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Coral Reefs in the Persian Gulf and Oman Sea: An Integrated Perspective on Some Important Stressors

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ABSTRACT

This study provides a review of the status of some important stressors on coral reefs in the Persian Gulf and Oman Sea with emphasis on temperature and salinity and their associated biological responses. Coral reefs in this area live under unique temperature conditions and the seawater temperature ranges are 14 to 34°C. This sharp ten degrees centigrade change occurs in warm to cold season transition in December and might cause a thermal stress. Coral reefs are amongst the most diverse and productive ecosystems in the earth and the resources resulting from coral reefs are essential to the food quality of millions of people residing in tropical coastal populations. Unfortunately, the health of the world's coral reefs is in severe risk. Best estimates suggest that about 10% of coral reefs are already degraded. Another 30% are likely to destroy further within the next 20 years. Coral reefs are distributed throughout the tropical and sub-tropical waters of the world, mostly in developing countries.

Key words: Status, thermal, salinity, stress, ROPME

INTRODUCTION

Coral reefs are important constituents of marine ecosystems (Perkol-Finkel and Benayahu, 2007) and is getting an important place in search for new drugs also (Anbuselvi *et al*., 2009; Sukarmi and Radjasa, 2007). But they are suffering significant changes in diversity; species abundance and habitat structure worldwide (Hughes *et al*., 2007). Over the last few decades, they have been rapidly deteriorating because of a variety of environmental and anthropogenic pressures, such as elevated seawater temperature (Abram *et al*., 2003; Brown *et al*., 2000; Weber *et al*., 2006), sedimentation (Rees *et al*., 2005; Weber *et al*., 2006) fishing with cyanide (Cervino *et al*., 2003), pollution and over fishing (Eghtesadi-Araghi, 2005; Eghtesadi *et al*., 2002; Vestergaard *et al*., 2003; WWF, 2007b) that lead to a loss of coral diversity, increased incidence of disease, reduced growth, reduced reproduction and mass mortality (Heilman *et al*., 2008). Temperature, irradiance, turbidity, sedimentation, salinity, pH and nutrients affect survival of corals. These parameters control the physiological processes of photosynthesis and calcification as well as coral survival and consequently, coral reefs arise only in select areas of the world's oceans. Generally, coral reefs diversity in the Persian Gulf and parts of the Oman Sea (also called ROPME Sea Area (RSA)) is typically low (100-130 species) (Maghsoudlou, 2008) comparing to Indian Ocean (quarter the number of Indian Ocean) (Mohammadi, 2005). This is due to extremes of water temperature and salinity that are close to the physiological tolerance limits of many species. Coral Species composition in this area is typically Indo-Pacific and hard corals species richness in the Oman Sea (which is about 70 species) is more than the entire Persian Gulf (Sheppard and Salm, 1988). The increasing trend of temperature and salinity in the Persian Gulf and Oman Sea (Heilman *et al.*, 2008) adds significance of the articles in this regard.

Stressors environmental conditions and their biomarkers in the persian gulf: Coral reefs in the Northern Persian Gulf live under unique temperature conditions and the seawater temperature ranges are between 14 to 34°C (Coles and Fadlallah, 1991). This sharp ten degrees centigrade change (which is an intense decrease in sea water temperature) occurs in warm to cold season transition in December and might cause a cold stress in the corals (Fadlallah *et al.*, 1995). The physiological and biochemical responses to these stressors can be used as the biomarkers for understanding of caveat in coral reefs (Eghtesadi-Araghi *et al.*, 1999) which will be reviewed in this article with emphasis on temperature, salinity and ultraviolet radiation.

Seasonal changes in environment of the coral reefs may exert a physiological effect on this organism. Branching and massive coral species show different responses to temperature stress which might affect their growth and metabolic rates (Gates and Edmunds, 1999), i.e., their resistance toward stressful environmental conditions. Slow-growing massive coral species live longer when compared to branching ones. Branching corals have thinner tissue layers which provide less photosynthetic products and energy-rich compounds, resulting in lower adaptability to sudden environmental changes (Gates and Edmunds, 1999).

Total protein concentration as biomarker of temperature in coral reefs: Schlder and D'Croz (2004) reported previously that tissue concentration of total soluble proteins is an indicator of the health condition of the coral host. For example, protein metabolism is a key factor for the stabilization of the physiological condition in corals and variation is reported to result from environmental disturbances. This was observed in the Caribbean corals Acropora cervicornis and Montastraea franksi, which showed up to 43% variation in protein concentration within a day period, when exposed to elevated water temperatures. Corals with high resistance to bleaching have high concentrations of symbionts, chlorophyll and soluble proteins.

They also suggested that massive corals are better able to survive with changing environmental conditions compared to branching corals. Present studies also revealed that massive (*Favia* sp.) and branching (*Acropora* sp.) corals have different behaviors in similar environmental conditions (Eghtesadi-Araghi, 2005).

Schlder and D'Croz (2004) used 23.8, 29.1 and 29.3°C as low, ambient and high temperatures on their studies, respectively. Their results showed that total protein concentration of massive corals exhibited highest amount in 29.1°C and a moderate amount in 23.8 °C which is in agreement with our results in 27.0 and 22.0°C, respectively (Eghtesadi-Araghi, 2005).

Coral reefs in the Persian Gulf are usually exposed to annual ranges of temperatures that exceed the extremes reported for any other reef area in the world. Normal winter water temperatures in the Persian Gulf rank among the lowest recorded on coral reefs (Coles and Fadlallah, 1991). A sharp ten degrees centigrade change which is an intense decrease in sea water temperature occurs in warm to cold season transition in December and might cause a cold stress in the corals of this region (Fadlallah *et al.*, 1995).

Zooxanthellae are the main primary producers on coral reefs (Van Oppen and Gates, 2006). Low temperature stress usually results in mortality of these algae and reduction in coloration to pale in coral species and finally decadence of corals. Investigations indicated that only 1- 2 weeks of continuous exposure to 18°C or less might result in low survival rate and change of metabolic activity of corals which eventually leads to their degradation. Low temperature also could limit distribution of corals in the marine and oceans; Some reef corals can live and survive in cold water as low as 10.5°C but they cannot create reefs but the duration of exposure to such low temperature has not been determined. In our study, field studies confirm that the Acropora spp. in the Persian Gulf is sensitive to low range of temperature from 15-27°C (Eghtesadi-Araghi, 2005).

UV radiation and coral biomarkers: The most important prerequisite for photosynthesis is solar radiation. Photoautotrophic organisms convert light energy into chemically bound energy in the process of photosynthesis, which is used for biomass production. But many biological processes may be deceased by excessive light quality and UV irradiance (Barber and Andersson, 1992), or if short wavelength radiation with high energy content, such as UV radiation, is absorbed by biomolecules. Therefore, reduced photosynthetic and general metabolic activity is expected to occur when important components in plant metabolism are damaged. It has also been reported that UV radiation independently increase the activities of different enzymes (e.g., ascorbate peroxidase, catalase and superoxide dismutase) within the zooxanthellae of the zoanthid Palythoa caribaeorum. When coral reefs are exposed to UV, H_2O_2 and Sodium arsenite, an increase in oxidative stress proteins production occurs. Reports have been indicating that UV couple to high temperature primarily stimulates in situ photo-bleaching of photosynthetic pigments in Acrpora digitifera. It is shown that acclimation to moderate or low light in corals occurs mostly via two mechanisms: accumulation of photosynthetic pigments in zooxanthellae and increasing the population density of zooxanthellae. Present result showed that a negative significant correlations were observed between chlorophyll-a and water temperatures as well as chlorophyll-a and UV radiation index in *Favia* sp. and *Acropora* sp. Present result also revealed that minimum value of chlorophyll-a for coral reefs was observed in Summer, whilst maximum value was recorded in winter (Eghtesadi-Araghi, 2005). Present studies (Eghtesadi-Araghi, 2005) also confirmed that acclimation in *Favia* sp. and *Acropora* sp. to low light in winter was accompanied by a significant increase in accumulation of chlorophyll-a. The increase of chlorophyll-a of corals with lowering light intensity in habitat was detected by us and by other authors on different coral species (Brown *et al.*, 1999).

Stress protein concentration as biomarker of temperature in coral reefs: Health assessment of scleractinian corals, which are major components of the coral reef ecosystem, is an important issue for the conservation of coral reefs. During the last decade, molecular biomarkers have become useful tools to evaluate the health of organisms (Eghtesadi-Araghi *et al.*, 1999). Several studies have investigated the relationship between stressors and gene expression of cnidarians (Morgan *et al.*, 2001). These studies used heat shock proteins (HSP) as indicators and demonstrated the induction of these proteins by stressors (Wiens *et al.*, 2000). In response to cellular stress such as heat, cold, anoxia, cyanide and heavy metal a set of proteins, called stress proteins or Heat Shock Proteins (HSPs) is induced. Under environmental stressors, most HSPs provide various mechanisms that protect and recover stress damaged proteins. Determination of heat shock proteins (e.g., HSP 70) has been reported to be a suitable marker for environmental stress in the tissues of corals and their symbioants.

Thermal stress is suggested to play a role as a stressor for corals and their symbioants. Changes at the cellular and biochemical level are usually the first detectable response to an environmental stress and can be observed before the morphological signs of stress are evident (Bierkens, 2000). Organisms respond to cellular stress by synthesizing several stress proteins (e.g,. heat-shock proteins (HSPs)) (Dunn *et al.*, 2004). Members of the 70 kDa heat shock proteins (HSP70s) play an essential role in protein folding, transport of proteins into different cellular compartments, regulation of apoptosis and regulation of the heat-shock response (Brown, 1997). Seasonal changes in the environment may exert a physiological effect on coral reefs. Sharp *et al.* (1997) reported the presence of an HSPs70 in Goniopora djiboutiensis detected by immunoblotting. Fang *et al.* (1997) reported the appearance of a newly synthesized 35 kDa protein both in Acropora grandis and in its symbiotic algae after heat exposure. In our studies, we have found significant higher levels 70 kDa protein densities occurs in winter coinciding with decreased temperature when compared to warm season. Present results also revealed that average numbers of colony decreased in Winter which high levels of 70 kDa protein in *Porites* sp. were observed. We found that a significant negative correlation was existed between 70 kDa protein density (%) and water temperatures. Therefore, we suggest that 70 kDa protein densities can be applied as a useful tool for determination of cold stress in *Porites* sp. (Eghtesadi-Araghi, 2005).

Kendall *et al.* (1983) reported previously that tissue concentration of total soluble proteins is an indicator of the health condition of the coral host. For example, protein metabolism is a key factor for the stabilization of the physiological condition in corals and variation is reported to result from environmental disturbances. This was observed in the Caribbean corals *Acropora cervicornis* and *Montastraea franksi*, which showed up to 43% variation in protein concentration within a day period, when exposed to elevated water temperature (Kendall *et al.*, 1983).

All organisms have lethal limits to their temperature range and yet within this range they also have optimal temperatures for development of structure and function (Rombough, 1976). Within an ectotherms tolerance limit, variation in temperature will influence metabolism and therefore related physiological processes, affecting growth and development. Coral reefs in the Persian Gulf are usually exposed to annual ranges of temperatures that exceed the extremes reported for any other reef area in the world. Normal winter water temperatures in the Persian Gulf rank among the lowest recorded on coral reefs (Coles and Fadlallah, 1991). Zooxanthellae are the main primary producers on coral reefs (Van Oppen and Gates, 2006). Low temperature stress usually results in mortality of these algae and reduction in coloration to pale in coral species and finally decadence of corals. Investigations indicated that only 1-2 weeks of continuous exposure to 18°C or less might result in low survival rate and change of metabolic activity of corals which eventually leads to their degradation.

CONCLUSION

The coral reefs of the Persian Gulf and Oman Sea are critical habitats of cultural, socioeconomic and scientific value. However, their development is constrained by a variety of oceanographic factors including: extreme temperatures and salinity, high levels of suspended sediments, limited surface area of substratum suitable for the settlement of recruits and the scoring action of mobile sediments. Disease and outbreaks of Crown-of-Thorns starfish represent naturally occurring threats to coral reefs though the former may be aggravate by stressor derived from human activities. The diversity of coral reefs as indicated by the number of recognized species in each of the regions littoral countries are mentioned in Table 1. The threats on Coral Reefs in the region are shown in Table 2 which has been recognized by regional experts during meetings from

Table 1: The diversity of coral reefs as indicated by the number of recognized species in each of the regions littoral countries

Country	No. of hard and soft coral species in the Persian Gulf	Reference
Bahrain	30	(Khalaf and Barder, 2005; WWF, 2007a)
Iran	75	(Eghtesadi-Araghi, 2005; Maghsoudlou and Eghtesadi, 2005; Rezaei and Maohammadi, 2007)
		(Vestergaard *et al*., 2003)
Kuwait	35	(Faraj and Al-Tamimi, 2007)
Oman	107	(Al-Jabri, 2007 ; Sheppard and Salm, 1988)
Qatar	<20	(Al-Muftah and Al-Mansouri, 2007; Eghtesadi-Araghi, 2005)
UAE	34	(WWF, 2007b)
Saudi Arabia	50	(Al-Sofyani, 2007)

Table 2: The threats on Coral Reefs in the region

Country	Threats
Kuwait	Fishing and recreational boating, Littering smothers reef organisms, oil pollution, discharge of ballast water, coastal development, global warming
Oman	Coastal destruction, destructive fishing, hazardous/solid waste, over fishing, depletion of rare species, oil pollution, trampling, eutrophication and siltation due to coastal development
Saudi Arabia	Discharge of sewage from vessels, ship discharge of solid waste, oil spills from exploration-production and transport, Illegal disposal of toxic wastes, global warming effect, diseases
I.R. Iran	Oil production and oil pollution, Temperature fluctuations, breakwater construction, sedimentation during the Land reclamation, dredging, depletion of corals by local peoples, ornamental fishing for aquarium, extensive anchoring damage, discharge of nutrients and sewage
UAE	Oils spill, sewage runoff, anchoring, over fishing, COTS, increasing coral disease by human stressors
Bahrain	Anchoring damage, over fishing, spear fishing, littering, oil pollution, trawling nets, sedimentation
Qatar	Bleaching, anchors of local fishing boats, oil pollution

2003 to 2007. According to these information and the capacities (mentioned below) in each of the countries a series of needs are informed for conservation and management coral reefs in the Persian Gulf and Oman Sea.

Existing capabilities of region:

Littoral countries capacities: During the above mentioned meeting all participants agreed that there are a few capabilities for coral conservation and research in the region. Some of these capacities include:

- Local diving facilities in each country
- Private professionals divers
- Universities and marine colleges along the coast
- National data centers in some Persian Gulf and Oman Sea countries in the framework of ODINCINDIO project

GCRMN-RSA node (INCO) existing capabilities: The Responsible National Oceanographic Data Center (RNODC-PG) in the Persian Gulf was established in April 2004 at INCO and there is enough capability in this section to establish a Regional Coral Reef Data Center (RCRDC) for the RSA if a small budget would be allocated for equipment and training of coral reef database operators (for data entry, verification, analysis and preparing regional summaries). In addition of

RNODC responsibility, INCO has participated in Ocean Data and Information Network for Central Indian Ocean (ODINCINDIO) Project in October 2004.

Regional needs for coral reefs conservation and management:

- There is a need to reduce diver and boat anchor damage. In all countries, mooring buoys should be installed at the major reef sites to prevent further anchor damage to corals. Additionally, spear fishing should be banned (and the ban enforced) to allow reef fish populations to recover
- Solid waste cleanup projects need to be organized in each country to remove accumulated debris from the reefs, including plastics, metals, glass and discarded fishing equipment
- Public education campaigns are needed to increase understanding of the importance of coral reefs and their sensitivity to damage and pollution. These should highlight the use of moorings to prevent damage to corals, the need for restrictions on fishing on these reefs, the problems caused by littering and refuse and the need for public and private participation in the management of coral reefs
- There is a need to develop and expand local capacity to monitor and carry out research on coral reefs. This must also include the designation, where applicable, of competent authorities to manage and conserve coral reefs and preparation of detailed management plans to promote the sustainable and wise use of reef resources
- There is a need to designate additional Marine National Parks and Marine Protected Areas (MPA) in the context of integrated management plans. Only within these protected areas will the countries be able to fully protect coral reefs
- Coastal development and in particular dredging and land filling, should be curtailed and properly managed. The use of silt curtains should be mandatory in landfill operations and only after stringent Environmental Impact Analyses. Given the limited extent of coral reefs, coral reef areas should never be approved for land filling
- There is a need to improve navigational aids and radio communication in RSA waters, especially on major shipping channels and implement current Oil Spill Contingency Plan, including the development of site specific plans, improve capacity to respond to spills of oil and other hazardous materials, including a review and upgrading of port reception facilities for solid and liquid waste

Recommendations for development of GCRMN activities: It is believed that the following actions are useful for each littoral Persian Gulf and Oman Sea countries to build and increase its capacities on coral reefs:

- Technology transfer, training and monitoring to communities: establishment of trainer teams in each country through training courses etc
- Designation and implementation of Strategic Capacity Building Programs according to the needs of each country and region
- Recognition of the national monitoring networks in each Persian Gulf and Oman Sea countries to collaborate with regional node and facilitate interaction among the institutions and the agencies which form the core of the network in each country and region
- Establishment and equipment of a regional database center as well as establishment of a National Database Center in each country that interacts closely with the regional/sub-regional Network Node Database

- Public awareness through: annual reporting, updating of the web site, regular working/networking and information workshops, poster and media (a tentative website has been develop by INCO through following http://www.inco.ac.ir/coralreefs/home.htm)
- Designing and implementation of Coral Reefs Action Plan according to the needs of each country and region

After eight years of establishment GCRMN node in the Persian Gulf and Oman Sea and conducting many essential actions in the region, we need to shift to field training and monitoring actions that should be conducted at three selected GCRMN sites of the region. Then the needs and equipments are to be assessed through training workshops, for each country and regional node. In this way, the results could be incorporated into the capacity building strategies. The Global Coordinator of GCRMN assist the regions and countries to identify existing national and regional monitoring capabilities and activities and determine capacity for monitoring network development and requirements for training and equipment. We believe that application of successful earlier experiences in this regard such as South East Asia node and also ICRI Middle East Strategy can lead us to act rapidly for development of a cost-effective plan for conservation and management of coral reefs in the region.

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