include Bahrain, Jebal Ali Marine Sanctuary (UAE), Bushehr (Iran), Ruwais (UAE) and Qalhat (Oman).

Conservation and Management Issues

Law, Enforcement and Institutional Capacity

There are sufficient legal instruments to protect the marine environment in most countries, including the principles and guidelines laid down by ROPME. For example, UAE Federal Law no. 23, 1999 on the Exploitation, Protection and Development of Marine Biological Resources specifically protects coral areas. However, this essential legislation is insufficient to reduce damage to reefs without sufficient enforcement capacity within governments; and many countries have no capacity. There are few effective NGOs in the region and the universities

are largely silent on environmental concerns. Notable exceptions are a small WWF presence in UAE and the newly formed Environmental Society of Oman (ESO). Many universities are funded by the oil industry and heavily occupied in teaching.

Strategic Planning
Saudi Arabia has developed a National Action Plan for Coral Reef Conservation, which focuses on improving the knowledge base about coral reef ecosystems in its territorial waters and reducing human induced pressure. Oman has a National Coral Reef Management Plan (1996), and National Biodiversity Strategy and Action Plan (2000); these plans were developed to manage natural resources, but little has been done to convert plans into action in the region. Regional cooperation in coral reef management has recently improved with a regional conference in Riyadh on coral bleaching (2000), a workshop in Kish Island (2003) and a meeting in Tehran (2004).

Marine Protected Areas
These are a key tool for protecting coral reef areas, but existing MPAs throughout the region require significant improvements in their management to become truly effective. For much of The Gulf, MPAs need to be established on offshore islands away from the rapid coastal developments that have already damaged some areas of high conservation value e.g. Murawwa Island (UAE). Similarly in Oman, management of the Daymaniyat Islands National Nature Reserve needs to be strengthened to meet the conservation objectives.

Public Awareness, Research and Monitoring
The long-term success of conservation efforts requires public acceptance and support, and a sustained education and public awareness campaign is required for issues as complicated and remote as out-of-sight coral reefs. An interactive CD has been developed in Oman for all schools in Oman describing the marine environment (including coral reefs, seagrasses, mangroves, beaches). The authors could find little information on the reefs of this region; a clear indication that more applied research is required. It is widely accepted that research and monitoring are important to support reef management, especially in MPAs, but there are no consistent research or monitoring programs in place. The reason is often a lack of trained personnel, equipment and financial resources, but more importantly a lack of awareness and political will in governments.

Recommendations

To improve research and coral monitoring, the following recommendations are advanced:

- Develop national coral reef policies followed by establishing focal points within the existing institutions to coordinate research and monitoring among national and foreign scientists;
- Implement the policies, both those that exist and new ones recommended above. In this region above all else, there is scant regard for much of the existing regulation.
- Calibrate or standardise monitoring survey procedures, data storage, analysis and reporting, using regional (PERSGA - ROPME) and international protocols (e.g. Reef Check, GCRMN); and
- Provide financial support through ROPME, ICRI, ICRAN, ICLARM, IOC-UNESCO for training of coral reef monitors and scientists, and initiate coral reef monitoring, analysis and reporting projects.

To improve the conservation, management and sustainable use of coral reefs, the following recommendations are suggested:

- Implement national coral reef policies and where necessary develop or refine legislation regulating use of reef resources, including MPAs;
- Enforce the regulations relating to MPAs, fisheries and resource use, both those that exist and new ones recommended above;
- Provide financial support through ROPME, ICRI, ICRAN, ICLARM, IOC-UNESCO for capacity-building and training of coral reef MPA managers; and
- Develop and expand education and awareness programs.

Conclusions

The Gulf area has been very badly affected by global warming, with greater coral mortality than most areas. The prognosis for some groups of corals and reefs, notably the shallow *Acropora* dominated reefs, is not good. Recruitment is occurring in many other areas, particularly of faviids, although this appears to be changing the coral reef community in many locations, with unknown consequences. In many states, there are apparently strong portfolios of environmental regulation. The problem lies not in the need for more legislation, but in the need to adhere to and enforce the existing provisions. There have been more management plans, protocols, surveys and protected area declarations and proposals than in most other areas of similar size in the world. However, the environmental bodies have clearly much less influence than the development bodies, which prefer to build over the sea rather than on the vast empty interiors. This creates problems which are beyond the capacity of nearshore reefs to sustain.

"I have already had occasion to speak, in the course of my travels, of the astonishing mats of works formed by marine insects; namely the immense banks of coral bordering, and almost filling up, the Arabic Gulf… The reader may therefore conceive with himself what a variety of madrepores and millepores are to be met with in these seas" (Niebuhr 1792).

100 Years ago: The vast oil reserves of the region had not been developed, and human uses of the marine area were mostly small-scale traditional fishing and pearling. Reefs were almost certainly vibrant, although their diversity was lower than the Indian Ocean, due to natural causes including limited recruitment after the last ice age when the Gulf was dry land, severe annual variation of temperature, and extreme salinity. These are simple reefs, dominated by staghorn *Acropora* corals to about 4-5 m depth, then by massive corals (*Porites*, faviids) from 5 m to about 10 m.

In 1994: Shipping, particularly tanker traffic for oil transport, had expanded massively with the development of the oil fields, with marked increases in ship-derived pollution. Coastal development had also burgeoned. The substantial nearshore construction, landfill, and oil and civil development have altered much coastal habitat. This applied to seagrass areas as much as to reefs, though the sedimentation affected nearshore reefs in particular. The Gulf War of 1992 damaged coastal habitats but had little obvious effect on subtidal coral cover. Corals remained in similar condition in most areas. There was no coral reef monitoring and minimal awareness of the potential economic and biodiversity value of the coral reefs and the need to conserve them.

In 2004: Major coral bleaching events caused by elevated sea surface temperatures (SST) in 1996 and 1998 resulted in massive coral reef damage. In many areas, the entire shallow water staghorn coral zones were killed. Many of these areas have been reduced to shifting rubble fields, with no sign of recovery. This mobile rubble is now making new recruitment more difficult. Some sites are showing signs of recovery, especially in deeper water where there is significant recruitment of faviids of some species not previously especially dominant, such that there appears to be a shift in species dominance on the Gulf reefs. Levels of estimated reef destruction range widely within the region, from a low of 1% in Oman to a high of 97% in Bahrain. The region has established a regional monitoring network and there is rising awareness of the need for effective coral reef management. In parallel there is rapidly expanding coastal development, especially in the Gulf, which is resulting in considerable reef damage and destruction.

Predictions for 2014: Forecasts for SST indicate that the shallow *Acropora* reefs will continue to come under increasing temperature stresses and therefore are unlikely to flourish. There may be an increase in coral cover on deeper reefs, with a probable shift in the identity of dominant species in the communities. The recovery on these deeper reefs is conditional on no major increases in SSTs. The reefs in the Gulf of Oman and Arabian Sea are unlikely to change and will probably continue to look like they do now. Coastal Development will continue in the Gulf with increased rates of landfill and dredging, providing more stresses to nearshore reefs, and a continuation of what has happened in the past, creating further degradation. It is hoped that rising awareness of the value of coral reefs will stimulate vigorous monitoring and effective management of the reefs of the Gulf, and a stronger awareness and management of the unusual reefs in the Gulf of Oman and the Arabian Sea.

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RAMSAR

SHEEDVAR ISLAND, IRAN – RAMSAR SITE

This wetlands site is located in the Province of Hormozgan, 2 km off the eastern tip of Lavan Island and 9 km off the mainland, in the central Persian Gulf. It covers 870 hectares and is surrounded by coral reefs that are in excellent condition. Sheedvar Island also has important nesting areas for the endangered hawksbill and green turtles. Large colonies of breeding seabirds often containing more than 20,000 individuals use the site for nesting.

Sheedvar Island was designated as a Protected Area in 1971 and upgraded to a Wildlife Refuge in 1972. The uninhabited island and its surroundings are owned by the government of Iran and the Department of the Environment manages the area. Although there are hardly any visitors to the island and no recreational activity, there are rangers on the island during the bird-breeding season.

The Hormozgan Provincial Office and Shahid Beheshti University have prepared a poster and booklet about the environment in the province of Hormozgan, with special reference to Sheedvar Island. Some collection of bird or turtle eggs occurs, but far less than previously. Because of the oil terminal on nearby Lavan Island, Sheedvar island is potentially threatened by oil spills and pollution from oil tankers in nearby shipping lanes.

Ecological Monitoring: Field surveys of birds and turtles have been conducted during recent decades by the Ornithology Unit from the Department of the Environment.

Socio-economic Monitoring: The Island is uninhabited and monitoring is unnecessary.

Contact: Department of the Environment, PO Box 5181, Tehran, Iran 15875 (phone: 98 21 321 3322).

Coral Reefs are an **unknown** percentage of the natural resources.
Ecological monitoring is **occasional**.
Socio-economic monitoring is **not planned** as it is not necessary.