3. Status of Coral Reefs of the Persian/Arabian Gulf and Arabian Sea Region

Simon Wilson, Seyed Mohammad Reza Fatemi,
Mohammad Reza Shokri and Michel Claereboudt

Abstract

Corals growing in most of this region are subjected to extreme environmental conditions, in particular wide fluctuations of temperature and salinity. Mass coral bleaching and mortality in 1996 and 1998 reduced live coral cover significantly in many areas, particularly the *Acropora* species. However, the effects of the 1998 bleaching event in the Arabian Sea was minimised by the onset of the summer upwelling, which moderated the extreme temperatures in Southern Arabia. There are signs that recovery has commenced, but there have been new reports (September 2002) of bleaching in the Gulf of Oman and the Straits of Hormuz and it is too early to determine the ultimate effects of the bleaching on coral health. Human stresses to corals in the region are mostly caused by industrial activity, dredging and land reclamation. Cooling water discharges from desalination and power plants add to the thermal load of a naturally stressed environment. Fishing activity, particularly industrial trawling and the use of artisanal gillnets is causing low level damage to corals throughout the region. However, many of the other stresses that damage coral reefs around the world such as pollution in fresh water runoff, destructive fishing, and over-exploitation are largely absent.

Introduction

The Persian/Arabian Gulf (hereafter called 'the Gulf') is a semi-enclosed, sub-tropical marginal sea surrounded by very dry land. The Gulf is very shallow sea (average depth 35m), and was dry 10 thousand years ago during the last ice age. The Gulf is linked to the Gulf of Oman and the wider Indian Ocean by the narrow Straits of Hormuz which limits water exchanges. Freshwater inputs come from a few rivers that flow from Iran and Iraq, the largest of which is the Tigris/Euphrates, but these contribute little compared to the extreme evaporation rates in the Gulf. The combination of these conditions, particularly the arid desert climate and extensive areas of shallow water, cause extreme conditions for coral growth, with variations in salinity (28 to 60ppt; normal sea water around 35ppt) and temperatures (10 to 40°C) being among the most extreme in the world. Thus coral reefs and communities in the Gulf generally have relatively low biodiversity, and the ability of corals to survive is probably due to their strong genetic adaptability.

In contrast, the Gulf of Oman and Arabian Sea are deep seas (more than 2000m) with more stable and moderate physical conditions, compared to the Gulf. A particularly important feature in moderating summer temperatures in the Arabian Sea is the influence of upwellings. These are driven by the strong southwest monsoon winds that blow across

southern Arabia. This upwelling cools the waters and protects corals from extreme temperatures (see Box). Coral reefs and communities in the Gulf of Oman and Arabian Sea have relatively higher biodiversity compared to Gulf reefs, but are still lower compared to the central Indian Ocean or the Red Sea. However, new research on coral taxonomy in the region is indicating that coral species diversity may be higher than previously reported.

Industry, shipping and fishing are the most significant human stresses to coral reefs in the region. With the abundance of cheap energy, heavy industry has developed rapidly in the past 15 years, with much of this industry located on the coast for easy port access and the abundance of seawater for cooling. Massive electricity generating plants provide power for desalination plants, which provide much of the freshwater in the region. However, thermal pollution from the cooling waters adds to the extreme temperature regimes in the industrialised coastal areas. Oil and gas production, processing and transport also add stress to coral reefs, particularly in the straits of Hormuz where there are major risks of shipping accidents.

The corals in the Gulf were adapted to wide temperature fluctuations and were considered to be temperature resistant, until the major El Niño related climate changes in 1996 and 1998. These resulted in virtually the total death of corals from bleaching in the shallow western side of the Gulf. The reefs on the Iranian side of the Gulf, and those off Oman in the Arabian Sea suffered only minor to moderate bleaching in 1998, due in part to protection from upwelling in June and July.

The Geography of the Coral Reefs

Coral reefs in the Gulf are mostly fringing along the coast and around the most of the islands on the Arabian side and grow on a hard base of old limestone. There are similar reefs on the Iran side, although the nearby waters are about 100m deep. While coral diversity is low, the fish diversity is much higher. Coral growth in the north of the Gulf is limited to southern Kuwait with small patch and fringing reefs inshore, some offshore platform reefs and coral cays, but all grow in relatively shallow water. The reefs along the coast of Saudi Arabia are similar, being a mix of small pinnacles, fringing and patch reefs, particularly around the offshore islands. Although there are also few coral reefs around Bahrain and along the coast of Qatar, in the mid and southern sections of the Gulf, most of the corals occur as isolated or scattered colonies because of the high sedimentation rates and lack of suitable substrate, and the only true coral reefs occur offshore. Much of the coast of the United Arab Emirates is a low-lying, salt-pan (known as *sabkha*) that is rich in seagrasses and generally unsuitable for corals. There are large areas of coral growth and patch reefs on shallow rocky platforms offshore and fringing reefs around many of the islands, but these have largely been destroyed by the bleaching in 1996 and 1998.

The best reefs in Iran are around Khark and Kharku islands in the far north of the Gulf, and from the Lavan to Hormuz Islands in the south, otherwise there are fringing reefs along much of the Gulf coast. Much of the Iranian coast in the Gulf of Oman is sedimentary and exposed, therefore unsuitable for corals, although patchy corals with low diversity are common in some of the more sheltered bays (e.g. Bahar).

In Oman, much of the coast is sedimentary and rocky with limited areas that are suitable for coral growth. Reefs are generally not well developed, although corals and coral communities do occur where there is suitable substrate. The best areas for coral growth are in the Straits of Hormuz, the offshore islands in the Gulf of Oman and areas in the south that are more protected from the full intensity of the rough sea conditions associated with the summer upwelling.

Status of Coral Reefs

Bahrain

No new information was received.

Iran

Some of the northern islands such as Kish and Qeshm in the Gulf are a continuation of the Zagros Mountain Range, and others grow on an uplifted salt dome (Bandar Abbas area). The eastern islands in the Straits of Hormuz are less influenced by the less saline and nutrient-rich waters from the upwelling that pass through the Gulf of Oman especially in the summer monsoon. The Inner Islands tolerate the most saline and least fertile conditions of the region, and coral communities growing around these islands are patchy in the shallow waters and protected areas along the shoreline (e.g. Bandar Taheri Port and Khalij-e-Nay Band Bay in Bushehr Province).

There are 27 species (9 families; 20 genera) in the Nay Band Bay, Kish and Farur Islands area, with the most abundant families being the Faviidae, Acroporidae and Poritidae. Coral species diversity is highest at Kish Island with 21 species, with 16 at Farur Island and 5 at Nay Band Bay. Dominant species for cover and frequency are *Porites lutea* and *P. compressa* in Nay Band Bay and Kish Island, and *P. compressa* and *Acropora clathrata* at Farur Island. There are only a few species of alcyonacean soft corals or reef building hydrozoa, which are common on other high-latitude reefs in the Red Sea and the Indian Ocean.

Live coral cover ranges from 9% on Kish Island, to 30% on Nay Band Bay, with coral extending 3m to 15m in depth. The highest coral cover on Kish Island is on the eastern and southeast margin, whereas the most dead coral cover is on the northern part, adjacent to the main shipping and harbour activities, and the desalination plant. Five years ago, coral, especially *Acropora,* was abundant with little or no dead coral. On Farur Island, live corals occur mostly on the eastern and northeastern part dominated by *Acropora*, with *Porites* dominant on other parts of the island.

In Nay Band Bay, the highest live coral cover was found in the northern portion of the bay, whereas sand flats dominate the southern parts facing the Gulf. Corals are found from 2m to 10m depth. Old dead corals are more abundant in the middle portion of the bay to the east. Outside the bay to the west, small coral patches extend for tens of kilometres. Recent oil and gas installation constructions have severely damaged these patches and they are now mostly dead.

No bleached corals have been observed in the study areas in the Gulf since 1999. However, considerable bleaching occurred throughout the area from 1996 to 1999. At Kish Island in 1999, approximately 15% of massive (*Favia*) and sub-massive coral (*Porites*) colonies showed bleaching, typically with 70% of each colony bleached. There was no evidence of bleaching in 2000 and 2001. Some Yellow-Band Disease was observed for the first time at Farur Island in 2000, and very low incidences were seen in 2001. The corals most affected were *Porites lutea*, *P. compressa*, *Favia pallida*, and *Platygyra daedela*.

Kuwait
No new information was received.

Oman
A bleaching 'hot spot' occurred in early July 2002 when warm water 2˚C above the monthly average occurred near Muscat. There was some bleaching of *Goniopora* colonies in the Daymaniyat National Nature Reserve, 40km off the coast of Muscat in August, with most corals affected in shallow water. The most severely affected species were *Astreopora* (100% of colonies totally bleached), *Symphyllia recta* (60-70% of colonies bleached), *Goniopora* (50% of colonies bleached), *Platygyra* (20% of colonies partially bleached), and soft corals (25% of colonies bleached). These corals constitute approximately 20% out of the 85% hard coral cover. Minor bleaching was also observed at Qalhat in October 2002 (some *Goniopora* and *Acropora* only) but corals on the mainland coast of Muscat were largely unaffected.

Further bleaching was reported in the Straits of Hormuz along the coast of the Musandam peninsula during September 2002. The worst affects were in restricted water circulation, while areas with strong currents were unaffected. *Platygyra*, other faviids and *Porites* that are normally resistant to bleaching, were significantly affected with 60% of all colonies bleached or partially bleached. Seawater temperatures over the summer 2002 remained consistently at 33ºC for 30 days during July and August, while the temperature averaged 31.5ºC over the same months in 2001.

The bleaching in southern Oman in 1998 only affected very shallow corals on a small part of the coast near Mirbat, however, surveys in January 2002 showed 5-10% coral cover, compared to 20-30% cover in 1996. The decline is partially due to the bleaching in 1998, but more likely to be caused by summer upwellings, crown-of-thorns starfish (COTS), and the effects of abalone fishing and scuba diving. The density of coral recruits was low compared to other sites in Southern Arabia (e.g. Socotra Archipelago), indicating that recovery will be slow.

Hard coral cover at Qibliah Island in the Hallaniyat Archipelago in January 2002 was moderate in shallow areas (10m depth), with about 25-30% 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. No COTS were found, however, during searches in areas where there were feeding scars. There was a significant COTS outbreak in 2001 and 2002 at Bandar Khayran in the Muscat area where more than 50 starfish were found in each 30 minute survey. Coral cover was reduced by 10-80% by the COTS, affecting mostly acroporids and

Upwelling Areas as Thermal Refuges

The upwelling that occurs during the southwest monsoons provides a thermal refuge for marine life in southern Arabia during summer months when other parts of the region are exposed to maximum temperatures. In upwelling areas, there are two peaks in seawater temperatures during the year. One is in late May and one in October, and rarely do these maxima exceed 30°C. Temperatures during the upwelling season can fall to 18°C, but generally average 20°C. In contrast, non-upwelling areas in the region (e.g. Sohar, Oman) have a single annual temperature maximum in June, July and August of 32-33°C. The cool water brought to the surface by the upwelling also contains high levels of nutrients and can also contain very low levels of dissolved oxygen. The high nutrient conditions stimulate rapid growth of phytoplankton and seaweeds that reduces the amount of light reaching the corals and increases rates of bio-erosion, whereas the periodic anoxia results in large fish kills. Blooms of harmful algae are also common in areas influenced by upwelling. These also cause periodic fish kills and mass mortality of marine wildlife, such as that observed in Southern Oman, Yemen and Somalia in November 2001. Although the strongest effects of the upwelling are felt along the Arabian Sea coasts of Oman, India, and Pakistan, the influence occurs in many parts of the Gulf of Oman, particularly along the northern Iranian shores. On the southern coast of the Gulf of Oman, upwelled water remains below a strong thermocline that in turn is pumped up and down by long-shore winds. In shallow water, this rapid pumping of the thermocline induces rapid temperature fluctuations of up to 8°C in less than 2 hours. Corals appear unaffected by this rapid fluctuation and its cooling effect probably serves to reduce the thermal stress, which otherwise could cause bleaching. From Steve Coles and Simon Wilson.

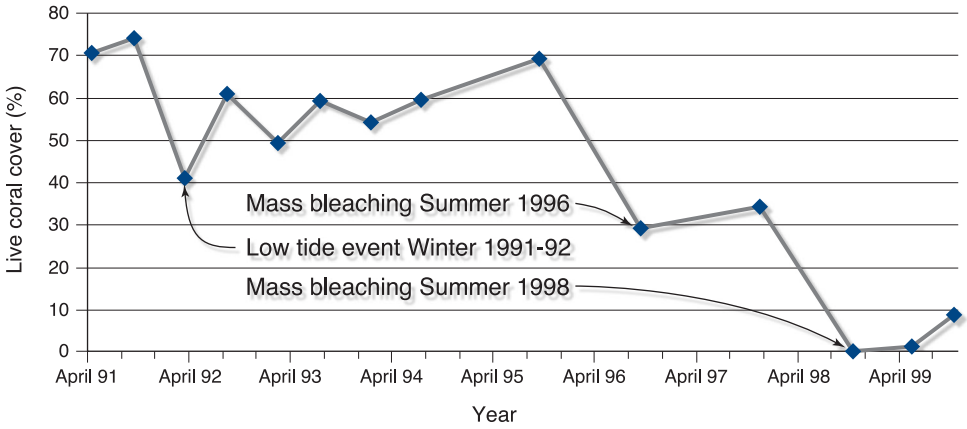
Platygyra. Only a few shallow water *Acropora* communities survive in the area and this suggests that chronic COTS infestations have caused a reduction of *Acropora* cover. Fishing activities have also damaged the corals, as many *Acropora* tables were broken by fishermen recovering their tangled nets. The outbreak has subsided although relatively high densities of COTS are still visible on some reefs (5-10 per 30min dive in September 2002). The numbers of COTS have been reduced by control operations organised by local dive clubs with the agreement of government ministries.

Qatar

No new information was received.

Saudi Arabia

No new information was received.



The early trends in coral cover at 5 sites along the Gulf coast of Saudi Arabia (Safaniya, Manifa, Abu Ali, Ras Tanura, Tarut Bay) amongst the major oil industry facilities were of minor changes, except for a period of extreme low water during the winter of 1991-92. Then two severe warm water events in the summer of 1996 and 1998 resulted in the almost total loss of live coral cover on these inshore coral reefs.

United Arab Emirates

The highest cover and diversity of corals along the mainland coast of Dubai is southwest of Jebal Ali Port in the Jebal Ali Wildlife Sanctuary (established 1997). There are 34 hard coral species and 77 species of reef fish and areas of corals have been surveyed extensively. The Sanctuary has a wide diversity of habitats (lagoons, seagrass beds and coral communities) all close together with strong ecological links. This is also the only stretch of the Dubai coastline that has remained free from industrial development, dredging and land reclamation.

Coral cover dropped from 90% in 1995 to 25% in 1999 after the bleaching events of 1996 and 1998, with most of the *Acropora* corals being killed. In 2000, there was a proposal to build a combined electricity generating and desalination plant at Ra's Ghantoot on the edge of the Sanctuary that would discharge chlorinated water 10ºC above ambient into the Sanctuary. The area immediately offshore of the development site had lower coral cover (1-5%, with patches at 10%) than in the coral rich area. If the development proceeds, the thermal pollution may exacerbate bleaching in the future.

Threats to Coral Reef Biodiversity

The Gulf

The major direct anthropogenic threats to coral reefs in the Gulf are industrial development, land-reclamation, dredging and shipping. Commercial trawl fishing, over-fishing, and anchor damage are also of concern. Most heavy industries (e.g. power generation, desalinisation, petrochemicals and oil refining, aluminium and steel smelting) are on the coast to make use of seawater for cooling purposes. The discharged cooling water results in localised thermal pollution that adds to the natural heat stress during summer months, which in extreme years results in coral bleaching mortality.

There has been extensive development of ports and airports, industrial estates, especially for the oil and gas industries, and some hotels and tourist facilities. Despite the high level of activity in oil and gas industries, oil pollution has caused relatively little direct damage to corals and reefs, although the risk of acute pollution from spills is significant. The effects of the 1992 Gulf War oil spills on the coral reefs were minimal along the mainland coast and offshore islands of Kuwait and Saudi Arabia. This is possibly due to acclimatisation to low levels of hydrocarbons in the water caused by a combination of natural seeps and chronic incidence of small operational spills. Dredging activity is high in the Gulf because of the need to maintain shipping channels in the shallow waters and to exploit sand for construction, shoreline nourishment, and land reclamation. Dredging has resulted in increased concentrations of suspended sediments in many areas and this has smothered corals e.g. dredging in the Muharraq area of Bahrain caused the loss of 182,000m^2 of reef area between 1985 and 1992.

The effectiveness of the EIA (Environmental Impact Assessment) process varies considerably from country to country, and national development takes a higher priority than environmental protection with the result that natural coastal resources are often destroyed by development. The situation is exacerbated by the lack of integrated coastal planning to allocate areas of lower ecological value for industrial development.

There is small-scale or subsistence level fishing for shrimp and reef fish using smaller trawls, traps and shore-based beach seine nets. There are also a few large commercial trawlers for shrimp. Both have caused anchor damage. Many trawlers fish close to reefs and damage corals and there are abandoned nets that continue to cause damage. Commercial fishing has been banned in Bahrain, and there are signs of coral recovery. In some places, such as Farur Island in the northern Gulf, anchoring fishing vessels are causing significant damage to corals especially *Acropora*.

The coral reefs have also been damaged by 'natural' stresses such as chronic infestations of crown-of-thorns starfish (COTS) and coral diseases, however the major source of loss to these reefs was massive coral bleaching and mortality in 1996 and 1998. These reefs will take many decades to recover because breeding stocks have been lost and natural recruitment is highly variable even under natural conditions. Recovery is dependent on no repeats of the high seawater temperatures of 1996 and 1998.

The Gulf of Oman and Arabian Sea

There are two major industrial developments in coral rich areas of the Gulf of Oman that could damage corals: a large hotel development; and a mineral fertiliser plant. Hotels are being built near the scenic Bandar Jissah, 10km southeast of Muscat. An EIA in 2001 identified threats to coral reefs from the approach road and small boat-landing site. The alignment of the approach road was altered, but the threat from the small boat landing site remains. Some corals have already been damaged during the construction of temporary landing sites, which is near one of the few remaining *Acropora* communities in the Muscat area. Construction of an ammonia and urea plant at Qalhat, 200km southeast of Muscat, will commence in late 2002 at a site adjacent to an existing natural gas processing facility. Pipelines and the loading jetty extend approximately 1km through coral-rich areas. Precautions are planned to mitigate the impact of construction on coral communities, and a marine environmental monitoring program is in place.

Marine Protected Areas and Levels of Management

The Marine Pollution Section of the Ministry of Regional Municipalities, Environment and Water Resources of Oman has implemented a National Coral Reef Management Plan in 2002 to include coral reef monitoring around Muscat, surveys to the southeast of Muscat, and public awareness campaigns. Coral reef rehabilitation trials using natural settlement on artificial reef structures (Reefballs) are currently underway and will be continued for a further 12 months. The general level of management in Marine Protected Areas in Oman is currently being reviewed, particularly at the Daymaniyat Islands National Nature Reserve, and an assessment is currently underway to indicate the feasibility of a World Heritage Site on the coast of Oman that would incorporate the country's best coral reefs.

Conclusions

There is considerable concern over the health status of corals following the mass coral bleaching and mortality in 1996 and 1998 in the Gulf. Mortality was widespread, however there is now evidence of recovery with new coral growth at Kish Island, Iran of mainly *Acropora* species. These corals are growing at around 10cm per year, suggesting that healthy *Acropora* populations will be established in a few years, provided there is no similar bleaching. Human impacts on the marine environment in the Gulf area, especially large oil spills in the last years and also the continuation of oil pollutants from shipping activity in the area (particularly through the smuggling of oil in old and uncertified Iraqi tankers in the northern parts of the Gulf), have narrowed the tolerance limits of these stressed coral species, therefore increasing their susceptibility.

Recommendations to Improve Conservation of Coral Reef Resources

The capacity for **Integrated Coastal Management** at national and regional levels is insufficient to develop and implement effective plans for the sustainable management of coastal resources. Weak or poorly disseminated plans underlie some developments in which serious environmental damage has resulted. Furthermore, plans should refer to the obligations of countries to international conventions particularly the Convention on Biological Diversity, MARPOL, and regional agreements such as Regional Organisation for the Protection of the Marine Environment (ROPME).

The EIA process is part of national legislation for any development. This is a significant achievement during the last 10 years, however, the system can be improved through the development of clearer and more detailed government policies, environmental quality standards and monitoring requirements, which would strengthen government control over private and public sector development. Discharges of cooling water, and dredging and land reclamation activities in coral rich areas result in direct damage and efforts should be focused initially on these issues.

The first priority in the region should be to strengthen the management of existing marine protected areas and parks so that they can meet their primary objectives. These MPAs should be used as a catalyst to train more marine park rangers and wardens, and use these staff to assess additional sites for conservation to ensure that a representative number of habitats and species are included in a network of effectively managed protected areas.

Greater awareness needs to be raised with the public, fishing communities and industry of the importance of reefs and how human activities may damage them. Fishing activity needs to be effectively controlled in MPAs to prevent damage from gillnets and trawling. By actively involving the public in practical measures (e.g. COTS control programs, net clearance, installation of mooring buoys, beach clean-ups, and reporting of spear-fishing) the necessary messages can be more effectively conveyed to targeted audiences.

In order to implement uniform management in the region it is recommended that a regional monitoring network be established through national and regional cooperation and contributions. Community based organisations, non-governmental organisations, governments and ROPME all have an important role to play in setting up and implementing such an initiative.

A panel of experts drawn from around the region should be formed to coordinate and oversee the monitoring network, and to advise on regional issues like COTS outbreaks, mass bleaching events, oil spills affecting reef areas, dissemination of reef related research and to improve on existing knowledge of coral taxonomy in the region.

Acknowledgements

We wish to thank Yusef Fadlallah and Kent Allen for the data on coral cover changes in Saudi Arabia.

Author Contacts

Simon Wilson, Dept of Biological Sciences, Warwick University UK and Oman, simon.wilson@adelphi-env.com Seyed Mohammad Reza Fatemi, Dept. of Fisheries and Marine Biology, Islamic Azad University, Tehran, Iran, fatemi@tavana.net; Mohammad Reza Shokri, Iranian National Center for Oceanography, Tehran, Iran, mrshok@hotmail.com; Michel Claereboudt, Sultan Qaboos University, Sultanate of Oman, michelc@squ.edu.om

Supporting Documentation

Allen KW, Fadallah YH (in press). Long-term Monitoring of Coral Reefs along the Saudi Arabian Gulf Coastline. Proceedings of the International Workshop on the Extent and Impact of Coral Bleaching in the Arabian Region, Riyadh 5-9 February 2000.

Coles, SL (1997). Reef corals occurring in highly fluctuating temperature environment at Fahal Island, Gulf of Oman (Indian Ocean). Coral Reefs: 16: 269 – 272.

Riegl B (2002). Effects of the 1996 and 1998 positive sea-surface temperature anomalies on corals, coral diseases and fish in the Arabian Gulf (Dubai, UAE). Marine Biology 140: 29 – 40.

Sheppard CRC, Wilson SC, Salm RV, Dixon D (2000). Reefs and Coral Communities of the Arabian Gulf and Arabian Sea. In: Coral Reefs of the Indian Ocean: Their Ecology and Conservation. Chapter 9. Ed. McClanahan TR, Sheppard CRC, Obura DO, Oxford University Press, New York.

Shokri MR, Haeri-Ardajkani O, Sharifi A, Abdoullahi P, Nazarian M (in press). Seawater Temperatures and Bleaching Events in Oman. Proceedings of the International Workshop on the Extent and Impact af Coral Bleaching in the Arabian Region, Riyadh 5-9 February 2000.

Subba Rao DV, Al-Yamani F, (2000). Arabian Gulf. Chapter 53 in: Seas at the Millennium. Ed. Sheppard CRC, Pergamon Press, UK.

Wilson SC, Claereboudt M, (in press). Seawater Temperatures and Bleaching Events in Oman. Proceedings of the International Workshop on the Extent and Impact af Coral Bleaching in the Arabian Region, Riyadh 5-9 February 2000.

Wilson SC, (2000). The Arabian Sea and Gulf of Oman. Chapter 54 in: Seas at the Millennium. Ed. Sheppard CRC, Pergamon Press, UK.