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सत्यमेव जयते

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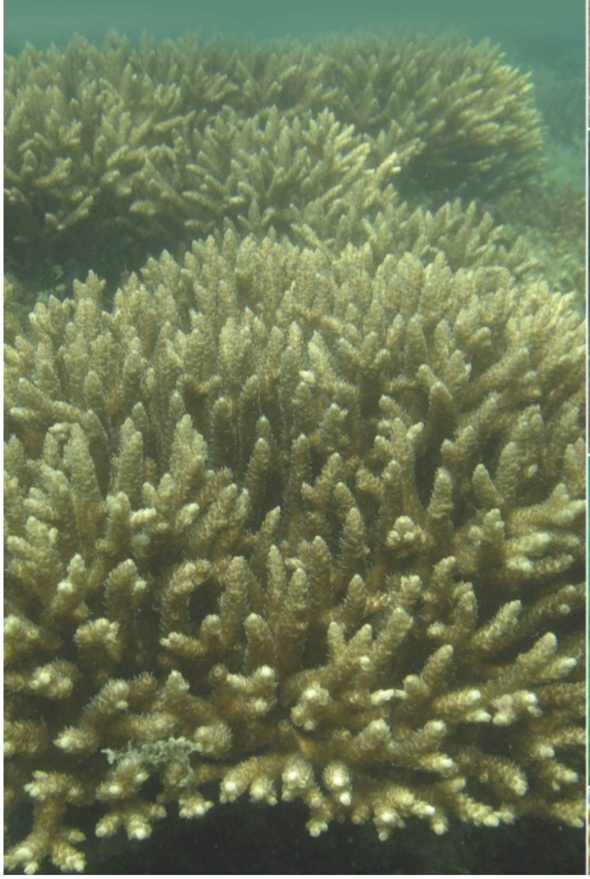
Ministry of Environment and Forests
Government of India

Mangroves for the Future
INVESTING IN COASTAL ECOSYSTEMS

Coral reefs in India
status threats and conservation measures

Editors

J R Bhatt
J K Patterson Edward
D J Macintosh
B P Nilaratna



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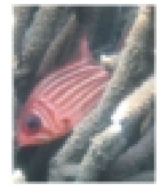

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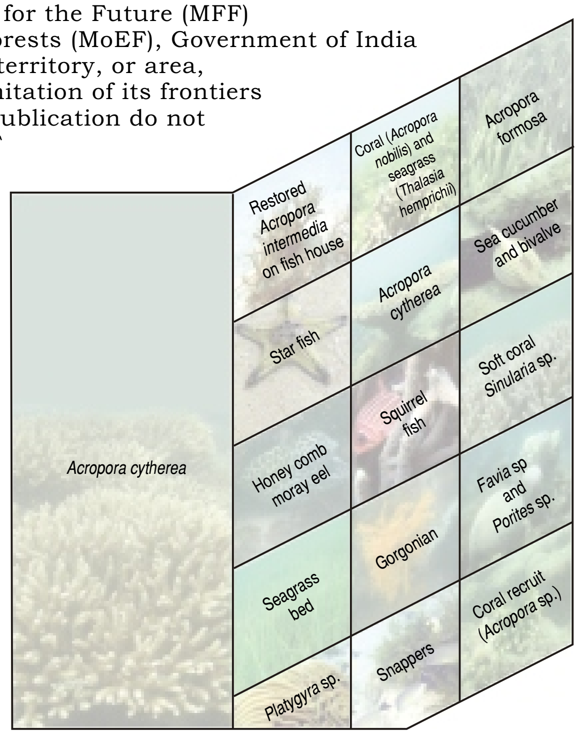

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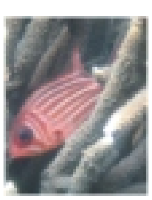

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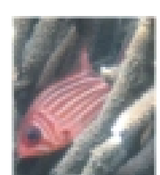

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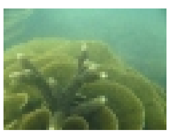

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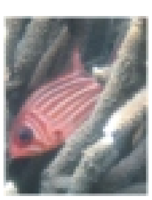

जयंती नटराजन
Jayanthi Natarajan

राज्य मंत्री (स्वतंत्र प्रभार)
पर्यावरण एवं वन मंत्रालय
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ENVIRONMENT & FORESTS
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NEW DELHI - 110 003

FOREWORD

Coral reefs are complex marine ecosystems comparable to rainforests of terrestrial ecosystem in terms of their species diversity. Reefs act as a barrier against waves and reduce erosion; they provide habitat, food and protection to countless marine species and breeding and nursery grounds for many commercially important fish and invertebrate species. Socio-economically coral reefs are sources of employment, income and food to millions of human beings through fishery and tourism based activities.

India has four major coral reef area, viz. Gulf of Mannar, Gulf of Katchchh, Lakshadweep and Andaman & Nicobar Islands with a total reef area of about 2,384 km^2. Coral reefs and their living resources are facing deterioration all over the world and Indian reefs are no exception. Various anthropogenic activities besides natural impacts like coral diseases, cyclones, tsunami and climate change have resulted in destruction of reef areas and their associated living resources. The intrinsic value and high level of dependency of coastal population on reef-associated fisheries call for evolving adequate conservation strategies for the protection and management of coral reef ecosystems.

I am happy to present this book on the occasion of the UN Decade on Biodiversity (2011-2020). The current Year is important as it is during 2012 when India hosts COP-11 to the Convention on Biological Diversity. All these, I hope, will go a long way in reaffirming our collective commitment to nurturing all facets of biodiversity.

The Ministry is promoting constructive conservation and management initiatives in all the four reef areas through its centrally sponsored schemes and other focused research projects. India had the credit of organizing the 1st International Conference on the Coral Reef System in Mandapam, Tamil Nadu in 1969, but reef research gained momentum only in the last decade.

The publication of this book titled "Coral Reefs in India - Status, Threats and Conservation Measures" is timely and I am sure, will be very helpful in strengthening conservation, management and research on coral reefs not only in India but also in many other countries where reefs grow and perpetuate.

I congratulate the editors for their editorial ventures and authors for contribution of the articles, both made this endeavour a great success.

I wish to put on record the overall guidance and support provided by Shri. M.F.Farooqui, Special Secretary and chairman of National Coordination Body of the MFF (India) Programme and diligent efforts put in by Dr. J.R. Bhatt, Adviser and Dr.B.P. Nilaratna, the then Joint Secretary in this assignment.

(Jayanthi Natarajan)

Acknowledgements

The editors thank the Ministry of Environment and Forests, Government of India for supporting the workshop entitled "Coral Reefs of India - Current Status, Threats and Conservation Measures" which was aimed at preparing a benchmark publication on conservation and management of coral reef ecosystems in India. The present book is a product of this workshop.

The workshop and this publication have been made possible through generous support from the Mangroves for the Future (MFF) initiative. The Suganthi Devadason Marine Research Institute (SDMRI) also provided partial financial support for printing this book. We thank IUCN, International Union for Conservation and Nature and Natural Resources, India Office and the MFF Regional Secretariat; especially Dr. J.S. Rawat, Ms. Hanying Li, Mr. Biren Bhuta and Ms. Aditi Mehandiratta for their valuable assistance during the workshop. Thanks are also due to Dr. N.M. Ishwar, MFF (India) Coordinator for his ever willing help in bringing out this publication.

We would like to thank all the authors who have contributed to the scientific information on coral reefs through their papers in this book.

We are grateful to Professors S. Ajmal Khan, K. Kathiresan and Dr. A. Gopala Krishnan, CAS in Marine Biology, Annamalai University, Parangipettai; Dr. S. Godwin Wesley, Emeritus Professor, Scott Christian College (Autonomous), Nagercoil; Dr. A. Biju Kumar, Associate Professor and Head, Dept. of Aquatic Biology and Fisheries, University of Kerala; Drs. E. Vivekanandan and R. Jeyabaskaran, Central Marine Fisheries Research Institute and Dr. Deepak Apte, Bombay Natural History Society for their helpful comments, suggestions and other timely assistance regarding the various papers that they reviewed.

We are also grateful to the SDMRI and its staff, especially Dr. Jamila Patterson, Associate Professor, Drs. G. Mathews and K. Diraviya Raj, Assistant Professors and Ms. S. Monolisha, Junior Research Fellow for their help in the proof reading and final preparation of this publication.

Thanks are aslo due to Mr. M. Vijay, Mr. Shantanu Goel, Ms. Usha Dangwal and Ms. Nisha D'Souza for their help in proof reading.

It is our pleasure to thank all those who generously contributed photographs to enhance the value of the book. Their names appear in the page devoted to photo credits.

The editors also thank Shri Hem Pande, Joint Secretary, Ministry of Environment and Forests for his constant encouragement and support in bringing out this publication.

Finally, we would like to place on record our gratitude and appreciation for the support received from Shri M.F. Farooqui, Special Secretary, Ministry of Environment and Forests, New Delhi and Chairman, National Coordination Body of MFF (India).

Editors

PREFACE

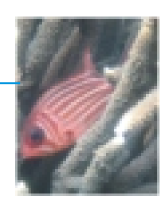
The Mangroves for the Future (MFF) initiative implemented the first MFF Small Grants Project in India through the conduct of a two day national brainstorming workshop on the "Coral Reefs of India - Current Status, Threats and Conservation Measures" at Tuticorin, Tamil Nadu, India held from 29 to 30 December, 2008. This national workshop was organized by the Suganthi Devadason Marine Research Institute (SDMRI), Tuticorin under the auspices of the Ministry of Environment and Forests (MoEF), Government of India, to commemorate the International Year of the Reef 2008 (IYOR 2008); and also to mark the end of year long IYOR 2008 celebrations.

The workshop was attended by administrators, natural resource managers, scientists and research students from the four major reef areas (Gulf of Mannar, Gulf of Kachchh, Lakshadweep, Andaman & Nicobar Islands) in India, including representatives from Government and Non-Governmental organizations/institutions. The papers presented in the workshop were peer reviewed by experts and 26 of them are included in this book titled, "Coral reefs in India status threats and conservation measures". Theme I - *Coral status and conservation* includes eight papers which mainly deal with the status of coral reefs in all four major reef areas and participatory biodiversity conservation. Theme II - *Coral associates* includes ten papers which explain the reef-associated ecosystems like mangroves and seagrasses, reef-associated fishes, and reef visitors like sea turtles, dugongs and whale shark. Theme III - *Reproduction, recruitment and restoration* contains two papers based on the research work conducted in the Gulf of Mannar on coral reproductive biology and coral restoration. Theme IV - *Coral environment and threats* include six papers covering issues like coral diseases, climate change impacts on coastal ecosystems, threats to corals and their environment, and the impact of alien seaweed on corals. The various maps included in this book are nearly diagramatic representations and not upto scale.

The research papers are based on the work carried out by various scientists through a number of diverse research projects funded by various national and international funding agencies. The editors do not assume any responsibility for the views expressed by the individual authors in this book.

We sincerely hope that this publication will be helpful to scientists, students and natural resource managers in their ongoing efforts to research, conserve and manage India's coral reefs.

Editors



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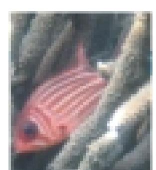


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Conservation and management of coral reefs in India : An overview

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Abstract

Coral reefs are rain forests of the sea. They are a source of food security and livelihood options for millions of people, and serve as coastal defense and tourist hot spots. There are four identified coral reef areas in India with all major reef types. These ecosystems are under stress from several anthropogenic and natural drivers and pressures and apart from some areas in Andaman-Nicobar Islands, no pristine reefs exist. Current conservation and management efforts are limited to creation of network of protected areas, policy and legislation and support to multilateral environmental agreements which have reference to reef systems. The overall knowledge base on status and trends, ecosystem services and biodiversity of reefs is patchy and needs strengthening to support informed decision making. There is also an urgent need to promote implementation of integrated management plans which address the landscape as well as the seascape elements in a holistic way. The increasing coastal population and crowded fishing grounds stress the need for sustainable management of the livelihood interactions which form a crucial part of this process. As climate change rapidly emerges as an additional major stress to the reef systems, finer modeling and projections would be required to inform management planning processes. There is a need to upscale efforts towards strengthening protection and awareness building at multiple levels, restoration and implementation of participatory conservation and management practices in order to effectively protect and conserve the existing reef areas for the conservation of biodiversity and sustained provision of reef ecosystem services.

Introduction

Coral reefs are one of the Earth's most beautiful, ancient and complex ecosystems. They play an essential role in sustaining life in the sea as well as providing for a large coastal population through a range of ecosystem services. Covering roughly 284,300 km^2 i.e. only 0.09 % of the total area of the world's oceans, they are comparable to tropical rainforests in biodiversity (Spalding *et al.,* 2001). However, they are also globally one of the most threatened ecosystems, both from natural as well as anthropogenic pressures. The Indian coastline harbours around 1% of the global reef area. They form an important part of our natural capital endowment, and are a high priority for conservation and management.

The current paper presents an overview of conservation and management of coral reefs in India and is structured in four sections. The first section provides information on status and trends of Indian coral reefs, reviewing the available information on area and extent, biodiversity and ecosystem services. In the following section, drivers and pressures are discussed. An overview

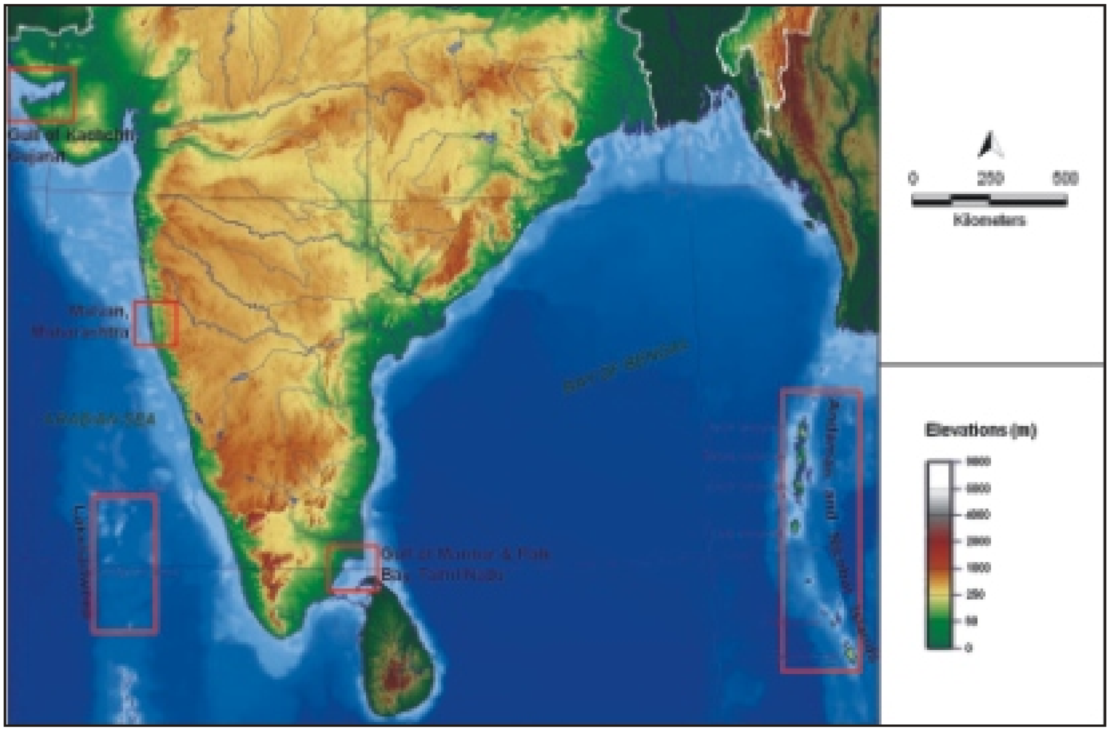


Fig. 1. Major coral reef areas in Indian coastline

of the management efforts is presented next, including identification of gaps. The paper concludes with recommendations for further strengthening the conservation and management of these ecosystems in the country.

Status and trends

Area and extent

Coral reefs are known to have a highly restricted distribution and mostly found within shallow tropical and subtropical waters, with maximum diversity between 10 to 30 meters below the surface, and within 25° N and 25° S latitudes. Globally, presence of coral reefs corresponds to the distribution of shallow, submarine platforms within the tropics, concentrated towards the three major ocean basins, i.e. Atlantic, Pacific and Indian. About 90.9% of world's reef area is found within the Indo-Pacific region with only 7.6% and 0.5% in the Atlantic-Caribbean and Eastern Pacific regions, respectively. Distribution amongst countries is highly skewed, with Indonesia and Australia alone accounting for 35% of the world's reef area *(ibid).*

The Indian subcontinent has scanty growth of reefs along its coastline. Several factors limit reef development, the major being high nearshore turbidity and freshwater runoff from rivers. Despite their limited distribution, all the major reef types are present, i.e. fringing (reefs that grow close to the shore and extend to the sea like a submerged platform), barrier (reefs separated from land by wide

Table 1. Coral reef – extent and ecological status

Reef location	Date of satellite data	Area (km^2)	Ecological status
Gulf of Kachchh, Gujarat	2005-06	352.50 km^2	Fringing reefs in degrading condition with majority area occupied by macro-algae, mud and sand. Areas harboring live corals restricted to reef edge and crest.
Malvan, Maharashtra	2005-06	0.28 km^2	Offshore fringing reef with vulnerability towards degradation.
Lakshadweep	2004-06	933.7 km^2 (including 510.70 km^2 as lagoon and 147.40 km^2 as coralline shelf)	Near pristine reefs at some atolls of undisturbed islands.
Gulf of Mannar, Palk Bay	2005	75.93 km^2 (including 10.80 km^2 as lagoons and 10.20 km^2 as continental shelf)	Fringing and atoll reefs classified as vulnerable, overgrown at various places with seagrasses and algae. Ribbon reef at Adam's bridge exclusively found in this area.
Andaman and Nicobar Group of Islands	2004-06	1021.46 km^2	Fringing type in vulnerable condition

(Source: Compiled and adapted from Space Application Centre, 2010)

expanses of water and following the coastline) and atolls (rough circular ring of reefs surrounding a lagoon or a low lying island). Gulf of Kachchh and Lakshadweep in Arabian Sea and Gulf of Mannar, Andaman and Nicobar Islands in Bay of Bengal are the major reef areas of India. Malvan, Maharashtra has an offshore reef. Lakshadweep is an archipelago of 12 atolls surrounded by deep waters, on the northern end of the Laccadive-Chagos ridge (Fig. 1).

In the Gulf of Kachchh, there are shallow patchy reefs growing on sandstone platforms that surround 34 islands. The reefs experience high salinity, frequent emersion, high temperature fluctuations and heavy sedimentation. In the Gulf of Mannar, coral reefs are found mainly around 21 islands between Rameshwaram and Tuticorin. The Andaman and Nicobar Islands consist of 572 islands (uninhabited-534 and inhabited-38)

with extensive fringing reefs which are mostly in good condition. Corals have also been reported from Gaveshani Bank about 100 km offshore from Mangalore, and several areas along the eastern and western coast of mainland India.

There is, in general, lack of comprehensive assessments of coral reefs along the Indian coastline except Gulf of Mannar. Ministry of Earth Sciences and Space Application Centre, based on IRS LISS II, Landsat and SPOT data estimated the overall reef area in the country to be 2,330 km^2 (DOD and SAC: 1997). SAC (2010) present a more recent picture of reef area and extent using remote sensing imageries for the period 2004-2006 (Table 1). As per the assessment, the overall reef area is 3,062.97 km^2, including 521.5 km^2 as lagoons and 157.6 km^2 as coralline shelf interspersed within the system.

Biodiversity

Taxonomic studies on Indian corals until the 1980s are almost restricted to handful of contributions, namely Pillai (1971a, 1971b, 1972), Scheer and Pillai (1974), Reddiah (1977), Pillai and Patel (1988) and Pillai and Jasmine (1989). The total number of 199 species of scleractinian corals (155 hermatypes under 50 genera and 44 ahermatypes under 21 genera) recorded in the 80s has been reported in various publications, until extensive collections in Andamans wherein nearly 100 species not reported previously were found (Venkatraman *et al.*, 2003). More recent assessments indicate that of the 845 species of reef forming shallow water corals reported from the world, India has more than 208 species, which is far less when compared to 581 species reported from the neighbouring Indo-Pacific centre of diversity (Venkataraman *et al.*, 2003). There is a pronounced latitudinal gradient in the number of coral species, the lowest being in the Gulf of Kachchh (33 – 34) which increases to nearly 96 for south-eastern India. Globally, over one-quarter (27%) of the world's 845 species of reef-building corals have been listed as threatened, an additional 20% are considered near threatened and 17% as data deficient (IUCN, 2008).

Indian reefs are also subject to different bio-geographical influences, with predominantly Indo-Pacific affinities and low levels of endemicity. Thus, the Lakshadweep Islands have close faunal affinities with the Maldives, and serve as bridge between Southeast Asian and East African fauna. Similarly, the reef fauna of southeast India bear resemblance to Sri Lanka. High diversity of reefs of Andamans and Nicobar is characteristic of the Southeast Asian region.

Coral reefs from Andaman and Nicobar Islands are highly diverse represented by 15 families, 57 genera and 177 species. The common coral genera contributing to the reef formation in these islands are *Acropora florida, A. cytherea, A. monticulosa, A. humilis, A. palifera, A. hyacinthus, Heliopora* sp., *Pocillopora verrucosa, P. damicornis, P. eydouxyi*, *Fungia* sp., *Goniastrea* sp., *Favites* sp., *Porites lutea, P. lichen, Montipora* sp., *Platygyra pini, Ctenactis echinata, Hydnophora rigida, H.*

microconus and *Symphyllia radians.* Pillai and Jasmine (1989) reported 104 coral species under 37 genera in Lakshadweep. Jeyabaskaran (2009) recorded further 20 new coral species from these Islands. Species such as *Acropora humilis, A.muricata* (*A.formosa*), *A. intermedia, A. hyacinthus, Pocillopora verrucosa, Euphyllia glabrescens, Galaxea fascicularis, Psammocora contigua, P.haimeana, Pavona maldivensis, P.clavus, Fungia danai, Podobacia crustacea, Hydnophora microconus, Favites abdita, Goniastrea retiformis, Platygyra daedalea, P. sinensis, Leptastrea bottae, Porites solida, P. lichen* and *P. lutea* are common in these Islands.

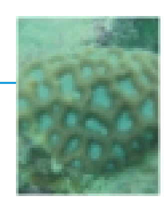
Pillai (1986) provided a comprehensive account of the coral fauna of Gulf of Mannar. He described 94 species of 37 genera, which has been updated by Patterson *et al.* (2007) to 117 species belonging to 40 genera. The most commonly occurring genera of corals are *Acropora, Montipora* and *Porites.* The shallow reefs of the Gulf of Mannar harbour around 41% live coral cover. Species such as *Montipora monasteriata, M. informis, M. spumosa, M. turgescens, M. venosa, M. verrucosa, M. digitata, M. millepora, M. manauliensis, Acropora digitifera, A. secale, A. intermedia, Pocillopora verrucosa, Porites mannarensis, P. exserta* and *Goniopora stutchburyi* are common in these islands. However, *Acropora rudis, A. valenciennesi* and *A. microphthalma* have been recently recorded in Andaman and Nicobar Islands and the specimens were registered in Zoological Survey of India, Port Blair (Ramakrishna *et al.,* 2010 and Venkataraman *et al.,* 2012).

Acropora valenciennesi in Lakshadweep Islands

The diversity of scleractinian corals in the Gulf of Kachchh is lower as compared to other regions in India, primarily due to geographical exclusion and extreme environmental conditions. Gujarat Ecology Commission (2010) presented a list of 45 species of hard corals and 23 species of soft corals in the region. *Montipora venosa, Coscinaraea monile, Hydnophora excesa, Turbinaria peltata, Goniastrea pectinata, Platygyra sinensis, Cyphastrea serialia, Porites compressa* and *Goniopora stutchburyi* are some of the common species found in all the islands of Gulf of Kachchh. Species such as *Siderastrea savignayana* and *Acanthastrea hillae* are reported from this area.

Ecosystem services

Coral reefs, despite accounting for only a small fraction of ocean area,



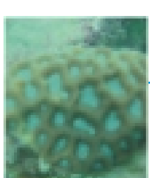
provide a range of ecosystem services which play a critical role in providing ecological and economic security to the coastal region. The high productivity of coral reef ecosystems within some low productivity environment of the oceans likens them to be as oases in marine deserts. Estimates of the number of people dependant globally on coral reefs for food range from 500 million to over one billion (Wilkinson, 2004; Whittingham *et al.,* 2003). Reef based resources serve as the primary means of food production for over 30 million poorest of the coastal communities (Gomez *et al.,* 1994; Wilkinson, 2004). Given the fact that nearly 8% (0.5 billion) of the global population lives within 100 kilometer of reef ecosystems, the role of these ecosystems in supporting coastal livelihoods is quite significant (Pomerance, 1999).

Globally, several attempts have been made to quantify the ecosystem services provided by the reefs to highlight their significant contribution, as well as make these comparable to alternate and tangible resource use options. In Southeast Asia, the potential sustainable economic benefit per square kilometer of healthy reef has been estimated to range from US$ 23,100 to US$ 270,000 per annum through fisheries, shoreline protection, tourism, recreation and aesthetic value (Burke *et al.,* 2002). Burke and Maidens (2004) estimated the benefits from coral reefs through fisheries alone to be US$ 300 million. The annual total economic value (sum of discounted benefits) of the reefs in Guam and Phi Phi, Thailand has been assessed to be US$ 127.3 million (Van Beuker *et al.,* 2007) and US$ 497.4 million, respectively (Seenprachawong, 2004). An ongoing analysis by TEEB Project (European Commission sponsored global initiative on assessment of The Economics of Ecosystems and Biodiversity) of around 90 economic assessments on benefits from ecosystem services in coral reef ecosystems estimated the annual benefits at 2007 prices to be US$ 115,704 per hectare (TEEB, 2009).

The status of research on ecosystem services of coral reefs in India is a major gap area, thereby limiting policy arguments to merely biodiversity benefits. Venkataraman *et al.* (2003) mentions that reefs provide 25% of fish catches and upto 75% of the animal protein consumed, but the assessment is unsubstantiated. Gujarat Ecology Commission (2010) has carried out an economic valuation of the coral reef ecosystems of the Gulf of Kachchh. The net annual benefit in 2007 through fisheries, tourism, biodiversity, protection against salinity ingression and protection against coastal erosion has been estimated to be US$ 47 million. However, the ecological basis for protection benefits is based on assumptions, which need to be verified through systematic monitoring and assessments.

Drivers and pressures

Coral reefs are one of the most threatened ecosystems. Various scientific studies underline the alarming rates of reef losses. Millennium Ecosystem Assessment concluded that over 20% of the coral reefs were badly degraded or under imminent risk of



collapse (Millennium Assessment, 2005). Assessments of the World Resources Institute in 1998 indicate that 58% of the reefs were at risk due to human activities. The intensity of these threats was highest in Southeast Asia, wherein 80% of the coral reef area was reported to be under medium to high threat. An estimated 20% of coral reefs worldwide have been destroyed (Wilkinson, 2004), while 15% are in critical state and a further 20% are threatened and predicted to be lost in 20 to 40 years; only 46% of the global reef cover are regarded as healthy (Wilkinson and Souter, 2008).

All major coral reef areas in India, including the Gulf of Mannar, Lakshadweep, Andaman and Nicobar Islands, and the Gulf of Kachchh experience pressures from human activities (Arthur, 2000; Rajasurya *et al.,* 2004). Except for some of the Andaman and Nicobar Islands, no pristine coral reefs exist today in India. In addition, the coral bleaching event in 1998 caused a significant decline in live coral cover in most areas (Wafar, 1999; Arthur, 2000; Muley *et al.,* 2002; Rajasuriya, 2002; Wilhelmsson, 2002). The following section describes some of the key drivers and pressures on coral reefs.

Shore seine fishing in Gulf of Mannar

Destructive fishing

Destructive and indiscriminate fishing activities are the major threats to the reefs and associated biodiversity. Though reef areas are protected, illegal fishing practices and boat anchoring cause physical damage to the reefs and associated fauna and flora. In the Gulf of Mannar, two islands (Poovara-sanpatti and Vilanguchalli) have already submerged due to excessive mining whereas erosion has been noticed in several other islands (Vaan, Koswari and Kariyachalli) (Patterson *et al.,* 2007). Bottom trawling by large mechanized boats, using banned gears, deplete fishery resources and cause damage to critical habitats, such as coral reefs and sea grass beds (Bavinck, 2003). Reefs are also impacted by the use of traps, especially during their laying and retrieving. In most cases, the traps are laid mainly to catch reef-dwelling herbivore fishes (e.g. Parrot fish), which in turn causes the proliferation of algae over live coral colonies due to lack of grazing pressure, leading to coral mortality.

Seaweed and mollusc collection

Collection of seaweed and mollusc pose major threat to the coral reefs and associated biodiversity. The seaweeds grow mainly on the dead corals, which also form a suitable substratum for attachment of new coral recruits (coral larvae). The seaweed collectors mechanically plug or scrap the seaweeds attached to the dead corals and therefore remove the entire seaweed along with dead corals. Due to this practice, the new coral recruits attached to dead corals also get removed along with seaweeds. This is affecting the corals growth and live coral cover, particularly in the Gulf of Mannar.

Pollution

The coral reefs in Gulf of Kachchh and southern part of Gulf of Mannar face threat from industrial pollution due to various oil refineries, fertilizer and chemical plants, port and thermal power plants in their vicinity. In addition, the discharge of domestic sewage into the reef areas is increasing steadily with rapid population growth stressing the coral habitats.

Invasive exotic species

Invasive exotic species, for example the seaweed *Kappaphycus alvarezii,* pose a threat to reef ecosystems. *K. alvarezii* was noticed in the reef area of two islands (Shingle and Krusadai) in Gulf of Mannar in 2008. Within 24 months, over 1 km^2 reef area with about 500 coral colonies were impacted due to *Kappaphycus* invasion in three islands (Shingle, Krusadai and Poomarichan). The source of spread is from the ongoing cultivation in the South Palk Bay through currents, which is evidenced by the observation of a large amount of *Kappaphycus* fragments on the dense seagrass beds along the Pamban Pass.

The *Kappaphycus* seaweed, a native to the Philippines, was introduced in the Palk Bay area for supporting livelihood of local fisher folk a decade back. Though Government of Tamil Nadu issued a notification in December 2005 [G.O Ms. No. 229, E& F (EC.3) Department dated 20.12.2005] identifying *K. alvarezii* as an exotic seaweed species, and thereby restricting its cultivation only to sea waters North of Palk Bay and South of Tuticorin coast, the cultivation continued on the southern side as well. The invasion led to shadowing and smothering of the corals by forming thick mats on the coral colony which penetrate deep up to 5-10 cm.

The economic returns on the other hand accrue only to a limited number of fishers while impacting livelihoods of more than 0.1 million fishers (Patterson and Bhatt, 2012).

Algal bloom

Algal bloom in reef areas is not common in India, however, algal bloom in Gulf of Mannar reef areas near three islands (Mulli, Valai and Thalaiyari)

Reef habitat in Lakshadweep Islands

was experienced during October 2008 causing considerable changes in physical, chemical and biological parameters in reef environment. The marine mortality was considered as "major" with a near complete absence of fish in the bloom affected reef areas. *Acropora cytherea* was most effected, wherein 118 colonies were bleached and 78 colonies dead. Vast seagrass beds near the islands were also degraded (Patterson *et al.,* 2009).

Coral diseases

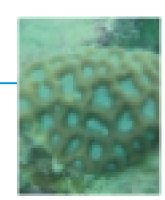
Coral disease is a rising problem within all reef areas in India. Coral disease can cause significant changes in reproduction, growth, community structure, species diversity of corals and many reef associated organisms. Environmental stressors including elevated seawater temperature, variation in salinity, water quality depletion, increased pollution loads, sedimentation and eutrophication lead to speedy disease prevalence. Currently the coral reefs of Gulf of Mannar and Palk Bay on the Southeast coast of India are showing signs of increasing prevalence of various coral diseases. Studies indicated that the percentage of disease affected live corals increased in one year from 10% (Feb. 2008) to 11.2% (Feb. 2009). Nine distinct coral diseases viz. white band, white plague, black band, white spot, black spot, pink spot, yellow spot, yellow band and tumour were observed in the Gulf of Mannar and five in Palk Bay viz. black band, white band, yellow band, pink spot and white plague. Seven coral genera (*Porites, Pocillopora, Acropora, Montipora, Favities, Goniosteria* and

Bleached *Acropora vaughani in* Andaman and Nicobar Islands

Favia) were noticed to be affected more. Maintenance of water quality parameters is one of the key factors influencing the health of the reefs. The uncontrolled and ever increasing disposal of untreated domestic sewage into the reef environment poses a serious threat to the corals in addition to environmental factors, mainly elevated seawater temperatures (Thinesh *et al.,* 2009).

Climate change

Climate change is fast emerging as one of the major drivers of coral ecosystem health. As per the IPCC 4th Assessment Report, "Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1–3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatization by corals" (Eakin *et al.,* 2008). The changes pertinent to coral reefs include rising sea surface temperatures, increasing concentrations of CO_2 in sea-



water, sea level rise, possible shifting of ocean currents, associated rises in UV concentrations and increases in hurricanes and cyclonic storms. Indian reefs have experienced 29 widespread bleaching events since 1989 (www.reefbase.org). Among these, events in 1998 and 2002 were intense (Arthur, 2000; Rajasurya *et al.,* 2002, 2004). In Gulf of Mannar, the temperature varied between 31.0^{0}C and 33.5^{0}C during summer (April - June) since 2005. The elevated sea surface temperature (SST) and coral bleaching have been noticed every year during summer and the average percentage of bleached corals during 2005, 2006, 2007 and 2008 was 14.6, 15.6, 12.9 and 10.5 respectively. The water temperature starts increasing from March and once it reaches 31°C during mid April, bleaching of coral is noticed. The pattern of affect was almost similar on the reefs every year except the modest fluctuations in the temperature levels (Patterson, 2009). Vivekanandan *et al.* (2008) have attempted to correlate the SST and bleaching and to find out the threshold SST in the coral regions in the Indian Seas. On the assumption that reefs will not be able to sustain catastrophic events more than three times a decade (Done, 2003), the authors project that reef-building corals may begin to decline between 2020 and 2040 and the reef- building corals would lose dominance between 2030 and 2040 in the Lakshadweep region and between 2050 and 2060 in the Andaman and Nicobar regions and the Gulf of Mannar. There is need for further assessments and finer scale modeling on climate change impacts on reefs systems in India.

Current conservation and management efforts

India's current efforts for conservation and management of coral reefs range from creation of network of protected areas, to supporting implementation of international conventions which have implications for reefs.

Creation and management of protected areas

Protected areas are one of the major means of reef conservation in the country. India currently has 36 marine protected areas of which 20 have entire areas in intertidal / subtidal or seawater. The list includes three Marine Biosphere Reserves: Gulf of Mannar Biosphere Reserve - 10,500 km^2 (includes Gulf of Mannar Marine National Park from Ramanathapuram to Tuticorin), Gulf of Kachchh Marine National Park - 400 km^2 (includes Marine Sanctuary, Gulf of Kachchh), Mahatma Gandhi Marine National Park in Andamans - 282 km^2, Great Nicobar Biosphere Reserve - 885 km^2 and Rani Jhansi Marine National Park - 256 km^2 (Richies Archipelago). In Andaman and Nicobar Islands, four MPAs (Marine Protected Areas) are exclusively for coral reef conservation. Great Nicobar Biosphere Reserve exists mainly to conserve the terrestrial region with some areas around the islands for protecting the marine region which contains extensive coral reefs.

The National Committee on Wetlands, Mangroves and Coral Reefs was constituted in 1986 so as to advise the Government on policy issues related to

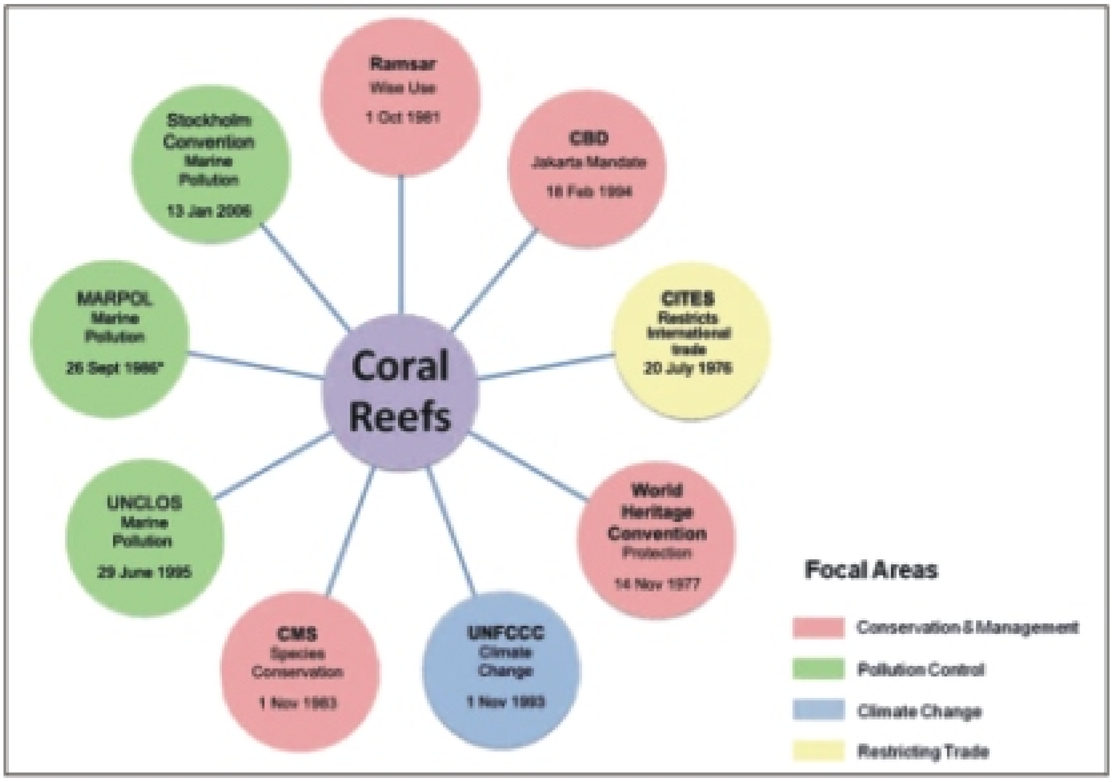
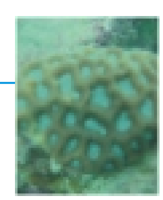


Fig. 2. Coral reefs and conventions (dates mentioned are those of ratification by India, colors indicate the broad scope of the convention) * (Other Annexes ratified in 1993)

conservation and management of these fragile ecosystems. On the recommendations of the National Committee, four Coral Reef areas in the country (Andaman and Nicobar Islands, Lakshdweep Islands, Gulf of Mannar and Gulf of Kachchh) have been identified for intensive conservation and management. State level Steering Committees have been constituted so as to prepare the Management Action Plans (MAPs) for these coral reef areas. Financial assistance is extended to the State Governments/UTs for implementation of their respective MAPs.

Policy and legislation

The Wildlife (Protection) Act 1972 provides protection for protected areas and certain species including marine species. All the scleractinian corals and gorgonids are included in the Schedule - I of the Wildlife (Protection) Act 1972, from July 2001. Environment (Protection) Act, 1986 prohibits the use of corals and sands from the beaches and coastal water for construction and other purposes. India's Coastal Regulation Zone Notification 1991 regulates onshore development activities, which affect coastal environments. Dredging and underwater blasting in and around coral formations is also prohibited. Collection and destruction of corals in Andaman and Nicobar Islands is



banned under the Andaman and Nicobar Islands Fisheries Regulation read with the Andaman and Nicobar Islands Shell Fishing Rules, 1978. Coral Reefs in Gulf of Mannar (Tamil Nadu) and Andaman and Nicobar Islands have been declared as Biosphere Reserves and financial assistance is extended to the respective State Governments for conservation of these areas under the Biosphere Reserve Programme of the MoEF.

Support to multilateral environmental agreements

Globally, around nine multilateral environmental agreements and processes directly or indirectly support conservation of coral reefs (Fig. 2). The Convention on Biological Diversity (CBD) adopted the Jakarta Mandate on Marine and Coastal Biological Diversity in 1995. The programme of work of the mandate focuses on integrated marine and coastal area management, sustainable use of living resources, protected areas, mariculture and alien species. Coral bleaching is an element of the programme, and has an associated work plan addressing physical degradation and destruction of coral reefs. The Ramsar Convention on Wetlands, which focuses on international cooperation for conservation and wise use of wetlands, identifies coral reefs as a wetland type, and seeks implementation of management plans to secure their conservation. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) identifies all species of stony corals , black corals , blue corals , organ pipe corals, fire corals, lace corals, giant clams, sea horses and queen conch as species for which trade must be restricted in order to avoid unsustainable utilization (Appendix II). Site designations under the World Heritage Convention include several coral reef areas, for which the co-operation for protection is solicited from member countries. The Intergovernmental Panel on Climate Change (IPCC) provides several scientific assessments on the impacts on corals due to changing climate, and also suggests possible remedial measures. The Convention on Conservation of Migratory Species of Wild Animals (CMS or the Bonn Convention), which focuses terrestrial, marine and avian migratory species through their range and habitats, is an important framework for regulating loss of habitat and over exploitation of species dependant on coral reefs.

Apart from the above, The United Nations Convention on the Law of the Seas (UNCLOS), The International Convention for the Prevention of Marine Pollution from Ships (MARPOL) and the Stockholm Convention on Persistent Organic Pollutants are agreements which focus on regulation of marine pollution. In Part XII of the UNCLOS, under the protection and preservation of marine environments, the States have an obligation to protect and preserve the marine environments and are required to prevent, reduce and control pollution of the marine environment from any source. Similarly, the Stockholm Convention is a global treaty aimed at protecting human health from persistent organic pollutants (POPs). Coral reefs run the risk of POP accumulation through releases or long range transport. UNEP runs a global

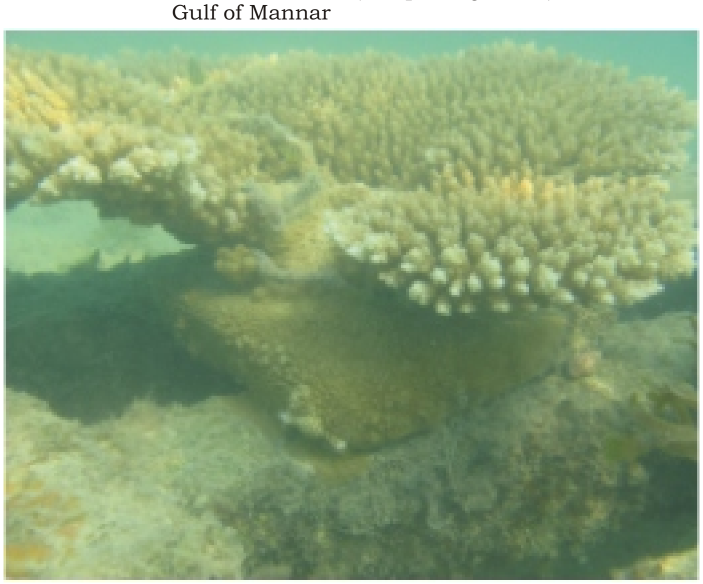
assessment programme focusing on POPs and other persistent toxic substances. MARPOL is a key instrument for making and enforcing regulations on pollution from ships, highly relevant for conservation of coral reefs. India is a signatory to all the above conventions, and the MoEF is undertaking the necessary steps to ensure implementation of the commitments.

Conservation, monitoring and research

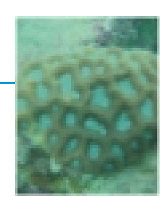
An Indian Coral Reef Monitoring Network (ICRMN) has been established by the MoEF on the recommendations of the National Committee on Mangroves and Coral Reefs. The important activities cover monitoring the health status of coral reefs, training and capacity building, strengthening of institutions for effective management and database management. The existing Centre of Zoological Survey of India at Port Blair in Andaman and Nicobar Islands is being designated as the National Coral Reef Research Centre.

The MoEF provides financial assistance on a 100% grant basis to the State/UT Forest and/or S&T Departments of all the four identified coral reef areas in the country for the following components: survey, assessment and mapping; capacity building-staff training and skills; protection and monitoring; biodiversity conservation; sustainable resource development; restoration measures; community participation in conservation; alternate/ supplementary livelihoods and eco-development activities; environmental education and awareness; and impact assessment through concurrent and terminal evaluation.

Coral restoration (*Acropora cytherea*) in Gulf of Mannar



The MoEF initiated experimental coral restoration in Gulf of Mannar in 2002 through Suganthi Devadason Marine Research Institute (SDMRI) which has standardized viable and low-tech reef restoration techniques for large-scale restoration using artificial substrates like concrete frames, fish houses and native coral species (Patterson *et al.,* 2005). An increase of 21% of live coral cover was observed in the restored sites between 2002 and 2007. Associated flora and fauna increased 5.99% and 8.08% respectively during the same time period. Fish abundance increased from 34 to 65 individuals per 100 m^2. Matured gametes were observed in transplanted corals of *A. cytherea* and *A. formosa* after one year. Spawning in the restored *Acropora* sp. was observed in 2009. These restored reefs serve as donor sites today. The successful coral restoration practices are also extended to the degraded reef areas in six islands (Shingle, Poomarichan, Kariyachalli, Vilanguchalli, Koswari and Vaan) in the Gulf of Mannar. Efforts are currently being made to restore more native resilient and resistant coral species to cope up with the impacts due



to elevated SST in the coming years (Mathews, 2009).

Gaps

Despite a range of interventions being undertaken, there are still several gaps that need to be addressed. The first and foremost is that of comprehensive knowledge base systems on these ecosystems. The current review has clearly indicated that several aspects still remain under researched such as long term qualitative and quantitative reef assessments on overall biodiversity and related ecosystem processes and taxonomically extended surveys of sessile organism that could highlight the environmental conditions in the reef systems. The knowledge on ecosystem services is a major gap area that limits understanding of the impacts of overall degradation on human well-being. The various drivers and pressures on reef systems are also very poorly understood and quantified. Similarly, the etiology of a growing number of diseases and pathologies need further concerted research. At larger scales, much needs to be done to ensure integrated management of coastal ecosystems, which can address terrestrial as well as coastal and marine processes. Most importantly, given the fact that human induced pressures are projected to continually increase, efforts made to integrate livelihoods need to be upscaled. Training and capacity building of researchers and managers; and development of any robust systems for monitoring effectiveness of current management, also need to be urgently addressed.

Future directions

The very fact that several of the coral reef areas within the coastline are still under stress and rapidly degrading underlines the need to upscale the efforts being made for conservation and management of these ecosystems. There is an urgent need to promote implementation of integrated management plans which address the landscape as well as the seascape elements in a holistic way. Sustainable management of the livelihood interactions forms a crucial part of this process, in order to be able to address human pressures. The current network of protected areas also needs strengthening, both in terms of enhancing implementation of the existing rules and regulations, but also increasing the capacity of park managers to undertake integrated management. This would require upscaling of the current investment in human resources and infrastructure. Comprehensive knowledge base systems are critical to conservation and management. Currently, the understanding of the ecosystem services of corals is quite limited. More focused research is required on biodiversity and ecosystem services of coral reefs, including an understanding of the ways human well-being is being affected by declining services. As climate change rapidly emerges as a major stressor to the reef systems, finer modeling and projections would be required to inform management planning processes. Finally, we need to promote on a larger scale, participation and local stewardship of reef ecosystems. This would need vigorous efforts towards creating awareness at multiple levels, and implementing incentive systems enabling participation of coastal communities in conservation and management processes.

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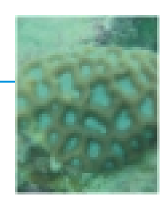

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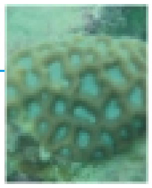
Dendronephthya hemprichi



Acropora humilis occurring in Gulf of Mannar

Status of coral reefs and conservation measures in the Gulf of Mannar Marine National Park

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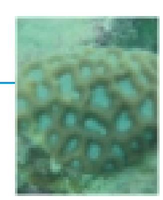
Abstract

The coral reefs in the Gulf of Mannar are formed around the 21 islands located between Rameswaram and Tuticorin. The islands and the surrounding shallow water areas covering 560 km^2 were declared as Marine National Park in 1986. The coral reefs were exploited heavily during 1960-2000, mainly for construction materials, the lime industry and for ornamental purposes. Though the reef areas were declared as a Marine National Park, there is no physical boundary and so, effective protection is very difficult and challenging. In addition, the destructive fishing practices by the traditional and commercial fisher folk, using various gears such as shore seine, push net and trawl net, enhanced the pressure on the reefs. Also the discharge of domestic sewage and effluents from the industries are rapidly depleting the water quality. Though, enforcement mechanism was fully practiced, reduction in the coral mining was effected due to the inclusion of all coral species in the schedule – I list of the Wildlife (Protection) Act, 1972 and the supreme court verdict on corals in 2005. The 2004 tsunami along with other conservation initiatives also helped in the complete halt of coral mining and reduction in other destructive fishing practices. There were major studies in the Gulf of Mannar and a comprehensive assessment of coral distribution and abundance was carried out during 2003-05 and documented that the live coral cover was about 37% and the degraded reef area about 32 km^2. Various conservation, management and enforcement mechanisms helped to enhance the live coral cover after 2005 due to the reduced disturbances to the substrates near the reef areas around all islands. There is good coral recruitment around all islands and an increase of about 5% live coral cover has been observed in the last 4 years since 2005. Though the live cover is increasing, threats like illegal exploitation of reef-associated fishes for commercial purposes, mainly through traps, skin diving, nets and also invasion of exotic seaweed like *Kappaphycus alvarezii,* pose challenges to the park management. Many organizations are working in close association with park management to address the issues in a holistic manner. Further to this, the challenge to park management is also to effectively monitor and manage the impacts of climate change on coral reefs.

Introduction

The health of coral reef ecosystems to perform a balanced ecological function has now been threatened severely because of impacts from poorly managed and continuing anthropogenic activities. Though the reef values are unlimited, they are now undergoing a worldwide decline (Wilkinson, 2002). Worldwide, roughly one-quarter of coral reefs are already considered damaged beyond repair, with another two-thirds under serious threat. For many years, increasing degradation of coral reefs has led to reduction in biodiversity, productivity and other utilitarian functions of reefs, such as provision of wave barriers for



shorelines (Brown, 1997).

Loss of healthy coral reefs would mean extinction or displacement of thousands of marine species, as well as elimination of a primary source of food, income and employment for millions of people around the world. Fishermen are often compelled to use more destructive fishing methods, such as dynamite fishing and seine nets, reducing the productivity of the coral reefs even further. In several cases, these human impacts can flatten the three dimensional reefs to rubble and shifting sediment (Alcala and Gomez, 1987; Sano *et al.,* 1987).

To cope with this degradation, relying on natural recruitment is one possible approach (Edwards and Clark, 1998), but several limitations have been reported. First, the rate of natural recruitment of corals is often so highly variable that the process can take up to several years, especially in species broadcasting their gametes (Wallace, 1985; Gleason, 1996; Connell *et al.,* 1997). Species releasing larvae (planulae) have high settlement rates in some areas, but more often settle near parents and show only a limited range of dispersal (Harrison and Wallace, 1990). Further, coral recruits, settling on monitored surfaces, are often low in species diversity (Harriott and Banks, 1995; Smith, 1997), which means a damaged reef may require a considerably long time to regain its original diversity. Another disadvantage is that recruits in nature usually suffer from high mortality and slow growth rates (Sato, 1985). Coral reefs can take as long as 20-50 years to recover from severe damage (Grigg and Maragos, 1974). However, reefs often recover in 5-10 years or less when numerous corals and coral fragments survive (Shinn, 1976; Highsmith *et al.,* 1980).

The Gulf of Mannar (GoM) is one of the four major reef areas in India, located on the Southeastern coast. Reefs in the Gulf of Mannar are developed around the 21 uninhabited islands that lie along the 140 km stretch between Tuticorin and Rameswaram in the state of Tamil Nadu (Fig.1). These islands are located between latitude 8°47' N and 9°15'N and longitude 78° 12'E and 79°14'E and the average distance of these islands from the mainland is about 8 km. The islands come under four groups; they are, Mandapam group (7 islands), Keezhakkarai group (7 islands), Vembar group (3 islands) and Tuticorin group (4 islands).

The once rich reef area is under pressure from a number of human activities that have degraded the reefs. One important reason for this situation is that the coastal areas are densely populated and that both traditional and "modern" activities such as traditional small-scale fishing and industrial fishing are competing (Patterson *et al.,* 2007 and Patterson *et al.,* 2008). The human activities such as coral mining, destructive and unsustainable fishing

Acropora nobilis occurring in Gulf of Mannar

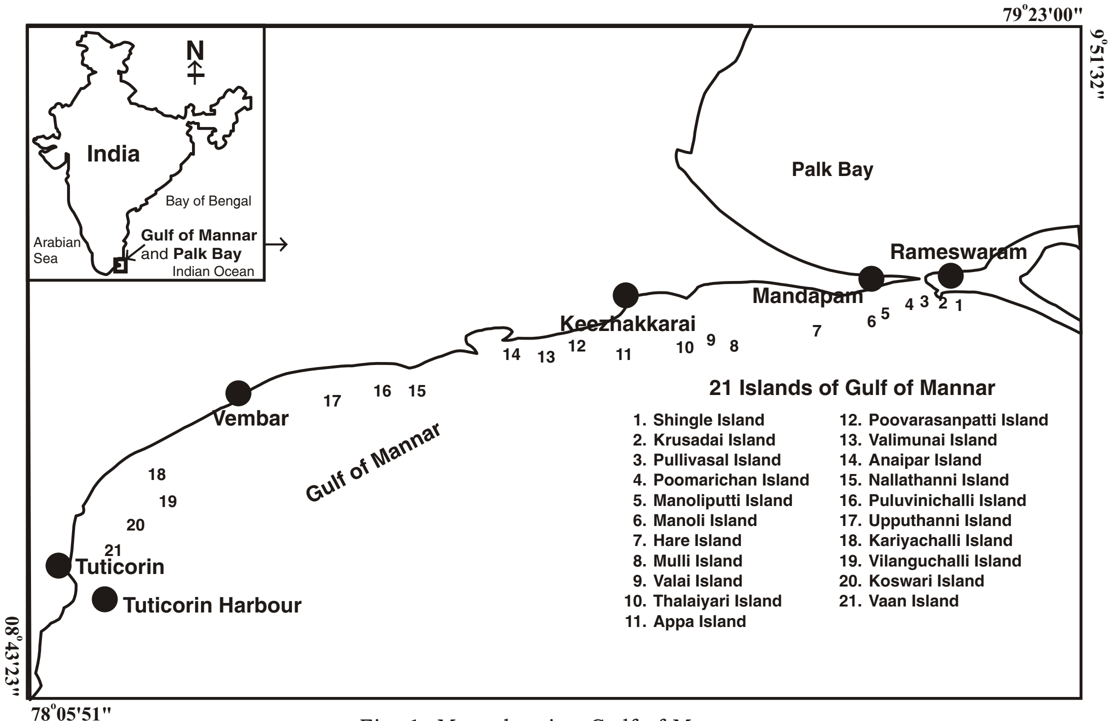
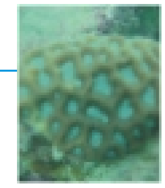


Fig. 1. Map showing Gulf of Mannar

Soft coral (*Sinularia* sp.) of Gulf of Mannar

practices, pollution and coastal development are the major factors responsible for the degradation of reef areas in the Gulf of Mannar. In the early 1970's it was estimated that the exploitation of corals was about 60,000 cubic meters (about 25,000 metric tones) per annum from Palk Bay and GoM together (Mahadevan and Nayar, 1972). However, active conser-vation schemes and measures includ-ing inclusion of all coral species under Schedule - I of the Wildlife (Protection) Act, 1972 and the Supreme Court verdict in 2005 banning coral mining, along with 2004 Indian Ocean Tsunami

Hard coral (*Symphyllia* sp.) of Gulf of Mannar



changed the situation in the Gulf of Mannar in reducing the destructive practices, in particular there was a complete halt to coral mining. Since then positive signs are noticed in the reef status, trends and population structure.

Material and methods

SDMRI Reef Research Team (RRT) surveyed all reef areas in GoM from January 2003 to October 2005 to collect comprehensive baseline information on the coral status, diversity, abundance and distribution. The baseline survey revealed that approximately 32 km^2 reef areas had been degraded. Similar surveys were conducted in this line during November 2007, March 2008 and November 2009. Recruit density and size class distribution was assessed during November 2007, March 2008 and November 2009. The Line Intercept Transect (LIT) method (English *et al.,* 1997) was used to assess the percentage of coral cover. 1 X 1 m quadrates were used to study the recruitment pattern and size class distribution of corals.

Results

A reasonable increase in the overall percentage of live coral cover was observed during the course of the study in the GoM. The mean live coral cover increased from (SE) 36.98±11.62 (2003-05) to (SE) 42.85±11.00 (2009). Keezhakkarai group of islands were having the highest percentage of live coral with 47.84% during 2009 followed

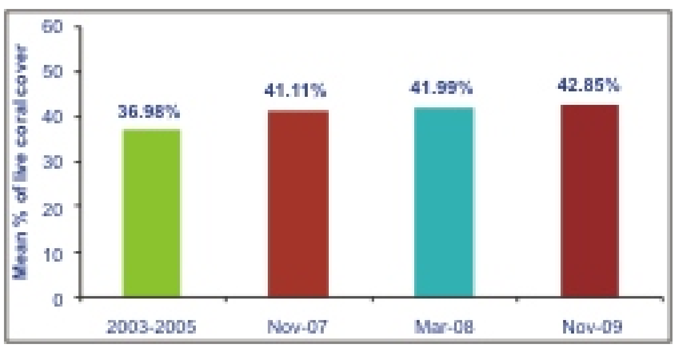


Fig. 2. Percentage of overall coral status in GoM during 2005 to 2009

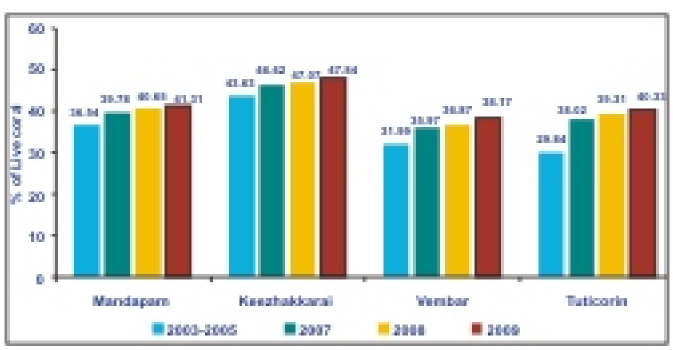


Fig. 3. Percentage of coral status in four groups of islands during 2005 to 2009

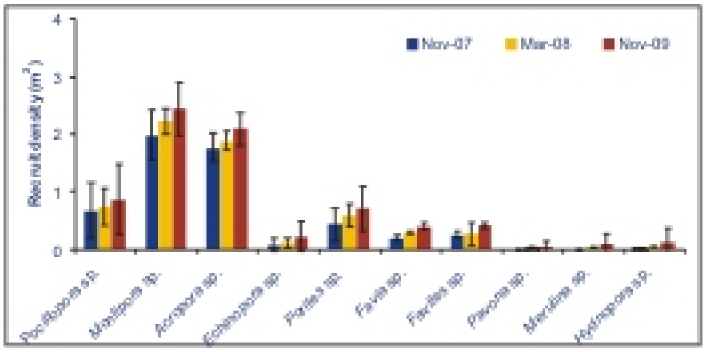


Fig. 4. Mean recruit density (m^{-2}) in the GoM during 2007 and 2009

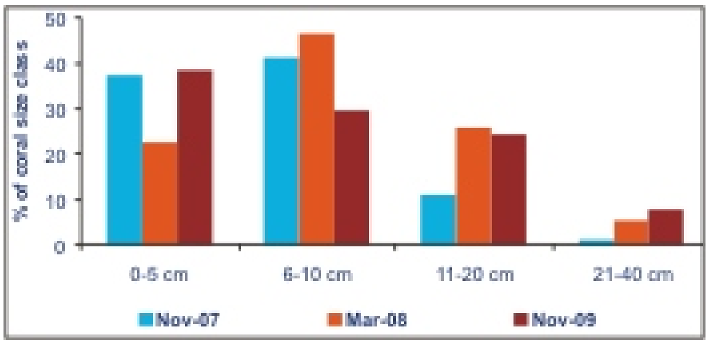


Fig. 5.Percentage of coral recruit size class distribution in the GoM during 2007 and 2009

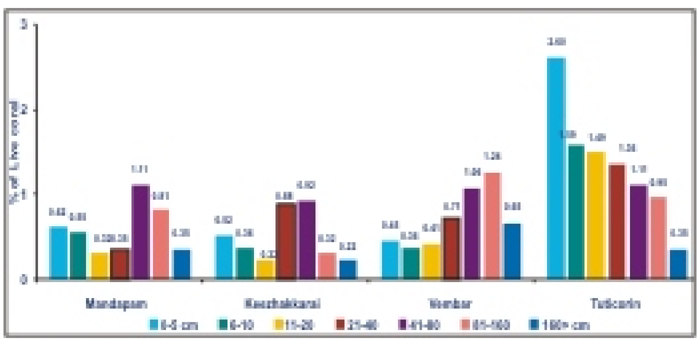
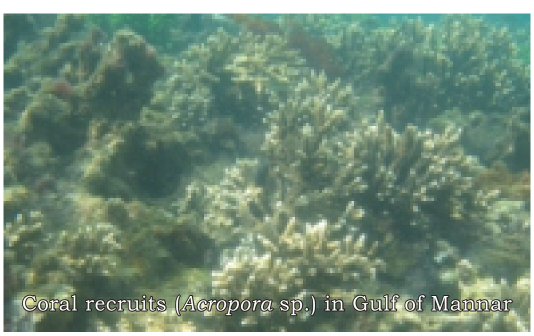
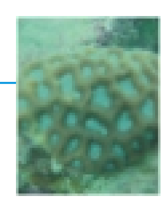


Fig. 6. Size class distribution of present live coral cover in four Island groups of the GoM



Coral recruits (*Acropora* sp.) in Gulf of Mannar

by the Mandapam group of islands with 41.31%, Tuticorin group with 40.33% and the lowest percentage of live coral cover was observed in Vembar group of islands with 38.17%. The percentage cover of live coral has increased significantly in all the four groups. The rate of increment was highest in Tuticorin group with 10.49% and the increments in the other groups were 4.77%, 4.22%



and 6.18% for Mandapam, Keezhakkarai and Vembar groups respectively. The details are given in figures 2 and 3.

A reasonably good increase in the overall recruit density was noted in November 2007 and November 2009. *Montipora* sp. dominated the assemblages of recruits, with a mean recruit density of 2.45±0.45 per m^2 followed by *Acropora* sp. (2.09±0.28) during March 2008 and November 2009. Other common genera among the recruits included *Pocillopora, Echinopora*, *Porites*, *Favia, Favites*, *Pavona*, *Merulina* and *Hydnopora*. The new recruits represented 6 families and 10 genera. The details are given in figure 4.

Fast growth of coral recruits from smaller to larger classes was observed in *Pocillopora* spp., *Montipora* spp. and *Acropora* spp. The fast growth in recruits was evidenced by a shift of cohorts from smaller to larger size classes. Percentage of recruits in the 0-5 cm size class went from 37.23% in November 2007 to 38.33% in November 2009; 6-10 cm size class from 41.02% to 29.44%; 11-20 cm size class from 10.71% to 24.36%; and 21-40 cm size class from 1.04% to 7.87% respectively. The details are given in figure 5. The overall size group distribution of live corals in each island group is given in figure 6.

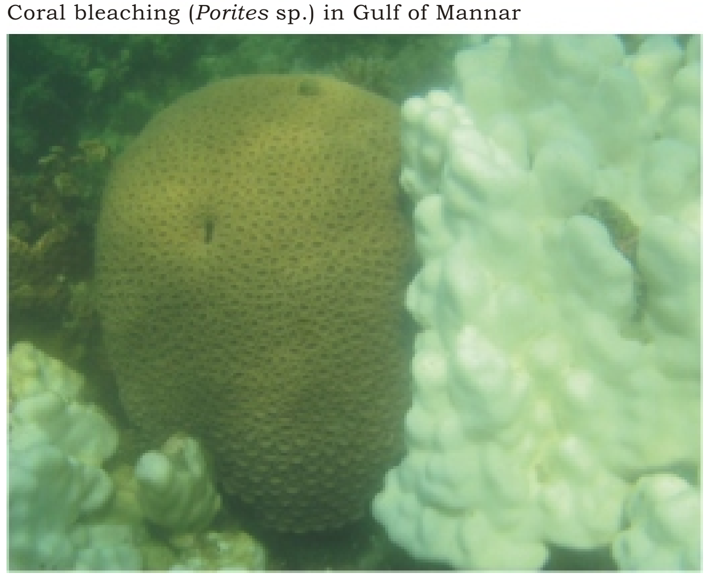
Discussion

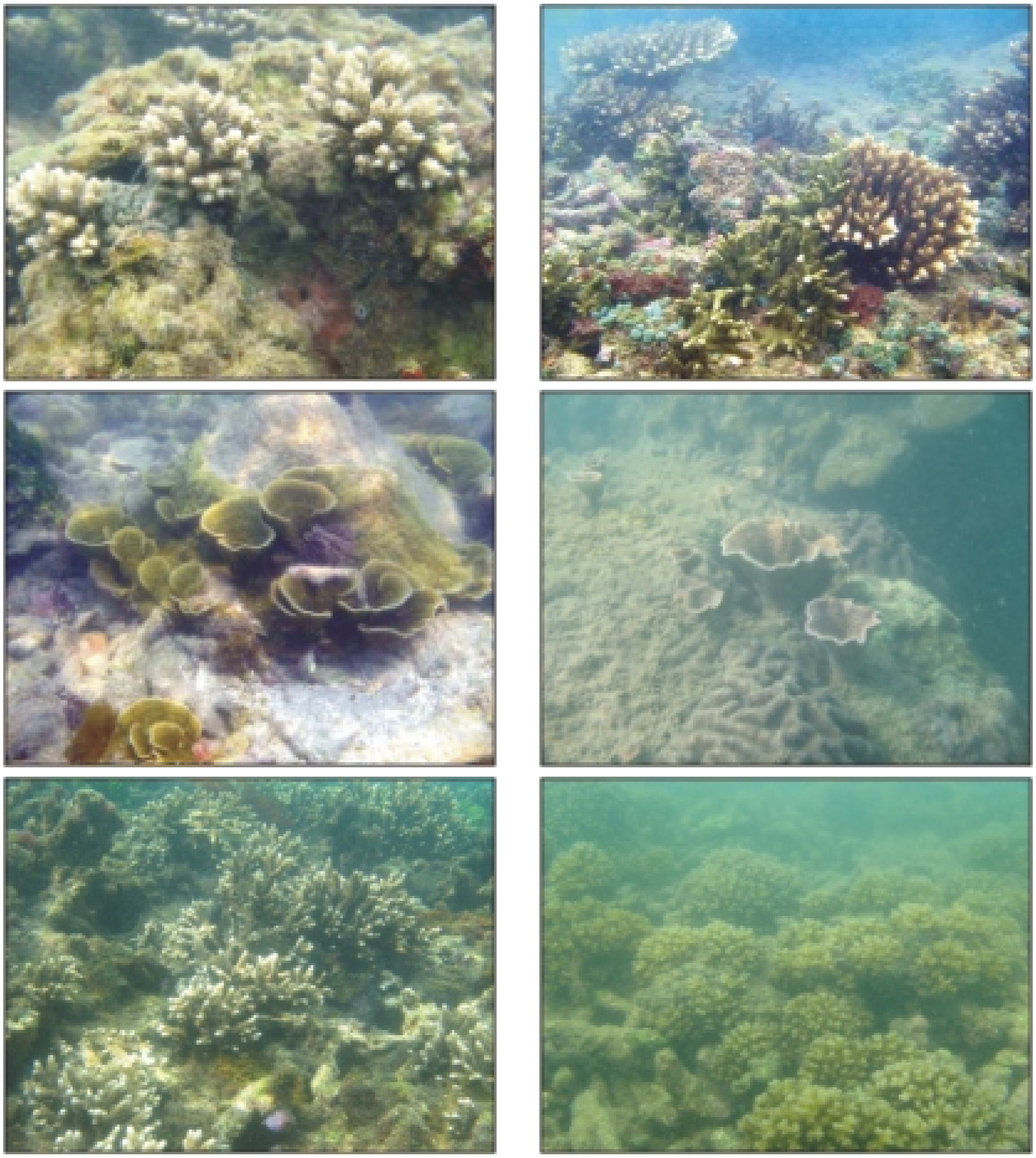
The coral reefs in Gulf of Mannar have been stressed in the last three to four decades due to various anthropogenic activities (like coral mining, trawl fishing, shore seine, crab fishing, blast fishing, trap fishing, seaweed collection, ornamental fish collection, sewage pollution, industrial pollution, coastal area development) coupled with natural factors (such as elevated Sea Surface Temperature (SST), fresh water run off and storms). The present study is a part of regular coral assessment and monitoring conducted over the past five years. The 2004 Indian Ocean tsunami along with various conservation initiatives and enforcement measures helped to bring a complete halt to coral mining and reduction in the other destructive fishing practices. This, in combination with successful reproduction and high recruitment, were the likely reasons responsible for the increase of live coral cover.

The Tuticorin Group was the worst damaged reef area due to coral mining until 2004, but the highest recovery of 10.49% was recorded here. The complete stop of coral mining caused a major difference in the increase of coral recruitment and live coral cover. Enforcement also plays a commendable role in restricting human induced damages.

Two possible mechanisms could be the reason for the improvement of live coral cover, local increase in larval supply and asexual reproduction via fragmentation (Edwards and Clark, 1998). A good increment in the recruit

Coral bleaching (*Porites* sp.) in Gulf of Mannar

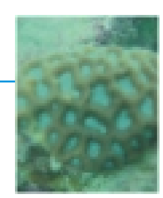




Coral recruits on degraded reef areas of Gulf of Mannar group of islands

densities was seen in all over the GoM reefs during the course of monitoring. Increase in recruit densities was recorded in November 2007 and November 2009. Growth rate of the new recruits also plays a vital role in the recovery; the shifting of the smaller size class to the larger size class proves this.

Even though successful reproduction and recruitment happen, the total increment in the live coral cover of a particular site can not be assumed to



be entirely the result of natural coral recruitment because coral larvae can be taken elsewhere by water currents distant from the original site (Willis and Oliver, 1988). However, through fragmentation, a particular site can be benefited more. Potentially, fragmentation allows species and genets to extend their distribution and abundance locally; producing a patchwork of adjacent clones (Jokiel *et al.,* 1983; Hunter, 1993). Live coral fragments may move passively up to tens of meters, due to water movement or gravity (Dollar and Tribble, 1993). Further more, fragmentation may allow colonization of habitats where larvae are unable to settle, such as sandy areas at the periphery of a coral reef (Bothwell, 1981). Fragments are more likely than larvae to tolerate unstable sediments because of their larger size and extension (Gilmore and Hall, 1976).

Corals of the GoM are also being subjected to harsh environmental conditions like elevated Sea Surface Temperature (SST), sedimentation, high waves and currents and poor water quality in several sites. They have developed resilience to these factors leading to negligible mortality in recent years. However, the emerging issues like increase in coral disease prevalence and invasion of exotic seaweed like *Kappaphycus alvarezii* in reef areas pose severe threats and challenges to managers. Though a significant increase in coral cover was noticed during 2005-2009, efforts have to be continued to manage the reefs and associated biodiversity in the Gulf of Mannar from both direct anthropogenic threats and climate change.

Acknowledgements

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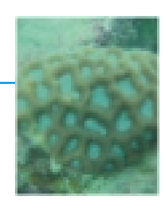
Lobophytum crassum



Acropora palifera occurring in Andaman and Nicobar Islands

Current status of coral reefs in the Andaman and Nicobar Islands

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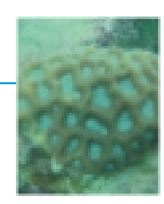
Abstract

Coral reefs of the Andaman and Nicobar Islands cover an area of about 1020 km^2 i.e. 6% of the total continental shelf of these islands. The corals of these islands are in the form of fringing, patchy and barrier reefs. There are as many as 228 scleractinian species belonging to 58 genera and 18 families. The common genera contributing to the reef formation in these islands are *Acropora, Montipora, Pocillopora, Porites, Goniopora, Favia, Echinopora, Fungia, Milleporina* and *Heliopora*. The earthquake and the consequent tsunami which struck these islands in December 2004 caused vast devastation of coral reefs leading to geomorphological changes, resulting in uplifting and exposure of reefs in the northern Andaman Islands and submergence of southern Nicobar Islands. Detailed investigations conducted around selected islands indicated coral mortality of approximately 20% in the Andaman group and 80% in the Nicobar group of islands. However, the data obtained from the surveys of 2008 showed rejuvenation of corals, with the density of new coral recruits recorded being 14-22 colonies/10m^2 in the Andaman Islands and 8-12 colonies/10m^2 in the Nicobar Islands. The major threats for coral reefs and their management strategies in these islands are also discussed in detail.

Introduction

Coral reefs of the Andaman and Nicobar Islands are perhaps among the most diverse reefs in the world. The 1962 km long coastline of these islands is characterized by coral reef ecosystems (Fig. 1). Coral formations are mostly in the form of fringing, patchy and barrier reefs. These islands are surrounded by fringing reefs on the eastern side, and by barrier reefs on the western side between 10° 26'N and 13° 40'E, for a distance of about 360km (Sewell, 1925). The reefs of these islands offer a varied and complex animal life of which the corals constitute the most fragile and interesting faunal element as elsewhere in the Indo-Pacific reefs. The majority of these coral

Fig.1. Andaman and Nicobar Islands



reefs are of the fringing type occurring close to the shore and covering an area of about 1020 km^2 (SAC 2010). The coral reef fauna and flora from these islands include 750 species of fishes, 1422 species of molluscs, 749 species of crustaceans, 427 species of echinoderms, 112 species of sponges, 235 species of hard corals, 111 species of soft corals and 64 species of algae.

The studies on taxonomy of Indian coral reef started as early as 1847 by Rink in the Nicobar Islands. Alcock (1893) published an account of some ahermatypic corals from the seas around India. Later Alcock (1902) described 25 species of deep sea Madreporaria dredged by the Royal Indian Marine Survey Ship Investigator from depth of more than hundred fathoms, around Andaman Islands. Sewell (1922, 1925) reported on the ecology and formation of coral reefs of these islands. Reef ecology and structure in various reef areas of these islands have been studied by several authors (Reddiah, 1977; Pillai, 1983; Mahadevan and Easterson, 1983; Wood, 1989; Arthur, 1996; Soundararajan, 1997; Venkataraman and Rajan, 1998; Jaybaskaran, 1999; Kulkarni *et al.,* 2001; Turner *et al.,* 2001).

The listing of coral species has continued since Matthai (1924), who listed coral species from the Andaman based on collections in the Indian Museum in Calcutta. Pillai (1983) listed 135 coral species from this region. Turner *et al.* (2001) listed 197 species within 58 genera. The latest status report (Wilkinson, 2000) lists 203 hard coral species occurring in these islands. The faunal studies other than on corals have also been carried out at different reef locations of the Andaman and Nicobar Islands. More than 1200 fish species have been recorded around Andaman and Nicobar (Rajasuriya *et al.,* 2002).

In-depth information on coral reef ecology and community structure are limited to a few investigations on some specific reef sites only. The percentage cover of live corals has been estimated for the islands in the Mahatma Gandhi Marine National Park (Arthur, 1996; Dorairaj and Soundararajan, 1997; Kulkarni *et al.,* 2001) and North Reef, Cinque Island, Twin Islands reef, West Rutland Island, Tarmugli Island, Flat Island, South Button, Outram Island, Henry Lawrence, Minerva ledges and Neil Islands (Turner *et al.,* 2001). These studies also listed the species wise distribution for these reef areas. In addition, Kulkarni *et al.* (2001) covered several ecological parameters in their study, which included sedimentation, terrestrial zone influence and other anthropogenic factors.

Diversity of corals

The Andaman and Nicobar Islands are the richest of the Indian region in coral diversity with as many as 228 species belonging to 58 genera and 18 families (Venkataraman 2003). The important (speciose) families are

Acropora cerealis in Andaman and Nicobar Islands

Table 1. Family-wise species diversity of corals recorded from the Andaman and Nicobar islands

Sl No.	Family	Genera	Species
1.	Astrocoeniidae	1	2
2.	Pocilloporidae	3	7
3.	Acroporidae	2	74
4.	Poritidae	2	15
5.	Siderasteridae	2	9
6.	Agariciidae	6	24
7.	Fungiidae	7	16
8.	Oculinidae	1	3
9.	Pectinidae	4	8
10.	Mussidae	5	9
11.	Merulinidae	3	8
12.	Faviidae	13	31
13.	Euphyllidae	2	6
14.	Dendrophyllidae	2	5
15.	Heliporidae	1	1
16.	Clavularidae	1	1
17.	Milleporidae	1	5
18.	Stylasteridae	2	2
	Total	58	228

Table 2. Percentage of live coral cover in reef area of the Andaman and Nicobar Islands

Reef area	Live coral cover	Status
Middle Andaman	57.0 -70.6%	Good
North Andaman	49.0 - 54.0%	Fair to Good
Ritchie's Archipelago	32.0 - 59.1%	Fair to Good
Mahatma Gandhi Marine National Park (South Andaman)	40.0 – 55.0%	Fair to Good
Car Nicobar	39.2 - 57.6%	Fair to Good
South Andaman	13.8 - 47.7%	Poor to Fair
Little Andaman	10.8 - 30.9%	Poor
Great Nicobar	16.0 - 31.8%	Poor
Nancowry	34.0 - 60.5%	Fair to Good

Acroporidae (74 species), Faviidae (31 species), Agariciidae (24 species), Fungiidae (16 species) and Poritidae (15 species) (Table 1). Among the various species occurring here, *Coeloseries mayeri* Vaughan belonging to the family Agariciidae is so far known only from Andaman waters. The generic diversity of corals was the highest in the family Faviidae as it contributed 13 genera followed by Fungiidae (7 genera) and Agariciidae (6 genera). The generic representation of remaining families is in the range of 1 - 5 only. The common genera contributing to reef formation in these islands are *Acropora, Montipora, Pocillopora* (branching type), *Porites, Goniopora, Favia* (massive type) and *Echinopora* (folioceous type). In addition the solitary *Fungia,* hydrocoral *Milleporina*, blue coral *Heliopora* and several gorgonaceans and alcynaceans contribute to the formation and structure of the coral reef ecosystem.

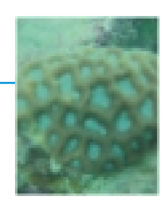
Status prior to tsunami

The status of live coral cover of the Andaman and Nicobar Islands was estimated by INTACH (Indian National Trust for Art and Cultural Heritage) during 1988-90 and by the Zoological Survey of India (ZSI) under a UNDP

Table 3. Live coral cover around selected Islands of the Andaman and Nicobar Islands

Island	Live coral cover (km^2)
North Reef Island	15.53
Rani Jhansi Marine National Park (John Lawrence, Henry Lawrence and Outram Islands)	27.15
Cinque Island	6.78
Little Andaman Island	58.29
Great Nicobar Island	30.81

Ctenactis echinata, Andaman and Nicobar Islands



programme during 2000 and the data are presented in Tables 2 and 3. These surveys revealed that the percentage cover of live corals in Middle Andaman was up to 70.6%, while in Nancowry Island it was 60.5% (Table 2). In general, the reefs of these islands were one of the healthiest and least impacted among the other Indian reefs with the estimated average live coral coverage of 55% (Jeyabaskaran, 1999).

The live coral cover around selected islands as estimated by ZSI was maximum ($58.29 km^2$) in Little Andaman followed by in Great Nicobar Island ($30.81\ km^2$) while it was only $27.15\ km^2$ in Rani Jhansi Marine National Park which comprises of three islands (Table 3). Nayak *et al.* (1994) estimated that the total live coral reef area of these islands was about 953.3 km^2. The quantification of reef areas has been carried out by Space Application Centre (MWRD, 2000) using Landsat TM, IRS LISS II and SPOT satellite imagery The reef area calculated by this study comprised 795.7 km^2 in the Andaman Islands, 30.8 km^2 in Great Nicobar, 15.5 km^2 in North Reef, 27.1 km^2 in Rani Jhansi Marine National

Table 4. Estimated loss of live coral cover in Mahatma Gandhi Marine National Park, South Andaman

Island	Live coral cover (pre-tsunami) (%)	Live coral cover (post-tsunami) (%)	Loss (%)
Alaxendra Island	30	15	50.00
Bellie Island	35	10	71.43
Boat Island	16	10	37.50
Chester Island	55	40	27.27
Grub Island	42	60	30.00(gained)
Redskin Island	33	20	39.40
Snob Island	37	20	45.95

Table 5. Estimated loss of live coral cover around selected Nicobar group islands

Island	Loss of live coral cover(%)	Affected Genera / Species
Andaman group		
Landfall Island	85	*Acropora florida, A. cytherea* and *A. monticulosa, A. humilis, A. palythoa, A. palifera* and *A. hyacinthus*
East Island	70	*Acropora, Platygyra, Pocillipora, Symphyllia* and *Porites*
Smith and Ross Islands	82	*Acropora, Porites, Montipora, Porites* and *Favites*
Aves Island	19	*Acropora* and *Porites*
North Reef	77	*Acropora*
Interview Island	80	*Diploastrea heliopra*
Nicobar group		
Car Nicobar Island	70	*Acropora, Pocillopora* and *Montipora*
Teressa Island	37	*Montipora, Porites* and *Platygyra*
Camorta Island	80	*Montipora, Porites* and *Platygyra*
Katchal Island	49	*Montipora, Porites* and *Pocillopora*
Trinket Island	62	*Acropora, Porites, Montipora* and *Goniastrea*
Nancowry Island	13	*Pocillopora, Porites* and *Echinopora*
Little Nicobar Island	90	*Acropora, Pocillopora* and *Montipora*
Great Nicobar Island	70	*Acropora, Pocillopora* and *Montipora*

Park, 6.8 km^2 in Cinque and 58.3 km^2 in Little Andaman. However the existing records show that the total reef area of these islands is about 2000 km^2 i.e. 6% of the total continental shelf of these islands (Saxena *et al.,* 2008).

Status after tsunami

The massive earthquake and tsunami which struck the Andaman and Nicobar Islands in December 2004 caused goemorphological changes and irreparable devastation to coral reefs. Post-tsunami surveys have been conducted by ZSI in selected islands of the Andaman and Nicobar groups during 2007-2008 to find out the status of live coral cover and the results are presented in Tables 4 and 5. The results revealed that loss of coral reef cover in 7 islands of Mahatma Gandhi Marine National Park ranged from 27.27 to 71.43%. However, in Grub Island a reverse trend has been observed as 30% increment has been noticed in total coral cover area (Table 4). This might be due to the geographical location of this island which was not affected by the tsunami waves as it is enclosed by a labyrinth of islands in the marine national park.

The estimated loss of live coral cover around selected islands ranged from 13% in Noncowry Island to 90% in Little Nicobar Islands. Species belonging to the genera *Acropora, Montipora, Pocillopora, Porites, Platygyra* and *Goniastrea* were the most affected ones (Table 5). It was also noticed that the reefs up to the depth of 20m were damaged around Car Nicobar Island.

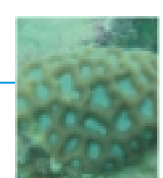
The mortality of corals in the Andaman group of islands was mainly due to the exposure of the reefs, while in Nicobar groups the damage was caused by severe wave action.

Status of new coral recruits

The extent of recruitment of new coral colonies was estimated around some of the tsunami-affected islands

Pachyseris rugosa in Andaman and Nicobar Islands

using the LIT method (English *et al.,* 1994) during March to November 2008. The results indicated the recovery of corals around most of the islands and the density of corals varied from 14 to 22 colonies/10m^2 area with the species diversity (H') of 1.98 - 2.85 in Rutland Island of South Andaman. However in the Nicobar group the density was in the range of 8-12 colonies/10m^2, with a species diversity of 1.73 – 2.18 around Great Nicobar Island. The occurrence of as many as 103 species belonging to 39 genera and 17 families in the Jolly Buoy Island of Mahatma Gandhi Marine National Park and 104 species belonging to 24 genera and 8 families in the North Bay region of South Andaman indicated the recovery of corals in the



affected areas.

Threats to coral reefs of Andaman and Nicobar Islands

The following are the potential threats to the coral reefs of the Andaman and Nicobar Islands:

Coral bleaching (*Acropora gemmifera*) in Andaman and Nicobar Islands

Bleaching

Mass bleaching of corals observed in the reefs of the Indo-Pacific coincided with the El Nino event in 1997-98. Reports of bleaching from the Andaman Islands revealed that the Little Andaman Island reef was severely affected and the live coral cover in Dugong creek was only 12.0% (Jeyabaskaran, 1999).

Sedimentation

Almost all the reefs fringing mainland India and the Andaman and Nicobar Islands are affected by sedimentation, due to developmental activities along the coast, as well as natural causes. Damage due to freshwater runoff has been observed in the semi-enclosed area in a channel near Mahatma Gandhi Marine National Park and also farming practices have been cited as reason for siltation in Hut Bay area of Little Andaman Island (Venkataraman, 2003).

Pollution

The fringing reefs of the Andaman and Nicobar Islands have experienced eutrophication through untreated sewage disposal and runoff from farm lands. Coral mortalities have also been observed in and around Port Blair (Venkataraman, 2003), which may be associated with pollution; increasing vessel traffic in these islands is also posing considerable threat from oil pollution.

Tidal/Tsunami waves

The tidal/tsunami waves are becoming a potential threat as they damage the coral reef framework and especially the branching corals; clogging of reef areas with garbage wastes and deposition of sand and mud on the reef surface, which leads to mass mortality, are the other main threats.

Crown-of-Thorns (COT) starfish

In the Andaman islands, the outbreak of crown-of-thorns starfish, *Acanthaster planci,* has been noticed in Outram Island of Rani Jhansi Marine National Park (Jeyabaskaran, 1999). The outbreaks of this species lead to intense feeding upon coral polyps by COT resulting in mass mortality of corals.

Tourism

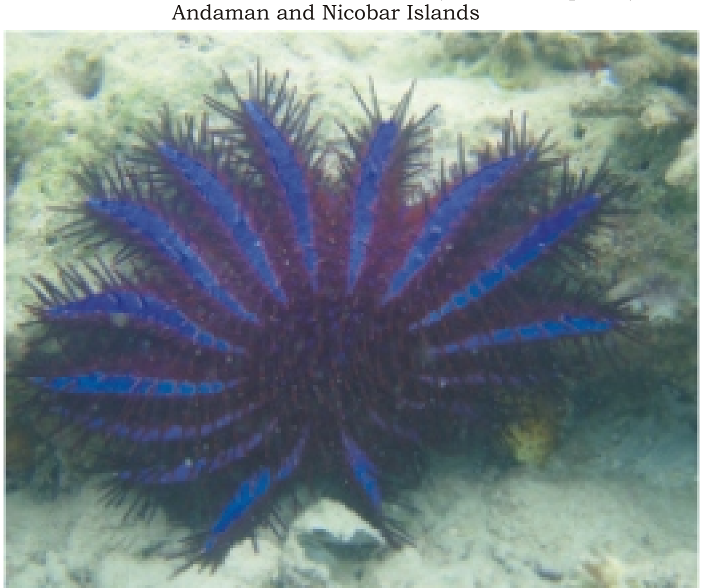
Tourism creates large amount of solid wastes and their inappropriate disposal and leaching of toxic substances leads to coral destruction.

In addition construction of tourism infrastructure causes increased sedimentation. Boat anchoring, snorkeling and diving activities lead to breakage of branching corals and cause lesions on the massive corals.

Conclusions

The assessments so far made have been restricted to certain reef and shallower depths in the Andaman and Nicobar Islands. Mikkelson and Cracroft (2001) pointed out the need for systematic inventories on more cryptic species in the reef areas, other than mapping just the cnidarians, fishes, larger sponges and macroalgae. Periodic monitoring of coral reefs and water quality is a prerequisite by setting up permanent monitoring locations at each reef site which will provide the useful information about the health, morphological changes, bleaching, disease outbreak and associated organisms. It is also noticed that the survey of corals conducted in the Andaman and Nicobar Islands is restricted to selected reefs as well as nearshore regions only. As per the estimates, about 55% of the reef area of these islands is yet to be explored. Survey of the entire reef areas and the offshore regions may bring out several new records of coral species.

Crown-of-thorns star fish (*Acanthaster planci)* in Andaman and Nicobar Islands



Acknowledgement

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Pocillopora woodjonesi in Andaman and Nicobar Islands

Status of coral reefs of Lakshadweep

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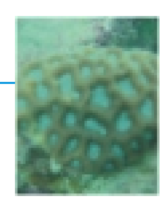
Abstract

The Lakshadweep coral reefs are the only atoll reefs in Indian waters. As a result of the 1998 bleaching event, the live coral cover around all these islands decreased drastically, to about 10% or less. Following this, the Lakshadweep Administration initiated several measures towards conservation and recovery of the corals around these islands. Among them include the establishment of the Lakshadweep Coral Reef Monitoring Network (LCRMN), training (SCUBA, survey techniques), capacity building (manpower, gear) and monitoring components. The sustained surveys of all islands during the last 5-7 years have shown that the recovery in general has led to a near-doubling of the live coral cover post-bleaching, with Bitra, Agatti and Kiltan reefs having now more than 40% live coral cover. Based on their current status, three reefs could be regarded as very good, four reefs as good, and the remaining four as satisfactory. In terms of conservation, the Administration has adopted intense awareness creation at all levels and enforcement. As a result, mining of corals has been considerably reduced. In order to accelerate the recovery of the reefs, coral transplantation has also been initiated since four years ago. The growth rate of most of the corals tested is quite high and several colonies have already been transferred to the reef.

Introduction

The Lakshadweep islands lie scattered in the Arabian Sea about 225 to 450 km from the Kerala Coast. Geographically the islands lie between 8° - 12 °3' N lat. and 71°E - 74°E long. They comprise 12 atolls, three reefs and five submerged banks with a total land area of 32 km^2(Fig. 1). Even though in terms of land mass Lakshadweep is the smallest territory of India, considering its lagoon area of 4200 km^2, 20,000 km^2 of territorial waters and about 4,00,000 km^2 out of the 8,59, 992 km^2 of Exclusive Economic Zone of the west coast of India, Lakshadweep has a very large territorial area.

Lakshadweep is comprised of 36 small islands, out of which 11 are inhabited (Agatti, Androth, Amini, Bitra, Bangaram, Chetlet, Kiltan, Kadamat, Kavaratti, Kalpeni and Minicoy). Kavaratti is the capital island. Androth is the largest island with an area of 4.8 km^2. Androth and Amini are the islands without a proper lagoon. Bitra is the smallest island with an area of 0.1 km^2. Androth alone lies east to west while other islands are oriented in a north-south direction. The distance between the islands varies from 11 to 378 km. The islands are coral formations grown on the 1500 m to 4000 m high Laccadive-Chagos submarine ridge. This ridge may be a continuation of the Arravali Mountains and the islands are understood to be remnants of the submerged mountain cliffs. The Lakshadweep islands, along with the Maldives and the Chagos Archipelagoes, form an uninterrupted chain of coral atolls and reefs on a continuous submarine bank covering a distance of over 2000 km. About 105 species of hard corals, 86 species of



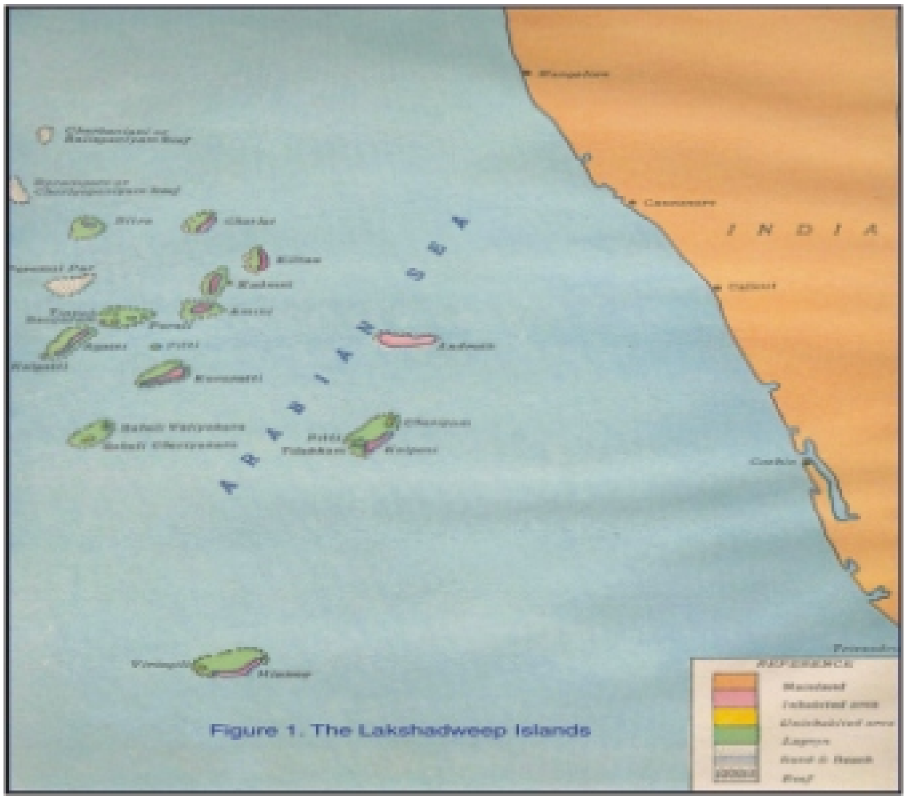


Fig. 1. Map showing the study area

macrophytes, 10 species of anomuran crabs, 81 species of brachyuran crabs, 155 species of gastropods, 24 species of bivalves, 13 species of asteroids, six species of ophioroids, 23 species of holothurions, 15 species of echinoids, 603 species of fishes and four species of turtles are recorded from Lakshadweep (Satyanarayana and Alfred, 2007). Besides, there are undisturbed virgin reefs, namely Suheli par with 78.96 km^2 of lagoon, Baliyapani par with 57.46 km^2 of lagoon, Cheiyapani par with 172.59 km^2 of lagoon and Perumul par with 83.02 km^2 of lagoon and one marine bird sanctuary namely Pitti.

The reefs of the present study area in Lakshadweep are of the atoll type. Atoll type reefs are the rarest among the reef types and are found in very few countries. The 10 inhabited islands (Agatti, Androth Chetlat, Kiltan, Kalpeni, Amini, Kadmat, Kavaratti, Bitra and Minicoy) and two uninhabited islands (Bangaram and Suheli) were selected to assess the coral status.

Bio-physical monitoring of coral reefs using the universally followed Line Intercept Transect method (English *et al.,* 1997) was carried out on yearly basis around all the selected islands. Even though all islands were not covered every year due to logistic problems, frequency of sampling was increased when problems were not a factor. Studies were carried out in the year 2007 around almost all the islands

to assess the status of coral reefs.

Both biotic (coral, algae, and other animals) and abiotic (sand, rubble and rocks) components were recorded (in terms of percentage). Live coral, dead coral and dead coral with algae were assessed carefully to know the actual increase or decline in the coral health after the bleaching event. Usually five Line Intercept Transects (20 m) were laid around the islands at a depth up to 10m.

The results of the study not only showed the trend of coral recovery after bleaching in 1998, but also indicated the inverse relationship between live coral cover and algal growth.

The live coral cover and the algal cover were used to investigate the trend of recovery of reefs. The live coral cover was compared with the oldest record to calculate the ratio of increase/ decrease of live coral cover.

The results clearly indicated a gradual increase in live coral cover and considerable decline in algal cover during the period 2001 - 2007.

Bitra Island

Bitra has a land area of 10.52 hectares and has a human population of only 264 persons, lying on the northeastern tip of a large coral ring reef enclosing a magnificent lagoon. It lies 48 km west of Chetlet. The island has a very large and deep lagoon. Coral reefs there are fully mature. During the fair weather season many fishermen from other islands camp there to exploit the potential fishing ground. Corals around the island are in excellent condition. The Lagoon Area is 45.61 km^2, Island Perimeter - 1.2 km, reef Perimeter - 32.71 km and reef area - 19.63 km^2.

Biophysical monitoring on Bitra reefs was conducted during 2001, 2004, 2005 and 2007 and the results are given in Table 1.

Table 1. Percentage composition of biotic and abiotic components of Bitra reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2001	32.7	30.3	3	34	0	100
2004	40.2	41.6	1	16.2	1	100
2005	45.6	50.7	1.2	2.5	0	100
2007	44.3	41.7	8.7	4.3	1	100

Chetlat Island

Chetlet is also a small island and is located about 40 km west of Kiltan island. Land Area is 1.40 km^2 with population of 2289 (2001). The lagoon area is 1.60 km^2, island perimeter - 5.82 km, reef perimeter 6.37 km and reef area - 3.8 km^2.

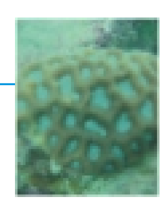
Biophysical monitoring of Chetlat reef was conducted during 2001, 2004, 2005, 2006 and 2007. The results are given in Table 2.

Table 2. The percentage composition of biotic and abiotic components of Chetlat reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2001	14.2	13.7	2.5	68.6	1	100
2004	23.4	46.4	1.2	29	0	100
2005	29.3	57.9	3.8	3.5	5.5	100
2006	30	53	4	7	6	100
2007	32.1	42.1	8.4	12.5	4.9	100

Kadmat Island

Kadamat Island is 8 km long and 550 meters wide at the broadest point and lies about 10 km north of Amini. This island is one of the best tourist



spots and has a good resort at the southern tip of the island. This island was severely affected during the 1998 coral bleaching event and the entire reef region and reef flat became devoid of life. Now new growth is restoring well. The land area is 3.2 km^2 with a population of 5319 (2001). The lagoon area is 37.50 km^2, island perimeter - 18.38 km, reef perimeter - 24.94km and reef area - 14.96 km^2.

Biophysical monitoring on Kadmat reef was conducted during 2000, 2004, and 2007. The results of surveys conducted in 1999 by LCRMN are also included in Table 3.

Table 3. The percentage composition of biotic and abiotic components of Kadmat

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
1999	9	15	3	73	0	100
2000	3.5	5	6.5	85	0	100
2004	11.5	62	1	25.5	0	100
2007	19.3	64.8	7.3	6.6	2	100

Amini Island

Amini is a thickly populated island lying about 66 km north of Kavaratti island. The corals around this island are healthy. The land area is 2.60 km^2 with a population of 7340 (2001). The lagoon area is 1.50 km^2, island perimeter - 6.67 km, reef perimeter - 7.88 km and reef area - 4.73 km^2.

Biophysical monitoring was conducted during 2001, 2002, 2004, 2005 and 2007 and the results are given in Table 4.

Table 4. Percentage composition of biotic and abiotic components of Amini reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2001	6.5	34.2	7.7	48.6	3	100
2002	5.5	31.5	35	27	1	100
2004	16.1	49.9	1	32	1	100
2006	21.5	68	4	5	1.5	100
2007	22.7	59.1	3.4	13.8	1	100

Kavaratti Island

Kavaratti is the headquarters of the Union Territory of Lakshadweep. The Land Area is 4.22 km^2 with a population of 10113 (2001). The lagoon area is 4.96 km^2, island perimeter - 11.46 km, reef perimeter - 12.88 km and reef area - 9.02 km^2. The biophysical monitoring was conducted from 2001 to 2007 owing to its accessibility and the results are given in Table 5.

Table 5. Percentage composition of biotic and abiotic components of Kavaratti reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2001	13.2	33	3.5	50.3	0	100
2002	23	43	19	15	0	100
2003	25.5	67.5	1	6	0	100
2004	20.2	54.5	1	24.3	0	100
2005	26.2	54.1	1	17.7	1	100
2006	28.5	53.8	4.5	11.2	2	100
2007	30.1	51.4	2.8	13.7	2	100

Kiltan Island

Kiltan is a comparatively small island with excellent coral development

Spotfin Lionfish, Lakshadweep

extending over about 800 m in length and about 250 m wide at a depth of 20 m on the northern and southern tips. The land area is 2.20 km^2 with a population of 3664 (2001). The lagoon area is 1.76 km^2, island perimeter - 7.81 km, reef perimeter - 8.32 km and reef area - 5.4 km^2. Biophysical monitoring was conducted in the years 2001, 2004, 2005 and 2007 and the results are shown in Table 6.

Table 6. Percentage composition of biotic and abiotic components of Kiltan reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2001	15.2	28	6.2	50.6	0	100
2004	36.4	32.8	1.2	28.6	1	100
2005	43.7	48.1	2.3	1.5	4.4	100
2007	41.1	43.5	7.2	6	2.2	100

Androth Island

The reef around the Androth island has a flat bottom at about 20 m depth towards the outside of the island with a width varying from 60 m to 400 m with a healthy growth of corals. The land area is 4.92 km^2 with a population of 10720 (2001). The lagoon area is 0.95 km^2, island perimeter -10.59 km, reef perimeter - 12.3 km and reef area - 9.84 km^2. Biophysical monitoring was conducted during 2002 and 2006 and the results are given in Table 7.

Soft coral (*Lobophytum* sp.), Lakshadweep

Table 7. Percentage composition of biotic and abiotic components of Androth reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2002	11.8	36.2	32.8	18.2	1	100
2006	18.5	66.5	8	5	2	100

Agatti Island

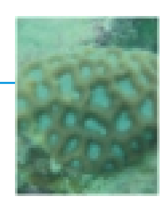
Agatti is the most westerly island of Lakshadweep. Its lagoon is very vast and has a good coral development. A wide reef flat is also present from Agatti to Bangaram. The reef spreads over a distance of 9 km long and 1 km width. The land area is 3.84 km^2 with a population of 7072 (2001). The lagoon area is 17.50 km^2, island perimeter - 16.14 km, reef perimeter - 21.44 km and reef area - 12.84 km^2. The biophysical monitoring was conducted during the years 2001, 2002, 2005, 2006 and 2007 and the results are shown in Table 8.

Table 8: Percentage composition of biotic and abiotic components of Agatti

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2001	23.7	42	2.5	28.5	3.3	100
2002	41.5	58.5	0	0	0	100
2005	43.9	49.6	4.5	1	1	100
2006	45	43	4	3	5	100
2007	39.2	43.6	10	6.2	1	100

Kalpeni Island

Kalpeni Island has many satellite islets in the same lagoon. The lagoon situated to the west of the island is enclosed by reefs which have an elliptical shape with good coral growth. The land area is 2.79 km^2 with a population of 4319 (2001). The lagoon area is 25.60 km^2, island perimeter-



11.86 km, reef perimeter - 25.60 km and reef area - 15.36 km^2. Biophysical monitoring was conducted during 2002 and 2006 and the results are shown in Table 9.

Table 9. Percentage composition of biotic and abiotic components of Kalpeni reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2002	10	47	34	9	0	100
2006	22	71	1	1	5	100

Minicoy Island

The lagoon in Minicoy Island is large and deep enough for small ships to enter. This is the only island having a good growth of mangroves. Lagoon and outside the reef have a rich growth of corals. The land area is 4.80 km^2 with a population of 9495 (2001). The lagoon area is 30.60 km^2, island perimeter - 23.08 km, reef perimeter - 29.55 km and reef area -17.73 km^2. Biophysical monitoring was conducted during 2002, 2006 and 2007 and the results are given in Table 10.

Table 10. Percentage composition of biotic and abiotic components of Minicoy reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2002	10	47	34	9	0	100
2002	12	66	15	7	0	100
2006	17	62	4	6	11	100
2007	21.3	61	2.4	8.6	6.7	100

Suheli Island

Suheli par is one of the most potential areas for fishing in the Lakshadweep. The lagoon has good coral growth with a variety of associated biodiversity. The land area is 4.22 km^2 , lagoon area - 78.96 km^2, island perimeter - 11.46 km, reef perimeter - 47.46 km and reef area - 28.48 km^2. Biophysical monitoring was conducted during 2002, 2005 and 2007 and the results are shown in Table 11.

Table 11. Percentage composition of biotic and abiotic components of Suheli reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2002	21	15.3	13.2	50.5	0	100
2005	16.7	57.9	3.7	21.7	0	100
2007	17.5	63.6	4.6	10	4.3	100

Bangaram Island

Bangaram group of islands lies of 10 km north of Agatti island in a separate reef formation. With beautiful sandy beaches and extensive lagoon all around, Bangaram has been declared as a tourist centre. The island has also become a favorite fishing and turtle watching ground for the people. The land area is 0.58 km^2 with only a tourist population. The lagoon area is 28.60 km^2, island perimeter - 3.52 km, reef

Table 12. Percentage composition of biotic and abiotic components of Bangaram reef

Year	Live coral	Dead coral	Other fauna	Algae	Abiotic	Total
2001	8	10	15	66	1	100
2004	27	64	1	7	1	100
2005	19.1	77.9	1	1	1	100
2006	22	61.1	2.1	9.8	5	100
2007	24.5	58.4	7.9	8.2	1	100

A view of Suhali Island beach, Lakshadweep

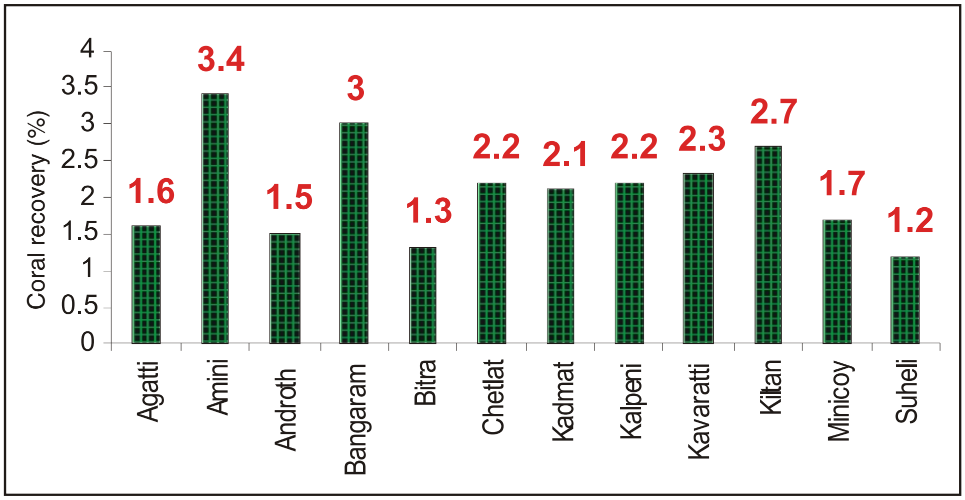


Fig. 2. Percentage recovery of coral reefs after bleaching in 12 atolls

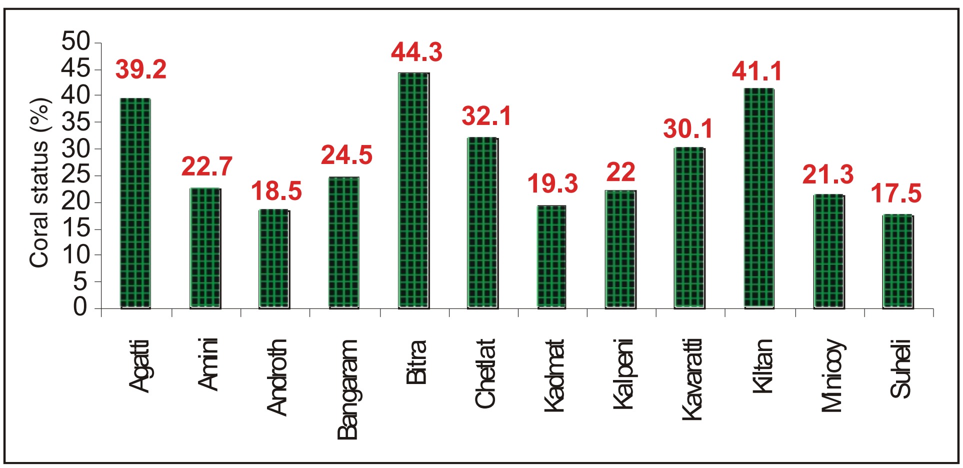


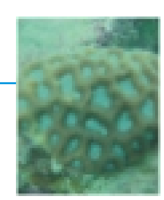
Fig. 3. Status of live corals of 12 Lakshadweep atolls

perimeter - 26.1 km and reef area - 15.66 km^2. Biophysical monitoring was conducted during 2001, 2004, 2005, 2006 and 2007 and the results are shown in Table 12.

The project was undertaken with the objective to monitor and assess the recovery of coral reefs after the bleaching event in 1998 and to provide baseline information. The percentage recovery of coral reefs after the bleaching event is presented in Fig. 2.

Fig. 3 indicates the present status of live corals in the 12 Lakshadweep atolls covered. Corals around Bitra Island are the best followed by Kiltan.

In conclusion, coral reefs of the Lakshadweep islands are recovering well after bleaching in 1998; however it



is always wise to reduce the stress to the coral reefs.

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A view of reef habitat, Lakshadweep

Status of recruitment and age estimation of selected genera of corals in Gulf of Kachchh, Gujarat

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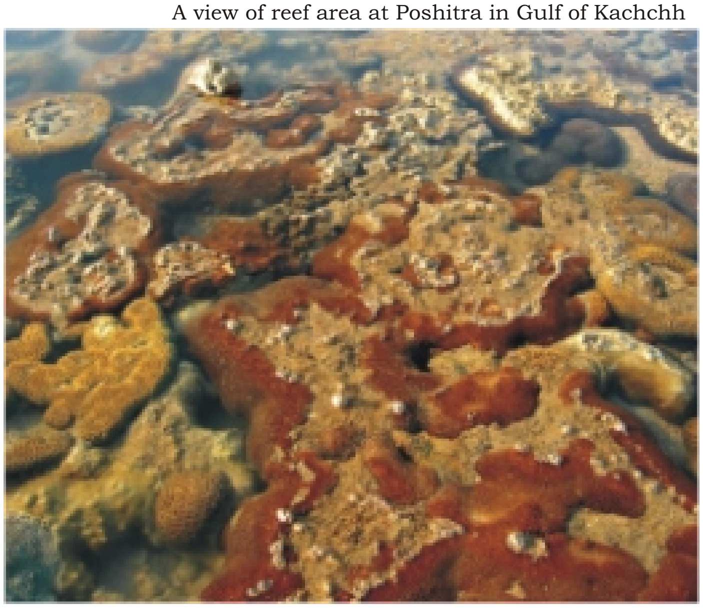
Abstract

Coral recruitment is the process of formation and growth of coral reefs and it occurs when the swimming coral larvae in the ocean attach to any hard surface (e.g., rocks) and develop. Recruitment plays an important role in the maintenance and regeneration of coral populations in the region. GEER Foundation has studied status of recruitment of selected genera of coral in Gulf of Kachchh, in the state of Gujarat. The study was conducted at 6 sites (4 islands and 2 coastal) covering western, central and eastern portions of the southern shore of the Gulf. To study the recruitment in selected genera (i.e., *Favia, Favites, Acanthastrea, Platygyra, Porites, Pseudosiderastrea, Cyphastrea, Turbinaria, Siderastrea, Montipora, Symphyllia* and *Goniopora*), underwater quadrats were laid and recruitment was determined in an unit area of 100 sq.m. Inter-genera comparison of recruitment among the selected corals has revealed that the recruitment was the highest in *Favia* spp. followed by *Favites* spp. Interestingly, the recruitment for *Turbinaria* spp. was recorded only at a coastal site, i.e., Poshitra. The only genus that exhibited noticeable recruitment at Poshitra was *Turbinaria.* Further, it was found that coral recruitment was maximum at Pirotan and Goose islands (i.e., 50 per 100 sq.m and 51 per 100 sq.m. respectively). Moreover, though Narara had maximum (i.e., 40%) surface covered with live corals, coral recruitment was minimum at this coastal site. Thus, the availability of suitable substrata may be one of the critical factors that are required for new recruitment.

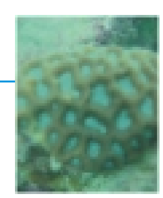
Introduction

Coral reefs endowed with live and dead corals on the fringes of the southern shore of the Gulf of Kachchh (GOK) constitute the northernmost reefs of the Indian continent. Here, temperature variation of 15 °C to 30° C and a salinity over 35ppt have been recorded. High sedimentation is observed in this region along with long exposure time of corals due to the high tidal amplitude (Pillai *et al.,* 1979). All such factors, along with the extent of availability of suitable substrata affect coral recruitment.

A view of reef area at Poshitra in Gulf of Kachchh



It may be noted that 'recruitment' is the measure of the number of young individuals (i.e., coral larvae) entering the adult population. In other words, it is the supply of new individuals to a population. Recruitment can play a critical role in the resilience of coral populations through the number of individuals and different species that repopulate a reef. Its importance for community dynamics and coral populations varies by species, habitat



Coral recruit (*Favia* sp.)

and reef location. The rates, scales, and spatial structure of dispersal among populations drive population replenishment, and therefore have significant implications for population dynamics, reserve orientation, and resiliency of a system (Anon, 2009).

Gulf of Kachchh is tectonically unstable and hydrographically harsh for the growth and recruitment of corals due to its high tidal amplitude, high salinity and temperature, high sedimentation rate and prolonged exposure to the atmosphere because of the high tidal amplitude. Natural disasters and anthropogenic activities have disturbed the reef ecosystem which, in turn, has affected the other marine organisms depending on the reef for their survival. Therefore, in order to monitor coral reef deterioration, a study was conducted to understand the recruitment of the selected species of the coral reefs. Along with the recruitment studies, the historical changes in the reef structure have also been analyzed. The objectives were as follows:

- To obtain baseline information on various genera of corals, along with their locations in GOK, and select appropriate genera for coral recruitment and age estimation studies.
- To carry out quadrat-based measurements to determine the number of newly recruited corals (along with percentage live coral cover).
- To apply a carbon dating technique using an Ultra Low Level Liquid Scintillation Counter for estimating the age of the corals.

The study area was located in Gulf of Kachchh (GOK). The area of the GOK is 7,350 sq. km. In GOK, 20 islands (out of a total of 42) have coral reefs. The different types of coral reefs and their distribution in the GOK are given below:

- *Fringing reef*: Narara, Singach, Sikka, Patra, Dhani and Ajad Reefs
- *Platform reef*: Kalubhar, Mundeka, Bural Chank, Pirotan and Paga reef
- *Patchy reef:* Jindra Reef
- *Coral pinnacles*: Two small reefs to the south of the Paga reef and four small reefs to the west of Bural Chank reef
- *Submerged reef*: Goose reef, Chandri reef, Boria reef

In these reefs, 41 species of corals belonging to 9 families and 24 genera have been recorded.

Apart from the coral species, the coral reefs are also the oasis for other forms of marine life. Thus, they provide shelter and food to various organisms such as reef vegetation, fishes and marine invertebrate. It may be noted that within the Gulf of Kachchh, there are 103

species of reef vegetation, which include green algae (37 species), red algae (26 species), brown algae (37 species) and sea grasses (3 species); 193 species of fishes (including bony/cartilaginous fish and prawns); and a variety of marine invertebrates like sponges (34 species), hydrozoans (5 species), jelly fish (3 species), sea anemones (4 species), zooanthids (7 species), flat worm (4 species) and echinoderm (8 species). (GEER Foundation, 2004). Unfortunately, the coastline of Gujarat is under pressure from natural and anthropogenic factors like cyclones, earthquakes, droughts, warm streams, industrialization and mining. All these factors have great potential to adversely affect corals and the associated flora and fauna of the reef ecosystems.

It must be noted here that the GOK has the first Marine Protected Area (i.e., Marine National Park and Sanctuary) of the country; this was established in the year 1982-83 covering a total area of 620.81 sq. km (GEER Foundation, 2004). Ecologically it mainly includes the islands and the intertidal zones along the coast. There are 42 islands in the Gulf of Kachchh which includes some submerged areas. Among these islands, some locations have been selected in order to analyze and study the coral reefs of the state.

Material and methods

The study area was divided into three different zones, viz. Eastern Gulf, Central Gulf and Western Gulf which included the islands Pirotan and Goose; Poshitra, and Chank; Narara and Kalubhar, respectively. All these islands are located on the southern shore of the Gulf of Kachchh (Fig. 1).

The study of the coral recruitment was carried out by laying 1x1 m quadrats

Coral recruit (*Favites* sp.) in Narara Island

in the study area. By keeping the quadrats parallel to the reef edge at different levels, the recruitment rate of newly recruited coral colonies was studied. The colonies, consisting of single, double and triple polyps, were considered as 'new recruits'. All live coral colonies having a size of less than 3 cm were also considered newly recruited colonies.

In order to identify the age of the coral reefs, a carbon dating technique was utilized by using an Ultra Low Level

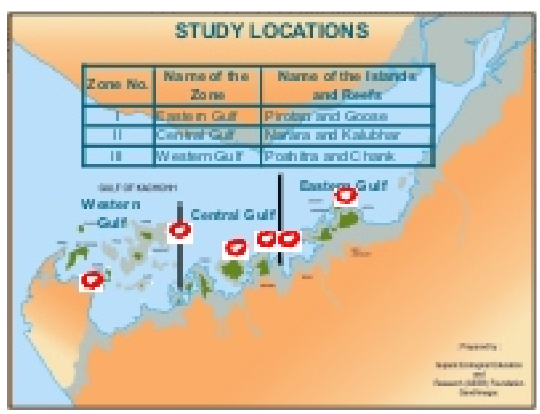


Fig. 1. Zones of the study area (Eastern, Central and Western Gulf)

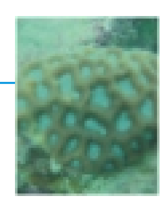


Table 1. Percentage of live coral cover and recruitment at different sites in the Gulf of Kachchh

Site	Total no of quadrats	% live coral cover	No. of new recruits	No. of new recruits per 100 sq. m.
Pirotan	280	14	140	50
Goose	250	23.6	128	51
Narara	530	5.05	116	2
Kalubhar	680	17.15	105	15
Chank	165	8.86	15	9
Poshitra	88	39.87	6	7

Liquid Scintillation Counter (ULLSC). The dating method was carried out in collaboration with Birbal Sahani Institute of Paleobotany, Lucknow. For carbon dating, five samples were collected from three locations using a hacksaw blade. Of these, one sample was collected from Goose Island and two samples each were collected from Kalubhar and Pirotan islands.

The samples were chemically processed with hydrochloric acid (HCL). The resulting CO_2 was purified and was allowed to pass through molten lithium in a reaction vessel at 750^{o}C and followed by raising to 900^{o}C. Hydrolysis was carried out resulting in collection of acetylene at liquid nitrogen temperature. At the time of biological ter-mination, C-12 and C-13 would remain the same, but C-14 would continue to decay with a half-life of 5,730 years. A specimen had all the three isotopes of carbon, namely, C-12, C-13 and C-14. Of these, C-14 is radioactive (known as radiocarbon) which would be further converted into benzene, weighed and transferred to a vial and placed in the counter.

Results and discussion

Recruitment rate at six different locations was found to vary considerably. The minimum rate was seven recruits per 100 sq. m., whereas the maximum rate was 51 recruits per 100 sq. m (Table 1). Such a wide variation in recruitment rate was probably due to the different environ-mental conditions at the six locations.

Table 2. Recruitment of different genera of corals (per 100 sq. m)

Genera	Sites in Gulf of Kachchh					
	Pirotan	Goose	Narara	Kalubhar	Chank	Poshitra
Favia	41	34	15	4	4	0
Favites	1	5	5	4	4	0
Porites	4	0	1	1	2	0
Pseudosiderastrea	2	0	0	0	0	0
Goniopora	0	6	0	2	0	0
Siderastrea	0	2	0	0	1	0
Symphillia	0	0	0	3	1	0
Cyphastrea	0	3	0	0	0	0
Goniastrea	0	0	0	0	0	0
Acanthestrea	1	0	0	0	0	0
Platygyra	1	0	0	0	0	0
Montipora	0	1	0	1	0	0
Coscinarea	0	0	0	0	0	0
Turbinaria	0	0	0	0	0	7
Leptastrea	0	0	0	0	0	0
Mysedium	0	0	0	0	0	0
Soft corals	0	0	0	0	0	0

From the view-point of recruitment, Goose and Pirotan islands were the best, as the recruitment rates were found to be 51 recruits per 100 sq. m and 50 recruits per100 sq.m respectively (Table 1). Coral recruitment rate was found to be moderate at Narara (i.e., 22 recruits per 100 sq. m) and it represented half the coral recruitment rate at Pirotan (i.e., 50 recruits per 100 sq. m). Thus, although Narara has got the lowest percentage of live coral (i.e., 5%, Table 1), the recruitment rate is quite high. This implies that some recent changes have occurred at this site in favour of recruitment.

A very low coral recruitment rate was recorded at Chank and Poshitra sites (Table 1). The possible reason for this seems to be lack/scarcity of necessary substrata, which is the crucial requirement for good coral recruitment. It may be noted that at Poshitra, contrary to the low recruitment rate, live coral cover is high (i.e. 39.87%). The likely reason for the higher live coral cover is the better water quality prevailing around Poshitra Island.

The study has made it possible to record the recruitment rate of 12 genera of hard corals at six different sites in GOK (Table 2).

It can be revealed from Table 2 that among all the genera, *Favia* was dominant at all the sites (except at

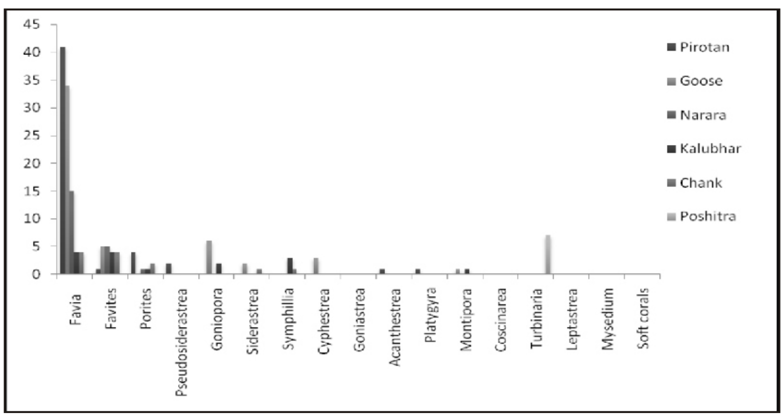


Fig. 2. Genera-wise comparative account of recruitment for different sites in Gulf of Kachchh

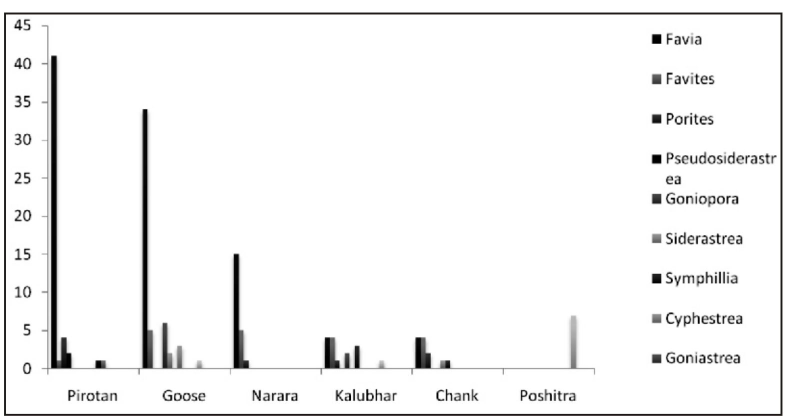


Fig. 3. Site-wise comparative account of recruitment of different coral genera in Gulf of Kachchh

Poshitra, where *Tubinaria* was dominant) due to some of its special features. Thus, the dominance of *Favia* might be due to its ability to survive against the high sedimentation, turbulence and long term exposure to the atmosphere. All such environmental conditions prevail quite commonly at the GOK (GEER Foundation, 2004). Apart from having a capability of surviving in harsh environmental conditions as mentioned above, *Favia* often undergoes a special mode of asexual reproduction known as polyp expulsion (Kramarsky-Winter *et al.,* 1996). The asexual reproduction helps this genus to multiply in the shallow, physically disturbed warm water areas.

Genera-wise comparison of the recruitment rate for the six sites in the GOK has revealed that the recruitment rate of *Favia* is the highest at Pirotan island, whereas it is the second-highest at Goose Island (Fig. 2).

Site-wise comparison of recruitment rate for different coral genera in the GOK (Fig.3) has revealed that at Pirotan Island, there is a considerable difference in the recruitment rate of *Favia* (41 recruits per 100 sq.m.) and that of other existing coral genera. Thus, the recruitment of *Favia* is 78.1% higher than the recruitment of all the other coral genera present considered collectively. Moreover, the recruitment of *Favia* is as high as 97.5% more than that of the genus *Favites* which has exhibited the second-highest recruitment at Pirotan, Unlike for Pirotan, at Goose Island the extent of dominance of *Favia* is comparatively less as the recruitment rate of *Favia* is only 50% higher than the recruitment of all the other existing coral genera considered together. Moreover, its recruitment is as high as 82.4% more than that of *Goniopora,* which has exhibited the second highest recruitment rate at Goose Island. This means that *Favia* has clear dominance over other genera at Pirotan, but at Goose Island, genera other than *Favia* (i.e., *Favites, Goniopora, Siderastrea, Cyphestrea* and *Montipora*) also have recruited well in comparison to the Pirotan site. This leads further to the inference that favourable environmental conditions exist at Goose Island for the growth and survival of corals.

It is well-known that coral reefs may take thousands of years to form. They are typically known to grow slowly; i.e. no more than 20 cm per year. It is known that the coral reefs evolved some 200 million years ago, and today, most reefs have an age of less than 10,000 years. However, the age of the coral reefs specifically in Gulf of Kachchh was hitherto unknown and the present study has attempted to fill this information gap. In the present study, the age of the coral has been determined with the help of a carbon-14 dating technique. Five samples from different sites on Pirotan, Kalubhar and Goose islands were collected (Table 3).

Table 3 shows that the age of the samples from Goose Island was estimated to be 2,018 ± 130 years B.P. (Before Present). At Goose the sample was taken at 50 cm depth from the

Sea anemone in Narara Island

Table 3. Age of the corals from a carbon-14 dating method; YBP refers to Years Before Present

Site	Age (YBP) of coral	Latitudes	Longitudes
Pirotan-1	5,700 ± 142	22°35.958' N	69°56.091'E
Pirotan-2	6,110 ± 168	22°35.958' N	69°56.091'E
Kalubhar-1	1,310 ± 100	22°27.831' N	69°39.412' E
Kalubhar-2	2,350 ± 137	22°27.837' N	69°39.419' E
Goose	2,018 ± 130	22°29.447' N	69°47.187' E

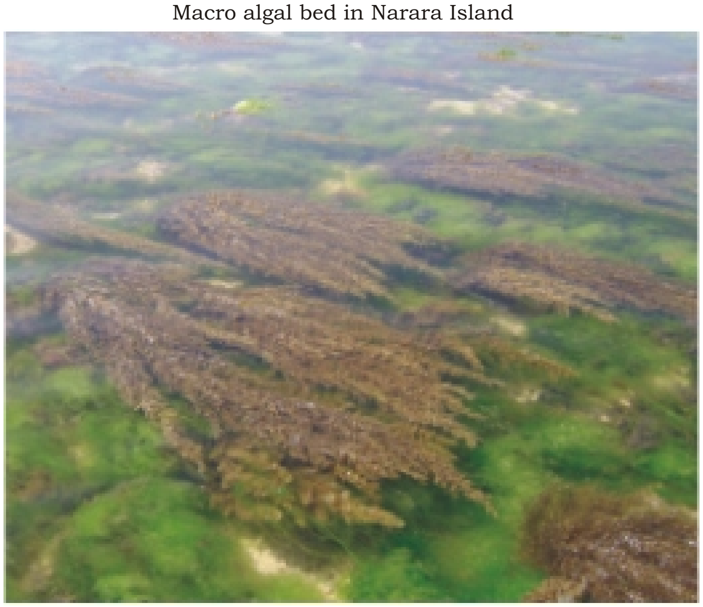
surface of the coral reef. This means, to achieve 50 cm growth the coral took approximately 2000 years.

From the coral reefs on Pirotan Island, the Pirotan - 1 and Pirotan - 2 samples were taken from 50 cm and 15 cm depth, respectively. It was revealed from these samples that their ages are 5,700 ± 142 and 6,110 ± 168 years. This implies that the coral took 5,700 ± 142 and 6,110 ± 168 years to grow 50 cm and 15 cm respectively.

Likewise, for the coral reefs on the Kalubhar Island, age of the two samples, viz., Kalubhar - 1 and Kalubhar - 2, was found to be 1,310 ± 100 and 2,350 ± 137 years B.P. respectively.

Thus, at Pirotan, after 5,700 ± 142 years, the growth had been 50 cm whereas at Goose the same growth of 50 cm occurred less than half this time. These results support the conclusion that environmental conditions at Goose are more favourable.

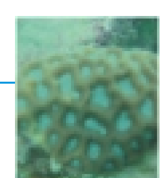
Macro algal bed in Narara Island



Conclusion

In the Gulf of Kachchh, six islands i.e. Pirotan, Goose, Narara, Kalubar, Chank and Poshitra were studied. Among these islands, only Goose has shown maximum recruitment of various species. Recruitment at Pirotan is nearly equal to Goose, though the *Favia* recruitment has dominated compared to recruitment of the other existing coral genera. Therefore, both the regions may be considered to be the excellent sites for recruitment of various coral species. Fair coral recruitment has been noted around Narara and Kalubhar islands. Considering the huge reef area of Kalubhar, the amount of coral recruitment on this island can be considered to be poor. Chank and Poshitra support much less recruitment, the reasons for this may be different for those two Islands.

All the six islands studied are the most suitable for recruitment of *Favia* except at Poshitra. Recruitment of the genera *Goniastrea, Coscinaria, Laptastrea, Mysedium* and soft coral is not recorded at any site in the study area. Pirotan is the only island supporting the recruitment of *Pseudosiderastrea, Acanthastrea* and *Platygyra*, among which *Pseudosiderastrea* is a rare genus (GEER Foundation, 2004). Another rare genus, *Cyphastrea* has shown recruitment only on Goose. The genus *Turbi-*



naria was found recruiting only on Poshitra, where no other genera were found recruiting. It was also revealed that *Favites* could also recruit at all the sites, excluding Poshitra. The rate of its recruitment has been far less than that of *Favia*. Among all the samples of coral reef from Gulf of Kachchh, Pirotan Island is endowed with the oldest reef, with an age more than 6,000 years. On the other hand, the Kalubhar reef was found to be only 1,310 years old. Thus the Kalubhar reef is the youngest among all the islands from which the samples were taken.

Acknowledgements

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Fish aggregation near a reef area in Narara Island

Biodiversity of octocorals

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Abstract

Coral reefs are the most productive ecosystems in the tropical marine environment and octocorals are among the most conspicuous and colourful components of reef communities. This paper summarises the published information on octocoral diversity and taxonomy for Indian waters and shows that this part of the Indian fauna is very poorly known. In fact since 1904 only 253 species belonging to 21 families and 66 genera have been recorded. A list of the currently recognised octocoral families present in the world's oceans and the number of included genera are given, along with a section on research methodology. The history of octocoral taxonomy and the exploitation of the resource in India is presented, the diversity and the most common species are discussed, and a table is given that lists all the reported Indian species and the location from where they were obtained. The octocoral diversity is extremely rich in Andaman and Nicobar islands (190 species) followed by Gulf of Mannar (47 species), and Lakshadweep islands (40 sepcies). The most dominant octocoral genus in Indian coral reef is *Sinularia.* The evidence shows that in order to understand the actual species diversity of octocorals in India, a thorough investigation to re-examine the specimens deposited in various museums and simultaneous surveys along the Indian coast are needed.

Introduction

Octocorals are the second most abundant benthic animals in coral reef communities of the Indo-Pacific. In the global scenario, there is a growing interest in octocorals as they are least known and have biomedical importance. Octocorals have an important role in reef ecology, contributing to the reef diversity, providing food to some animals and in constituting a vital part of reef trophodynamics where they filter particles from water into the reef system. They also play a significant contribution to the aesthetic experiences for divers and reef visitors, a role that is often undervalued. Although commonly called "soft corals," the Octocorals are not close relatives of the Scleractinia, or "true corals" living today. Unlike true corals, which have hexaradial symmetry, octocorals have eightfold radial symmetry. Octocorals worldwide belong to three orders (Helioporacea, Alcyonacea, Pennatulacea) and comprise 45 families, ca. 334 genera, and about 2000-4000 estimated species (Williams, 2010). The octocoral fauna of Indo-Pacific reefs is dominated by three families, Xeniidae, Nephtheidae and Alcyoniidae (Bayer 1957). However, a great number of species are yet undescribed, and field identification of most species is impossible.

Taxonomy of octocorals

The basic reference to the soft corals is the publication of Bayer (1956). Subsequently, a valuable reference book on the key to the genera of octocorals (Bayer, 1981) and an illustrated glossary for octocorals was published by Bayer *et al.* (1983). Pictorial field guides published by Williams (1993) and Fabricius and Alder-slade (2001) are also valuable sources of information. In addition, few thorough revisions of the common genera of octocorals are available. The genus *Sinularia* May, the most abundant of soft corals in the Indo Pacific region has been revised by Lüttschwager (1915), Kolonko (1926) and Tixier-Durivault (1945, 1951). Verseveldt (1980) published a detailed revision of the genus *Sinularia*, which included 93 valid species. A revision of the genus *Sarcophyton* May, was made by Verseveldt (1982) who devised four keys for their identification. About 35 valid species belonging to this genus were described. Further, the revision of the genus *Lobophytum* von Marenzeller with the inclusion of 46 valid species was also reported by Verseveldt (1983).

According to the classification of octocorals, three orders, 45 families, ca. 334 genera, 2000-4000 estimated species are present. This revised system is based on Bayer (1981) for Helioporacea and Alcyonacea; Kükenthal (1915) and Williams (1995) for Pennatulacea (Dr. Philip Alderslade, Institute of Antarctic and Southern Ocean Studies, Tasmania; personal communication) The current taxonomic position of the octocorals is as follows :

ORDER HELIOPORACEA (2 families, 2 genera); rigid skeleton composed of aragonite, sclerites when present are calcitic.

1. Lithotelestidae (1 genus)
2. Helioporidae (1 genus)

ORDER ALCYONACEA (29 families, ca. 274 genera); skeletal components composed of calcite and gorgonin, rarely with some aragonite. Polyps as individuals, which may or may not be united by basal stolons. Polyps solitary.

3. Taiaroidae (1 genus)
4. Haimeidae (2 genera)

Polyps connected to other polyps by basal stolons.

5. Cornulariidae (1or 2 genera)
6. Acrossotidae (1 genera)
7. Clavulariidae (17 or 18 genera)
8. Tubiporidae (1 genus)
9. Coelogorgiidae (1 genus)
10. Pseudogorgiidae (1 genus)

Polyps contained in massive bodies to form a coherent colony.

11. Paralcyoniidae (4 genera)
12. Alcyoniidae (29 genera)
13. Nephtheidae (18 genera)
14. Nidaliidae (8 genera)
15. Xeniidae (14 genera)

With free axial spicules, without consolidated axis (with a medulla and cortex);

16. Briareidae (2 genera)
17. Anthothelidae (13 genera)
18. Subergorgiidae (3 genera)
19. Paragorgiidae (2 genera)

with consolidated axis;

20. Coralliidae (3 genera)
21. Melithaeidae (6 nominal genera); branches from flexible proteinaceous nodes.
22. Parisididae (1 genus); branches from calcareous internodes.

Suborder *Holaxonia* - axis without free axial spicules; and with hollow cross-chambered central core.

23. Keroeididae (5 genera)
24. Acanthogorgiidae (6 genera)
25. Plexauridae (37 genera)

26. Gorgoniidae (15 genera)

Suborder *Calcaxonia* - axis without free axial spicules; and without hollow cross-chambered central core).

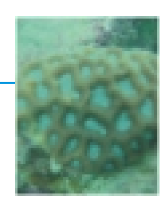
27. Ellisellidae (10 genera)
28. Ifalukellidae (2 genera)
29. Chrysogorgiidae (12 genera)
30. Primnoidae (36 genera)
31. Isididae (38 genera)
32. Dendrobrachiidae (l genus); with spiny axis (formerly aligned with Antipatharia).
33. Acanthoaxiidae (l genus)

ORDER PENNATULACEA (14 families, 34 genera); colony composed of an oozooid with basal peduncle an polyp-bearing rachis; Without polyp leaves;

34. Veretillidae (5 genera)
35. Echinoptilidae (2 genera)
36. Renillidae (1 genus)
37. Kophobelemnidae (4 genera)
38. Anthoptilidae (1 genus)
39. Funiculinidae (1 genus)
40. Protoptilidae (2 genera)
41. Stachyptilidae (2 genera)
42. Scleroptilidae (1 genus)
43. Chunellidae (3 genera)
44. Umbellulidae (1 genus)
45. Halipteridae (1 genus)
    with polyp leaves
46. Virgulariidae (5 genera)
47. Pennatulidae (6 genera)

Research methodology

In no other group of animals, with the possible exception of Sponges, classification and identification is so subjective as it is in the Octocorallia (Bayer, 1961). In fact, for a non-specialist, the task of identifying soft corals may appear insurmountable at first, as many species look alike, while the same species often look different. With experience, octocorals can be identified to family level, and many to genus, observing external features underwater. The characteristics to be noted include the shape, typical size, hardness, softness, smoothness, prickliness, and colour of colonies; arrangement, relative density, retractability or contractibility and roughness of polyps; presence of just autozooids or siphonozooids also; sclerite characteristics, such as presence of calyces; presence of a solid axis, and whether segmented. In order to identify the organisms to the species level, it is necessary to collect the whole specimen or a sample of it. Collected samples can be preserved directly in 70% ethanol immediately after collection. Samples may be relaxed by treating with 5-7% Magnesium sulfate solution for the emergence of retracted polyps. Octocorals do not possess the same kind of sclerites distributed throughout the colony. Octocorals possess different sclerites in surface coenenchyme (lobes, branches), interior coenenchyme, surface of the bases and interior of the base, polyp walls, calyces, anthocodiae, tentacles, crown and points. Hence it is necessary to sample within all these regions with due care to allow the colony to regenerate again in nature. The sclerites can be extracted using Sodium hypochlorite, washed, treated with hydrogen peroxide and dried. Sclerites thus prepared can be used for electron microscope examination. Permanent slides are prepared using acid free mounting media having a refractive index substantially different from that of calcite,



especially with the epoxy resin Durcupan ACM.

Diversity of octocorals

The octocoral fauna of India is very poorly known. The earliest comprehensive report on alcyonarians from the Indian coast dates back to the collection of James Hornell during 1904-1905, and described subsequently by Thomson and Crane (1909). About eight species (*Sclerophytum polydactylum, Dendronephthya dendrophyta, Dendronephthya brevirama, Astromuricea stellifera, Echinomuricea uliginosa* var. *tenerior, Lophogorgia lutkeni, Juncella juncea* and *Virgularia rumphii*) were reported from the Okhamandal, Gulf of Kutch. Among the eight species, *Astromuricea stellifera* was recorded as a new species. Further, Hickson (1903; 1905), Pratt (1903), Thomson and Henderson (1906) and Thomson and Henderson (1905) published an inventory of deep-sea alcyonaceans collected from the Indian Ocean. The distribution of alcyonaceans off Krusadai Island was recorded by Gravely (1927). Pratt (1903) reported many species of alcyonaceans belonging to genera such as *Sarcophyton, Lobophytum, Sclerophytum* and *Alcyonium* from Maldives. Pratt (1905) further investigated alcyoniids collected off Sri Lanka from Gulf of Mannar.

Ridley (1888) conducted a taxonomic investigations on a few new species of alcyonaceans collected from the Bay of Bengal and Indian Ocean. Ridley (1888) reported about the Alcyonaria of the Mergui Archipelago deposited at the Indian Museum.

Hickson (1931) reported that the small collection of Alcyonaria from the Gulf of Mannar raises some points of considerable interest. The specimens collected are much smaller that most of the species that have been described and show characters which would be quite consistent with the view that they are young stages in the growth of a larger species. Eventually the specimens have been described as *Clavularia margaritifera, Xenia nana* and *Cornularia cornucopiae*. The first named specimen was collected from Kurusadai and Shingle Islands and the other two species were from Kurusadai Island.

The exploitation of gorgonids on a commercial basis from the Indian seas since 1975 may be said to be a part of the world-wide hunt for raw materials to yield wonder drugs. During a survey, specimens were examined both from the fishing centers and export samples. This study indicated that 22 species of gorgonids are exploited from Indian seas and these are referable to seven families and 15 genera. Among the families, the Paramuriceidae (Bayer) is well represented in the commercial landings with nine widely distributed species under five genera. This is followed by Ellisellidae Gray with seven species under five genera. Species such as *Echinomuricea indica, Heterogorgia flabellum, Gorgonella umbraculum, Leptogorgia australiensis* and *Juncella juncea* form the mainstay of the export in order of abundance (Thomas and Rani Mary, 1986).

Thomas and Rani Mary (1987a) reported that for aesthetic reasons, gorgonians have been collected all over the world and from India too they have been exported for a long period. Though the reason behind such large scale imports

is not clear, it is inferred that the discovery of prostaglandins in 1969 by Weinheimer and Spraggins from *Plexaura homomalla,* a Caribbean species, triggered off a world wide 'hunt' for the species or its congeners. The quantity of gorgonids exported from India since then showed a downward trend, but, the price/kg showed a steady increase. The total number of gorgonids exported from India at present is 22 species referable to seven families and 15 genera. Gorgonids, though distributed widely along the coasts of India, are available in fishable magnitude only in the Gulf of Mannar. Northeast monsoon season is the period of gorgonid fishing in Gulf of Mannar. The most common and heavily fished species are *Echinogorgia indica, Heterogorgia umbraculum, Gorgonella umbraculum, Juncella juncea* and *Leptogorgia australiensis.* The areas where gorgonid fishing is active at present include eight zones. Information gathered from the major landing centers throws considerable light on the problem of depletion in genera. Recommendations for conservation are also provided.

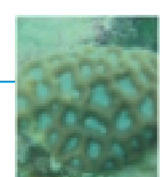
While engaged in the study from different landing centers along the Indian coast, a few species which have hitherto not been recorded from the Indian seas were collected and detailed taxonomic descriptions of these are presented. These species include *Thesia flava, Echinomuricea indica, E. flora, E. complexa* and *H. flabellum* with photographs of specimens and drawings of sclerites (Thomas and Rani Mary, 1987b).

Thomas and Rani Mary (1990) reported that during the 22nd cruise of FORV *Sagar Sampada* (1.10.1986 to 18.10.1986) a survey of the bottom fauna, especially of fishes, was made along the northwest coast of India between Lat. 18°N and 23°N, from 10 stations (Station Nos. 777-786) at depths varying between 65 and 130 m. Of these 10 stations, gorgonids were present at two stations (Station No. 783, Lat. 19°00'N and Long. 71°00'E; Station No. 784, Lat. 19°00'N and Long. 72°00'E) in appreciably good numbers.

The sample obtained from station 783 (depth ~86m) was quantitatively and qualitatively richer with eight species referable to five genera and four families, and was dominated numerically by two species, namely *Gorgonella umbella* Esper and *Parisis fruticosa* Verrill. Samples from station 784 (depth ~68m) included the above two species thereby indicating that both *G. umbella* and *P. fruticosa* are widely distributed in the depth range of 68 - 86m.

Two species, *Muricella initida* and *Acanthogorgia turgida* are reported from the Arabian Sea, and *Muricella dubia* from the Indian Ocean. It is also worth mentioning in this context that neither *G. umbella* nor *P. fruticosa* are common in the near shore area, and when present never form extensive beds. Hence, the presence of these two uncommon species in extensive areas off Bombay is significant.

The octocoral fauna from Laccadives is very poorly known. Six new species of soft corals from the family Alcyoniidae (*Sinularia jasminae* sp. nov., *S. parulekari* sp. nov., *S. kavarattiensis* sp.nov., *S. gaveshaniae* sp. nov., *Lobophytum tecticum* sp. nov. and *Sarcophytum spinospiculatum* sp.nov.) have been recorded along with 11 other



species (*Cladiella krempfi, Lobophytum batarum, L. durum, L. strictum, Sarcophyton trocheliophorum, S. serenei, Sinularia* cf. *gyrosa, S. muralis, S. querciformis, S. hirta* and *S. abrupta*). The material was collected by the National Institute of Oceanography from Kavaratti Island in the Laccadive Archipelago. All the new species of Sinularia in the collection belong to Verseveldt's (1980) group 1, having in the surface layers club-shaped scle-rites of the leptoclados type. Taxonomic characters of the species are compared with the related species (Alderslade and Shirvaiker, 1991).

Ofwegen and Vennam (1991) also reported 19 species of alcyonaceans (*Alcyonium flaccidum, Lobophytum altum, L. crassum, L. pauciflorum, L. schoedei, Sarcophyton crassocaule, Sinularia dissecta, S. elongata, S. facile, S. gaweli, S. gravis, S. hirta, S. inelegans, S. lochmodes, S. muralis, S. numerosa, S. variabilis, S. densa* and *S. abhishiktae)* and three species of gorgonians (*Clathraria maldivensis, Junceella juncea* and *Subergorgia suberosa*) from Laccadives. This included the description of a new species, *Sinularia abhishiktae* and also the redescription of S. densa.

Jayasree *et al.,* (1996) reported on the occurrence and new distributional records for 26 species of Alcyonaceans. These include 12 species of *Sinularia,* six of *Lobophytum,* one of *Cladiella* and one of *Nephthea.* Their ecological information on habitat and associations with the other organisms is also noted. A major factor limiting the distribution of soft corals is the availability of hard substrata for settlement. Other factors that determine their faunistic composition and abundance are correlated with resistance to harsh environments and life history parameters. Competitive interaction with other benthic reef-organisms also plays a major role in the distribution of soft corals in the Andaman and Nicobar Islands.

The Andaman Islands are very well known to support one of the richest coral formations in the Indo-Pacific region. An examination of the soft coral material collected by R.V. Gaveshani in the Andaman Sea during 1991-92 revealed the existence of a new species of the genus *Sarcophyton*, with heart-shaped, dark green colored colony. Comparison between the new species and other related species was also given. The type specimens were deposited in the Marine Biology Museum at the National Institute of Oceanography, Goa, India (Jayasree *et al.,* 1994).

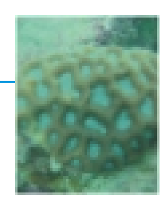
During the 51st cruise of FORV *Sagar Sampada* extensive trawling at six stations between Lat. 16°002 N and 20°002 N and in depths varying from 37 to 68 meters indicated the presence of gorgonids in three stations viz. No.7, 11 and 23. The total quantity collected from the above stations was approximately 500kg. Analyses of samples collected indicated the presence of 12 species of gorgonids in this area and are referable to nine genera in four families. The dominant species was *Heterogorgia flabellum,* followed by *Ellisella maculata* and *E. andamanensis.* All these three species are now being exploited from the inshore areas for export; the first one is commercially classified as 'black type' while the others, under 'monkey-tail type'. *Heterogorgia flabellum* is widely distributed in all the above three stations, but its concentration was

considerably higher in station 23. The maximum number of species (eight) was recorded at this station. An interesting point emerging from the study was that the specimens of *H. flabellum* were heavily infested with a variety of fouling organisms. Though barnacles were found to be the dominant group nume-rically, others such as sponges, bryo-zoans, corals (mainly solitary forms), ascidians and molluscs (mainly *Pteria* sp.) were also present in good numbers. The presence of fouling on specimens of *H. flabellum* indicated that this species synthesizes no antifouling substance, which will repel the settlement of fouling organisms (Thomas *et al.,* 1995).

Palk Bay and Gulf of Mannar on the southeast coast of India have mostly fringing reefs with a muddy bottom in the inshore regions. In spite of some investigations of South Indian coral reefs, our knowledge, particularly of the octocoral fauna is scanty. New distributional records for 27 species of Alcyonaceans are reported. These include 12 species belonging to the genus *Sinularia;* seven *Lobophytum* species; six species of *Sarcophyton* and one each species of *Dampia* and *Nephthya.* The factors that influence the distribution of corals, such as temperature, sedimentation and currents on these reefs are also discussed (Jayasree and Parulekar, 1997).

During the 42nd, 68th and 74th cruises of FORV *Sagar Sampada,* survey of the bottom fauna was made along the southwest coast of India between Trivandrum and Alleppy at depth zones varying between 48m and 150m. Though bottom trawling was attempted at several stations during each cruise, gorgonids were represented only in three stations during cruise 42 and in one station each in cruises 68 and 74. Analysis of the samples indicated the presence of eight species of gorgonids referable to four families and seven genera in the above area. Species of the Suborder Scleraxonia are represented by one species, while all the others belonged to the Suborder Holaxonia of the Order Gorgonacea. While analyzing the composition of the above species, it could be noticed that the gorgonid fauna of the above depth zone is constituted both by those species occurring commonly in the inshore realms, and by those which are specific to deepwater areas. While comparing the presently collected species with those obtained off Bombay during 22nd cruise of FORV *Sagar Sampada* from depths ranging from 65 to 130 m, a similar faunistic composition was discernible. The inshore species were fewer in number (25%) in the present study as well as in the collections from off Bombay, while the deep-water species constituted the bulk (75%). While comparing the distribution of species, which are specific to deep-water areas, it may be noticed that there are four species common to the present study as well as earlier collections from off Bombay; this indicates that deep-water gorgonids enjoy a wide distribution in the Arabian Sea. Biodiversity of gorgonids collected from deep-water realms off the southwest coast of India and off Bombay is also compared and contrasted with that of gorgonids from deep waters of the northeast coast of India reported earlier (Thomas *et al.,* 1998).

Soft corals (Alcyonaceans) are the most common group of sessile macroinvertebrates in the Andaman



and Nicobar Island reefs (Rao and Devi, 2003). A rich collection comprising of approximately 149 soft coral samples collected from the shallow reef regions of different localities of Andaman Islands revealed 45 species belonging to the families Alcyoniidae and Nephtheidae. The study established 30 new records for the Islands. However, it is certain that more intensive collection around the islands would reveal the existence of a number of species hitherto unknown. The report deals with a taxonomic account of these, along with information on colour pattern, habitats and geographical distribution. All the material studied was deposited in the reference collections of the Zoological Survey of India, Port Blair.

Anita Mary and Lazarus (2004) conducted a survey during 1997 which revealed the availability of 15 species of gorgonids belonging to five families and 11 genera in the southwest coast off India between Kanyakumari and Vizhinjam. High demand as an export commodity, and consequent indiscriminate exploitation using bottom set nets in the past, have resulted in partial to near depletion of many gorgonid beds in this region.

Gorgonians exported from India are commercially classified under four types, black, red, flower and monkey tail. Black type includes *Echinomuricea indica, Heterogorgia flabellum, Echinogorgia complexa*; Red type *Gorgonella umbraculum, Subergorgia suberosa, S. reticulata*; the monkey tail type including *Junceella juncea*, *Ellisella andamanensis* and flower type *Leptogorgia australiensis*. Gorgonians are also being exported from India under the head curio. India stepped up the commercial exploitation and export of gorgonians during 1975 to countries like France, West Germany, U.S.A and The Netherlands. Species wise distribution and abundance of gorgonians were investigated at three landing centers namely Rameswaram, Thoothukudi and Kanyakumari in the Gulf of Mannar region during 1991-92. Among the four different types of commercially important gorgonians, the red type contributed the highest with annual percentage contribution of 36.7% followed by black type (32.5%) at Rameswaram. The total landings of all commercially important gorgonians of Rameswaram area were 2378 kg, at Thoothukudi 2588 kg and at Kanyakumari 1725 kg. Among the four types, the red type contributed to the maximum percentage of total landing followed by black type, monkey tail type and flower tail type both at Rameswaram and at Thoothukudi. At the Kanyakumari landing centre, black type contributed the highest percentage of total landings followed by red type, monkey tail type and flower tail type (Velayutham *et al.,* 2005)

Soft corals of Gulf of Mannar has been the subject of several studies. However, species that are not reported earlier (*Sinularia parulekari, S. jasminae, S. kavarattiensis* and *Sarcophyton elegans*) are recorded and described in detail. Four species of soft corals from the family Alcyoniidae are described in the light of scanning electron microscopy of the sclerites to facilitate easy identification. Although, 28 species were recorded earlier, three species

Table 1. Octocorals recorded from various coastal and marine regions in India

Family	Genera	Species	Andaman & Nicobar	Lakshadweep	Northeast coast	Gulf ofMannar	Tuticorin to Kanyakumari	Southwest coasts (Kanyakumari to Quilon)	Northwest coast (Veraval, Bombay)	Gulf of Kutch
Cornularidae	2	4	3			1				
Clavulariidae	2	3	2			1				
Tubiporidae	1	1	1							
Alcyoniidae	8	87	59	34		30	15			2
Viguieriotidae	1	1	1							
Nephtheidae	5	44	40						1	3
Nidaliidae	4	11	11							
Paralcyoniidae	1	1							1	
Xeniidae	1	2				2				
Anthothelidae	1	2	1				1			
Subergorgiidae	2	6	4	2	2	2	1	1	1	
Melithaeidae	2	4	3	1				1	1	
Parisididae	1	2	2							
Paramuriceidae	14	43	32	1	9	6	7	9	3	1
Plexauridae	5	6	3		1	2	2			1
Acanthogorgiidae	2	8	6					2	2	
Ellisellidae	5	17	11	2	6	3	6	6	3	1
Gorgonidae	2	2	2							1
Chrysogorgiidae	2	3	3							
Primnoidae	2	3	3							
Isididae	3	3	3							
	66	253	190	40	18	47	32	19	12	9

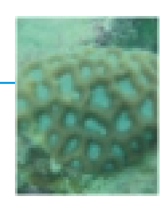
Table 2. Diversity of octocoral species recorded from the Indian coast

No	Species	Place of Report
	1. Family: Cornularidae	
1	*Cornularia cornucopiae*	Krusadai Is., Gulf of Mannar [12]*
2	*Sympodium decipiens*	Andaman [23]
3	*S. incrustans*	Andaman [23]
4	*S. indicum*	Andaman [23]
	2. Family: Clavulariidae	
5	*Clavularia margaritifera*	Shingle Is, Krusadai Is., Gulf of Mannar [26]
6	*Telesto arborea*	Andaman & Nicobar [23]
7	*T. rubra*	Andaman [23]
	3. Family: Tubiporidae	
8	*Tubipora musica*	Andaman & Nicobar [23]
	4. Family: Alcyoniidae	
9	*Anthomastic aberranus*	Andaman [23]
10	*Alcyonium flaccidum*	Laccadive [19]
11	*A. klunzinger*	Andaman [23]
12	*Cladiella australis*	Little Andaman [23]
13	*C. krempfi*	Little Andaman [23]; Kavaratti of Lakshadweep Archipelago [1]
14	*C. laciniosa*	Little Andaman [23], Gulf of Mannar

* The reference number cited

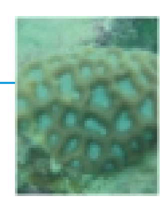
15	*C. pachyclados*	Chiriatapu, Burmanaal & Carbyn's Cove,Little Andaman[15, 23]
16	*Dampia poecilliformes*	Tuticorin[12]
17	*Lobophytum altum*	Laccadive [19]; Hobday Island (S Andaman)[23]
18	*L. batarum*	Wandoor , Little Andaman[15, 23]; Kavaratti of Lakshadweep Archipelago[1]
19	*L. catalai*	Twin Island, Henry Lawrence (S. Andaman)[23], Digilipur[15]
20	*L. compactum*	Tuticorin[12], Keelakarai, Mandapam group of Islands
21	*L. crassum*	Little Andaman, Henry Lawrence, Havelock Is., Jolly Buoy, Hobday Is., Peacock Is., East Is., West Is. [23]; Krusadai Is. [26], Mandapam, Keelakarai, Tuticorin group of Islands, Laccadive [19].
22	*L. crebriplicatum*	Peacock Is. (N. Andaman)[23]
23	*L. durum*	Kavaratti Island of Lakshadweep[1]
24	*L. hirsutum*	Rutland Is., Jolly Buoy (S. Andaman)[23], Mayabundar[15]
25	*L. latilobatum*	Krusadai Is. [26]
26	*L. pauciflorum*	Little Andaman, Pongibalu (S.And), Henry Lawrence, Havelock Is. Jolly Buoy, Landfall Is (N.A), Peacock Is., Temple Is. East Is. (N. Andaman), Chiriatapu, Andamans[15, 23], Krusadai Is. [26], Mandapam, Keelakarai, Tuticorin group of Islands; Beyt Shankhodar, Gulf of Kutchh; Laccadive [19]
27	*L. planum*	Little Andaman[17]
28	*L. pusillum*	Wandoor , Pongibalu little Andaman[15, 23]
29	*L. ransoni*	Mandapam[12]
30	*L. sarcophytoides*	Henry Lawrence (S. Andaman) [23], Off Krusadai Is. of Gulf of Mannar[12]
31	*L. schoedei*	Laccadive [19]
32	*L. strictum*	Wandoor, North Bay and Burmanaal, Little Andaman[15, 23], Kavaratti Is. o Lakshadweep[2]
33	*L. tecticum*	Havelock Is. (Ritchie's Archiepelago) [23]; Kavaratti Island, Lakshadweep Archipelago[1]
34	*L. variatum*	Little Andaman[17], Mandapam[12], Keelakarai, Tuticorin group of Islands
35	*Sarcophyton andamanensis*	Corbyn's Cove[11] & Chiriatapu, Andaman[15].
36	*S. buitendijiki*	Mayabundar, Middle Andaman[15]
37	*S. boettgeri*	Andamans[17]
38	*S. cherbonnieri*	Harmander Bay (Little Andaman)[23], Mandapam[12]
39	*S. crassocaule*	Havelock Is., Inglis Is. (S. Andaman), Hut Bay (Little Andaman), Pongibalu, Hobday Is. (S. Andaman), Car Nicobar, West Is., Peacock Is., East Is. (N. Andaman), Carbyn's Cove[15, 23], Vadakadu, Rameswaram [26], Laccadive [19]
40	*S. crassum*	Breakwater area-Little Andaman, Inglis Is. (S. Andaman), Peacock Is., Land fall Is., East Is. (N. Andaman)[23]
41	*S. digitatum*	Jolly Buoy, Pongibalu (S. Andaman)[23]
42	*S. ehrenbergi*	Little Andaman, Henry Lawrence Is. (Ritchie's Archipelago), Lamia Bay (N.Andaman)[23]
43	*S. elegans*	Digilipur[3], Henry Lawrence Is. (S. Andaman) [23], Krusadai Is. [26], Mandapam[9], Poomarichan, Keelakari group Islands, Gulf of Mannar
44	*S. glaucum*	Twin Is., Havelock Is. (S. Andaman) [23], Krusadai Is. [26], Mandapam, Keelakarai and Tuticorin, Gulf of Mannar
45	*S. infundibuliforme*	Rutland (S. Andaman), Little Andaman [23]
46	*S. roseum*	South Bay (Little Andaman), Henry Lawrence (S. Andaman) [23]
47	*S. serenei*	Kavaratti Island of Lakshadweep [1]
48	*S. stellatum*	Wandoor[15], Rutland (S. Andaman) [23], Mandapam [26], Keelakarai and Tuticorin group of Islands
49	*S. spinospiculatum*	Kavaratti Island of Lakshadweep Archipelago [1]

50	*S. tortuosum*	Havelock Is., (S. Andaman), Peacock Is., (N. Andaman) [23]
51	*S. trocheliophorum*	Rutland (S. Andaman), Hobday Is. (S. Andaman), Little Andaman, Inglis Is., Henry Lawrence Is., Havelock Is., (Ritchie's Archipelago), Carbyn's Cove & Digilipur [15, 23]; Kavaratti Island of Lakshadweep [1], Vadakadu, (Rameswaram) [26], Poomarichan (Mandapam) Keelakarai group Islands
52	*Sclerophytum polydactylum*	Okhamandal, Gulf of Kutch [31]
53	*Sinularia abhishiktae*	Laccadive [19]
54	*S. abrupta*	Rutland Is., Havelock Is. (S. Andaman) [23], Kavaratti Island of Lakshadweep [1]; Off Pulli Island, Tuticorin [12], Gulf of Mannar.
55	*S. andamanensis*	Andamans [23]
56	*S. brassica*	Hut Bay (Little Andaman) [23], Mandapam, Keelakarai and Tuticorin group [26] of Islands
57	*S. capitalis*	Henry Lawrence Is. (S. Andaman) [23]
58	*S. conferta*	Havelock Is., (S. Andaman) Trilby Island, Landfall Is., Peacock Is., (N. Andaman) [23]
59	*S. cristata*	Henry Lawrence Is. (S. Andaman) [23]
60	*S. densa*	Andamans [17]; Laccadive [19]
61	*S. depressa*	Mayabundar, Andamans & Nicobar [15]
62	*S. dissecta*	Off Manoli Is., Krusadai Is. [26]; Mandapam, Keelakarai and Tuticorin group of Islands; Laccadive [19]
63	*S. elongata*	Laccadive [19]
64	*S. erecta*	Off Mandapam Island [26]
65	*S. exilis*	Mandapam [26]
66	*S. facile*	Laccadive [19]
67	*S. flexibilis*	Pongibalu (S. Andaman) [23], Digilipur [37]
68	*S. gaveshaniae*	Kavaratti Island of Lakshadweep [2]; Gulf of Mannar
69	*S. gaweli*	Laccadive [19]
70	*S. gibberosa*	Harmander Bay Hut Bay, Richardson Bay, (Little Andaman), Pongibalu Is., Digilipur, North Bay, Henry Lawrence, Havelock Is., (S. Andaman), Trilby Is., Landfall Is., (N. Andaman) [37, 23]
71	*S. granosa*	Digilipur, Andamans & Nicobar [3], Mandapam [26], Keelakarai and Tuticorin Islands, Gulf of Mannar
72	*S. grandilobata*	Mandapam [26]
73	*S. gravis*	Laccadive [19]
74	*S. cf. gyrosa*	Kavaratti Island of Lakshadweep [1]
75	*S. hirta*	Digilipur, Havelock, N&S Andaman, Nicobar [3], Moyli Island [26], Mandapam, Keelakarai and Tuticorin group of Islands of Gulf of Mannar, Kavaratti Island of Lakshadweep [1]; Laccadive [19]
76	*S. inelegans*	Hut Bay (Little Andaman), Inglis Is., Havelock Is. (S.Andama), Landfall Is. (N. Andaman) [23]; Laccadive [19]
77	*S. intacta*	Mandapam [26], Keelakarai, Tuticorin Islands
78	*S. jasminae*	Kavaratti Island of Lakshadweep [1]; Mandapam [22]
79	*S. kavarattiensis*	Kavaratti Island, Mandapam [22]
80	*S. leptoclados*	John Richardson Bay (Little Andaman) [23], Moyli Island [26], Mandapam, Keelakarai, Tuticorin Islands of Gulf of Mannar.
81	*S. lochmodes*	Hut Bay, (Little Andaman), Landfall Is., Peacock Is., (N. Andaman) [23]; Laccadive [19]
82	*S. mannarensis*	Chiriatapu & Rangath, South & Middle Andaman [3], Krusadai Is. of Gulf of Mannar [26]
83	*S. maxima*	Little Andaman, Pongibalu, Havelock Is. (S. Andaman) [37, 23]
84	*S. microclavata*	Hobday Is. (S. Andaman) [23]
85	*S. muralis*	Harmander Bay (Little Andaman) [23], Kavaratti Island of Lakshadweep [2, 19]
86	*S. numerosa*	Laccadive [19]



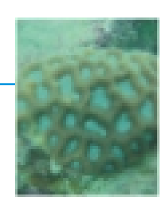
87	*S. ornata*	Havelock Is (S.Andaman)[37]
88	*S. ovispiculata*	Temple Is. (N. Andaman), Digilipur[37, 23]
89	*S. parulekari*	Kavaratti Island of Lakshadweep[2], Mandapam[22]
90	*S. peculiaris*	Little Andaman[23]
91	*S. polydactyla*	Havelock & Mayabundar , S&M Andaman[37], Off Pulli Island[26], Mandapam, Keelakarai and Tuticorin Islands of Gulf of Mannar
92	*S. querciformis*	Kavaratti Island of Lakshadweep[1]
93	*S. sandensis*	Havelock (S.Andaman)[37]
94	*S. variabilis*	Laccadive[19]
95	*S. vrijmoethi*	Mayabundar, Andamans[37]
	5. Family: Viguieriotidae	
96	*Studeriotes mirabili*	Andaman[23]
	6. Family: Nephtheidae	
97	*Capnella parva*	Little Andaman, Havelock Is. (Ritchie's Archipelago), Phongibalu (S. Andaman)[23]
98	*Dendronephthya albogilva*	Andaman[23]
99	*D. andamanensis*	Andaman[23]
100	*D. arbuscula*	Andaman[23]
101	*D. booleyi*	Andaman[23]
102	*D. brachycaulos*	Andaman[23]
103	*D. brevirama*	Boria Reef, Beyt Shankhodar, Okhamandal, Gulf of Kutch[31]
104	*D. brevirama* var. *andamanensis*	Andaman[23]
105	*D. cervicornis*	Andaman[23]
106	*D. conica*	Andaman[23]
107	*D. constatorubra*	Andaman[23]
108	*D. delicatissima*	Andaman[23]
109	*D. dendrophyta*	Karumbhar, Boria Reef, Beyt Shankhodar, Okhamandal, Gulf of Kutch[31]
110	*D. divaricata*	Andaman[23]
111	*D. elegans*	Andaman[23]
112	*D. foliata*	Andaman[23]
113	*D. gilva*	Andaman[23]
114	*D. harrisoni*	Andaman[23]
115	*D. irregularis*	Andaman[23]
116	*D. kollikeri var. andamanensis*	Andaman[23]
117	*D. lanxifera*	Andaman[23]
118	*D. lanxifera var. andamanensis*	Andaman[23]
119	*D. longispina*	Andaman[23]
120	*D. macrocaulis*	Andaman[23]
121	*D. masoni*	Andaman[23]
122	*D. microspiculata var. andamanensis*	Andaman[23]
123	*D. mirabilis*	Andaman[23]
124	*D. multispinosa*	Andaman[23]
125	*D. nicobarensis*	Andaman[23]
126	*D. ochracea*	Andaman[23]
127	*D. orientalis*	Andaman[23]
128	*D. pallida*	Andaman[23]
129	*D. pellucida*	Andaman[23]
130	*D. pentagona*	Andaman[23]
131	*D. purpurea*	Andaman[23]
132	*D. quadrata*	Andaman[23]
133	*D. rubescens*	Andaman[23]

134	*D. rubeola*	Andaman [23]
135	*D. variata*	Andaman [23]
136	*D. varicolor*	Andaman [23]
137	*Litophyton sp.*	Off Veraval coast [37]
138	*Nephthea tenuispina*	Andaman [23]
139	*Nephthea sp.*	Karumbhar, Boria reef, Beyt Shankhodar of Gulf of Kutch
140	*Spongodes uliginosa*	Andaman [23]
	7. Family: Nidaliidae	
141	*Chironephthya asperula*	Andaman [23]
142	*C. variabilis*	Andaman [23]
143	*Nidalia alciformes*	Andaman [23]
144	*N. celosioides*	Andaman [23]
145	*Siphonogorgia media*	Andaman [23]
146	*S. mirabilis*	Andaman [23]
147	*S. palmata*	Andaman [23]
148	*S. rotunda*	Andaman [23]
149	*S. variabilis*	Andaman [23]
150	*Stereacanthia armata*	Andaman [23]
151	*S. indica*	Andaman [23]
	8. Family: Paralcyoniidae	
152	*Studeriotes* sp.	Along off Veraval coast [37]
	9. Family: Xeniidae	
153	*Xenia nana*	Krusadai Is. [26]
154	*Xenia* sp.	Gulf of Mannar
	10. Family: Anthothelidae	
155	*Solenocaulon sterrokoloneum*	Andaman [23]
156	*S. tortuosum*	Andaman [23], Cape Comarin [2,25,26]
	11. Family: Subergorgiidae	
157	*Keroeides gracilis*	Andaman [23]
158	*K. koreni*	Andaman [23]
159	*Subergorgia kolliker* var. *ceylonensis*	Andaman [23]
160	*Subergorgia suberosa*	Tuticorin, Keelakarai, Rameswaram [38]; between main lands and Islands of Gulf of Mannar [2, 25], Between off Kaniyakumari & Vizhinjam [26, 38], Between off Paradeep & Visakhapatnam [29], along off veraval coast [37]; Laccadive [19]
161	*Subergorgia reticulata*	Tuticorin, Keelakarai, Rameswaram [2]; Kanyakumari [38]; Off Madras [2, 25]
162	*S. ornata*	Laccadive [34]; Andaman [23]
	12. Family: Melithaeidae	
163	*Clathraria maldivensis*	Laccadive [19]
164	*Melitodes ornata*	Andaman [23]
165	*M. philippinensis*	Andaman [23]
166	*M. variabiles*	Andaman [23]
	13. Family: Parisididae	
167	*Parisis fruticosa*	Andaman [23], Off Bombay [28], Off Quilon [30]
168	*P. indica*	Andaman [23]
	14. Family: Paramuriceidae	
169	*Acamptogorgia ceylonensis*	Andaman [23]
170	*A. rubra*	Andaman [23]
171	*A. tenuis*	Andaman [23]
172	*Acis ceylonensis*	Andaman [23]
173	*A. indica*	Andaman [23]
174	*A. pustulata*	Andaman [23]
175	*A. rigida*	Andaman [23]



176	*A. spinose*	Andaman [23]
177	*A. ulex Andaman* [23]	
178	*Bebryce mollis*	Andaman [23]
179	*Calicogorgia tenuis*	Andaman [23]
180	*Discogorgia companulifera*	Between Paradeep & Visakhapatnam [29]
181	*Echinogorgia complexa*	Tuticorin, Keelakarai, Rameswaram [38]; Cape Comorin, Colachel Between off Kanyakumari & Vizhinjam [2,25,38]
182	*E. flabellum* (=Heterogorgia flabellum)	Andaman, Tuticorin, Keelakarai, Rameswaram [38]; Nagapattinam, Madras, Cape Comorin, Colachel, Thengapattinam, Between off Kanyakumari & Vizhinjam [25,26,38], Quilon [30], South west & Southeast coast of India [2,27], Between off Paradeep & Visakhapatnam and Off Andhra Coast [29]
183	*E. flora*	Off Mulloor, south of Vizhinjam [27] and Between off Kanyakumari & Vizhinjam [2,25,26]
184	*E. intermedia*	Andaman
185	*E. macrospiculata*	Andaman [23], Between off Paradeep & Visakhapatnam [29]
186	*E. multispinosa*	Andaman [23]
187	*E. ramulosa*	Andaman [23]
188	*E. reticulata*	Andaman [23], Between off Kaniyakumari & Vizhinjam [2,26] Tuticorin, Raameswaram & Kovalam (Madras) [25]
189	*Echinomuricea andamanensis*	Andaman [17], Off Quilon [30]
190	*E. indomalaccensis*	Kovalam (Madras) [2,25], Between off Paradeep & Visakhapatnam [10]
191	*E. indica*	Off Arokyapuram, Rameswaram [38], Tuticorin [2,27,38], Keelakarai, Madras [25], off Bombay [28], Between off Paradeep & Visakhapatnam [29], Between off Kanyakumari & Vizhinjam [26,38]
192	*E. ochracea*	Andaman [23]
193	*E. reticulata*	Andaman [23], Rameswaram,
194	*E. splendens*	Andaman [23]
195	*E. uliginosa*	Laccadive [34]
196	*E. uliginosa var. tenerior*	Okhamandal, Gulf of Kutch [31]
197	*Elasmogorgia flexilis*	Andaman [23]
198	*Eumuricea ramose*	Andaman [23]
199	*Leptogorgia australiensis*	Tuticorin, Keelakarai, Rameswaram [38]; Madras, Cape Comorin [25], Between off Kanyakumari & Vizhinjam [26,38], Southwest & Southeast coast of India [2]
200	*Menacella gracilis*	Andaman [23]
201	*Muricella bengalensis*	Andaman [23]
202	*M. complanata*	Andaman [23], Tuticorin, Cape Comorin, Kadiapattanam [25] and Between off Kaniyakumari & Vizhinjam [2,26]
203	*M. dubia*	Off Bombay [28], Off Quilon [30]
204	*M. nitida*	Off Bombay [28]
205	*M. ramosa*	Andaman [23]
206	*M. robusta*	Andaman [23]
207	*M. rubra*	Andaman [23]
208	*M. umbraticoides*	Kovalam (Madras) [2,25]
209	*Paramuricea indica*	Andaman [23]
210	*Placogorgia indica*	Andaman [23]
211	*P. orientalis*	Andaman [23]
	15. Family: Plexauridae	
212	*Astromuricea stellifera*	Karumbhar, Okhamandal, Gulf of Kutch [31]
213	*Plexaura indica*	Andaman [17]
214	*Plexauroides praelonga*	Andaman [23], Tuticorin, Keelakarai, Gulf of Mannar [2,25]
215	*P. praelonga var. cinerea*	Between Paradeep & Visakhapatnam [29]
216	*P. ridleyi*	Andaman [23]
217	*Thesea flava*	Vedalai, Tuticorin [2], Rameswaram, Gulf of Mannar [25,27]

	16. Family: Acanthogorgiidae	
218	*Acanthogorgia ceylonensis*	Off Bombay [28], Off Quilon [30]
219	*A. glomerata*	Andaman [23]
220	*A. muricata*	Andaman [23]
221	*A. murrilli*	Andaman [23]
222	*A. turgida*	Off Bombay [28], Off Quilon
223	*Anthogorgia glomerata*	Andaman [23]
224	*A. racemosa*	Andaman [23]
225	*A. verrili*	Andaman [23]
	17. Family: Ellisellidae	
226	*Ellisella andamanensis*	Andaman [23], Kelakarai, kadiapattanam [2, 25], off Madras, Between off Paradeep & Visakhapatnam [29], Tuticorin, Rameswaram [38]; Between off Kanyakumari & Vizhinjam [26, 38]
227	*E. maculata*	Kadiapattanam [2, 25]; Between off Kanyakumari & Vizhinjam [26], Between off Paradeep & Visakhapatnam [29], Off Bombay & Off Quilon [30]
228	*Gorgonella flexuosa*	Andaman [23]
229	*G. granulata*	Andaman [23]
230	*G. rubra*	Tuticorin, Muttom, Kadiapattanam [2, 25], Between off Kaniyakumari & Vizhinjam [26]
231	*G. umbrachulum*	Tuticorin, Keelakarai, Rameswaram [38]; Nagapattinam, Madras, Cape Comorin, Muttom, Kadiapattinam, Thengapattinam, Vizhinjam [26, 38], Quilon, Andamans [2, 25], off Bombay [28], Soutwest & Southeast coast of India [4], Between off Paradeep & Visakhapatnam [29]
232	*G. umbella*	Off Bombay [28], Between off Paradeep & Visakhapatnam [29]
233	*Junceella juncea*	(Tuticorin, Keelakarai, Rameswaram) [38], Cape Comorin, Kadiapattinam, Colachel, Vizhinjam [25, 26, 38], along off Veraval coast [15], Soutwest & Southeast coast of India [2]; Okhamandal, Gulf of Kutch [31]; Laccadive [19]
234	*J. racemosa*	Andaman [23]
235	*J. trilineata*	Andaman [23]
236	*Nicella dichotoma*	Tuticorin [2, 25]
237	*N. flabellate*	Andaman [23]
238	*N. pustulosa*	Andaman [23]
239	*N. reticulata*	Laccadive [34]
240	*Scirpearia filiformis*	Andaman [23], Off Cape Comorin [2, 25], Between off Kanyakumari & Vizhinjam [26], Between off Paradeep & Visakhapatnam [29]
241	*S. hicksoni*	Andaman [23]
242	*S. verrucosa*	Andaman [23]
	18. Family: Gorgonidae	
243	*Callistephanus koreni*	Andaman [23]
244	*Lophogorgia lutkeni*	Andaman [23], Karumbhar, Okhamandal, Gulf of Kutch [31]
	19. Family: Chrysogorgiidae	
245	*Chrysogorgia dichotoma*	Andaman [23]
246	*C. flexilis*	Andaman [23]
247	*Lepidogorgia verrilli*	Andaman [23]
	20. Family: Primnoidae	
248	*Caligorgia flexilis*	Andaman [23]
249	*C. indica*	Andaman [23]
250	*Stenella horrida*	Andaman [23]
	21. Family: Isididae (Sub family: Isidinae)	
251	*Isis hippuris*	Andaman [2, 25, 23]
	(Sub family: Keratoisidinae)	
252	*Acanella robusta*	Andaman [23]
253	*Keratoisis gracilis*	Andaman [23]



listed in the account are new records to the Gulf of Mannar Bio-sphere Reserve (Rani Mary *et al.,* 2007).

Usha *et al.* (2008) reported the first record of live octocorals in the sub-tidal region of Veraval. The four species identified are *Litophyton* sp., *Studeriotes* sp., *Junceella juncea* and *Subergorgia suberosa*. The presence of octocorals in the trawling ground within a depth of 15-20 m justifies the need to carry out further studies on the impact of bottom trawling on the coral reef ecosystem. Associated fauna collected along with soft corals were also reported.

The biodiversity of octocorals is rich in India, but so far the organized effort to study the distribution, abundance, species richness, species diversity and ecology of octocorals is very limited. Most of the species are recorded from shallow water region. There is no repository or museum where all species collected can be deposited and subsequently made available for scientific examination at a later date. During the past four decades, the classification of octocorals has been revised and several species were redescribed. Table 1 indicates the number of species and the respective families of octocorals so far reported from various regions in India. Table 2 includes names of species reported by the respective authors as such. No attempt has been made in this work to incorporate the revised names or to verify the authenticity of the nomenclature. Such attempts would be futile as many of the specimens reported are either not available or inaccessible for study. In order to understand the actual species diversity of octocorals in India, a thorough investigation to reexamine the currently deposited specimens in various museums and also conduct simultaneous survey of diversity and distribution of octocorals along the Indian coast. In addition to this, perform taxonomic revisions, genetic studies, exploration of the deep sea region, preparation of reliable field and laboratory identification manuals, conduct training for young taxonomists, strengthen museums and establish marine museums to function as centres of taxonomic investigations would ultimately strengthen the knowledge base and information available on octocoral biodiversity.

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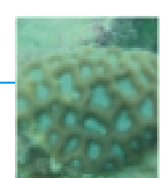

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Dendronephthya klunzingri

Status of soft corals (Alcyonacea) in the Gulf of Mannar, Southeast coast of India

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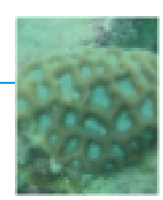
Abstract

In the Gulf of Mannar, a total of 27 species of soft corals belonging to five genera and three families have been reported. Among the three island groups, the Mandapam group of islands has abundant soft corals and the dominant genus is *Sinularia*. Earlier reports showed the percentage of soft corals to be 16 % and 6% in the Keelakarai and Mandapam groups of islands, respectively. The low diversity of soft corals observed in the Tuticorin group may be due to various anthropogenic activities, mainly destructive fishing and pollution.

Introduction

The Gulf of Mannar reef formations are of the fringing type, developed around 21 islands located in a chain between Tuticorin (8°48‘N; 78°9‘E) and Rameswaram (9°14‘N; 79°14‘E), on the Southeast coast of India. The Government of India declared Gulf of Mannar as a Biosphere Reserve (GoMBR) in 1989 to conserve its unique biodiversity. It covers a total area of 105,00 km^2.

Soft corals and sea fans are the common names for species of animals grouped under the scientific name Alcyonacea. Together with blue coral and sea pens, they make up a larger animal group called Octocorallia. The soft corals look like tree branches or fans. Soft corals and sea fans are amazingly beautiful and abundant inhabitants of the world’s coral reefs. As their name suggests, the colony is usually soft and fleshy, and they have no hard internal skeleton of calcium carbonate like the reef-building scleractinian corals. Hard skeletons provide support and structure for the colonies of the scleractinians. Coral reefs are warm, clear, shallow ocean habitats and are rich in life.They are usually attached to rocks or seaweed and are firm. The reef’s massive structure is formed from coral polyps, tiny animals that live in colonies; when coral polyps die, they leave a hard, stony, branching structure made of limestone. The coral provides shelter for many animals in this complex habitat, including sponges, nudibranchs, fishes (like blacktip reef sharks, groupers, clown fish, eels, parrotfish, snapper, and scorpion fish), jellyfish, anemones, sea stars (including the destructive Crown-of-Thorns), crustaceans (like crabs, shrimp, and lobsters), sea turtles, sea snakes, and molluscs (like octopuses, nautilus, and clams). Birds also feast on coral reef animals. Like many other soft-bodied reef animals, soft corals avoid predation by storing toxic chemical compounds in their tissues. This makes them highly unpalatable or even poisonous to most potential predators. These chemicals are called “secondary metabolites”, because they



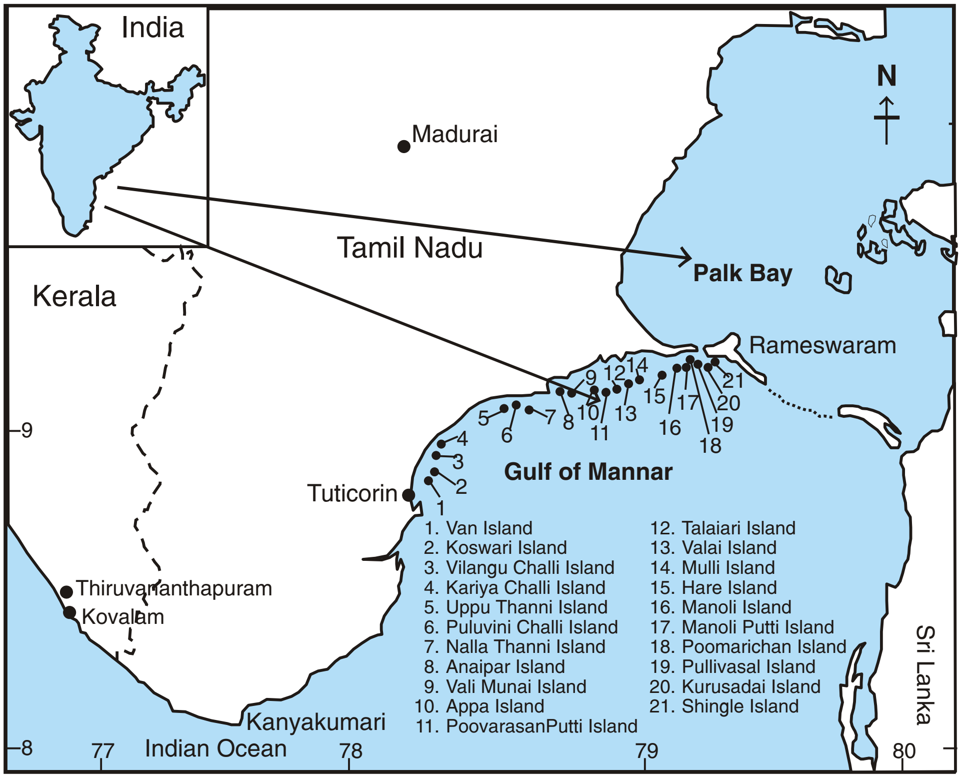


Fig. 1. Map showing the study area

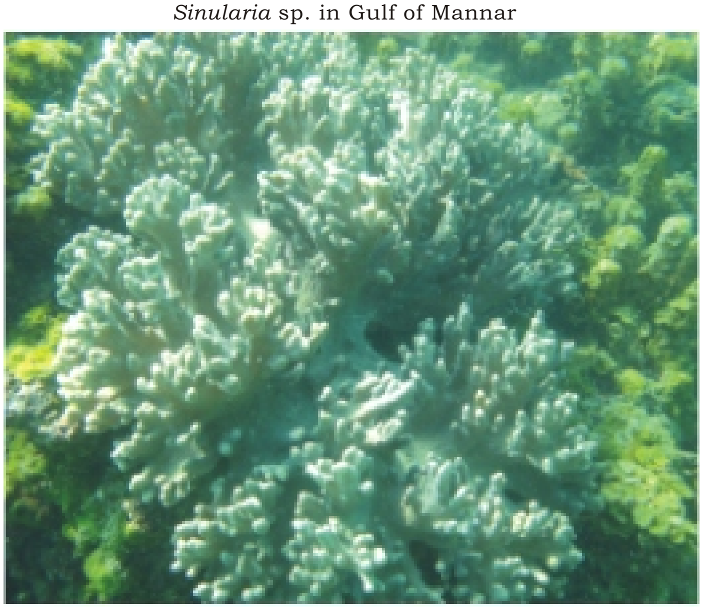
are not involved in the primary metabolic functions of the organism. The secondary metabolites found in soft corals come from a range of different chemical "families", but chemicals called terpenes are probably the most common. The types of chemicals found in soft corals are known for the following properties: anti-bacterial, anti-fungal, or anti-cancer agents, with a result that many pharmaceutical companies and marine chemists have spent considerable time and effort in screening and evaluating the chemicals found in soft corals on the Great Barrier Reef. The presence or absence of indicator species may be an index of environmental stress or pressure on reefs. The taxonomically extended surveys of sessile organisms such as sponges and soft corals can give clues to the state of the environmental conditions, while assessment of heterotrophic macroinvertebrates such as sponges, barnacles, hydroides, tunicates, echinoderms may give clues to the stress conditions due to pollution. Such studies are highly

Sacrophyton sp. in Gulf of Mannar

important for the management of coral reefs (Venkataraman and Raghuram, 2006).

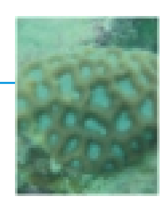
The alcyonacean fauna of India is poorly known. James Hornell during 1904-1905, and subsequently Thomson and Crane (1909), described eight species of soft corals from Okhamandal, Gulf of Kachchh. Further studies on soft corals by Hickson (1903, 1905), Pratt (1903), Thomson and Henderson (1906) and Thomson and Simpson (1909) enlightened the knowledge on alcyonaceans of Lakshadweep. Thomson and Henderson (1905) published an inventory of deep sea alcyonaceans from the Indian Ocean. Distribution of alcyonaceans off Krusadai Island was recorded by Gravely (1927). Ridley (1882) described a few new species of alcyonaceans collected from Bay of Bengal and Indian Ocean. Ofwegan Van and Vennam (1991) also reported 19 species of alcyonaceans belonging to genera such as *Alcyonium, Lobophytum, Sarcophyton,* and *Sinularia* from Lakshadweep. The octocoral fauna of the Lakshadweep was also investigated by Alderslade and Shirwaiker (1991) who reported 17 species. Rao and Devi (2003) reported 54 species of soft corals in the Andaman Islands.

Sinularia sp. in Gulf of Mannar



All the studies conducted on the west coast of India also indicated that the family Alcyonidae contributes considerably to the soft coral fauna. The data clearly indicated that an extensive assemblage of soft corals occurs in the Gulf of Mannar. Further surveys will enhance our knowledge on the biogeographic patterns of this group. Soft corals in the Mandapam group of islands, i.e. Shingle, Krusadai, Poomarichan, Pullivasal, Manouli, Manouliputti and Hare islands are represented by eight species. Nine species are known from in Keelakarai group of islands (Mullai, Valai, Thalaiyari, Anaipar, Appa and Nallathanni islands). Four species occur in the Tuticorin group of islands. Earlier studies showed that 16% of the soft corals occur in the Keelakarai group of islands and 6% in the Mandapam group of islands. The survey showed that the occurrence of soft corals in Keelakarai group was comparatively higher than in other island groups in the Gulf of Mannar. Lower human pressure and more favorable conditions for growth of these soft corals may be the reason for the greater occurrence. Low diversity of soft corals in the Tuticorin group may be due to the intensive coral mining, which was prevalent until 2005, plus coastal erosion and pollution. Jayasree and Parulekar (1997) reported that the most abundant species of soft corals in the Gulf of Mannar belong to the genus *Sinularia.*

The main attraction of any coral island is the occurrence of different varieties of multi coloured ornamental fishes. It has been reported that nearly 25 to 40% of the marine fishes occur in coral reef areas. Reef areas are also a major nutrient supplier



for primary production in marine food chains. A number of colourful nudibranchs and bryozoans were reported from the adjacent area of the islands. The Gulf of Mannar region is rich in fishery resources. The primary productivity of the area is comparatively very high. A total of 510 finfish species, including 125 reef associated fish species, 450 molluscan species, and 17 species of sea cucumbers have been recorded from this region. It is one of the richest sources of marine biodiversity hotspots of the world.

These reefs were used earlier for mining (the Tuticorin group) and organisms such as the sacred chank (*Turbinella pyrum*), sea cucumbers, pipefishes, sea horses and seaweeds were harvested from the Mandapam group of islands.

Coral reefs not only provide people around the world with food, invaluable pharmaceuticals, and economic benefits from commercial fisheries and tourism; they also protect coastlines from storms by providing the structure that creates surf. They also create famous white sand beaches and an underwater paradise. Despite the large number of new species already discovered, many new species may still be found on future expeditions. DNA barcoding will significantly expedite the identification of these species in future.

Current status of soft corals

A detailed survey was done by the Marine biological station, Zoological Survey of India (Suresh Kumar and Venkataraman, 2004) to know the occurrence and distribution of soft corals. In the Keelakarai group, comparatively a high percentage of soft corals was found compared to the Tuticorin and Mandapam groups of islands. The lower human pressure and favorable conditions for growth of these soft coral may be responsible for this occurrence. The low diversity of soft corals noticed in Tuticorin may be due to coastal erosion and pollution. *Sinularia dissecta* and *S. leptoclados* were found to be dominant (Sureshkumar and Venkataraman, 2004). The survey showed 25% live reef cover in 1998 and this had increased to 45% in 2003, revealing the regeneration of the reefs after 1998 unprecedented coral bleaching event which occurred throughout the world (Venkataraman and Raghuram, 2006). The destruction of reefs in Tuticorin started from the early 1960s to a tune of 80,000 tons per year at Tuticorin and $250m^3$/day at Mandapam (Pillai, 1996).

Sedimentation

Major problems faced by the coral reefs in GoMBR are sedimentation and bleaching. During the southwest monsoon season the wind blows from a northerly direction, creating large waves leading to higher turbidity. Visibility is affected by the high sedimentation load. However, the reefs here are more luxuriant and richer than the reefs of Palk Bay.

Recent threats affecting the soft corals of GoM include fishing and other human activities like collection for their research. As sedimentation occurs continuously, there is a need for continuous monitoring covering the full spectrum of reef types in GoM including those not covered so far. This will be helpful in developing appropriate reef management and conservation policies

in the region.

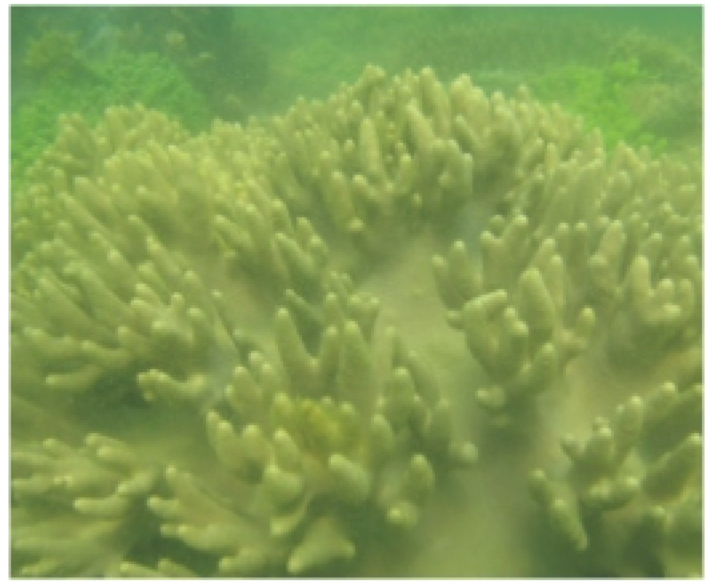
Human activities

The threats to the GoMBR are through indiscriminate exploitation of natural resources by poachers for commercial purposes. There are about 38 fishing villages on the coastal stretch of Ramnad district with a population of about 12,000 who depend entirely on fishing for their livelihood. Exploitation of fishery resources in the inshore waters has been the sole occupation of hundreds of fishing families along the coast for centuries. Reef exploitation includes reef fishery, chanks and pearl fishery, the ornamental shell trade and illegal mining of corals. Villagers around Palk Bay harvest holothurians, seahorses and pipefishes. The destruction of reefs and reef-associated organisms in the GoM and Palk Bay is perhaps unparalleled in the history of environmental damage to nature and natural resources in the recent past (Pillai, 1996). The coral reefs of Palk Bay and GoM have been quarried for industrial purposes from the early 1960s from Mandapam to Tuticorin.

Blast fishing is known to destroy the physical structure of the coral reef, leading to considerable losses to the society (Venkataraman and Wafar, 2005). Damage due to dragging of nets, explosion based fishing and boat anchoring contribute to the injury and breaking of fragile corals.

Pollution

The increase in shipping traffic would lead to an increase in oil spills and marine pollution. The area is already under stress from industries situated along the coast. Ash and



Sacrophyton sp. in Gulf of Mannar

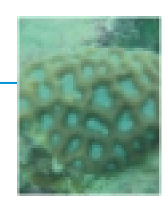
effluents from the Tuticorin Thermal Power Station, SPIC, Dharangadhra Chemical Works and the Tuticorin Salt and Marine Chemicals affect the soft corals here. The ash discharged from the power plant and chemical waste effluents from industries are adversely affecting the seagrasses and coral ecosystems. Pollution arising out of harbour operations and sewage deteriorate water quality impairing ecosystem health. Over fishing disturbs the natural balance of the reef community.

Climate change

Corals cannot survive if the water temperature is too high. Global warming has already led to increased levels of coral bleaching. Consequently, climate change poses a serious threat to all reefs in the region.

Conservation measures

Soft corals (Alcyonacea) are



covered under the CITES agreement, although they are currently exported in significant quantities. The original trade for which CITES regulations were developed was for hard coral skeletons for ornamental purposes. It was estimated that there may be up to three times as many soft corals as hard corals in home aquaria in the USA. Issues related to environmental sustainability of the collection of soft corals are similar to those for Scleractinian corals, but are outside the scope of this report.

There are government initiatives to conserve and manage the coral reefs in the GoMBR through a UNDP–GEF funded project implemented through Gulf of Mannar Biosphere Reserve Trust and other research projects funded by the Ministry of Environment and Forests, Government of India. The initiatives also create awareness among the local communities who are dependent on the reef resources for their day to day livelihood. Many research institutions and NGO's are doing research in and around the GoMBR.

Conservation measures

Awareness rising

The handbook on Hard corals of India (2003) and the Bibliography and check list of corals and corals associated organisms of India (2004) were published by the Zoological Survey of India to encourage researchers to study the diversity of Indian coral reefs. As many as 29 posters on marine animals and coral reef associated organisms were also published to create awareness among the Indian school children. SDMRI has published a field guide on stony corals of Tuticorin and implemented coral reef education programs for fisher women in the Gulf of Mannar.

Management of coral reef ecosystems

The following measures should be taken to protect coral reefs.

Local management measures including

- Restrict commercial trawling activities in the area between the islands and the mainland coast, thereby safeguarding the livelihood of traditional fisher folk and protection of reefs there.
- Control over-exploitation of reef resources for the ornamental trade.
- Create awareness in schools and villages.
- Ensure more effective use of scientific and monitoring data to inform the development of new laws and policies.
- Improve funding for restoration, capacity building, establishment or improvement of databases, networking including sharing of information and experiences.
- In addition: use of GIS based information system for sensitive ecosystem is essential.
- Improvement of socio-economic status of the coastal population may improve the situation in the GoMBR in the future.

Acknowledgement

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workshop.

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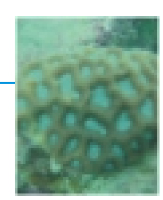
Lobophyllia diminuta



Soft coral (*Sacrophyton* sp.) occurring in Gulf of Mannar

Participatory marine biodiversity conservation - a step forward in the Gulf of Mannar region, Southeast coast of India

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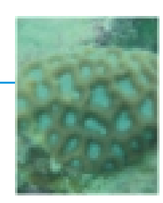
Abstract

Renewable natural resources are regenerated and consumed in a cyclic process in their associated ecosystems by nurturing, supporting and sustaining biodiversity. Conservation in isolation from its key components, which includes man, can never be achieved successfully as it is the constantly increasing demands of the people on the resources which pose a threat to the productivity and the potential of the ecosystems and to biodiversity. Inclusion of resource-dependent man in the conservation management protocols, policies and programmes is thus vital for establishing a win - win situation where both conservation of resources and their consumption co-exist and the concept of sustainability of resource use gains firm ground. Various attempts have been made over the last two decades in the country towards meeting the above approach of inclusion of man in conservation planning and management in terrestrial PA's and forest areas through the process of Eco-development and Joint Forest Management. However, a similar focus in marine and coastal areas has been lacking where levels of harvest and the practices followed are causing great concern for the welfare of the associated biodiversity in benthic and pelagic ecosystems and future prospects for the availability of marine resources, mainly fisheries. The Gulf of Mannar region, south east coast of Tamil Nadu in India is an internationally renowned site for rich marine biodiversity of global significance and its multiple use patterns and stakeholders. The Gulf of Mannar Marine National Park (1986) and Biosphere Reserve (1989) have been the coastal and marine areas where initial efforts were made in the country towards enhancing conservation action and planning. Yet the inclusion of local communities in these efforts is not on the desired level thereby affecting the key principles of conservation. The GOI - GOTN - GEF - UNDP supported project on "Conservation and sustainable utilization of Gulf of Mannar Biosphere Reserve's coastal biodiversity" has provided an excellent opportunity to include the local communities and solicit their support towards ongoing conservation efforts. The key areas of intervention include empowering and enabling the communities to jointly take ownership of resource availability and its use through building capacities, skills, enhancing understanding of the issues involved and adopting diverse livelihoods and income generation options instead of depending only on fisheries. The emerging trends are encouraging, and if pursued sincerely, the protocol now in action will develop as a role model for participatory coastal and marine biodiversity conservation. This inclusive approach has been able to contribute towards a total control of coral reef mining from the 21 coral rich islands constituting the Marine National Park and a rise of five percent plus in the live coral cover in the Gulf of Mannar region over the last three years.

Introduction

The agenda and the action plan of biodiversity conservation involves one serious element of a conflict between the humans on one side and the other living organisms inhabiting the land, freshwater bodies and marine environment on the other. Biodiversity encompasses an array of richness of genes, species and ecosystems, each depending on the other and enriching each other adding vibrancy and dynamism to the living earth. People are very much a part of the living earth and interact with biodiversity in a variety of ways as a resource and its use for their welfare. Within the limits of sustainability, this resource use might be acceptable, but with the growing human population, their resulting



needs and aspirations are showing accelerated growth in use patterns and quantum, thus posing severe threats to resource availability to other forms of biodiversity. Biodiversity, which is an asset and strength of the developing countries, is an unrecoverable resource and its loss can not be made good by human endevours. The conservation and sustainable utilization of this resource has to be central to all developmental planning where the economies of the countries depend upon natural resources accruing from the biodiversity – agriculture, horticulture, animal husbandry, fisheries, forestry, medicines, etc.

The paradigm shift

The rising use profiles of biodiversity and its products, and consequent threats to the supporting ecosystems and the targeted species, are by and large similar in terrestrial and coastal and marine areas. The conservation planning and action in the past, especially in the forestry and wildlife sectors, did not acknowledge or include the role of local dependent communities. The National Forest Policy 1988 envisaged the role of local communities and their involvement in forest conservation, regeneration and protection. The Convention on Biodiversity (CBD) also reiterated the role of local communities and their involvement in such initiatives for sustainable forest management and biodiversity conservation. These global and national obligations and understandings opened a new era of conservation management, both in the Forest and the Protected Area (PA) systems, where involvement of the local communities was planned and assured and various workable approaches e.g. Joint Forest Management (JFM) and Eco-development protocols were attempted with site specific modifications. Wherever attempted, these processes did contribute to changing the situation and reducing the rising conflicts between the management and the communities. The levels of achievement during field implementation might vary from site to site, yet the results clearly point towards reworking and re - orienting the focus and attention in these approaches to build in equity and sustainability.

The protected areas network scenario

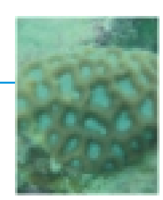
The focus on conservation and sustainable use of coastal and marine resources could arrive not only late, but also not to the desired levels. In the Protected Area network of the country there are 610 designated areas, but the PA's with coastal and marine elements are only about 60 and only six are entirely marine. Apart from the coverage of these PA's and their future expansion, the priority for involving local communities in conservation and sustainable utilization of marine biodiversity and its products has yet to receive a meaningful focus. The over harvest of marine resources and the current practices of harvest have started depleting fisheries and related resource bases, adversely affecting the livelihoods of thousands of fisher folk. Fisheries being a traditional livelihood, the aspirations of the dependent communities need to be taken care of, as well as their active inclusion in conservation planning and action has to be ensured. Marine biodiversity conservation will have to aim at

sustained availability of fisheries resources for use. Efforts to sensitize the community for the role they can play towards conservation of marine biodiversity, and contributing to it through enhanced understanding of issues, reducing their anti conservation practices of harvest, and limiting harvest levels, have to be pursued very seriously. Such a changed scenario alone will ensure a win - win situation for both the conservation of marine and coastal resources and sustainable utilization of resultant biodiversity and its products that shall sustain the well being of the local communities in the long run. Today, a Conservation program needs to be socially acceptable and it has to secure cooperation, coordination and support from multi - sectoral agencies and organizations working in and around the natural resource rich areas (Sreedharan and Melkani, 2006).

The area and its biological richness

Gulf of Mannar (GoM) on the southeast coast of India in the state of Tamilnadu falls within the Indo-Pacific region and is one of the world's richest marine biodiversity areas. The Gulf of Mannar region is an ecologically sensitive marine ecosystem and is one of the four main coral reef ecosystems in India. Pillai (1986) provided a comprehensive account of coral diversity of the Gulf of Mannar with 94 species belonging to 37 genera, wherein *Acropora* spp., *Montipora* spp. and *Porites* spp. are dominant. Subsequently, Patterson *et.al.,* (2007) have updated the coral diversity to 117 species coming under 38 genera. The Gulf of Mannar region is also well known for its diversity of sea grasses. Out of 14 species of sea grasses under six genera recorded from Indian seas, 13 species occur here (Venkataraman and Wafar, 2005). As many as 147 species of sea weeds (Kaliyaperumal, 1998), 17 species of sea cucumbers (James, 2001), 510 species of fin fishes (Durairaj, 1998), 106 species of shell fishes (Jayabhaskaran and Ajmal Khan, 1998), four species of shrimps (Ramaiyan, 1996) and four species of lobsters (Susheelan, 1993) have been reported. The molluscan diversity include five species of polyplacophorans, 174 species of bivalves, 271 species of gastropods, five species of scaphopods (recorded first time) and 16 species of cephalopods (Deepak and Patterson, 2004). Ten true mangrove and 24 mangrove-associated species are recorded from the area. Out of seven species of sea turtles, five are recorded from GoM. The endangered sea cow inhabits the sea grass meadows of GoM. With about 3600 species of marine flora and fauna, GoM is India's biologically richest coastal region and is a priority area for conservation because of its richness of species and ecosystems and the multiple users it supports.

The Gulf of Mannar region has bio-physical and ecological uniqueness, economic, social, cultural and scientific importance, and national and global significance (Kelleher, 1995). The IUCN commission on NP and Protected Areas with the assistance of UNED, UNESCO and WWF have identified the Gulf of Mannar Biosphere Reserve area as an area of "particular concern" given its diversity and special, multiple use management values. The Reserve was one of the six areas chosen for inclusion into an action programme to save India's Protected Areas for



future generations on the basis of its threatened status and richness of biological wealth (Rajiv Gandhi Foundation, 1995).

The problem profile

All over the world the pressures on diverse ecosystems and their resources have been on the rise, leading to increasing conflicts between conservation and dependency on natural resources by local communities, especially in developing countries. The situation in Gulf of Mannar is in no way different. The increasing population in the coastal area, plus a lack of proper and meaningful coordination among various agencies, impose threats to the biological wealth of the area. Destruction of habitat, over-harvesting of marine resources and damaging fishing practices, pollution of the marine environment arising from industrial and civic society, lack of integrated management of the area, insufficient regulatory frameworks, lack of support from local communities for conservation, insufficient public awareness and lack of viable alternative livelihood options, are some of the critical facts posing threats to the long term well being of the Gulf of Mannar region. About 1200 mechanized and 11000 non-mechanized boats exploit the marine resources on an almost daily basis (Sreedharan and Melkani, 2006). The recent study conducted by the Fisheries College and Research Institute, Tuticorin revealed that the human population has increased by 34 % in the past 15 years, while fishing vessels over the some period have increased by 54% (Sundaramurthy, 2008). This over-harvesting of resources is a serious threat and has to be controlled and brought within sustainable limits.

The fish production in the Gulf of Mannar region was stable at around 105,000 tonnes from 1998 to 2004, then decreased to about 81,000 tonnes during 2004-05. The growth in human population and the subsequent increase in the demand for marine products are the main reasons that fishers are involved in destructive fishing practices and over harvesting of resources in the Open Access Marine Regime. This is posing grave threats to the fragile ecosystems and marine biodiversity of GoM. The concept of craft lord has made in roads in the coastal belt as the *land lord* concept hitherto, prevailing in terrestrial regions (All India Fisheries Census, 2005). The growing population and the consequent increase in pollution load into the Gulf of Mannar is a major problem today. In the absence of alternative livelihood options, the pressure on fishing is on the rise in an already depleting resource base. Lack of awareness among often conflicting stake holders does not allow the people to understand the looming threat and its consequences, thereby hindering efforts to utilise coastal resources sustainably.

Past management practices

Of the four major coral reef areas in the country, the Gulf of Mannar (GoM) is the most productive coral ecosystem and is distinguished because it has received recognition for conservation ahead of many other areas along the Indian coastline. The coral reefs in the Gulf of Mannar are found around the 21 islands in the Gulf of

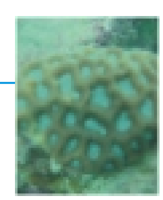
Mannar Marine National Park extending over an area of 560 sq.km covering the islands and their shallow surroundings and are protected under the provisions of the Wildlife Protection Act, 1972. The total extent of reef cover in GoM is about 100 sq.km. Scientific studies carried out in the area have confirmed that 40% of the marine biodiversity is dependent on the coral reef ecosystem. Considering the biological richness of the area and its multiple users, the Gulf of Mannar Biosphere Reserve is the first Biosphere Reserve in the marine environment, not only in India but in the entire South and South East Asia; it extends over 10,500 km^2 in the Indian waters of the Gulf abutting the coastline of four districts of the State of Tamilnadu i.e. Ramanathpuram, Tuticorin, Tirunelveli and Kanyakumari. The Reserve covers a coastal length of about 300km; the GoMNP is the core area of the Biosphere Reserve.

Though these initiatives towards enhanced conservation and protection of marine ecosystems (coral reefs, seagrass beds, mangroves, etc. and the associated marine flora and fauna) started yielding some results, the efforts were not able to create a changed scenario for conservation and its management. This was primarily due to the fact that the local communities are dependent on marine resources for their livelihood needs and are not able to understand the value of conservation. Therefore, their support for the conservation initiatives in GoMBR was not forthcoming. As mentioned earlier, the local communities need to be considered as part and parcel of the management regime if the conservation efforts are to succeed. Because of lack of meaningful support from the local communities and other stakeholders, both short and the long-term conservation efforts have not succeeded to date.

The new initiative

India is a signatory to the Convention on Biological Diversity (CBD). Considering the biological richness, its problem profile and the multiple users with their own mandates and aspirations in GoMBR area, a workable intervention focusing on improved co-ordination among stakeholders, especially to secure the involvement of local communities in conservation management of the area, was launched through the GEF-UNDP programme in collaboration with Government of Tamil Nadu (GOTN), and Government of India (GOI). The programme, named "*Conservation and sustainable use of Gulf of Mannar Biosphere Reserve's coastal bio-diversity*" was launched in 2002. The project is a pioneering initiative in South East Asia in eliciting people's participation in marine biodiversity conservation and sustainable marine resource management. This seven year project with funding from GEF–UNDP of Rs. 40 crores along with parallel contributions from GOI, GOTN and other project partners (approx. Rs.100 crores) is being coordinated by a special agency, the Gulf of Mannar Biosphere Reserve Trust (GoMBRT), a registered Trust of the Government of Tamil Nadu to ensure effective inter-sectoral co-ordination and main streaming of bio-diversity conservation issues into the productive sector and policy development.

The overall objective of the project is to conserve the Gulf of



Mannar Biosphere Reserve's globally significant assemblage of marine and coastal biodiversity, and to demonstrate in a large Biosphere Reserve with various multiple uses, the integration of biodiversity conservation, sustainable coastal zone management and livelihood development. The focus of the project is on empowering local communities to manage the coastal ecosystem and natural resources in partnership with Government and other stakeholders, and making all accountable for the quality of the resulting stewardship. Specific Government and village-level institutional capacities will be strengthened, stakeholders will apply sustainable livelihoods, and the independent Trust (GoMBRT) will ensure effective inter-sectoral co-operation in the sustainable conservation and utilization of the GoMBR's biodiversity resources. The project is to attempt to evolve suitable strategies to establish an implementable design for participatory marine biodiversity conservation and sustainable use of marine resources in the Gulf of Mannar as a model which can later be adopted in many other parts of the country and across the world .

The following are five important areas where the project initiatives have been concentrated:

1. Managing the affairs of the Trust, developing a Long Term Funding mechanism for related activities after the present project period close and facilitating co-ordination among various stake holders.
2. Strengthening the capacity and infrastructure of the Gulf of Mannar Marine National Park for enhanced conservation and management functions.
3. Base line research and monitoring on key ecological, biological, environmental and management issues of Gulf of Mannar Biosphere Reserve.
4. Building capacity of various groups of stakeholders.
5. Eliciting local community's participation in conservation and sustainable marine resource use through building awareness, capacity and skills; organizing local communities at the grass root level; empowering them and facilitating provision and adoption of alternate / enhanced livelihood options to reduce the pressure on the fisheries resources.

Involving local communities in conservation in the Gulf of Mannar

Eliciting Local Communities Participation towards conservation and sustainable use of marine resources has been the key focus area of the GEF UNDP initiatives. The process and protocol of eco-development has been followed in the area which is the first such attempt in the coastal belt in the country. The process of eco-development has been practiced in some of the important Tiger Reserves and other Protected Areas in the country since 1980s. The fundamental principle on which the process is based and which governs the whole participatory approach in planning and implementation of agreed actions rely on bottom up planning in active consultation of participating community and dialogue that shapes discussion and action in field realities (Melkani, 2001). Two important components of eco-development are

- Enhancement of resources in the areas used by the people; and
- Reduction of the dependence of the people on the resources through development of alternate income generation and livelihood security programmes.

The following sequence of events and steps have been initiated so far towards securing local people's participation towards conservation of marine resources and their sustainable use in the Gulf of Mannar:

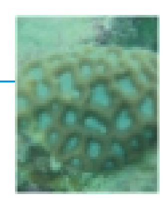
Organising local communities

Grass root level community organizations - Village Marine Conservation and Eco-development Committees (VMC and EDCs) with a mandate for linking conservation and livelihood improvements have been established in 252 villages/hamlets along the 160 km coastal stretch from Rameshwar in Ramanathapuram District to Periathalai in Tuticorin District in the 10 km wide buffer zone in the approach area. The VMC and EDCs are registered under the Tamil Nadu Registration of Societies Act 1975 and thus are organizations under legal mandate. All the residents of the village/helmets are encouraged to become members of the VMC and EDC. Two members (one male and one female from a household) can join the VMC & EDC by contributing an annual subscription of Rs. 5/- per member per year. The VMC and EDC has a General Body and an Executive Committee. All the members of the VMC and EDC are members in the general body and they elect seven members (not less than 50% of whom have to be women which ensures the participation of women). The executive committee then selects one of them as the Chairperson of the VMC and EDC. A staff of the Trust works as the Member Secretary of the VMC and EDC. Around 55% of the households have so far joined in the VMC and EDC's and the membership is on the rise.

In the project villages, the Self Help Groups (SHG) already established by various local NGOs are bought under the umbrella of VMC and EDCs. Many women SHGs have been formed in the project area by various NGOs prior to the present initiative and, therefore the project initiative has focused on formation of new women SHGs wherever they are required as well as the formation of men SHGs and joint SHGs. About 2,400 SHGs are functioning in the project area. In addition, the project initiative is also focusing on developing enterprise groups from among the various SHGs considering their skills and capacity and interest by providing them options to start suitable enterprises for enhanced income.

Empowering the local communities

Ater establishing the VMC and EDCs, micro plans are prepared by planning teams consisting of Trust staff, local NGOs and their representatives and the villagers by adopting PRA tools and other information collected from the village. The negative and positive interactions between the Reserve and the village people are analyzed and strategies for field implementation are finalized in consultation with local fishers. In order to facilitate required intervention in the selected VMC and EDCs, the threats to the well being of marine biodiversity as imposed by that village are identified



and for that purpose the villages have been categorized into high threat, medium threat and low threat categories. Rs. three lakhs, two lakhs and one lakh are disbursed as seed capital to the bank account of the VMC and EDC for providing credit support towards alternative livelihood development for the members in high threat, medium threat and low threat category VMC and EDCs, respectively.

Developing sustainable alternate livelihood

The micro plan of VMC & EDCs focuses on various options and resources available to develop economically feasible and socially acceptable livelihood and income generation activities to assist the members, with an objective that such effort will bring down the resource dependency on fisheries gradually and also provide some income during lean periods and rough weather seasons when fisheries cannot be practiced. Presently the micro credit is provided to SHGs based on the action plans prepared by SHGs for livelihood activities. The credits are to be repaid back to the VMC and EDCs with a simple interest (12% per annum). These funds are managed by VMC and EDCs as revolving funds enabling them to continue such assistance to local people for sustainable alternate livelihood on a continuous basis and to secure financial sustainability to these organisations. An amount of Rs.4.72 crores has been released to the VMC and EDC's so far as the seed capital to be managed by the revolving fund and 1,400 SHG's have availed credits of varying amounts to start various alternate and income generating livelihood activities and the repayment of credits has been prompt. As many as 52 types of activities are being pursued by various groups presently (MTE Report of the Project, May 2008).

Enhancing awareness about marine biodiversity conservation

The project initiatives have high focus on awareness creation among the local communities about the value and need for conservation in GoM. Various media for awareness generation - folk, audio-visual, puppetry, All India Radio, local TV networks, cultural programmes, print media and materials – information booklets, manuals, pamphlets, brochures etc. are utilised. The biodiversity values related to GoM, the problems faced by the Conservation Management and the role of communities in supporting conservation and imbibing the sense of ownership for the long-term welfare of of GoM are being very actively pursued with the support and involvement of both experienced local and external NGO's.

Building capacities

In order to enable the local communities to adopt various alternate livelihood activities, concurrent action is being taken to upgrade the skills and to provide new skills wherever required. Local institutions and NGOs are primarily engaged in such efforts.

Investment on the future generation for improved conservation in GoM

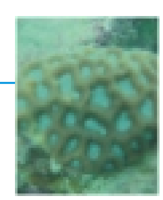
The project initiatives have a pioneering component of providing vocational training to the fisher youth (both boys and girls) in order to equip them in new skills which shall assist them in adopting alternative livelihoods. Based on the interest of the youth (youth who have passed SSLC, and plus two school level examinations) are encouraged to opt for a vocational training course in the field of their interest. The vocational courses ranging from three months to one year and are organized at recognized and approved institutions of the Government, making the youths passing out with a new vocational skills better placed in securing related jobs and to pursue a career. The ongoing vocational training programmes are - computer education (hardware and software), AC mechanic, plumbing, electrical works, marine engineering and technology, Desk Top Publishing (DTP) printing, driving of heavy and light vehicles, village health assistant, tailoring and embroidery, dress designing and beautician course and many other types of vocational trainings based on the liking of the youth. Out of the 118 youths trained during 2007, 70% have already received employment offers from various agencies and are now working mostly outside the project area. During 2008, 640 youths have been identified for such courses and the courses are ongoing. These initiatives will go a long way to ensure that in the coming years the reduction of pressure on fishing can be achieved by encouraging the youth to adopt other vocations.

Institutional linkages

For the activities where the initial investments are larger, the SHGs and VMC and EDCs are linked with the bank. During 2007, three SHGs were linked with the State Bank of India, Ramanathanpuram wherein 75% of the activity cost was provided by the bank and 25% supported by the Trust on a three year repayment period for undertaking sea weed cultivation of indigenous species (*Gracilaria edulis* and *Gelilidila acerosa*). Similarly one SHG was provided with similar support to undertake Solar Fish Drying and Marketing Enterprise. In addition, 12 joint SHGs were linked with the District Rural Development Agencies.

Facilating coordination

It has been one of main objectives of the project to bring all and often conflicting departments and agencies in to one forum to sort out their differences, to build a new focus for conservation and to bring in a changed mind set among them. To achieve this the Trust has developed a number of training manuals, booklets and awareness materials predominantly in the local vernacular for use by a variety of stakeholders for easy understanding of information. The initiatives focus equally on the capacity building of other stakeholders – Line Departments, NGOs, Industries and others. The efforts made have sensitized the other stakeholders equally towards the various issues related to the conservation and sustainable use of marine resources in the GoM. Various Government departments and agencies are sensitized enough to provide critical attention towards biodiversity conservation in the GoM while developing their action plans for the area. The access of local communities for securing help, information and technical assistance from these agencies has also improved. The officials and field staff of departments of Forests, Fisheries and Coastal Security Police have now started joint patrolling in the area to



improve the protection of marine resources. The Board of Trustees chaired by the Chief Secretary to the Government of Tamil Nadu and various other higher officials of key departments, NGOs and people's representatives, provide guidance and support for successful implementation of the project activities. The State Level Co-ordination Committee (SLCC) provides directions and interventions for improved inter departmental coordination and co-operation which are helpful to project implementation and its outcome.

In two project districts, District Level Co-ordination Committees (DLCCs) have been established by the Government to facilitate departmental cooperation and coordination as well as to ensure that various developmental activities required in the project villages are undertaken on a priority basis through the line department. These committees are chaired by the respective District Collectors. The Chairpersons of VMC and EDCs are members in these committees on a rotation basis and they have an opportunity to present their problems to the district administration. Four VMC and EDCs Chairpersons are also members of the Empowered Sub Committee (ESC) of the Trust under the chairmanship of Chief Wildlife Warden. One of the important functions of the ESC is to approve the annual work plans for the project initiatives. The presence of VMC and EDCs representatives in ESC is helpful in providing representation to local communities to express their views regarding the work plans and various strategies for project implementation. This is also a part of empowering the local communities.

The journey so far

The present initiative in the Biosphere Reserve has been an opportunity for the Trust and other key departments to open the way for involving local communities towards enhanced conservation and sustainable use of marine resource in the area. The initial experience has been positive and encouraging. The coral reef mining, which was rampant in the past, has been completely stopped because of better under-standing among local communities and improved protection and sustainable livelihood provisions to various dependent communities. In a recent study conducted by SDMRI, 5% increase in live coral reef cover has been reported in GoM over the last three years (Patterson *et al.,* 2008). The wild collection of seaweeds from the National Park Area is gradually decreasing. Further, the collectors of sea weeds are now sensitized not to scratch corals while collecting the sea-weeds. The initiation of seaweed culture of enterprises will further reduce the wild collection. The initial indications point towards gradually improving habitat quality which will support conservation of biodiversity. The sightings of sea cows, *Dugong dugon*, have marginally increased in the project area. The awareness level among the local communities and other key stake holders about biodiversity conservation, sustainable use of resources and their role in supporting conservation has definitely increased significantly compared to the pre-project situation. The inclusion of local communities in conservation planning and action has reduced conflicts noticed quite frequently earlier.

Conclusion

A foundation has been laid for a vibrant start to participatory marine biodiversity conservation in the Gulf of Mannar under the project. Collaborative bonds are being developed and new relations forged among the resource-dependent communities, government departments and agencies, research institutions, industries and local NGOs with a shared vision to conserve the rich marine biodiversity of the Gulf of Mannar and to improve the livelihoods and income levels of the local communities. The efforts made so far have been duly appreciated by the team of independent evaluators in April 2008 (MTE Report of the Project, May- 2008). The long-term success, however, will depend on further refining and sustaining the efforts being made currently and improving upon the relationship and understanding between the local communities and other stake holders for the judicious use of the resources. The agencies responsible for controlling, regulating and enforcing various provisions of law in the area will also need to keep the focus on conservation needs and realities in their programmes and activities. A balance among the conflicting needs and aspirations of local communities and other stake holders, improved understanding and a shaired vision among them for the cause and concern of conservation, will surely safeguard the welfare of both the biodiversity and the local communities in the Gulf of Mannar, a globally renowned marine biodiversity hot spot area, for all time to come.

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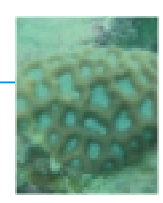

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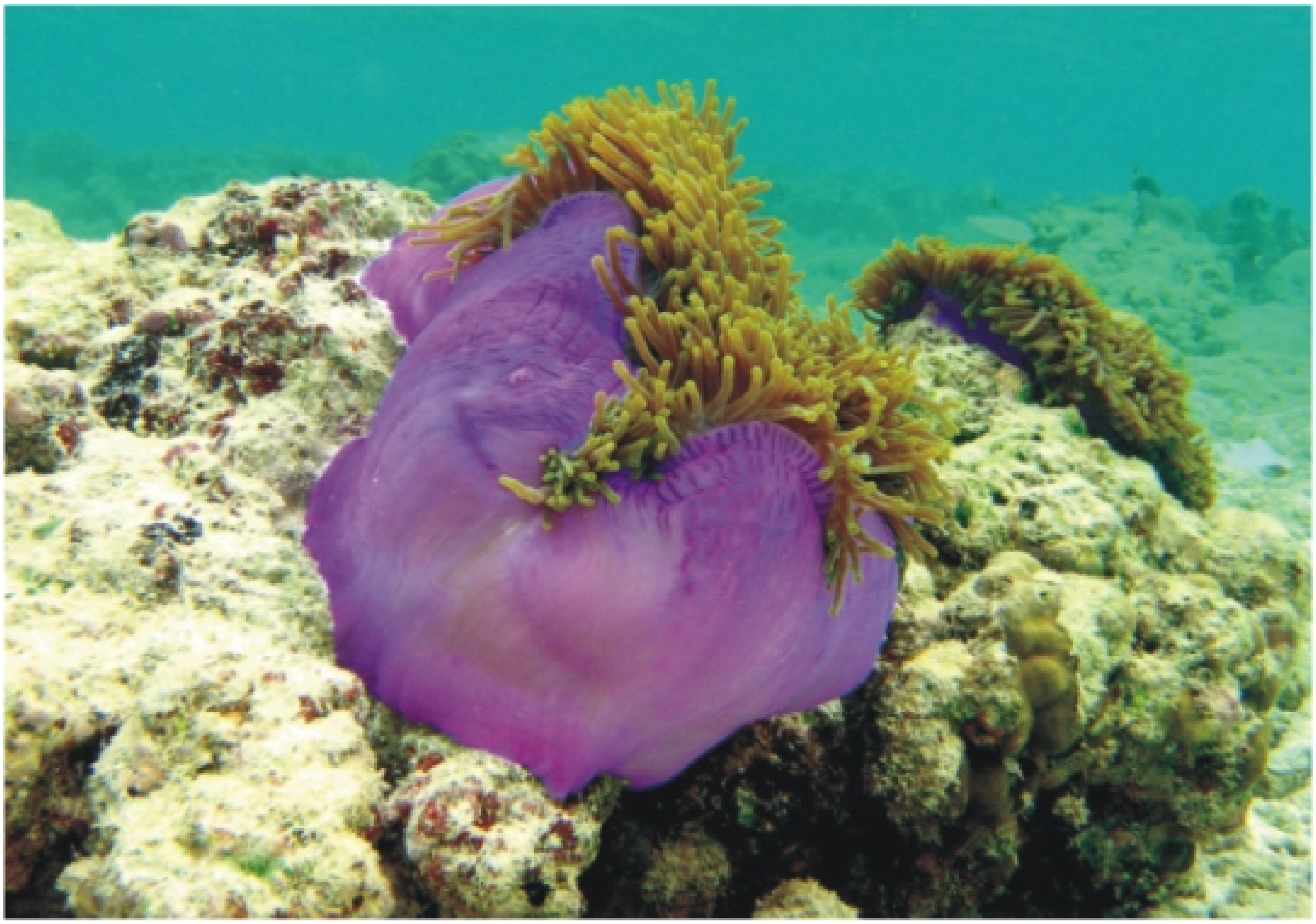
Cypraea tigris



Theme II: Coral associates

Mangroves in Andaman and Nicobar Islands

Mangrove ecosystem in India: biodiversity, threat, conservation and management

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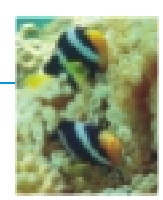
Abstract

Constituted by 73 tree species belonging to intertidal forest communities, the mangrove ecosystem is one of the most productive ecosystems in the world. India has an area of 4,662.56 sq. km under mangrove vegetation which constitutes 2.69% of the world mangrove area. Recent surveys have shown that all the states and UTs registered an increase in mangrove forest cover, except Andhra Pradesh. This ecosystem harbours a surprisingly rich biodiversity which varies from algae to angiosperms and protozoans to large mammals. About 16 location-specific threat factors are stressing mangrove ecosystems in India. Local extinction of several species has also been reported. There is a need to adopt landscape-based conservation approaches integrating the coastal areas as well as the river basins for sustainable management with emphasis on stakeholders' participation and addressing local livelihoods. Restoration of the ecosystem demands knowledge about population dynamics, reproductive biology, seedling demography, pollinators and dispersers of important species in the ecosystem. Adaptability and zonal preferences of species employed for restoration, besides tidal amplitude, soil and light condition, coastal changes and pollution status, are other critical factors. Efforts on these aspects are to be complemented meaningfully by management policies, action plans and legislative and regulatory measures at State and Central Government levels. This article provides an account of biodiversity, conservation and management of the mangrove ecosystem and highlights the need for integration of efforts on these fronts for practical conservation of the existing mangrove forests in India.

Introduction

The mangrove ecosystem is constituted by plants belonging to intertidal forest communities. The striking characteristic is its constitution by a limited number of species exhibiting close physiographic relationships. These species either maximise their intrinsic rate of population increase or maintain populations at the maximum carrying capacity of the environment (MacArthur and Wilson, 1967). That is why Tomlinson (1986) remarked: "mangroves can have their cake and eat it too". Initial problems for mangrove species are to locate a habitat within a short period of time in patchy and varied areas. Once this happens, they establish themselves and form pure strands due to their unique biological characteristics like vivipary and salt exclusion ability. The mangrove community is devoid of prominent structure and hence, it does not have successional development, an understory or stratification.

Mangrove vegetation has major and minor components. The former is constituted by 34 species and the latter by 20 species worldwide (Tomlinson, 1986). Characters like fidelity true to the mangrove environment, dominance in community structure, morphological specializations like aerial roots and vivipary, salt exclusion ability and taxonomic



isolation of species from their respective terrestrial relatives make these 54 species as true or eu-mangroves. Besides these, the mangrove vegetation comprises another estimated 60 species which are known as mangrove associates. Chapman (1976) included 90 species under true mangroves from the tropics and the subtropics, while IUCN (1983) and Duke, (1992) agree that there are only 69 species. Kathiresan (2003) remarks that there are 100 true mangrove species in the world.

Mangrove vegetation represents all major life forms – trees, shrubs, herbs, climbers, epiphytes and parasites. Mangroves occur precisely in 112 countries, mainly in the old world tropics, and cover an area of 1,81,399 sq. km (Table 1).

Table 1. Region wise distribution of mangrove vegetation

	Region	Area km^2	%
1	South and South East Asia	75,172	41.4
2	America	49,096	27.1
3	West Africa	27,995	15.4
4	Australia	18,788	10.4
5	East Africa and Middle East	10,348	5.7
	Total	1,81,399	100

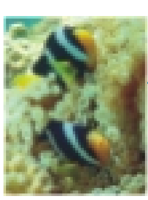
Utility of mangroves

Mangroves are considered one of the most productive ecosystems in the world. They use renewable energy sources and produce lignocellulose from seawater. Besides sunlight, they can make use of tidal energy. Even though mangroves are not counted as major forest resources, many species of this community produce quality timbers that have high density and termite and marine borer resistance (e.g. *Heritiera* and *Xylocarpus*). They are also a rich source for extraction of unsawn poles and fuel wood. Mangroves are good sources of tannin and dyes. Quality honey extracted from mangrove forests is an important non-wood forest product.

Mangroves are used in indigenous medicine. *Bruguiera* species leaves are used for reducing blood pressures and *Excoecaria* species in the treatment of leprosy and epilepsy. Seeds of *Xylocarpus* have anti-diarrhoeal property and *Avicennia* has tonic effect whereas *Ceriops* produces hemostasis and cures oral cancer and HIV-causing AIDS (Kathiresan and Qasim, 2005).

Mangroves support inshore fish and shrimp production. They provide nutrition to the marine community through detritus and make suitable habitats for commercially important marine organisms to successfully complete some stages of their life cycle. They directly provide shelter for oysters and many other species of shell fishes.

Mangroves play a key role in stabilising shore lines and protecting inshore fish habitats from sediment pollution. In some tropical countries, local communities consume viviparous seedlings after boiling. Mangroves are used for the production of pulpwood and cheap synthetics. They function as natural sewage treatment plants. Mangrove habitats are areas that can be profitably used for salt production. Some mangrove species can secrete pure salt. The Indian Ocean Tsunami of December 2004 and cyclones have brought into focus the role of coastal ecosystems especially mangroves in shoreline stabilization. This is a critical function in tropical countries like India which has a long coastline that is periodically battered by tropical storms



and hurricanes. Badola and Hussain (2005) carried out economic assessment of the storm protection function of Bhitarkanika mangrove ecosystem and estimated the cyclone damage avoided in three selected villages taking the cyclone of 1999 as a reference. Economic assessments indicated the highest loss in the village that was not sheltered by mangroves but by embankments and with the least per capita damage in the village with mangroves as a barrier. Das and Vincent (2009) validated the storm protection function of mangroves in Orissa; they established that villages with wider mangroves between them and the coast experienced significantly fewer deaths than the ones with narrower or no mangroves. Evidence from the Indian Ocean Tsunami indicates that mangroves (in conjunction with other forms of beach plantations and other geomorphological factors) played an important role in reducing the impact of waves and provided protection to varying degrees to human lives and property (Kathiresan and Rajendran, 2005; Danielsen *et al.,* 2005). Analytical model shows that 30 trees in 10 square metre area in 100 metre wide belt may reduce the maximum tsunami flow pressure by >90% if the wave height is <4-5 m (Hiraishi and Harada, 2003). Mangroves also enhance fisheries and forestry protection. These benefits are not expected with concrete coastal protection structures.

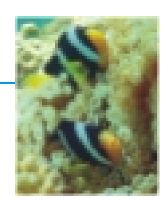
Rhizophora mucronata

Apart from the above, mangroves play a major role in the global cycle of Nitrogen and Sulphur. There is hardly any ecosystem on the earth which is so productive and hence economically very complex but ecologically so simple; and in terms of tree species, the least diverse. A value of US $ 7,51,368.30 per hectare was established for the restitution of mangroves in Puerto Rico due to an oil spill (Pool *et al.,* 1977).

Mangroves are among the most carbon rich forests in the tropics. Carbon sequestration potential is 50 times greater than other tropical forests. This is because of high levels of above and below ground biomass and considerable storage of organic carbon in mangrove sediment. Mangrove deforestation constitutes 10% of the global emission (Donato, 2011).

Status of Indian mangroves

India harbours three types of mangrove habitats-deltaic, back water-estuarine and insular. The deltaic mangroves are found along the east coast (Bay of Bengal) on the deltas of Ganga, Brahmaputra, Mahanadhi, Krishna, Godavari and Cauvery. They show luxuriant growth. The estuarine type occurs in the west coast in the funnel shaped estuaries of the Indus, Narmada and Tapti. They are also seen in the backwaters, creeks and neritic



inlets. Mangrove ecosystems of the east coast of India are different from those of the west coast in their geomorphic settings. The coastal zone of the west coast is narrow and steep in slope due to the Western Ghats. As there is no major west flowing river, mangrove ecosystems of the west coast are small in size, low in diversity and less complex in terms of tidal creek network. The situation is the reverse on the east coast, mainly because of larger deltas created by east flowing rivers and the gentle slope of the coast. Insular type mangroves are found in the Andaman and Nicobar Islands. Their growth is supported by tidal estuaries, lagoons and riverlets.

India has an area of 4,662.56 sq. km under mangrove vegetation which constitutes 2.69% of the world mangrove area. About 59% of Indian mangroves are found along the east coast, 28% on the west coast and remaining 13% in the Andaman and Nicobar Islands. Mangrove areas in Andhra Pradesh, Maharashtra and Tamil Nadu declined between 1987 and 1999 while those in Goa, Gujarat, Karnataka, Odisha, West Bengal and the Andaman and Nicobar Islands registered an increase, especially in Gujarat and the Andaman and Nicobar Islands.

The Sundarbans in West Bengal is the largest single contiguous mangrove spread between India and Bangladesh. Mangroves in Orissa occur on the deltas of Mahanadhi, Brahmani and Baitarani and on the Balasore coast. Kalibanjdia, Bhitarkanika, Talchua, Thkuran and Gahirrmatha harbour very good mangrove forests. Major mangrove forests in Andhra Pradesh are seen in the estuaries of Krishna and Godavari. Coastal areas harbour more luxuriant vegetation than the shore land because coastal areas have denser creeks. Cauvery delta possesses the main mangrove forest area in Tamil Nadu; Pichavaram

Table 2. State wise status of mangrove vegetation in India (square kilometers)

State/UT	Assessment Year												
	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005	2007	2011	Change w.r.t 2009
Andhra Pradesh	495	405	399	378	383	383	397	333	329	354	353	352	-1
Goa	0	3	3	3	3	5	5	5	16	16	17	22	5
Gujarat	427	412	397	419	689	901	1031	911	916	991	1046	1058	12
Karnataka	0	0	0	0	2	3	3	2	3	3	3	3	0
Kerala	0	0	0	0	0	0	0	0	8	5	5	6	1
Maharashtra	140	114	113	155	155	124	108	118	158	186	186	186	0
Orissa	199	192	195	195	195	211	215	219	203	217	221	222	1
Tamil Nadu	23	47	47	21	21	21	21	23	35	36	39	39	0
West Bengal	2076	2109	2119	2119	2119	2123	2125	2081	2120	2136	2152	2155	3
A&N Islands	686	973	971	966	966	966	966	789	658	635	615	617	2
Daman & Diu	0	0	0	0	0	0	0	0	1	1	1	1.56	0.56
Puducherry	0	0	0	0	0	0	0	1	1	1	1	1	0
Total	4,046	4,255	4,244	4,256	4,533	4,737	4,871	4,482	4,448	4,581	4,639	4,662.56	23.56

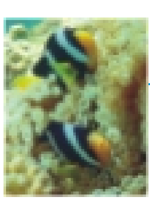


Table 3. State wise areas (2011) and number of mangrove species

	State	Area (sq.km)	No.of species
1	West Bengal	2155	57
2	Orissa	222	60
3	Andhra Pradesh	352	31
4	Tamil Nadu and Pondicherry	40	24
5	Andaman and Nicobar Islands	617	44
6	Gujarat	1058	12
7	Maharashtra and Goa	208	26
8	Karnataka	3	29
9	Kerala	6	27

and Muthupet have good mangrove forests besides Vedaranyam, Kodaikarai, Chatram and Gulf of Mannar islands. Mangrove forests in Gujarat occur in Kori Creek, Gulf of Kachchh, Saurashtra coast, Gulf of Khambhat and South Gujarat. Gujarat has the second largest mangrove forests in India and the Gulf of Kuchchh is the most luxuriant. In Maharashtra, estuaries of Mandovi, Vasistha, Savitri and Kundalika and creeks of Dharamtar, Panvel, Vasai, Thane and Vaitarana harbour mangroves. There are 15 river mouths, five major creeks and 30 backwater areas that have good mangrove forests in Maharashtra. Karnataka, Goa, Kerala and Pondicherry have much smaller areas under

Mangrove afforestation (*Rhizophora mucronata*)

Table 4. Lower groups of plants reported from different mangrove habitats in India

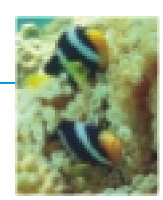
	Plants	No. of species
1	Marine algae	559
2	Bacteria	69
3	Fungi	103
4	Actinomycetes	23
5	Lichens	32

mangrove cover (Table 2).

Mangrove species

There are varying estimates of the number of mangrove species in India (Untawale, 1985; Banerjee *et al.*, 1989; Singh *et al.*, 1990). Kathiresan (2004) remarked that the absence of a clear cut definition of mangrove species explained much of this variation. He proposed categorization of mangroves into two groups, viz: the exclusive species (those species found in mangrove habitats between mean sea level and high tide levels); and the non exclusive species (those species not restricted to mangrove habitats alone, but also found above the highest high tide level of the landward region); he identified 69 species under 42 genera and 27 families. Of these, 63 species are present on the east coast, 37 species on the west coast and 44 species in the Andaman and Nicobar Islands. He concluded that there were 26 species common to all these regions (Table 3).

Maximum species diversity has been observed in mangroves of Orissa. There are 60 species in the state even though the total area occupied by these forests is only one tenth of the mangroves in West Bengal, which have 57 species. Karnataka and Kerala also



show more species diversity, 29 and 27 respectively, though the mangrove areas occupied in these states are much smaller (Table 3). Besides the mangrove species, salt marsh vegetation harbours 12 species and seagrass vegetation 11 species (Kathiresan, 2004).

Lower groups of plants

Mangroves belong to angiosperms but even lower groups of plants are important components of the mangrove ecosystem. There are a number of publications and reports on the occurrence of algae in mangrove habitats (Untawale and Parulekar, 1976; Pal *et al.,* 1988; Jagatap, 1992; Mani, 1994; Palaniselvan, 1998; Sen and Naskar, 2003; Anandaraman and Kannan, 2004). A compilation made by Kathiresan (2004) reports 559 species of algae from different mangrove habitats of India. Sixty nine species of bacteria (Martin, 1981; Abhaykumar and Dube, 1991; Vethanayagam, 1991; Chaudhuri and Choudhury, 1994; Shome *et al.,* 1995; Ravikumar, 1995), more than 100 species of fungi (including actinomycets) (Kathiresan, 2004; Ravikumar and Vittal 1996; Balagurunathan, 1992; Sivakumar, 2001) and 32 species of lichens (Santra, 1998) are reported from various mangrove habitats in India (Table 4). Of the 11 globally threatened mangroves, two species are found in India viz. *Sonneratia griffithii* and *Heritiera fomes* (Sundari) (Kathiresan, 2010).

Fauna

The mangrove ecosystem harbours a rich and varied fauna. An assessment of research so far carried out (Achuthankutty and Sreekumaran Nair, 1982; Rajagopalan *et al.,* 1986; Das and Dev Roy, 1989; Mandal and Nandi 1989; Chaudhuri and Choudhury, 1994; Hemal, 1997; Rajendran, 1997; Chadha and Kar, 1999) shows that there are 55 species of prawn and lobster in the mangrove ecosystem of India. Published works indicate that there are 138 species of crabs (Sethuramalingam and Ajmal Khan, 1991; Hemal, 1997; Chadha and Kar, 1999;

Table 5. Threatened species of fish in mangrove ecosystems of India

No	Name of species	Family	Status
1	*Arius subrostratus*	Ariidae	Vulnerable
2	*Boleophthalmus boddarti*	Gobiidae	Vulnerable
3	*Boleophthalmus dussumieri*	,,	Endangered
4	*Scartelaos viridis*	,,	Endangered
5	*Periophthalmus koelreuteri*	,,	Vulnerable
6	*Dasyatis uarnak*	Trygonidae	Vulnerable
7	*Elops machnata*	Elopidae	Vulnerable
8	*Leiognathus splendens*	Leiognathidae	Vulnerable
9	*Muraenichthys schultzei*	Muraenidae	Vulnerable
10	*Psammaperca waigiensis*	Centropomidae	Vulnerable
11	*Secutor ruconius*	Leiognathidae	Vulnerable

Source: Kathiresan (2000)

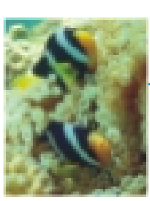


Table 6. Threatened species of invertebrates in mangrove ecosystems of India

No	Name of species	Family	Status
1	*Cardisoma carnifex*	Gecarcinidae	Critically endangered
2	*Geloina erosa*	Geloindae	Endangered
3	*Macrophthalmus convexus*	Ocypodidae	Endangered
4	*Meretrix casta*	Veneridae	Vulnerable
5	*Penaeus canaliculatus*	Palaemonidae	Vulnerable
6	*Penaeus japonicus*	Palaemonidae	Vulnerable
7	*Pilodius nigrocrinitus*	Xanthidae	Endangered
8	*Sesarma taeniolata*	Grapsidae	Vulnerable
9	*Uca tetragonon*	Ocypodidae	Endangered

Source: Kathiresan (2000)

Dev Roy and Das, 2000), 308 species of molluscs (Ganapathi and Rao, 1959; Subha Rao, 1968; Srinivasan and Chandramohan, 1973; Radhakrishna and Janakiram,1975; Dharmaraj and Nair, 1981; Rao, 1986; Kathiresan, 2004), 711 species of insects (Mandal and Nandi, 1989; Das and Dev Roy, 1989; Thangam and Kathiresan, 1993; Veenakumari *et al.,* 1997; Kathiresan, 2004) in Indian mangrove habitats. About 745 species of invertebrates have been recorded from the ecosystem (Radhakrishna and Janakiram, 1975; Shanmugam *et al.,* 1986; Das and Dev Roy, 1989; Ramamurthy and Kondala Rao, 1993; Balasubrahmanyan, 1994; Sunilkumar, 1995; Govindasamy and Kannan, 1996; Goswami and Padmavati, 1996; Srikrishnadhas *et al.,* 1998; Santhakumaran, 2000; Sultan and Ajmal Khan, 2000). Finfish group is represented by 546 species (Krishnamurthy and Prince Jeyaseelan, 1981; Prince Jeyaseelan, 1981; Das and Dev Roy, 1989; Mandal and Nandi, 1989; Ramamurthy and Kondala Rao , 1993 ; Chaudhuri and Choudhury, 1994; Venkateswaralu *et al.,* 1995; Chadha and Kar 1999; Gujarat Institute of Desert Ecology, 1997; Kathiresan, 2000); amphibians by 13 species (Das and Dev Roy, 1989; Mandal and Nandi, 1989; Rajasekharan and Subba Rao, 1993; Chaudhuri and Choudhury, 1994; Oswin, 1998; Chadha and Kar, 1999); reptiles by 85 species (Das and Dev Roy, 1989; Mandal and Nandi, 1989; Rajasekharan and Subba Rao, 1993; Chaudhuri and Choudhury, 1994; Hemal, 1997; Oswin, 1998; Chadha and Kar, 1999); birds by 433 species (Samanth, 1985; Das and Dev Roy, 1989; Mandal and Nandi, 1989; Rajasekharan and Subba Rao, 1993, Sampath and Krishnamurthy, 1993; Chaudhuri and Choudhury, 1994; Pandav, 1996; Chadha and Kar, 1999; Kathiresan, 2000) and mammals by 70 species (Mandal and Nandi, 1989; Chaudhuri and Choudhury, 1994; Oswin, 1998; Chadha and Kar, 1999; Kathiresan, 2000).

It has been found that out of 52 species of marine fish assessed, nine are vulnerable and two are endangered and of the 41 invertebrates assessed, four species are endangered, another four species are vulnerable and one species is critically endangered (Table 5

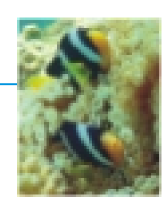


Table 7. Threat factors on mangrove ecosystems in India and their intensity

Threats	West Bengal	Orissa (Bhitarkanika)	Andhra Pradesh (Godavari)	Tamil Nadu (Pichavaram)	Andaman & Nicobar	Gujarat	Maharashtra	Goa	Karnataka	Kerala
Grazing	+	+	+	+++	+	++	-	-	-	-
Firewood & wood products	++	+	++	+++	+	+	+	+	-	-
Over exploitation of fishery resources	+++	+	+++	+++	+	-	-	+	-	++
Reclamation for agriculture	++	+	+	-	-	-	+	-	+	++
Aquaculture	+	-	+	-	-	-	-	-	-	-
Urban development/ human settlement	++	+	-	-	+	+	++	+	-	+
Bridge construction	+	-	+	++	-	++	-	-	-	-
Tourism	-	-	-	+	+	-	-	-	-	-
Shoreline/ Geomorphic changes	+	-	+	++	-	++	+	-	-	-
Pollution	++	-	+	-	-	+++	++	+	-	-
Port/harbour development	+	-	-	-	-	+++	-	-	-	-
Mining	-	-	+	-	-	++	+	-	-	-
Lack of awareness	-	+	+	+	+	++	+	+	+	++
Hyper salinity	+	-	-	++	-	++	-	-	-	-
Natural calamities	+	+	+	+	-	++	-	-	-	-
Siltation and sedimentation	++	+	++	++	-	-	-	-	-	-
	20	8	16	20	6	22	9	5	2	7

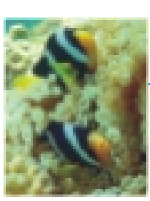
Number of + indicates intensity of threats, - not significant threats (after Kathiresan, 2004)

and 6). In Sundarbans, four species of reptiles (*Chelonia mydas, Eretmochelys imbricata, Caretta caretta, Demochelys coriacea*), three species of birds (*Leptoptilos javanicus, Sarkiodoruis melanotus, Cairina scutulata*) and five species of mammals (*Muntiacus muntjae, Bubalis bubalis, Rhinoceros sondaicus, Cervus deruches, Axis porcinus*) have become locally extinct (Chaudhuri and Choudhury, 1994).

Threat to mangroves

Mangroves are an entrepreneur's dream as they are capable of producing lignocellulose from sea-water. Industries such as forestry, fisheries and agriculture make use of mangrove ecosystems to their advantage and are often in conflict on sharing administrative domain and user rights. But it is the nature of this conflict that provides fertile ground for basic and applied research on conservation and management of mangrove communities.

Wood and non-wood products come first in exploitation of mangroves. Presence of quality timbers like *Heritiera fomes*, proximity to water for transportation and low diversity of ecosystem for extraction function as the beneficial factors for the industry.



However, use of heavy equipment for large scale exploitation is detrimental to the ecosystem. Unsawn poles extracted on a large scale destroy the ecosystem's health. Direct or indirect use of fuel wood after converting it to charcoal by local people exerts a heavy toll on mangrove ecosystem. Mangrove species having high tannin content (e.g. Rhizophoraceae species) are commercially exploited for industrial ethanol. *Nypa* palm is another source material. Phloem sap from the inflorescences of *Nypa* is used for this purpose. Intensive inshore commercial fishing and shrimp production adversely affect the ecosystem. Mangrove areas are converted for salt resistant varieties of crops like rice and for mariculture and aquaculture. Urbanization poses another major threat. Conversion of mangrove forests to salt pans in the dry season and shrimp production in the wet season also has serious impact. Apart from the above main threats, location specific threats are equally important.

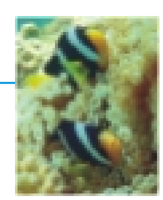
Location specific threats to mangroves in India

Major location specific threats to mangroves in India are over exploitation, changes in hydrological regimes, deforestation and local people's lack of awareness about the ecological services mangroves provide. Kathiresan (2004) has estimated that there are about 16 threat factors operating to cause degradation of mangrove ecosystems in different parts of India (Table 7).

Over exploitation

Destruction of mangroves by local populations is location specific. In West Bengal agriculture and prawn seed collection pose major threats while in Odisha the threats are from prawn farming and encroachment. In Tamil Nadu and Gujarat, locals over exploit mangroves mainly for cattle feed. In Mumbai, urbanization is the main thre-at. Constructing embankments for protection of agriculture fields in man-grove areas causes poor tidal flushing and poor natural regeneration and re-sults in reduction of mangrove area. Embankments in West Bengal (Sundarbans) reach a height of 3-4m, in Kerala 0.5-1 m and in Goa 2 m (Kathiresan, 2004). Pollution is another serious threat to them, especially in West Bengal and Maharashtra.

Mangroves require an appropriate salinity regime for maintenance of their ecological processes and ecosystem services. The salinity regimes are generated by mixing of freshwater and seawater. However, intensifying land uses within the river basins often leads to a higher priority for upstream water uses - for example, for agriculture, domestic and industrial uses, leading to reduced flows to downstream ecosystems and thereby altering the salinity regimes required for mangroves to survive. Preliminary studies indicate changes in mangroves species diversity within Tamil Nadu, Andhra Pradesh and West Bengal due to reduction in quantity and periodicity of freshwater flow. For example, freshwater discharge into the Coleroon river that supplies freshwater to the Pichavaram mangroves of Tamil Nadu reduced from 73 TMC (thousand million cubic feet) in 1930s to 31 TMC during 1980s and further to 12 TMC during early 1990s. Correspondingly, during this period mangroves with affinity for lower salinity levels and those sensitive to salinity,



disappeared from the Pichavaram mangroves leading to domination of saline tolerant species such as *Avicennia marina* (Selvam, 2001). Similar changes have been recorded in mangroves of Krishna and Godavari in Andhra Pradesh. In Sundarbans, reduction in freshwater flows from the Ganges has caused an increase in salinity and changes in sedimentation pattern and thereby a rapid decline in population density of *Heritiera fomes* (locally called Sundari) and *Nypa fruticans.*

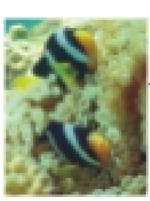
Changes in river courses resulting in erosion, reclamation of intertidal areas and natural calamities like cyclones and tsunami do extensive damage to mangroves. There were 366 cyclones between 1891 and 1970 along the Bay of Bengal, out of which 133 were severe in nature. There were 98 cyclones in the Arabian sea, of which 55 were highly destructive (Koteswaram, 1984). There were 72 earth quakes of severe to mild intensity in the Kachchh area alone. The tsunami that occurred on 26th December 2004 devastated many mangrove forests along the west coast (ISRO, 2005). High atmospheric temperature, a high rate of evaporation and low rainfall make mangrove areas hyper saline. This is a common situation in Tamil Nadu, Andhra Pradesh and Kachchh, which adversely affects plant growth. Flushing the hyper saline soil with tidal water through construction of artificial trenches is a good device. This is practised in Tami Nadu and Andhra Pradesh. Poor supply of fresh water has reduced the population density of *Kandelia candel, Bruguiera gymnorrhiza, Sonneratia apetala* and *Xylocarpus granatum* in Pichavaram (Selvam, 2001). Kathiresan (2004) reported that *Kandelia candel*, *Bruguiera gymnorrhiza* and *Sonneratia apetala* have become locally extinct in this area. Studies have revealed that wood borers cause heavy damage to mangroves (Rambabu *et al.,* 1987; Santhakumaran and Sawant, 1991).

Area specific threats

Main threats in Sundarbans are from conversion of mangrove areas for agriculture and over-exploitation of fisheries, especially for seeds of tiger prawns (Das *et al.,* 1987; Bhaumik *et al.,* 1992; Chaudhuri and Choudhury, 1994; Kathiresan, 2004). Reduced inflow of fresh water has badly affected the density of *Nypa fruticans* and *Heritiera fomes* in Sundarbans. Top dying disease has made heavy damage to *H. fomes.* Acid sulphate soil, pollution, siltation and sedimentation, erosion and embankment constructions are other serious threats.

Over-exploitation of juvenile tiger prawn is a serious problem in Sundarbans, as it affects adversely the food chain and fishery resources. In Sundarbans 540 million tiger prawn juveniles are collected every year and during this operation 10-26 billion other fish juveniles are killed (Kathiresan, 2000).

Major threats to mangroves of Bhitarkanika and Mahanadhi sites in Orissa are population pressure, indiscriminate felling, paddy cultivation, prawn farming and industrial development. About 20 villages in Mahanadhi area and 59 villages in Bhitarkanika are dependent on mangroves for their livelihood and it has been observed that the forests have degraded by 5 to 30% in Bhitarkanika and 20 to 60% in Mahanadhi areas. *Avicennia* is heavily pruned for its



excellent fodder. Cropping season aggrevates the situation. Encroachment by locals and Bangladeshi refugees has created a serious problem for the narrow mangrove forests in Odisha. Statistics show that an area of 8502 acres of mangroves is converted for aquaculture, 7690 acres in Mahanadhi deltas and 812 acres in Bhitarkanika (Kathiresan, 2004). Development of Paradip Port at the mouth of Mahanadhi river and Dhamra fishing harbour in Bhadrak district have taken a heavy toll on mangroves in the state.

Agriculture and prawn culture, tree felling for firewood and house/boat construction and extraction of cattle feed are the main threats to mangroves in Andhra Pradesh. Establishment of a fertilizer factory nearer to mangrove forests has aggrevated the situation (Banerjee *et al.,* 1998). Heavy human pressure and associated problems of cattle grazing, siltation and hyper salinity are the important threats to mangroves in Tamil Nadu. In Pichavaram, the daily firewood need is estimated at 6 tonnes for 2000 families and the daily fodder need about 7 tonnes for 1800 cattle and goats (Kathiresan, 2004) which mostly graze on *Avicennia.* Pichavaram mangrove forest has already lost 75% of its green cover in the last century.

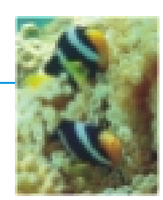
Heavy deposition of suspended sediments is the major problem in the Gulf of Mannar. The suspended load moves from Vedaranyam towards Rameshwaram Islands ultimately damaging the coral reef and seagrass ecosystem in the islands (Shanmugaraj, 1998).

Gujarat mangroves are unique as they are called 'open scrub mangroves' and are considered as the 'most degraded' (Blasco, 1975). Local demand for fodder and firewood and developmental activities like dam construction, mining, cement and salt pan industries, pipeline passages and refineries have caused destruction to the ecosystem. In Kandla Port area, vast mangrove areas have been reclaimed for port development. Urbanization, human settlement and industrial and sewage pollution are the major problems faced by mangrove ecosystems in Maharashtra. Private ownership of large mangrove areas in the state has intensified the situation. Mangrove vegetation on the Karnataka coast faces threats from agriculture or aquaculture operations, tree felling and pollution. Kerala had 70 Km^2 of mangrove cover once and this is now reduced to 5 Km^2. Out of this, 88% are in private ownership. Removal of mangrove lands for agriculture, firewood, construction of roads, houses and bunds has drastically affected the mangrove swamps in the state. Mangrove habitats in the Andaman and Nicobar Islands are better preserved than those on the mainland. Still, demand for wood and wood products, conversion of these habitats for agriculture, tourism development and encroachment have been adversely affecting this ecosystem in many sites of the Islands.

Remedial measures to threat factors

Tree felling

Local communities may be persuaded to cultivate fast growing species like *Avicennia* in degraded areas. Simple technical know-how can be imparted for this purpose. Alternate sources of timber such as *Casuarina* may be encouraged. Silviculture



strategies of practising crop rotation once in 15 years in alternate strips (60m wide at an angle of 45° to the waterways) and natural regeneration using seeds of nearby mangrove trees can be implemented.

Cattle grazing

Ban on entry of cattle can be implemented during the monsoon as they graze on mangrove seeds and seedlings in this period. Alternate sources of locally available fodder can be provided. Locals may be encouraged to cultivate fodder species through inter-cropping with *Casuarina*. Dairy Development schemes can be implemented for local communities. Biofencing using toxic mangroves like *Excoecaria agallocha* can also be practiced.

Unsustainable fishing practices

There should be devices that can prevent mechanised craft operations in shallow waters. Only fishing nets with >20mm mesh size that prevent the catch of juvenile fishes should be allowed for fishing. Fishing activities during the critical stage of fish breeding (pre-monsoon and summer) may be banned thereby allowing development of juvenile fishes.

Shrimp farming

Government of India has put a ban on intensive or semi-intensive shrimp farming practices, especially along the ecologically sensitive mangrove areas. The extent of mangrove areas that are reclaimed for prawn farming practices and the area of abandoned ponds are not clearly known. Abandoned shrimp ponds can be restored and recovered by mangrove planting. Environmentally sound aquaculture integrated with mangrove silviculture and fisheries for the benefit of local communities may be developed.

Lack of people's participation

Educating people who dwell in and around mangrove habitats about the ecosystem services of mangroves and involving them in conservation processes are the best strategies. Local people, particularly womenfolk, should be involved in planning and implementation of management action plans. Firearms should not be allowed so as to prevent poaching of wildlife in mangrove forests.

Reduced freshwater supply

Poor rainfall and dam construction in upstream areas reduce freshwater supply that is required for germination and sprouting of seeds and seedlings of mangroves. Reduction in freshwater inflow has changed the plant species composition of mangroves: reduction of *Nypa fruticans* and *Heritiera fomes* and increase of *Ceriops* species in Sundarbans increase in focus, so also the spread of salt marsh bushes (*Suaeda* spp.) in Tamil Nadu and Andhra Pradesh (Kathiresan, 2000). The water flow reduction in rivers, that feed mangrove habitats should be prevented for this purpose. Any waterway barrier that drastically affects mangroves may also be banned or controlled.

Hyper salinity

The brackish waters which accumulate in the bowl-shaped mangrove habitats during monsoons turn hyper saline during summer and ultimately kill or retard growth of mangroves. These areas become barren after some years. The situation is aggravated by

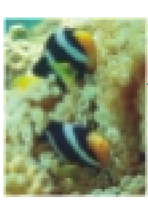


Table 8. Mangrove cover in India (Forest Survey of India, 2011)

Sl. No.	State/UT	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change w.r.t. 2009 assessment
1.	Andhra Pradesh	0	126	226	352	-1
2.	Goa	0	20	2	22	5
3.	Gujarat	0	182	876	1058	12
4.	Karnataka	0	3	0	3	0
5.	Kerala	0	3	3	6	1
6.	Maharashtra	0	69	117	186	0
7.	Odisha	82	97	43	222	1
8.	Tamil Nadu	0	16	23	39	0
9.	West Bengal	1038	881	236	2155	3
10.	A & N Islands	283	261	73	617	2
11.	Daman & Diu	0	0.12	1.44	1.56	0.56
12.	Puducherry	0	0	1	1	0
	Total	1403	1658.12	1601.44	4662.56	23.56

Table 9. Rare, endemic and restricted mangrove species in India

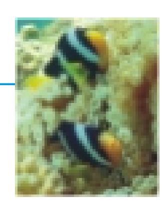
No	Species	Rare/Endemic/ Restricted distribution
1	*Acanthus ebracteatus*	Restricted to Andaman
2	*Aegialitis rotundifolia*	Confined to West Bengal, Orissa & Andhra Pradesh
3	*Aglaia cuculata*	Restricted to West Bengal & Orissa
4	*Brownlowia tersa*	Restricted to West Bengal, Orissa & Andhra Pradesh
5	*Heritiera fomes*	Restricted to West Bengal & Orissa
6	*Heritiera kanikensis*	Endemic to Bhitarkanika
7	*Lumnitzera littorea*	Restricted to Andaman
8	*Merope angulata*	Confined to West Bengal & Orissa
9	*Nypa fruticans*	Restricted to West Bengal & Andaman
10	*Phoenix paludosa*	Restricted to West Bengal, Orissa & Andaman
11	*Rhizophora annamalayana*	Endemic to Pichavaram
12	*Rhizophora stylosa*	Confined to Orissa
13	*Scyphiphora hydrophyllacea*	Restricted to Andaman & Andhra Pradesh
14	*Sonneratia apetala*	Rare in several areas
15	*Sonneratia griffithii*	Restricted to West Bengal, Orissa & Andaman
16	*Tylophora tenuis*	West Bengal & Orissa
17	*Urochondra setulosa*	Endemic to Gujarat
18	*Thespesia populneoides*	Restricted to West Bengal & Orissa
19	*Xylocarpus mekongensis*	Restricted to West Bengal, Orissa & Andaman
20	*Xylocarpus mollucensis*	Restricted to Andaman

Source : Kathiresan (2003)

poor precipitation and poor flux of fresh or tidal waters. The dry hyper saline soil should be flushed with tidal waters through the construction of artificial creeks. There should be devices to drain stagnant saltwater in the mangrove habitats before summer.

Heavy siltation

This blocks river mouths and



reduces fertility of the estuarine ecosystem. There should be programmes to implement massive planting to strengthen river banks. Mangroves may be planted on the mudflats that are newly formed by siltation.

Natural calamities

The cyclone and tsunami prone areas should be identified and these areas should be strengthened with mangrove planting.

Climate change

Sea level rise is the greatest climate change that mangroves will face. Mangroves are likely to absorb and respond to the climate change if the rate of sediment accretion is sufficient to keep with sea level rise and if adequate expansion space exists without any interference caused by infrastructure and topography. Thus mangrove restoration can be an efficient counter-measure for sea level rise.

Conservation status

Mangrove cover and species

Forest Survey of India (2011) categorised mangrove cover into *very dense* (canopy density more than 70%), *moderately dense* (canopy density between 40-70%) and *open* mangrove (canopy density between 10-40%). This assessment shows that mangrove cover in India is 4,662.56 km^2, which is 0.14% of the country's total geographical area. The *very dense* mangrove comprises 1,403 km^2 (30.1% of mangrove cover), *moderately dense* mangrove has 1,658.12 km^2 (35.57%), while *open* mangrove covers an area of 1,601.44 km^2 (34.33%) (Table 8). A marginal net increase has been recorded in the mangrove cover of the country. Gujarat has shown a significant net increase in mangrove cover (see Table 2). The increase in Gujarat is the result of large

Table 10. Species selection with respect to the purpose of planting

Purpose of planting	Species
Natural regeneration	*Avicennia officinalis, Aegiceras corniculatum, Excoecaria agallocha, Acanthus ilicifolius*
Coastal protection against tidal waters, erosion and cyclones	*Rhizophora apiculata, R. mucronata, Sonneratia alba, Avicennia officinalis, Heritiera fomes, Kandelia candel*
Protection of lagoons and estuaries	*Avicennia marina, A. officinalis, A. alba, Bruguiera cylindrica, Rhizophora apiculata, R. mucronata, R. stylosa, Sonneratia caseolaris, S. alba, Kandelia candel, Acanthus ilicifolius*
Dike protection along the sea and aquaculture farms	*Avicennia marina, A. officinalis, A. alba, Ceriops tagal, Rhizophora apiculata, R. mucronata, R. stylosa, Sonneratia caseolaris, Bruguiera gymnorrhiza, Excoecaria agallocha*
Greening of barren coasts	*Avicennia officinalis, Ceriops tagal*
Restoration of mining areas	*Rhizophora* spp.
Introduction to new mudflats	*Rhizophora mucronata, R. apiculata, Avicennia marina, A. officinalis, Aegiceras corniculatum*
Harvest of forest products, timber, charcoal and fire wood	*Sonneratia alba, S. apetala, Avicennia marina, A. officinalis, Rhizophora apiculata, R. mucronata, Ceriops tagal, Bruguiera gymnorrhiza, Kandelia candel, Heritiera fomes, Xylocarpus granatum*
Enhancement of fishery resources	*Avicennia and Bruguiera* spp.

Source : Kathiresan (2003)

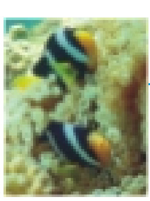


Table 11. Adaptability of species to different sites

Species	Adaptability/Preferable site
Avicennia marina	Relatively dry tidal lands, river banks or highly saline flats, arid zones
Bruguiera gymnorrhiza	With large freshwater supply
Ceriops tagal	High saline areas
Nypa fruticans	Site covered with grasses having lower level tidal inundation, low salinity
Rhizophora apiculata	Muddy sites of estuaries and mudflats
Rhizophora mucronata	Muddy sites of estuaries and mudflats
Rhizophora stylosa	Close to sea, to be grown in areas of low tidal amplitude
Sonneratia alba	Close to sea, moderately saline areas
Xylocarpus granatum	Low saline sites, at tidal amplitude area

Source : Kathiresan (2003)

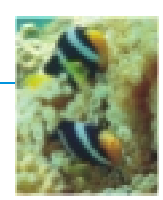
Table 12. Zonal preference of species

Tidal zone	Preferred species
High and mid-water levels	*Avicennia marina, Bruguiera cylindrica, B. gymnorrhiza, B. parviflora, B. sexangula, Ceriops decandra, C. tagal, Excoecaria agallocha, Scyphiphora hydrophyllacea, Heritiera littoralis, H. fomes, Sonneratia caseolaris, Xylocarpus granatum, X. mekongensis*
Mid and low-water levels	*Rhizophora* spp., *Sonneratia alba, Aegiceras corniculatum*
High-water levels	*Nypa fruticans and Lumnitzera* sp. = *L.littorea*

scale plantations as well as the protection measures taken by the state (Singh, 2006; FSI 2011).

It is estimated that mangrove forests are declining at a rate of 2.8% per year. This figure will be much more for India if degrading forests are also taken into account. Since mangroves are constituted by floristic and faunistic elements, conservation measures should be targeted towards conservation of the ecosystem as a whole rather than the individual species. At the same time it is desirable that the conservation status of important components of the ecosystem and different aspects of ecosystem functioning are studied. Rare, endemic and threatened species should come in the priority list and their population dynamics and reproductive phases should be assessed to develop conservation strategies for individual species at local level as the nature of threats may vary from location to location. The nature of interactions, especially connected with food webs, among different species in the ecosystem has to be analysed for conservation of the mangrove ecosystem. No study in this direction has been carried out in India. Kathiresan

Aegiceras corniculatum fruit



(2004) has listed 20 species of mangroves as rare, endemic and restricted in distribution (see Table 9, modified).

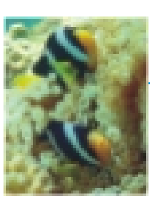
Widely distributed species like *Aegiceras corniculatum, Acanthus ilicifolius, Avicennia marina, A. officinalis* and *Excoecaria agallocha* have greater ecological amplitude and they show a remarkable ability for vegetative regeneration. Even such species and other common species like *Avicennia, Excoecaria, Bruguiera* and *Rhizophora* may come under the threatened category if mangrove forests are exploited continuously for fuel, timber, fodder, building materials, tannin and paper pulp.

Conserving biodiversity by restoration

Mangroves can be successfully restored by direct planting of seeds and propagules or planting seedlings reared in nurseries. Reared seedlings can be used for species which produce seeds seasonally or in small quantities. Species with lengthy propagules like Rhizophoraceae members can be planted directly whereas small seeds or propagules of species like *Avicennia, Sonneratia* and *Excoecaria* can be raised in a nursery. Restoration should be aimed at conserving biodiversity, protecting native species and introducing suitable indigenous species which are compatible to enhance the productivity of forest ecosystems. Knowledge about population dynamics, reproductive biology, seedling demography and pollinators and dispersers of the species in question makes species selection an easy process. The purpose of planting, adaptability and zonal preferences of

Table 13. Mangrove areas of India under Management Action Plan

State/Union Territories		Mangrove sites
West Bengal	1.	Sundarbans
Odisha	2.	Bhitarkanika
	3.	Mahanadi
	4.	Subernarekha
	5.	Devi
	6.	Dhamra
	7.	Mangrove Genetic Resources Centre
	8.	Chilka
Andhra Pradesh	9.	Coringa
	10.	East Godavari
	11.	Krishna
Tamil Nadu	12.	Pichavaram
	13.	Muthupet
	14.	Ramna
	15.	Pulicat
	16.	Kazhuveli
Andaman & Nicobar	17.	North Andamans
	18.	Nicobar
Kerala	19.	Vembanad
	20.	Kannur (Northern Kerala
Karnataka	21.	Coondapur
	22.	DakshinKannada/Honnavar
	23.	Karwar
	24.	Manglore Forest Division
Goa	25.	Goa
Maharashtra	26.	Achra-Ratnagiri
	27.	Devgarh-Vijay Durg
	28.	Veldur
	29.	Kundalika-Revdanda
	30.	Mumbra-Diva
	31.	Vikroli
	32.	Shreevardhan
	33.	Vaitarna
	34.	Vasai-Manori
	35.	Malvan
Gujarat	36.	Gulf of Kuchchh
	37.	Gulf of Khambhat
	38.	Dumas-Ubhrat



species are also very important for successful restoration programmes (see Tables 10-12).

Tidal amplitude, soil and light conditions, coastal changes and pollution status are other important factors that should be considered while selecting species for restoration. It has been found that *Rhizophora* spp., *Sonneratia apetala* and *S. alba* prefer high tidal amplitudes while *Avicennia* spp. middle tidal amplitude and *Xylocarpus moluccensis, Sonneratia caseolaris, Nypa fruticans, Bruguiera gymnorrhiza, Acanthus ilicifolius* and *Excoecaria agallocha* prefer low tidal amplitude.

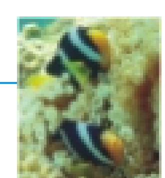
Mangrove species which show tolerance to salinity are *Avicennia marina, Lumnitzera littorea, L. racemosa, Rhizophora* spp., *Aegiceras corniculatum, Ceriops tagal, Excoecaria agallocha, Kandelia candel, Sonnertia alba, Xylocarpus granatum* and *X. mekongensis* and those which need low saline condition are *Sonneratia caseolaris, Nypa fruticans, Heritiera fomes, Bruguiera sexangula, B. cylindrica, Xylocarpus moluccensis* and *Acanthus illicifolius*. They prefer sites with a flow of freshwater. The presence of salt marsh species like *Suaeda* indicates hyper salinity of soil. In such sites it is better that salt marsh species are removed before planting mangroves (Kathiresan and Qasim, 2005).

Accumulation of H_2S can kill mangroves if their pneumatophores are covered by silt as they would not be in a position to transport oxygen to rhizosphere. *Rhizophora* spp. can survive on aged mangrove soil with deep mud and a high concentration of H_2S as they have aerial roots. *Avicennia* species have been found ideal for soils with high organic load if pneumatophores remain healthy.

Avicennia marina is capable of resisting high sunlight intensity with hot and dry conditions. Other species which tolerate more light are *Lumnitzera racemosa, L. littorea, Sonneratia alba, Xylocarpus granatum, X. mekongensis, Kandelia candel, Excoecaria agallocha, Ceriops tagal, Bruguiera gymnorrhiza* and *Aegiceras corniculatum*. Species which are not suitable for hot and dry conditions are *Nypa fruticans, Bruguiera sexangula, Heritiera fomes, Sonneratia caseolaris, Bruguiera parviflora, Heritiera littoralis* and *Cynametra iripa*. Mangrove species which are tolerant of shady conditions are *Acanthus ilicifolius, Bruguiera gymnorrhiza, B. sexangula, B. cylindrica, Ceriops decandra, Excoecaria agallocha, Xylocarpus granatum, X. mekongensis* and *Heritiera littoralis*.

It is observed that pneumatophore-bearing *Avicennia* species are not suitable for areas where sedi-

A view of mangrove afforestation, Muthupet



ment accretion is high. Stilt root-bearing species are better in such conditions. Members of Rhizophoraceae are better suited in sites with high metal and oil pollution. Avicennia spp. are found to be tolerant to high organic pollution (Kathiresan and Qasim, 2005).

Management policies

The Ministry of Environment and Forests, Government of India, constituted a National Committee in 1979 to promote research, development and management of the coastal environment. The Committee was endowed with the following objectives:

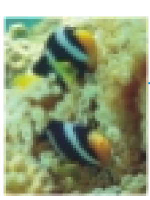
- Nationwide mapping of coastal areas, preferably by remote sensing techniques coupled with land surveys, to make an assessment of the rate of degradation of the ecosystem.
- Quantitative assessment of mangrove forests and their areas, climatic regime, rate of growth of forest trees and seasonal variations in environmental parameters.
- Research and development activities such as ecology, resource inventory, associated flora and fauna, hydrology, energy flow, qualitative and quantitative studies on organic production, biochemistry of organic matter and sediments, afforestation of degraded mangrove areas and management of mangrove forests.
- Assessment of suitable sites for declaration as Reserve Forests and undertaking of their intensive conservation programmes.
- Development of plans to manage key species of economic and ecological importance for sustainable utilisation.
- Regulation or stoppage of exploration of resources from sensitive sites depending on the levels of genetic diversity of the site.
- Monitoring of the environment on a regular basis.
- Formation of a high powered Advisory Committee representing State Government Departments, NGOs, Scientific Institutions and local stakeholders for making effective policy decisions.
- Maintenance of linkages with research and educational institutions.

This Committee was also entrusted with duties such as :

- Advising the Government on appropriate policies and action plans for conservation of mangroves.
- Advising on research and training on mangroves.
- Suggesting selective areas for conservation.
- Helping the Government in the development of collaborative projects with international funding agencies and intergovernmental bodies in the field of conservation of mangroves.

There are Steering Committees besides the National Committee at

Rhizophora mucronata nursery



different state levels functioning since 1986. These Committees are entrusted with the responsibilities to identify the potential areas and draft management action plans for these areas. They submit their plans to the National Committee for financial assistance. There are 38 such areas in nine states which receive financial support from the Government of India (see Table 13).

Management action plans

Location specific management and conservation techniques have to be adapted to different mangrove areas and interaction among the managers of different mangrove areas is necessary for the success of Management Action Plans which in turn should be supplemented by research inputs. The Ministry of Environment and Forests (MoEF) provides financial assistance on a 100% grant basis for the following components:

- Survey, assessment and demarcation.
- Capacity building, staff training and skills.
- Shelter belt development
- Protection and monitoring
- Restoration measures
- Community participation
- Mangrove afforestation/plantation (degraded areas and open mud flat cover by mangrove planting)
- Biodiversity conservation
- Sustainable resource development
- De-silting
- Weed control
- Pollution control
- Alternate / supplementary livelihoods and eco-development activities.
- Environmental education and awareness.
- Impact assessment through concurrent and terminal evaluation.

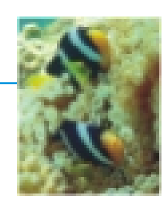
Sonneratia alba, with pneumatophores

The MoEF is one of the funding agencies for mangrove research programmes. It has identified the following thrust areas for under-taking research projects :

- Taxonomy and biodiversity
- Species under threat
- Restoration technology
- Status of mangrove health
- Aquaculture impacts
- Mangroves for prevention of coastal erosion and in the mitigation of flood damage.

Projects on the above thrust areas are being implemented through identified nodal institutions. The National Committee helps to integrate the outcomes of research projects with the management action plan; reviews the progress of the ongoing research projects and recommends new projects in identified thrust areas for funding.

The Government of India has es-



tablished a National Mangrove Genetic Resource Center at a place where the maximum number of mangrove species of the country is present in a single area – Kalibhanji Di at Bhitarkanika in Orissa. This center helps to protect genetic diversity of mangroves and safeguard the endangered species so that propagation and multiplication can be done to maintain the biodiversity. Web sites on mangroves and establishment of Database Net Work with focal points on the east and west coasts, along with other network partners in the country, have been launched. The Government of India has prepared a National Action Plan on mangroves and has evolved strategies for its implementation ensuring community participation in conservation efforts.

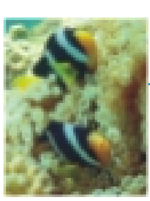
To streamline the activities of mangrove afforestation, conservation and management, a sub-committee was constituted by the Ministry of Environment and Forests in June 2000. The Committee recommended the following:

- Assess the accurate figure for the status of mangrove cover in different parts of our country.
- Bring all the agencies of each state working for the cause of mangroves under the umbrella of a state level Mangrove Steering Committee.
- Conduct compulsory mangrove training for the field staff at national level once in a year with afforestation and management aspects.
- Make small and large industries responsible for Compensatory Mangrove Afforestation Programme and encourage private owners to protect mangroves.
- Identify and encourage well established NGOs who are effectively working for mangroves.
- Identify much more potential areas by the state level Steering Committee for effective afforestation and management.
- Consider seriously the diversification of species in plantation programmes instead of confining these to a few species like *Avicennia.*

A review of scientific literature on mangroves of India carried out by Kathiresan (2000) emphasised the need for promoting research in the following fields:

- Techniques for efficient propagation of threatened mangrove species.
- Techniques for efficient rehabilitation of degrading mangrove areas and development of potential mangrove areas.
- Methodology for strengthening strong participation of mangrove dependent communities in management of mangroves.
- Technology for providing alternative livelihood options and income generation for mangrove dependent communities.

Avicennia marina



- Investigation on causes of mangrove degradation/damage to suggest appropriate remedial measures, especially for the problems related to pests and diseases.
- Exploration of faunal and floristic species in all the areas of mangroves.
- Bioprospecting of high value products of mangroves like medicines.
- Continuous monitoring of protected mangrove ecosystems.

An amount of Rs 13.17 crores was given to States and Union Territories for implementation of Management Action Plans for mangroves (including coral reefs) during the 9th Five Year Plan. About Rs 12 crores were released to coastal States and Union Territories from 2002 to 2005 for activities like survey and demarcation, afforestation, restoration, alternative / supplementary livelihoods, protection measures and education and awareness programmes. The draft National Environment Policy 2005 lays great emphasis on conservation and management of mangroves in the country. It calls for mainstreaming sustainable management of mangroves into the forestry sector regulatory regime.

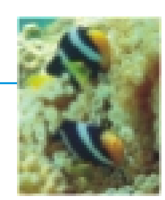
Legal framework

The Government of India protects mangroves with the support of legislative and regulatory measures. The Forest Conservation Act 1980 insists on avoiding conversion of mangrove forest areas for non-forestry purposes. Mangrove ecosystems are recognised as ecologically sensitive areas under the Environmental (Protection) Act 1986. This has legally prevented the discharge of industrial waste and dumping of other kinds of solid and liquid wastes to these areas. A total ban has been imposed in 1986 on felling of mangrove trees.

The Coastal Regulation Zone (CRZ) notified in 1991 by the Ministry of Environment and Forests, Government of India prohibits any developmental activities in mangroves having an area of 100 m^2 or more along the beaches which are included as ecologically sensitive areas in the CRZ 1 with a buffer zone of at least 50m along the coast from the highest high tide mark.

Environment Impact Assessment (EIA) carried out under the EIA Notification 1994 for specialized industries, monitoring of compliance with conditions imposed while according Environment Clearance by Regional Offices of the Ministry and State Pollution Control Boards, enforcement of emission and effluent standards by industries and other entities and recourse to legal action against the defaulters provided legal protection for conservation of mangrove ecosystem. However, we have many instances to prove that legal protection alone can not create any impact on mangrove conservation.

National Conservation Strategy and Policy Statement on Environment and Development (1992) highlight conservation and sustainable development of mangroves including coastal areas and riverine and island ecosystems. Similarly, National Forest Policy and National Wildlife Action Plan emphasise conservation of mangroves on scientific principles of evolution and genetics. Though mangrove areas of the county are mostly under the control of the Forest Departments, the legal and regulatory agencies are manned by



personnel from other Departments. Hence, in most of the cases, there has not been any serious effort for imposition of various laws and enactments meant for protection of mangroves.

Marine Protected Areas (MPA) established by the Government of India (1973-1999) aim to conserve the natural marine ecosystems in their pristine condition.

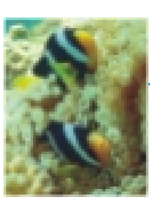
Conclusions

Mangrove ecosystems provide ecological security and support coastal livelihoods through a multitude of ecosystem services. Decision makers at many levels are often unaware of the connections between ecosystem condition, provision of ecosystem services and consequent impact on human well being. In very few instances are the decisions informed by estimates of total economic value of both marketed and non marketed benefits provided by the ecosystems.

Mangroves provide ecosystem services under all the four categories of ecosystem services. They serve as breeding, feeding and nursery grounds for many fishes in the offshore and inshore waters. They also provide feeding and breeding grounds for birds, reptiles and mammals. They are a source of forestry products such as firewood, timber and honey. For instance, mangroves of Sunderbans provide employment to more than 2,000 households engaged in extracting 111 tonnes of honey annually. The mangroves also have bioprospecting potential such as black tea beverage, mosquito repellents, microbial fertilizers, and medicines for various diseases. These ecosystems play a major role in the global cycle of carbon, nitrogen as well as sulphur and act as reservoirs in the tertiary assimilation of wastes (Kathiresan and Qasim, 2005).

In the recent years, there is an increasing body of research elucidating the immense contribution of these ecosystems in concrete economic terms, making comparison possible with alternate economic opportunities with defined cost and benefit streams. Application has been varied globally, resulting in economic estimates for various ecosystem services. For example, in American Samoa, mangroves with an extent of just 0.5 sq km have an estimated annual value of US$ 50 million (Spurgeon and Roxburgh, 2005). In Thailand, high values of US$ 2.7 – 3.5 million per sq km have been reported for the mangroves (Santhirathai and Barbier, 2001). Mangroves of India constitute upto 2.5% of the total economic value of global mangroves, which is estimated as equivalent to US $ 4.5 billion (Costanza *et al.,* 1998). This is considered greater than the economic value of coral reefs, continental shelves and the open sea. The economic value of 1 hectare area of Sundarban forest in India has been rated at Rs 5,43,547 (US$ 11,819). The total value of one hectare of mangrove area, over 20 years of its life span, works out at Rs 1,08,73,480 (US$ 2,36,380). It is considered that the benefits of mangroves are 25 times higher than that of paddy cultivation in India (Kathiresan, 2003). Over the past 50 years, approximately one-third of the world's mangrove forests has been lost (Alongi, 2002).

The current review indicates that significant efforts are underway, both at policy as well implementation levels, to ensure conservation and management of mangroves in India. However, the task involves coordination with multiple sectors and stakeholders and therefore much still remains to be done. There is an impending need to link mangroves with



ICZM, river basin catchment management and oceans and fisheries management so as to secure their conservation and sustainable use.

Badola and Hussain (2005) carried economic assessment of storm protection function of Bhitarkanika mangrove ecosystem and estimated cyclone damage avoided in three selected villages, taking cyclone of 1999 as reference. Economic assessments indicated highest loss in village that was not sheltered by mangroves but by embankments, with the least per capita damage in village with mangroves as barrier. Das and Vincent (2009) validated the storm protection function of mangroves of Orissa on India's east coast and established that villages with wider mangroves between them and the coast experienced significantly fewer deaths than ones with narrower or no mangroves. These benefits are not expected with concrete coastal protection structures (Danielsen *et al.,* 2005). The tsunami (26th December 2004) which devastated parts of south western coast of India devoid of mangrove vegetation has amply demonstrated the role of mangroves in coastal protection in terms of human life (Kathiresan and Rajendran, 2005), the benefit of which can not be equated to US dollars or Indian rupees.

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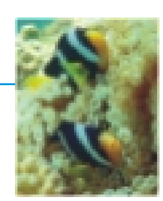

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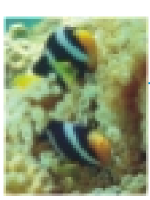

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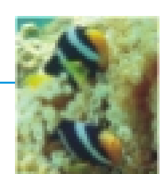

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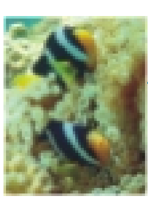

Seagrasses of India: present status and future needs for effective conservation

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Abstract

Compilation on biodiversity of seagrasses lists about 19 species, but in reality it is only 14 species and some of the species which are reported to be present have been misidentified and interpreted. Seagrasses in Gulf of Mannar and Lakshadweep have been well studied, while in other areas like Palk Bay, Gulf of Kachchh and Andaman and Nicobar islands they have been given only a little attention. Distribution, morphology and anatomy studies, ecology, biomass and productivity of seagrasses have been studied in detail in different parts of the country. Reports on biochemical composition, antimicrobial activity, microbiological investigations, insecticidal activity, seagrass liquid fertilizers, floral and faunal association and as bioindicators are also available. There are lacunae in seagrass conservation, which include no distributional maps, no continuous monitoring, no historical data collections for comparison and estimation of seagrass loss, no economical valuation of the ecosystem services, no standardized site specific seagrass restoration techniques, no identified species for restoration, and lack of awareness among the people and policy makers. All these factors necessitate intense studies on the above aspects besides better conservation of this fragile ecosystem through proper integrated management plans.

Introduction

Seagrasses are the only flowering plants, capable of completing their life cycles when they are submerged completely in seawater. They occur in all the coastal areas of the world except the polar regions probably due to ice scouring (Robertson and Mann, 1984). Of the 13 genera and 60 species of seagrasses reported all over the world, India has 14 species belonging to six genera (Kannan *et al.*, 1999). Seagrass meadows play a significant role in the near shore dynamics and nutrient cycling in coastal ecosystems. These ecosystems are becoming well known for their high primary and secondary productivity, ability to stabilize sediments, production of vast quantities of detritus and support to diverse floral and faunal communities. Above all, this ecosystem supports the very existence of endangered marine animals like sea cow (*Dugong dugon*) and green turtle (*Chelonia mydas*).

Distribution

Reports on seagrass distribution along the Indian coast have been available since 1959. Most of those early reports on seagrasses were made in association with other flora. Occurrence and distribution of seagrasses in different parts of the Indian coast were reported by several workers. However, there is no agreement regarding the number of seagrasses distributed along India's coast. The compilation made by Kannan and Thangaradjou (2006) using published literature provides a list of 19 species of seagrasses (Table 1).

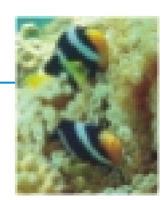


Table 1. List of seagrass species reported from India

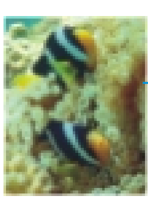
S.No.	Seagrass species	1	2	3	4	5	6
	Correct Species						
1.	*Enhalus acoroides*	+	+	+	+	+	+
2.	*Halophila beccarii*	+	+	+	+	+	
3.	*H. decipiens*	+	+	+	+	+	
4.	*H. ovalis* sp. *ovalis*	+	+	+	+	+	+
5.	*H. ovalis* sp. *ramamurthiana*	-	+	+	+	+	
6.	*H. ovata*	+	+	+	+	+	
7.	*H. stipulacea*	+	+	+	+	+	
8.	*Thalassia hemprichii*	+	+	+	+	+	+
9.	*Cymodocea rotundata*	+	+	+	+	+	+
10.	*C. serrulata*	+	+	+	+	+	
11.	*Halodule pinifolia*	-	+	+	+	+	
12.	*H. uninervis*	+	+	+	+	+	+
13.	*H. wrightii*	-	+	-	+	+	
14.	*Syringodium isoetifolium*	+	+	+	+	+	+
	Species in question						
15.	*S. acorodes*	-	-	-	-	+	-
16.	*Ruppia marittima*	+	-	+	-	-	-
17.	*Portresia coarctata*	-	-	-	-	+	-
18.	*Urochondra setulosa*	-	-	-	-	-	+
19.	*Zostera marina*	-	-	-	-	-	+

Source: 1, Jagtap, 1991; 2. Ramamurthy, *et al.,* 1992; 3. Jagtap, 1996; 4. Kannan, *et al.,* 1999; 5. Ramesh and Ramachandran, 2001; 6. Srinivasan and Rajendran, 2003.

But in reality it is only 14 species of seagrasses that are present in India (Ramamurthy *et al.,* 1992; Kannan *et al.,* 1999). Some of the species which are reported to be present might have been misidentified and interpreted. There are reports about the distribution of *Ruppia marittima* from the Krusadai Island, but recent surveys and surveys conducted by Ramamurthy *et al.* (1992) could not record this species from this island of the Gulf of Mannar. Likewise, *Zostera marina* is a typical temperate species and there is no possibility of its distribution on India's coast. Some of the reports have included *Portresia coarchtata* and *Urochondra setulosa* as seagrasses, but they are terrestrial grasses growing in marshy environments. There are no reports about the presence of the seagrass species *Syringodium acoroides* as reported by some workers, and this could have been confused with *Stratiotes acoroides,* which is the old name for *Enhalus acoroides*.

Ecology

Literature on ecological investigation on seagrasses has been available since 1963. *Halophila beccarii* grows luxuriantly in the temperature range of 26-33°C and during the flowering season, the biomass of this species increases up to 24.44g/m^2 (Jagtap and Untawale, 1984). Balakrishananair *et al.* (1983) found that when sand was predominant in the substratum (92.56%) the plant density was low, whereas in clay dominated substratum



the density of the seagrass was high. *Halodule uninervis* and *Halophila* spp. are the major species in the seagrass ecosystem of the Gulf of Mannar. The growth rate of other species was found to be determined *inter alia* by the establishment of these species, which tend to be form monospecific communities and even pure stands of a single species (Rajeshwari and Kamala, 1987). The ecology of seagrass beds in different regions was studied by different authors during various periods: Gulf of Mannar (Ganesan, 1992; Vinithkumar *et al.*, 1999; Thangaradjou, 2000, Jagtap *et al.*, 2003, Thangaradjou and Kannan, 2005; Thangaradjou and Kannan, 2007); Palk Bay (Kannan, 1992; Kannan and Kannan, 1996; Sridhar *et al.,* 2008); Andaman and Nicobar (Thangaradjou *et al.,* 2010a,b). Thangaradjou and Kannan (2005) found that the seagrasses *Enhalus acoroides*, *Thalassia hemprichii, Halodule* spp. and *Halophila* spp. preferred silty to clayey soils, while *Cymodocea* spp. and *Syringodium isoetifolium* preferred sandy soil for their growth in the Gulf of Mannar region. Differences in nutrients concentrations and silt compositions favour higher diversity and density of seagrasses (Thangaradjou and Kannan, 2007).

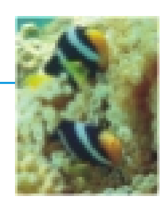
Biomass and productivity

Qasim and Bhattathri (1971) investigated the primary productivity of seagrasses of Kavaratti Atoll (Laccadives), other productivity studies on seagrasses have gained momentum in Indian seas. However, the studies are incomplete and most of the data were obtained by conventional methods, many sites were not covered, several species were not studied and in general productivity studies using C^{14} techniques are required. It is reported that the seagrass *Halophila beccarii* possess both C3 and C4 pathways of carbon fixation (Ghevade and Joshi, 1980). Productivity of seagrasses of Lakshadweep was studied at various periods by Kaladharan and David Raj (1989), Kaladharan (1998a), Kaladharan *et al.* (1998), Kaladharan (1998b) and Suresh and Mathew (1999). Das (1996) report is the only detailed study available for the entire Andaman and Nicobar coast. Thangaradjou (2000) has reported the seasonal variations in productivity and biomass of seagrasses of Gulf of Mannar. However such detailed studies are very much lacking in other parts of the Indian coast. Table 2 provides a comprehensive data on biomass and productivity of the seagrasses of India .

Similarly, biomass of the Indian seagrasses has been less documented. Gulf of Mannar and Palk Bay expected to have a seagrass cover of ca 30 Km^2 and standing crop of ca 7000 metric tons (Jagtap, 1996) and Gulf of Mannar 467 - 1780 gm^2 (Ganesan and Kannan, 1995). Biomass (wet weight) of

Table 2. Biomass and productivity of dominant seagrass species of Gulf of Mannar

No.	Species	Biomass (g fr. wt.m^{-2})	Productivity (g C m^{-2} d^{-1})
1.	*Enhalus acoroides*	5000.00	0.77
2.	*Halophila* sp.	367.74	2.54
3.	*Thalassia hemprichii*	3165.40	10.77
4.	*Cymodocea* sp.	2020.20	14.97
5.	*Halodule* sp.	752.50	2.99
6.	*Syringodium isoetifolium*	848.20	4.79



seagrasses in Lakshadweep was found varying with species and location - *T. hemprichii* ranged from 900gm^{-2} in the lagoon to 8kg m^{-2} in the creek, while the average biomass of *Halophila ovalis* and *Halophila uninervis* was 1.5 and 1 kg m^{-2} (Untawale and Jagtap, 1984). Jagtap *et al.* (2003) found the biomass of Indian seagrasses to vary from 180-720 m^{-2} (wet weight) with standing crop varying from 2.3 to 7.1 metric tons ha. It is evident that *Cymodocea serrulata*, *Halodule* sp. *Syringodium isoetifolium* (Jagtap, 1996), *Thalassia hemprichii* and *Enhalus acoroides* (Kannan *et al.,* 1999) are the major contributors towards the total seagrass biomass and productivity in the Gulf of Mannar region and *Cymodocea* sp. in Lakshadweep islands.

Floral and faunal association

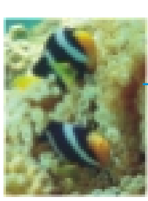
The faunal association in the seagrass meadows of the world has been largely investigated, but the trend is not reflected in India. Ansari *et al.* (1991) studied the seagrass habitat complexity and macro invertebrate abundance in Lakshadweep coral reef lagoon. Macrofauna of seagrass community in the five lakshadweep atolls were studied and compared. The associated epifaunal and infaunal taxa comprising nine major taxonomic groups, showed significant difference in the total number of individuals (1041-8411m^{2}) among sites and habitats. The density of macrofauna was directly related to mean macrophytic biomass (405-895 g wet wt. m^{-2}). Das and Dey (1999) who investigated the *Dugong dugon* distribution in the Andaman and Nicobar Island concluded that dugongs are less abundant than in the recent past. Although their numbers are highly reduced and large populations are seen no more, dugongs still exist at least around Ritchie's Archipelago, North reef, Little Andaman, Camorta (Allimpong, Trinket and Pilpilow), Little Nicobar and parts of the Great Nicobar Island. On the basis of the data collected, they proposed that the following measures should be taken for the conservation of dugongs in the Andaman and Nicobar Islands: (1) initiation of the environment education programes in the coastal villages, (2) production of potential dugong habitats and enforcing strict legislation to protect dugongs in and around their feeding habitats by restricting human activities such as fishing and trafficking, and (3) regular monitoring of the dugong population. Jagtap *et al.* (2003) provided a list of floral and faunal groups associated with the seagrasses of India (Table 3).

Threats

Several authors have reported about the threats to the seagrasses of

Table 3. Associated biota from seagrass beds of India

Group	Number of Species
Fauna	
Bait fishes	21
Ornamental fishes	138
Fin fishes	33
Crustaceans	150
Molluscs	143
Echinoderms	77
Turtles	4
Dugong	1
Flora	
Marine alga	100
Phytoplankton	13
Fungi	9



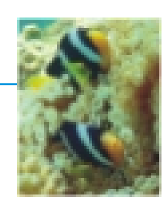
India and emphasized the need for conservation of seagrasses. Rapid industrialization and urbanization pose serious threats to the seagrasses of the world. Decline of seagrass meadows are documented in many parts of the world as a result of coastline development. Other threats include those from global climate change to local unregulated and unlawful activities besides unexpected natural disasters. Human activities like the operation of shore seine nets, anchoring and fishing on the seagrass beds, trawling, shell collection and man-made engineering works are the important factors causing considerable physical damage to seagrasses. They are stressed due to salinity, reduced light penetration, nutrient enrichment, thermal discharges from the power stations, pollution and coral mining which adversely affect the seagrasses of India. Jagtap and Rodrigues (2004) reported that the anthropogenic activities such as deforestation in the hinterland or of mangroves, construction of harbour or jetty, loading and unloading of construction material, as well as anchoring and moving of boats and ships, dredging and discharge of sediments, land filling and untreated sewage disposal are some of the major causes of seagrass destruction in India.

Conclusion

From the foregoing account on the research work done on Indian seagrasses, it can be inferred that work has been carried out by several workers on few areas for a long period, especially in the Gulf of Mannar and Lakshadweep where seagrasses have been well studied. However, areas like Palk Bay, Gulf of Kachchh and Andaman and Nicobar islands have received only little attention. Seagrass research is largely concentrated on aspects like seagrass distribution, morphological and anatomical studies, seagrass ecology, biomass and productivity; less importance has been paid to aspects like biochemical composition, antimicrobial activity, microbiological investigations, insecticidal activity of seagrasses, seagrass liquid fertilizers, floral and faunal association, seagrasses as bio-indicators, seagrass resource mapping, threats to seagrasses and conservation efforts (culture and transplantation). It is found that there are large gaps in seagrass research with the following aspects in need of immediate attention

Seagrass habitat with sea anemone in Gulf of Mannar

- Seagrass distribution maps at regular intervals as that of mangroves and coral reefs.
- Compilation of historical data for future comparisons.



- Seagrass loss estimation and identification of sites for seagrass restoration .
- Seagrass economic valuation interms of fisheries production, nitrogen production and other ecosystem services .
- Standardization of site specific restoration techniques and species.
- Promotion of community participated eco-restoration .
- Creation of awareness about the importance and need for conservation of seagrasses at all levels from peoples to implementing agencies to policy makers.

The degradation and destruction of the dynamic seagrass ecosystems would ultimately affect the health of the entire coastal ecosystem. If the present trend of seagrass reduction continues further, then we may not able see seagrass meadows along India's coast, which will lead to reduction in commercial fishery production, destruction of coral reefs, loss of biodiversity, migration or even possibilities of extinction of sea cows and green turtles from the coast and severe coastal erosion. To avoid such an untoward situation, it is important to take adequate measures to conserve the seagrass ecosystem and its resources. It is high time to develop an integrated seagrass management plan for implementation.

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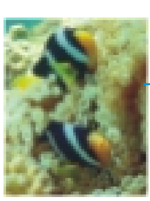

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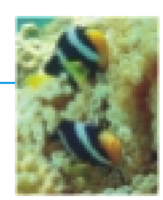

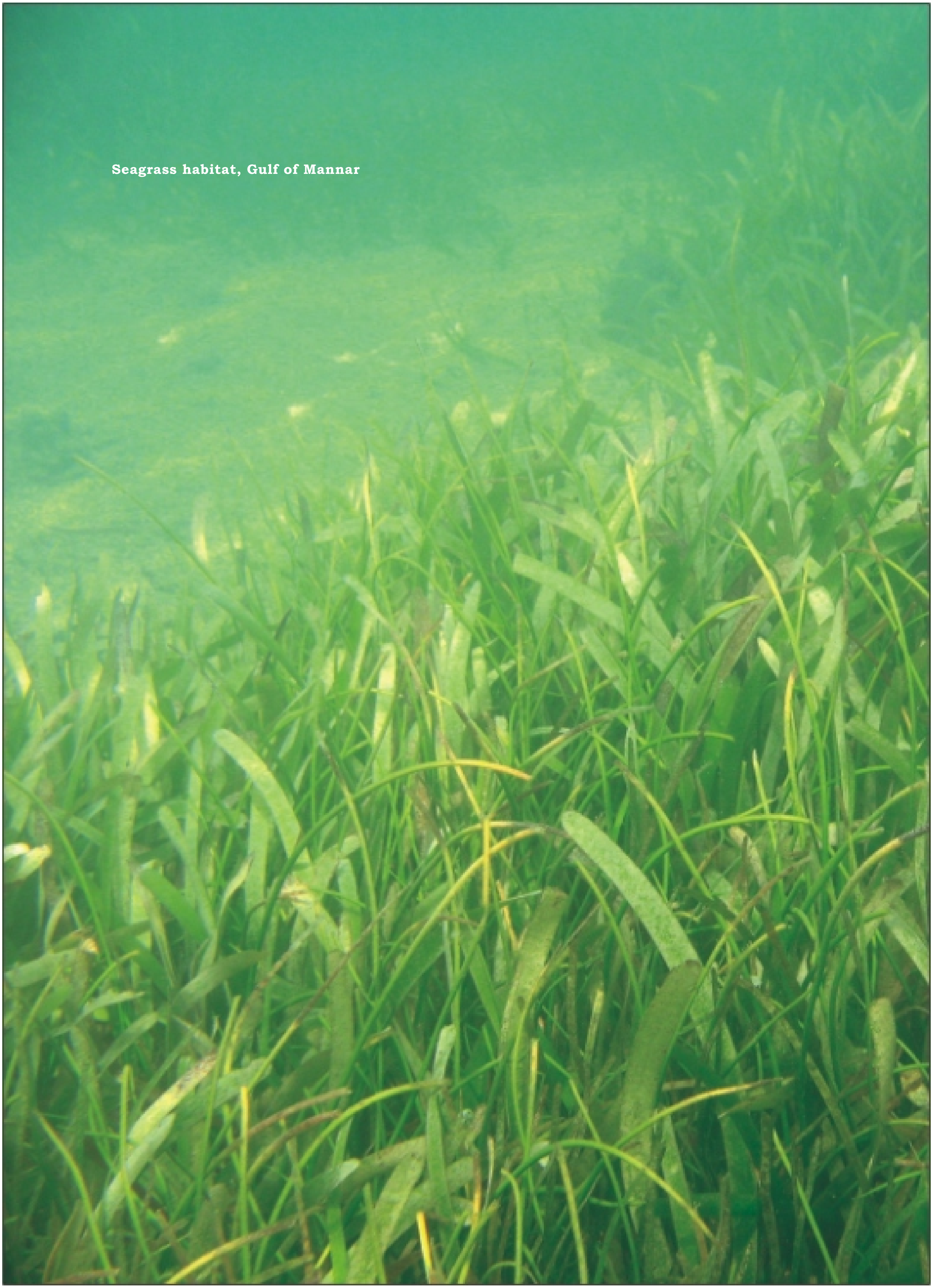

Seagrass habitat, Gulf of Mannar

Biodiversity and resources of dominant groups of crustaceans in Gulf of Mannar

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Abstract

The Gulf of Mannar situated on the southeast coast of India extending from Adams Bridge in the north to Cape Comorin in the south of the Bay of Bengal is unique for its heterogenous biological resources. This most colourful and picturesque environment is dominated by coral reefs of the fringing type. The faunal richness is very high, but compared to other organisms, studies relating to the taxonomy and systematics of crustaceans have been limited in the Gulf of Mannar region. The biodiversity and resources of crustacean groups of organisms namely shrimps, lobsters, brachyuran crabs and stomatopods are discussed. What remains to be done with respect to biodiversity and resources are also discussed. The need to adopt an ecosystem approach to management is also emphasized.

Introduction

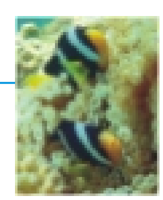
The Gulf of Mannar (GoM) is a large shallow bay that is an arm of the Laccadive Sea in the Indian Ocean. It lies between the south eastern tip of India and the west coast of Sri Lanka with widths varying between 160 and 200 km (100 to 125 miles). A chain of low islands and reefs known as Adam's Bridge, also called Ramsethu, separates the GoM from the Palk Strait, which lies to the north between India and Sri Lanka. Tambaraparani River of south India and Aruvi Aru of Sri Lanka drain into the GoM.

Penaeus monodon

GoM is endowed with a rich variety of marine organisms because its biosphere includes ecosystems of coral reefs, rocky shores, sandy beaches, mud flats, estuaries, mangrove forests, seaweed stretches and sea grass beds. These ecosystems support a wide variety of fauna and flora, including rare cowries, cones, volutes, murices, whelks, strombids, chanks, tonnids, prawns, lobsters, pearl oysters, sea-horses and sea cucumbers. The biosphere reserve, and particularly the Marine National Park of the GoM, also have gained more importance because of the alarmingly declining population of the endangered dugongs. The present article deals with the biodiversity and bioresources of the dominant groups of crustaceans in the GoM.

Shrimps

In view of the commercial consequences, investigations on the shrimps are innumerable. Therefore only some aspects of work done are mentioned here.



Biodiversity

As many as 41 species of shrimps have been reported to occur in GoM. These include *Aristeomorpha woodmasoni, Aristeus edwardsianus, Metapenaeopsis andamanensis, M.coniger, M. mogiensis, M. stridulans*, *Metapenaeus affinis, M. alcocki, M. brevicornis, M. dobsoni, M. ensis, M. lysianassa*, *M. monoceros, M. brevicornis, Parapenaeopsis coromandelica, P. sculptilis, P. stylifera, P. longipes, P. maxillipede, P. sculptilis, P. uncta, Parapenaeus investigatoris, Penaeus canaliculatus, P. indicus, P.monodon, P. semisulcatus, P.latisulcatus P. affinis, P.merguiensis, P. longipes, Trachtpenaeus curvirostris, T. asper, T. pescadoreensis, T. sedili, Acetes indicus, Solenocera chopra* and *S. crassicornis.*

Biology

Diurnal activity of shrimps is to remain active above the substratum at night and stay quiet, buried in sand during the day (Kutty and Murugapoopathy, 1968). Other studies on reproduction, fecundity, sex ratio, age and growth, length-weight relationship, food and feeding habits, relative condition factor of *Penaeus semisulcatus, P.indicus* and *P.monodon* include Thomas (1974, 1978). The relationship between total length and weight of shrimps during the growth phase (Kunju, 1978); the migration of the Indian white prawn, *P. indicus* (CMFRI, 1982); biochemical genetics of selected commercially important penaeid prawns (George and Philip Samuel 1993); factors determining spawning success in *P. monodon* (Babu *et al.*, 2001); and biological charact-eristics of the exploited penaeid shrimp stocks along southeast coast at Rameswaram and Tuticorin (CMFRI, 2004) have also been studied and reported.

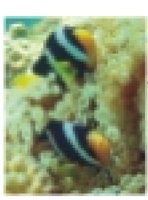
Disease

Studies deal with Sporozoan infection in *Penaeus semisulcatus* (Thomas, 1976); pathological investigations in shrimps (Vedavyasa Rao and Soni, 1993); and the association of *Vibrio alginolyticus* with white spot disease of *Penaeus monodon (*Lipton and Selvin,2003).

Fishery

Studies include preliminary observations on the shrimp catches off Punnakayal near Tuticorin (Venkataraman *et al.,* 1958); shrimp resources on the continental shelf situated off Tuticorin (Virabhadra Rao and Dorairaj, 1973) as revealed by the trawler fishery for the Indian white shrimp *Penaeus indicus* along the Tirunelveli coast (Mary Manisseri and

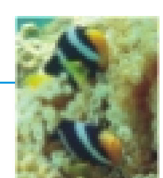
Aristeus alcocki



Manimaran, 1981); status of shrimp fishery (Vedavyasa Rao, 1986); fishery of the juveniles of *P.semisulcatus* in the above area (Mary Manisseri, 1982a, 1992); shrimp fishing- a sustenance for rural women (Santhanam *et al.*, 1985), also the nursery ground of the above species (Mary Manisseri, 1982b); fishery of the above species and its distribution in relation to depth (Mary Manisseri, 1986); seasonal fishery of *P.indicus* (Mary Manisseri, 1988); new grounds for deep sea shrimp off Tuticorin (Balasubramanian *et al.*, 1990**);** quantitative distribution of pelagic shrimps in deep scattering layers of the Indian EEZ (Suseelan and Manmadan Nair, 1990); bumper catch of white prawns *(Penaeus indicus)* by disco-net along the Tuticorin coast (Balasubramanian *et al.,* 1991); commercial fishery of the king shrimp *Penaeus latisulcatus* and *P.semisulcatus* off Tuticorin (Rajamani and Manickaraja, 1991, 1995a, b); stock assessment of species of genus *Penaeus (*Syda Rao *et al.,* 1993); sea ranching of shrimp seeds as a means of increasing wild production (Vedavyasa Rao *et al.,* 1993); preparation of products such as pickle (Rathnakumar *et al.,* 1995); fishery of *P. indicus* off Tuticorin and gill net fishery of *P.indicus* in Tutiorin (Rajamani and Manickaraja, 1996, 2000); effect of dry ice in preserving the fresh shrimps, *P.semisulcatus* (Jeyasekaran *et al.,* 2002); deep sea shrimp resources of Tuticorin (Rajamani and Manickaraja, 2003); fishery characteristics of the exploited penaeid shrimp stocks along southeast coast at Rameswaram and Tuticorin (CMFRI, 2004); and quality of shrimps landed in different fish landing centres of Tuticorin (Michael Antony *et al.,* 2004).

Culture

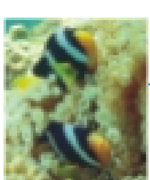
Imperatives of shrimp culture (Silas, 1978); suitability of shrimp species for culture (Surendranatha Kurup, 1978); maturation and spawning of cultivable shrimps (Vedavyasa Rao, 1978); need for supplementary feeds (Thomas, 1978), environmental requirements for shrimp culture (Suseelan, 1978); economics of culture of shrimps (Kathirvel, 1978); problems of shrimp farming (Ramamurthy, 1978); traditional culture of shrimps in India (Muthu, 1978a; Neelakanta Pillai, 1978); trend in shrimp culture at the world level in the nineteen seventies (Muthu, 1978b); feeding larval and juvenile shrimps in culture operations (Merrylal James, 1978); rearing of hatchery produced seeds in saltpan reservoirs (Mohamed Kasim *et al.,* 1980); experimental culture of shrimps in coastal pens at Tuticorin (Shanmugam and Bensam, 1982); culture of *P.indicus* in cages (Venkatasamy, 1983); food value of rotifer, brine shrimp and moina to postlarvae of *P. indicus* reared in the laboratory (Easterson, 1984); development of indigenous hatchery technology for shrimp seed production (Muthu and Neelakanta Pillai, 1988); performance of *Penaeus indicus* and *P. monodon* under mono and mixed culture systems (Felix and Sukumaran, 1988); seed production of banana shrimp *P. merguiensis* (Mahyavanshi, 1988); experimental rearing of PL 20 of *P. monodon* in nursery pond (Sriraman and Sathiyamoorthy, 1988); seed production of the green tiger shrimp in a non-circulatory and and non-aerated outdoor tank (Maheswarudu *et al.*, 1990); culture of *P.monodon* in the salt pan areas (James *et al.*, 1990); effect of



feed stimulants on the biochemical composition and growth of Indian white prawn *P. indicus (*Indra Jasmine *et al.*, 1993); growth of shrimps *P.indicus, P. monodon, P. semisulcatus* and *M. dobsoni* stocked in cages (Srikrishnadhas and Sundararaj, 1993); shrimp seed resources of estuaries of Ramanad district (Sambandam, 1994); wide prevalence of ciliate infestation in shrimp aquaculture systems (Felix *et al.,* 1994); abnormality in the protozoea of shrimp *P.semisulcatus* (Rajamani and Manickaraja, 1995); effect of crystalline amino acids on the growth performance of Indian white shrimp *P.indicus* (Fernandez and Sukumaran, 1995); need for large scale hatchery production of shrimp seed for aquaculture (Neelakanda Pillai *et al.,* 1996). Effects of feeding *Artemia* enriched with stresstol and cod liver oil on growth and stress resistance in the India white shrimp *Penaeus indicus* post larvae (Citarasu *et a*l., 1999); importance of augmenting shrimp production through culture (Maheswarudu, 2000); effects of feeding lipid enriched *Artemia* nauplii on survival, growth, tissue fatty acids and stress resistance of post larvae *P. indicus* (Immanuel *et al.,* 2001); development of *Artemia* enriched herbal diet for producing quality larvae in *Penaeus monodon* (Citarasu *et al.,* 2002); optimum dietary protein requirement for *Penaeus semisulcatus* (Gopakumar, 2002); influence of dietary lipid on survival, growth and moulting strategies of *Penaeus indicus* (Milne Edwards) post larvae (Immanuel *et al.*, 2003); Pro-PO based assessment of eco-friendly immunostimulation in *P. monodon* (Felix *et al.*, 2004); effect of butanolic extracts from terrestrial herbs and seaweeds on the survival, growth and pathogen (*Vibrio parahaemolyticus*) load on shrimp *P.indicus* juveniles (Immanuel *et al.,* 2004a); effect of feeding trash fish, *Odonus niger,* lipid enriched *Artemia* nauplii on growth, stress resistance and HUFA requirements of *Penaeus monodon* postlarvae (Immanuel *et al.,* 2004b); broodstock development, selective breeding and restocking of *P.semisulcatus* (CMFRI, 2004a, 2005); organic farming (CMFRI, 2004b)**,** polyculture of shrimp *P. monodon* (Athithan *et al.*, 2005); effect of different seaweeds as a dietary supplement on growth and survival of *P. monodon* (Sivakumari and Sundararaman, 2006) were reported.

Lobsters

Lobsters are highly priced, commercially important marine organisms and are considered to be the dish of the emperors. Due to their delicious taste, they are one among the most expensive items of seafood. There is a heavy demand for lobsters in India and overseas and therefore the stocks are under tremendous fishing pressure in the whole of India, not withstanding the GoM. They are found more in the coral reef and rocky areas. The lobsters in India are generally known as the spiny lobsters, which are distinguished from the so-called true lobsters of other countries by the absence of the crushing claw; also the carapace is subcylindrical, eyes are not enclosed in orbits and a long antennular flagellum is present. Until a few years ago, lobsters were looked down upon as food fit only for the poor. It is only recently, since the demand from the western counties began increasing, that a regular fishery for the lobster has come



into existence.

Biodiversity

Gulf of Mannar has six species of spiny lobsters namely *Panulirus homarus, P. polyphagus, P. ornatus, P. versicolor. P. longipes* and *P. dosypus,* and five species of squat lobsters, namely *Thenus orientalis*, *Scyllarus posteli, S. batei, S. tutiensis* and *S. sordidus.* Research carried out on various aspects of lobster biology management are elaborated here.

Biology

Rajamani and Manickaraja (1991) studied the size frequency distribution of *P. ornatus* collected by skin divers from the sea off Tuticorin.

Growth

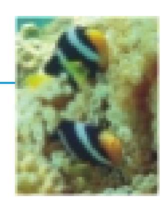
The growth of *P. homarus* in captivity was traced in relation to moulting. The growth per moult of lobsters of 4 to 9 mm carapace length showed an annual rate of growth of 30 mm in male and 17 mm in female; these were growth rates in agreement with those of its congeners. Instances of moulting without growth, and death during exuviations, were also observed (Thomas, 1972).

Physiology

Kasim (1968) studied the effect of salinity, temperature and oxygen partial pressure on the respiratory metabolism of *P. polyphagus.*

Fishery

The size and sex composition of the lobster *P.dosypus* was reported form the Kanyakumari coast (Chacko and Nair, 1963). Mark-recovery experiments, conducted with the help of suture tags on Indian spiny lobster *Panulirus homarus* (Linn.), showed that their movement in the fishing ground is of a very restricted nature. Long migratory movements were not observed. The species grows very fast and attains commercial size by the end of the first year, after the puerulus stage settles down to the bottom of the fishing ground. The growth rate slows down after the second year. Sizes attained at successive ages have been estimated with the help of von Bertalanffy's growth equation. The commercial fishery is largely supported by 1 and 2 year animals (Mohamed Kasim and George, 1968). George (1973) reported that the increasing demand for frozen lobster tails from world markets has brought the Indian spiny lobster to the lime light. Among the six species of spiny lobsters reported from GoM, *P.homarus* and *P.ornatus* are the most important from the commercial point of view. Kanyakumari area in the southern most part of GoM was reported to be the area with the maximum production. The average monthly catch of *Panulirus ornatus* and *P. homarus* landed by bottom set gill nets at Tharuvaikulam was studied during the years 1990-92 by Rajamani and Manickaraja (1997). The above authors also studied the estimated catch, effort and catch rate (kg/ unit) of lobsters landed by mechanized trawlers at Tuticorin Fisheries Harbour during 1991-93. An experimental artificial habitat for spiny lobsters was created in the sea off Vellapatti, a fishing village near Tuticorin in the Gulf of Mannar during June 1997. A total of 49 modules fabricated out of 147 stoneware pipes were used to create the artificial habitat, which covered a floor area of approximately 1000 sq.m. Inhabitation of lobsters in the artificial habitat was recorded for the first time three months after the



installation of the modules. Both *P. ornatus* and *P. homarus* were encountered in bottom set gill net catches operated in the vicinity of the artificial habitat. *P. ornatus* was the dominant species constituting on an average 76.8% of the total lobster catches. The size (total length) of the lobsters captured from the artificial habitat ranged from 115 to 255 mm and from 135 to 165 mm in *P. ornatus* and *P. homarus* respectively. The importance of artificial habitat in the production, conservation and optimum exploitation of the spiny lobster resources from the sea was also discussed (Rajamani, 2001). The total landing of spiny lobsters in Tuticorin by bottom set gill net was reported to be 6 tonnes. *P.ornatus* was found to dominate the catch (58%), followed by *P.homarus* (CMFRI, 2004). Manickaraja (2004) reported that the lobster fishery is a traditional vocation throughout the year in Kayalpattanam, south of Tuticorin in Gulf of Mannar. Lobsters are fished by bottom set gill nets with 85 mm mesh size. Each boat with inboard engine of 10 to 15 HP carries two to three bundles of nets; the length of a net varies from 90 to 120 m. There used to be four to five fishermen in a boat. The fishermen leave the shore around 14.00 hrs, leave the nets at a depth of 4 to 6m and return to the shore. The fishermen go the next day at 04.00 hrs and collect the bundles of nets along with lobsters and return to the shore around 10.00 hrs (Manickaraja, 2004).Vijayanand *et al.* (2007), who assessed the lobster resources along the Kanyakumari coast, reported that 90% of the lobsters landed are juveniles. This is matter of great concern.

Packing and export

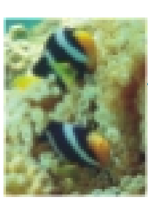
Tuticorin, a small town on the south coast of Tamil Nadu in India, is the main centre of activity for the live spiny lobster (*Panulirus* spp.) trade. These lobsters have a unique physiological adaptation to survive out of water for a couple of hours in humid conditions and for several hours at low temperatures. Details are given about this method (which exploits this physiological feature), developed by exporters for the transport of live lobsters. The method involves the packing of the lobsters in thermocol boxes on top of chilled sawdust/straw/ sack cloth layers, with bottles of frozen water packed at the sides of the boxes not in contact with the lobsters. Up to 5-7 kg of lobsters may be packed on the bed of straw, then finally are covered with sack cloth before sealing the boxes. When properly packed, the lobsters can survive up to 96 hours of rigid transport conditions (Rahman and Srikirishnadhas, 1994).

Management

Heavy demand and attractive prices for lobsters in the international market have resulted in increased exploitation of lobsters. Unless new grounds are located, scope for improvement in the fishery in the coming years is limited. The multi-species and multi-gear lobster fishery involving both traditional and mechanized fishermen poses a multitude of problems for management of this valuable resource from overexploitation and conservation (Radhakrishnan and Mary Manisseri, 2001). Therefore aquaculture has assumed significance.

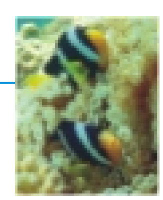
Aquaculture

The squat lobster *S. sordidus*



was obtained in the shore seine catches from the Gulf of Mannar near Mandapam, during the months of January and February (several adults of *S. sordidus* both males and berried females). De Man (1916) mentioned this species as occurring in the Gulf of Mannar and commented that the adults are usually found in shallow waters inhabiting coral reefs or places where the bottom is composed of sand and shells. The berried females were kept in the aquarium and the larvae were successfully hatched out, and a description was published. This species, however, could not be seen in the Gulf of Mannar since De Man's account (Raghu Prasad, 1960). Srikrishnadhas and Sundararaj (1989) reported that the six species of spiny lobsters occurring in India may be easily cultured in control conditions and confined marine environments, provided the water quality is good and necessary food and hiding places are provided sufficiently. They also advocated the application of eyestalk ablation in lobster culture systems. Velappan Nair *et al.* (1981) studied the growth and moulting of 3 species of *Panulirus,* namely *P. homarus, P.ornatus* and *P. penicillatus* in captivity. The average growth increment per moult was found to be 2.3-3.4 mm carapace length (6.9-9.6 mm total length) for male and 2.3-3.0 mm C.L. (6.5-9.1 mm T.L.) for female *P.homarus* , 2.7 mm C.L. (11.3 mm T.L.) for male and 3.3-4.4 mm C.L. (11.8-13.8 mm T.L.) for female *P. ornatus* and 1.5 mm C.L. (5.5 mm T.L.) for male *P.penicillatus.* The growth rate was found to be higher in younger individuals than in older ones. *P.homarus* moulted eight times in about 5 months, *P. ornatus* moulted seven times and *P. penicillatus* six times in about 21 months. An instance of breeding in captivity of *P. homarus* was reported. They also indicated the prospects of culturing lobsters in Mandapam area. Rahman *et al.*(1994) carried out spiny lobster (*P.homarus*) culture in controlled conditions. Increment in growth of 172.67 g body weight and carapace increment of 2 cm in 150 days were obtained in this experiment. Rahman and Srikrishnadhas (1994) further suggested that the spiny lobsters *P.homarus* and *P. ornatus* may be cultured economically in large cement tanks of 5-10 mt capacity using clams, mussels, oysters, crabs, trash fish, etc. as feed. Early larval development of the spiny lobster *P.homarus* was completed in the laboratory by Radhakrishnan *et al.* (1995). Maturation and breeding of the commercially important slipper lobster *T. orientalis* have been achieved. The phyllosoma larvae were reared to settlement for the first time in India. The technology developed comprised brood stock constitution and management, induced maturation, larval culture, feed development and harvest of postlarvae. Broodstock of the slipper lobster *T. orientalis* were constituted from wild collection of juveniles and sub-adults from a gill net fishery (CMFRI, 2004). NIOT has been popularizing the

Portunus pelagicus



fattening of lobsters among the fishermen community.

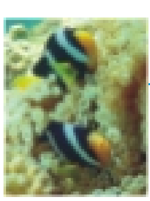
Brachyuran crabs

The crustacean, decapodan sub-order Brachyura includes the crabs in which the cephalothorax is much enlarged and covered by a hard chitinous partly calcified carapace. Crabs are rich in variety of species occupying the marine and estuarine or brackish water habitats. Respiration is essentially aquatic by means of gills, but the branchial chamber being lined by an integument which is highly vascular, aerial respiration also is possible, which accounts for their survival outside water for prolonged periods and also the penetration by some members into the terrestrial zones. A few species of crabs live in close association with other organisms in the environment; these are pinnotherid crabs found in the mantle cavity of several species of bivalve molluscs.

There are over 700 crab species occurring in the Indian waters, but only very few of them are being used for food purposes. The fishery is of not of high magnitude compared to that of shrimps and supports mostly a sustenance fishery. However, it is also valuable due to the pull from overseas markets and from inland demand.

Biodiversity

As many as 161 species of crabs have been reported to occur in GoM. They are *Cryptodromia hilgendorfi, Dromidiopsis abrolhensis, Dromia dehaani, D. dromia* (Dromiidae), *Ranina ranina(*Raninidae*), Dorippe facchino, Dorippoides frascone*, *Neodorippe callida, Paradorippe granulata,* (Dorippidae), *Calappa bicornis*, *C.gallus, C. gallus capellonis, C. lophos, C. philargius, C. spinosissima, C.japonicus,* (Calappidae), *Charybdis acutifrons, C. affinis, C. annulata, C.feriata, C. granulate, C. edwardsi, C.helleri, C. hoplites, C. lucifera, C.merguiensis, C. miles, C.natator, C.quadrimaculata*, *C. rostratum, C.riversandersoni, C. truncata, C.variegata, Podophthalmus vigil, Portunus argentatus, P. gladiator*, *P.gracilimanus*, *P. granulatus*, *P.hastatoides, P. longispinosus, P.minutes, P. pubescens, P. pelagicus*, *P.petreus*, *P. sanguinolentus*, *P.samoiensis, P. spinipes, P. whitei, Scylla serrata, S. tranguebarica, Thalamita admete, T. chaptalii, T.crenata*, *T. danae, T. parvidens, T.prymna*, *T. Integra(*Portunidae*), Carpilius maculates, C. convexus*, *Liagore rubromaculata* (Carpiliidae), *Menippe rumphii, Ozius rugulosus* (Menippidae), *Cymo melanodactylus, C.andreossyi, Demania baccalipes, D.splendida, Etisus laevimanus, Galene bispinosa, Halimeda octodes* , *Leptodius euglyptus, L. crassimanus, L. exaratus, L. gracilis, Macromedaeus bidentatus, Pilumnopeus indicus, Atergatis floridus, A. subdentatus*, *A. integerrimus, A.frontalis, A. roseus, Zosymus aeneus, Platypodia cristata, Pseudoliomera speciosa, Pilodius areolatus, Phymodius monticulosus, P. granulosus, P.ungulatus, P. ungulatus, P. nitidus, Chlorodiella nigra, Cymo melanodactylus, C. andreossyi, Paractaea ruppelli orientalis* (Xanthidae), *Pilumnus vespertilio*, *P.tomentosus, P.minutes, P.indicus* (Pilumnidae), *Tetralia cavimana, Trapezia cymodoce, Trapezia aereolata, Trapezia ferruginea (*Trapeziidae),



Composia retusa, Cyclax suborbicularis, Doclea alcocki, D.canalifera, D. hybrida, D. ovis, Hyastenus oryx, H. pleione, Ophthalmias cervicornis, Phalangipus hystrix, Naxioides hirta, Schizophryx aspera, Tylocarcinus styx (Majidae), *Parathenope (Partheriope) longimanus, Parthenope (platylambrus) prensor, P.echinatus, P. contraries, Daldorfia horrida, Aethra scruposa, Heteropanope indica,* (Parthenopidae), *Arcania quinguespinosa, A. septemspinosa, A.heptacantha, A. erinaceus, A.novemspinosa, A. tuberculata, A.undecimspinosa, Ixa cylindrus, Philyra syndactyla, Ixoides cornutus, Leucosia anatum, L. craniolaris, L.longifroni, L.pubescensis L.craniolaris, L. longifroni, L.pubescensis, L. pubescensis, Myra affinis, M. fugax, Parilla alcockii, Philyra alcocki* (Leucosidae), *Matuta lunaris, M.planipes, M.miesii* (Matutidae), *Elamena truncata* (Hymensomatidae), *Notonyx vitreus, Ceratoplax ciliata, Eucrate alcocki, E. sexdentata, Litochira quardispinosa* (Goneplacidae), *Ebalia malefactrix, Macropthalmus (Mareotis) depressus, Ocypode ceratophthalma, Scopimera proxima* (Ocypodidae), *Grapsus albolineatus, Metopograpsus messor* (Grapsidae) and *Cardiosoma carnifex* (Geocarcinidae).

Abnormality in the right chela of the portunid crab, *Portunus pelagicus* was reported by Ammer Hamsa (1973). Jameson *et al.* (1982) studied the distribution pattern and morphometry of *Scylla serrata* along the Tuticorin coast. James (1986) reported about an anomaly in the cheliped of the portunid crab, *Portunus pelagicus* - having two additional dactyli on the left cheliped. Jeyabaskaran and Ajmalkhan (1998) studied the biodiversity values of brachyuran crabs of GoM. The above authors also suggested the use of trapezian crabs as bioindicators for coral reef monitoring. Jeyabaskaran *et al.* (1999) reported the occurrence of 106 species of brach-yuran crabs and provided figurative keys for the identification of the above crabs in their monograph. Jeya-baskaran and Venkataraman (2000) reported the mass mortality of bio-indicator trapezian crabs in coral reefs of GoM. Jeyabaskaran *et al.* (2000) assessed the biodiversity of brachyuran crabs associated with coral *Pavona decussata* in GoM. Gokul and Venkataraman (2003) who studied the status and biology of coral reef associated xanthid crabs in GoM Biosphere Reserve reported that xanthid crabs are associated more with dead corals rather than live corals.

Biology

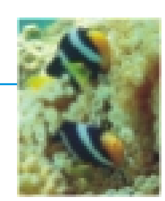
Ameer Hamsa (1979, 1982) studied moulting in the brachyuran crab *Portunus pelagicus*. Silas and Sankarankutty (1965) carried out field investigations on the shore crabs of the Gulf of Mannar with special reference to the ecology and behaviour of the pellet crab *Scopimera proxima.*

Biochemistry

Ameer Hamsa (1978) studied the chemical composition of the swimming crab *Portunus pelagicus* while Nammalwar (1978) estimated the blood sugar level of *S. serrata and* found it to be 124 mg glucose/ml.

Fishery

Raghu Prasad and Tampi (1952)



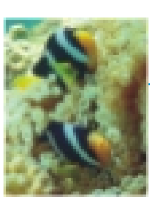
were the first to study the fishery and fishing method of *Portunus pelagicus* (now *Neptunus pelagicus*) near Mandapam. The above authors also studied the relative growth of this crab in 1954. Vedavyasa Rao *et al.* (1973) who carried out a detailed study on the crab fishery resources found the crabs to support a sustenance fishery of appreciable importance, although, it is not comparable with that of major crustacean fisheries such as prawns and lobsters. An attempt was also made to study the abundance and production of crabs from GoM with a view to understand the crab resources here. The need for biological investigations on factors governing yield and crab population was stressed. Ameer Hamsa (1978) studied the meat content of *Portunus pelagicus* with some observations on lunar periodicity in relation to abundance, weight and moulting. In the same year he also studied the fishery of the swimming crab *Portunus pelagicus* in GoM. Nagappan Nayar *et al.*(1980) who dealt with the fishery of the mud crab *Scylla serrata* at Tuticorin found the crab to occur in fairly good numbers at Tuticorin, throughout the year. It was caught in the northern part from the shallow coastal waters by shore-seines and cast-nets, and in the backwaters and canals of the southern region by a simple trapping device. Apart from these, certain dragnets, stake nets, baited hooks and hand-picking were also found to be used. Manickaraja (1999) reported about the heavy landings of the reticulate crab *Portunus pelagicus* at Tharuvaikulam near Tuticorin caught using bottom set gillnets in shallows and deeper areas. Emilin Renitta *et al.* (2003) reported about the fishery in Vellapatti one of the fishing villages on the Tuticorin coast exclusively doing crab fishing for decades. The fishery there comprised of *Portunus pelagicus, P. sanguinolentus, Charybdis feriata, C. natator* and *S.serrata* and among these, a major portion of the catch was occupied by *P.pelagicus.* The total catch of *P. pelagicus* during 2002-03 was high (167.98 tons) followed by *Charybdis* sp. (2.404 tons) and *S. serrata* (1.211 tons). CMFRI (2005) which carried out investigations on the crab resource characteristics and development of management strategies reported that 200 tons of crabs were landed at Mandapam by trawl nets and 30 tons by bottom-set gill-nets with an average CPUE of 7 and 8 kg, respectively. The fishery was reported to be supported exclusively by *Portunus pelagicus.*

Processing

Manickaraja and Balasubra manian (2004) commented about the innovative method of processing of crabs being followed at fishing hamlets Vellapatty and Tharuvaikulam, situated near Tuticorin. The need arose there as the mid nineties witnessed a sudden spurt in the crab export due to good demand in the foreign market. Hence a sizable number of fisherfolk diverted their fishing effort to the crab fishery. Better catch of crabs urged the processors to adopt indigenous processing technology. Both these fishing hamlets became well known for crab fishery along the Tuticorin coast in Gulf of Mannar.

Culture

Marichamy *et al.* (1979) elaborated about the culture of mud crab *Scylla serrata* in enclosures of bamboo splits

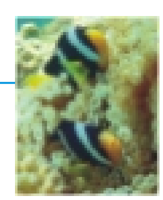


(thatti), fixed in shallow inshore waters at Tuticorin. Marichamy and Rajapackiam (1984) carried out the culture of larvae of *S. serrata* besides mass rearing of mud crab in coastal ponds in Tuticorin Bay. Marichamy *et al.* (1986) further elaborated the results obtained in the experimental culture of the mud crab *Scylla serrata* in different types of cages in a shallow bay at Tuticorin during 1978-79. They collected seeds from the estuarine area along creeks, mangrove swamps and impoundments and intertidal flats in and around Tuticorin. The young crabs were reared first in basket type cages made of cane splits for 2-3 months. Box type cages made of soft wooden planks, each comprising 8-10 compartments and metal framed synthetic twine mesh cages with compartment were preferred for culturing the grown up crabs. The crabs were fed with trash fish, clam meat and gutted wastes of the fish market. The growth rate of mud crabs in the existing environments appeared to be good as a fair number of the stock moulted frequently at an interval of 25-50 days. They were observed to reach marketable size through four-five moults in a period of 9-10 months. Eye stalk ablation accelerated the growth rate in young crabs and promoted gonadal maturation in adult crabs. Breeding behaviour of this species was also studied. Bensam (1986) carried out an experiment as early as during 1975-77 at Veppalodai, Tuticorin rearing mud crab *Scylla serrata* in individual plastic cages, for ascertaining its survival, growth and production with artificial food supplied. Marichamy (1996) exhorted that intensive and indiscriminate fishing of mud crab *Scylla serrata* and the absence of any management measures will lead to further decline in the population. He also commented that because the reproductive capacity is high, it is possible to culture them in specially designed coastal ponds, pens and cages and he further elaborated the prospects for culture in India.

Josileen Jose *et al.* (1996) reared the larvae of the crab, *Portunus pelagicus* in a hatchery at Mandapam after the selection of the right brood-stock, and larval spawning. Marichamy and Rajapackiam (1999) found that fattening of water crabs for a period of 7-8 weeks fetched an attractive revenue. They also evolved the technology for production of gravid females which fetch a premium price in export trade. Josileen Jose (2000) added that in our country, crab fishery is mainly contributed by portunid crabs those which belong to the three genera ie., *Scylla, Portunus* and *Charybdis.* The culture of mud crab *Scylla tranquebaricus* in the earthen pond at Tuticorin was tried by Lakshmi Pillai *et al.* (2002). Josileen Jose and Gopinatha Menon (2004) also reared the larvae of *Portunus pelagicus* in the laboratory on hatching from wild ovigerous females. The larval stages included four zoeal stages and one megalopa. The megalopa moulted to the first crab instar. The zoeae and megalopa were very similar to those of other portunids. The duration of each of the first two stages was 3-4 days, and of the following two stages 2-3 days, and the megalopa 3-5 days, reaching the first crab stage in 15-17 days. All zoeal and megalopa stages were described in detail.

Stock replenishment

CMFRI (2005) at Mandapam



carried out 16 sets of experiments on breeding and seed production of *Portunus pelagicus.* As many as 26 million zoeae were produced and 25.7 million released into Gulf of Mannar. Out of the remaining zoeae, 4,630 crablets were produced .

Stomatopods

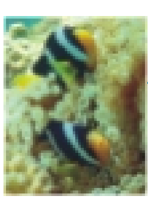
Stomatopods, also known commonly as mantis shrimps, are caught incidentally with penaeid shrimps. Stomatopoda is the only living order of the subclass Hoplocarida. They are ubiquitous in tropical marine environments and represent the most common top benthic predator on reefs as well as in commercially important shrimp beds. Mantis shrimps are highly specialized predators of fishes, crabs, shrimps and molluscs, and many of their distinctive features are related to their predatory behaviour. Mantis shrimps range in size from approximately 4 cm long in the case of small species to giant forms greater than 36 cm in length. Most stomatopods are brilliantly coloured. Green, blue and red with deep mottling are common and some species are striped or display other patterns. Given the size and abundance of stomatopods in some marine habitats, they serve as major predators on a variety of different prey (Dingle and Caldwell, 1978).

Only in the 1960s, stomatopods increased in popularity as experimental animals in addition to their existing systematic interest as geographically widespread and phylogenetically primitive malacostracan crustaceans (Ferrero, 1989). Prior to that because of their cryptic or burrowing habits and their largely tropical distribution, stomatopods evoked comparatively little attention from marine scientists. However, now their unique morphology and ancient derivation make them exceptionally interesting subjects for physiological, functional, morphological and evolutionary studies. In Italy, *Squilla mantis*, the main representative species, still gathers the interest of research workers not only as an experimental model, but also as economic resource for fishers and potentially, for aquaculture. *Oratosquilla oratoria* from Japan is another closely investigated species. Thus apart from scientific interests, the mantis shrimp is also considered an important seafood product in the Western Hemisphere and in far eastern countries.

Biodiversity

Only seven species of stomatopods have been reported from the GoM. They are *Oratosquilla holoschista, O.interrupta, O. nepa, O. woodmasoni, Squilloides gilesi, Acanthosquilla acanthocarpus and Harpiosquilla raphidea.* A potential and biodiversity rich area like GoM should support more species of stomatopods. Probably this group did not receive the importance other decapod crustacean groups have received. That is why the investigations on this important group of organisms are conspicuous by their absence. More work on these organisms is needed for successful utilization of these organisms.

It is surprising that in a biodiversity rich area as GoM only seven species of stomatopods are present while from a small place like Parangipettai, 18 species have been reported (personal observation). Definitely a greater number of species should be present here as varied biotopes are present and the extent of biosphere



covers an area of 10,500 sq.km. Therefore more studies are required on this group of organisms as stomatopods can be used as food and for preparing various value added food products. Detailed studies on various valuable by-products like chitin, chitosan and hydroxyglucosamine, detailed studies should also be applied to these organisms.

Oratosquilla woodmasoni

What remains to be done with respect to biodiversity in Gulf of Mannar?

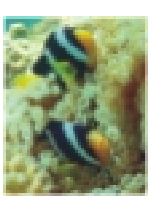
The present study reveals the occurrence of 41 species of shrimps, 6 species of spiny lobsters, 5 species of squat lobsters, 161 species of brachyurans crabs and 7 species of lobsters (total number of species 220 species). The above information is the outcome of individual efforts by scientists belonging to various institutes. However a concerted effort to study the biodiversity of the above groups in GoM was conspicuous by its absence. As GoM is a potential area, an intensive study on biodiversity on the lines of CoML (Census of Marine Life) should be undertaken and such an effort can also be code named as CoGoM (Census of Gulf of Mannar). Information on biodiversity increased after the introduction of trawl nets in the Indian waters. As the trawl net is a non-selective gear taking in whatever organism is coming its way, more of the above groups of organisms came to light. However what has to be borne in mind is that the trawl net can not be operated in all the places. Also the fishermen operate the net where more catches will accrue. There is no reason that the entire marine biodiversity occurs in the area swept by the trawlers. Therefore biodiversity investigation has to be carried out in areas not frequented by trawlers. Trawling is also not done in areas where the bottom is not even, in rocky areas and in coral reef areas. Therefore in these areas, biodiversity surveys making use of other methods have to be undertaken. Rocky area and coral reefs provide many holes and other niches for a diverse fauna of crustaceans. As brachyuran crabs have a good association with corals and mangroves, detailed studies on their biodiversity have to be undertaken. Special attention has to be taken on groups such as syllarids and stomatopods which may bring to light many more species. The existing information should be consolidated and put in a portal named after GoM for easy reference and dissemination.

A consolidated information on all the plants, animals and micro-organisms notwithstanding the above groups should be published as monographs and also in CD for easy distribution among the user groups. Barcoding is a new initiative to discover all the planet's species. Barcoding is a standardized approach for identifying the world's species making use of a particular region of the genome called as barcode. Catching up with the development at the world level, all the organisms occurring in GoM should also be barcoded. A museum depicting the biodiversity of the GoM should be set up (the museum of CMFRI at Mandapam should adopted or given more funds for modernization and improvement. This will help to create awareness regarding the importance of biodiversity of GoM and the need to protect the same. CDs having the movies on the importance of biodiversity, threats can be circulated to the people in the GoM and others which will go a long way in improving their understanding of the biodiversity. An Marine Aquarium is the GoM will fulfill the long time need. When it has been functioning in other parts of the world, why not in GoM?

What remains to be done with respect to resources in Gulf of Mannar?

Fishing being under an open access system in India, things in GoM are not different from the other places in our country. GoM being relatively a small area can be managed with respect to exploitation of the resources. Studies done here showed that the exploitation is not in terms of the standing stock of the resources. Therefore continuous assessment of the stock , average size of the exploited stock and catch per unit effort should be undertaken for better management of the shrimp fishery resources and sustenance. Even though sea ranching of the shrimps have been done, the survival of seeds in the wild, the extent of stock replenishment and impact on catch have not been monitored. It should be done and based on the results the sea ranching should be done regularly. The collection of mother spawners from the wild should also be monitored and the extent of their collection and the impact should also be assessed. Information on the biology is available only for important species of shrimps. Biology of other species should also be studied.

The lobsters are being exploited continuously The average size of lobsters coming to the market has decreased considerably. This is a matter of great concern. Unlike shrimps, stock enhancement can not be undertaken, due to absence of hatchery technology. Therefore the management of the fishery has become all the more important. The finding of Vijayanand *et al.* (2007) that 90% of the lobsters caught are juveniles is a matter of grave concern. This fact has to be



verified in other parts of the GoM in addition to Kanyakumari and if it is found true, moratorium on lobster fishing should be done without loss of time. Also the impact of fattening programme being offered to fishing community and others on the stock position should be assessed very carefully and if it is found detrimental (as juveniles are collected for fattening and further marketing denying the juveniles to reproduce atleast once in their life), it should be banned outright. Stock assessment of lobster is an immediate priority so also the perfection of hatchery technology. Scyllarid lobsters should be studied in depth.

With respect to crabs, *Portunus pelagicus* is found to be an important resource in terms of quantum of landing and its export market. As in the case of shrimps the exploitation should commensurate with the standing stock. As the larval development has been completed in the laboratory, technology for mass scale production of seeds of this species should be perfected.Sea ranching and its impact on the stock position and exploitation should also be probed. What has happened to the spiny lobsters, has happened with respect to the mud crabs also. Here also the average size of the mud crabs landed has come down drastically. The size marketed should be monitored continuously and exploitation regulated. Sea ranching programme has to be launched immediately despite low survival in the hatchery as all is not well with respect to the stock position of mud crabs.

This millennium has been declared as the millennium without hunger and malnutrition. As the exploited fishery resources are not commensurating with the requirement, utilization of non-conventional resources has become imperative. One such non-conventional resource is stomatopods. These organisms should be popularized among the people living in the GoM area and training should be imparted to them on the preparation of the value added fishery products thus providing them with alternate employment.

Ecosystem approaches

Earlier fisheries constituted by a single group was individually looked and studied. However each and every group is an integral part of the ecosystem and that way ecosystem approaches have gained importance. The ecosystem approach has been defined as "the comprehensive integrated management of human activities based on best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of the marine ecosystems, there by achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity" (Frid *et al.*, 1999). GoM being a relatively small area could be treated as a single ecosystem, and the ecosystem approach should be followed for managing the fisheries constituted by decapod crustaceans.

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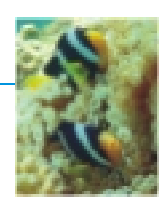

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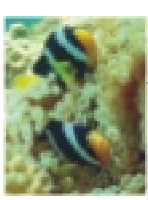

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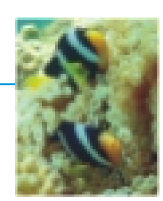

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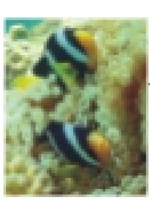

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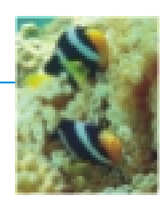

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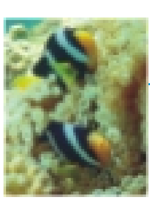

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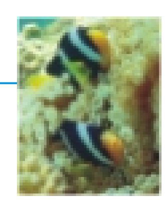
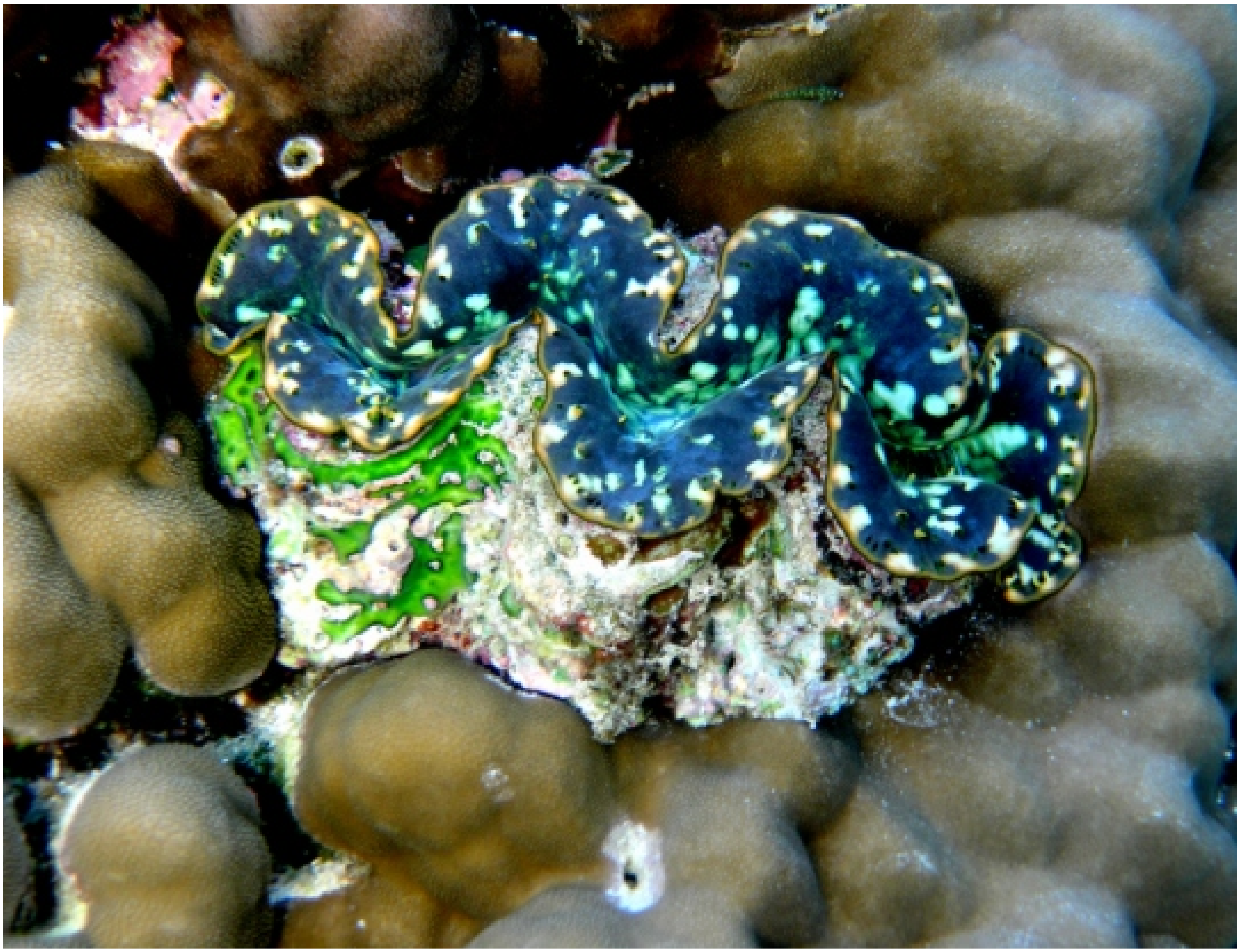
Echinothrix calamaris





Giant clam (*Tridacna maxima*), Lakshadweep Islands

Density estimation of *Tridacna maxima* in Lakshadweep Archipelago

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Abstract

The ecology and population dynamics of *Tridacna maxima* were studied in Lakshadweep Archipelago, India. A comparison of *T. maxima* populations was carried out in 10 lagoons covering 24 islands for three consecutive years. Various aspects related to ecology and population dynamics of *T. maxima* such as microhabitat, associate, substratum preference, reef canopy distribution, mortality (predation, diseases, bleaching, etc.) and recruitment were studied in 10 lagoons. Agatti Island has the highest population of *T. maxima. Porites lutea* and *P. solida* are most important species which offer suitable substrata for *T. maxima* in all islands. Role of herbivores in maintenance of the micro-habitat of *T. maxima* was studied in Kavaratti Island. Convict Surgeon fish (*Acanthurus triostegus*) is the most important browser within the lagoon and is responsible for maintenance of coral tops of *P. lutea* and *P. solida.* The trends clearly indicate high mortality of *T. maxima* in all islands while recruitment is very low. Suheli and Bangaram group of islands have shown good recruitment. Bleaching of *T. maxima* has been noticed on a few occasions. However, habitat degradation due to human induced alteration in lagoon ecology is the main cause of mortality of *T. maxima* in many islands. In few lagoons like Kalpeni, Bangaram and Bitra, large sized *T. maxima* have been observed (480-500 mm). The above size exceeds all the known size records for the species.

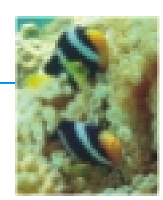
Introduction

Giant Clams, as they are popularly known, are among the most specialized bivalves. These are the largest living bivalves, with *T. gigas* growing over a metre in length. They have a narrow range of distribution and occur exclusively within tropical reefs under the Indo-Pacific faunal region. There are ten living species in the family Tridacnidae within two genera, namely *Tridacna* and *Hippopus*.

Giant clam (*Tridacna maxima*), Lakshadweep

During the early 1970's to late 1980's several authors worked on various aspects of Giant Clams especially mariculture. Some important investigations among these studies were by Wada (1952); Rosewater (1965); LaBarbera (1975); Yamaguchi (1977); Yonge (1980); Beckvar (1981); Heslinga *et al.* (1984); Fitt *et al.* (1984); Alcazar and Solis (1986); and Rutzler *et al.* (1983).

Richard (1977, 1981) and Ricard and Salvat (1977) studied the population structure of Giant Clams in Takapoto lagoon. Bradley (1987a,b), Villanoy *et al.* (1988), Alder and Bradley (1989) and Pearson and Munro (1991) studied mortality in wild populations of Giant Clams. Islands of



Tahiti, Moorea of Polynesian islands regularly served *T. maxima* as a sea food for tourists (Planes *et al.*, 1992).

These studies have provided new insights to these magnificent bivalves. However, not much work is available on wild populations of Giant Clams and the field ecology and population structures of these bivalves still remain an enigma. The present comprehensive work on *T. maxima* is the first of its kind in the Indian subcontinent and Arabian Sea.

Protection status of giant clams in India

Out of ten species known worldwide, five species are known to occur in Indian waters. These are *Tridacna maxima, T. squamosa, T.crocea, T.gigas* and *Hippopus hippopus*. However, in Lakshadweep only *T. maxima* and *T. squamosa* are found. Except *T. crocea*, all the species are included under Schedule I of the Indian Wildlife (Protection) Act, 1972, showing these species have the highest degree of protection.

Nothing is known about the ecology and biology of these species in India. The present study focused on the ecology and population dynamics of *Tridacna maxima* and *T. squamosa* in Lakshadweep Archipelago.

Study site: Lakshadweep Archipelago

The studies were carried out in Lakshadweep archipelago, the smallest Union Territory of India measuring 32 km^2 and spread over 36 islands, 12 atolls and 5 submerged sand banks. They lie scattered in the Arabian Sea about 225 to 445 km from the Kerala coast between 80^{0} and 12^{0} North and between 71^{0} and 74^{0} East.

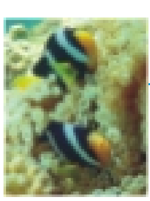
Population studies on *T. maxima* were carried out in 24 islands within 11 lagoons, such as Kavaratti, Kalpeni (Kalpeni Pitti 1, Kalpeni Pitti, Tillakkam 2, Tillakkam 1, Cheriyam, Kalpeni, Koddithala), Bangaram (Tinnakara, Bangaram, Parali 1 and 2, Parali 1), Agatti (Kalpetti, Agatti), Kadmat, Amini, Bitra, Chetlat, Kiltan, Suheli (Suheli Veliakara, Suheli Cheriyakara, Suheli Pitti) and Minicoy (Viringili).

Methodology

For population estimates of *T. maxima* fixed-width line transects, or belt transects of 100 m x 10 m were used. The island's lagoon was divided into 1 sq. km grids and transects were randomly placed. For each transect, the start and end point was marked with permanent markers, as well as GPS locations. This helped while monitoring the same transects for three consecutive years, from 2005 to 2007. Corresponding to each sighting of a Giant Clam, the length and height of the individual, perpendicular distance from the line, age class, status (in the 2nd and 3rd sampling years), substratum, nature of placement on the substrate, mantle colour, height from the sea floor and nearest adult neighbour distance were recorded. Photographic documentation of each individual was also maintained. Altogether, 165 transects were sampled in 2005-06, 134 in 2006-07 and 50 in 2007-08.

Statistical analyses

Density of giant clam *T. maxima* was estimated through the software DISTANCE 5.0[2], vital population indicators like mortality and recruit-



ment were estimated from successive samplings. Age specific growth was calculated from length measurements of individuals in successive recounts and simulated for the entire population. Population projections were modelled through age structured Leslie transition matrix analysis (Hood, 2005), using the software POPTOOLS. Details of the analytical procedures have been provided in each of the concerned sections.

Density

Planes *et al.* (1992) observed a close relationship between live coral cover and clam density on the barrier

Giant clam (*Tridacna maxima*) occurring in Lakshadweep Islands

reef. In contrast, clam density was poor on a fringing reef even with good coral cover. This is primarily due to easy access by foot for people to fringing reefs, which lie adjacent to the land mass. He also observed low density of adult *T. maxima,* along with low mean size (75 mm), on fringing reefs as compared to 89 mm on the barrier reef.

Basker (1991) studied Giant Clam densities in Maldives. He observed density of *T. maxima* in fished water as 29.9 clams/ha and 39.6 clams/ha in unfished waters (Raa atoll). The Shaviyani and Lhaviyani reefs showed density of *T. maxima* varying between 2.8 and 171.9 clams/ha.

T. squamosa density was much lower at 3.4 clams/ha and 10.6 clams/ha in fished and unfished waters respectively (Raa atoll). However, this varied significantly among various islands. The Shaviyani and Lhaviyani reefs on the other hand showed a density of *T. squamosa* varying from 2.8 to 65.6 clams/ha.

Richard (1977) reported densities of *T. maxima* from Tuamotu Atoll, French Polynesia up to 60,000 clams/ha. Braley (1988) reported 63-101 *T. maxima*/ha from Tuvalu. Salvat (1967, 1971, 1972) estimated about 11 million *T. maxima* in Reao Atoll with 40,000 clams/ ha. Preston *et al.* (1995) reported the density of *T. maxima* at Palmerston Atoll of Cook Island as 2900 clams/ha. Green and Craig (1999) reported 5000 *T. maxima/* ha in Rose Atoll in Samoa. Richard (1982) reported 4.6 clams/m^2 from Moorea Island. Kinch (2002) reported a density of 17.9 clams/ha from Milne Bay in Papua New Guinea. Gilbert *et al.* (2005) reported 544 *T. maxima*/m^{-2} in Tatakoto lagoon of French Polynesia. Andrefouet *et al.* (2005) reported 23.6 million *T. maxima* in the 4.05 sq. km Fangatau atoll of French Polynesia. Gilbert *et al.* (2006) reported 88.3 and 47.5 million *T. maxima* in Tatakoto (11.46 sq. km) and Tubuai (16.3 sq. km) lagoons of French Polynesia respectively. Fangatau and Tatakoto are the world's highest density localities for *T. maxima*.

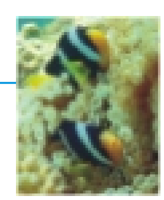


Table 1 Model information, detection probability and density estimates (No./ha) of different age classes of *T. maxima* population across islands of Lakshadweep during 2005-2007

Island		Juvenile							Sub-adult							Adult						
	Year	Model	P	D	CV	LCL	UCL	n	Model	p	D	CV	LCL	UCL	n	Model	p	D	CV	LCL	UCL	n
Agatti	2005	Half-normal/Cosine	0.69	37.95	21.99	24.18	59.55	92	Half-normal/Cosine	0.73	107.32	19.33	72.00	159.98	313	Half-normal/Cosine	0.66	83.01	18.53	56.63	121.67	220
	2006			28.87	25.94	16.99	49.08	70			93.61	18.68	63.64	137.69	273			64.14	18.37	43.91	93.70	170
	2007			32.57	26.61	18.87	56.21	75			94.57	19.30	63.39	141.07	262			61.16	19.51	40.84	91.60	154
Amini	2005	Uniform /Cosine	0.64	4.08	75.72	0.83	20.02	4	Uniform /cosine	0.68	8.22	56.88	2.35	28.73	9	Half-normal/Polynomial	0.68	7.34	46.45	2.59	20.82	8
	2006	Uniform /Cosine	0.48	5.92	75.33	1.16	30.33	4	Uniform/cosine	0.67	4.24	52.13	1.28	14.06	4	Half-normal/Polynomial	0.71	4.03	64.69	0.95	17.08	4
Bangaram	2005	Half-normal/Cosine	0.94	14.01	29.09	7.40	26.54	21	Half-normal/Cosine	0.80	55.21	25.17	31.09	98.03	71	Half-normal/Cosine	0.81	67.84	23.74	39.64	116.10	88
	2006			13.34	22.89	8.15	21.85	20			65.31	22.28	39.33	108.46	84			53.96	30.18	27.21	107.05	70
	2007			14.68	24.17	8.70	24.78	22			67.65	22.55	40.48	113.05	87			50.11	31.09	24.75	101.45	65
Bitra	2005	Half-normal/Cosine	0.60	15.32	20.33	10.10	23.23	33	Half-normal/Cosine	0.62	115.47	24.28	69.82	190.99	257	Half-normal/Cosine	0.66	67.39	29.69	36.60	124.09	159
	2006			20.42	20.00	13.56	30.76	44			111.88	24.15	67.83	184.53	249			58.49	27.93	32.91	103.96	138
Chetlat	2005	Half-normal/Cosine	0.47	11.63	43.41	4.82	28.03	11	Half-normal/Cosine	0.61	67.18	33.86	32.19	140.21	82	Half-normal/Cosine	0.66	100.48	38.49	43.58	231.64	133
	2006			14.80	47.32	5.67	38.65	14			64.72	34.15	30.83	135.90	79			93.68	37.77	41.24	212.78	124

Table 1. Continued...

Kadmat	2005	Uniform /Cosine	0.64	0.71	100.35	0.11	4.44	1	Uniform /cosine	0.68	6.59	36.05	3.15	13.83	10	Half-normal/ Cosine	0.38	27.73	34.65	13.68	56.23	25
	2006	Uniform /Cosine	0.48	0.94	100.25	0.15	6.03	1	Uniform/ cosine	0.67	6.47	35.81	3.09	13.59	9			20.57	38.03	9.40	45.01	17
Kalpeni	2005	Uniform /Cosine	0.68	3.14	44.57	1.31	7.53	9	Half-normal /Cosine	0.47	28.06	31.98	14.83	53.10	55	Half-normal/ Polynomial	0.68	98.06	17.54	68.76	139.86	281
	2006			4.88	34.29	2.48	9.63	14			24.49	32.74	12.75	47.04	48			93.18	17.56	65.31	132.94	267
Kavaratti	2005	Half-normal/ Cosine	0.51	36.60	31.05	19.19	69.82	56	Half-normal/ Polynomial	0.88	35.63	27.16	20.21	62.84	94	Half-normal/ Cosine	1.00	35.67	20.07	23.47	54.21	107
	2006			25.49	35.71	12.17	53.37	39			39.80	26.47	22.90	69.20	105			31.34	22.72	19.50	50.35	94
	2007		21.01	33.70 10.39	42.43 30		46.71	24.12	8.12 27.60 115		28.22	24.21	16.94	46.91 79								
Kiltan	2005	Half-normal/ Cosine	0.66	0.76	101.04	0.12	5.02	1	Half-normal/ Cosine	0.66	46.48	48.72	16.80	128.64	61	Half-normal/ Cosine	0.66	28.96	67.31	7.40	113.28	38
Minicoy	2005	Uniform /Cosine	1.00	7.40	54.43	2.54	21.58	27	Half-normal/ Cosine	0.52	34.22	46.62	13.67	85.66	68	Uniform/Cosine	0.50	32.42	23.95	20.09	52.32	61
Suheli	2005	Half-normal/ Cosine	0.29	6.24	101.94	1.02	38.13	5	Half-normal/ Polynomial	0.43	24.70	52.73	8.54	71.45	30	Half-normal/ Cosine	0.45	114.15	24.35	69.96	186.26	144
	2006			13.73	50.59	5.03	37.48	11			51.05	28.81	28.13	92.65	62			84.03	25.04	50.75	139.11	106
Tinakkara	2005	Half-normal/ Polynomial	0.61	19.70	25.55	11.43	33.96	24	Half-normal/ Polynomial	1.00	26.50	25.32	15.08	46.58	53	Half-normal/ Polynomial	0.75	64.73	18.66	43.25	96.90	97
	2006			20.52	22.47	12.76	33.01	25			32.00	21.37	19.84	51.62	64			46.05	24.08	27.24	77.84	69
	2007			19.15	26.78	10.73	34.20	21			33.33	24.87	18.95	58.65	60			39.30	25.65	22.25	69.41	53

Hammer and Jones (1976) reported over 100 *T. crocea* /m^2 at Great Barrier Reef. *T. squamosa* densities from these areas were very low; 0.68 and 1.4 clams/ha from Tuvulu and Tokelau respectively (Braley, 1988; Braley, 1989). Motada (1938) reported very low recruitment and juvenile density of *T. gigas* despite an abundant adult population in Palau. Richard (1977) reported the density of *T. maxima* in Takapoto lagoon of French Polynesia which was 1440 clams/ha.

T. maxima densities in Lakshadweep Archipelago

In the first analysis, Giant Clam *T. maxima* density for entire Lakshadweep was estimated by the default settings of the conventional distance sampling engine for 2005 and 2006. Extrapolation of global density was not done for the year 2007 due to paucity of sampling efforts. Density estimates were found to be 141.2/ha (n = 2748, 95% CL 118.17 - 168.74) in 2005 and 122.7/ha (n = 1948, 95% CL 103.60 - 145.37) in 2006. Detection probability and effective strip width were 0.59 (0.55 - 0.64) and 5.9m respectively in 2005, and 0.69 (0.67 - 0.72) and 6.9 m respectively in 2006.

With the assumption that factors affecting visibility in a lagoon would remain unchanged through successive sampling years, detection probability of giant clam *T. maxima* in each island/lagoon was pooled over the study period during 2005-2007, and island wise density for each year was estimated through post stratification. Such an adjustment provided adequate number of sightings (60-80) for reliable density estimates in case of all the islands except Amini. In the case of Amini, detection probability was pooled across all islands and density was estimated by post stratification. Age class was used as a factor covariate in the multicovariate distance sampling analysis using the half-normal detection function model with cosine and polynomial series expansions. Models were selected on the basis of minimum Akaike Information Criteria.

Lastly, to estimate separate densities of juvenile, sub-adult and adults in each island/lagoon, age classes were selected as different layers; detection probability was estimated globally over the study period and density estimation was post stratified for each year. Half-normal and uniform models with cosine and polynomial series expansions were used in the conventional distance sampling analysis and model selection was based on the minimum Akaike Information Criteria. Adjustments were made in the cases where number of sightings was unreliably low, and these included pooling of detection probability across islands or age classes (Table 1).

Conclusion

T. maxima occurs in low density in Lakshadweep. Agatti has the highest density being 228 clams/ha declining to 188 clams/ha. Amini has the lowest density of 21 clams/ha declining to 14 clams/ha.

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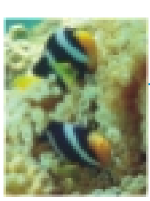

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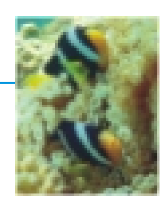

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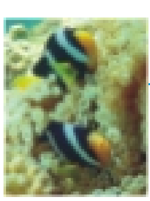
Giant clam (*Tridacna maxima*), Lakshadweep Islands



Status of ornamental reef fishes of the Gulf of Mannar Marine National Park, Southeastern India

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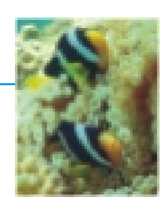
Abstract

An ornamental reef fish survey in the Gulf of Mannar had been carried out during 2002-2008. A total of 62 species of reef-dwelling fishes and seven species of reef-associated fishes had been recorded. The sightings were classified into four categories: Highly Threatened (<2), Rare (2–4), Minimal Impact (5–20) and Common (>20). The survey revealed 11 species to be threatened, 41 rare, 5 having minimal impact and 12 to be common in 2008. This is a contradiction when compared to the 2002 records where 11 of the species were found to be rare and 58 were commonly sighted. The highly threatened species include coral cat fish, green razor, powder blue tang, clown tang, Indian yellow tail angel, Koran angel, sargassum fish, argur grouper, blue and yellow grouper, queen coris and Africana coris. A specific group of fisherfolk is involved in the collection of these marine jewels. The paper focuses on the distribution, exploitation and trade in ornamental fishes, with a special note on their likely fate if proper measures of conservation are not adopted.

Introduction

The lifeline of a reef ecosystem is revealed by the presence of reef fishes that feed, dwell and breed in the reef area. Reef fishes are also termed as 'associated fauna' with regard to their interaction with the spread of reef cover. Today, fishes form an integral part of the reef communities, modifying benthic community structure and forming a major conduit for the movement of energy and material (Wainwright and Bellwood, 2002). Like the reefs, the reef fish fauna have been shaped by history, but this historical influence may not be as apparent, although it is becoming increasingly clear that history plays an important role in structuring communities. The Gulf of Mannar region in the southeastern coast of India is home to many species of reef fishes and very specifically to the ones that catch the attention of marine ornamental fish traders. Venkatramani *et al.* (2005) reported 113 species of ornamental fishes throughout the Gulf of Mannar region. Further underwater studies on a long term basis will throw light on the categorization of different fish classes inhabiting different small niches of this

Maldives anemone fish, *Amphiprion nigripes*



highly diverse ecosystem. The present information is provided with an aim to reveal the existing scenario on the fishing activities, status of distribution of reef fishes in known reef pockets where diversity is noted to be high and the marine ornamental trade that exists in these regions. The significant changes that have taken place in the last six years have been recorded in relation to the sightings of the fish species.

Material and methods

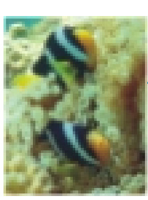
Fish survey was carried out every year between 2002 and 2008 at regular quarterly intervals. The underwater visual census (UVC) protocol and the belt transect method was followed (English *et al.,* 1997; Fowler 1987). The unknown species were photographed, verified and identified with standard fish identification guides. The categorization of fish sightings (number of fishes in each species) were modified for better understanding as: <2 (Highly Threatened); 2-4 (Rare); 5-20 (Minimal Impact); and >20 (Common).

Results

The Gulf of Mannar region is home to a chain of 21 islands and a wide diversity of flora and fauna. The islands are divided into four groups namely Mandapam, Keezhakkari, Vembar and Tuticorin. Among the groups, the peripheral groups namely the Mandapam and the Tuticorin groups were found to be important areas, from where marine ornamentals are collected and exported. In comparison, Mandapam was found to have a better diversity of ornamental fishes collected. The peak season for collection of marine ornamentals was found to be from November to April. This season is basically post-monsoon, where the reef areas are identified to have good visibility. Sometimes after good rains, the water becomes very turbid but due to the movement of currents, the water becomes clear in a couple of days. The months from May to October become rough, turbid and very windy. During this period, though there is no sediment influx from land runoffs, underwater currents keep the water visibility to less than 30 cm. The winds make the sea very rough, thereby hindering the collection of reef fishes or setting traps near the reef areas. Though some fishermen engage in collection during these seasons, usually the harvest is low and not up to expectations.

Nearly 40 to 50 fishermen, on average, are actively involved in the harvesting of attractive reef fishes in the Mandapam region. They engage country crafts called 'Vallam' and 'Vathai'. Each Vallam can carry up to five fishermen while the Vathai is a very small boat which can carry a maximum of two persons only. Approximately 8–10 country crafts are now employed by the fishermen of the Gulf of Mannar region for the collection of marine ornamental fishes. The

Clark's anemone fish, *Amphiprion clarkii*

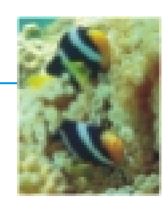


collection of marine ornamentals is mainly done by using fish traps, scoop nets and skin diving. Fish traps are indigenous bottom set gears that are left overnight and are pulled out during the next visit the following day. It is an effective and safe method to collect the reef fishes because there is no or minimal damage to their whole body or specifically their skin. Scoop nets and skin diving methods are also useful at times for collecting lethargic movers like clowns or gobid fishes. Unfortunately, these methods often result in some kind of extra stress or loss of scales from the bodies of the collected fishes. Fishermen engaged in the collection of marine ornamentals make from Rs. 6000 to Rs. 8000 per month. Some fishermen from Kanyakumari and Vizhinjam in Kerala are also involved in the collection of marine ornamentals. After collection, the fishes are brought to Mandapam where they are quarantined and then exported.

The fishermen take the collected reef fishes to buyers with much care. During 2001–2002, fishermen used to change water continually before the fishes were brought to the buyers. Nowadays, battery-operated aerators provide a convenient alternative which the fishermen utilize to bring the collected fishes with almost nil mortality. As soon as the fishes are brought to the buyer, they are sent to the quarantine division where proper acclimatization, medicinal treatment and accommodation processes are carried out. Methylene blue and methyl green treatment, or a dip in diluted formalin for a period of time, are usually carried out as quarantine measures. This is done to make any injured areas free of secondary microbial infections and to keep the fish healthy. This is a must-do process because newly introduced fish might infect previously quarantined, healthy individuals. Feeding is basically avoided while the fish are being quarantined. The quarantine period varies from 2 to 10 days. If it is more than two days, feed is provided to keep the fish healthy.

Basically, the feed given includes clam meat, *Artemia*, polychaete worms and fish tissue. The choice of feed also depends upon the feeding pattern of a particular fish. *Artemia* is much preferred by fishes with small mouths while other fishes are opportunistic feeders, feeding on almost anything that is provided. After the quarantine is over and the fishes start to feed normally, they are transferred to display tanks where they are maintained until their export. When they are packed, they are double packed in good-quality transparent covers and filled with oxygen which can sustain the fish up to 24 h. This oxygen packing is prescribed even for very short distances to avoid anoxic conditions. A mild dose (1 ml) of methylene blue is also added to the packing to check bacterial growth. The ready consignments of reef fishes are airlifted to many places within the country and select marine ornamental

Reef habitat with fishes (*Abudefduf saxatilis*)



hubs in Southeast Asia. The local market destinations include Trivandrum, Bangalore, Mumbai and Chennai while Sri Lanka and Singapore are the major centres where marine ornamentals are exported from India. Various aquariums maintained in corporate offices, research organizations and public areas are also important local markets.

Status of reef fishes

A modified method of Fowler, (1987) was followed to assess the status of the reef fishes in the Gulf of Mannar Marine National Park (GoMMNP) area. This is a standard method which evolved from repeated experiments and studies. Thus visual census was adopted for the present assessment. The advantages of UVC are that it is commonly used, quantitative, rapid, non-destructive and inexpensive, involves minimum use of personnel and specialized equip-ments, amenable to resurvey through time and can lead to the production of large databases. There are also certain disadvantages when we adopt UVC. Observers have to be well trained and experienced, and there are chances of fishes getting attracted towards divers or scared and swim away from them, there can be observer errors and biases, low statistical power in detection of changes in rare species and the technique is restricted to shallow depths only. Keeping all these facts in mind, special care was taken every time a survey was made. The survey revealed 11 species to

Table 1. List of fishes exploited for ornamental purposes and their status

Common name	Scientific name	Vernacular name	Status 2002	Status 2008
Honeycomb eel	*Gymnothorax favagineus*	Anjalai	Common	Rare
Broadfin moray eel	*Gymnothorax pseudothyrsoideus*	Anjalai	Common	Rare
Shortfin lion fish	*Dendrochirus brachypterus*	Saamy meen	Common	Rare
Moorish idol	*Zanclus cornutus*	Vannathi	Common	Common
Coral cat fish	*Plotosus lineatus*	Chungaan	Rare	Highly threatened
Golden trevally	*Gnathanodon speciosus*	Vari paarai	Common	Common
Red coat squirrelfish	*Sargocentron rubrum*	Mundakanni meen	Common	Common
Blue streak cleaner wrasse	*Labroides dimidiatus*	Kilinjaan	Common	Rare
Blackeye thicklip wrasse	*Hemigymnus melapterus*	Kilinjaan	Common	Minimal impact
Green razor fish	*Xyrichtys splendens*	Kilinjaan	Rare	Highly threatened
Zigzag wrasse	*Halichoeres scapularis*	Kilinjaan	Common	Rare
Undulate trigger fish	*Balistapus undulatus*	Claathi	Common	Common
Mustache trigger fish	*Balistoides viridescens*	Claathi	Common	Rare
Redtooth trigger fish	*Odonus* sp.	Claathi	Common	Common
Banded goby	*Amblygobius phalaena*	Kuzhi meen	Common	Rare
Ornate goby	*Istigobius ornatus*	Kuzhi meen	Common	Rare
Striped poison-fang blenny	*Meiacanthus grammistes*	Kilinjaan	Common	Rare
Doederlein's cardinal fish	*Apogon doederleini*	Kannadi meen	Common	Common
Two-spot cardinal fish	*Apogon maculatus*	Kannadi meen	Common	Rare
Spotted sharpnose puffer	*Canthigaster punctatissima*	Pethai	Common	Rare
Spotted trunkfish	*Lactophrys bicaudalis*	Kada maadu	Common	Rare

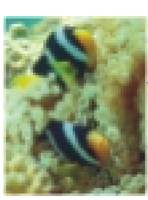
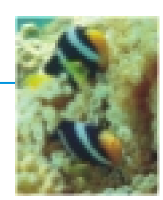


Table 1. Continued...

Common name	Scientific name	Vernacular name	Status	
			2002	2008
Long horn cow fish	*Lactoria cornuta*	Kada maadu	Common	Common
Sergeant major damsel	*Abudefduf saxatilis*	Paar meen	Common	Common
Yellow tail damsel	*Chrysiptera parasema*	Paar meen	Common	Rare
Yellow tail blue damsel	*Chromis xanthura*	Paar meen	Common	Rare
Hombug damsel	*Dascyllus aruanus*	Paar meen	Common	Rare
Three spot damsel	*Dascyllus trimaculatus*	Paar meen	Common	Rare
Blue-green reef chromis	*Chromis viridis*	Paar meen	Common	Rare
Powder blue surgeon fish	*Acanthurus leucosternon*	Vorandai	Rare	Highly threatened
Clown surgeon fish	*Acanthurus lineatus*	Vorandai	Rare	Highly threatened
Convict surgeon fish	*Acanthurus triostegus*	Vorandai	Common	Rare
Ring tail surgeon fish	*Acanthurus blochii*	Vorandai	Common	Rare
Indian yellow tail angel	*Apolemichthys xanthurus*	Vorandai	Rare	Highly threatened
Blue ring angel	*Pomacanthus annularis*	Vari vannathi	Common	Rare
Koran angel	*Pomacanthus semicirculatus*	Vari vannathi	Rare	Highly threatened
Threadfin butterfly	*Chaetodon auriga*	Vannathi	Common	Minimal impact
Butterfly	*Chaetodon collare*	Vannathi	Common	Common
Falcula butterfly	*Chaetodon falcula*	Vannathi	Common	Rare
Raccoon butterfly	*Chaetodon lunula*	Vannathi	Common	Rare
Spot tail butterfly	*Chaetodon ocellicaudus*	Vannathi	Common	Rare
Eight-band butterfly	*Chaetodon octofasciatus*	Vannathi	Common	Rare
Chevron butterfly	*Chaetodon xanthurus*	Vannathi	Common	Rare
Melon butterfly	*Chaetodon austriacus*	Vannathi	Common	Rare
Yellow-head butterfly	*Chaetodon xanthocephalus*	Vannathi	Common	Rare
Indian vagabond butterfly	*Chaetodon decussatus*	Vannathi	Common	Minimal impact
Lined butterfly	*Chaetodon lineolatus*	Vannathi	Common	Rare
Blue-blotch butterfly	*Chaetodon plebeius*	Vannathi	Common	Rare
Longfin bannerfish	*Heniochus acuminatus*	Vannathi	Common	Minimal impact
Diana's hogfish	*Bodianus diana*	Vannathi	Common	Rare
Green birdmouth wrasse	*Gomphosus caeruleus*	Kilinjaan	Common	Rare
Checkerboard wrasse	*Halichoeres hortulanus*	Kilinjaan	Common	Minimal impact
Moon wrasse	*Thalassoma lunare*	Kilinjaan	Common	Rare
Bird wrasse	*Gomphosus varius*	Kilinjaan	Common	Rare
Six bar wrasse	*Thalassoma hardwicke*	Kilinjaan	Common	Rare
Srilankan dottyback	*Pseudochromis dilectus*	Kilinjaan	Common	Rare
Whitecheck monocle bream	*Scolopsis lineata*	Kilinjaan	Common	Rare
Bleekeri hawkfish	*Cirrhitichthys bleekeri*	Mundakanni meen	Common	Rare
Freckled hawkfish	*Paracirrhites forsteri*	Thumbi	Common	Rare
Parrot fish	*Scarus ghobban*	Kalava	Common	Common
Sargassum fish	*Histrio histrio*	Saamy meen	Rare	Highly threatened
Argus grouper	*Cephalopholis argus*	Pulli kalava	Rare	Highly threatened
Blue line grouper	*Cephalopholis* sp.	Kalava	Common	Rare
Blue and yellow grouper	*Epinephelus flavocaeruleus*	Kalava	Rare	Highly threatened
Common blue strip snapper	*Lutjanus kasmira*	Manjal keeli	Common	Common
Striped sweetlips	*Plectorhinchus diagrammus*	Paruthi meen	Common	Rare
Diana's hogfish	*Bodianus diana*	Kilinjaan	Common	Rare
Queen coris	*Coris*	KIlinjaan	Rare	Highly threatened
Africana coris	*Coris cuvieri*	Kilinjaan	Rare	Highly threatened
Black tail snapper	*Lutjanus fulvus*	Par keeli	Common	Common



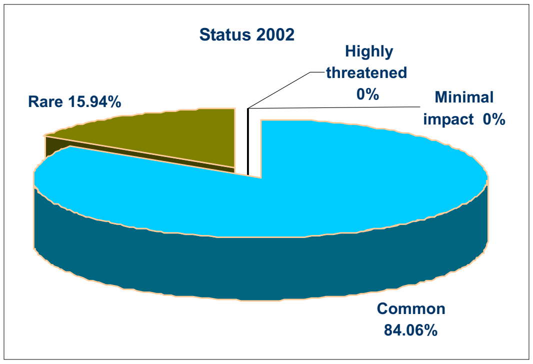


Fig. 1. Status of ornamental fishes in the Gulf of Mannar during 2002

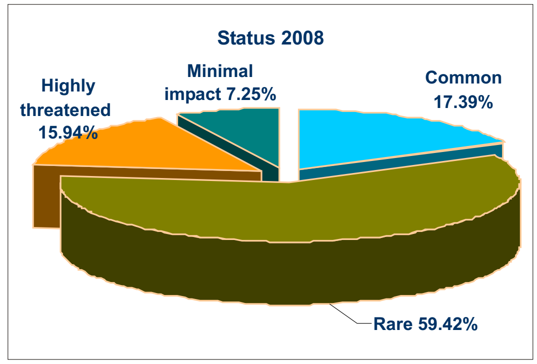


Fig. 2. Status of ornamental fishes in the Gulf of Mannar during 2008

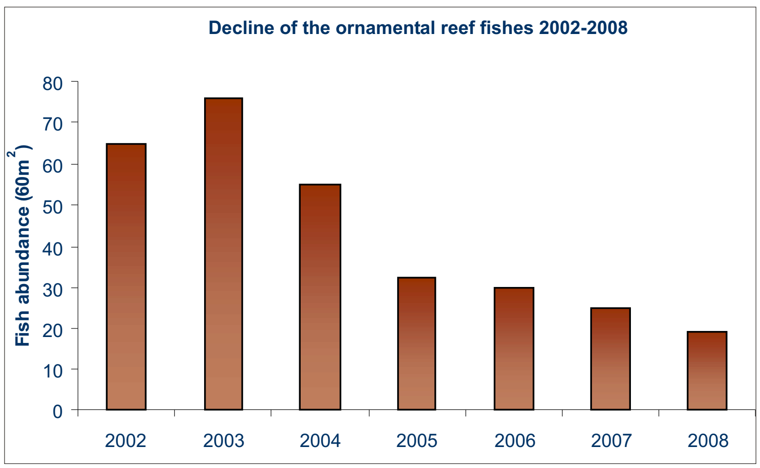


Fig. 3. Comparison of the reef fish availability

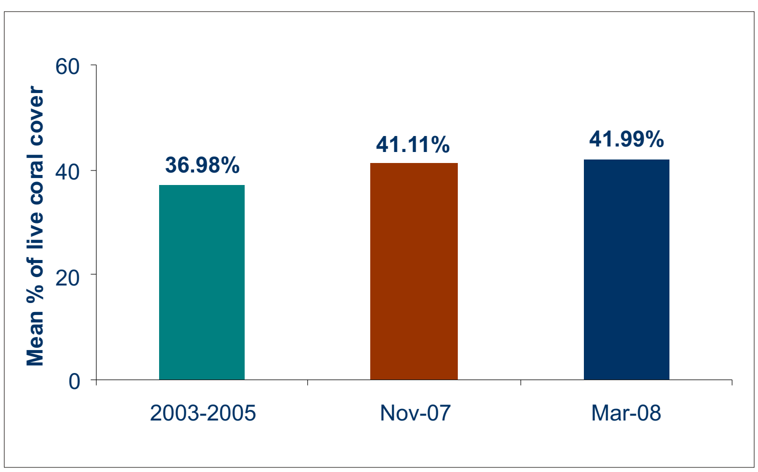
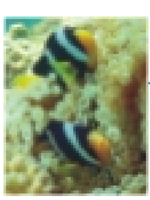


Fig. 4. Live coral cover increase in the Gulf of Mannar 2003 - 2008



be threatened, 41 rare, five having minimal impact and 12 to be common in 2008. This is a contradiction when compared to the 2002 records where 11 of the species were found to be rare and 58 were commonly sighted (Table 1). The highly threatened species include coral cat fish, green razor, powder blue tang, clown tang, Indian yellow tail angel, Koran angel, sargassum fish, argur grouper, blue and yellow grouper, queen coris and Africana coris. During 2002, 15.94% of fishes were rare, the rest were common and no highly threatened species were reported (Figures 1 and 2). But in 2008, 15.94% of fishes were highly threatened which were rare during 2002. Moreover, 59.42% became rare, 7.25% were minimal impact and only 17.39% were common during 2008. A comparative graphical representation of ornamental fish status over the years is highlighted in Figure 3 and coral live cover status is given in Figure 4. It is to be noted that the live coral cover has been increasing since 2005 after the complete halt of mining with about 5% increase observed in 2008. In total, 62 fish species are reef-dependent and seven species of fishes were found to be reef-associated.

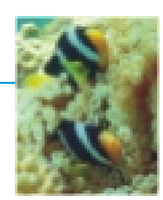
Dascyllus sp. in Gulf of Mannar

Emperor angel fish, *Pomacanthus imperator* occurring in Gulf of Mannar

Discussion

The global trade value of exported ornamental fish and related products in terms of their production and maintenance costs was estimated at over US$ 15,000 million (CARI, 2009). The world trade of ornamental fish has been estimated to be around US$ 8.5 billion in 2005 and this is growing, with an annual growth rate of about 10% (CARI, 2009). This growing trend is alarming to conservationists because 90% of the harvested fish are from the wild. For the Indian marine ornamental trade industry, there are no specific norms for exporting reef fishes.

A phase of decline in the commonly sighted ornamental fish species



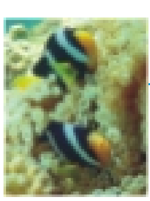
was the most important finding in the present study. In 2002, the survey reve-aled 11 species of fishes to be rare and about 58 species to be common where-as in 2008, the survey revealed 11 spe-cies to be highly threatened, 41 rare, five having minimal impact and only 12 to be commonly sighted. This has been an area of concern in many countries exporting live marine ornamentals. In Brazil, 34 exotic species figured on the permits and amounted to nearly 16% of the exports; however, most of them consist of misidentified native species (Monteiro-Neto *et al.*, 2004). This is true in the case of the ornamental fish trade throughout the world and Gulf of Mannar is no exception. The buyers are basically non-fisherfolk and there are times when species are wrongly identified or the common name or trade name of an important export fish is confused.

India is yet to make a mark in the marine ornamental trade business. India stands nowhere when compared to some of the Southeast Asian countries. Together with Indonesia, the Philippines supplies an estimated 85% of the world's saltwater ornamental aquarium fish (Nolting and Schrim, 2003). They have their own problems like illegal dynamite and cyanide fishing methods. Though these are banned, some vested interests have created an interest within the local fishing communities engaging them to conduct destructive fishing methods. In India, the use of destructive fishing methods like dynamite and poison are banned. Fishermen nowadays are using fish traps in the reef areas. The setting up and retrieval of traps pose a big threat to the live reef cover and the damage is very deleterious. Thus there is a need for continuous monitoring to study the density, diversity and exploitation levels of marine ornamental fishes of the Gulf of Mannar.

The percentage of live coral cover in the Gulf of Mannar has been increasing since 2005, mainly because of the complete halt to mining, reduction in the destructive fishing practices and strict enforcement of the law. But the revival of coral reefs has not had any impact on the ornamental fishes since they keep reducing in number every year. This is because of the increasing illegal exploitation in the protected reef areas of the Marine National Park with the help of local traditional fishermen. Even fingerlings of any kind of ornamental fish are caught by these fishers.

The major fishing grounds for the ornamental fishers are located around the Gulf of Mannar islands in the reef areas. Even though they are not allowed to enter this reef area by law, they illegally fish in this area regularly. Because of the limited manpower in the Marine Park Management, the surveillance of the entire area is very difficult. Furthermore, the nearby Palk Bay is not under any legal protection and the fishermen often say that they catch these ornamental reef fishes from Palk

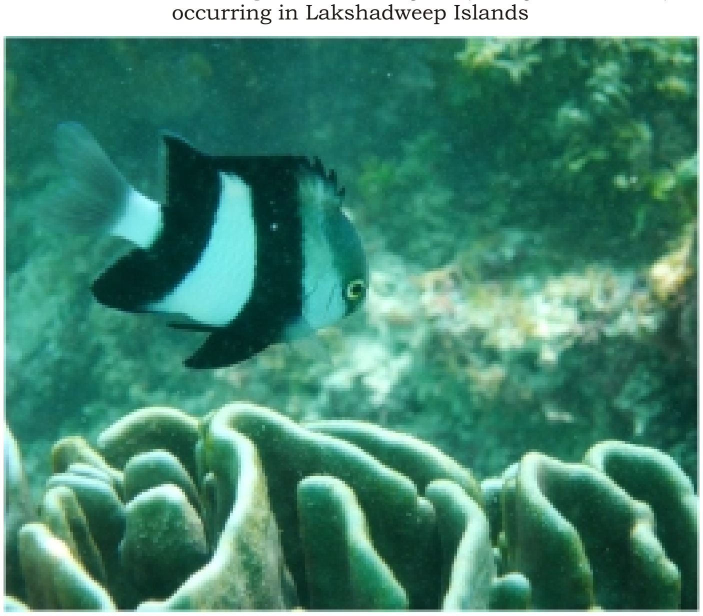
Lion fish (*Pterois* sp.) occurring in Gulf of Mannar



Bay area. But in reality, most of the catch is from the coral reef areas of Gulf of Mannar Marine National Park. In addition, no ornamental reef fish is protected by law.

If this illegal ornamental reef fishery is left unchecked for a few more years the results would be disastrous. This could also affect the health of the coral reef ecosystem and there would also be ecological imbalance. There must be some strong regulations and implementations to protect the remnant fishes. More effort should be taken to check this illegal activity which happens in the reef areas around the islands. A ban on the 'Highly Threatened' and 'Rare' ornamental fishes is a good approach to prevent their local extinction, but it is not advisable to ban all the known ornamental fishes. A ban is desperately needed on the trade in the 'Highly Threatened' and 'Rare' species to prevent their local extinction. "Highly threatened" and "Rare" fishes must be brought under the Schedule I of the Wildlife (Protection) Act, 1972, so that these ocean jewels can be protected and conserved. Since coral cover is increasing, if steps are taken to check the illegal ornamental fishery, it is likely that the ornamental fish population of the Gulf of Mannar will recover to add beauty and diversity to the reefs.

Humbug damsel, *Dascyllus* (*Dascyllus aruanus*) occurring in Lakshadweep Islands



Acknowledgements

The authors are thankful to the Principal Chief Conservator of Forests and the Chief Wildlife Warden and the Wildlife Warden, GoMMNP for research permission.

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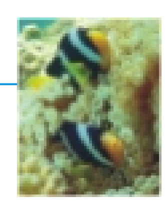

Coral reef habitat in Andman and Nicobar Islands

Reef fish diversity of Andaman and Nicobar Islands, Bay of Bengal

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Abstract

The fringing reefs of Andaman and Nicobar Islands, with a variety of habitats such as lagoons, reef slopes, reef flats with heavy surf breaks, sand-rubble and weed and coralline algal beds, harbour rich and diverse fish faunal groups. Over 1370 species of marine fish have been recorded from the Island waters. The detailed studies on reef fish diversity revealed the occurrence of 720 species of fish belonging to 90 families in and around the reef habitats. About 290 species comprising 42% of reef fish resources are found to be food fishes, while 315 species comprising 43% are of an ornamental nature. The most common and dominant reef fishes are butterflyfishes, angelfishes, damsels, wrasses, parrotfishes, puffers, balisteds, snappers, groupers, fusilers, lethrinids, eels, squirrelfishes, gobiids. Poor management, over exploitation and natural calamities like cyclones and the tsunami drastically reduced and altered the reef habitats thereby affecting the reef fish resources during recent times. The reef fish diversity and distribution in different reef habitats of the islands, threats, exploitation, and conservation aspects have been discussed.

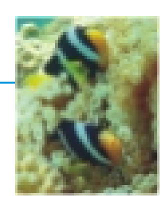
Introduction

Coral reefs are one of the oldest ecosystems on the earth and have provided sustenance for coastal communities in the tropics, yielding a bountiful harvest of food, as well as many other products as diverse as building materials to medicines. The fishes constitute the largest and dominant group of animals associated with coral reefs. The ecological and biological aspects of reef fishes have received considerable attention in the recent past in the tropical region of the Indo-Pacific and Atlantic Oceans.

The fringing reefs of Andaman and Nicobar Islands include lagoons, patch reefs, exposed reef flats with heavy surf breaks, silt-sand, sand-coral rubble, weed and coralline algal beds. They harbour a rich and diverse associated fauna including a large number of fish assemblages. Recent reports by Talwar (1990), Dorairaj *et al.* (1994), Rao *et al.* (1997) and Rao (2008) recorded the presence of more than 1370 species of fishes in the marine ecosystem of these islands, but there are only a few studies with specific reference to reef fishes (Rao, 1996 and 2003; Kamla Devi and Rao, 2003; Rao and Kamla Devi, 2004). The present report gives an account of the diversity, threats and conservation aspects of the reef fishes of the above islands.

Material and methods

To assess the diversity of reef fish fauna, random surveys and collections were made around the islands over a decade. The fish samples were collected using various methods like spearing and operation of cast nets, small shore seines, and hand nets. Samples were also collected from fish markets. The fishes were photographed before their colour patterns faded



immediately in the field for easy identification. Underwater videography was also done to know the species composition. All the samples were preserved in 5% neutral formaldehyde solution and deposited in the National Zoological Collections of Zoological Survey of India, Port Blair.

Reef fish diversity

Usually the species diversity of reef fishes is higher in any of the reef regions than the population size of individual species. Reef fish diversity in some coral reef regions of the Indo-Pacific is given in Table 1. The reef fishes formed about 53% of the total number of marine fish species hitherto known from different marine habitats of these islands. This represents a total of 720 species belonging to 90 families.

Table 1. Reef fish Diversity in some Coral Reef Regions of the Indo-Pacific

Region	No. of Reef Fish Species
Kuwait	85
Bahamas	507
Seychelles	880
Madagascar	552
Philippines	2177*
New Guinea	170
Great Barrier Reef	2500
New Caledonia	1000
Hawaii	448
Virgin Island (Section of Togue Bay)	125
Lakshadweep	565
Andaman and Nicobar Islands	720

Source : Goldman and Talbot, 1973.

It was found that of the total 90 families, 57 families were represented each between 1 to 5 species, 7 families between 6 to 10 species, 13 families

Table 2. Family wise species abundance

Family	No. of species recorded
Acanthuridae	18
Antennaridae	3
Apogonidae	25
Atherinidae	2
Balistidae	16
Belonidae	2
Blennidae	23
Bothidae	3
Bythitidae	1
Caesionidae	13
Callionymidea	5
Caracanthidae	1
Carangidae	29
Carapidae	1
Carcharhinidae	14
Centricisidae	2
Chaetodontidae	33
Chanidae	1
Cirrhitidae	4
Clupeidae	2
Congridae	2
Coryphinidae	1
Cynoglossidae	2
Dactylopteridae	1
Dasyatidae	8
Diodontidae	3
Drepanidae	1
Echeneidae	2
Ephippidae	3
Exocoetidae	2
Fistularidae	1
Gerreidae	2
Gobiidae	23
Haemulidae	7
Hemiramphidae	2
Hemiscyllidae	4
Holocentridae	11
Istiophoridae	1
Kuhlidae	2
Kyphosidae	2
Labridae	51
Lethrinidae	20
Lutjanidae	31
Malacanthidae	2
Meneidae	1
Microdesmidae	4
Monacanthidae	11
Monocentridae	1
Monodactylidae	1
Mugilidae	3
Mullidae	12
Muraenidae	13
Myliobatidae	2

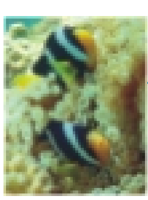


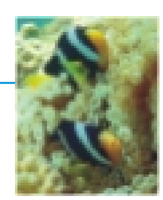
Table 2. Continued...

Family	No. of species recorded
Narkidae	1
Nemipteridae	17
Ophichthidae	6
Ophiididae	1
Ostraciidae	5
Pegasidae	2
Pempheridae	3
Pingupedidae	5
Platycephalidae	5
Plesiopidae	3
Plotosidae	2
Pomacanthidae	9
Pomacenridae	46
Priacanthidae	3
Psettodidae	1
Pseudochromidae	4
Rachycentridae	1
Rhinobatidae	3
Scaridae	14
Scombridae	10
Scorpaenidae	12
Serranidae	44
Siganidae	12
Soleidae	7
Solenostomidae	2
Sphyraenidae	5
Sphyrnidae	4
Synaceidae	4
Syngnathidae	11
Synodontidae	5
Teraponidae	2
Tetraodontidae	13
Tetrarogidae	5
Triacanthidae	2
Trichonotidae	1
Trypterygidae	3
Zanclidae	1

between 11 to 20 species, 4 families between 21 to 30 species, 2 families each between 31 to 40 and 41 to 50 species respectively (Table 2). Fishes of the family Labridae were the most dominant with 51 species followed by Pomacentridae with 46 species, Serranidae 44 species, Chaetodontidae 33 species and Lutjanidae 31 species, Carangidae 29 species and Apogonidae with 25 species constituting about 36%

Table 3. Some commercially important food fishes

Group and Species
SHARKS
Carcharhinus melanopterus
Carcharhinus dussumieri
Carcharhinus albimarginatus
Carcharhinus sorrah
Carcharhinus wheeleri
Rhizoprionodon acutus
Rhizoprionodon oligolinx
Triaenodon obesus
Sphyrna zygaena
Stingrays
Dasyatis kuhlii
Himantura gerrardi
Himanturs uranak
Hypholophus sephen
Squirrelfishes
Myripristis murdjan
Myripristis adusta
Sargocentron caudimaculatum
Sargocentron rubrum
Flatheads
Platycephalus indicus
Needlefishes
Strongylura strongylura
Tylosurus crocodilus
Groupers
Aethaloperca roggaa
Anyperodon leucogrammicus
Cephalopholis argus
Cephalopholis formosa
Cephalopholis microdon
Cephalopholis miniata
Cephalopholis urodeta
Cromileptes altivelis
Epinephelus areolatus
Epinephelus caeruleopunctatus
Epinephelus fasciatus
Epinephelus flavocaeruleus
Epinephelus lanceolatus
Epinephelus merra
Epinephelus malabaricus
Epinephelus undulosus
Epinephelus ongus
Epinephelus haxagonatus
Plectropomus maculatus
Plectropomus pessuliferus
Variola louti
Snappers
Aphareus rutilans
Lutjanus bohar
Lutjanus argentimaculatus
Lutjanus biguttatus
Lutjanus gibbus
Lutjanus johnii
Lutjanus lunulatus
Lutjanus madras
Lutjanus kasmira
Fusiliers
Caesio caerulaeria

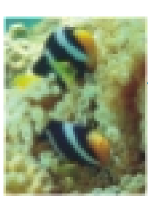


Caesio cuning
Caesio lunaris
Gymnocaesio gymnoptera
Carangids (Jacks)
Alectis ciliaris
Alepes djedaba
Carangoides armatus
Carangoides fulvoguttatus
Carangoides hedlandensis
Carangoides malabaricus
Caranx melampygus
Caranx sexfasciatus
Decapterus russelli
Elagatis bipinnulatus
Megalaspis cordyla
Scomberoides commersonnianus
Scomberoides lysan
Selar crumenophthalmus
Trachinotus blochii
Sweetlips
Plectrorhinchus gibbosus
Pomadasys kaakan
Pomadasys maculatus
Pig-faced breams
Lethrinus harak
Lethrinus nebulosus
Lethrinus ornatus
Lethrinus elongatus
Gymnocranius elongatus
Coral Breams
Nemipterus bleekeri
Nemipterus japonicus
Nemipterus tolu
Scolopsis ciliatus
Scolopsis personatus
Drummers
Kyphosus cinerascens
Kyphosus vaigiensis
Goatfishes
Parupeneus barberinus
Parupeneus indicus
Parupeneus cinnabarinus
Surgeons
Acanthurus triostegus
Acanthurus lineatus
Naso lituratus
Naso vlamingi
Rabbitfishes
Siganus javus
Siganus vermiculatus
Siganus stellatus
Scombrids
Gymnosarda unicolor
Grammatorcynus bilineatus
Grammatorcynus bicarinatus
Rastrelliger brachysoma
Rastrelliger kanagurta
Scomberomorus commersonii
Flatfishes
Pseudorhombus arsius

Source : Rajan, 2003

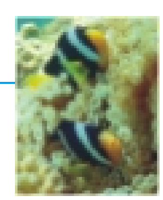
Table 4. Some important ornamental reef fishes

Anglerfishes
Antennarius commersoni
Antennarius coccineus
Histrio histrio
Razorfishes
Aeoliscus strigarts
Centriscus scutatus
Pipefishes
Choeroichthys sculptus
Doryramphus excisus
Hippocampus kuda
Hippocampus hystrix
Hippocampus horai
Hippocampus trimaculatus
Syngnathoides biaculeatus
Gournards
Dactyloptena orientalis
Scorpionfishes
Pterois antennata
Pterois volitans
Pterois radiata
Pterois russelli
Dendrochirus zebra
Dendrochirus brachypretus
Scorpaenodes guamensis
Scorpaenopsis gibbosa
Scorpaenopsis venosa
Stonefishes
Synanceia verrucosa
Velvetfishes
Caracanthus unipinna
Goldies
Anthias squamipinnis
Anthias spp.
Soapfishes
Grammistes sexlineatus
Cardinalfishes
Chilodipterus macrodon
Chilodipterus lineatus
Apogon cookii
Apogon fasciatus
Apogon aureus
Sphaeramia orbicularis
Kingfishes
Gnathanodon speciosus
Sweetlips
Plectrorhinchus orientalis
Plectrorhinchus gibbosus
Plectorhinchus chaetodonoides
Batfishes
Platax orbicularis
Platax pinnatus
Eeel catfishes
Plotosus lineatus



Butterflyfishes
Chaetodon auriga
Chaetodon collare
Chaetodon ephippium
Chaetodon falcula
Chaetodon guttatissimus
Chaetodon lineolatus
Chaetodon lunula
Chaetodon myerei
Chaetodon plebeius
Chaetodon triangulum
Chaetodon vagabundus
Chaetodon trifasciatus
Forcipiger longirostris
Henochus singularis
Heniochus acuminatus
Heniochus varius
Angelfishes
Centropyge eibli
Pomacanthus imperator
Pomacanthus semicirculatus
Pomacanthus xanthomatapon
Pygoplites diacanthus
Damsels and Clowns
Amphiprion clarckii
Amphiprion ocellaris
Amphiprion ephippium
Amphiprion akallopisos
Amphiprion frenatus
Amphiprion polymnus
Amphiprion sebae
Chromis caerulea
Chrysiptera biocellata
Chrysiptera unimaculata
Dascyllus aruanus
Dascyllus marginatus
Dascyllus trimaculatus
Pomacentrus lividus
Pomacentrus trimaculatus
Premnas biaculeatus
Stegastes lividus
Hawkfishes
Cirrhitus pinnulatus
Paracirrhites forsteri
Wrasses
Cheilinus chlorurus
Cheilinus diagrammus
Cheilinus trilobatus
Cheilinus undulatus
Cymoluteus lecluse
Epibulus insidiator
Halichoeres argus
Halichoeres hortulanus
Halichoeres scapularis
Halichoeres marginatus
Hemigymnus melapterus
Stethojulis trilineata
Stethojulis strigiventor
Thalassoma herbraicum
Thalassoma jansenii
Thalassoma lunare
Xyricththys pentasactylus
Parrotfishes
Scarus ghobban
Scarus rubroviolaceous
Scarus dubius
Scarus frenatus
Scarus gibbus
Scarus niger
Scarus rivulatus
Scarus sordidus
Surgeonfishes
Acanthurus leucosternon
Acanthurus triostegus
Zebrasoma veliferum
Zanclus canescens
Gobiids
Asterropteryx semipunctatus
Gobiodon citrinus
Gobiodon erythrospilus
Oplopomus oplopomus
Gobiodon quinquecincta
Leatherjackets
Aluterus scriptus
Aluterus monoceros
Amnases scopas
Oxymonacanthus longirostris
Triggerfishes
Abalistes stellatus
Balistapus undulatus
Balistoides conspicillium
Balistoides viridescens
Melichthys indicus
Odonus niger
Rhinecanthus aculeatus
Rhinecanthus rectangulus
Rhinecanthus verrucosus
Sufflamen chrysoptera
Boxfishes
Lactoria cornuta
Ostracion meleagris
Ostracion cubicus
Puffers
Arothron mappa
Arothron stellatus
Canthigaster solandri
Canthigaster bennetti
Chelonodon patoca
Porcupinefishes
Diodon hystrix
Diodon holacanthus

Source : Rao, 2004



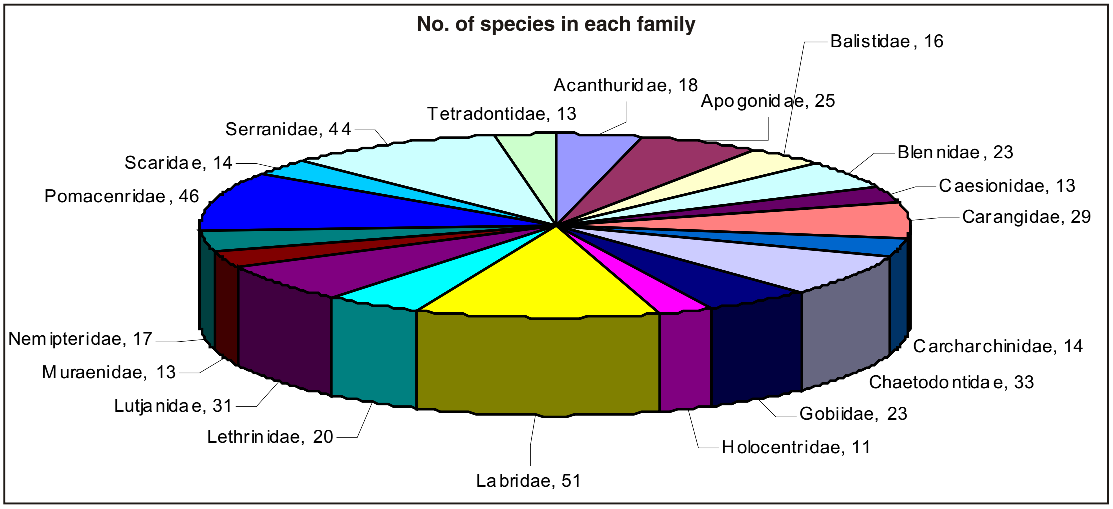


Fig. 1. Percentage contribution to abundance by major fish families

of the total reef fishes. The fishes of the families like Carcharhinidae (Sharks), Holocentridae (Squirrelfishes), Syngnanthidae (Pipefishes), Scorpaenidae (Scorpionfishes), Caesionidae (Fusiliers), Balistidae (Triggerfishes), Tetraodontidae (Puffers) were represented between 10 and 20 species, while a large number of families like Pegasidae, Ophidiidae, Antennariidae, Centricidae, Rachycentridae, Haemulidae, Pempheridae, Ephippidae, Tripterygiidae, Bothidae, Cynoglosidae were represented by few species and contribute much to the diversity of fish communities in the reefs of the Islands. The species abundance of major fish families is given in Fig.1. Out of the entire reef fishes reported, 290 species (40%) belonged to clupeids, breams, fusiliers, snappers, groupers, jacks, scombrids, surgeons and other miscellaneous groups which, largely fulfill the protein needs of the inhabitants of these islands. Of these, 132 species (45%) were considered commercially important including sharks, groupers, snappers, jacks and breams. The different reef fish categories of the islands are given in Fig.2. About 315 species (44%) of fish are of ornamental nature. The list of some commercially important food fishes and ornamental fishes is given in Tables 3 and 4, respectively.

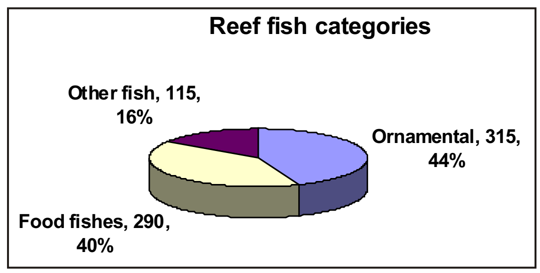
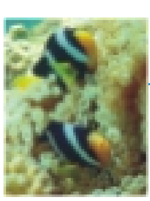


Fig. 2. Percentage contribution of categories of fishes

In fish diversity, Andaman and Nicobar Islands were found to be comparatively richer than the other reef areas. The basic reason for the high fish diversity in many tropical reef regions is due to high productivity and long and stable ecological conditions on the reefs (Talbot, 1970).



Exploitation and conservation

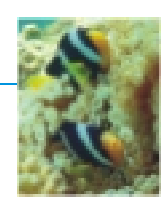
As the reef species judiciously share their reef environment and depend on each other for survival, intensive fishing of any living component, particularly the reef fishes, creates an imbalance in the web of reef life and alters the entire ecosystem.

It has been estimated that the reefs provide 12% of the global marine fish catch and may account for up to 25% of the fish caught by third world countries. As estimated globally, four million small scale fishers, about a third of all the subsistence fishers, rely on reefs for their livelihood and nutrition. Reef fisheries are also an important foreign exchange earner for a number of countries like Maldives, Sri Lanka and Indonesia. Most of the several hundred tropical fish species which are kept in marine aquaria around the world come from coral reefs only. The world marine aquarium fish trade has been valued at about US$ 9.5 billion annually.

Traditional fishing methods generally have had relatively little impact on the reef habitat, but many of the modern techniques accelerate over-fishing and cause damage to the reefs. Over-fishing of any one species of fish can cause dramatic population decline or explosion in other species. For instance, overexploitation of herbivorous fish such as surgeons or parrot-fish can lead to an increase in seaweed growth on the reefs; the seaweeds then compete with the corals since there is no natural check on their growth. Sometimes over-fishing on reefs could even be a contributory factor to the outbreak of the crown-of-thorns starfish (CoT) because commercial food fishes such as emperors and some triggers feed on juveniles of CoTs.

The rich potential of food and ornamental reef fishes occurring on the fringing reefs around these islands offer an ample scope for their sustenance and judicious commercial exploitation. There is no real time assessment of reef fish resources in these islands. However, the present estimate indicates an average potential of about 3 tons per sq. km. in the reef. So the expected yield from undamaged coral reef areas of these islands could be around 25,000 tons per year. Even though the potential is high, the reef fish resources could not be exploited fully in the islands due to limitations like topographical conditions of the reef system where commercial gears can not be operated efficiently.

In addition, the coral reefs of these islands harbour very diverse and colourful ornamental fishes and offering excellent chance for export trade. The fishes like angels, butterflyfishes, anemones, wrasses and leather jackets, have very high value in the international market. In the absence of detailed information on the biology, ecology and population structure of these reef fishes, harvesting the natural stocks for commercial exploitation has to be totally discouraged to avoid any damage to the reef ecosystem. Hook and line, cast netting and trap fishing could be developed and encouraged as sustenance fisheries in the islands. Commercial exploitation of ornamental reef fishes from the wild should be totally avoided, as the species diversity is always higher than their density on any reef area. Selected species may be bred in captivity to supplement the wild stock to avoid



indiscriminate over exploitation. In the long run, their breeding and culture can help considerably in sustaining a viable fish trade in this territory.

Only carefully managed mari-culture of some reef species with low intensity, preferably with management by local communities, should be encouraged. Any project on breeding fish in captivity needs proper assessment of the likely economic and social consequences, as well as ecological implications, so that farming can be regulated. Spawning sites of the commercially important fish species should be identified for proper conservation.

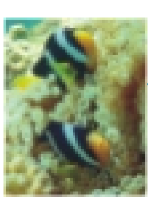
Threats to the reef fish resources

Most of the threats, which are common to and limiting factors for survival of coral reefs, are common to reef fishes also, with a little degree of variation. Over exploitation of reef fish resources is gaining momentum in the islands for the following reasons :

- Habitat loss and degradation, over fishing in limited areas and destructive fishing methods are some of the threats to the reef fish fauna.
- Due to lack of proper Fisheries Management Practices, most of the fishermen fish in limited areas and in the same localities continuously just off the reef, or in channels and lagoons, either by cast nets or shore seines in shallow reef areas near shores, causing adverse impact on fish assemblages.
- There is no regulation of mesh size of the nets for fishing. Nets with finer meshing are being used and more immature fishes are taken in each catch resulting in the gradual decrease of the fish stock.
- The modern nylon nets that are extensively used in fishing, when lost or discarded, do not degrade and pose a threat to corals.
- The destructive methods used for fishing are one of the major threats in the islands. The local Nicobari tribe collects fish from shallow pools during low tide on the reef flats by using poisonous juice extracted from the fruits of *Barringtonia* sp. This poisonous juice narcotises all the fish in the pool including small juveniles and other reef organisms. Because of the extensive use of these methods, many reef habitats around the islands such as Car Nicobar, Great Nicobar and Little Andaman are greatly damaged, therby affecting the juvenile fish stock considerably.
- Even though the local fishermen do not employ dynamite fishing, the threat still exists in the islands. The poachers from Myanmar and Thailand use dynamite for exploiting the reef wealth around the far flung islands, causing much damage to the reefs.

Conservation and recommendations

- Traditional fishing methods like hook and line and cast netting could be developed and encouraged as sustenance fishing practices in the islands.
- Use of nylon nets and traps near reefs should be banned.
- Intensive awareness building programmes for discouraging destructive fishing methods by local Tribals must be continued (e.g. use of poisons: *Barringtonia* fruit, bleaching powder).
- Ban on fishing activities near reefs



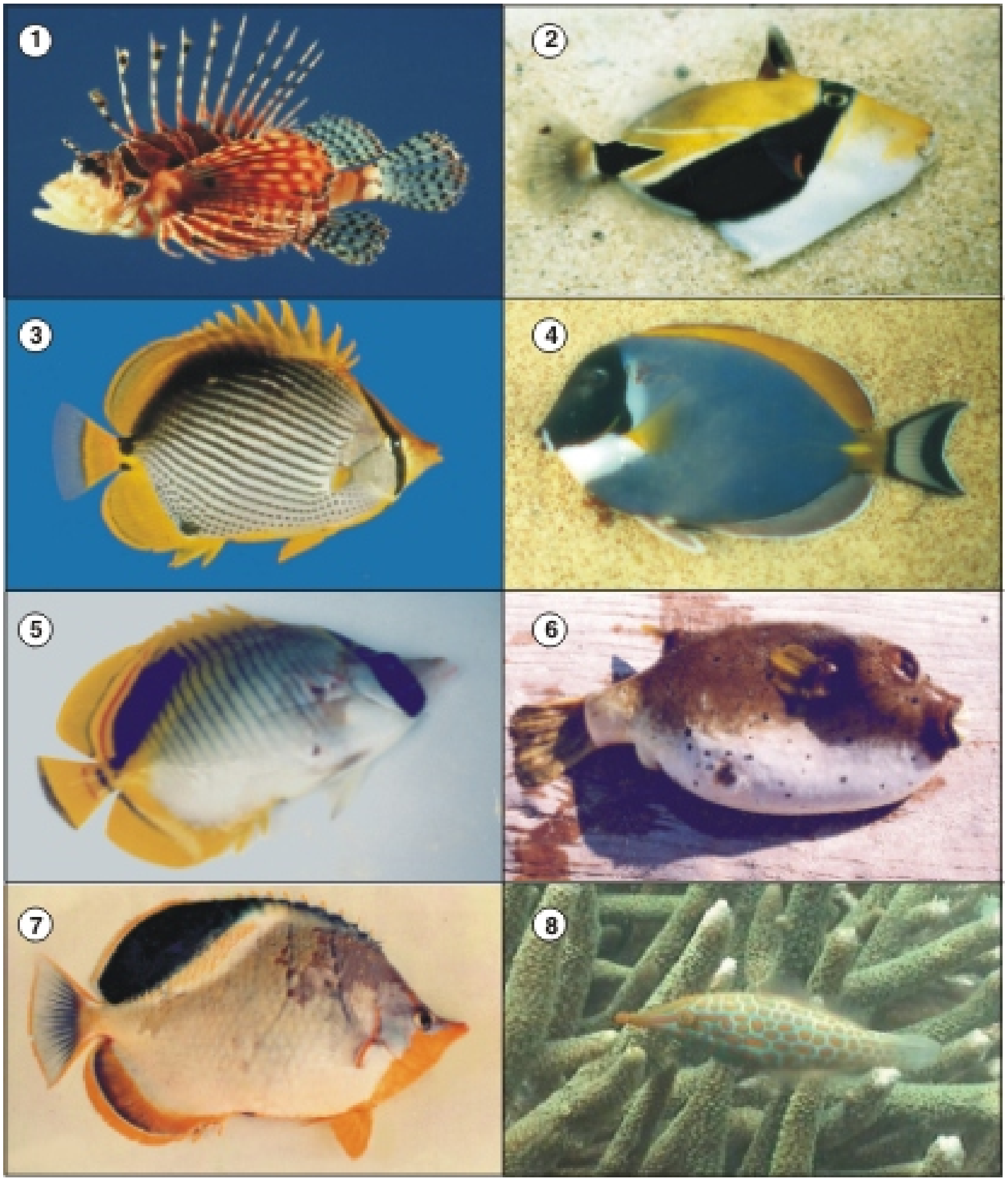
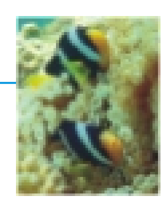


PLATE-I (Ornamental fishes)

Fig. 1. *Dendrochirus zebra* (Zebra lionfish); Fig. 2. *Rhinecanthus rectangulus* (Wedge-tailed trigger); Fig. 3. *Chaetodon melannotus* (Blackback butterflyfish); Fig. 4. *Acanthurus leucosternon* (Powderblue surgeon); Fig. 5. *Chaetodon lineolatus* (Lined butterflyfish); Fig. 6. *Arothron nigropunctatus* (Black spotted puffer); Fig. 7. *Chaetodon ephippium* (Saddled butterflyfish); Fig. 8. *Oxymonacanthus longirostris* (Beaked leatherjacket)



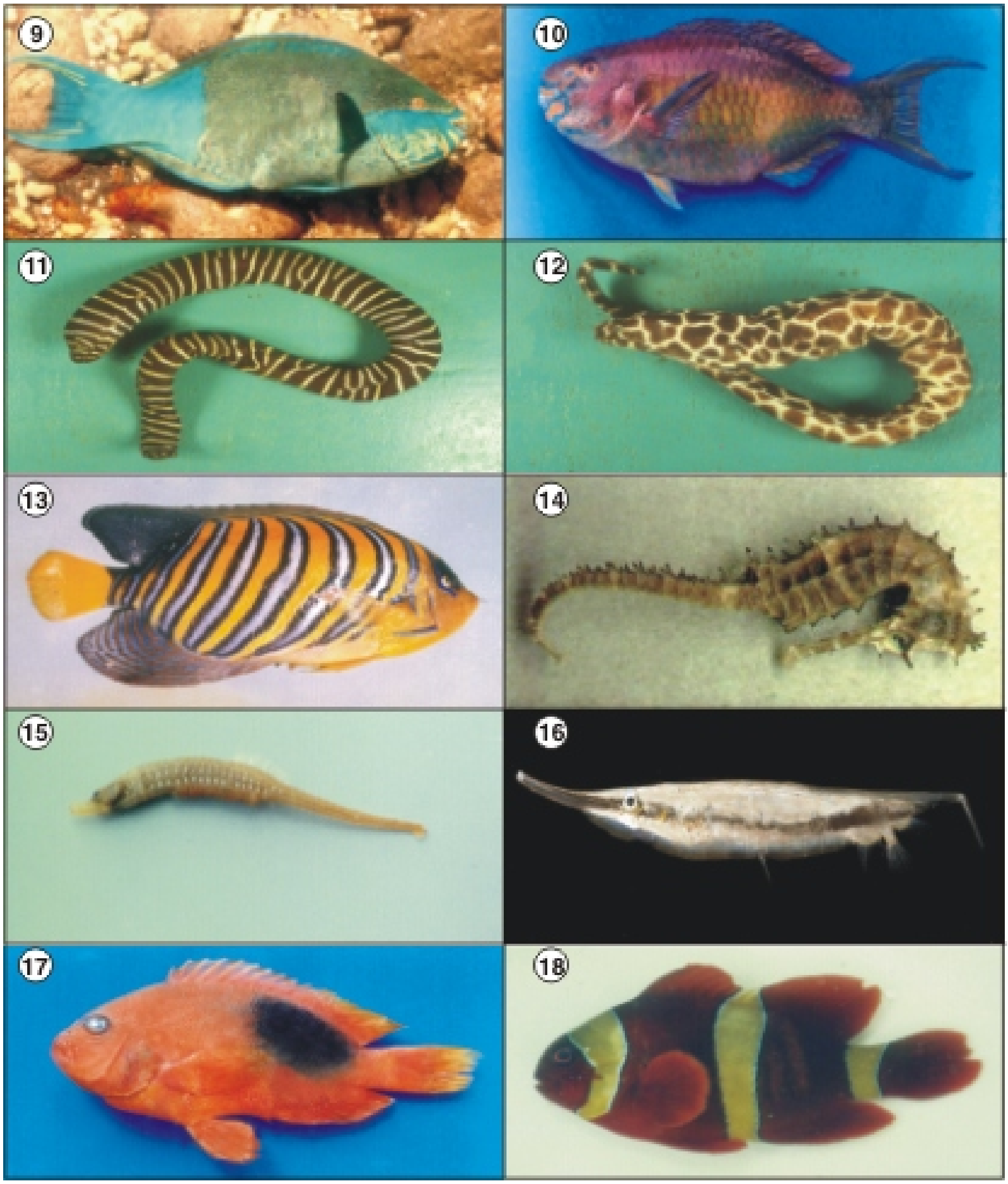


PLATE-II (Ornamental fishes)

Fig.9. *Scarus frenatus* (Bridled parrotfish); Fig.10. *Scarus rubroviolaceous* (Ember parrotfish); Fig.11. *Gymnomuearna zebra* (Zebra moray); Fig. 12. *Gymnothorax favagineus* (Blackspotted moray); Fig. 13. *Pygoplites diacanthus* (Regal angelfish); Fig.14. *Hippocampus histrix* (Thorny seahorse); Fig. 15. *Choeroichthys sculptus* (Sculptured pipefish); Fig. 16. *Aeoliscus strigatus* (Razorfish); Fig. 17. *Amphiprion ephippium* (Black-backed clown); Fig.18. *Premnas biaculeatus* (Spine-cheek anemonefish)

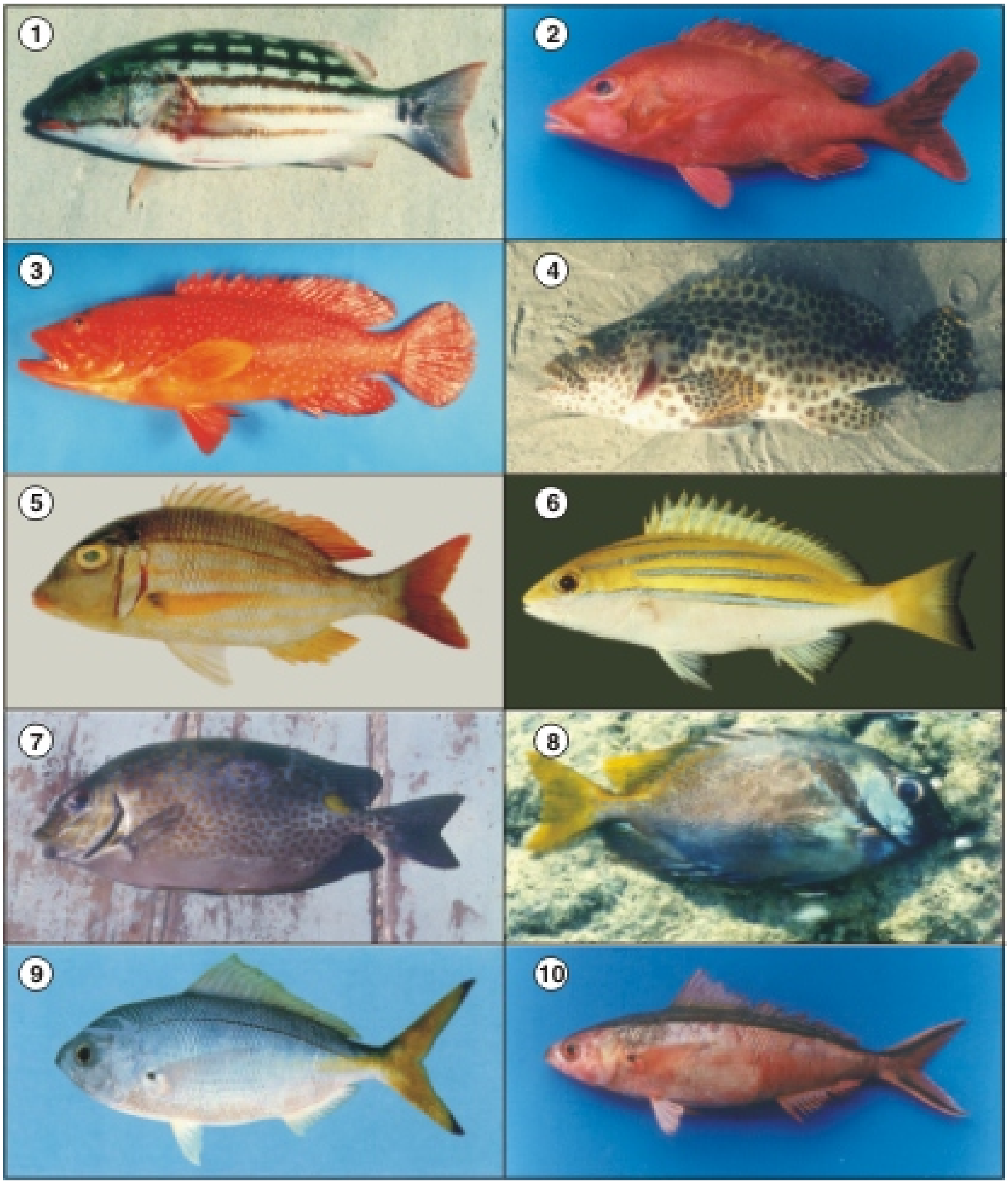


PLATE-III (Food fishes)

Fig.1. *Lutjanus decussatus* (Checkered snapper); Fig. 2. *Lutjanus gibbus* (Humpback red snapper); Fig.3. *Cephalopholis miniata* (Coral hind); Fig. 4. *Epinephelus merra* (Dwarf spotted grouper); Fig.5. *Lethrinus ornatus* (Ornate emperor); Fig. 6. *Lutjanus bengalensis* (Bengal snapper); Fig.7. *Siganus guttatus* (Yellow spotted rabbitfish); Fig. 8. *Siganus virgatus* (Barred rabbitfish); Fig.9. *Caesio lunaris* (Lunar fusilier); Fig.10. *Pterocaesio tile* (Dark-banded fusilier)

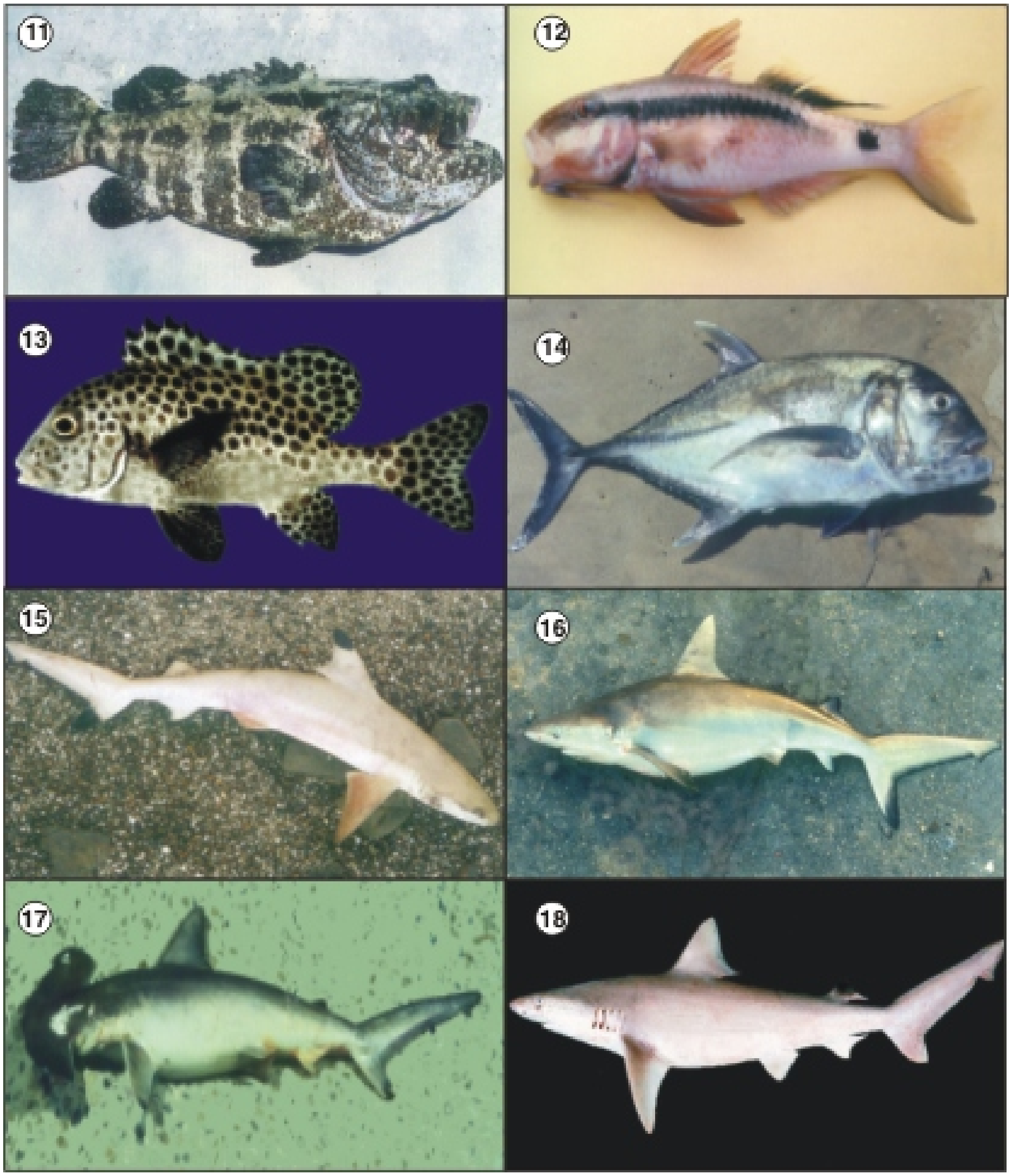


PLATE-IV (Food fishes)

Fig. 11. *Epinephelus fuscoguttatus* (Brown-marbled grouper); Fig. 12. *Parupeneus barberinus* (Dash-dot goatfish); Fig. 13. *Plectorhinchus chaetodonoides* (Spotted sweetlip); Fig. 14. *Caranx ignobilis* (Giany travely); Fig.15. *Carcharhinus melanopterus* (Black-tip reefshark); Fig.16. *Carcharhinus amblyrhynchos* (Blacktail reefshark); Fig. 17. *Sphyma lewini* (Scalloped hammerhead shark); Fig. 18. *Rhizoprionodon acutus* (Milk shark)

during fish breeding seasons must be strictly enforced.

- Commercial exploitation of ornamental reef fishes from the wild should be totally avoided.
- Only carefully managed low intensity mariculture of some reef species, preferably with management by local communities, should be encouraged.
- Proper fishery management practices are to be formulated and strictly implemented.
- Laws on regulation of mesh sizes of gear should be enforced to avoid gradual depletion of fish stocks.

Except for taxonomic studies, other aspects of reef fish resources have not been reported with reference to the Andaman and Nicobar Islands. Therefore, for sustainable utilization of reef fishes the following studies on exploitable fish resources are urgently needed:

- Population dynamics
- Food and breeding habits
- Impact of large scale exploitation
- Development of commercially viable breeding and culture techniques of ornamental fishes
- Feasibility of cage culture

Acknowledgement

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Coral, *Montipora* sp., and Butterfly fish, *Chaetodon* sp. in Gulf of Mannar

Reef fish spawning aggregation - pilot survey report from Gulf of Mannar, Southeastern India

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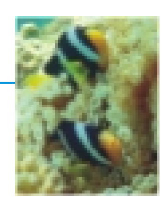
Abstract

Spawning aggregations of reef fishes are a most remarkable biological phenomena that occur on or around coral reefs worldwide. There is no published information on spawning aggregations in India. The data on reef fish spawning aggregations in the Mandapam coast of the Gulf of Mannar were gathered through interview-based surveys with key informants and older fishermen belonging to coastal villages on known species, aggregation sites and timing. The reef Fish Spawning Aggregation (FSA) survey was conducted in nine villages (Thankachimadam, Pamban, Mandapam, Vethalai, Seeniappatharga, Muthupettai, Periapattinam, Keezhakarai and Erwadi) in the Mandapam and Keezhakkarai coasts of the Gulf of Mannar during November–December 2007. This preliminary survey revealed that FSA happens in the rocky areas, located 4 to 10 miles away from the islands (reef area) at a depth of between 10 and 20 m. Only those fishermen who use big country boats could fish in these areas and notice the FSAs. Fishermen from all the surveyed villages mentioned the same season (monsoon) for FSAs, particularly the months of October and November.

Introduction

Reef Fish Spawning Aggregations (FSAs) are a vital part of the breeding cycle of many commercially important fishes. The Society for the Conservation of Reef Fish Aggregations (SCRFA) glo-bal database reports over 140 species, in more than 20 families that reproduce in aggregations. It is lucrative to fish during reef FSAs, particularly for those fish most vulnerable to fishing (Sadovy and Domeier, 2005). FSAs may occur regularly for many consecutive months, or last just a few days or weeks each year. Two types of aggregations are noted: 'Resident' aggregations are formed regularly, and frequently, close to home reefs and in many different locations. 'Transient' aggregations are formed tens or hundreds of kilometres away from home reefs for short periods each year and in relatively few places. Many species of reef fish form spawning aggregations, in which large numbers (up to many thousands) of mature fish travel to specific locations at a specific time to reproduce (Domeier and Colin, 1997; Colin *et al.*, 2003).

Throughout the tropics, many species of reef fishes, including groupers, snappers and jacks aggregate to spawn at specific locations, seasons and lunar phases (Johannes, 1978; Carter *et al.*, 1994; Carter and Perrine, 1994; Sadovy, 1994; Domeier and Colin, 1997). Samoilys and Squire (1994) observed the preliminary spawning behaviour of the coral trout, *Plectropomus leopardus* and Samoilys (1997) studied the periodicity of spawning aggregations of this species in the northern Great Barrier Reef. Heyman (2001) published a report on the spawning aggregations of Nassau groupers in Belize for the sustainable



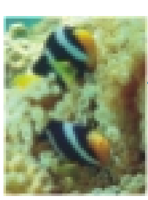
management of this species. Rhodes and Sadovy (2002) studied the temporal and spatial trends in spawning aggregations of the camouflage grouper, *Epinephelus polyphekadion*, in Pohnpei, Micronesia.

Spawning aggregations may be the only opportunity for many species to mate and produce the next generation; aggregations may also be the only time that adults come together in large numbers. These gatherings, therefore, are important for maintaining fish populations, while at the same time often providing excellent opportunities for fishing. Claro and Lindeman (2003) identified 21 spawning aggregation sites in the Cuban shelf for eight species of snappers (*Lutjanus*) and groupers (*Epinephelus* and *Mycteroperca*) using information from experienced fishers and field studies and the information was applied in the design of marine reserve networks in several islands of the Cuban archipelago. Aguilar-Perera (2006) noted that in the traditional Nassau grouper spawning aggregation site off Mahahual, Mexico, large numbers of groupers used to aggregate every year for about 50 years, but in the early 1990s the aggregation ceased forming at the site, and only small aggregations were found south of the site. Johannes *et al.* (1999) uncovered substantial, interesting and valuable new information on spawning aggregations of groupers in Palau. The Great Barrier Reef Marine Park Authority is taking steps to ensure that FSA sites in the Great Barrier Reef Marine Park are not being overexploited by fishing or disturbed by tourism (Russell, 2003). Mass spawning aggregations of Caribbean grouper species are a conservation priority because of declines due to overfishing (Whaylen *et al.*, 2004).

Many aggregations happen on outer reef slopes and in reef channels. Several species often prefer the same spawning locations, although not always at the same time every year. Spawning sites once established may be used consistently for decades. However, the importance of specific habitats for spawning is not fully understood. Uncontrolled fishing of aggregations and habitat (coral reefs) disturbances can result in their depletion and possible disappearance. There is no published information on the occurrence of spawning aggregations of reef fishes in India.

Spawning aggregations occur in many reef fish species worldwide and such aggregations are also likely in the Indian reef areas. Baseline data on the reef FSA, the species involved, season and habitats will not only help to protect and conserve the resources and sites for sustainable utilization through proper management strategies, but would also assist in further regular monitoring. Therefore, a pilot study on reef FSA in the Mandapam coast of the Gulf of Mannar was conducted and coastal people were interviewed to gather information on known species,

Snapper (*Lutjanus* sp.), near rocky area off Tuticorin coast, Gulf of Mannar



aggregation sites and timing.

Methodology

A holistic reef FSA study as described by Samoilys *et al.* (2006) includes the following steps.

Interview survey with fishermen using questionnaire

A field sampling questionnaire was prepared as per requirements to gather sufficient information from fisher communities. Pictorial material was also prepared to accompany the questionnaire. This material was to assist in species identification and to describe spawning aggregations. Laminated photographs of species likely to aggregate to spawn in the region were included.

Selected fishers were interviewed with the help of a local guide in each village. Due to the sensitivity of the subject among fishers and the need to interview informative fishers, attempts were made to interview either the most 'patriarchal fisher' or the most willing fisher. Respondent selection was there-fore non-random and covered most gear types. The number of interviews were limited and varied between 30 and 50 fishers per village. Interviews were carried out on a near-daily basis for three to four months. Spawning sites as per the information from the fishers were recorded using local names, often derived from prominent seascape features.

Observations of *in situ* fish behavior and gonad condition

Evidence for spawning aggregations ranges from *in situ* observations of fish behaviour to observations of gonad condition mainly in landings. Fishers, irrespective of age, who swim with indigenous masks and flippers (skin diving) for chank and lobster, as well as fishers who lay nets in water, were more likely to know about spawning aggregations than boat or shore-based fishers.

Habitat survey, assessment and mapping

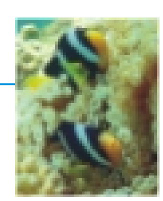
After confirming the aggregation sites and reef fishes through interview survey, underwater survey was carried out using scuba diving to assess the habitat and aggregating reef fish species; and the area was mapped in order to take further protection and conservation steps.

Data analysis

A cautious approach to data interpretation, which involved a process of elimination through three key sequential steps, was followed: (i) verification of positive responses to knowledge of spawning aggregations; (ii) knowledge of species mentioned by respondent; (iii) knowledge of spawning aggregation sites mentioned by more than one respondent, or for more than one species.

Pilot report from Gulf of Mannar

The FSA survey was conducted in nine villages (Thankachimadam, Pamban, Mandapam, Vethalai, Seeniappatharga, Muthupettai, Periapattinam, Keezhakarai and Erwadi) in the Mandapam and Keezhakkarai coasts of the Gulf of Mannar. The results seem to be similar in all surveyed villages. Fishermen informed that no FSA was noticed near the reef areas around the islands, where the depth is between 0.5 and 4.5 m. FSA is therefore restricted to the rocky areas, located 6 to 16 kms away from the islands (reef area) and the depth is bet-



ween 10 and 20 m. Only those fishermen who use big country boats could fish in these areas and noticed FSAs. Normally, the fishermen operating big country boats use gill nets and hooks.

Even though lot of trawlers are seen in Erwadi, Keezhakkarai, Mandapam and Pamban, they do not fish in the rocky areas, fearing damage to their gears. The fishermen from all the surveyed villages mentioned the same season (monsoon) for FSA, particularly the months of October and November. During the northeast monsoon, the Gulf of Mannar experiences calm and fair weather, i.e. the water is clear, the intensity of the waves, winds and currents is low and water and air temperature is also low. In this season, people from other areas (southern part of the Gulf of Mannar Marine National Park Area, Mookaiyoor, Vaipar, Tharuvaikulam, and Tuticorin), also go to the sea in their big country boats and get good catches from the rocky areas during the FSA. The spawning aggregation is noticed largely in fish species belonging to Lethrinidae, Siganidae, Lutjanidae, Scaridae, Labridae, Acanthuridae, Haemulidae, Carangidae and *Odonus* sp. However, Lethri-nidae forms the dominant family. The following are the four rocky areas, where fishermen of the nine surveyed villages notice FSAs regularly every year.

1) The fishermen from Thankachimadam, Pamban and Mandapam noticed FSA in the rocky area locally named as 'Disco Madai', which lies parallel to the Shingle and Poomarichan Islands (Mandapam group of islands), 16 kms away from the island shore.

2) The fishermen from Seeniappatharga and Vethalai noticed FSA in the rocky area locally named 'VR Madai', which lies parallel to the Manoli (Mandapam group) and Mulli (Keezhakkarai group) Islands, 13 kms away from the islands.

3) The fishermen from Muthupettai and Periapattinam noticed FSA in the rocky area locally named 'Votupar', which lies parallel to the Valai and Thalaiyari Islands (Keezhakkari group), 16 kms away from the island shore.

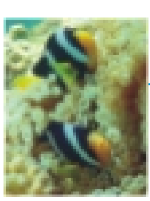
4) The fishermen from Keezhakkarai and Erwadi noticed FSA in the rocky area locally named 'Vettanai', which lies parallel to the Appa Island to Anaipar Islands (Keezhakkarai group), 6 kms away from the island shore.

Normally, about 300 big country boats fish in the above-mentioned four rocky areas during October and November, targeting the FSAs. Both on new moon and full moon days, fish aggregation is comparatively higher. Fishing is normally done during day time and early morning hours.

Gonadal observation

Gonadal observation was carried out in November–December 2007. Fresh reef fishes were collected from the fish caught near the suspected FSA area where the fishes aggregate for spawning. Fishes were collected irrespective of length and weight. Totally, eight species were collected for gonadal observation, i.e. *Lethrinus nebulosus*, *Lutjanus fulvus*, *Scarus ghobban*, *Siganus javus*, *Parupeneus indicus*, *Caranx* sp., *Sphyraena obtusata* and *Odonus* sp.

The collected fishes were dissected immediately on their abdominal



side for the observation of gonads. If the gonads were large and gametes visible, they were considered as mature; if the gonads were small and transparent they were considered as immature; and if the gonads were broken and empty, they were considered as spent. Before the dissection, all the fishes were measured for length and width, and weighed using standard scales. The observations on each species are given below.

Lethrinus nebulosus

Fifteen fishes (length 13 to 22 cm and weight 150 to 350 g) were dissected for observation. Among these, 73% fishes were identified as spent, the rest (27%) were immature and no fish was seen with mature gonads.

Lutjanus fulvus

Ten fishes (length 10 to 16 cm and weight 50 to 75 g) were dissected for observation. Among the dissected fishes, 70% were identified as spent, the rest (30%) were immature and no fish was seen with mature gonads.

Scarus ghobban

Eleven fishes (length 15 to 22 cm and weight 140 to 240 g) were dissected for observation. Among these, 73% fishes were identified as spent, the rest (27%) were immature and no fish was seen with mature gonads.

Siganus javus

Twelve fishes (length 14 to 21 cm and weight 190 to 360 g) were dissected for observation. Among these, 50% fishes were identified as spent, 25% were immature and 25% had mature gonads.

Parupeneus indicus

Twelve fishes (length 14 to 22 cm and weight 140 to 260 g) were dissected for observation. Among these, 83% fishes were identified as spent, the rest (17%) were immature and no fish was seen with mature gonads.

***Caranx* sp.**

Five fishes (length 14 to 21 cm and weight 190 to 290 g) were dissected for observation and all fishes were identified as spent.

Sphyraena obtusata

We were able to collect only two fishes in this species with length 42 and 45 cm and weight 400 and 410 g, respectively. One fish was mature and another immature.

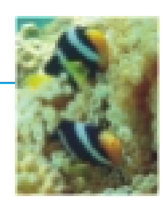
***Odonus* sp.**

Two fishes were collected in this species with length 13 and 19 cm and weight 190 and 320 g, respectively, and both fishes were immature.

Results showed that spawning must have happened one to two months earlier, because in most of the species, the observed fishes were either immature or just spent. The fish having immature gonads had transparent and very small gonads, which presumably developed after the spawning.

Conclusion

Reef FSA in various parts of the world indicate overexploitation due to uncontrolled fishing in terms of disappearance, reduction in number, fluctuations in size and habitat (coral reefs) and disturbance. Claydon (2004) observed that spawning aggregations of commercially important coral reef fishes have been lost in many locations throughout the tropics because unsustainable fishing targets the spawning aggregations themselves. The global disappearance of tropical reef



FSAs, and the associated decline in fish populations from aggregation overfishing, are now widely recognized (Sadovy, 1995; Coleman *et al.*, 2000; Domeier *et al.*, 2002). Therefore, a thorough study is essential, not only in the Gulf of Mannar, but also in other reef areas in India, in order to collect baseline information on the reef FSAs, the species involved and season and habitats so as to protect and conserve the resources and sites for sustainable utilization through proper management strategies and monitoring.

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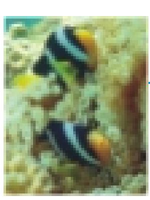

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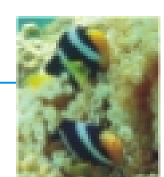
Blue-lined Snapper



Hatchlings of olive ridley emerging from the nest

Marine turtles in India: research and conservation

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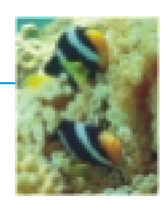
Abstract

India has a coastline of ~ 8000 km, including the mainland and the offshore islands of Andaman and Nicobar, and Lakshadweep. Four species of turtles namely the olive ridley (*Lepidochelys olivacea*), green turtle (*Chelonia mydas*), leatherback (*Dermochelys coriacea*) and hawksbill (*Eretmochelys imbricata*) nest on Indian coasts and are found in Indian waters. There are a few reports of loggerheads (*Caretta caretta)* from Indian waters, but no known nesting beaches have been reported, though they do nest in small numbers in Sri Lanka. There are mass nesting beaches for olive ridley turtles in Orissa, and they nest in small numbers along the east and west coasts of mainland India as well as the offshore islands. Green turtles nest and forage in Gujarat, and the offshore islands of Andaman and Nicobar, and Lakshadweep. Hawksbill and leatherback turtles are found mostly in the Andaman and Nicobar Islands. While there are a few historical records of sea turtles and their use, most of the information comes from the last three to four decades. Monitoring and research was initiated around the same time in the early 1970s in Orissa and Tamil Nadu. Since then, research has been carried out on various aspects such as reproductive biology, population biology, migration and evolutionary history, using a variety of tools such as tagging, telemetry and genetics. Sea turtle populations are impacted by a variety of threats including fisheries related mortality, depredation of eggs by humans and animals (mostly feral), lighting pollution, coastal development and climate change. Conservation efforts along the coast have involved both government and non-governmental organisations. There are one or two NGOs working towards the conservation of sea turtles in almost every state along the mainland coast and on the islands. Networks such as the Turtle Action Group-India, and the Orissa Marine Resources Conservation Consortium have been formed to coordinate efforts towards the conservation of sea turtles and their habitats, and to integrate livelihood concerns of coastal fishing communities.

Introduction

Four species of sea turtles namely the olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*) and hawksbill (*Eretmochelys imbricata*) are found in Indian waters and nest on Indian coasts (for early reviews, see Bhaskar, 1981, 1984; Kar and Bhaskar, 1982). There are few reports of loggerheads (*Caretta caretta*), and no known nesting beaches, although they do nest in small numbers in Sri Lanka (Tripathy, 2005a,b). Some records may also involve misidentification, as the olive ridley was formerly known as the olive-backed loggerhead turtle, and was frequently confused with loggerheads (Frazier, 1985).

India has a coastline of ~ 8000 km, including the mainland and the offshore islands of Andaman and Nicobar, and Lakshadweep. Olive ridleys nest on both east and west coasts of the



Indian mainland, including Sri Lanka, Bangladesh and Pakistan, and on the offshore islands (Biswas, 1982; Kar and Bhaskar, 1982). The olive ridley population in Orissa is of global significance, since it is one the major mass nesting rookeries in the world, along with Mexico and Costa Rica (Pritchard, 1997). Furthermore, recent studies have indicated the uniqueness of the Indian olive ridley population in comparison to other global populations (Shanker *et al.,* 2004a). These turtles may have served as an evolutionary source for the recolonisation of ridleys in the Pacific and Atlantic oceans after the extirpation of populations in those basins (Shanker *et al.,* 2004a). Several thousand ridleys may also nest in Andhra Pradesh (Tripathy *et al.,* 2003; 2006a), Tamil Nadu (Bhupathy and Saravanan, 2002, 2006) and the Andaman and Nicobar Islands (Andrews *et al.,* 2001, 2006a).

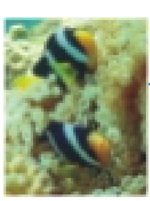
Large leatherback populations were found on the Great and Little Nicobar islands, but these beaches were destroyed by the December 2004 tsunami (Andrews *et al.,* 2006b); these beaches may currently be forming again. A few leatherback turtles nest in the Andamans (Andrews *et al.,* 2001), particularly Little Andaman, and in Sri Lanka (Ekanayake *et al.,* 2002). Given the recent decline of leatherbacks in the Pacific Ocean, the Indian Ocean populations are of great importance, especially the ones in Nicobar (Andrews and Shanker, 2002). Green turtles nest in Pakistan and Gujarat on the west coast of India, and in Lakshadweep, Andaman and Nicobar Islands and Sri Lanka (Kar and Bhaskar, 1982). Hawksbills nest in large numbers only in the Andamans, but some nesting occurs in Nicobar, Lakshadweep and Sri Lanka (Kar and Bhaskar, 1982). In the region, the only nesting grounds for loggerheads are in Sri Lanka. Major sea turtle feeding areas occur off the west coast of India in the Gulf of Kachchh, in the lagoons of the Lakshadweep islands, off the coasts of Sri Lanka and Tamil Nadu to the south, and in the Andaman and Nicobar islands.

For many sites, the first information was obtained from surveys conducted more than twenty years ago by Satish Bhaskar for the Madras Crocodile Bank Trust (see Kar and Bhaskar, 1982; Bhaskar, 1984). More recently, a series of surveys was carried out during 2000–2002 under a Government of India – UNDP project to provide an update on the status and threats to sea turtles in the Indian subcontinent (Shanker and Choudhury, 2006). However, despite decades of research at some sites, the data are not standardised and are difficult to interpret (Shanker *et al.,* 2004b), though current monitoring programmes and networks are attempting to address this gap.

These turtles are under threat from fishery-related mortality, depredation of eggs and other threats related to development. In this paper, we provide an overview of sea turtle research in India over the past four decades. We also document the threats and conservation measures for sea turtles in different parts of the mainland coast and islands.

Early records of sea turtles

There is relatively little information on prehistoric interactions between humans and turtles in the region, although there are accounts of the

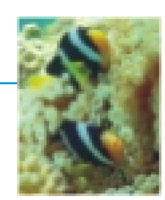


trade in tortoiseshell from India and SriLanka from pre Christian times (Frazier, 2003; de Silva, 2006). There is a Tamil poem from the 4th century AD describing nesting by a turtle (Sanjeeva Raj, 1958), and in the 18th century, a ship's captain writes of thousands of turtles on the Balasore coast in Orissa (Hamilton 1727, c.f. Mohanty Hejmadi, 2000). There are also records from the 19th century from the Andaman and Nicobar islands (see Andrews *et al.,* 2006a). Frazier (1980) reviewed exploitation of marine turtles in the Indian Ocean.

In many parts of the Indian subcontinent, adult sea turtles have not been harmed because of Hindu religious beliefs that turtles are an incarnation (named 'kurma') of Vishnu, one of the Gods of the Hindu trinity. There are temples on the east coast of India at Srikurmam in Andhra Pradesh, close to the Orissa border. In the Indian subcontinent, muslims generally do not eat turtles or turtle products. Christian and ethnic tribal communities do eat turtle meat and eggs. In many areas, when turtle eggs were exploited, many communities would leave a few eggs (two to five) in the nest to ensure the perpetuation of the species (Madhyastha *et al.,* 1986; Pandav *et al.,* 1994; Giri, 2001).

Despite the absence of records, sea turtles were well known along the coast of India. In Orissa, the locals exploited the eggs, which were collected by the boatload (Dash and Kar, 1987). There have been records of their occurrence by early maritime visitors, particularly along the Kerala, Gujarat and Orissa coasts (Hamilton, 1727; Mannadiar, 1977). There are also species records in the ZSI and CMFRI archives and the district gazettes of various states along both west and east coasts with special reference to trade in hawksbill, green and olive ridley turtles. (Annandale, 1915; Greaves, 1933; Chari, 1964; Shanmugasundaram, 1968; Santharam, 1975; Mannadiar, 1977; Dutt, 1979; Das, 1984; Anon., 1991). Most early accounts deal with chelo-nians in the context of their consump-tive value (Acharji, 1950; Murthy and Menon, 1976; Murthy 1981). Though sea turtles were killed at many sites, the two main centres of turtle trade were the Gulf of Mannar (Kuriyan, 1950) and Orissa (Dash and Kar, 1990). In the Gulf of Mannar, green turtles were taken in large numbers both on Sri Lankan and Tamil Nadu coasts (Jones and Fernando, 1968). They estimate that four to six thousand turtles were taken annually in the late 1960s in southern Tamil Nadu, with about three

Olive ridley turtles nesting in an arribada (mass nesting) at Rushikulya, Orissa



quarters being green turtles.

In Orissa, 'Kanika' was under a Zamindary during the British period, which levied a revenue (called 'anda-kara') for the collection of eggs from the Gahirmatha mass nesting beaches. The management was transferred to 'Anchal Sasan' of Revenue Department of the state in 1957. The Forest Department of Orissa issued licenses for collection of eggs at the rate of Rs.15/- only per boatload of eggs, each boat containing roughly 35,000 to 1,00,000 eggs (Dash and Kar, 1987; Kar, 1988). Eggs were sold in all the riverside villages where they were consumed by poorer communities, or transported to Calcutta. Locally, turtle eggs were preserved in large quantities by sun drying and used as cattle feed. The estimated legal take in the 1973 season was 150,000 eggs (FAO, 1974), but the actual illegal take was probably much more (Dash and Kar, 1987). The Forest Department of Govt. of Orissa stopped issuing egg collection licenses from the 1974-75 nesting season.

Survey and monitoring of sea turtles

Surveys and documentation of sea turtles in India began at two sites, namely Gahirmatha in Orissa, and Madras in Tamil Nadu. The mass nesting of turtles in Orissa was first reported by J.C. Daniel and S.A. Hussain of the Bombay Natural History Society in 1973 and this was confirmed and announced to the scientific world at large by H.R. Bustard, an FAO consultant following his survey in the region for crocodiles (FAO, 1974; Bustard, 1976). Following this, a research programme was established and monitoring was initiated (see Kar and, Dash 1984; Dash and Kar, 1990). This led to the discovery of other mass nesting sites at Devi River mouth (Kar, 1982) and at Rushikulya (Pandav *et al.,* 1994). Subsequently, the Orissa coast was monitored by the Orissa Forest Department and Wildlife Institute of India (Pandav, 2000). In Chennai (Madras), monitoring of status and threats (and hatchery programs for conservation) was initiated by the Madras Snake Park Trust (Valliapan and Whitaker, 1974).

Satish Bhaskar, who was part of the initial group in Chennai, surveyed much of the Indian coast over the next few years, including Gujarat (Bhaskar, 1978, 1984), Lakshadweep (Bhaskar, 1979a, 1984), Andaman and Nicobar Islands (Bhaskar, 1979b), Goa, Andhra Pradesh and Kerala (Bhaskar, 1984). His extensive surveys in the Andaman and Nicobar Islands provide a wealth of information for the region (see Whitaker, 2006; Andrews *et al.,* 2006a).

Olive ridley turtles mating in the offshore waters of Rushikulya, Orissa

Sea turtle monitoring in Chennai has been nearly continuous over the last thirty years; thanks to the efforts of the Madras Snake Park Trust (1973 –1976), Central Marine Fisheries Research Institute (1977-1981), Tamil Nadu Forest Department (1982 – 1987) and Students Sea Turtle Conservation Network (1988 to present) (Shanker, 1995, 2003). Surveys were also carried out in Andhra Pradesh (Raja Sekhar and Subba Rao, 1988; Priyadarshini, 1998) and Karnataka (Madyastha *et al.* 1986; Frazier, 1989b).

Apart from this, efforts are fragmented, barring the long term monitoring programs in Orissa and in Chennai on the east coast of India. Detailed surveys were carried out under the GOI UNDP project during 2000 – 2003 in all the coastal states and islands (Shanker and Choudhury, 2006). Following this, monitoring was carried out in many states under the auspices of a project funded by the Convention on the Conservation of Migratory species, including Gujarat (Gujarat Institute of Desert Ecology), Maharashtra and Goa (Bombay Natural History Society) and Tamil Nadu and Kerala (Salim Ali Centre for Ornithology and Natural History).

The Andaman and Nicobar Environmental Team (ANET) has been monitoring the nesting beach at Galathea, Great Nicobar, from 2001. Tagging and monitoring of leatherback turtles was carried out for several years between 2000 and 2004 at Galathea on the east coast of Great Nicobar. However, the beaches on the east and west coasts were destroyed by the December 2004 tsunami and many important nesting beaches were reported to have been severely affected (Andrews *et al.,* 2006b). However, post-tsunami monitoring has been initiated in South Bay, Little Andaman Island since 2008 by the Indian Institute of Science and ANET and there are encouraging signs of leatherback nesting recovery from the sites (Subramaniam *et al.,* 2009).

On the main land coasts, monitoring is carried out by different NGOs, including Naythal and Theeram in Kerala, Tree Foundation and Students Sea Turtle Conservation Network (SSTCN) in Tamil Nadu, Green Mercy, Vishakha Society for Prevention of Cruelty to Animals (VSPCA) and Tree Foundation in Andhra Pradesh, Canara Green Academy in Karnataka, Sahyadri Nisarga Mitra in Maharashtra, Prakruti Nature Club in Gujarat and several local NGOs in Orissa.

Olive ridley turtle nesting at Gahiramatha, Orissa during an arribada

An overview of research

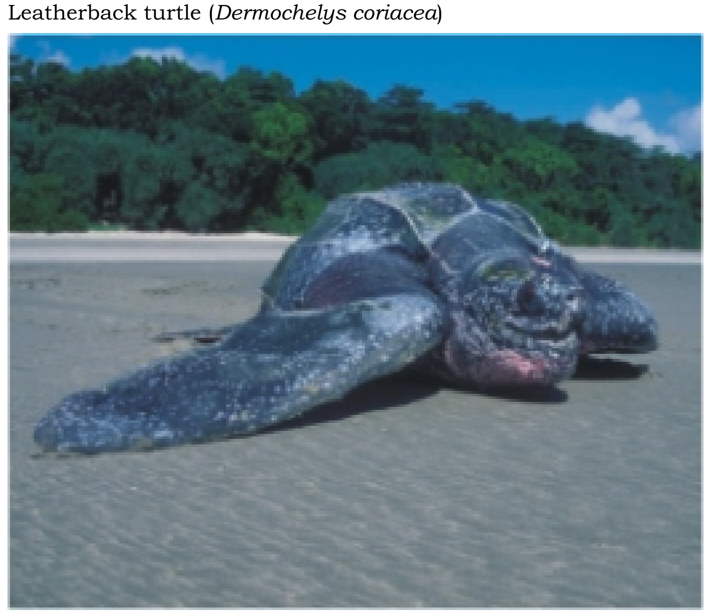
H.R. Bustard initiated research programs in Orissa with several forest officers, most notably C.S. Kar who worked for his Ph.D. on olive ridleys in Gahirmatha (Kar, 1988). The Orissa Forest Department continued its research and monitoring program at Gahirmatha. Kar tagged more than 10,000 nesting turtles during 1975 – 1980, and carried out extensive research, which is summarised in Dash and Kar (1990). Rajasekhar (1987) also submitted a doctoral thesis on sea turtles in Andhra Pradesh.

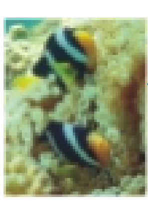
Several research programs were initiated during the 1990s, notably the Wildlife Institute of India's programme in Orissa, which led to the discovery of the mass nesting site at Rushikulya (Pandav *et al.,* 1994). The program carried out extensive tagging of mating pairs (for the first time in India) and nesting turtles on the coast of India (Pandav, 2000). Pandav (2000) conducted research on the offshore distributions, nesting and other aspects of reproductive biology in Orissa, with extensive tagging of over 1500 mating pairs and 10,000 nesting turtles. The program also documented a rapid increase in the fishery related mortality of ridleys in Orissa (Pandav *et al.,* 1998; Pandav and Choudhury, 1999), leading to a number of NGO campaigns and an increase in media interest in olive rid-leys. Ram (2000a) and Tripathy (2004) studied the offshore distributions of mating turtles in Gahirmatha and Rushikulya, respectively.

In the 1980s, research was initiated at the Utkal University on temperature sex determination in olive ridley turtles and on other aspects of their biology (Dimond and Mohanty Hejmadi, 1983; Mohanty Hejmadi *et al.,* 1984, 1989; Sahoo *et al.,* 1996, 1998). At around the same time, the Central Marine Fisheries Research Institute initiated studies in Orissa and Madras (Silas *et al.,* 1983a,b; see papers in Silas, 1984). Rajagopalan (1989) completed his Ph.D. research on ecophysiological studies on sea turtles, while his students have recently completed their Ph.D. research on sea turtles as well (Kannan, 2004; Venkatesan, 2004).

Recently, several students have completed Ph.D. and Masters disserta-tions on sea turtles, particularly at Rushikulya. Tripathy (2005) worked on various aspects of ecology of olive ridley turtles at Rushikulya. Suresh Kumar (in prep.) recently completed his research on offshore distributions of sea turtles and other aspects of their ecology in Rushikulya. Divya Karnad (Karnad, 2008; Karnad *et al.,* 2009) carried out research on the impact of lighting on sea turtles and the effects of *Casuarina* plantations as light barriers. Muralidharan (2009) worked on the effect of predation and lighting on hatchlings at Rushikulya rookery.

Leatherback turtle (*Dermochelys coriacea*)

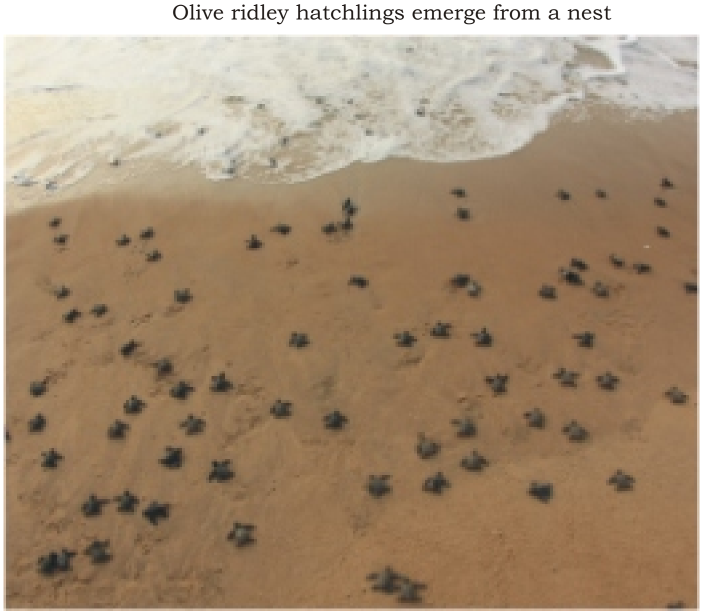




Little is known about the migratory paths followed by the marine turtles that nest in Orissa, though anecdotal accounts (Oliver, 1946; Deraniyagala, 1953; Whitaker and Kar, 1984) suggest that large numbers of turtles have been seen migrating together along the east coast of India. As part of the GOI-UNDP Sea Turtle Project, the Wildlife Institute of India, Orissa Forest Department and Smithsonian Institution collaborated to attach satellite transmitters on four female olive ridleys in Orissa in April, 2001. In the last two years, the Wildlife Institute has deployed more than 60 satellite transmitters on olive ridley turtles in Orissa, through a project from the Department of Hydrocarbons, Ministry of Petroleum. While some of the turtles remain in the offshore waters of Orissa, others migrate to the coast of Sri Lanka and to the Gulf of Mannar.

Studies have been initiated on the molecular genetics of sea turtles along the mainland coast and islands of India. Olive ridleys on the east coast of India appear to be genetically distinct from other global populations, and even differ significantly from the adjacent population in Sri Lanka (Shanker *et al.,* 2004a). Shanker *et al.* (2004a) also propose that Indian ridleys and Kemp's ridleys could be remnants of a global population which was otherwise extirpated following climatic changes prior to and after the closure of the isthmus of Panama. Thus the Indian ocean region, in particular the distinct Indian population, may have served as a source for ridley re-colonisations following the extirpation of populations in other ocean basins.

Olive ridley hatchlings emerge from a nest



Threats to marine turtles

The list of threats to marine turtles is long and can be divided into direct threats to their populations and indirect threats due to habitat degradation and loss.

Direct threats

Fisheries induced mortality

Olive ridley turtles were caught for consumption prior to the enactment of the Wildlife (Protection) Act, 1972. Biswas (1982) reported the shipping of 6,000 turtles during three months in 1974–1975 and 21,000 turtles during three months in 1978–1979 from Orissa and West Bengal. Das (1985) reported that, prior to 1981, 6–7 truck-loads of turtles (each with 125–150 turtles) arrived in Calcutta every day. He calculated that this amounts to 80,000 turtles per season. Since the ban on the trade of turtle meat, eggs and other turtle parts, marine turtles are no longer targeted in the marine fisheries of India. But nevertheless, they do get caught unintentionally in fishing gears meant to target other species, especially in fisheries in pelagic and coastal foraging areas and in migratory corridors (James *et al.,* 1989; Dash and Kar, 1990; Pandav *et al.,* 1994; Pandav *et al.,* 1997). Many types of marine fisheries pose threats, with pelagic (floating) longline, gillnet and driftnet fisheries being prominent (though prohibited, some driftnet fisheries continue illegally). Entangled turtles will drown if unable to free themselves, but may also lose limbs, or become more vulnerable to predation. However, bottom trawling operations in shallow waters have caused the highest levels of marine turtle mortality in the region.

In India, turtle mortality occurs at an alarming rate on the coast of Orissa, with approximately 1,00,000 turtles reported dead within a period of eight years 1994-2002 (Shanker *et al.*, 2004b), i.e. more than 10,000 turtles per year. Accidental/incidental death of turtles occurs along the coasts of Andhra Pradesh and Tamil Nadu too.

Collection of eggs by humans

Harvest of eggs for human consumption is a serious threat to turtles the world over, especially in the developing nations. Though large scale egg harvesting in Orissa has been stopped, the consumption of eggs continues along various parts of the coast.

Nest and hatchling predation

Many natural predators, such as rats, mongooses, birds, monitor lizards, snakes, crabs, and other invertebrates prey on turtle eggs and hatchlings. But another major threat to turtle populations along the mainland coast of India is nest predation due to domesticated and feral dogs. In Orissa, jackals, hyenas and feral dogs, were found to predate on nests, while feral dogs, house crows, brahminy kites and ghost crabs were found to be the major predators of hatchlings (Tripathy and Rajashekar, 2009). More than 70% of the sporadic nests were predated during the years 2003-04 and 2004-05, while it was much less in the arribada sites (Tripathy and Rajashekar, 2009).

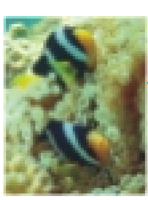
Olive ridley turtle nesting, Rushikulya, Orissa

Increased human presence

Human activities such as foot traffic, noise and lighting on nesting beaches can disturb nesting females and their eggs. Females may abort nesting attempts, shift nesting beaches, delay egg-laying or select poor sites. Compaction of sand from people walking over nests can slow hatchling emergence.

Artificial lighting

Sea turtle hatchlings usually emerge at night and orient towards the brighter horizon (Mrosovsky and Kingsmill, 1985). The naturally brighter horizon is the seaward side. In recent decades, increasing coastal development and subsequent lighting



on the landward side has led to creation of an artificial light horizon on the landward side along many parts of the coast of India. Hatchlings therefore have been observed to orient away from the sea, resulting in mortality. Studies along the Orissa coast have shown considerable hatchling mortality induced by artificial lighting from the landward side (Tripathy *et al.,* 2003; Karnad, 2008; Karnad *et al.*, 2009).

Threats to habitat

A variety of activities result in elimination or degradation of nesting habitat. They include:

Construction and mining

Any man-made construction on the coast can affect the natural sediment transport of beaches. Constructions such as ports, piers and jetties are not only physical obstacles for turtles, but can cause large-scale degradation of their nesting habitats. Constructions on the east coast of India especially, affect the long-shore currents that carry considerable amounts of sand/sediment and help replenish beaches (Mani, 2001). Construction of ports is proving to be a significant threat to turtle nesting grounds along the coast of Orissa and in other coastal regions of India. Sand mining on the beaches and leveling of coastal dunes are also significant threats to the sea turtle nesting beaches (Namboothri *et al.,* 2008a).

Beach armouring

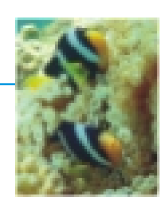
While a combination of natural and anthropogenic induced disturbances are rendering the coastal ecosystems fragile, leading to increasing erosion and reducing nesting habitats, another cause of concern is the construction of artificial hard beach armouring options, such as sea walls, rock revetments, sandbags, groins, and jetties. These coastal construction efforts affect nesting by preventing females from reaching good nesting grounds. They also trap or delay hatchlings and females on the journey back to sea, increasing their exposure to predators. Further, such options interfere with the natural sediment dynamics of the beaches, leading to increased erosion of adjoining beaches (Rodriguez *et al.*, 2008).

Beach nourishment

Attempts to replace sand lost to erosion can cause problems for sea turtle nesting. Nests may become too deeply buried. New sand may be unsuitable for nesting. Heavy machinery used to clean and rake beaches can destroy nests. The machinery used to haul and distribute sand can compact the beach, destroy nests and cause difficulties in digging new ones.

Exotic vegetation

Introduced plants can displace natural vegetation and proliferate on nesting beaches. In recent years, *Casuarina equisetifolia* has been planted as a measure of control for beach erosion, for creation of vegetation shelterbelts against cyclonic storms and afforestation of the coastal zone (Mukherjee *et al.,* 2008; Namboothri *et al.,* 2008b; Feagin *et al.,* 2009). But these plantations, when established close to the high tide line, can potentially disrupt the natural cyclic sediment processes that help in the formation and preservation of beaches, leading to erosion and loss of turtle nesting habitat. *Casuarina* is also known to have allelopathic



properties that suppress local biodiversity (Namboothri *et al.,* 2008a). Once established, the shade and the thick litter layer under the trees prevent germination and growth of native vegetation (Schmid *et al.,* 2008) and thereby exclude native species in coastal areas (Nelson, 1994). When plantations are established very close to the high tide line, there is loss of habitat for fauna such as sea turtles and shore crabs (Selvam, 2006). *Casuarina* plantations in Orissa are believed to have had negative impacts on nesting beaches and nesting (Pandav, 2005). Further, dense vegetation shades nests, potentially altering natural hatchling sex ratios. The effect of *Casuarina* on the nesting of loggerhead turtles has been demonstrated elsewhere (Schmelz and Mezich, 1988). Thick root masses of the plantations can also entangle hatchlings. Recent studies along the Chennai-Pondicherry coastline have shown that *Casuarina* plantations suppress native vegetation that are valuable for dune formation and thereby affect beach profiles. Beaches with plantations close to the high tide line were found to be steeper, making them less accessible to nesting turtles, with reduced beach width available for nesting turtles. The numbers of turtle nests were also found to have reduced after *Casuarina* had been planted on some of these beaches (Choudhari *et al.,* 2009).

Despite considerable criticism on the scientific and ecological efficacy of *Casuarina* plantations, recent research along the coast of Orissa has however highlighted the value of these plantations in increasing hatchling survival (Karnad, 2008; Karnad *et al.,* 2009). *Casuarina* plantations close to the high tide line helped in considerably reducing ingress of light on to the nesting beaches. *Casuarina* plantations planted close to the high tide line (50 m from high tide line) were useful in effectively cutting out excess light from the landward side and help the hatchlings orient seaward, while plantations more than 500 metres from the high tide line and open unprotected beaches resulted in more hatchlings orienting landwards (Karnad, 2008; Karnad *et al.,* 2009).

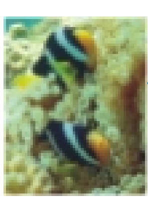
Casuarina plantations are thus both harmful and beneficial, but cannot be recommended as a conservation tool over large areas of the coast without first quantifying their negative impacts on coastal ecosystems.

Contamination and pollution

Beaches tend to concentrate debris and pollution which are hazardous at sea, such as plastics, abandoned netting and spilled oil (Fisheries and Oceans Canada (DFO) and the Pacific Leatherback Turtle Recovery Team 2004).

Turtles and climate change

Marine turtles have life history traits, behaviour and physiology that are strongly tied to environmental variables (Hamann *et al.,* 2007). Offspring sex in marine turtles is determined by temperature experienced during the incubation period. The sex ratio of hatchlings is strongly influenced even by temperature changes as minor as 1°C (Janzen, 1994) with a 50-50 male-female balance achieved at a certain pivotal temperature. Above this temperature, females are produced and below this, more males are produced

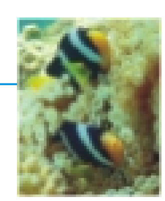


(Janzen and Paukstis, 1991; Mrosovsky and Pieau, 1991). While global warming and consequential skewing of the sex ratio remains a serious threat to marine turtle populations globally, other climate induced changes could play equal if not more significant roles, in affecting turtle populations. Climate change is expected to affect temperature and precipitation patterns, oceanic circulation, increase rates of rising sea level, and the intensity and timing of hurricanes and tropical storms (Michener *et al.,* 1997). Changing sea surface temperature and changes in the patterns of oceanic circulation are likely to cause substantial variation in distribution and migration patterns of marine turtles and their prey resources (McMahon and Hays, 2006). Increasing intensities of hydrometereological events, coupled with increasing sea levels could also lead to loss of habitat (nesting beaches) (Fish *et al.,* 2005). These processes, coupled with various localised anthropogenic disturbances, could considerably undermine coastal vulnerability, rendering the coastline inhospitable for nesting turtles.

Sea turtle conservation

Prior to the 1970s, there was no organised turtle fishery in Orissa, but whenever live adult sea turtles were found in fishing nets they were collected and transported to the nearest railway station from where they were sent to Calcutta. Live turtles were transported almost everyday to Calcutta from Puri, Bhubaneshwar, Maltipatpur and almost all coastal railway stations in Orissa. Often the turtles were booked as fishery products, so the magnitude of this trade is difficult to assess (Kar, 1988; Dash and Kar, 1990). Many accounts report an annual catch of 50,000 turtles from the Orissa and West Bengal coasts until about 1980 (see Silas *et al.,* 1983a; Kar and Dash, 1984; Das, 1985). Obviously, the increase in adult take was due to the introduction of mechanization in the 1970s. Due to launching of a massive programme involving the Indian Navy, Indian Coast Guard and State law enforcing agencies like the Forest, Fisheries and Police departments of Orissa, this illegal trade in sea turtles was almost completely stopped around 1984-85 (Kar and Dash, 1984).

Along with the monitoring programs, sea turtle conservation was also initiated in Orissa and Madras in the early 1970s. While the Orissa program was coordinated by the Forest Department, the turtle hatcheries in Madras were operated by first the Madras Snake Park, followed by the CMFRI and Tamil Nadu Forest Department. Since 1988, it has been operated by a non government organisation, the Students Sea Turtle Conservation Network (SSTCN) (see Shanker, 2003a for a review). Student and NGO programs were initiated at a number of other sites (Shanker, 2007). Many programs like THEERAM in Kolaavipalam, Kerala, the Students Sea Turtle Conservation Network, Madras and Green Mercy in Visakhapatnam, have beach protection programs as well as hatcheries for the protection of sea turtles. More importantly, these programs have served as powerful tools of education, spreading awareness about sea turtles and coastal conservation. In Madras, the Trust for Environmental Education (TREE) has recently mobilised youth



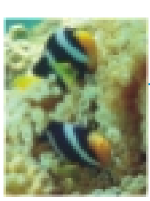
groups in several fishing villages to protect turtles and nests in the vicinity of their villages. THEERAM in Kerala is of particular interest since it was initiated by a young group of fishers (Kutty, 2002).

Other similar programs have sprung up all along the coast, including Goa, where the local communities have worked with the Forest Department to try and combine turtle protection with eco tourism (Kutty, 2002). The Sahyadri Nisarga Mitra in Maharashtra has been working with numerous villages along the coast of Maharashtra (Katdare and Mone, 2003). The Trust for Environmental Education in Madras organizes fishing village youth into turtle protection units for in situ protection of nests near their villages (Dharini, 2003). The Madras Crocodile Bank Trust conducts weekend mobile exhibitions in the fishing villages.

A national sea turtle network called Turtle Action Group (TAG) was formed in January 2009 towards bringing greater synergy and collaboration in sea turtle conservation efforts (see http://india.seaturtle.org/tag). The network includes the various organisations mentioned above, and several sea turtle biologists and conservationists. National NGOs such as Worldwide Fund for Nature (WWF) and Greenpeace also have conservation programmes for sea turtles in Orissa and at other sites. Dakshin Foundation supports the activities of the network and OMRCC (see below) by assisting with coordination, raising funds, conducting workshops and building capacity.

Sea turtle conservation in Orissa

Sea turtle conservation efforts in Orissa have a storied past, beginning in the early 1970s when the large scale legal/incidental take of turtles from Gahirmatha was widely reported (Davis and Bedi, 1978; see also Frazier, 1980). In the early 1980s, numerous petitions and letter writing campaigns were supported and endorsed through the Marine Turtle Newsletter, an international newsletter, (Mrosovsky *et al.,* 1982), and several hundred letters were in fact written to the Prime Minister Indira Gandhi (Mrosovsky, 1983). J. Vijaya, conducted field surveys in the early 1980s and reported on the large numbers of turtles being sold in fish markets near Calcutta (Vijaya, 1982; Moll *et al.,* 1983); and this, along with her photographs of hundreds of turtle carcasses (published in India Today, Bobb, 1982), brought even more attention to the extraordinary numbers of turtles being killed in Orissa. Prime Minister Gandhi's support and her initiative to involve the Coast Guard in protecting the marine area at Gahirmatha, helped in drastically reducing the direct take to a point where it was thought to be negligible. However, even then, incidental mortality was considered as a major threat by E.G. Silas, then Director of the Central Marine Fisheries Research Institute (Silas, 1984), and was reported through the 1980s (James *et al.,* 1989). In the 1990s, B. Pandav of the Wildlife Institute of India, Dehradun, reported thousands of stranded carcasses on Gahirmatha and other neighbouring beaches, attributed to high incidental mortality in offshore trawling, and he advised immediate remedial action (Pandav and Choudhury, 1999;



Pandav, 2000).

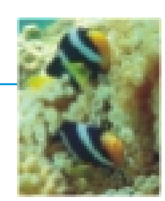
Other conservation programs were launched during this period, most notably Operation Kachhapa in Orissa, with collaboration between governmental and non-governmental organisations to protect sea turtles on the Orissa coast, particularly with a view to reduce trawler related mortality (Shanker and Mohanty, 1999; Wright and Mohanty, 2006). This project, active in the early 2000s, was coordinated by the Wildlife Protection Society of India, New Delhi and Wildlife Society of Orissa. Several local NGOs including Rushikulya Sea Turtle Protection Committee (RSTPC), Sea Turtle Action Programme (STAP), Green Life Rural Association, Action for Protection of Wild Animals (APOWA) and others work towards the conservation and monitoring of olive ridley turtles. In late 2004, traditional fishworkers, local conservation groups and national conservation agencies came together as the Orissa Marine Resources Conservation Consortium to pursue common objectives for the conservation of marine resources, including marine turtles, while promoting the livelihoods of the fishing communities (Aleya, 2004).

The Dhamra Port – conservation vs development

The Dhamra port experience is a classic example of the challenges and conflicts in addressing conservation issues in the light of national developmental interests. The project to build a port at Dhamra, that is perceived to be one of the largest ports in India (Dutta, 2008), or perhaps in South Asia (Lenin *et al.,* 2009), is being built by Dhamra Port Company Limited (DPCL) less than 15 km from Gahirmatha Marine Sanctuary, one of the few olive ridley mass nesting beaches in the world (Lenin *et al.,* 2009) and about 4 km from Bhitarkanika National Park, a Ramsar site that hosts remarkable ecological and species diversity, many of regional and global importance (Frazier, 2008). A large community, including academics, biologists, conservationists and other practitioners from a variety of institutions and backgrounds, voiced their concerns for the biodiversity of the region, interactions with local communities and the conservation of olive ridley turtles (Frazier, 2008).

Conclusion

The degree of similarity between the threats to sea turtles discussed at the CMFRI workshop in 1984 and major threats to sea turtles today is not an encouraging sign. Fishery related mortality, depredation of eggs, beach erosion, development, and plantations were all emphasised then, and remain threats today, some more so than before. Despite twenty five years of research and conservation efforts, few of these threats have been mitigated. On the other hand, the number of agencies, individuals and government sectors that are today interested and involved in sea turtle conservation is greatly encouraging. There are small conservation programs all around the country. Within the government, the Ministries of Commerce and Agriculture have become involved in sea turtle conservation. Organisations such as the Central Institute of Fisheries Technology and Marine Products Export Development



Authority and several state fisheries agencies are involved in developing and promoting Turtle Excluder Devices. Nearly all state Forest Departments run sea turtle hatcheries or support small non-governmental organisations. The Coast Guard has been interested and involved in turtle conservation in many states, particularly in Orissa, where they have been active since the early 1980s.

However, there is still clearly a disjunct between intent and success. Despite the interest and involvement of a diversity of stakeholders, things have not improved for sea turtles. There is clearly a need for dialogue and cooperation and coordination between agencies, both within the government and between government and non-governmental agencies. The participatory approach to management has been greatly stressed in recent times and this includes networking and involvement of multiple stakeholders. Another important issue would be the economic concerns of stakeholders, particularly local communities. Responsible marine fisheries is required, and not merely from the point of view of sea turtle conservation. We hope that following past decades that witnessed the birth of research, conservation and NGO participation, this will be the decade of partnership and collaboration and of consensual action between diverse stakeholders, towards the common objective of sea turtle conservation in the Indian sub-continent.

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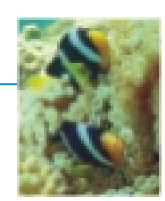

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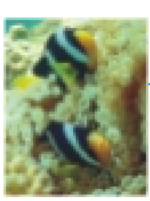

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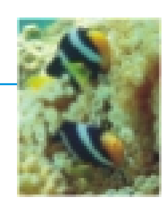

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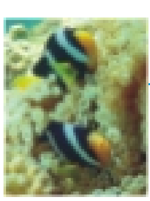

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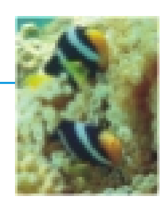
Hawksbill Turtle



Dugong dugon from Neil Island, Andaman

Current status of dugong *(Dugong dugon)* in the Andaman and Nicobar Islands

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Abstract

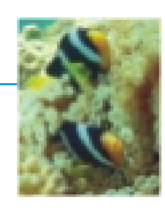
The dugong (Sea cow) is a severely threatened marine mammal and is vulnerable to extinction globally. In India, dugongs have been reported from many regions including the Andaman and Nicobar Islands. In this study, sightings of dugongs and the causative factors affecting their population in the Andaman and Nicobar Islands were recorded. Data were collected through literature survey, interview-based field survey and other field-based methods. The maximum likely population of dugong was inferred to be 81 individuals in Andaman and Nicobar Islands. Human activities like destructive fishing and increased boat trafficking are found to be the major threatening factors ahead of natural factors. Little Andaman, Nancowrie and Northern Andamans, where most of the sightings were recorded, should be given highest priority from the view-point of protecting dugongs. Middle Andaman, South Andaman, Camorta (Kamorta), Great Nicobar and Katchal should also be managed from the view-point of dugong conservation.

Introduction

Dugong *(Dugong dugon)*, also known as the sea cow, is the only Sirenian found in the marine and coastal habitats of India. The dugong is classified as vulnerable to extinction by the World Conservation Union on the basis of declines in area or extent of occupancy, habitat quality, and actual or potential levels of exploitation (IUCN, 2008). It is also listed in Appendix I of the Convention on International Trade in Endangered species of Wild Fauna and Flora (CITES), which prohibits all trade in this species, or any products derived from it.

In India, the dugong has been given the highest level of legal protection and is listed under Schedule I of the Indian Wildlife Protection Act, 1972 (D' souza and Patankar, 2009). In India, dugongs have been reported from the mainland regions, Gulf of Kachchh, Gujarat (Lal Mohan, 1963; Frazier and Mundkur 1990) and Gulf of Mannar and Palk Bay in Tamil Nadu (Jones 1967; James 1974; Lal Mohan, 1976; Frazier and Mundkur, 1990). These reports have been based on studies carried out on stranded and incidentally caught dugongs. Their status is not encouraging as several researchers have mentioned that the dugong population has been declining (Lal Mohan, 1980; Das and Dey, 1999; Marsh *et al.,* 2002; D'souza and Patankar, 2009).

Apart from the mainland, dugongs have also been reported in Andaman and Nicobar Islands (Jones, 1980; James, 1988; Rao, 1990; Bhaskar and Rao, 1992). However, there are not many records such as photographs or morphometric descriptions of dead or live dugongs from the Andaman and Nicobar coast (Das and Dey, 1999). Though the dugong has been declared the State Animal of these Islands, comprehensive studies have not been



conducted yet. Das and Dey (1999) surveyed various parts of Andaman and Nicobar Islands between 1990 and 1994. They located live dugongs using boats and random snorkeling, through regular diving and by conducting interview surveys of fishermen. This prompted GEER Foundation's attempt to conduct a detailed national dugong survey in late 2000s (i.e. after a time gap of over a decade with respect to the work by Das and Dey (1999), covering the maritime states of Gujarat and Tamil Nadu and the Lakshadweep Islands and Andaman and Nicobar Islands. The following were the specific objectives of this study in the Andaman and Nicobar Islands:

a) To record the sightings of dugongs to know their abundance; and

b) To identify the causative factors adversely affecting the dugong population.

Material and methods

The area of the interview surveys forming the present study covered villages/fish-landing centers in North, Middle and South Andaman, Little Andaman, Nancowrie, Camorta (Kamorta), Katchal and Great Nicobar.

Moreover, area of boat surveys covered Neil Island, Havelock Island and Trinket Island (Figs 1 and 2). All these locations were selected based on documented records for the presence of seagrass beds, dugong occurrence and informal discussions with local authorities (ZSI) and islanders. The methodology used in the present study was i) Literature survey; ii) Interview- based field surveys using questionnaires; and iii) Other supplementary field-based methods (i.e., boat surveys, snorkeling). For ii and iii), the survey team conducted

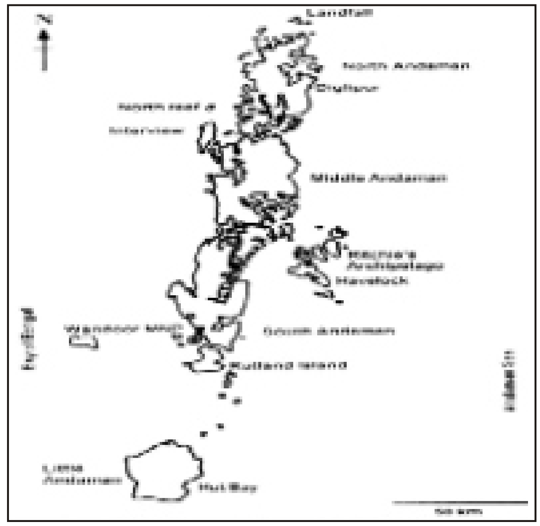


Fig. 1. Area covered in Andaman Islands, India (Source: Das and Dey, 1999)

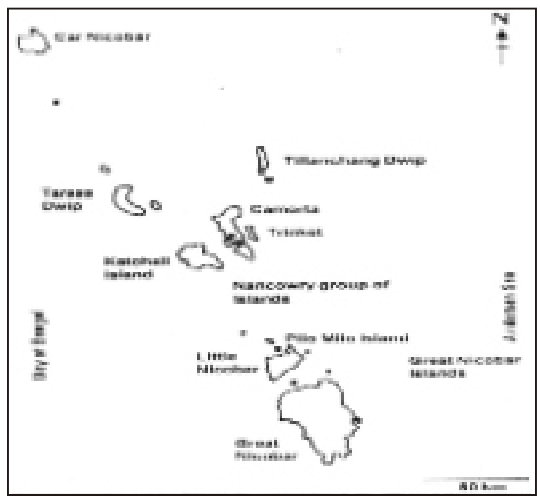
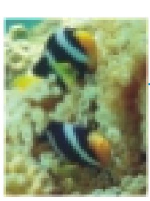


Fig. 2. Area covered in Nicobar Islands, India Source: (Das and Dey, 1999)

field-work by visiting Andaman and Nicobar Islands twice, i.e. from 3 February to March 2008 and from 17 February to 8 April 2009. The details of the methodology are described below:

Literature survey

For reviewing the literature, the survey team used various national and international journals (either online or



in print) pertaining to the natural history and marine biology and also certain books and websites. In addition, relevant Indian organizations and other authorities were also contacted to obtain information on any past or current dugong sightings, location of potential habitats, records research and conservation initiatives.

Interview-based survey

Selection of a cost-effective and efficient methodology for dugong survey has been a challenging task as the dugong is known for its rarity, wide distribution and silent under water occurrence. Several marine biologists have opined that for such a challenging species, interview surveys represent a simple and relatively inexpensive method to implement and therefore are appropriate for developing countries. Specifically, for the Andaman and Nicobar Islands, Das and Dey (1999) have stated that field-based methods like motor or rowing boat surveys failed to locate dugongs in the wild, whereas information gathered through interviews with local communities was very useful. Due to these reasons, it was decided that short term field study alone would not give reliable results. It was also premised that the people in the coastal areas, being mainly fishermen, would have considerable information about this marine animal. In view of these reasons, an interview survey method using a questionnaire was mainly used for the study.

Questionnaire for the interview-based survey

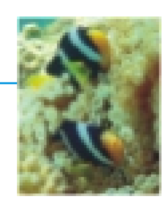
A simple, yet comprehensive questionnaire (in the form of a data sheet) was developed covering all the important aspects about dugongs. This data sheet contained 20 questions about the dugong, including its biology, habitat, rate of live dugong sightings and dugong stranding incidents. Information about fishing vessels, fishing net and fishing area preferred by fishermen was also sought through the questionnaire. Questions pertaining to the closed season when fisher-men do not go for fishing and duration of this season in view of breeding, were also incorporated in to the questionnaire.

Interviewing

In the interview-based survey method, the survey team members met fisher community leaders in every village. The leaders made arrangements for a meeting with some fishermen of his village for the interview survey. After building a rapport through informal conversation and introduction of each other, the survey team members briefed about the dugong project and purpose of their visit. After such rapport-building activities, the survey team members started interviewing the fishermen. The answers given by the fishermen were recorded in the questionnaire form. Ambiguity and doubts were discussed. When the survey team felt that a fisherman had excellent additional information about dugongs, but could not communicate clearly in view of the language barrier, the help of an interpreter was sought. After completion of interviews with fishermen, the survey team also noted down the GPS coordinates of every village.

Other field-based methods

The survey team also carried out



limited field survey to record sightings of live dugongs and to assess its habitat conditions qualitatively. In this method the survey team carried out survey by boat and snorkeling in the home range area of dugongs in the near shore areas of the islands.

Results and discussion

Das and Dey (1999) mentioned that dugongs were common in the 1950s, but the population has dropped drastically in the late 1980s/early 1990s. Supporting this statement, in the present study there was also a low number of dugong sightings.

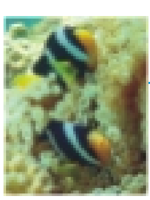
In the present study too, the researchers depended mainly on interview survey and to certain extent, on boat surveys. Such kinds of surveys cannot provide population estimates due to underwater existence and mainly solitary occurrence of dugong in the modern times. Despite this, it has been considered that it might be helpful from management/conservation point of view to infer likely population in Andaman and Nicobar Islands. As this can be done only on the basis of actual dugong sightings reported during the present study, a summary of sightings of dugong during the present study is given in Table 1.

Table 1. Summary of dugong sightings in the Andaman and Nicobar Islands (2007-09)

Sr. No.	Location (Zone)	Number of dugong sightings (n)	Approximate proportion (%) of sightings in each locality
1	North Andaman	11	14
2	Middle Andaman	7	9
3	South Andaman	5	6
4	Little Andaman	33	41
5	Nancowrie	12	15
6	Katchal	4	5
7	Camorta	5	6
8	Great Nicobar	4	5
	Total	81	100

Table 1 indicates that 81 sightings of dugong had been reported by fishermen during the present study. These sightings had been reported for the "current" time-frame covering the year of fishermen interviews and one year prior to the fishermen interviews (i.e., 2007-2009 time-frame). Based on the above-mentioned numbers of sightings and based on the premise that each sighting would represent a separate dugong, this study has reached an inference that maximum likely population of dugongs in Andaman and Nicobar Islands may be 75 to 85 individuals. Marsh *et al.* (2002) mentioned that the number of dugongs around Andaman and Nicobar Islands may be in the order of 100 individuals. Thus, the maximum numbers of dugong predicted through the present study have been close to the numbers suggested by Marsh *et al.* (2002).

The present study has also been useful in identifying the areas in Andaman and Nicobar Islands that are important from the view-point of dugong conservation. Table 1 shows that the fishermen have reported the highest number of sightings (i.e., n=33 or 41% of all the dugong sightings) in Little Andaman of the Andaman Islands. Thus, Little Andaman is a highly preferred area for dugongs in Andaman and Nicobar Islands. Apart from the Little Andaman, noticeable number of sightings (i.e., n=12 or 15% of all the sightings) has been reported near the waters of Nancowrie Island, in the Nicobar Islands group which in turn, indicates the importance of this area from the view point of dugong



conservation. In fact, the numbers of sightings in Little Andaman and Nancowrie Island have been the highest and the second highest respectively in the entire area of Andaman and Nicobar Islands. Apart from these two localities, Northern Andaman can also be considered important for conservation. This is because the fishermen reported the third highest number of sightings (n=11, i.e., 14% of all the dugongs recorded in this study) here. All these three localities therefore should be given high priority for protecting dugongs and their habitats.

Though not the highest, but fairly good number of dugong sightings have been recorded by the fishermen in the sea waters of Middle Andaman, Southern Andaman, Camorta (Kamorta), Great Nicobar and Katchal. Therefore, these localities should be also considered for protection and conservation of dugong.

The dugong population is certainly not thriving in Andaman and Nicobar Islands, as almost 37 % (i.e., n = 186) of all the fishermen interviewed (n = 504) in Andaman and Nicobar Islands, have not seen a dugong (Fig. 3). Das and Dey (1999) have rightly mentioned that the sporadic sightings of dugongs since early 1990s bear testimony to the drastic decline in the dugong population.

The decline in dugong numbers is a matter of great concern for those who want to conserve the species. Decline in dugong population is attributed to various reasons; both man-induced and natural. During the present study, the local fishermen were interviewed also to get information regarding the potential causes for decline in the dugong population from the remote past. The responses by the fishermen not only revealed the causes of population decline, but also facilitated information about the impact of each cause that would have been responsible for the decline in population (Table 2).

Table 2 reveals that greater number of fishermen's replies (63% of total replies) were in favour of population decline due to man-induced

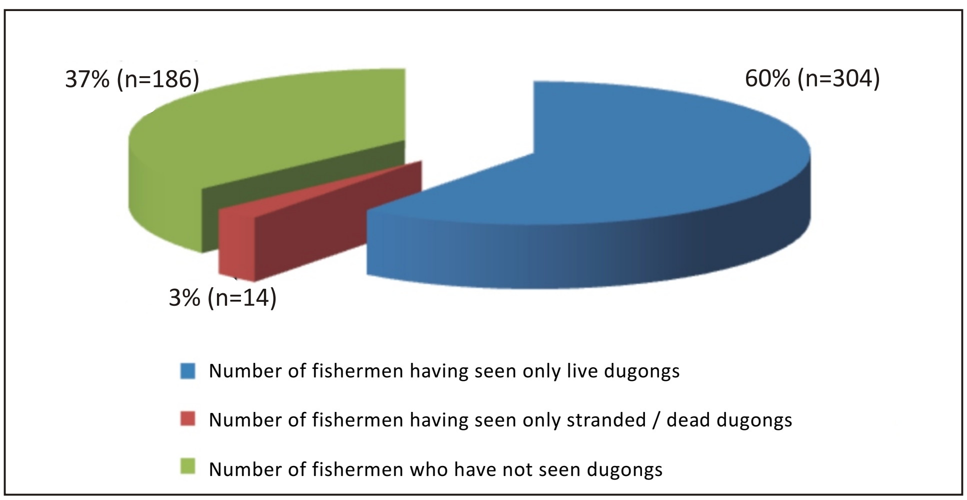


Fig. 3. Proportion of fishermen who have seen live/stranded/dead dugongs

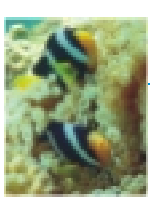
Table 2. Causes for decline in dugong population in the view of local fishermen

Broad nature of the causes	Causes for decline in dugong population in Andaman and Nicobar Islands	Number of replies (with %)	Total (n=394) of replies
Man-induced reasons	Trawlers	2 (0.51)	248 (62.94%)
	Poaching	182 (46.2)	
	Accidental catch in nets	64 (16.2)	
Natural reasons	Tsunami leading to large-scale seagrass habitat destruction	146 (37.1)	146 (37.06%)

reasons as compared to the replies (37%) in favour of population decline due to natural causes. Thus, it is likely that man-induced causes such as trawling, poaching and accidental catch might be contributing more towards dugong population decline. Interestingly, among the natural causes, only tsunami (in 2004) was believed to be a responsible cause as the fishermen knew that seagrass habitats constitute an obligatory life requisite of the dugong and seagrass cover was extensively damaged during the tsunami. Attributing the tsunami as the sole factor responsible for habitat destruction is an exaggeration. However, the fact that tsunami has caused damage to the habitat of dugong cannot be ignored. During that period before the tsunami disaster, Das and Dey (1999) have suggested that the main factor responsible for habitat loss has been increasing boat traffic and faulty land use practices, such as conversion of forests to plantations (Das and Dey, 1999; Marsh *et al.,* 2002).

Among man-made causes for decline in the dugong population, higher proportion of replies (i.e., 182 or 46% of all the replies) suggested hunting as the major factor for the population decline of dugong. However, Das (1996), Das and Day (1999) and Marsh *et al.* (2002) have mentioned that dugong hunting occurs occasionally, and in view of the protection that has been given to dugongs, it may not take place. It is also true that, with the decline in dugong population, the number of skilled hunters has also declined. It might have happened when dugongs were abundant and skilled hunters were also available in good numbers. It should be noted that most of the tribes of the Andamans, namely the Andamanese, Onges and Nicobarese, traditionally hunt dugongs with iron harpoons tied to their boats (Das and Dey, 1999) and thus, undoubtedly, they might have hunted dugongs in great numbers when the species was common before the 1950s (Das and Dey, 1999).

Table 2 also indicates incidental catch in fishing nets to be the second-largest man-induced cause of dugong decline, as 16% of the total replies from fishermen attributed this factor. In recent times, the expansion of offshore gill net fisheries in response to the needs of a burgeoning human population is considered to have been largely responsible for the decline in dugong numbers (Marsh *et al.,* 2002).



The present study concludes that dugongs are rare in the Andaman and Nicobar Islands. Their sightings have become sporadic and they are mainly seen singly. Little Andaman, Nancowrie and Northern Andamans should be prioritized for protecting dugongs and seagrass beds, followed by Middle Andaman, South Andaman, Camorta (Kamorta), Great Nicobar and Katchal. Human activities like commercial fishing and trafficking should also be restricted.

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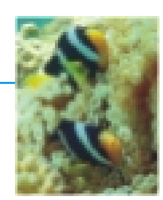

Whale shark

A note on community led whale shark conservation along the Gujarat Coast

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Whale sharks travel thousands of kilometers every year from far-off shores to visit the coast of Gujarat. The presence of this rare and elusive creature is a matter of great pride and joy for the people of Gujarat. Whale sharks grow up to 15 mt. in length, weigh about 12 tons and are known to live over 100 years. Distinctive light whitish yellow markings make it truly unmistakable. Despite their size, they are docile and completely harmless to humans. They are largely vegetarian; eat plankton which they filter through their gills. In the past, local fishermen have traditionally hunted them for oil to waterproof their boats and for their meat for export. Whale shark comes under the Schedule I of the Wildlife (Protection) Act, 1972. Hunting of Whale shark will lead to an imprisonment of three to seven years and a fine of not less than Rs. 10,000/-.

To address the issue of conservation of Whale shark, the Wildlife Trust of India (WTI) launched a multi-pronged campaign to save the whale shark in 2004 with support of Gujarat Forest Department and Tata Chemicals. A life-sized inflatable model, street plays in the local language, theme-based painting competitions in schools, fetes with the whale shark conservation theme, an educational film and public events all worked together to take the campaign from an 'awareness campaign' to a 'Pride Campaign'. A series of adoptions of the whale shark as the city mascot by municipal corporations (Porbandar, Diu, Dwarka, Ahmedabad an Veraval-Patan) saw the involvement of decision makers and government bodies. The Postal Department of Gujarat has come out with a special cover on the whale shark.

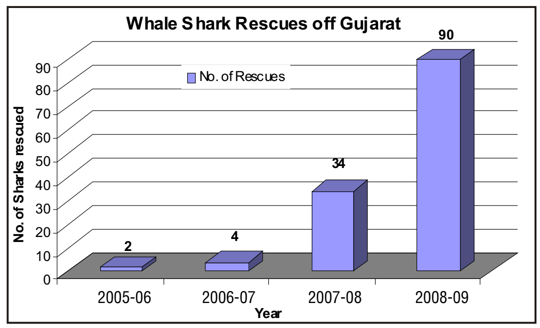
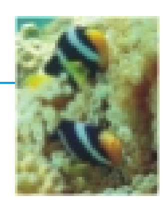


Fig. 1. Number of whale sharks rescued in Gujarat coast during 2005 - 2009

The awareness campaign received a further boost when a highly revered religious leader of Gujarat - Shri Morari Bapu was involved as the ambassador for the save Whale Shark Campaign. He called the animal 'VHALI' which, in Gujarati means a 'daughter'. He appealed to the local people to save the pregnant daughter who visits Gujarat Shore for childbirth. The appeal was received exceptionally well by the local people and it created a social environment that resulted in the release of trapped whale sharks to the Sea.

The Gujarat government on December 25, 2006 for the first time announced compensation up to Rs. 25,000/- for fishermen whose nets get



Release of trapped whale shark

destroyed during release of trapped whale sharks. Awareness among the fishing community built up to a level where hunters turned protectors and instances were recorded where fishermen willingly cut their fishing nets to release trapped whale sharks. The Gujarat Forest Department, the Coast Guard and the Department of Fisheries are now actively involved in rescue and release of whale sharks and over 130 releases have been recorded between 2005 and February 2009 (Fig. 1). In February, 2007, the government of Gujarat declared *Kartik Amas* as the official 'whale shark day' or '*Vhali* Utsav' in view of the popular sentiment about the majestic fish generated by the whale shark campaign. The first whale shark day was celebrated on November 27, 2008 where large numbers of school children, fishermen, forest officials, coast guards, police officials, NGO representatives, marine experts, as well as international film makers and whale shark experts, participated in the road march.

The entire initiative has evolved from a simple awareness programme to an intensive and focused campaign involving various sections of society.

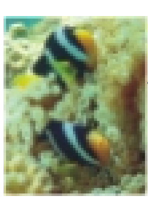
Whale shark conservation in Gujarat is mainly focused on collecting baseline data base on whale shark migration, population, genetics and habitat study. In the last three years, a couple of photo identities and marker tagging to estimate population, analysis of genetic sample, seasonal sampling of water from core areas of rescues and satellite tagging on one whale shark were achieved by the Wildlife Trust of India (Personal Communication from Manoj Matwal, 2012).

The satellite tagged animal showed interesting movement between Gujarat and Maharastra waters, same animal was tracked for 45 days. During 2012, more satellite tagging work is planned on free ranging whale sharks. Population estimation work will be sustained through participation of local fishermen community who are now equipped with underwater cameras and further habitat studies will be done with the help of satellite imagery data. Reducing stress on whale sharks during rescues is emerging as an important point.

Acknowledgement

Thanks are due to Mr. Vivek Menon, WTI for going through the manuscript and supplying data on the whale shark.

Life-sized inflatable Whale shark model awareness campaign by school children



Theme III: Reproduction, recruitment and restoration


Montastrea curta

Studies on the reproduction and recruitment of the corals of Tuticorin coast in the Gulf of Mannar

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Abstract

Since the degradation of coral reefs is happening all over the world because of various natural and anthropogenic factors, studying their reproduction and recruitment becomes vital for better management. Gulf of Mannar is one of the most heavily degraded reef ecosystems due to mainly anthropogenic disturbances. Coral reproductive behaviour and recruitment pattern were studied along the Tuticorin coast of the Gulf of Mannar between 2006 and 2008. The reproductive behaviour of the branching coral, *Acropora* sp., was studied since they have a unique colouring pattern during their reproductive cycle. Visible gametes were observed from most of the coral colonies during January every year and the percentage of corals with visible gametes increased in the next month and in March the gametes mature and spawning occurs. Spawning was observed in *A. cytherea* on 24 March in 2006, 28 March in 2007 and 8 March in 2008. Recruit density was high in April every year, but the survival of the recruits was checked by the elevated sea surface temperature during May. The genera *Montipora* and *Acropora* had a higher density of recruits than all the other genera. Numerous recruits of massive corals like *Favia* spp., *Favites* spp. and *Goniastrea* spp. were found attached to the ferro-cement concrete modules. Among the environmental factors, water temperature plays a crucial role in inducing coral spawning and it is also a key factor in the survival of new recruits.

Introduction

The Gulf of Mannar (GoM) is one of the four major coral reef areas in India, covering an area of approximately 10,500 sq.km from Rameswaram to Kanyakumari. The area includes a chain of 21 uninhabited islands surrounded by fringing and patch reefs rising from the shallow sea floor. Even though many research papers have been published on corals, no work has been done on the reproduction and recruitment of corals in this once rich reef area. This situation is not surprising, in the light of the remoteness of coral reefs, lack of research facilities and the logistical difficulties in studying corals *in situ*.

Sexual reproduction in corals involves the process of gametogenesis, which may require from a few weeks to over 10 months. Spawning and subsequent fertilization of eggs by sperm result in small, presumably genetically unique, dispersive propagules (planula larvae) which may settle, metamorphose and develop into primary polyps. The timing of reproduction in corals has received considerable attention in recent years.

Successful reproduction is the first step in the replenishment of corals on the reef. Recruitment to reef habitats is dependent on the ability of the coral larvae to find a suitable place to settle and metamorphose (Harrison and Wallace, 1990). Recruitment is widely acknowledged as one of the most important processes in the maintenance of coral reef systems, particularly in their recovery and replenishment following disturbances (Glassom *et al.*, 2006).

Reef recovery will be dependent largely on the supply of larvae where mortality has been severe. However, recruitment processes are subject to high levels of variability (Hughes *et al.,* 1999).

The coral reefs of the GoM along the southeastern coast of India are formed mainly around the 21 islands, located between Pamban and Tuticorin. Tuticorin (8°45'N, 78°10'E) is located at the southern end of the Gulf of Mannar Marine National Park. Different types of reef forms such as shore, platform, patch and fringing type are observed in the GoM. The islands have predominantly fringing reefs and also patch reefs around them. Narrow fringing reefs are located mostly at a distance of 50 to 100 m from the islands. On the other hand, patch reefs rise from depths of 2 to 9 m and extend 1 to 2 km in length with width as much as 50 m. The reef flat is extensive in almost all the reefs of the GoM.

In India, no studies of coral reproductive biology have been undertaken and this study is a first. Since vast reef areas have already been destroyed by various means, it is highly important to study the complete reproductive biology, spawning season and recruitment pattern of corals in order to protect them via proper management practices to eventually increase the percentage of live coral cover. The reef areas of Tuticorin coast in the GoM have been damaged due to anthropogenic activities, in particular coral mining, fishing using dynamite and other destructive practices; and hence it is important to have a basic knowledge and information about coral reproduction in this area.

Methodology

The monitoring of the reproductive behaviour of the acroporans of Tuticorin region of the GoM was carried out from January 2006 to March 2008 in five different locations.

Study sites

Mainland Punnakayal patch reef

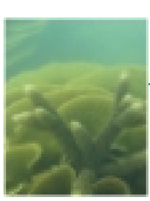
The mainland reef (8°43'N, 78°11'E) is almost monospecific with *Turbinaria* spp., it starts from 1.2 km offshore and is 5 km long. Starting from a depth of 2 m, the genus *Turbinaria* is widespread up to more than 10 m. Acroporans are present only as patches in the shallow depths below 2 m. Ten species of *Acropora* were monitored in this location: *A. formosa, A. intermedia, A. micropthalma, A. nobilis, A. cytherea, A. hyacinthus, A. diversa, A. hemprichi, A. corymbosa* and *A. valenciennesi*.

Vaan Island

Vaan Island (8°50'N, 78°13'E) has a fringing reef which extends up to a depth of 3 m. The fringing reef along the windward side of the island protects the island from direct wave action. The percentage of live coral cover (33.13%) in this island is considered as fair. Massive corals are dominant (12.82%) and a reasonable amount of acroporans (6.97%) are also present (Patterson *et al.*, 2007). The monitored acroporan species in the Vaan Island were *A. cytherea, A. formosa, A. valenciennesi, A. intermedia* and *A. nobilis*.

Koswari Island

Koswari Island (8°52'N, 78°13'E) has reefs of the fringing type which extend up to 2.8 m depth; small patchy reefs are also found in the southeastern direction at 3.5 m depth.



This island is poor in diversity and percentage of live coral cover (15.27%). Massive corals are dominant (6.11%) and a very low percentage of *Acropora* (1.17%) is present (Patterson *et al.*, 2007). Because of the relatively low coral cover only four species, *A. cytherea, A. formosa, A. valenciennesi* and *A. nobilis*, were monitored at this island. At Koswari Island, monitoring was initiated only in January 2007.

Kariyachalli Island

Kariyachalli Island (8°57'N, 78°15'E) has reefs of the fringing type which extend up to 3 m depth; small patchy reefs are also found in the southeastern direction at 3.5 m depth. This island has a relatively high percentage of live coral cover (46.61%) and is more diverse than other locations. Massive corals are dominant (20.73%) at this island and acroporans are also abundant (11.23%) (Patterson *et al.*, 2007). Twelve species of acroporans were monitored: *A. cytherea, A. intermedia, A. valenciennesi, A. microthalma, A. corymbosa, A. nobilis, A. valida, A. hemprichi, A. hyacinthus, A. stoddarti, A. diversa* and *A. formosa*.

Port breakwater area

The reef in the Tuticorin Port breakwater area (8°45'N, 78°13'E) is totally free of any anthropogenic activities. The patch reef is dominated by branching corals. The species monitored were *A. cytherea, A. formosa, A. valenciennesi, A. intermedia* and *A. nobilis.* In the port breakwater area, monitoring was carried out only up to April 2007.

Monitoring of gametic maturity

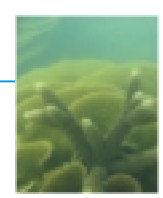
An extensive survey was made in all the study locations of Tuticorin coast to select the study sites. The sampling protocol involved SCUBA diving. The researcher (diver) swam parallel to the reef for a distance of approximately 200m, once along the top of the reef area (1 to 5 m depth, approximate area 20 × 200 m). Any *Acropora* colony encountered during the survey was studied. The reproductive state of *Acropora* species can be gauged easily by scratching off a branch below the expected sterile zone (Wallace, 1985) and noting the presence or absence of eggs. Corals with eggs that are visible, but unpigmented (immature), are likely to spawn within 1 to 3 months; visible and pigmented (mature) are likely to spawn within a month; and colonies with no visible eggs (empty) have either just spawned or are likely to spawn after 3 months (Harrison *et al.*, 1984; Baird *et al.*, 2002). However, this study did not provide any details about the size of mature oocytes, and the length of the gametogenic cycle.

Monitoring of spawning

The timing of spawning was monitored by night diving using a scuba unit and an underwater torch. Frequent dives were made after sunset every day when mature gametes were seen frequently in the coral colonies. Photographs were taken when spawning was observed with an underwater digital camera.

Collection of the spawned gametes

The gametes were collected from the spawned corals by setting a funnel-shaped bundle-collecting device (bundle collector) under the water surface and above the coral colony (Kitada, 2002). Bundle-collecting devices were set during the suspected



spawning season.

Analysis of gametes

The collected bundles were taken to the laboratory and were measured to their nearest margin using a motic digital microscope with imaging software (model no. DMB1-223) and photographs were taken.

Physical and chemical parameters

The physical and chemical parameters such as temperature, salinity, pH, transparency, dissolved oxygen and nutrients were analysed monthly in the water samples collected from all study locations. Temperature was measured with a digital thermometer; salinity using a refractometer; pH with a pH meter; transparency with a Secchi disc; dissolved oxygen was measured by using Winkler's method; calcium and magnesium were measured titrimetrically; phosphate was measured by the method of Murphy and Riley (1962); nitrates and nitrites were measured spectrophotometrically by following Strickland and Parson (1972).

Results

Maturation of gametes

In *Acropora,* visible but immature gametes were seen from January each year and the percentage of immature gametes increased during the next month. The gametes became mature during March and were spawned in the same month. The coral colonies did not have visible eggs for the rest of the year in all the study sites. The overall percentage of immature colonies of *A. cytherea* ranged between 48% and 79% in January; in February it ranged between 56% and 76%; and mature colonies in March ranged between 36% and 86%. Similarly, there were 50% to 75% of immature colonies in January which increased 10% to 20% in February, and they matured in March in all the study sites. The average percentage of mature colonies of other acroporans during March in all the study sites throughout the study period was as follows: *A. formosa* : 47–76%; *A. valenciennesi*: 50–81%; *A. intermedia*: 50–81%; *A. nobilis*: 25–82%; *A. micropthalma*: 56–83%; *A. hemprichi*: 39–83%; *A. hyacinthus*: 33–100% and *A. corymbosa*: 59–65%.

In the mainland Punnakayal patch reef, in January every year, there were around 50% immature acroporan colonies in all species and in February the percentage of immature colonies was between 60% and 100%. During March, the percentage of immature colonies decreased, while mature colonies ranged between 60% and 100% (Table 1).

In Vaan island, the percentage of immature colonies ranged between 60% and 100% during January in the 3 years, which increased to 75–100% during February and in March the mature colonies ranged from 60% to 100% (Table 2).

In the case of Koswari island, the percentage of immature colonies ranged between 80% and 100% in January, immature colonies from 60% to 100% in February and mature colonies between 60% and 100% in March (Table 3).

The Kariyachalli island is relatively more diverse than the other islands of the Tuticorin coast. In January, the percentage of immature colonies of *Acropora* ranged from Nil to may be 100%, while in February it ranged from 50% to 100%. During March, the percentage of mature colonies ranged

Table 1. Percentage of coral maturation in the mainland Punnakayal patch reef

Species		Jan			Feb			Mar	
	M	IM	E	M	IM	E	M	IM	E
Acropora formosa	0	44	56	20	63	17	76	16	8.4
Acropora intermedia	0	46	54	22	67	11	65	23	12
Acropora micropthalma	0	39	28	0	100	0	83	17	0
Acropora nobilis	0	50	50	21	75	5	82	8	10
Acropora cytherea	0	53	47	31	60	9	71	14	14
Acropora hyacinthus	0	50	50	0	56	11	100	0	0
Acropora diversa	0	67	33	0	83	17	72	17	11
Acropora hemprichii	0	33	33	0	67	0	83	0	17
Acropora corymbosa	0	60	40	18	60	22	65	23	23
Acropora valenciennesi	0	48	52	22	68	9	69	12	19

Table 2. Percentage of coral maturation in Vaan island

Species		Jan			Feb			Mar	
	M	IM	E	M	IM	E	M	IM	E
Acropora cytherea	0	79	21	13	76	12	86	5	
Acropora formosa	0	65	35	24	69	7	72	2	2
Acropora valenciennesi	0	75	25	17	83	0	82	10	8
Acropora intermedia	0	76	24	0	100	0	81	11	
Acropora nobilis	0	71	29	7	82	34	68	9	23

Table 3. Percentage of coral maturation in Koswari island

Species		Jan			Feb			Mar	
	M	IM	E	M	IM	E	M	IM	E
Acropora cytherea	0	73	21	27	67	12	76	10	15
Acropora formosa	0	61	24	30	66	20	64	13	24
Acropora valenciennesi	0	90	10	10	80	10	100	0	0
Acropora nobilis	0	83	13	17	79	9	75	8	17

Table 4. Percentage of coral maturation in Kariyachalli island

Species		Jan			Feb			Mar	
	M	IM	E	M	IM	E	M	IM	E
Acropora cytherea	13	69	18	18	67	16	66	24	11
Acropora intermedia	0	57	43	4	79	17	56	44	
Acropora valenciennesi	6	61	50	15	69	17	53	35	1
Acropora micropthalma	0	67	33	0	67	0	56	11	0
Acropora corymbosa	6	67	28	23	77	17	59	34	7
Acropora nobilis	3	61	39	17	71	12	53	36	11
Acropora valida	0	50	50	0	89	11	50	0	33
Acropora hemprichii	0	33	67	17	67	17	39	28	17
Acropora hyacinthus	17	50	33	0	83	17	33	50	0
Acropora stoddarti	0	100	0	0	89	11	50	0	17
Acropora diversa	0	83	17	0	67	33	28	22	50
Acropora formosa	13	70	16	17	67	16	59	27	13

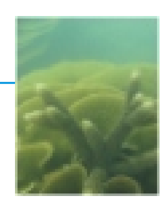


Table 5. Percentage of coral maturation in harbour breakwater area

Species	Jan			Feb			Mar		
	M	IM	E	M	IM	E	M	IM	E
Acropora cytherea	0	48	52	9	56	35	36	41	24
Acropora formosa	0	31	69	14	48	39	47	10	43
Acropora valenciennesi	0	50	50	17	53	30	25	50	2
Acropora intermedia	0	34	71	0	75	25	50	39	11
Acropora nobilis	0	20	80	6	33	61	25	15	60

between 60% and 100% (Table 4).

In the harbour breakwater area, the percentage of immature colonies in January was about 0% to 50%, while in February the immature colonies were about 60–100% in 2007. In March, only 19% of the colonies were mature in 2006 but in 2007, 50–100% of colonies were mature (Table 5).

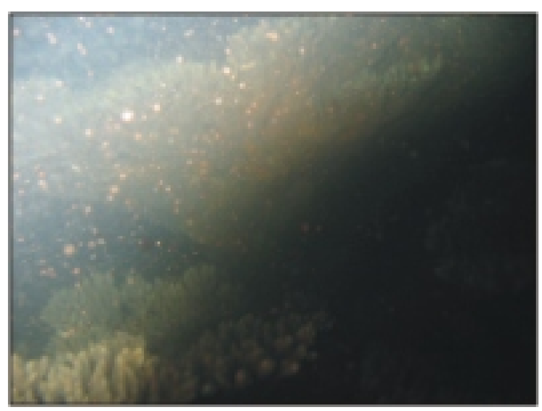
Montipora sp., is common at all three islands and does not have a colouring pattern in gametes, but showed visible gametes from January to March in the study period.

Spawning event

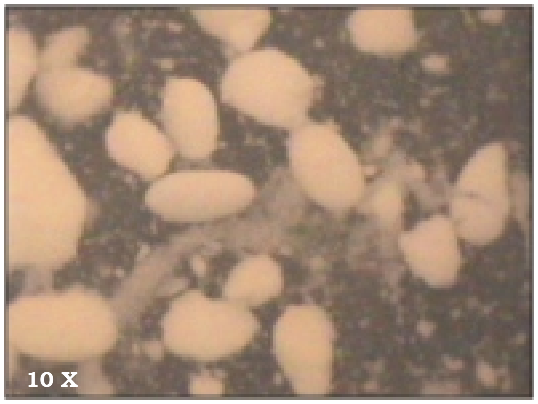
In 2006, spawning was noticed in *Acropora cytherea* on 24 March, 10 days after the full moon. In 2007, it happened on 28 March which is 5 days before the full moon, and gametes were collected. In 2008, spawning was observed on the 8 and 9 March which was 2 days after the new moon. All the branching corals spawned on the night of 8 March (at 8.50 pm) and spawning lasted only 15 minutes; many gametes were seen floating on the water. On 9 March, spawning was observed only in *A. cytherea* at 9.20 pm and it lasted for 10 minutes (Figures 1 and 2).

Fecundity

Approximately 30,000 bundles were collected in 1 litre of water and each bundle had at least 20 to 25 eggs in *A. cytherea* during 2006. Fecundity rate was 35,000 to 40,000 egg and sperm bundles per litre of water in the same species during 2007 and each bundle had 8 to 15 eggs. The size of each bundle was around 24 µm in diameter (Figures 3 and 4).



Figs. 1 and 2. Photos showing spawning of *Acropora cytherea*



Figs. 3 and 4. Spawned gametes of *Acropora cytherea*

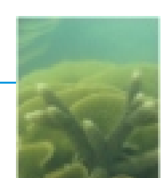
Coral recruitment

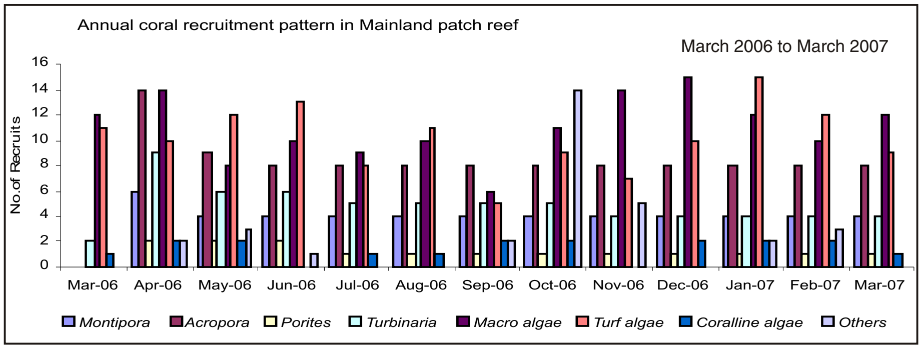
Studies on natural recruitment showed that all the islands had the highest recruitment density in April; this is because of the spawning event which happens in March. Planula larvae swim freely in the water for about 4–5 days; they then attach to suitable hard substrata, especially to dead corals, and start growing. In May, there is considerable mortality and decrease in the recruit density every year because of the bleaching caused by the elevated sea surface temperature. During May the temperature goes up to 33°C in GoM and every year coral bleaching events occur. Corals become bleached during May and the adult corals recover in 2–3 months when the temperature becomes normal. But juvenile corals which get bleached mostly die because of the high temperature.

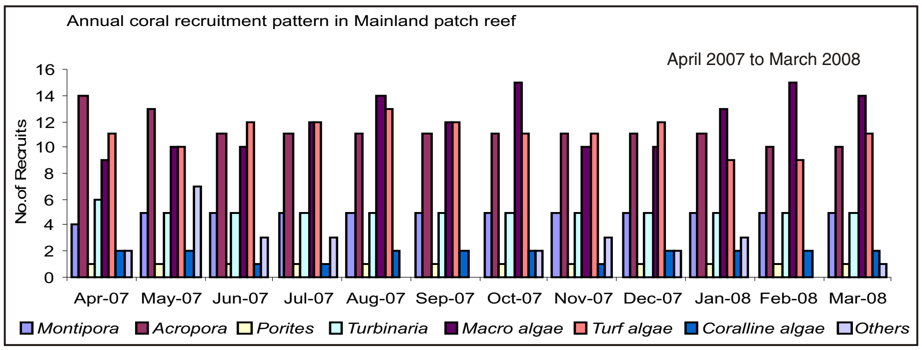
In the rest of the months there was not much deviation in the density of recruits each year, and a few recruits died in the mid-year because of unknown reasons. All the three islands (Vaan, Koswari and Kariyachalli) showed nearly the same results with some exceptions. *Montipora* spp. and *Acropora* spp., were high in recruits, followed by *Pocillopora* spp., in the islands (Fig. 5). In the mainland patch

Fig. 5. Natural coral recruits

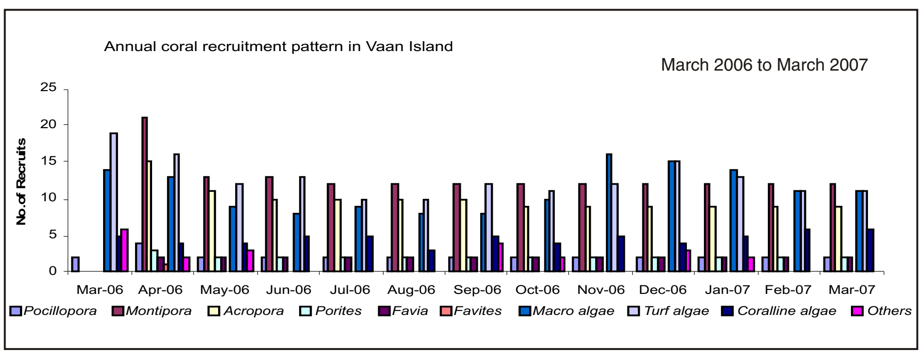
Fig. 6. Coral recruits on ferro-cement module

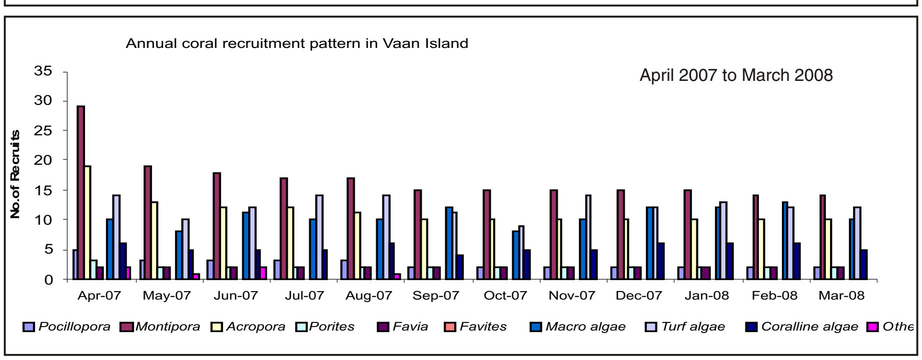






Figs. 7 and 8. Annual coral recruitment pattern in mainland Punnakayal patch reef, 2006-2008





Figs. 9 and 10. Annual coral recruitment pattern in Vaan island, 2006-2008

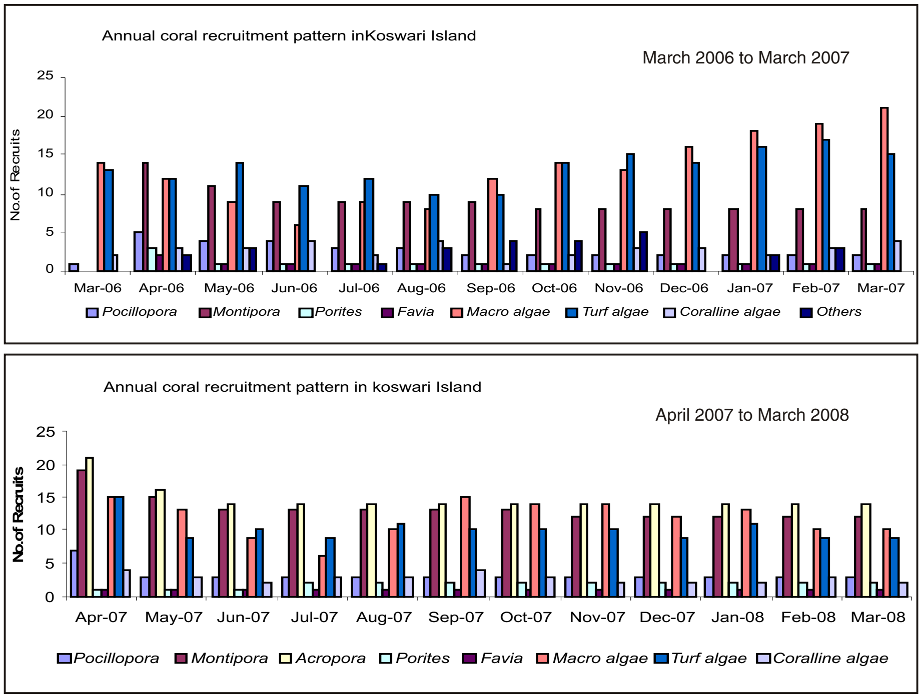
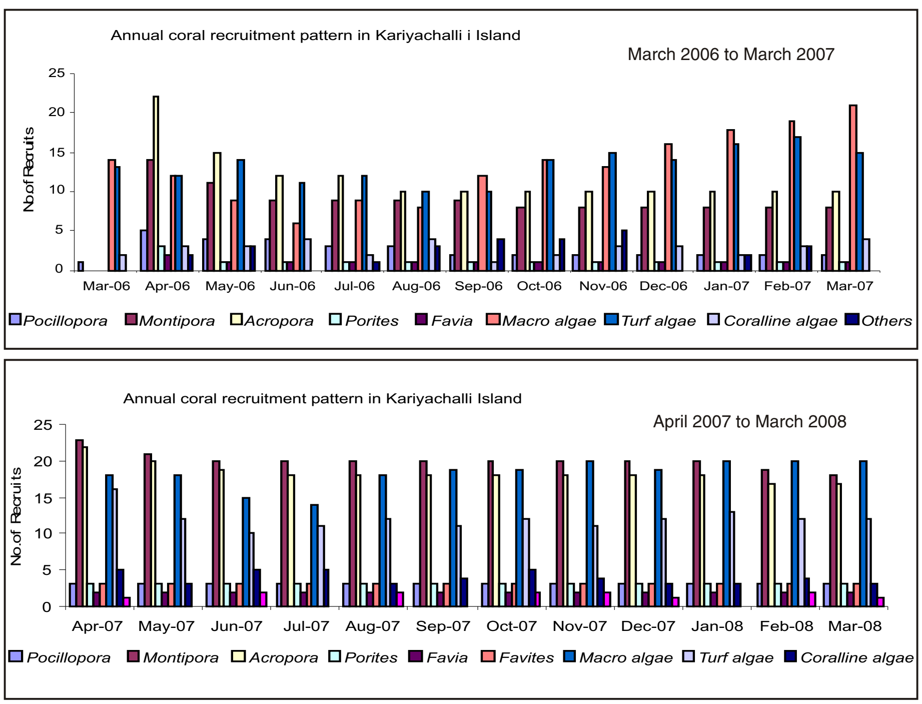
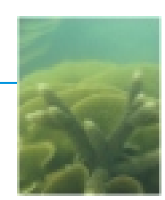


Fig. 11 and 12. Annual coral recruitment pattern in Koswari Island, 2006-2008



Figs. 13 and 14. Annual coral recruitment pattern in Kariyachalli island, 2006-2008



reef, *Pocillopora* spp. was completely absent and the density of *Montipora* spp. was very low, while *Turbinaria* spp. was dominant. Macroalgae and turf algae were the dominant categories occupying the quadrats. The annual recruitment pattern in all the study sites is given in Figures 7–14.

Coral recruitment studies using artificial substrata

In the artificial attachment plates, no new coral recruits were observed, but all the plates were fully occupied by the algae and other organisms. However, lots of new recruits of massive corals were seen attached to the ferro-cement concrete modules. Recruits of *Favia* sp., *Favites* sp. and *Goniastria* sp. were seen abundantly on the modules followed by *Turbinaria* sp. and *Pocillopora* sp. (Fig. 6). Recruits of branching corals, *Acropora* sp. and *Montipora* sp., were not seen on the modules.

Physical and chemical parameters

Water temperature ranged between 26.5 and 33.2°C throughout the study period; the highest value was observed in May 2007 at Koswari Island and the lowest in December 2006 and 2007 at Vaan Island. It is widely accepted that temperature plays a vital role in coral reproduction. Coral spawning is stimulated by the sudden increment of temperature from around 27 to 30°C. Salinity did not fluctuate greatly as it ranged between 34‰ and 36‰. pH values ranged between 7.5 and 8.2. Transparency was very low during April to June every year, and at that time it ranged between 0.5 and 2 m in all the study sites; transparency was reasonably high during November to March in the range 3.5 to 5 m.

The dissolved oxygen level in all the study sites was between 3.3 and 5.8 mg/l. The highest calcium content was recorded in Vaan Island in December 2006 (560 mg/l) and the lowest in the mainland in February 2007 (320 mg/l). The amount of magnesium ranged between 1120 and 1520 mg/l throughout the study period in all the study sites. Phosphate content was between 1.15 and 3.59 µg/l. Nitrate content was between 0.23 and 0.68 µg/l and nitrite content was between 0.009 and 0.048 µg/l.

Discussion

As global degradation of coral reefs is happening rapidly and restoration processes are very slow, it is vital to have a clear understanding of natural coral reproduction and recruitment. The study of coral advanced through numerous theses and dissertations over the last two decades, especially in the Great Barrier Reef of Australia. Sexual reproduction of scleractinian corals has been reviewed by Fadlallah (1983), Richmond and Hunter (1990), Harrison and Wallace (1990) and Richmond (1997). In the light of these reviews, most of the studies have been carried out in the Caribbean, the Great Barrier Reef, the Central Pacific and the

Coral recruits (*Turbinaria* sp.and *Favites* sp.) in Gulf of Mannar

Red Sea. Studies in the Asia-Pacific are restricted to Okinawa (Japan), Taiwan and Philippines. Data from different regions show different patterns, with considerable variation in mode, timing, and synchrony among species.

Very few studies have been carried out on coral reproduction in the western Indian Ocean. Surprisingly, there is limited evidence of the timing of coral reproduction in Southeast Asia, a region that contains more than 30% of the world's reef area and home to 600 of the almost 800 scleractinian species. This lack of basic information is worrying, as an estimated 88% of Southeast Asia's reefs are threatened by human activities. So far, no attempt has been made to study the reproductive timing of scleractinian corals in the GoM as well, one of the heavily exploited reefs of the world.

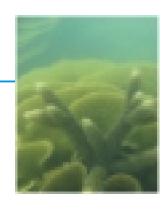
Spawning slicks were observed in March 1997 on Ari Atoll in the Maldives, which is relatively closer to the GoM. In the present study, visible eggs were seen from January every year in almost all the species of *Acropora* and mature gametes and spawning were seen in March. All the monitored acroporan species had mature gametes in all study sites during March. This was also supported by the observation of spawning of acroporans in the same month for three years and collection of egg bundles of *A. cytherea*. Mangubhai (2008) observed that the peak spawning period for *Acropora* species in Kenya is between January and April.

Coral recruit (*Favites* sp.) in Gulf of Mannar

It is widely accepted that sudden elevation in temperature is the primary and ultimate inducer of coral spawning. Even though temperature fluctuation is not great in the GoM, the sudden increment in the temperature from 27 to 29 and 30°C happens in March, the beginning of summer. This sudden increase in temperature induces the corals to spawn in the GoM. Other physico-chemical parameters like salinity, pH, transparency, dissolved oxygen and nutrients were well within the limits and did not have any impact on coral reproduction.

The density of the recruits was high in the month of April, whereas a sudden decrease in the recruit density was recorded in the very next month. It is because of the increment in temperature.

Temperature goes up to 33°C during summer in GoM. The bleaching of corals, through the loss of their symbiotic algae (zooxanthellae) and their pigments, is a global phenomenon that is also possibly linked to global climate change and increasing ocean temperatures (Glynn, 1991, 1993; Brown, 1997; Hoegh-Guldberg, 1999; Strong *et al.*, 2000). Coral bleaching is observed every year during summer in GoM because of the elevated sea surface temperature and this bleaching prevails for 2–4 months. Then corals tend to recover from the bleaching when the temperature returns to normal. There is not much deviation in the



recruitment density in other months.

The recruitment density was reasonably good during the study period and this is because of the decrease in disturbance to the reef area due to several factors such as increased enforcement of laws, conservation measures including awareness creation and the impact of the 2004 Indian Ocean tsunami, which made the people aware of the importance of reefs. This caused an increment in suitable substrata for the coral larvae, which is dead reefs; in turn enhanced coral recruitment. Moreover, the observation of the recruits of massive corals on the artificial substrata is encouraging.

The present study gives baseline information on coral reproduction and recruitment, particularly maturation stages and spawning times in the Tuticorin region of the GoM. Since coral gametes and larvae can be taken to distant places from the parent reef by waves and currents, new reefs can be formed in highly damaged reef areas. If the environment favours reproduction and recruitment, the recovery of precious reefs of the Gulf of Mannar, which have been lost, is not impossible.

Acknowledgements

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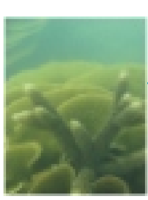

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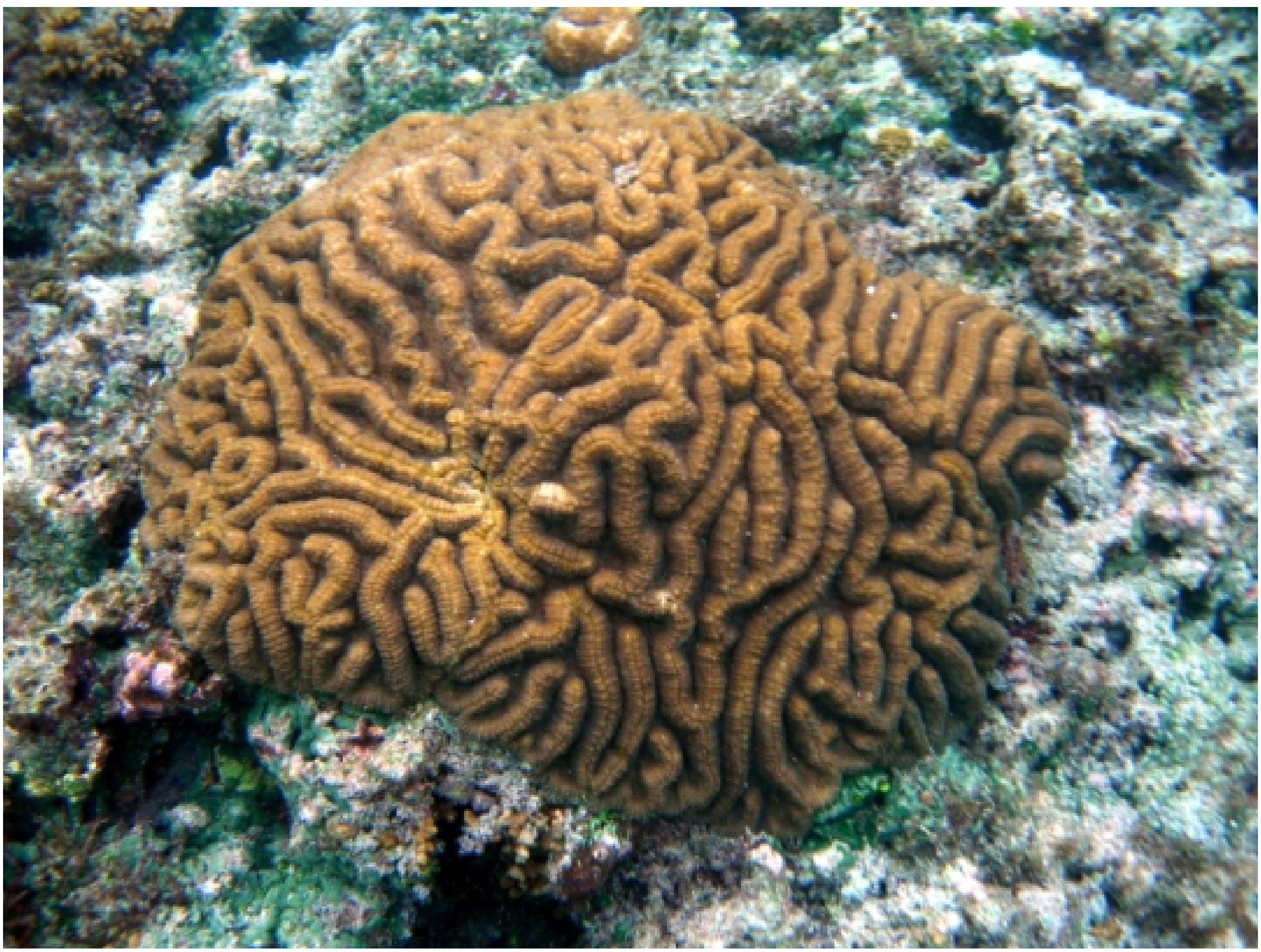
Symphyllia radians



Coral recruit (*Acropora* sp.) in Gulf of Mannar

Coral restoration in the Gulf of Mannar, Southeastern India

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Abstract

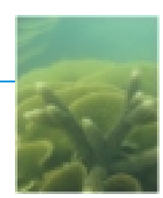
Coral restoration has been carried out on the Tuticorin coast of the Gulf of Mannar (GoM) since 2002 using native coral species and artificial substrata like fish houses and concrete frames. The overall survival of the restored corals during 2002–2007 was 88–95% for branching corals and 87–94% for non-branching corals. The annual growth varied between 11.34 and 13.96 cm for branching corals (*Acropora intermedia, A. cytherea, A. nobilis, A. formosa* and *Montipora foliosa*) and between 1.63 and 1.80 cm for non-branching corals (*Favia* sp., *Turbinaria* sp. and *Porites* sp.). An increase of about 21% live coral cover was noticed in the restored site. The recruit density was enhanced in the restored areas from 0.53 to 2.55 per m^2 from 2002 to 2007. Precision in the use of techniques (fragmentation and fixing), fragment size, substrate and species selection, and regular monitoring are the key factors for the success of the restoration. The successfully restored coral reef areas in GoM serve as donor sites for further restoration and a source of new recruits through asexual and sexual reproduction, which expands the live coral cover in the area. To some extent, restoration could also help in conserving/enhancing the endangered and threatened coral species. The abundance of flora and fauna associated with the artificial substrata enhances the biomass and stability in the restored sites.

Introduction

Coral reefs are rapidly declining worldwide, but efficient restoration techniques are not available. Coral reef destruction has led to decreased productivity of ecosystems with adverse effects on people's food security and livelihoods, shoreline stability, and national economy (Spurgeon, 1992; Berg *et al.*, 1998). The fast degradation of coral reefs has prompted greater attention to remediation and restoration activities. In many reef areas, the status of the reef has reached a critical point of reduced resilience (Young, 2000), necessitating active restoration measures. Efforts to restore degraded coral reef areas require a basic understanding of the natural recovery process, as well as thorough knowledge of the conditions under which these natural processes succeed or fail.

Methodologies for restoration of degraded coral reefs are still in the experimental stages in most areas. Considerable uncertainty exists about the effectiveness and efficiency of current approaches to coral restoration (Edwards and Clark, 1998). Unfortunately, most of the restoration techniques are expensive, labour-intensive and not viable.

Transplantation of coral fragments or coral heads has been considered to be a useful technique for restoring coral reefs. This technique has been suggested to remedy human-induced physical damages caused by events such as ship groundings, mining and harbour construction (Harriott and Fisk, 1988; Edwards and Clark, 1998; Okubo and Omori, 2001). Transplantation of corals to artificial habitats provides a unique opportunity for a detailed examination of their optimal niches by means of survivorship and



growth rates (Oren and Benayahu, 1997). Several restoration experiments have revealed that the use of coral fragments may serve as a good tool for reef rehabilitation.

The coral reefs of the Gulf of Mannar along the southeastern Indian coast are mainly found scattered around the 21 islands that are distributed between Pamban and Tuticorin. The average distance between each island and the mainland is 8–10 km. The Gulf of Mannar was considered as one of the biologically richest reef ecosystems few decades back, but anthropogenic activities coupled with natural disasters have severely damaged the reef areas. In particular, the reefs of Tuticorin coast are under severe threat mainly due to human interference such as coral mining, destructive fishing activities like blast fishing, cyanide fishing, bottom trawling, crab fishing, anchorage, and pollution from domestic sewage and industries. Even though coral mining has been stopped, the destructive fishing activities are still in practice.

In this present study, a few degraded reef sites on the Tutcorin coast of the Gulf Mannar were restored by transplanting coral fragments on two different artificial substrata. The study was conducted with fragments from nearby natural reefs in the study sites to estimate the survival, growth, community structure and the increment in the live coral cover through recruitment.

Material and methods

The study site is located outside the Vaan Island (08°49’404’’N; 78°13’059”E) in the Tuticorin coast. Transplantation of coral fragments was done in 2002. The two substrata, concrete frames and fish houses, were found to be most suitable based on the stability and quick attachment of fragments on to the substratum. The fragments (6–8 cm) of identified native coral species were cut precisely at the nearby donor reefs with a maximum of 3–5% of the colony size and tied to the artificial substrata using nylon ropes. The eight native coral species identified were *A. cytherea, A. intermedia, A. nobilis, A. formosa, Montipora foliosa, Favia* sp., *Porites* sp. and *Turbinaria* sp. Monthly monitoring was carried out to study the survival and growth of the transplanted fragments and community structure in the rehabilitated areas.

The assessment of the benthic community was carried out in the transplantation site at six month intervals. To assess the sessile benthic community of coral reefs, line intercept transect (LIT) method (English *et al.*, 1997) was used. The density of recruits was recorded using haphazardly placed 1 × 1 m^2 permanent quadrats. The belt transect method (McCormick and Choat, 1987; English *et al.*, 1994) was used for visual survey of fishes.

Restored corals (*Turbinaria* sp. and *A.intermedia*) on concrete frame with recruits in Gulf of Mannar

Results

Transplantation of the coral fragments in the degraded areas of Tuticorin region of the Gulf of Mannar has made a positive change in the live coral cover. Over one sq.km of degraded coral reef area has been rehabilitated through transplantation in the Tuticorin coast. The overall survival of the rehabilitated corals is very high, ranging from 85% to 90%, for both branching and non-branching corals. The fast-growing branching corals had the higher annual growth rates and the growth rates of the non-branching corals were also good. The growth varied between 11.34 and 13.96 cm/year for branching corals and 1.63 and 1.80 cm/year for non-branching corals (Figures 1–4).

A good increase in the recruit density was observed after the transplantation. The mean coral recruit density increased from 0.53 to 2.55 per m^2 from 2002 to 2007 after the coral transplantation. The highest mean

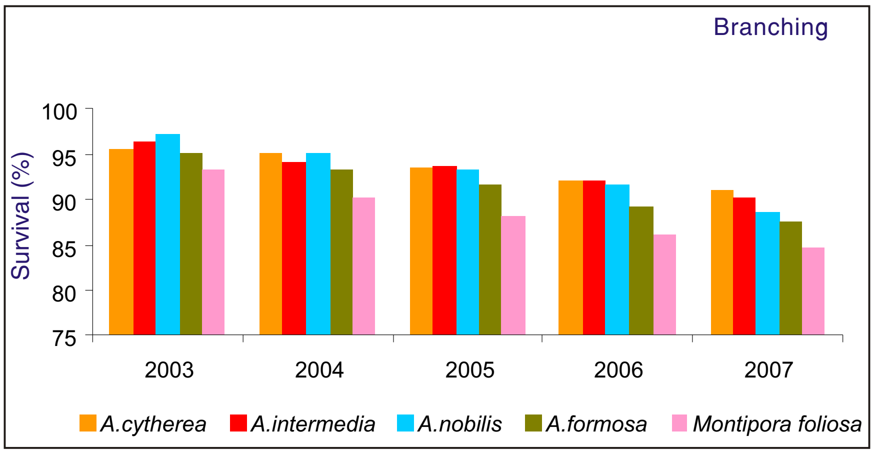


Fig. 1. Percent survival of transplanted branching coral fragments on concrete frames and fish houses

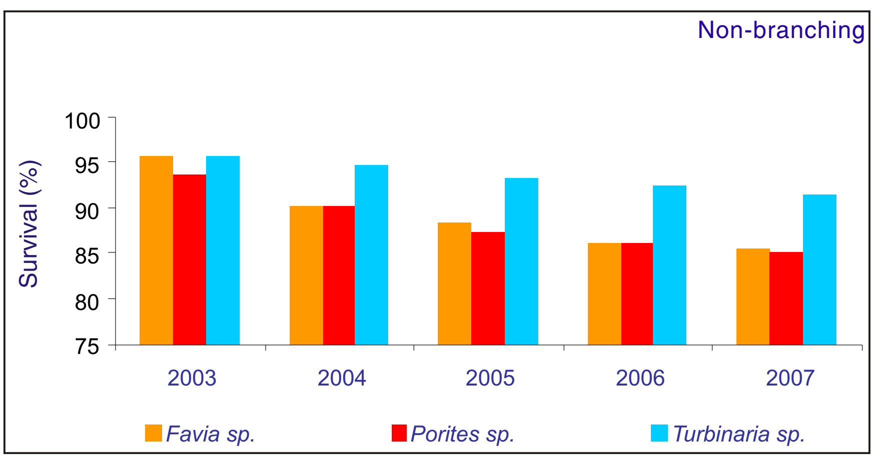


Fig. 2. Percent survival of transplanted non-branching coral fragments on concrete frames and fish houses

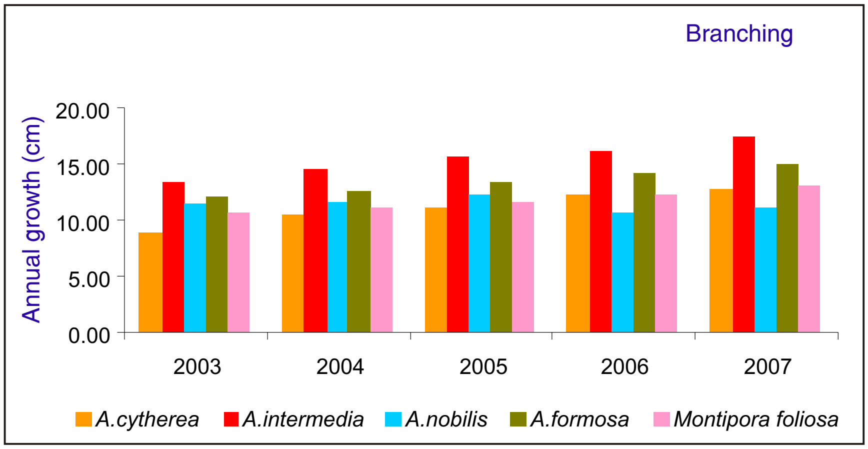


Fig. 3. Annual growth of transplanted branching corals on concrete frames and fish houses

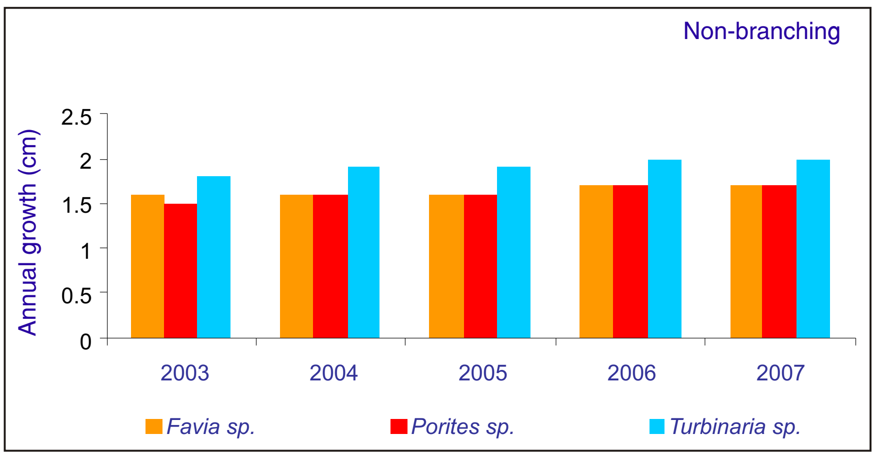


Fig. 4. Annual growth of transplanted non-branching corals on concrete frames and fish houses

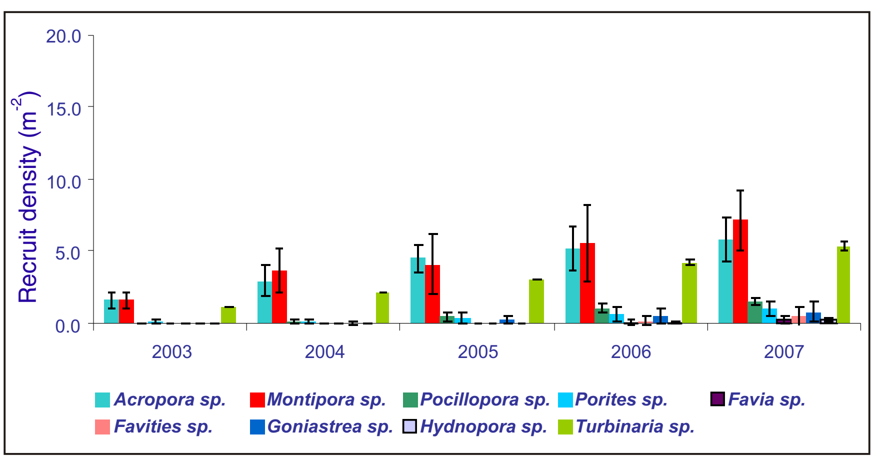
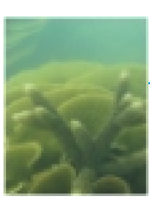


Fig. 5. Average recruitment density from restored areas



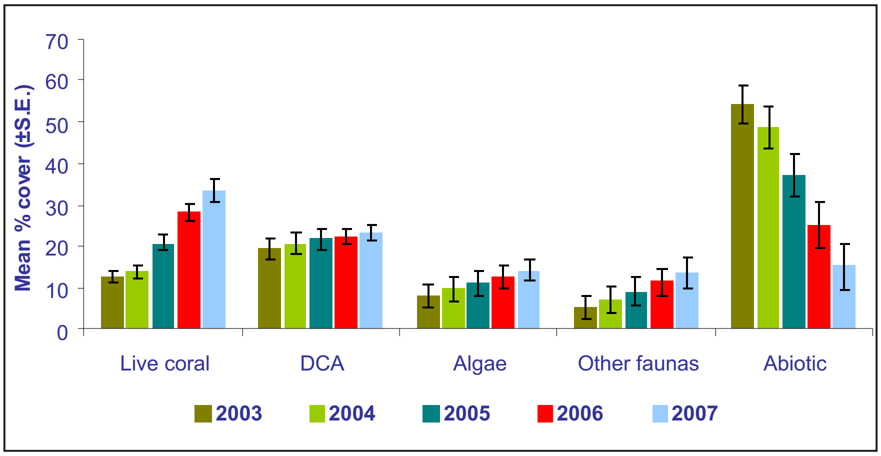


Fig. 6. Mean percentage cover of benthic community structure at near restored sites

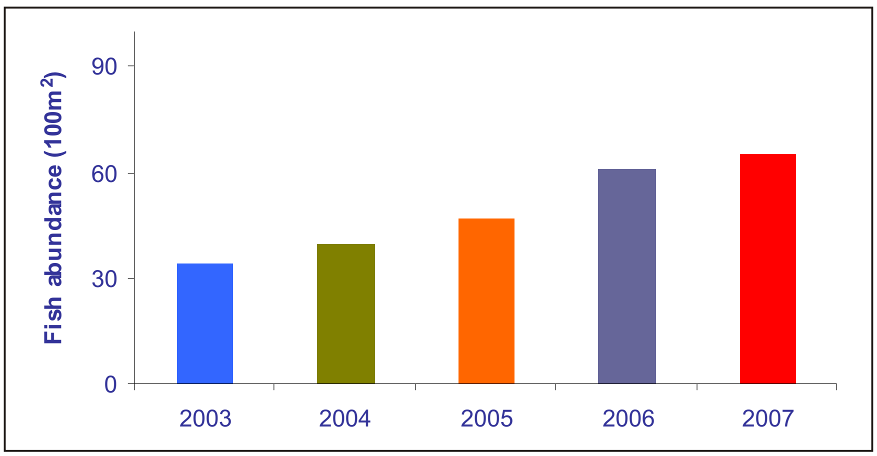
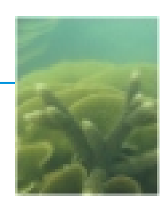


Fig. 7. Fish abundance near restored sites

coral recruit density was recorded for *Montipora* sp. (7.21 per m^2) followed by *Acropora* sp. (5.88 per m^2). The mean coral recruit densities of other coral species were *Pocillopora* sp. (1.53 per m^2), *Porites* sp. (1.07 per m^2), *Favia* sp. (0.23 per m^2), *Goniastrea* sp. (0.83 per m^2), *Hydnopora* sp. (0.3 per m^2) and *Turbinaria* sp. (5.35 per m^2) (Figure 5).

The live coral cover of the transplanted site increased significantly during the course of the study. An increment of 21.21% of live coral cover was observed in the rehabilitated sites along with increments of 5.99% and 8.08% in the associated flora and other fauna, respectively, from 2002 to 2007 (Figure 6). The fragmentation of the transplanted corals was also responsible for the increment in coral cover in the rehabilitated areas. A good improvement was observed in the fish abundance as it increased from 34 to 65 per 100 m^2 after rehabilitation (Figure 7). Mature gametes were observed in some transplanted corals of *A. cytherea* and *A. formosa* after 1 year.



Discussion

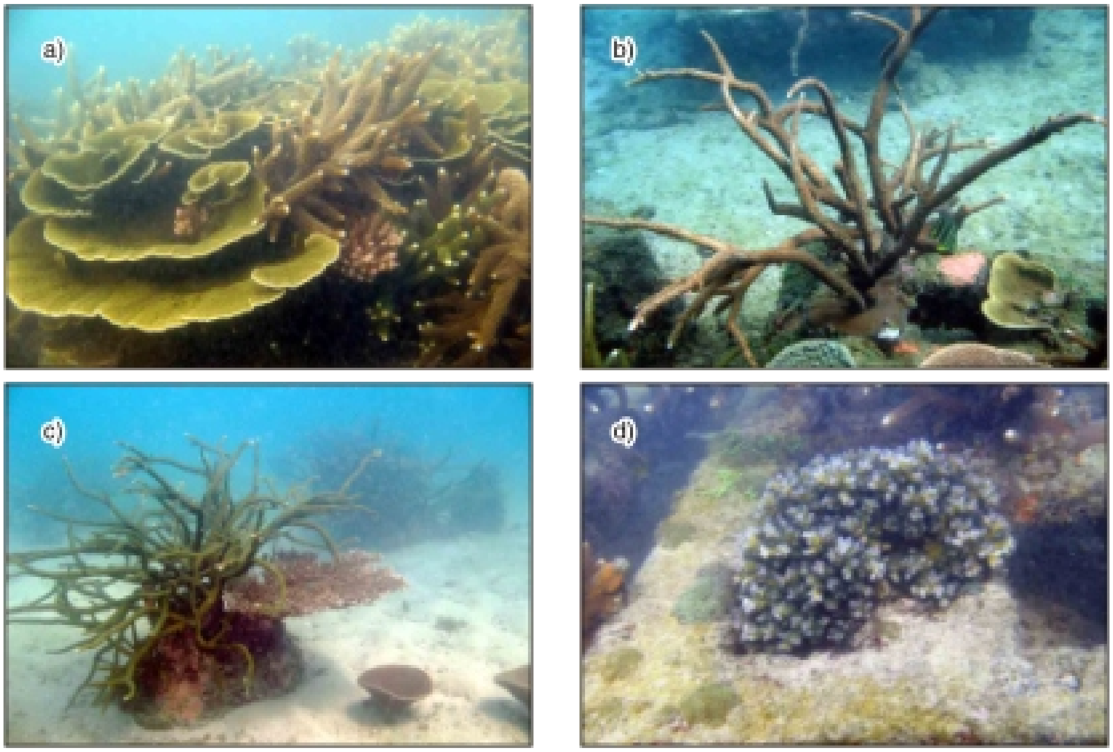
Survival of the coral transplants is of prime and utmost importance in the success of any coral transplantation work. Ideally, in a successful transplantation project, transplanted corals will survive and grow in a manner similar to that of naturally occurring corals (Yap *et al.*, 1992). The present study recorded a good annual survival of about 85–90% in the transplanted fragments. The availability of source material for transplantation is one of the most important factors in coral restoration, as the breakage and removal of fragments from the source areas may result in further damage and reduced fecundity of donor colonies. However, no such problem was faced in the present study regarding the donor sites; instead they are healthy because of the supportive environmental conditions, use of precise techniques and regular monitoring. Growths of the fragments were also significantly high because of the conducive environmental conditions such as light intensity, temperature and sedimentation.

Recruitment is widely acknowledged as one of the most important processes in the maintenance of coral reef systems, particularly in their recovery and replenishment following disturbances (Glassom *et al.,* 2006). Successful reproduction is the first step in the replenishment of corals on the reef. Recruitment to reef habitats is dependent on the ability of coral larvae to find a suitable place to settle and metamorphose (Harrison and Wallace, 1990). In this study, mature gametes were witnessed in some of the transplanted colonies indicating the sexual maturity of the transplants. After the transplantation in 2002, a significant rise in recruit density was observed in the subsequent years. Moreover, the concrete frames and fish houses deployed for the purpose of coral transplantation also helped in the attachment of many new recruits.

Recently restored coral (*Acropora* sp.) on fish house in Gulf of Mannar

Transplantation of corals is believed to provide an obvious and immediate increase in coral cover and diversity at an impacted site, creating a near-original community structure. However, the site suitable for coral growth should have a good supply of

Recently restored corals (*Acropora* sp. and *Montipora* sp.) on concrete frame in Gulf of Mannar



(a) -Two years old transplanted coral on concrete frames; (b) - Two years old transplanted branching and non-branchiing coral on concete frames; (c) - Two years old transplanted branching corals on fish houses; (d)- Coral recruits on concrete frames

larvae and should not suffer excessive post-settlement mortality; and it should, in due course, recover naturally (Edwards and Clark, 1998). A few studies have shown a marked increase in coral cover following coral transplantation; for example, Lindahl (1998) indicated a 51% increase in *Acropora* cover over two years; Guzman (1993) reported a doubling of coral cover over three years at Platanillo.

In this study an improvement of 21.21% of live coral cover was observed along with the significant increase in fish abundance and in other flora and fauna, indicating the success of transplantation. Fragmentation of the transplanted corals was one of the most important factors for the increment in coral cover in the rehabilitated areas. More than one sq.km of degraded coral reef area has been rehabilitated through transplantation in the Tuticorin coast of the Gulf of Mannar. The contribution of fragments from the rehabilitated corals after two years helped to reduce or avoid dependence on natural donor reefs.

Coral rehabilitation by transplantation using suitable artificial substrata is efficient and cost-effective, and large-scale rehabilitation of degraded reef areas is possible in a phased manner. The artificial substrata used in this study played a key role in the success of the transplantation as they were effective in terms of stability, leading to quick attachment of the transplants. The artificial substrata also acted as a good base for the new recruits and thereby supported the natural recovery process. The observation of the recruits of massive corals is a good sign for the future along the heavily damaged Tuticorin coast.

The experiences from the ongoing coral rehabilitation study since 2002 indicate that the coral rehabilitation with comparatively low-cost transplantation method using suitable artificial substrata, fragments of native species, precise standardized techniques and regular monitoring would help to rehabilitate large degraded reef areas and further to support the natural recovery process not only in the Gulf of Mannar, but also in other reef areas in India.

Acknowledgements

The authors are thankful to the Ministry of Environment and Forests, Govt. of India and Coastal Ocean Research and Development in the Indian Ocean (CORDIO) for the financial support.

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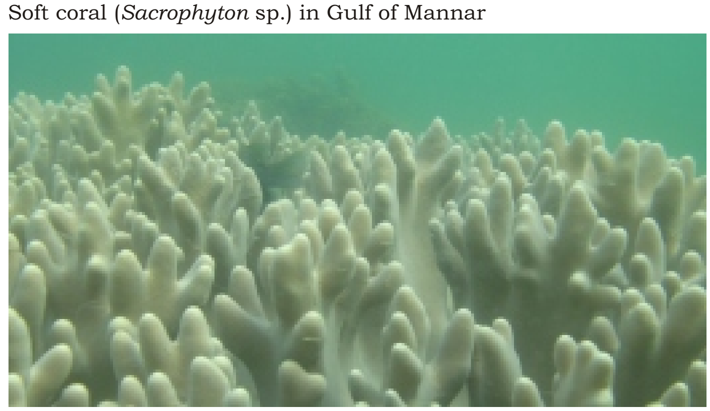
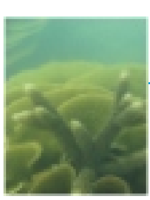
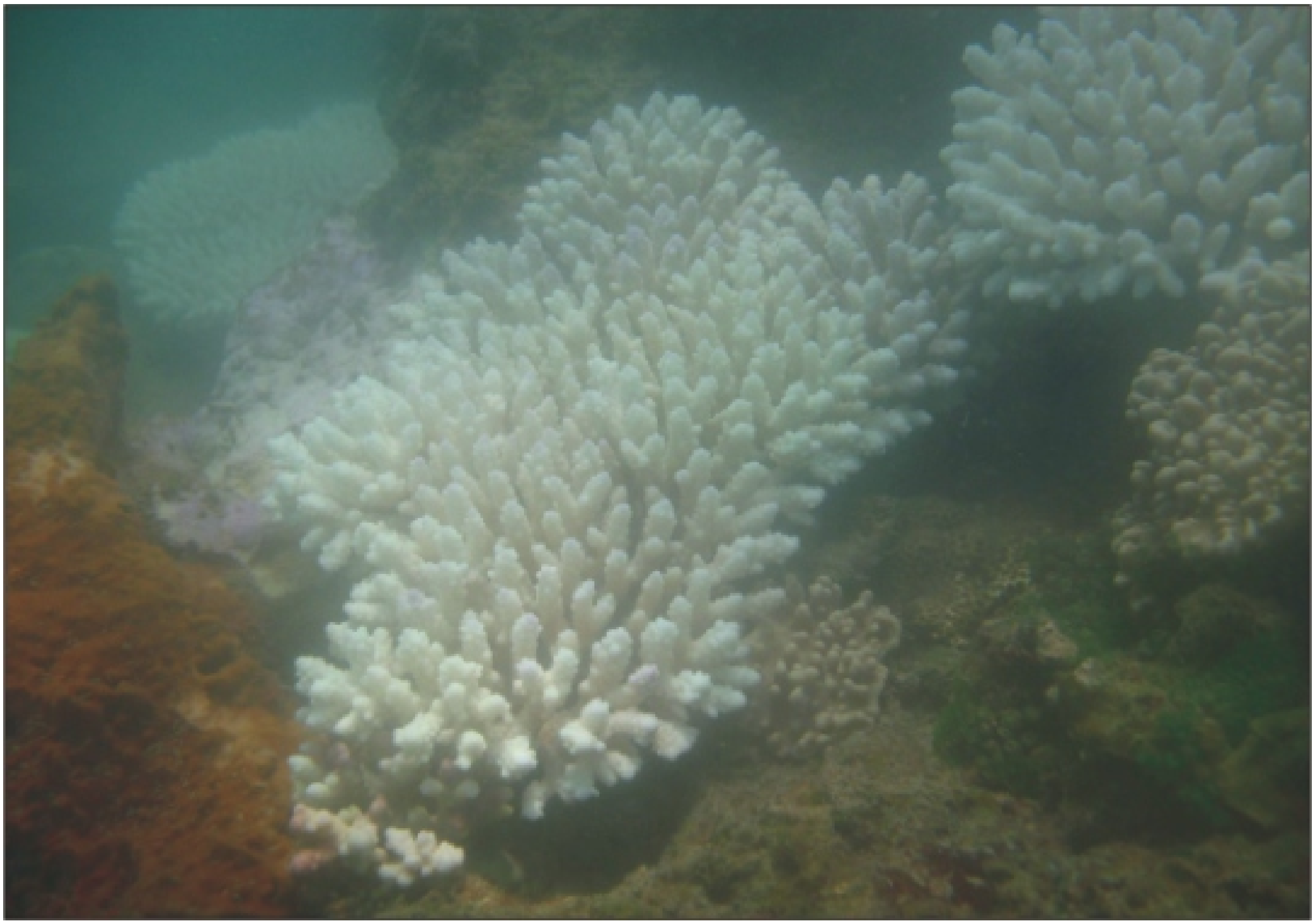
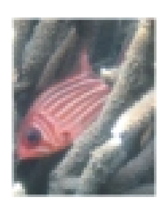
Soft coral (*Sacrophyton* sp.) in Gulf of Mannar







Theme IV: Coral environment and threats




Sarcophyton trocheliophorum

Diseases of corals with particular reference to Indian reefs

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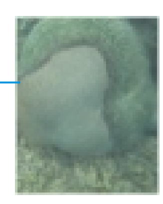
Abstract

Diseases are one of the factors that change the structure and functioning of coral-reef communities as they cause irreversible damage to the corals. Reports on coral diseases describe the etiological agents responsible for the disease and in a few cases, Koch's postulates have been proved. The report of Black Band Disease (BBD) among the corals of Caribbean reefs kick-started awareness on coral diseases among ecologists and naturalists leading to reports on the prevalence of new band diseases from other reefs. Outbreaks of several other diseases have also been reported from other reefs around the world. Other diseases reported so far are the White Band Disease (WBD), Rapid Wasting Syndrome (RWS), White Syndrome (WS), White Plaque, Shut Down reaction (SDR), Pink Line Syndrome (PLS) and bleaching in hexacorals. The Pink Line Syndrome (PLS) that affected *Porites lutea* colonies in Lakshadweep corals is the only disease in Indian reefs investigated extensively. It has been established that *Phormidium valderianum,* a cyanobacterium causes the PLS. Histological observations showed that the tissue was destroyed in PLS. The coral bleaching is the only abiotic disease known in the corals. Bleaching is triggered by anomalous high water temperature during summer in which the endosymbiont zooxanthellae are expelled from the coral tissue causing a break in symbiosis. Bleaching in the polluted or eutrophicated reefs delays or completely stops the recovery processes. This will be a major threat to the global coral reefs as forecast by the recent IPCC report. In octacorals, BBD, Red Band Disease (RBD) and *Aspergillosis* are reported to be affecting the colonies. The *Aspergillosis,* caused by the fungus *Aspergillus* sp. in gorgonians is the first coral disease in which the complete processes, such as entry and spread of the pathogen in the coral reef ecosystem, and the role of global change in the disease propagation, have been studied in detail.

Introduction

Coral reefs are among the earth's most diverse ecosystems in terms of biodiversity and are widely recognized as the ocean's rain forest (Reaka-Kudla, 1997). Coral reefs are being degraded on a global scale due to various threats. It is estimated that about 27% of the coral reefs were lost mainly due to the major bleaching episode in 1998 (AIMS, 2000). While bleaching episodes leave a chance for corals to recover, diseases of corals change the structure and functioning of coral-reef communities as they cause irreversible damage to the corals. Disease is defined as any impairment (interruption, cessation, proliferation, or other disorder) of vital body functions, systems or organs (Peters, 1997). The importance of pathogens as regulators of coral populations in the tropical marine environments is poorly understood (Peters, 1988). A disease not only kills the coral colony, but also exposes the substratum from diseased corals for new recruits (Connel and Keough, 1985), but this may not be favorable in case of the eutrophicated waters where algal forms compete with new recruits for the space. Reports on coral diseases describe the presence of etiological agents in the affected colonies, and in few cases, they prove Koch's postulates. One of the most important, yet least understood, aspects of coral disease is the relationship between incidence of



disease and the environment. While it has been suggested that the recent increase in coral diseases is associated with a decline in reef environmental quality, very little quantitative work has been carried out in this area.

Global scenario

Some disease causing organisms of corals have been identified and mechanisms of mortality have been studied in some diseases, such as the Black Band Disease. However, many others remain poorly investigated. Infectious diseases in corals are different from genetic diseases found in them, such as unusual growth patterns resembling tumors, neoplasms or galls, which have been analogous to cancer (Goreau *et al.,* 1998). Often vectors spread pathogenic agents. For example, parrotfishes are believed to spread pathogens through oral mucus (Antonius, 1981a). Diseases can be classified as biotic and abiotic (Peters, 1997). In biotic diseases, various biological factors are responsible for the disease, while in abiotic diseases, abnormal features among environmental factors such as salinity, temperature, ultraviolet light, sedimentation or exposures to toxic chemicals may cause disorder. Biotic and abiotic factors are often interrelated. Physiological disorders often result from extreme environmental conditions. For example, corals expel zooxanthellae during times of anomaly in sea surface temperature (Bruno *et al.,* 2001). Many coral diseases are reported from all over the world in hexacorals and octocorals.

Diseases of scleractinian corals

The report on the Black Band Disease (BBD) in the corals of Caribbean reefs kick started the awareness on coral diseases (Antonius, 1973) among ecologists and naturalists that brought in reports on new band diseases from other reefs. The name of the band diseases were specified using the prefix of the color of the band that appears in the affected colony. In general, most of the coral diseases were called 'band diseases'. The BBD is a major factor in decline of coral reefs in Florida reefs (Porter and Meier, 1992; Peters, 1993). The BBD contains a microbial consortium of microbes consisting mainly *Phormidium corallyticum*. In addition to this cyanobacterium, the band consists of numerous heterotrophic bacteria (Garrett and Ducklow, 1975), fungi (Ramos-Flores, 1983) and sulphur-reducing bacteria like *Desulfovibrio* and the sulphur oxidizer, *Beggiatoa* sp. (Ducklow and Mitchell, 1979; Antonius, 1981b). The main cause of the coral tissue mortality covered by *P. corallyticum* is due to sulphur accumulation underneath the band where the tissue is undergoing lysis.

White Band Disease (WBD) is a sharp advancing line where the distally located brown zooxanthellae bearing coral tissue is cleanly and completely removed from the skeleton, leaving a sharp white zone about 1 cm wide that grade proximally into algal successional stages (Gladfelter, 1982). The white band spreads from the basal region of the colony to the tip. No environmental factors that alter the speed of the white band are known. However recent reports indicate relationship between increase in SST and WBD. The white band causes substantial decrease in skeletal deposition. The affected tissues contain both gram

positive and gram-negative bacteria especially *Vibrio* spp. (Peters, 1984; Santavy and Peters, 1997; Ritchie and Smith, 1995, 1998). Koch's postulate experiments have yet to prove the role of this bacterium associated with the WBD in causing the disease.

The white plague was first reported from Florida Keys (Dustan, 1977) and subsequently from the Puerto Rico reefs (Bruckner and Bruckner, 1998). The affected colonies had no visible microbial flora on the surface of the colony. Microscopic studies revealed tissue degeneration and remnants of zooxanthellae, giving a bleached effect to the diseased colonies (Richardson *et al.,* 1998). A bacterium, *Sphingomonas* sp. was isolated from the diseased corals (Richardson *et al.,* 1998). The bacterium was later proved to be the pathogen through laboratory studies. This disease is transmissible and occurs seasonally (Richardson *et al.,* 1998).

The Rapid Wasting Syndrome (RWS) was reported from the Caribbean reefs. The disease leaves an eroded skeleton as it spreads laterally on the colony. The skeletal erosion may be as deep as 2 cm (Goreau *et al.,* 1998). A fungus and a ciliate were found on microscopic examination of the affected specimens (Cervino *et al.,* 1998).

White syndrome is the whitening of coral tissues that is thought to be a reaction to toxic chemicals leached from antifouling paintings of marine installations (Antonius and Riegl, 1997) .

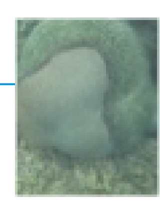
Shut Down Reaction (SDR) is a complete, spontaneous disintegration of the coral tissue, starting at the borderlines of the injury. Coenosarcal tissue sloughs off in thick strands or blobs. The disease spreads along the branches in a ramose form, leaving denuded coral skeleton without a trace of tissue. The disease advancement on the affected colony is about 10-cm per hour. The advancement is a non-intermittent process, which does not stop before killing the entire colony. SDR is transmitted by contact. A piece of sloughed tissue triggers SDR within 5-10 min after a contact with another healthy colony.

Diseases of octocorals

The octocorals, similar to the scleractinian hexacorals, serve as hosts for numerous commensals, symbionts and parasites and also provide refuge for reef fish (Bayer, 1961). Among the octocorals, the diseases affected the gorgonians. Causes that result in the loss of tissue in gorgonians are detachment, fracture of the skeleton and overgrowth by fouling organisms (Yoshioka and Yoshioka, 1991). There are a few reports of disease-related mortality in gorgonians and other octocorals. Some of the diseases of gorgonians are described below.

BBD is known in the scleractinian corals caused by the cyanobacterium *Phormidium corallyticum* (Rützler and Santavy, 1983). The same pathogen, *P. corallyticum,* also causes black band disease in the gorgonia *Pseudopterogorgia acerosa* and *P. americana* (Feingold, 1988) and the mode of tissue loss in the gorgonians is similar to that of BBD in the scleractinians corals.

The RBD was reported to affect the octocoral *Gorgonia ventalina* in Belize (Rützler and Santavy, 1983).



RBD contains a cyanobacterium from the genus *Oscillatoria* (Richardson, 1992) in addition to other cyanobacteria. No particular cyanobacterium was observed to be associated with the diseased corals, and different species have been thought to be responsible in different locations (Santavy and Peters, 1996). RBD is similar to the BBD in its development of a microbial consortium in the mat, containing other cyanobacteria, the sulphur-oxidizing bacterium (*Beggiatoa*), heterotrophic bacteria and the nematode, *Araeolaimus* (Santavy and Peters, 1996).

The fungal disease in a gorgonian is the first coral disease in which the complete processes such as entry and spread of the pathogen in the coral reef ecosystem and the role of global change in the disease propagation have been studied. There has been a correlation between the decline in the Caribbean coral reef and sharp increase in the transport of the African dust over the western Atlantic (Shinn *et al.,* 2000). It is hypothesised that the prolonged drought in the highly grazed grasslands of the Sahel in Africa and the desiccation of the water bodies resulted in abundant fungal spores that are transported through the wind to the western Atlantic Ocean (Shinn *et al.,* 2000). This finding was further supported by a study that showed that there were no spores in the clear air (Weir *et al.,* 2000) and, therefore, the African wind was established as an effective carrier of fungal spores from African deserts to the western Atlantic region. *Gorgonia ventalina* and *G. flabellam* in the Caribbean suffer by the recession of rind tissues called coenenchyme, which is the outer organic rich matrix containing the living polyps (Smith *et al.,* 1996). Only one species of fungus was found common to all the affected colonies. The fungus was identified to be *Aspergillus* sp. The 18S ribosomal RNA analysis showed that the fungus may be *A. fumigatus* (Smith *et al.,* 1996). The fungus was later identified as *Aspergillus sydowii* (Geiser *et al.,* 1998). Weir *et al.* (2000) successfully established Koch's postulates by inoculating the *A. sydowii* cultured from the spores collected from the African dust.

Indian scenario

Preliminary work on diseases of corals in Indian reefs was reported in Gulf of Kuchchh, Andaman and Lakshadweep corals (Ravindran *et al.,* 1999). Coral mortality due to various factors was discussed and a survey on the extent of coral bleaching in Andamans during mass bleaching episode in 1998 was reported. Subsequently, few reports appeared on a specific disease, pink line syndrome (PLS) that affected the *Porites lutea* colonies in Lakshadweep corals (Ravindran *et al.,* 2001; Ravindran and Raghukumar, 2002; Ravindran and Raghukumar, 2006 a, b). It has been established that the *Phormidium valderianum*, a cyanobacteria causes the PLS (Ravindran and Raghukumar, 2006b). Histological observations showed that the tissue was destroyed (Ravindran and Raghukumar, 2006a). There are observations on the skeletal deformation in the healthy looking coral colonies in the *P. lutea* colonies in Lakshadweep (Ravindran and Kannapiran - unpublished). Bacterial diversity associated with coral mucus in the colonies of Gulf of Mannar was

reported (Ganesh Babu *et al.,* 2004 and Kannapiran *et al.,* 2006). The diversity included *Vibrio, Pseudomonas. Micrococcus, Aeromonas, Bacillus, Arthrobacter and Flavobacterium.* A disease, 'pink line disease syndrome' in the Gulf of Mannar reefs was observed (Kumaraguru *et al.,* 2005). Nine types of coral diseases namely black band, white band, white plague, white spot, pink spot, black spot, yellow spot, yellow band and tumour were reported in Gulf of Mannar (Thinesh *et al.,* 2009).

Conclusion and recommendations

There is widespread degradation of coral reefs due to many factors including man-made and natural disasters. In addition to direct and indirect human influences, disease is another key factor killing the corals silently. As studies on diseases in corals indicates their presence in almost all parts of the global coral reefs, there is a need to understand the pathogenesis of corals with reference to local environmental conditions, host physiology and its susceptibility.

Terrestrial fungi reported in many studies show that they are more omnipresent and ecologically important than had been realized, besides their role as secondary invaders and known borers in corals. Endolithic fungi represent normal inhabitants of healthy corals. However, like opportunistic pathogens, these fungi may cause damage to environmentally stressed corals. Efforts must be made to prove their role as primary invaders wherever it is suspected to be the pathogen. The combination of terrestrial run off and nutrient enrichment with an intermittent supply of fungal and bacterial spores, combined with warm El Nino conditions, sets the conditions rolling for environmental stress. The environmental conditions in triggering or supporting the disease process and the status of susceptibility of host for infection has to be explored scientifically. Concentration of stress indicator molecules such as Lipid peroxide (LPO), glutathione (GHO), ubiquitin, Hsp60 and Hsp70, small heat shock proteins, Superoxide dismutase (SOD) in corals with reference to environmental stressors need to be monitored to assess the level of stressors in the environment.

The knowledge generated through these investigations will contribute substantially to the drawing up of a management plan to conserve the corals.

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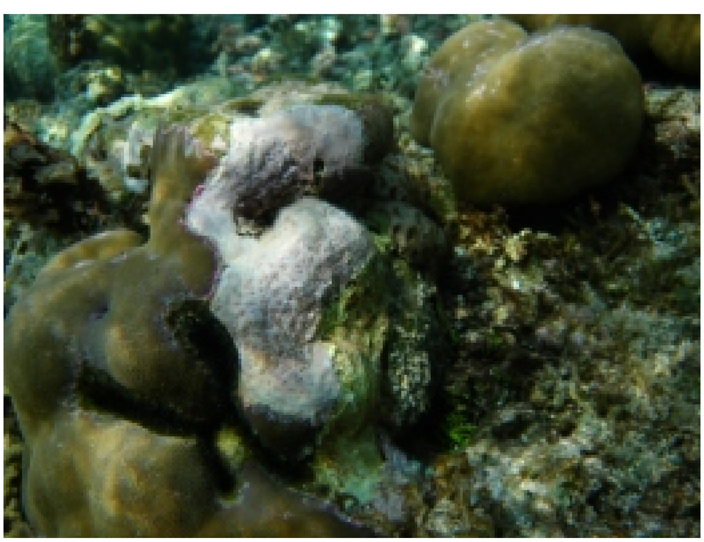
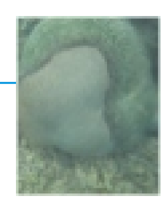
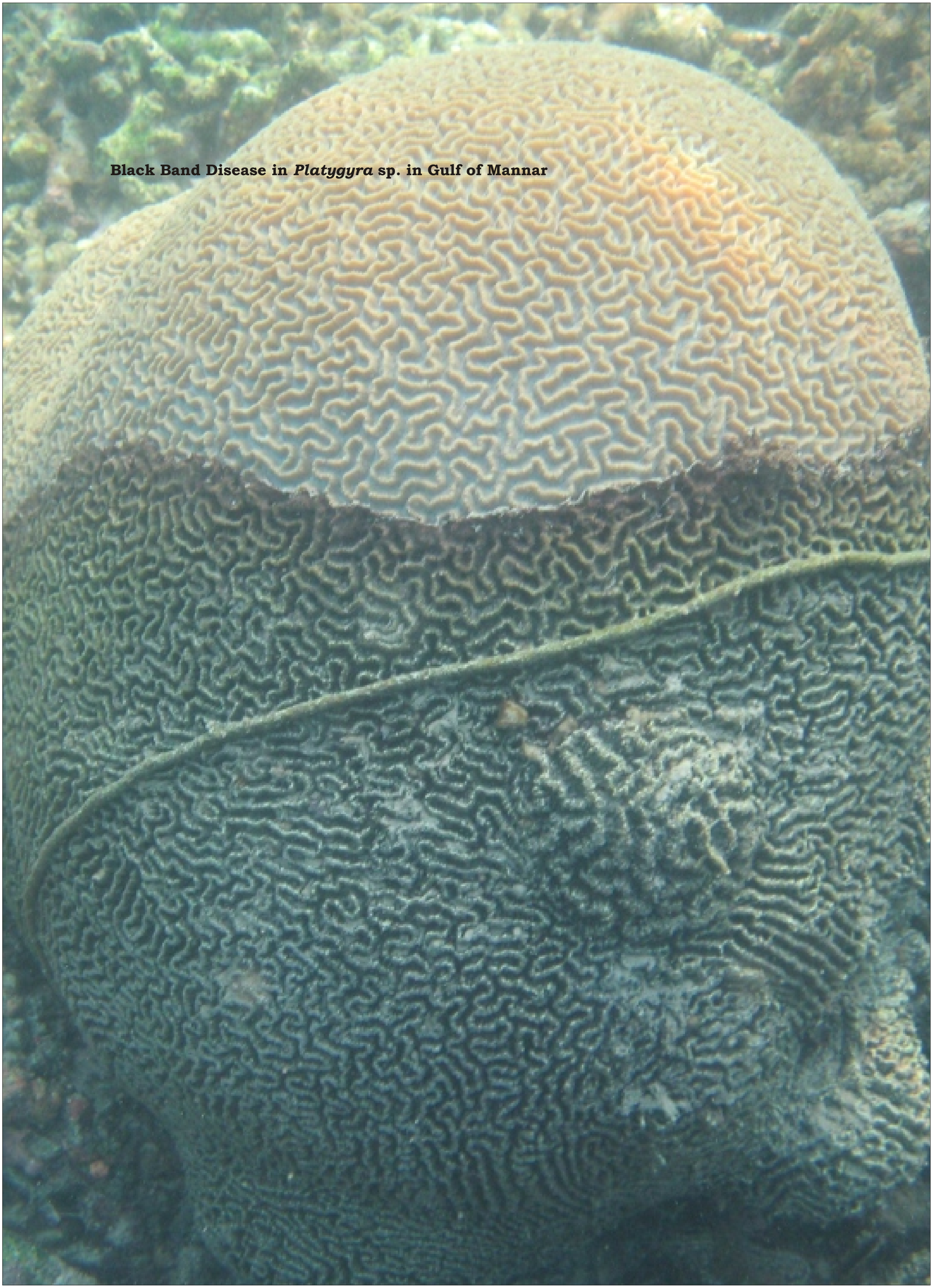
Pink-line Syndrome







Black Band Disease in *Platygyra* sp. in Gulf of Mannar

Observation and outbreak of coral diseases in the Gulf of Mannar and Palk Bay of Mandapam area

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Abstract

Assessment of coral disease prevalence was carried out in the Gulf of Mannar (Mandapam group of islands) and Palk Bay patch reef in Mandapam area between February 2007 and Feb 2008. In the Mandapam group of islands disease-affected corals increased from 8.9% to 9.3%. Nine disease states were documented (white band, white plaque, white spot, pink spot, black spot, black band, yellow spot, yellow band and tumor) with the most common disease being pink spot in *Porites* sp. The next most prevalent disease was white band disease in *Montipora* sp. Among the nine disease categories, white band disease infected colonies were most often found dead. White plague disease was found to be high during higher temperature. The corals were found to recover when the temperature came to the normal level. Among the seven islands, Poomarichan Island was found extensively affected by diseases followed by Manoli Island. Most commonly affected species were *Porites* sp., *Montipora* sp., *Pocillopora* sp., *Favia* sp. and *Favites* sp. In the Palk Bay patch reef, five disease states namely white band, white plaque, pink spot, black band and yellow band were documented. The percentage of corals affected by the disease increased from 18% to 20%. Black band disease was found to be high in *Acropora cytherea.* Mortality rate of black band disease was 3cm /month in *Acropora* sp. infected colony was most often found dead. Disease affected species were *Acropora* sp., *Porites* sp., *Favia* sp. and *Favites* sp. Microbial consortium of cyanobacteria *Phormidium* sp., *Apanococcus* sp., *Psudomonas* sp. and *Vibrio* species were isolated from the black band mat. Disease prevalence was found to be higher in shallow water areas compared to the deeper waters. Effects of the environmental parameters which influence the diseases were monitored.

Introduction

Coral diseases or syndromes are increasingly being recognized as a major cause of coral mortality (Richardson *et al.,* 1998). Diseases in the Caribbean have caused large scale mortalities of corals (Aronson and Precht, 2001). These conditions prompted increased awareness and focused studies on coral disease and bleaching to understand what processes are causing the deterioration. Losses of corals and thus reef habitats by disease have been observed throughout the Caribbean (Bruckner and Bruckner, 1997). Most recently, a comprehensive five-year study has documented a 38% decline in live coral coverage in the Florida Keys National Marine Sanctuary (FKNMS) (Porter *et al.,* 2001).

Black band disease in *Symphyllia* sp. in Gulf of Mannar

Over the last two decades, new and emerging coral diseases, as well as

existing diseases affecting new host species have been reported. Black band disease, the first disease reported to affect scleractinian corals, was originally observed by Antonius (1973) on the reefs of Belize and the Florida Keys. Since 1973, black band disease has been reported on reefs throughout the Caribbean basin (Edmunds, 1991), the Indo-Pacific (Antonius, 1985), and the Red Sea (Antonius, 1988). Black band disease is suspected to be an important factor in coral reef habitat degradation (Edmunds,1991).

Black band disease is characterized by a dark line, or band, which separates apparently healthy coral tissue from recently exposed carbonate skeleton. While the width of the band ranges from <1 mm to several centimeters, the band is always less than 1 mm thick. The band is a complex microbial community dominated by a filamentous cyanobacterium and appears dark due to the red cyanobacterial pigment phycoerythrin (Rutzler and Santavy, 1983)."White diseases" (Bythell *et al.,* 2004) of hard corals, including white band disease (WBD) type I and II, white plague (WP) type I, II and III, have been reported to affect 40 species of scleractinian corals within the wider Caribbean (Weil, 2004). Throughout the Indo-Pacific region, 38 coral species have been observed with progressive disease mortality exposing the calcium carbonate skeleton, which has subsequently been termed white syndrome (Willis *et al.,* 2004) or white plague-like disease (Sutherland and Ritchie, 2004).

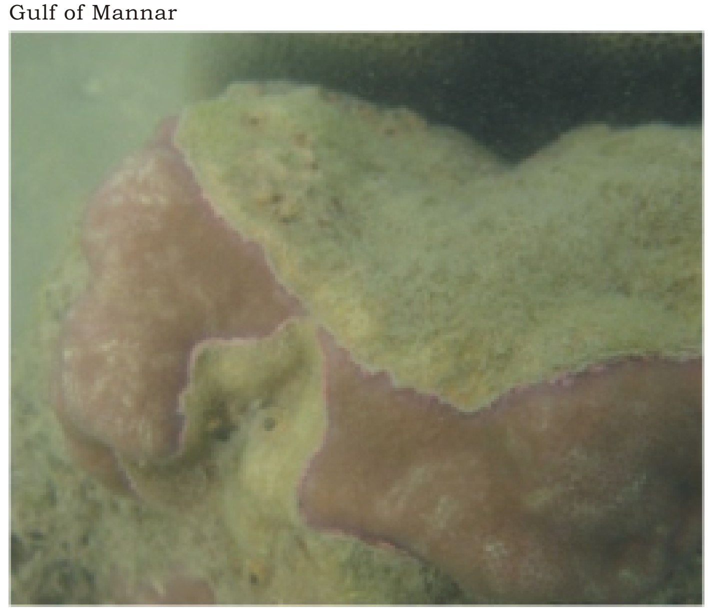
In order to understand the role of coral diseases in effecting changes in community structure, it is necessary to quantify their temporal and spatial dynamics over multiple year time frames. Some postulated anthropogenic stresses linked to coral reef disease include deforestation and soil erosion. Also wind or ocean transport of dust could potentially result in the introduction of terrestrial microbes into the marine environment (Smith *et al.,* 1996).

The objective of our study was to assess the status of coral diseases throughout Gulf of Mannar and Palk Bay. Results from this study indicated a combination of environmental factors including temperature, and nutrients play key roles in progression and transmission of the diseases.

Material and method

Surveys were conducted between the months of February 2007 and February 2008. Seven Mandapam group of islands (Shingle, Krusadai, Pullivasal, Poomarichan, Manoliputti, Manoli and Hare) in Gulf of Mannar and Palk Bay Mandapam patch reef areas were selected for the prevalence of diseases. Sites were selected using manta tows to assess broad changes in benthic communities. Two sites were identified in each island with different depth (up to 2m and above 2 m). Surveys were

Pink line disease in *Goniastrea* sp. of Gulf of Mannar



conducted using the Line Intercept Transect (LIT) (English *et al.,* 1997) method to quantify the prevalence of coral disease. Each transect covered an area of 20m x 4m (2m on each side of the transact line). At each site, three 20m transects were placed randomly parallel to the reef and spaced 20m apart.

Diseased coral colonies within each transect were recorded. After calculating the intercept (length) from the transition points recorded along the transect, the percent cover of a disease-affected life form category was calculated using the formula :

$$\text{Percent disease cover} = \frac{\text{Total length of disease category}}{\text{Length of transect}} \times 100$$

The analyses provided quantitative information on the community structure of the sample sites. All diseased colonies within the transect were noted and colonies per species were counted.

Rate of BBD Measurement

One specific site for active black bands of the two coral colonies were studied over a time period of six months. Cable was tied between the recently diseased area (leading edge of the diseased area) and healthy area to measure the growth of the disease. Photographs were taken at monthly intervals to measure the disease spreading ratio.

White plague disease in *Porites* sp. of Gulf of Mannar

Microbial analysis

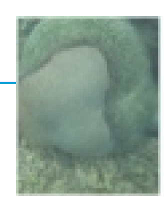
Portions of active BBD mats were peeled off from the diseased coral colony with sterilized forceps and brought to the laboratory in sterile condition for further analysis. Samples were preserved in 1% ethanol for microscopic cyanobacterial analysis. Portions of the samples were plated with Zobel marine agar to study the microbial communities associated with BBD.

Water samples were collected from the study sites. The physical and chemical parameters such as temperature, salinity, dissolved oxygen, and pH, besides the nutrient parameters such as calcium, magnesium, nitrate, nitrite, phosphate and silicate, were analyzed using standard methods (Grasshoff *et al.,* 1999). The pour plate technique was used to estimate total bacterial count in marine water samples (Vanderzant and Splittstoesser, 1992).

Results

Gulf of Mannar

The overall disease prevalence in the seven islands increased from 8.9 to 9.3% within the one year period of study. The corals in the Poomarichan Island were the most affected ones with 11.32%, followed by Manoli 9.64%, Pullivasal 9.48%, Manoliputti 9.26%, Hare 8.95%, Krusadai 8.42% and Shingle 7.82%. The extent of the prevalence of diseases in Gulf of Mannar and Palk Bay is given in Fig.1. Disease prevalence increased in all the



islands and the details are given in Fig.2.

Nine types of diseases were observed. Among these, pink spot disease was the most prevalent with the highest average of 16.2% followed by black band disease 10.0%, Yellow band 7.2% and White band 4.9%. The lowest

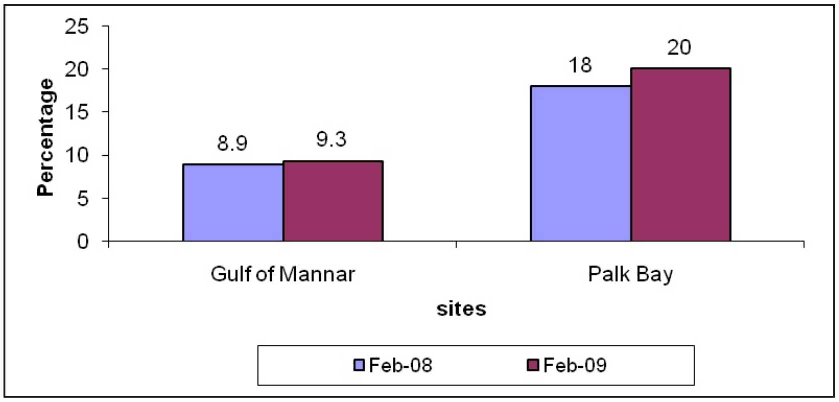


Fig.1. Percentage of diseases variation in Gulf of Mannar and Palk Bay

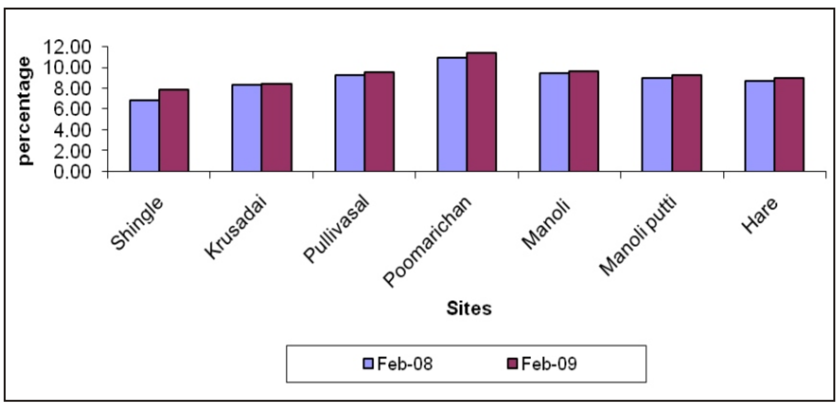


Fig. 2. Percentage of diseases in Mandapam group of islands

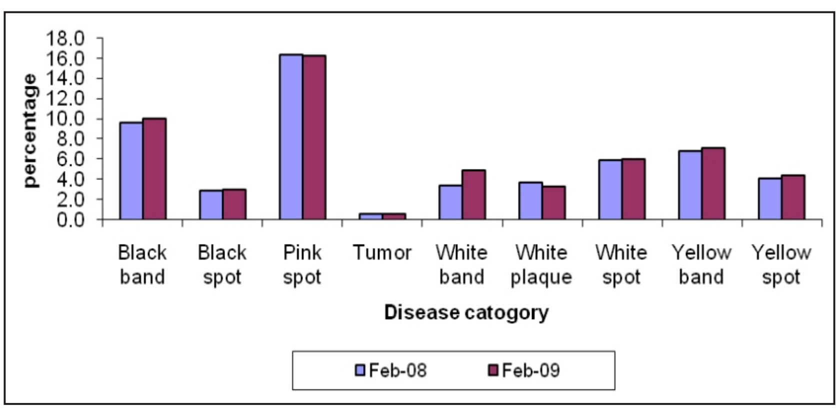
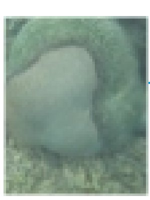


Fig. 3. Percentage of diseases types in Mandapam group of islands



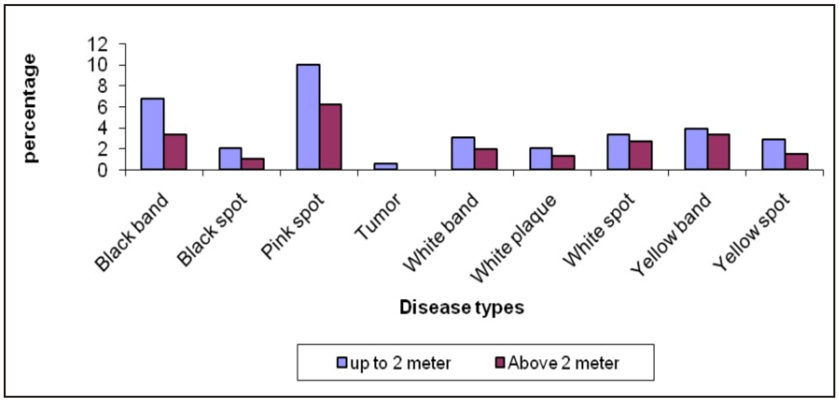


Fig. 4. Percentage of diseases in Mandapam group of islands at different depth

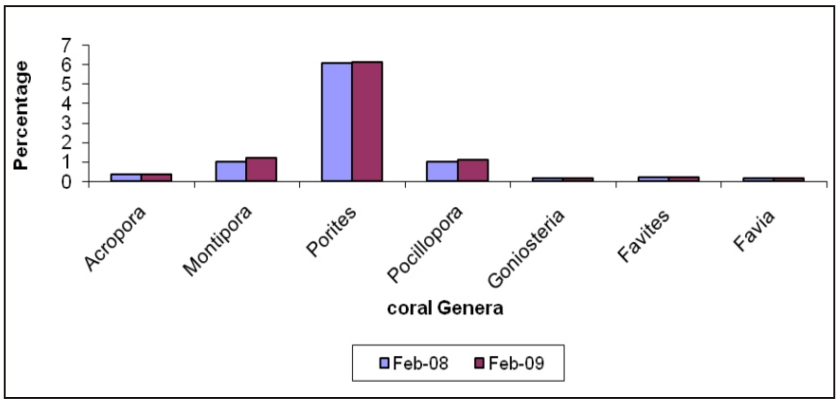


Fig. 5. Disease affected genera in Mandapam group of islands

recorded was tumour (0.6%). Among all the diseases, white band disease spread fast from 3.4% to 4.9% compared to other diseases. The prevalence of white plague disease decreased from 3.7% to 3.3% during the study period. Other data are given in the Fig. 3.

Disease prevalence was low in the second site (above 2m depth) in all the islands compared to the first site (up to 2m). The highest prevalence of black black band disease was 6.74% in shallow area and the lowest value was 3.3% in above 2m. The percentage of prevalence of other disease types are given in Fig. 4.

Nine different disease states were documented from seven major coral genera in the Gulf of Mannar. Prevalence of different coral diseases varied widely. The coral genera *Porites* was highly affected (6.1%), followed by *Montipora* (1.2%), *Pocillopora* (1.1%), *Acropora* (0.37%), *Favites* (0.17%), *Goniosteria* and *Favia* (each 0.17%). The pink spot was found widespread (occurring at all islands surveyed), while others, such as black band disease and white band disease were not found in all the surveyed sites. Among the seven coral genera, the disease prevalence differed from species to species. Other data are given

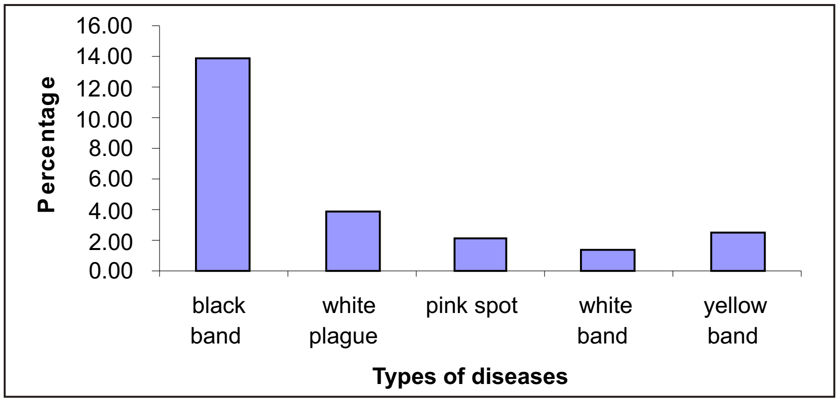


Fig. 6. Percentage of disease types in Palk Bay

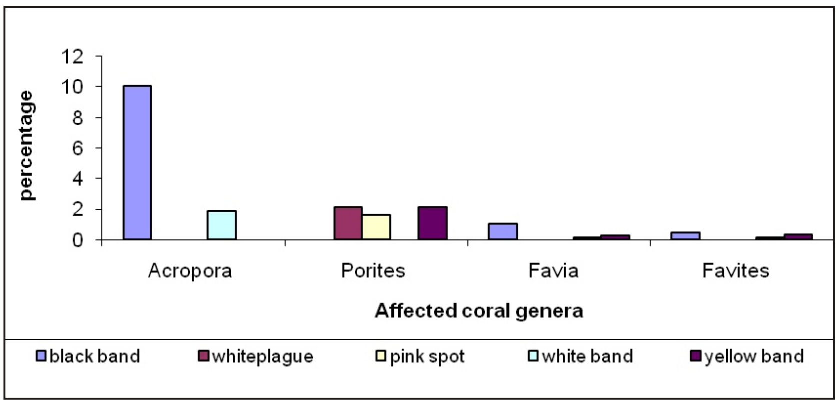


Fig. 7. Disease affected genera in Palk Bay

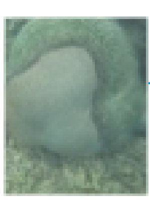
in Fig. 5.

Palk Bay

The prevalence of disease in Mandapam shore patch reef area increased from 18% to 20% within the one year period of study. Black band, white plague, pink spot, white band and yellow band diseases were observed. Among all, black band disease was dominant with 11.57% followed by yellow band 2.65%, white plague 2.13%, and white band 2.05%. The lowest prevalence of disease was recorded with respect to pink spot (1.6%). Other data are given in Fig.6.

Five different disease states were documented from four major coral genera found in the Mandapam Palk Bay patch reef. The coral genus *Acropora* was found to be highly affected by black band (11.95%), followed by white band disease. The next most affected coral genus was *Porites* by white plague, black band and pink spot with 5.83%. *Favia* and *Favites* were affected by black band, yellow band and white band (1.35% and 0.87%, respectively). Other data are given in Fig. 7.

Migration of black band disease in the corals was observed in *Acropora.* A series of photographs of black band disease progression were taken at monthly intervals. There was a highly



significant forward movement (towards living coral) distance of 3cm per month for each coral colony. Cyanobacteria: *Phormidium* sp. and *Apanococcus* sp. were found in the BBD mat along with *Vibrio* sp. and *Pseudomonas* sp.

Discussion

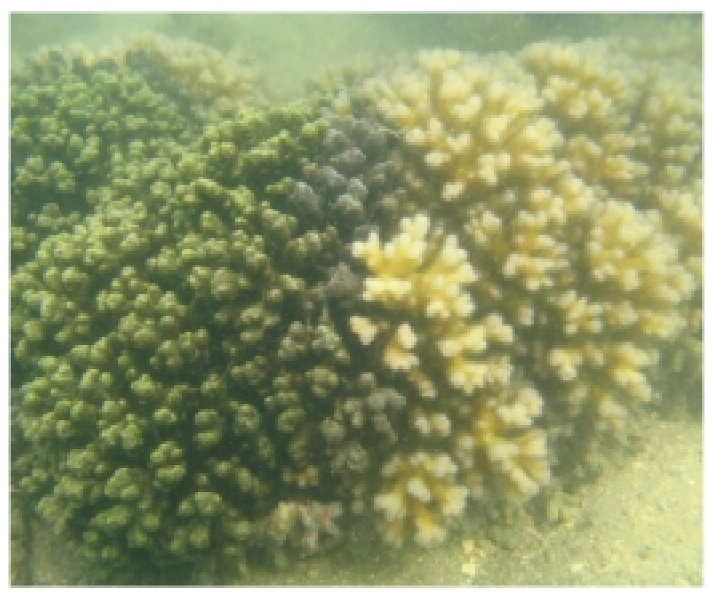
Coral diseases have increased in extent and virulence in the recent past (Goreau *et al.,* 1998). The present study on the prevalence of coral diseases in Gulf of Mannar and Palk Bay showed high percentages (with 9.3% and 20% respectively). This percentage seems to be very high when compared with other reefs like the Great Barrier Reef (7.2-10.7%) and in Philippines (14.2%)(Boyett *et al.,* 2007).

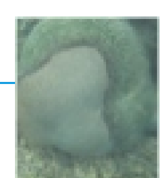
Ten coral disease states were described from four major coral genera on the reefs of NWHI (Northwestern Hawaiian Islands) (Aeby, 2006). Four diseases were found to affect *Porites,* three affected *Montipora,* two affected *Acropora* and one affected *Pocillopora.* In this present study, it was observed that the corals in Gulf of Mannar and Palk Bay were affected by nine and five types of diseases, respectively. Thinesh *et al.* (2009) reported nine coral disease types in Gulf of Mannar. Seven and four genera were affected by diseases in Gulf of Mannar and Palk Bay, respectively.

Disease percentage differed between Gulf of Mannar and Palk Bay. The dominance of certain diseases differed from site to site. This is due to site level variation in the distribution of coral species. It was reported that the abundance of *Acropora* sp. was highest on the reefs at French Frigate Shoals (Rodriguez-Martinez *et al.,* 2001). In line with this, acroporid diseases were also dominant. *Porites* sp. in Gulf of Mannar and *Acropora* sp. in Palk Bay were highly affected by diseases. This is due to the dominance of these species in the respective sites.

Increased temperatures could affect vital biological and physiological properties of corals, particularly their ability to fight infection, thus influencing the balance between potential pathogen and host (Willis *et al.,* 2004). In addition, the pathogens themselves could become more virulent at higher temperatures (Porter *et al.,* 2001). With increased human populations, the scale of human impacts on reefs has grown exponentially. According to this study, disease prevalence was high in 2m depth when compared with above 2m depth. The human disturbance and water temperature were higher in the 2m depth when compared to above 2m depth. The prevalence of all the types of disease was low in above 2 m depth and

Disease affected *Pocillopora damicornis* in Gulf of Mannar





this indicates that human impacts, coupled with temperature increase, play an important role in disease prevalence.

Edmunds (1991) found that Black band disease of one coral species was responsible for significant decrease in the amount of tissue in the population of surviving corals. This agrees with our present study, where the live coral cover has been greatly reduced because of the highest prevalence of this Black band disease since *Acropora* sp. is the dominant genus in this area.

BBD progression across a single colony was as high as 6.2mm per day (Kuta and Richardson, 1996). It has the capacity to eliminate small coral colonies in days to weeks and is highly infectious spreading from one colony to next. Black band disease moves over colonies destroying tissue at rates that can reach 2cm/day (Antonius, 1973). In the present study, BBD was found to move on the healthy coral at a rate of 3cm per month. This rate is not much compared with other areas but some small colonies were found dead in a short period of one month time. If this disease spreads in this manner it would affect vast extent of live coral cover.

A variety of microorganisms have been reported to be associated with the black band necrotic areas. The cyanobacterium *Phormidium corallyticum* (Rutzler and Santavy, 1983) and the bacteria *Beggiatoa* and *Desulfovibrio* (Carlton and Richardson, 1995) were most commonly encountered. In the present study, cyanobacterial species *Phormidium* sp., *Apanococcus* sp. along with *Vibrio* sp. and *Pseudomonas* sp. were isolated from the diseased colonies infected by BBD in this area.

It has been suggested that increase in disease outbreaks may be associated with environmental stress including increased seawater temperatures, variation in salinity, changes in water quality and increased pollution, sedimentation and eutrophication (Mitchell and Chet, 1975). It has been reported that nutrient enrichment, higher temperatures and irradiance accelerate the rate of BBD progression (Boyett *et al.,* 2007). In the present study, significant variation in environmental variables, such as higher temperature around 29.5°c, higher colony density and increased nutrient value and salinity variations, were observed in the highly diseased areas. These unfavorable environmental factors could be due to the waste disposal from a nearby fish processing unit and fish landing sites.

Though high temperature was recorded all over Palk Bay, when it was coupled with high nutrient content, disease prevalence increased in the affected areas. Both temperature and nutrients acted synergistically to influence the incidence of coral diseases.

The Palk Bay and Gulf of Mannar are the most affected reefs in India because of various anthropogenic activities. The situation is now changing positively and live coral cover is also increasing due to strengthened enforcement, protection and conservation measures. Investigation on coral diseases and their causative factors are helpful in restoring the affected corals through suitable management practices.

Acknowledgements

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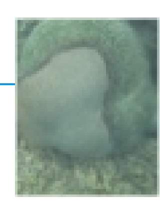

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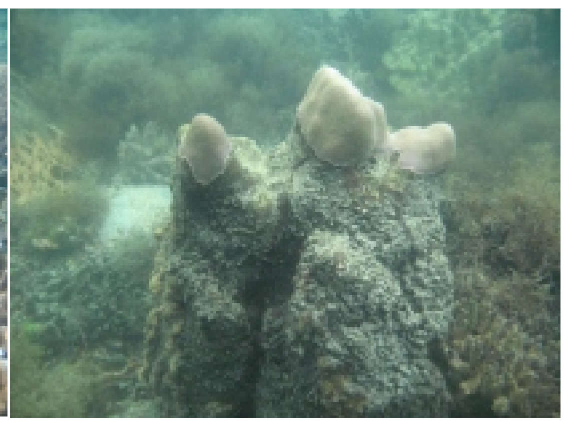
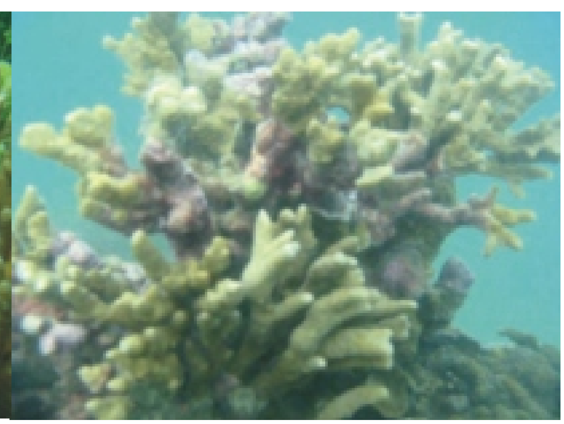
Black band disease in *Acropora* sp. in GoM

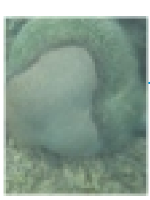


Black band disease in *Porites* sp. in GoM

White band disease in *Acropora* sp. in GoM



White band disease in *Montipora* sp. in GoM



Climate change impacts and adaptation intervention in coastal ecosystems - a community based response

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Abstract

Changes in precipitation, ocean currents, and sea level rise associated with climate variability, are being seen as increasingly affecting the world's already changing coastal ecosystems and declining fisheries. The Inter Governmental Panel on Climate Change (IPCC) has provided clear evidence of the impacts of climate change on our biodiversity and the increasing vulnerability of some of our critical ecosystems and consequences for livelihoods of people. The recent erratic weather and monsoon patterns along the Indian coastline, coupled with climate variability and rise in the incidences of extreme events like cyclones, are major threats to the ecosystem. Some of the low-lying islands are already facing partial submergence leading to shoreline changes. In Sundarbans, West Bengal these changes have had adverse impacts on the biological diversity. The marginal economy of local communities dependent on single crop agriculture, fishing and harvesting of other local resources is adversely affected by changes such as sea level rise, increase in salination, changing patterns of rainfall, and increase in moisture content in the atmosphere leading to increasing incidences of vector-borne diseases. In southern India, fishing communities are at increased risk due to reduced fish catches as a consequence of warmer seas. Research programmes need to be conceptualised and implemented with a focus on integration of biodiversity and socio economic concerns of local communities. Promoting long term adaptation measures through a wide ranging consultative process is therefore necessary to ensure sustainable growth and integration of climate change concerns in to local development planning.

Introduction

Since the industrial revolution, emissions resulting from anthropogenic activities have led to a substantial increase in the atmospheric concentration of greenhouse gases. The resultant warming of the earth's atmosphere, has led to a rise in the average global surface temperature of 0.8 °C.

As a result of these changes, widespread ecological and socio-economic impacts of climate change could threaten the future growth and economic activities of several countries in the Asia Pacific region. Some indicators and triggers of global warming include increased extreme weather events (including more flooding, drought, frequent heat waves, cyclones, depressions), increased agricultural losses, sea ice melt, retreating glaciers, sea level rise, coral bleaching, and decline in biodiversity. Communities in both developed and developing countries are already suffering from these impacts, and tropical countries are likely to be more vulnerable than developed countries.

Scenarios compiled by the Intergovernmental Panel on Climate Change (IPCC, 2007) suggest that unless greenhouse gas emissions are dramatically reduced, we will see a doubling of pre-industrial carbon dioxide concentrations resulting in an increase of the earth's temperature between 1.1°C and 6.4°C (depending on estimates for low and high scenarios), with the recent modeling data suggesting upwards to about 11°C by the end of the century (Stainforth *et al.,* 2005).

The last decade was observed as the warmest with India and Southeast Asia experiencing frequent extreme climatic events. While recent climate models predict an increase in rainfall patterns, regional change may be different (Rupa Kumar *et al.,* 2006).

Climate change and coastal ecosystems

The oceans and seas are an integral part of the earth's climate system and are responsible for maintaining the natural circulation patterns. According to IPCC, climate change impacts on the ocean and marine ecosystems are likely to play a significant role in shaping the changes of the sea surface temperature, sea level, sea ice cover, salinity, ocean circulation and climate related oscillations. Some of the main features observed and projected in the characteristics of ocean systems include:

- An increase in the global ocean heat content since 1950s.
- Global average sea level rise between 0.1 and 0.2 m due to thermal expansion of water and the loss of mass from glaciers and ice caps. This is expected to increase to 0.6m or more till 2100 (IPCC, 2007).
- A decrease in the extent of sea ice in the Northern hemisphere of more than 10% including a decrease of 40% in thickness of later.
- An increase in the frequency, persistence and intensity of extreme weather events based on the El Nino southern oscillation (ENSO) cycle since the mid 1970's.

In the past few years changes in rainfall, currents, and sea level associated with global warming, are already affecting the world's coastal ecosystems and fisheries. The recent IPCC report has also provided ample evidence of the implication of climate change on our biodiversity and the increasing vulnerability of some of our critical ecosystems and consequences for livelihoods of people. Erratic weather and monsoon patterns, along the Indian coastline along with frequent extreme climatic events like cyclones are major threats to the ecosystem including in some cases low lying islands some of which are already facing partial submergence resulting in shoreline changes.

Coastal ecosystems are particularly sensitive to physical and biochemical changes with reference to :

- Increased level of flooding, loss of wetlands and mangroves and saline water intrusion into freshwater habitats.
- Severity and increase of cyclonic events leading to coastal erosion , loss of ecological diversity along shorelines.

Marine ecosystems are also likely to be affected by changes in sea water temperature, oceanic circulation patterns which may lead to changes in composition of marine biota, changes in migratory patterns, changes in ecosystem function. The increased amounts of CO_2 absorbed by oceans are also likely to have significant impacts on the acidity of ocean waters which in turn can have serious consequences for certain marine animals like molluscs and corals.

In coastal regions like the Sundarbans delta in West Bengal, the recent drastic changes in weather conditions and monsoon patterns, along with frequent extreme climatic events like cyclones pose serious threats to the ecosystem of the region. Climate change induced by anthropogenic activities is thought to be behind the observed rise in sea level, lengthier summers, and a dramatic increase in rainfall over the past 15-20 years. The already marginal economy of human populations dependent on single crop agriculture, fishing and harvesting of forest resources is also adversely affected by changes such as sea level rise, increase in salination, changing patterns of rainfall, and increase in moisture content in the atmosphere leading to increasing incidences of vector borne diseases. This has increased their vulnerability and possibly their dependence on the forest resources.

Similarly, fluctuations in the sea surface temperature along the coasts of Bay of Bengal and Arabian Seas have also resulted in changes and decline in the availability of fish species some of which are of good commercial value. Impact of climate change on regional fisheries can be ranked in terms of likelihood (for either warming or cooling) of impacts. Most of this knowledge comes from empirical studies made over the recent 50 years, when weather and environmental records became fundamental for explaining individual species' behaviour and population responses to changes in local conditions.

Climate events such as ENSO warm and cold events promote different levels of productivity. Krishna Kumar *et al.* (1999) reported that the weakening link between ENSO and the Indian monsoon could be a result of global warming.

The fisheries most sensitive to climate change are also amongst the most affected by human interventions, such as dams, diminished access to river migrations, encroachment of wetlands, human population growth and habitat manipulation, particularly expanded agricultural water use and urbanization.

WWF initiatives

Recognizing the value of information available from the broader community, and also the changing framework of traditional knowledge and local perceptions, WWF India started initiatives aimed at enhancing the coping capacity of the local community and vulnerability reduction in selected locations.

Sundarbans

The WWF study in the Sundarbans primarily focused on documenting local community knowledge and perception about the adverse impacts of climate change through the "*Climate Witness*" Initiative. The idea of initiating a climate witness project originated from the strong indicators of climate change that were available in the region through the various scientific studies that were being carried out by various academic institutions and universities.

The "Climate Witness" approach is a methodology, which aims at documenting the perception of the community at various stakeholders' level on the adverse impacts of the climate change. This was expected to stimulate an integration of climate change concerns in overall development planning through bottom-up approach in the decision making process. As part of this initiative by WWF India, the following approach was adopted to study and understand community knowledge about the adverse impacts of climate change :

- ❖ Study traditional community responses with scientific assessment of the local impacts.
- ❖ Involvement of different levels of stakeholders to identify and develop a model intervention.
- ❖ Identification of homogeneous geographical area for validation of the model.
- ❖ Policy intervention for mainstreaming climate change concerns in overall development planning.

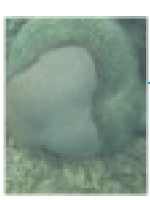
The islands selected for the Climate Witness Initiative studies are mostly located in the South Western corner of Sundarbans, except Chhoto Mollakhali and Bali islands situated at the North eastern part of the delta. There are more than 100 islands spread over the entire Sundarban region of which the sea facing ones are influenced by both the tidal action and delta forming processes. This coastline is remarkable for its highly productive mangrove forest and nutrient rich backwaters nourishing the aquatic diversity of the Indian east coast.

Several physico-climatic factors provided an indication of climate-induced changes in natural systems and helped to understand the trends and potential hazards in future e.g. temperature and rainfall. For the local community in these sites, the rise in level of temperature was not a matter of concern. Rather the erratic weather patterns, e.g. a gradual delay in the onset of monsoon during the last few years was of great importance, as this had implications for local agricultural productivity. Average maximum temperature in the Sundarban delta ranged between 35°C and 39°C, while the minimum level was between 12°C and 15°C. Delayed monsoon and untimely rain often hampered the agricultural productivity leading to crop loss. An extended period of hot weather was observed during the last few years. A majority of the farmers reported pest attacks on account of irregular climate pattern.

Rise in sea surface temperature during the monsoon season was correlated with the frequency and intensity of tropical cyclones. Tidal amplitude ranged between 4.5 and 5.5m during April - September which had resulted in inundation. Local residents reported very high frequency of thunder and lightning during storms in the last 10-15 years. In their opinion, depression and cyclonic storms occurred more frequently than earlier. The extreme dependence on monsoon fed agriculture system in these islands influenced the productivity and economy to a great extent.

Impacts on ecosystems and community

The loss of landmass and submergence of vast areas in the deltaic region are affecting the lives of large numbers of people in and around the Sundarbans. More and more people are becoming homeless whenever the water



floods any landmass in the Sundarbans because the area is highly populated. Sagar and Ghoramara islands, two of the most prominent islands in the southern part of the delta, have witnessed major impacts from subsidence, accretion, environmental changes and anthropogenic pressure. While Sagar Island has lost nearly 59 sq. km over the past few decades, the total land area of Ghoramara has been reduced to 5.35 sq. km between 1969 and 2001, accounting for a loss of 41% of the land.

The east coast of India itself is highly prone to cyclones and storms generated in the Bay of Bengal. The records of natural calamities affecting Sagar Island show several such incidents, which claimed several human lives and caused damage to property. Historical records show that storm surges in 1668 killed almost 60,000 people on Sagar Island suggesting the presence of a large population on the island. Other natural disasters have also occurred (e.g. an earthquake in 1737 with 40 ft high water level and a death toll of 30,000 people). In the past 300 years the region has been exposed to as many as 15 natural disasters (cyclones, storms) contributing to loss of human lives and properties on Sagar, Ghoramara and Mousuni islands. People living on these islands have reported frequent cases of lightning, which has become a common phenomenon during summer and even in monsoon period. Local communities have also reported an increase in the building of low-pressure areas in Bay of Bengal and consequent high intensity of storms in this region. Most communities indicated that there is a lack of emergency preparedness in case of an imminent natural disaster.

Community interactions and responses

An extensive field survey was carried out on the community living in this delta, especially on those islands, which experienced loss of landmass over the past few decades.

The survey revealed that ecosystem-dependent communities like farmers and fishermen formed a major part of the work force of these islands. In the absence of industries and other developmental activities livelihood options were limited here. Nearly 62% of the respondents surveyed were involved with farming and fishing, while fishing was an exclusive occupation for nearly 10% of respondents. The general livelihood pattern indicated that the majority inhabitants were vulnerable to climate-related adversities.

The interventions adopted by the community in developing adaptation responses have been primarily a localized effort with village communities implementing short term actions as a reactive response to the threat of climate change impacts. Some of these responses have included:

- Shifting of farming dates in anticipation of shifting of the monsoon season.
- Diversification into different weather resistant crops.
- Construction and renovation of ponds and canals for rain water harvesting and use in winter cultivation.
- Constructing of mud-barrages around the island to protect it from incursion of saline water.

- Reforestation activity (mangroves) on the mud barrage.
- Alternative livelihood options for proper substitution of certain harmful livelihood activities, like baby prawn/shrimp netting and timber collecting.

The survey results also highlighted the traditional knowledge of the local community and their perception of climate related impacts through development of case studies, testimonials by local witnesses and by producing a documentary film. The film Sundarbans-Future Imperfect was released during an event organised at the United Nations Framework Convention on Climate Change, Conference of Parties - 10 at Buenos Aires, Argentina in December 2004. The film unfolds case studies on perception of climate change impacts in the Sundarbans, as well as scientific evidence on ecosystem changes. This film is an important communication tool to raise awareness of climate impacts in a vulnerable community and region amongst both national and international communities.

Way forward

The coastal ecosystems are known to be one of the most productive ecosystems across the world harbouring a diverse range of floral and faunal elements. The range of ecological services generated by marine ecosystems has tremendous implications for the well-being of coastal communities in sustaining local livelihoods. The increasing pressures being brought upon the coastal region as a consequence of unplanned development along the fragile coastal belt have already resulted in severe pressures for both local ecology and dependent communities. Climate variability would further accelerate the changes causing greater impacts on the natural ecosystem of the region. Future efforts in building the resilience of the local community and the ecosystems should take into account a concerted and integrated approach.

As part of these processes, different stakeholders at multiple levels need to come together to address the issue of climate change and environmental security. The stakeholders will include:

- Poor and vulnerable;
- Ecosystem dependent communities (Agriculture, fisherfolk communities, etc.);
- Decision-making bodies at local, state and national levels;
- Urban consumers;
- Business and Industry;
- Coastal Zone Regulatory groups;
- Scientists and Academic bodies.

A multidisciplinary approach involving several stakeholders on a common platform can stimulate integration of climate change concerns in overall development planning process. The recent National Action Plan on Climate Change by the Government of India lays focus on building and strengthening the knowledge base on impacts on our natural resources as well as developing suitable mitigation and adaptation responses against the adverse impacts of climate change.

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Acropora lamarcki

Coral bleaching (*Porites* sp.) in Gulf of Mannar

Threats to coral reefs of Gulf of Mannar Marine National Park

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Abstract

The Gulf of Mannar is home to a diverse group of corals and their associates. Due to indiscriminate collection of ornamentally valuable species and destructive fishing practices, the decline and disappearance of certain species have begun. Use of fish traps and scoop nets, skin diving, anchoring while fishing, illegal coral mining, fishing using dynamite and explosives, and use of shore seines and certain other nets have led to the destruction of reefs in the last three decades. Measures to conserve and protect this sensitive ecosystem are an immediate need to stop the disappearance of important species.

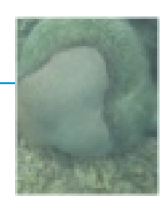
Introduction

Coral reefs are among the most diverse and biologically complex ecosystems on Earth. The *Status of Coral Reefs of the World 2000* report estimates that 27% of the world's coral reefs have effectively been lost due to human activities and climate change impacts (Wilkinson, 2000). By 1997, an estimated 11% of the world's reefs had been lost to a variety of human activities, including shoreline development, polluted run-off from agricultural lands, wrong land-use practices, over-harvesting, destructive fishing practices and ship groundings. The Gulf of Mannar Marine Protected Area (MPA), southeast coast of India, is not an exception to these anthropogenic effects. With the 21 islands having a varied coral cover due to natural phenomena like bleaching, the reef sites are facing severe threats from all sides due to the 'human factor'. Multi-date shoreline maps showed that 4.34 and 23.49 km^2 of the mainland coast and 4.14 and 3.31 km^2 areas of island coast have been eroded and accreted, respectively, in the Gulf of Mannar. Multi-date coral reef maps showed that 25.52 km^2 of reef area and 2.16 km^2 of reef vegetation in Gulf of Mannar have been lost over a period of 10 years (Thanigachalam and Ramachandran, 2003). A field study during 2003–2005 revealed that about 32 km^2 of reef area has been degraded (Patterson *et al.*, 2007). The shoreline has eroded and accreted, changing the topography of the coastal areas. When a combination of physical, natural and anthropogenic effects occurs, the outcome is serious. This paper focuses on the threats to the reefs of Gulf of Mannar and the associated flora and fauna.

Natural threats

Coral bleaching

Coral bleaching, a consequence of elevated sea surface temperature (SST), has been noticed during summer every year since 2005. The average percentage of bleached corals during 2005, 2006, 2007 and 2008 was 14.6%, 15.6%, 12.9% and 10.5%, respectively. Coral bleaching was noticed from mid-



April, and the temperature rose for about a month from the end of April. Massive corals, especially *Porites* sp., were the first to be affected and the other dominant coral species that were partially or fully bleached were *Acropora cytherea*, *A. formosa, A. intermedia, A. nobilis, Montipora foliosa, M. digitata* and *Pocillopora damicornis*. Branching corals recovered faster than the massive corals; the fastest recovery rates were noted in size groups between 40 and 80 cm and between 80 and 160 cm. The patterns were almost similar on the reefs between years, except for modest differences in temperature levels. Temperatures over 31.0°C caused bleaching and the corals started to recover when the temperature fell. Depending on rainfall and winds, recovery began during June/July and was completed in 1-4 months. There was no SST-induced coral mortality in 4 years (2005-2008), but in 2007, 80% of the bleached recruits died. The intensity of coral diseases normally increases during elevated SST and the risk of other deleterious damages is higher.

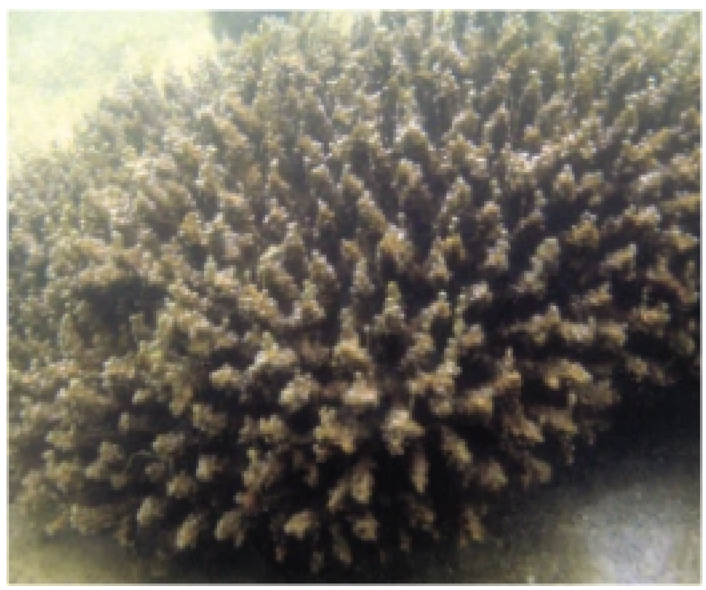
Impact of tsunami

There were no significant impacts on coral reefs and on associated habitats including resources apart from some minor transitional damages due to the 2004 Indian Ocean tsunami. Due to strong waves, a few table corals (*A. cytherea*) were tilted and branching corals (*A. intermedia* and *A. nobilis*) were broken. The damage was estimated to be about 1–2% of the total live table and branching corals. Fine sand had been deposited (layers of 4–6 cm) in almost all cup corals (*Turbinaria* sp.) in the patch reefs. Fragments of seaweed and seagrass had been washed ashore. In the Keezhakkarai group of islands, fragments of seaweed and seagrass were entangled with branching corals. Beach erosion had increased in two islands (Thalaiyari Island in the Keezhakkarai group and Krusadai Island in the Mandapam group) and a few trees were uprooted. However, no deposition of sand and debris on table, branching and massive corals nor on seaweed and seagrass beds could be observed there.

Algal bloom

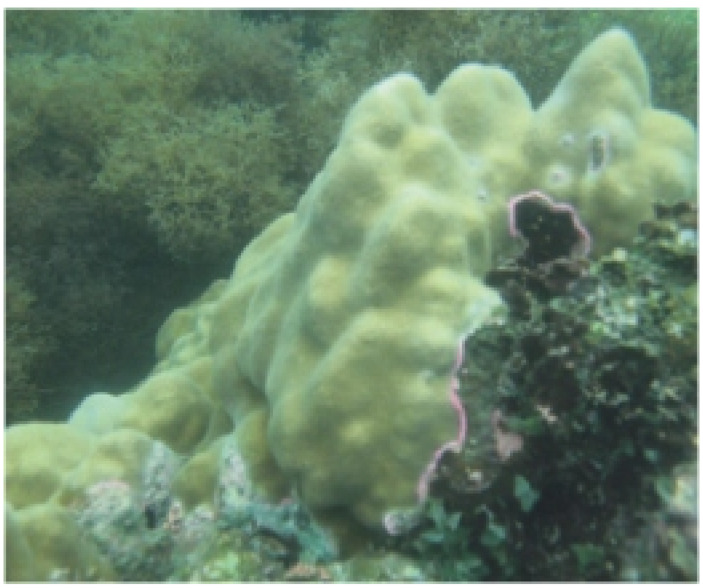
Fishermen from the villages of Muthupettai, Kalimankundu and Periapattanam, on the Keezhakkarai coast of the Gulf of Mannar noticed an algal bloom of the dinoflagellate, *Noctiluca scintillans,* on 6 October 2008 in the Gulf. The subsequent breakdown of this dinoflagellate depleted the dissolved oxygen level in the water, causing mortality of finfishes and shellfishes and other organisms. Physical

Dead coral (*Acropora* sp.), due to algal bloom in Gulf of Mannar



parameters such as temperature, turbidity and total suspended solids (TSS) showed high values on the Keezhakkarai coast. The oxygen level was very low on the Keezhakkarai coast in all surveyed locations (e.g. 1.2 and 0.7 mg/l in surface and bottom water off Valai Island, respectively). The number of dead fish and other dead organisms were more on the seaward side of the Valai Island (over 5,000 dead fish and bivalves were observed) and this is considered as 'major' marine mortality. The major dead fishes in the islands (Valai, Mulli and Appa) were *Siganus* sp. (rabbit fish), *Congresox* sp. (anjaala), *Scarus* sp. (parrot fish) and *Lutjanus* sp. (snapper).

Disease affected massive coral (*Porites* sp.) in Gulf of Mannar



An underwater survey revealed that fish were completely absent around Valai, Mulli and Appa Islands. In the shallow area (0.5–0.75 m depth) of the seaward and shoreward sides, partial and complete coral bleaching was observed in Mulli, Valai and Thalayari Islands, but corals remained healthy at areas above 1 m depth. Vast seagrass beds were degraded on the shoreward side of Mulli, Valai and Thalaiyari Islands.

Coral disease

In the Gulf of Mannar Marine National Park, disposal of domestic sewage and other wastes from fish-processing units and fish-landing sites is increasing steadily, causing depletion of water quality in the reef environment and increased chances of microbial contamination and disease prevalence. The percentage of coral disease prevalence has increased from 8.9% in 2007 to 10% in 2008. Nine types of coral diseases (white band, white plague, black band, white spot, black spot, pink spot, yellow spot, yellow band and tumour) have been identified so far in the Gulf of Mannar. Among these, the black band disease spreads rapidly, killing 3 cm coral area in a month in a colony when the temperature and nutrient values are higher. Some of the reef sites, where sewage disposal is minimal, witness very low percentage of diseases. Studies are in progress at SDMRI to find out the exact causative agents for these diseases.

Anthropogenic threats

Industrial and domestic pollution

The southern part of the Gulf of Mannar region has many industries, factories and power plants. Tuticorin is a city which harbours a major port, a thermal power plant (TTPS), a heavy water plant (HWP), many chemical industries and a chain of salt pans. The northern region of the Gulf of Mannar basically suffers from domestic sewage let out directly into the sea.

The TTPS discharges large

quantities of fly ash through air and slurry into the Karapad Bay. This has resulted in the decline in benthic communities and filter feeders were found to be disappearing quickly. Though some steps have been taken by the authorities to send the fly ash to cement industries and to produce bricks in the later stage, the demand is not very high. The water released from the turbines is found to have higher temperature than the ambient water temperature, which can kill plankton and chase away fishes to cooler regions. Salt pans are no exceptions. In fact, the Ramanathapuram and Tuticorin districts have salt pans along the entire stretch of the Gulf of Mannar. Tuticorin is south India's largest salt producer. The hypersaline water, after evaporation, is flushed out every day into the canals that open at different places in the Marine National Park. Mangrove plants lining the periphery of these salt pans along the canals have stunted growth due to the hypersaline conditions. One can witness mass mortality of finfishes along the banks of these canals, especially towards the end of the harvest of the crystallized salt. In addition, sewage disposal is increasing throughout the coast of Gulf of Mannar Marine National Park area.

Coral mining

Corals had been collected from the seabed in earlier days for use in construction or as raw material for the lime industry. In addition, corals have always been collected for ornamental purposes. For a long time the collection of corals did not pose an obvious threat to the resource as there were large reef areas in good condition in the Gulf of Mannar. However, gradually the removal of corals became too intensive and the deterioration of the reefs was obvious to anyone. In the early 1970s it was estimated that the exploitation of corals was about 60,000 cubic metres (about 25,000 metric tonnes) per annum from Palk Bay and Gulf of Mannar together (Mahadevan and Nayar, 1972). In 2001, the federal government included all scleractinian, antipatharian, *Millipora* sp., gorgonian and *Tubipora musicace* under Schedule I of the Wildlife (Protection) Act, 1972.

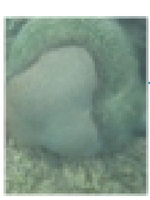
The rate of coral mining was reduced considerably due to the stringent enforcement of the Act. However, a group of poor fishermen continued with the mining activity. The number of boats involved in mining varied with the fishing season, with the highest number involved during the lean fishing season. The tsunami, along with the Supreme Court verdict on the ban on the collection of corals, and other conservation initiatives, however, made a change in the minds of fishermen. Therefore, the majority of them have voluntarily stopped coral mining since 2005. Due to mining, the Gulf of Mannar lost vast reef areas and there were no signs of new recruitment in many areas, especially in the mined sites with unstable substratum.

Destructive fishing activities

Anchoring of boats

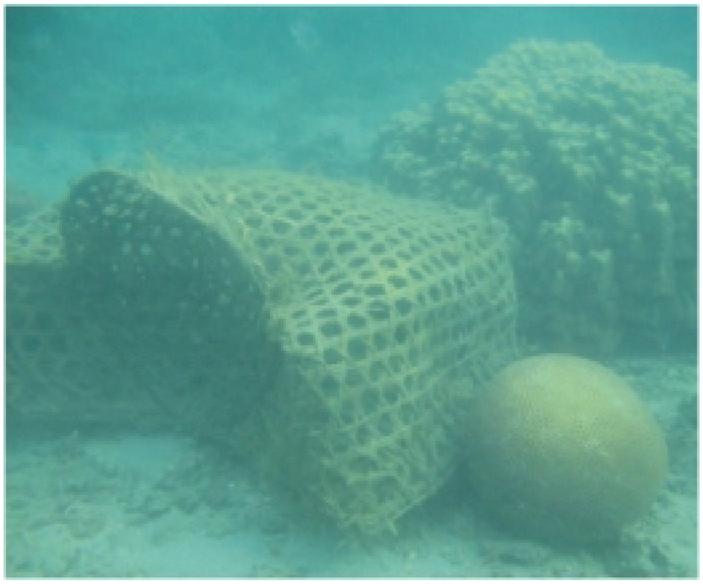
Although the park area is

Seaweed collection in reef area of Gulf of Mannar



protected, fishing near the reef area by traditional fishermen is common in the Gulf of Mannar and anchoring of boats on the corals causes severe mechanical damage to the corals and associated benthic organisms.

Trap fishing in Gulf of Mannar



Blast fishing

Dynamite fishing had been common in Gulf of Mannar for a few decades. The targeted species of fishes are basically of the shoaling type, including sardines, mackerels, anchovies, sweet lips, silver bellies and carangids and reef-dwellers like groupers, rock cods and wrasses (Samuel *et al.*, 2002). After stringent implementation of laws, the fishermen have slowly ended this fishing practice and have taken work as crew members in trawler operations.

Fishermen carrying fish traps for deployment in reef areas of Gulf of Mannar

Shore seines, purse seines and inshore bottom trawling

Shore seine is widely used in almost every maritime state of our country. As the mesh size at the centre is 10 mm, almost all the fishes including juveniles, fry, fingerlings and invertebrates are trapped within that area. The operation of this gear is a common scene in the coastal villages of the Gulf of Mannar region especially in the islands. As the reefs are close to the shore, they are damaged by these nets. Recruits on dead rubble are brought ashore, killing them instantaneously. This is another threat spoken about for many years without much of follow up. Bottom trawling in the reef area is also a deleterious method for fishing which damages the entire benthic community. Even though fishing using purse seines is not very common it happens illegally, leading to the capture of all the fishes, including juveniles, damaging the reefs.

Operation of fish traps

As there is a huge demand for marine ornamental fishes, fishermen set indigenous fish traps in the reef areas or along the outer reef. Initially, the fisherfolk used to skin dive and collect ornamentally important marine fishes using scoop nets. But due to the demand for some fishes, there is an increase in fishermen operating the fish traps. About 6–10 fishermen carry 20–25 traps in one vallam (a type of

craft) and set them close to the reef, or between reef-covered areas. To hide the traps in the reef, the fisherfolk break off live coral, mostly massive corals, to cover them. The improper handling of traps during trap retrieval also leads to immediate destruction of branching corals like *Acropora* sp. and *Montipora* sp. or severely damages a portion of massive corals like *Porites* sp. or *Favia* sp. With the use of these traps, reef-dwelling parrot fishes are caught widely, which in turn causes the proliferation of algae over live coral colonies, leading to coral mortality and also ecological imbalance.

Seaweed and shell collection

Seaweed collection is also a major threat in the Mandapam and Keezhakarai areas. Fisherfolk, mostly women, collect tonnes of seaweeds every day around the islands, damaging the corals. They break the corals while collecting seaweeds. Mollusc shell collection through skin diving also poses a threat to the reefs in the Gulf of Mannar.

Invasion of exotic species

The red algae (seaweed), *Kappaphycus alvarezii* is native to Philippines. It has high growth rate and can double in biomass in 15 to 30 days. The reproduction of *Kappaphycus* is mainly by vegetative fragmentation. A broken tip can grow into full-sized thalli (plural of thallus, a plant body that is not differentiated into root, stem or leaf) in a short period of time.

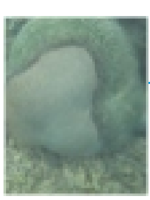
Kappaphycus alvarezii is cultivated by about 150 fisherfolk at present (a few belong to Self-Help Groups) from three coastal villages (T. Nagar, Munaikadu and Thonithurai) in the Palk Bay (near Mandapam, Gulf of Mannar) for commercial purposes. *Kappaphycus* cultivation is practised on dense seagrass beds using floating rafts.

It was observed by the Suganthi Devadason Marine Research Institute (SDMRI) that this alien seaweed had invaded the coral reef colonies of Shingle, Krusadai and Poomarichan Islands in the Mandapam Coast of the Gulf of Mannar. Fragments of *K. alvarezii* cultivated in the Palk Bay spread through currents, and this is evidenced by the large amount of fragments on the dense seagrass beds along the Pamban Pass.

The *Kappaphycus*-invaded coral colonies were dead because of the shadowing and smothering effects of the attached fragments, which attach firmly and form a thick mat on the coral colony and also penetrate deep up to 5–10 cm. The invasion also largely affected other reef-associated fauna, especially native fish species. Due to the fast growth of this alien seaweed, low nutrient level is observed in the impacted coral reef area, which affects the surrounding environment and resources very much. *Kappaphycus* is not preferred by native herbivorous fishes like surgeon fish (acanthurids) and parrot fish (scarids), and this enables the invasive algae to grow very rapidly.

Sedimentation

Increasing sedimentation caused by human activities, as well as by natural factors, can have damaging or even lethal effects, depending on its intensity and duration. Impacts include smothering of corals by sediments, low light penetration due to increased turbidity, and release of



nutrients/pollutants. The stress symptoms due to sedimentation in corals include loss of zooxanthellae, polyp swelling and excess mucus secretion. In the Gulf of Mannar reef areas, the average annual sedimentation ranges between 19.51±6.20 and 71.15±22.41 mg/cm^2/day. However, the coral reefs of Gulf of Mannar, despite relatively high sedimentation and numerous other threats, seem to be healthy and in good condition at present.

Discussion

The coral reef conservation and management in Gulf of Mannar is one of the most complex. This is because the traditional fishers, who form the major population along Gulf of Mannar have increased in numbers. Crowded fishing grounds, increasing demand for fishery products and declining catches deprive artisanal fisher families of livelihoods and food security (Samuel *et al.*, 2002, Bavinck, 2003). The fisher communities of Gulf of Mannar are characterized by low literacy rate, lack of awareness of environmental issues, low income and a resulting reluctance to take up livelihood options other than fishing. This leads them to involve themselves in more effective but illegal, destructive and unsustainable fishing practices, such as shore seine, purse seine and push net fishing, dynamite fishing and cyanide fishing (Patterson *et al.*, 2007). Any conservation and management measure should be holistic, participatory and address all these issues. Therefore, awareness building, environmental education, alternative livelihood, capacity building of stakeholders, enforcement, research and monitoring should be part and parcel of the conservation programmes. It is also essential that all stakeholders understand the importance of coral reefs and associated resources and contribute to the conservation of ecologically sensitive and productive habitats for sustainable utilization.

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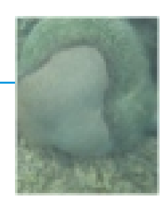

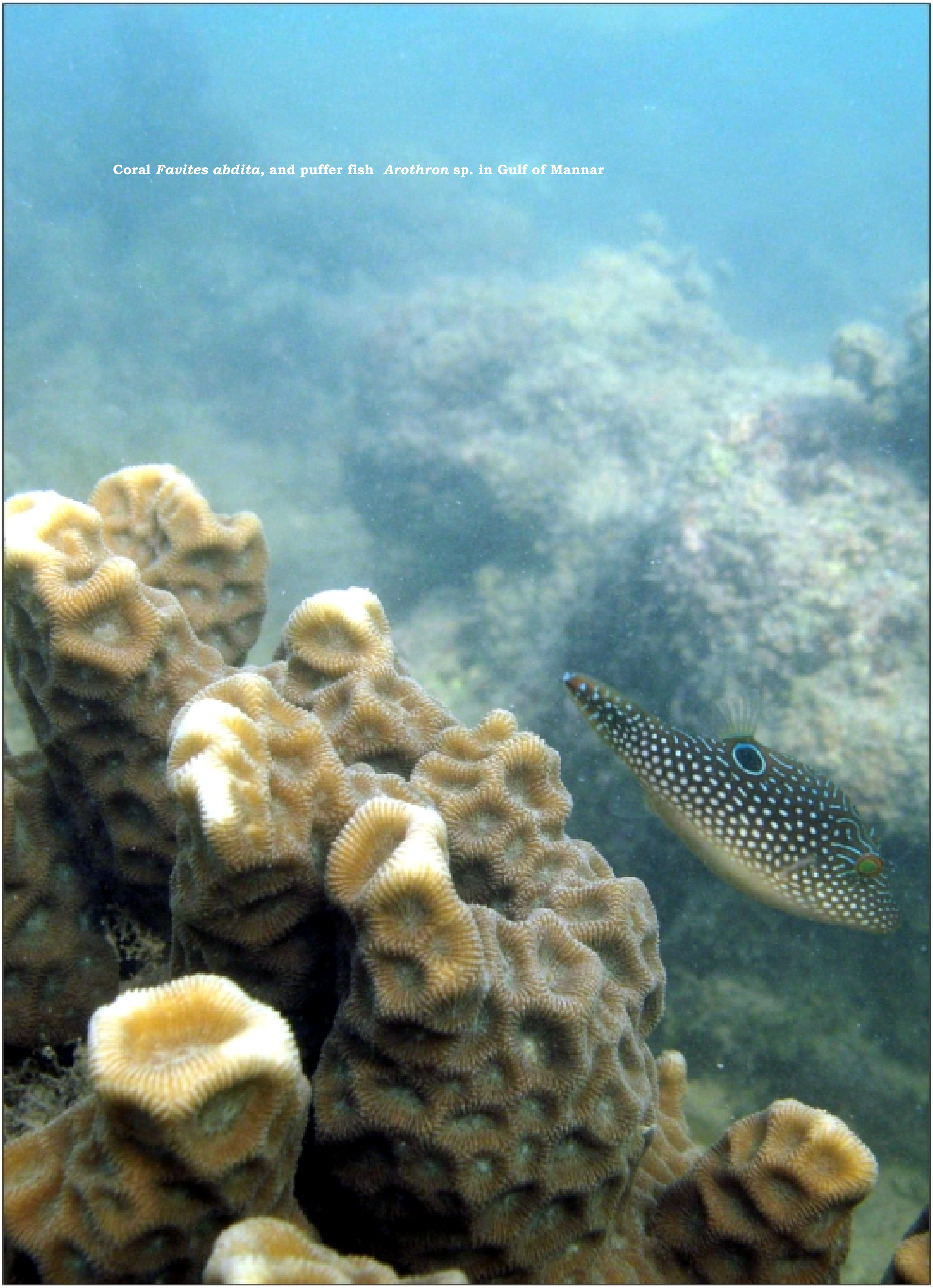

Coral *Favites abdita,* and puffer fish *Arothron* sp. in Gulf of Mannar

Issues relating to water quality changes in the coral reef environment

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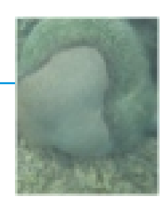
Abstract

In tropical islands and coastal regions, coral reefs serve as a store house of fishery resources. Their importance is viewed seriously because it is the most sensitive nutrient generating base for all faunal and floral habitats. Threats to the reefs addressed by the environmentalists are largely owing to the influence of biotic and abiotic parameters. Most reefs are affected by marine algal growth because of intrusion of sewage derived organic nutrients and runoff. Critical concentrations of nitrogen and phosphorous in near shore waters seem to be many times above the acceptable standards causing slow dangers to coral reef system. The existing coral reef environment needs to be protected from water pollution, excessive nutrient inputs, watershed hydrology and discharge of raw sewage from municipal and household origins along the Gulf of Mannar Biosphere Reserve Coast. Since eutrophication is also threat to reefs in most island reefs, conservation strategies are to be formulated. This paper discusses some of the critical and complex factors responsible for the deterioration of reefs, with special reference to water quality parameters and other physical and chemical threats in the Gulf of Mannar.

Introduction

The world's major coral reef ecosystems are found in naturally nutrient poor surface waters in the tropics and sub tropics. It was once thought that coral reefs would thrive in areas of nutrient upwelling or other nutrient sources, but this idea has been shown to be incorrect. In fact, high nutrient levels are generally detrimental to reef health. A portion of some offshore reefs in the Florida Keys that contained more than 70% coral cover in the 1970s now only about 20% coral cover (Aiken, 1991). Mats of algal turf and seaweeds dominate these reefs, accounting for 48 to 84% of cover. It is due to high nutrient levels. Laponite and Clark (1992) and Bell (1992), Laponite *et al.* (1993) and Grall and Chauvaud (2002) emphasized that nutrient inputs from the watershed are highly responsible for coastal eutrophication.The effects of nutrient pollution however can often be exacebrated either by disease or over fishing, which reduce populations of sea urchins, fish, and other animals that graze on algae and help to keep coral reefs clear. Rajdeep *et al.* (2005) showed the influence of sewage causing severe sea water pollution. Tewari *et al.* (2006) pointed out the uptake kinetics of nutrients and ammonia, besides their effect on the blooming of the marine alga *Enteromorpha compressa.*

Coral reefs are one among the most biologically diverse ecosystems in the world. Reefs account for 0.2% only of the ocean's area, yet they provide habitat for one third of all marine species including fishes, sponges, jelly fish, anemones, snails, crabs, lobsters, sea turtles and sea birds too. As far as coral ecosystems are concerned, corals



require clean, nutrient free waters for sustained life. Over the years, there are reports that corals are impaired by multiple stress factors like fertilizers, inadequate sewage and storm water treatment, siltation from coastal development and beach renourishment projects, contaminants from petroleum products and sewage, oil and toxic discharges from boats, including antifouling paint applied to boat bottoms. In view of the danger posed by pollution to the coral reefs, the present paper discusses the implications of pollution to the corals in the Gulf of Mannar region of Tuticorin district.

Material and methods

Survey was conducted between Kilakarai and Vethalai covering 15 km coastal length in order to assess the physical, chemical and biological factors responsible for the mortality of fish which occurred due to algal blooming during the month of October, 2008. Plankton, water, soil and fish samples were collected from the islands and analyzed for the water quality characteristics and microbial load in fish and water.

The impact of seawater pollution caused by sewage disposal was studied for about 10 months from September, 2007 to June, 2008 in the outskirts of Tuticorin in Thirespuram fish landing coastal region and tail end of Buckle Canal which has become a perennial source of pollution in the Tuticorin area, adopting the procedure of APHA (1995).

Results

Studies made between Kilakarai and Vethalai, as well as between the island and mainland, showed heavy blooming of the dinoflagellate *Noctiluca scintillans*, a bioluminescent alga which changes the water greenish and turbid. Surface seawater temperature varied between 32.0 and 32.5°C; salinity, between 28.8 and 30.0 ppt and dissolved oxygen, between 2.0 and 2.5 ml/l. Nutrients such as ammonia - N ranged between 70 and 75 g at./l, nitrate-N between 98 and 100 µgat./l and phosphate at 48 and 50 µg at./l along Kilakarai coastal waters. In Appa thivu, temperature was between 32 and 32.5°C, dissolved oxygen between 3.0 and 3.24 ml/l, salinity between 32.0 and 32.6 ppt, ammonia between 80 and 82.4 µg at./l, nitrate – N between 90 and 96.5 µg at./l and phosphorus –P between 55.5 and 60.1 µg at./l. The biomass of *Noctiluca scintillans* was found to be between 5000 and 5400 cells/l at Kilakkarai coastal waters and between 3500 and 3920 cells/l in Appa thivu. *Microstella rosea*, *Corycaeus danae*, gastropod veliger and bivalve veliger were found along with the dinoflagellate which bloomed in Kilakarai coast. The dead fishes washed ashore in the vicinity of the islands occupied by coral reef were eels such as *Muraena picta*, *Gymnothorax favagineus;* squirrel fish , *Sargocentran rubrum, Atherina forskali,* grouper, *Epinephelus formosa* and *Cephalopholis* sp.; seabass, *Lates calcarifer;* silverbelly, *Leiognathus daura* and other fishes like *Pempheris* spp., *Chaetodon oxycephalus*, *Acanthurus bleekeri. Pomacentrus* spp., *Adudefduf sexatilis*; parrot fish like *Scarus ghobban*, *S. fasciatus* and *S.gibbus*, *Canthigaster solandri*, *Triacanthurus brevirostris*; rabbit fish like *Siganus javus* and gobid,

Pseudopocryptes sp.

In Thirespuram area, surface sea water temperature varied between 26°C and 35.5 °C, pH between 7.5 and 7.8, salinity between 26.1 and 32.5 ppt, dissolved oxygen between 0.4 and 2.28 mg/l, dissolved CO_2 varying between 41 and 64.4 mg/l, BOD between 40.5 and 93.9 mg/l and COD between 82.5 and 183 mg/l. Ammonia-N varied from 30 to 284 µg at.N/l. The impact of sedimentary nitrogen was extreme along the tail end sewage mixing zone of Buckle canal. The levels of NO_2 -N were found to be between 8.7 and 11.8 µg at.N/l with the extreme value of 32.45 µg at.N/l during non – monsoonal month (Dec, 2007). Similarly high NO_3 -N values were observed in these polluted regions and were found varying between 14.0 and 28.0 µg at/l. NO_3-N. The phosphate - P was found to vary between 9.3 and 9.9 µg.at.P/l in the sewage waste polluted sea water. A peak in PO_4 -P value of 112 µg at-P/l was recorded at the tail end of Buckle canal and sea water mixing zone.

Discussion

From the study, it is obvious that coral reef ecosystems are subjected to physical and chemical threats. The frequent rise in sea water temperature caused coral bleaching, stress the corals which then expel their symbiotic algal species. Patterson *et al.* (2008) also reported this phenomenon.

In Thondidurai and Mandapam area of Gulf of Mannar, influx of nutrients through waste, especially during northeast monsoon, caused increased rate of growth of algae. The incidence of *Noctiluca scintillans* noticed in the Appa Island was a clear indication of the extreme temperature in the layers of upper water around the coral ecosystem. Some of the cyanophyte bacteria have already been reported to cause severe impact on reefs of Gulf of Mannar. A report showed that as many as 25,000 septic tanks were installed close to the sea in Florida, where coral reef ecosystem faced severe threat (Pamela *et al.*, 1993).

The nutrient and water quality studies conducted along the Tuticorin coast surrounded with reef islands suggested that algal blooms developed due to excess nutrients in the water column; this caused slow growth of corals and reduced oxygen levels. Such blooming also decreases visibility, because chlorophyll levels increase within the coral environment. The invasion of algae like *Kappaphycus alvarezii* (Dots), a Philippine derived rhodophyte invaded the Gulf of Mannar coastal waters during the year 2000 and started establishing itself on the fringing coral reef as noticed in the reefs of the Hawaii Islands, where it was introduced for mariculture purposes. Carlton (1999) also observed that biological invasions of invasive algae are causing severe ecological consequences in the world's oceans. Grall and Chauvaud (2002) stressed the need for immediate attention by the ocean environmentalists to find suitable mechanisms to combat marine eutrophication. The single largest coastal system affected by eutrophication in the United States along the Gulf of Mexico, where an extensive reef area suffered due to reduced oxygen levels (Dove and Guldberg, 2006). A rhythmic hypoxia and anoxia can change the make up of a community by killing of

more sensitive or less mobile organisms, reducing suitable habitat for others, and changing interactions between predators and prey as happened to the coral reef system. All these situations happened mainly because of the discharge of municipal sewage rich in nutrients which stimulated the growth of algae. Hunte and Wittenberg (1992) and Jenson *et al.* (1995) assessed the impact of sedimentation on the settlement of juvenile corals.

In the present study, dissolved CO_2 showed values ranging between 41 and 64 mg/l with pH values between 7.5 and 7.8. The corals provide shelter for the zooxanthellae to live, and adequate sun light for the photosynthesis. The metabolic wastes of the corals (CO_2 and nitrogenous wastes) are required by the zooxanthellae for photosynthesis. The benefits to the coral reef are equally important. Oxygen (as a product of photosynthesis) is made available to the coral, and up to 60 percent of the organic molecules produced by the dinoflagellates during photosynthesis escape the membranes of the cell to be used by the coral as food. The presence of the zooxanthellae also promotes the rate of growth of the calcium carbonate exoskeleton of the coral. The coral limestone skeleton is produced from calcium ions (Ca^{++}) dissolved in seawater and dissolved carbon dioxide gas (CO_2) from coral metabolism. The zooxanthellae create an alkaline pH, and the coral responds to this higher pH by increasing the deposition of limestone. In this way, the zooxanthellae promote the growth of the coral reef. The majority of growth of the corals is based on food energy from the zooxanthellae. Corals with zooxanthellae grow up to nine times faster than corals deprived of their zooxanthellae by experimentation. The zooxanthellae account for up to 75 percent of the tissue weight of the coral.

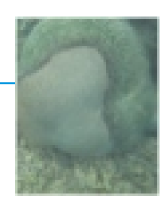
As far as biological productivity is concerned, there are many more species on a coral reef than in the surrounding water or sediments. The productivity as measured by photosynthesis is ten times greater than that of the surrounding ocean waters. This high primary productivity has been a puzzle because most tropical waters are nutrient poor and have relatively low rates of photosynthesis. The higher productivity of coral reefs is related to nutrient enrichment from benthic blue-green algae that can convert nitrogen gas to nutrient ions. Hunte and Wittenberg (1992) found that eutrophication and sedimentation badly affect the juvenile coral settlement. Umar *et al.* (1998) came across the impact of sediment on the enormous growth of the sea weed, *Sargassum* sp. close to the fringing reef. Therefore the results obtained for the polluted Thirespuram coastal region showing nutrients expressing sedimentary nitrogen (0.9 – 1.9%) is a clear evidence for the coast being enriched with sediment nitrate. The presence of the underwater mountain on which many coral reefs are located interferes with oceanic circulation and causes a form of island upwelling. Coral reefs truly are islands of intense biological productivity in the relative desert of the surrounding water. The report on the death of *Acropora* corals in Krusadai Island of the Gulf of Mannar revealed the excessive nutrients in the water which were deleterious to the coral environment. The same phenomenon

was also observed by Goreau (1992) in Jamaican reefs, where the degraded corals were replaced by fleshy algae. Stimson *et al.* (1996) also observed that seasonal growth of the coral reef macro - alga, *Dicpyaspharia cuvernosa* was mainly due to sustained availability of nutrients in the vicinity of coral which stimulated the growth of the alga.

It is evident that there exists a concrete combined effect of high temperature and rapid decomposition of organic material derived from sewage wastes. A high magnitude of BOD (170.4 mg/l) signified the impact of organic pollution in the sea water of Tuticorin coast. High COD values of the polluted coastal waters also declared that there was chemically created oxygen demand for oxidation of the nutrients present in the chemical mixed sewage wastes. These wastes showed direct impact upon the coral reef bases of islands, located in the vicinity of Gulf of Mannar of Tuticorin coast. Devassy *et al.* (1987) emphasized that intrusion of effluents in the sea coast has severe impact on the ecosystem. Aiken (1991) stressed that nutrient inputs need to be reduced to an extent that is both site-specific and seasonally dependent on weather fluctuations. BOD, the most obvious harmful effect of biodegradable organic matter in wastewater, created a biochemical oxygen demand for dissolved oxygen by micro organism – mediated degradation of the organic matter. Aiken (1991) emphasized that nutrient inputs need to be reduced to an extent that is both site - specific and seasonally dependent on weather fluctuations. As the reef islands are located within 5 – 8 km of the Tuticorin coast of Gulf of Mannar, impact of physico – chemical components in the seawater was regular.

From the study, it was ascertained that coral reef ecosystem has been subjected to physical and chemical threats. Patterson *et al.* (2008) came across a similar situation with increased water temperature and flushing of the critical nutrients from the land into Gulf of Mannar. The mass kill of reef fishes occurred in the Mandapam coast could be also due to biogeochemical fluxes occurred through the production of nutrients such as N_2 and N_2O facilitated by an acute deficiency of dissolved oxygen in the vicinity of the reefs. As sea is a significant source for N_2O_2, a major sink for fixed –N is mainly due to enhanced rate of denitrification that could occur in suboxic portions of the water column.

Bell (1992) and Patterson *et al.* (2008) stated that, because reefs are the most sensitive of all ecosystems to changes in water quality, the critical levels of nutrients need to be maintained at a far lower level than in any other ecosystem. Wade (1976) observed that acceptable levels of nutrients that are low enough to prevent eutrophication of temperate estuaries are many times higher than those that trigger eutrophication of coral reefs. The dead fish species reported in the Gulf of Mannar region were mostly represented by residential types which were associated with the coral reef and they were not able to move away from the coral reef habitat. Analysis of dead fishes indicated chocked gills due to algal mass deposits. Eutrophication of the region not only lowered oxygen level, but left the water with high ammonia and caused mass mortality of reef fishes. The coral polyp too suffered



greatly because of the emergence of blooming *Noctiluca scientillans*.

The phosphate level of the water collected from the Kilakarai and Vethalai coastal region and Appa Island showed an extreme level of phosphate to the tune of 99 µg at./l in a diluted level. This caused heavy algal bloom of the dinoflagellate species *Noctiluca scintillans* and the seawater surrounding the coral reef ecosystem became completely dark green in colour. The sudden outbreak of such unusual algal blooming was mainly due to frequent mixing of municipal wastes containing sewage matter washed into the seas through drains. Raw municipal wastes typically contain about 25 mg/l of phosphate as orthophosphates, polyphosphates and insoluble phosphates, and the efficiency of phosphate removal must be quite high to prevent algal growth. Jenson *et al.* (1995) stated that phosphorus cycling in sediment has great influence on the coastal biota. In Thirespuram fish landing coastal region, the polluted sea water had a phosphate level of 9.9 µg at./l, which supported the sustainable growth of the blue green alga, *Enteromorpha flexuosa*. In a laboratory study made by Cross (2008), this particular alga was found to grow in sewage mixed sea water collected from the polluted area rich in nutrients such as NH_3-N $\simeq$ 44 µg at./l and PO_4 $\simeq$ 11.5 µg at./l. Carlton (1999) observed that invasion of algae and other specific sea weeds create large scale ecological consequences in the oceans and it needs to be overcome by adequate management practices. Manimaran (1986) reported that the enriched phosphate nutrient of the Tuticorin coast was due to mixing of the sewage wastes in to the seas. Manimaran *et al.* (2000) emphasized that phosphorus derived from sewage discharges the seawater facilitating bio energy production in the Tuticorin coast.

Marine researchers, biologists and environmentalists have long advocated for appropriate guidelines to minimize marine pollution, together with the participation of sea food processing plants and industrialists so as to monitor the risks and effects of pollution (Goreau, 1994 and Patterson *et al.*, 2005). In the protection and preservation of reef ecosystem from pollution, the rare coral organisms should be protected strictly as threatened / endangered species. Another causative factor for reef water quality changes is pertaining to magnesium and cadmium ions in sea water which are precipitated as hydroxides and carbonates if the discharged effluent changes the pH of the water to levels above 9.5. Iron and aluminum sulphate present in the effluent are also responsible for the formation of a flocculent precipitate of the hydroxides.

Patterson *et al.* (2002) and Patterson *et al.* (2005) stated that a significant portion of the threats to coral ecosystem is caused by non point source pollutions, and hence the damage should be redressed with appropriate techniques in the light of restoration of the coral reef and its environment. In order to minimize further damage to coral reef ecosystems, tertiary biological sewage treatment should be done. Nutrient reduction strategies need to focus first on those areas where coral cover is still sufficiently high and the reefs can quickly recover once the nutrient levels are reduced. Just like in the United States, the wastes should be discharged only after knowing that the effluents involved have obtained a certain level of treatment, as mandated by federal law.

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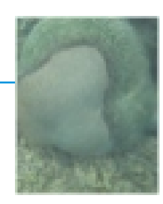

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Briareum hamrum

A note on bio-invasion of *Kappaphycus alvarezii* on coral reefs and seagrass beds in the Gulf of Mannar and Palk Bay

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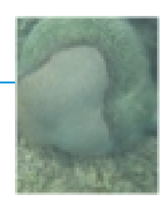
Invasive species invade, grow, perpetuate, colonize and eventually destabilize ecosystems in non-native environments. *Kappaphycus alvarezii* is native to the Philippines and among the largest tropical red algae with a high growth rate (can double in biomass in 15 to 30 days), resilient morphology and extremely successful vegetative regeneration, making it a potentially invasive species (Doty Ex Silva, *Kappaphycus alvarezii* (http:// www. hawai.edu/reefalgae/invasive_algae/rhodo/Kappaphycus_alvarezii.htm).

Kappaphycus is cultivated because it produces sulfated polysaccharides, commonly called 'carrageenans', which are used in the food and pharmaceutical industries. Globally, the largest producer is the Philippines, where cultivated seaweed produces about 80% of the world supply. Carrageenans are natural ingredients in the food industry, and are generally regarded as safe; they are widely used as thickening, gelling and stabilizing agents (Van de Velde and De Ruiter, 2002). The different types of carrageenan are obtained from different species of the Rhodophyta. Kappa (K)-carrageenan is predominantly obtained by extraction of *K. alvarezii,* known in the trade by its earlier name of *Eucheuma cottonii* or simply *Cottonii* (Rudolph, 2000).

Commercial cultivation of *K. alvarezii* was developed in the Philippines during the late 1960s and expanded further to Indonesia, Fiji, Micronesia, Vietnam, China and South Africa. The successful vegetative regeneration makes this alga a potential invasive species which poses danger to the coral reef and seagrass ecosystems.

Scientific reports suggest that the impact of this exotic alga in Gulf of Mannar and Palk Bay is serious, destructive and causing continued loss of coral reefs, seagrass beds, associated biodiversity and livelihood of thousands of dependent fisher folk (Patterson and Bhatt, 2012).

Woo *et al.* (1989) reported that, the alga is able to coalesce into the tissue of the coral, providing a strong means for attachment, and thus allowing the alga to persist in high wave energy environments. The algae provide may permit settlement of epiphytes previously absent, as well as shelter and protection for mesograzers. It is strongly believed that this species will not reproduce sexually but recent findings confirmed that it is capable of switching to sexual reproduction under cultivation and also when environmental conditions favour. Conklin and Smith (2005) revealed the sexual repro-



duction in the species. Woo (1999) documented fragments of *Kappaphycus* weighing 0.05 g that were capable of net growth in the field, suggesting that fragments created by physical disturbance can be carried by waves and currents to new locations where they can possibly establish.

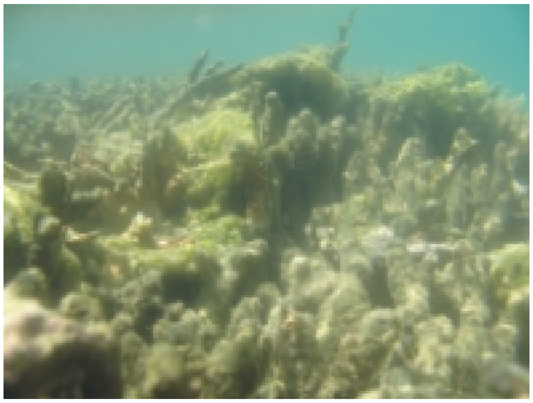
The most well documented case of the impacts of non-indigenous marine algae in the tropics is from Hawaii. *Eucheuma striatum* (this species was later split into *Kappaphycus striatum* and *K. alvarezii*) and *E. denticulatum* were intentionally introduced into the fringing reef surrounding the Hawaii Institute of Marine Biology (HIMB) at Coconut Island (Moku o Loe), Kane'ohe Bay, Oahu, Hawaiian Islands throughout the 1970s, for experimental research and cultivation (Russell, 1983). Subsequent research has demonstrated that these algae have spread rapidly throughout the bay and can be found in a variety of reef habitats overgrowing and killing corals (Conklin and Smith, 2005). Re-growth of the algae following their removal was rapid at most sites, likely due to the experimentally demonstrated ability of the algae to regrow from minute attachment points and the low palatability of the algae to native herbivorous fishes (Conklin and Smith, 2005). Coles *et al.* (2003) stated that the smothering and subsequent weakening of the reef structure at Kan'eohe Bay, Hawaii by the introduced *K. striatum* is of a grave concern as this alga has been introduced to most Pacific Islands for cultivation. Permanent photoquadrats have established the ability of this alga to overgrow and kill corals, while benthic surveys have shown that the alga has already overgrown >50% of the reef substrate in some area (Conklin *et al.,* 2005). Evidence suggests that *Kappaphycus* spp. has significantly altered benthic community structure and species diversity in Kane'ohe Bay (Smith, 2003).

Pereira and Verlecar (2005) first raised the question "Is *K. alvarezii* heading towards marine bio-invasion?" They reported that the fast-growing marine alga *K. alvarezii*, native of the Indonesia and Philippines and introduced to India for seaweed cultivation, has already established its growth in many parts of Gulf of Mannar (GoM) Marine Biosphere Reserve. The ecological danger associated with its commercial cultivation in the GoM was reported in various articles (Anon, 2006; The Hindu, 2006, 2008, 2010; The Indian Express 2010; Times of India, 2010 and Vijayalakshmi, 2003). Chandrasekaran *et al.* (2008) stated that this alga has already exhibited its invasive ability on branching corals (*Acropora* sp.) at Krusadai Island and its shadowing and smothering effects over the coral colonies; fears have also been established that it may switch over to sexual reproduction by spores under favourable environmental conditions in future. Namboothri and Shankar (2011) have also described harmful effects of *K. alvarezii* on corals. The Suganthi Devadason Marine Research Institute (SDMRI) Reef Research Team (RRT) conducted underwater surveys on the extent of invasion by *Kappaphycus* in coral reef from October 2008 to December 2010 using the Line Intercept Transect (LIT) method (English *et al.,* 1997). Transects were laid parallel to a series of islands at 0.5 - 2.0 m depth during high tide, the number of transects depending on the

Bio-invasion of *Kappaphycus alvarezii* on branching coral, *Acropora* sp. in GoM

Thick *Kappaphycus* mat on the branching coral colony in GoM

Dead branching coral colony due to *Kappaphycus alvarezii* invasion in GoM

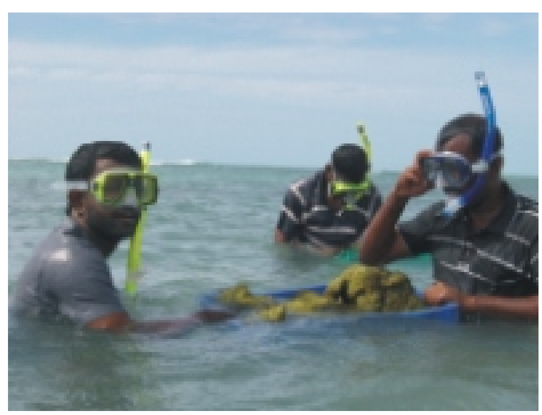


Dead and smothered branching corals due to *Kappaphycus* invasion in GoM

Kappaphycus cultivation on seagrass beds in South Palk Bay and the highly turbid environment

Impact of *Kappaphycus* cultivation on corals in the South Palk Bay

District Collector of Ramanathapuram initiating *Kappaphycus* control measures in GoM



SDMRI reef researchers engaged in *Kappaphycus* control measures in GoM size of the reef. Six transects in Shingle Island, 15 in Krusadai Island and 6 in Poomari-chan Island were laid in each assessment, which was carried out regularly at quarterly intervals. Thirty local fishermen were interviewed for their views on recent trends in fish catch. During the first week of October 2008, SDMRI - RRT reported to Tamil Nadu Forest Department that the alga, *K. alvarezii* invaded in coral areas from South Palk Bay and firmly attached to the branching corals, *Acropora formosa* and *A. nobilis* in Krusadai and Shingle Islands and is spreading to other nearby coral colonies (SDMRI Report, 2008). SDMRI Report (2010) revealed that over 500 coral colonies of coral species like *Acropora cytherea, A. formosa, A.nobilis, Montipora digitata* and *Porites solida* were affected in Shingle, Krusadai and Poomarichan Islands covering a reef area over 1 km^2. The entire *Kappaphycus* cultivation in the South Palk Bay side (Mandapam region) is observed to be conducted on luxuriant seagrass beds and corals which were very productive fishing areas for the local fisher folk earlier. Underwater survey reveal that the cultivation reduces light penetration which is highly essential for seagrass growth and health, resulting in stunted growth with less shoot density and a turbid environment. Loss of fish production is observed in and around the cultivation area. Prior to *Kappaphycus* cultivation, fisher folk mostly practiced hand line and gill net fishing and now there is no fishing activity near the cultivation area as according to local people the fish catch has declined in these areas. More research is required to substantiate the local claims. The findings of Chandrasekaran *et al.* (2008) and SDMRI (2008, 2010) disproved all arguments and mis-apprehensions reported earlier about this alga as coral-friendly and as a safe candidate for mariculture for the production of carrageenan under wild conditions in the Gulf of Mannar and Palk Bay. Their observations under-score the need for urgent reconsideration of its cultivation in the biologically diverse and ecologically sensitive Gulf of Mannar and Palk Bay coastal regions (Patterson and Bhatt, 2012).

Krishnan and Narayanakumar (2010) documented the detailed history of this algal cultivation initatives in Tamil Nadu along with socio-economic benefits to cultivators especially Self Help Groups and production projections. The present study is not in conflict with their work but points out the harmful invasive nature of the exotic alga, *K. alvarezii.* The Government of Tamil Nadu (GOTN) issued orders in December 2005 [G.O. Ms. No.229, E&F (EC.3) Department dated 20.12.2005] which allow cultivation of *K. alvarezii* only in sea waters North of Palk Bay and South of Tuticorin coast. However, cultivation is now practised on seagrass beds on the south side of the Palk Bay, which is very close to the coral reef areas. The GOTN order also clearly mentions that in the event of any adverse impact during environmental impact assessment studies, permission to use the Coastal Regulation Zone area would be withdrawn. Considering the adverse impact of *K. alvarezii* to marine environment and resources, in particular coral reefs, seagrass beds and associated fisheries, the G.O. has to be revisited and action may be taken up to stop cultivation in Gulf of Mannar and Palk Bay.

The National Biodiversity

Authority of India has signed an agreement with Pepsico (Hindu Business Line Report, 2010), and the latter has provided Rs. 37 lakh royalty money to be shared among the local fishing community in Tamil Nadu for acquisition of *Kappaphycus* to be used by the multinational firm under the Access and Benefit Sharing (ABS) scheme. In the light of damage caused by the *Kappapycus*, there is a need to revise this agreement in order to protect and conserve ecologically sensitive habitats such as coral reefs and seagrass beds and the livelihoods of over 250,000 fisherfolk who are dependent on associated fishery resources. The agreement needs to be suitably modified to incorporate the basic principles of benefit-sharing, such as conservation and local socio-economic development, in particular on the basis of economic valuation of damages caused by *Kappaphycus*.

Further to that proper management, protection and remedial measures have to be taken up to eradicate and control the already invaded coral reefs and seagrass areas. The Forest Department, along with Ramanathapuram District Administration, initiated remedial measures through manual removal of this alga, but it is a continuous and expensive effort. The UNEP-WCMC (2006) estimated that the total economic value of healthy coral reefs range from US$ 100,000 to 600,000 per Km^2 area per annum.

It is the impact of *Kappaphycus alvarezii* on coral reefs and seagrass beds that will ultimately have considerable bearing on the dependent fisher folks' livelihood. Losses are largely caused because of the disappearance of native species and the instability of coastal areas due to loss of habitats such as coral reefs and seagrass beds. Considering the deleterious impact of *Kappaphycus* on corals in other parts of the world also, it is now time to reconsider the cultivation of *Kappaphycus* in the Gulf of Mannar and Palk Bay, both of which are exceptionally rich in species diversity, including both endemic and threatened species. Further, in-depth detailed research, conservation, management strategies and comprehensive guidelines are needed to be set in place before the introduction of exotic species in any marine environment. A coordinated approach among various departments, scientists and conservation managers is the key prior to the introduction of new exotic species.

Acknowledgements

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Kappaphycus fragments on the seagarss beds, Pamban Pass

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Coral colonies covered by exotic seaweed, *Kappaphycus alvarezii,* in Krusadai Island, Gulf of Mannar

An assessment on 21st February 2011 during the lowest tide period revealed that the exotic seaweed, *Kappaphycus alvarezii* spreads over 1.24 km^2 of reef area in Krusadai Island, Gulf of Mannar on the seaward side (south east and south west directions).

Photo credits

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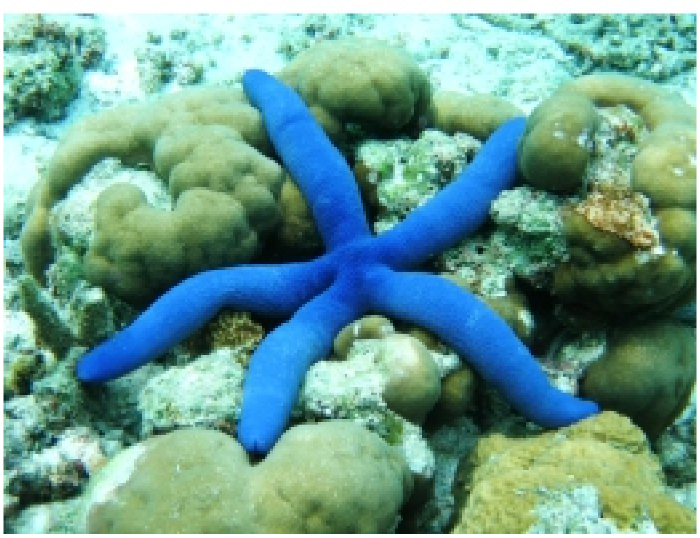

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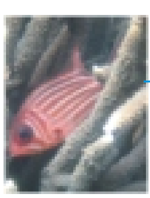
Heterocentros mammilatus



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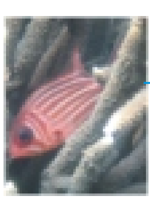

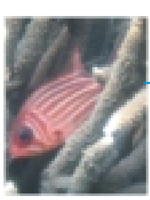

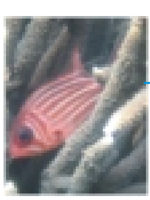

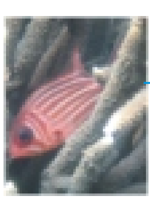

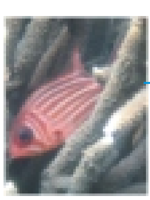

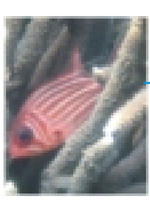

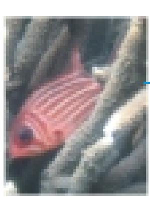

Acropora hyacinthus

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