National Research & Monitoring
Moderation Workshop

Edited by
V.K. Melkani, V. Naganathan, R. Uma Maheswari

Compilation of Research papers
Volume I

Gulf of Mannar Biosphere Reserve Trust
Ramanathapuram - 623 501
Tamilnadu, India
National Research and Monitoring
Moderation Workshop

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V.K. Melkani
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Gulf of Mannar Biosphere Reserve Trust
Ramanathapuram - 623 501, Tamilnadu

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Back cover - Island view of Hare Island, Gulf of Mannar

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PREFACE

Gulf of Mannar Biosphere Reserve Trust is co-coordinating implementation of GEF-UNDP project on “Conservation and Sustainable Use of Gulf of Mannar Biosphere Reserve’s Coastal Bio-diversity”. This is a pioneering and unique initiative of the government of Tamil Nadu with objectives to integrate bio-diversity conservation and sustainable utilization of resources in the Gulf of Mannar Biosphere Reserve area through meaningful co-ordination and support from various stake holders and to secure local community support for conservation through awareness, capacity building and providing alternative livelihoods.

The Gulf of Mannar is no doubt a biologically rich area. Today the threats to its richness are increasing at faster rates which need to be controlled through an integrated management approach with support from all the stakeholders.

In order to understand the richness and the problem profile of the area the Trust has bought out a detailed bibliography on scientific information on the Gulf of Mannar through active involvement of the centre for marine and coastal studies, Madurai Kamaraj University recently. The research work done by various individuals and institutions in the area has now been well documented.

Based on the outcome of this documentation the Trust is now organizing a National Research Monitoring and Moderation workshop on 15th - 16th Dec. ’06 at Madurai where distinguished scientists, experts other stakeholders will gather to deliberate on various issues on Research and Monitoring in the Gulf of Mannar region and jointly develop programmes and activities for field action by next year.

The Trust has also compiled some research papers as a publication for use in this workshop wherein the future perspective of research, monitoring and management of this area are covered. The Trust Director and his team deserve appreciation for this effort.

I wish the workshop all success.

(Vishwanath Shegaonkar)
MESSAGE

Conservation and sustainable use of coastal and marine resources is very important for security and well being of coastal communities. Coastal and marine ecosystem are extremely diverse and complex as well as highly sensitive to disturbances and threats which are continuously on increase due to growing populations and their need clubbed with fast growing economies.

The Gulf of Mannar Region in South east coast of Tamil Nadu is equally under threat as many other parts of the Country. A new initiative for integrated conservation of this area with full involvement of local communities is being made in a collaborative project of GEF, UNDP, GoI and GoTN.

In order to minimize and control the threats it is necessary to understand about the richness of the resources and the profiles of the threats so that the management interventions can be developed and implemented for enhanced conservation and sustainable use of the resources.

As a first step Gulf of Mannar Biosphere Reserve Trust has bought out a detailed bibliography on the scientific information on the Gulf of Mannar which is of much use to the scientists, researchers, managers and the other agencies involved in the Gulf of Mannar area. I am glad to learn that the Trust is organizing a two day workshop at Madurai in order to deliberate on various issues related to priority areas and options for research and monitoring activities in the area and releasing a publication on compilation of some research papers focusing on the future perspective of biological, ecological and environmental research and monitoring activities in this area. I hope that scientists, experts and other stake holders will utilize this opportunity and provide inputs towards developing workable, short term and long term programmes on research and monitoring aspects in the Gulf of Mannar Region.

I wish to extend my greeting to all the participants and wish the workshop all success.

(C.K. SREEDHARAN)
Once a biological paradise, the Gulf of Mannar Region in south-east coast of Tamil Nadu is currently encountering a variety of threats which are robbing the richness of this area. Sincere and committed action on part of all the stakeholders and local communities is necessary to control and curb the threats and to use the resources judiciously so that the glamour, beauty and richness of the area is maintained on a sustainable basis.

Gulf of Mannar Biosphere Reserve Trust has made sincere beginning under the GEF-UNDP Project to secure coordination, cooperation the support of all stakeholders towards achieving conservation and sustainable utilization of the resources of Gulf of Mannar Region. The Trust has documented the scientific information on the area by compiling various works done by individuals and institutions in the area in past more than hundred years. This bibliography is highly useful not only to scientists and researchers but also to administrators, managers and other stakeholders working in this area.

I am very happy to learn that the Trust is conducting a National Research Monitoring and Moderating Workshop on 15-16 December 2006. This effort of the Trust is to share valuable information and experience of scientists, experts, researchers and others in order to prioritize future thrust areas of research and monitoring in the Gulf of Mannar. The Trust is also releasing a publication on compilation of some research papers related to the workshop theme.

I appreciate the effort taken by the Trust Director and his team to conduct this workshop in a befitting manner. I wish the workshop all success.

(SUKHDEV THAKUR)
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MESSAGE

Gulf of Manner region in the south east coast in Tamilnadu is a priority area for conservation because of its richness of species and ecosystems which support a large number of coastal people and others. Sustainable management of this fragile resource capital alone will hold the key for real prosperity and wellbeing of this area and the people. The threats to the richness of biodiversity of this area are increasing at alarming rates and if not curbed and controlled now will lead to a situation of no return.

The conservation and sustainable utilization of the resources require an integrated approach in management of this area where all stakeholders understand and accept the limitations of resource availability and control their negative interactions with the resources and its over extraction. The GEF – UNDP initiative in active participation of the Government of India and Government of Tamilnadu in a project mode is making sincere attempts in securing co-ordination, co-operation and meaningful support of multisectorial stakeholders and local communities towards achieving conservation of rich biodiversity of this region and sensitizing all stakeholders to adopt to sustainable use of resources.

The current situation of resource use and abuse, status of biodiversity, and other needed information’s through available data as baselines has to be developed and subjected to robust monitoring protocols both in short and long term perspectives in order to know whether over a period of time the situation is improving and to what extent? Similarly baselines on issues and themes will have to be developed wherever it is not available. The Trust has since compiled all the scientific information available on the area in hard and soft versions as the initial step. Now to expand the activity further the Trust is organizing a two day “National Research and Monitoring Moderation Workshop” on 15 & 16 December 2006 at Madurai. A compilation of some research papers is also being released during the workshop.

This gathering of scientists, experts and other stakeholders will deliberate on various issues of concerns and areas of priority action on research and monitoring in Gulf of Manner region which shall pave way for developing short and long term activities, programmes and projects which will be in action by next year through Trust funds and also through collaborative approaches.

I wish to extend warm greetings from Gulf of Mannnar Biosphere Reserve Trust to all the delegates.

V. K. Melkani
Gulf of Mannar Marine Biosphere Reserve

Gulf of Mannar in the southeast coast of India extends from Rameswaram Island in the north to Kanyakumari in the south. It has a chain of 21 islands stretching from Mandapam to Tuticorin to a distance of 140 km along the coast. Each one of the islands is located anywhere between 2 and 10 km from the mainland. The Gulf of Mannar Biosphere Reserve was set up on 18th February 1989 jointly by the Government of India and the state of Tamilnadu. The government of Tamilnadu in G.O. M.S. No 962 dated 10th September 1986 notified under section 35(1) of the Wildlife (Protection) Act 1972 the intention to declare the 21 islands as Marine National Park for the purpose of protecting marine wildlife and its environment including depths of 3.5 fathoms on the bay side to 5 fathoms on the seaward side.

The compilation of all available scientific literature in the form of an annotated bibliography of the Gulf of Mannar biosphere reserve has brought to light the existence of nearly 3,000 publications up to date. This covers the literature published from as early as 1864 to the current year. A large number of publications in the first half of the 20th century have brought out information on the variety of fauna and flora found in the Gulf of Mannar, their biology and ecology. A lot of emphasis on the fish and fisheries research has been given only in the second half of the 20th century. Emphasis is being given on biochemical aspects of flora and fauna in the later part of the 20th century and at present.

Ecosystems and Biodiversity

Gulf of Mannar 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 seagrass 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, seahorses, seacucumbers etc. The biosphere reserve and particularly the Marine National Park of the Gulf of Mannar also gains more importance because of the alarmingly declining population of the endangered Dugongs.

The Gulf of Mannar biosphere reserve has an area of about 10,500 km² running along the mainland coast for about 170 nautical miles including the 21 islands in the gulf. The total area of the islands is about 623 hectares. The Exclusive Economic Zone (EEZ) of Gulf of Mannar is about 15,000 km² in which, commercial fishing is carried out in about 5,500 km² up to a depth of 50m. Gulf of Mannar is considered as “Biologists’ paradise” for, it has 3600 species of flora and fauna. The diverse nature of ecosystems in the Gulf of Mannar supports a wide variety of significant species including 117 species of corals, 641 species of crustaceans, 731 species of molluscs, 441 species of finfishes and 147 species of seaweeds apart from the seasonally migrating marine mammals like whales, dolphins, porpoises and turtles. The mangrove habitats in the Gulf of Mannar have
9 different species of vegetation supporting a variety of marine fauna including seabirds and sea snakes.

**Major Scientific Research**

The major scientific areas of research in the Gulf of Mannar include 1) Finfish fishery 2) Shellfish fishery 3) Aquaculture and 4) Seaweed research. The finfish fishery includes perches, carangids, barracudas, mackerels, milkfish, mullets, tunas, sardines, scombroids, silverbellies, pomfrets, lethrinids, groupers, sharks and rays. The shellfish fishery includes oysters, mussels, clams, prawns, lobsters and crabs. Aquaculture research has been concentrated on pearl oysters, edible oysters, crabs, prawns, milkfish, etc. Extensive research has been carried out on the biology, ecology, biochemistry and production of seaweeds of the Gulf of Mannar. Dedicated researches on these aspects of seaweeds have been going on in the Central Salt and Marine Chemicals Research Institute (CSMCRI) and the algal study unit of the Central Marine Fisheries Research Institute (CMFRI). In recent years a number of academic institutions have also evinced interest in seaweeds mainly to do research on bioactive compounds especially on those with antibacterial qualities. Researches on culture of organisms of export value such as seacucumbers, seahorses and ornamental fishes have been carried out by institutions including the State and Central fisheries departments and academic institutions.

Corals and coral reefs of Gulf of Mannar form an important ecosystem, which support a variety of ornamental fishes and provide feeding and breeding grounds for a number of edible species of finfishes and shellfishes. The available publications on corals include taxonomy, identification and available locations.

The existing literature indicates that chank fishery (Sacred Chank) and Pearl oyster fishery have dwindled in the last few decades and the reasons attributed to this decline are overexploitation and the introduction of mechanized fishing including trawl fishing in the Gulf.

Relatively few studies exist on the endangered marine mammal dugong of the Gulf of Mannar. These studies done in the 1970s are based on a few captive animals kept in the CMFRI facility. Available research publications on Dolphins include only data on either stranding or of those caught in fishing nets. Many of the reports are based on dead animals washed ashore. This is the case with Whales, which are stranded periodically, and porpoises that are washed ashore occasionally.

Although the sea turtles were exploited for meat, until they were protected by law, not many research publications have come out. The available reports indicate that some of the islands in the Gulf of Mannar have nesting grounds of these turtles. Extensive research on sea cucumbers, which includes captive breeding, rearing and culture, has been carried out by the CMFRI. Research publications on seahorses of Gulf of Mannar are only limited and they are about their fishery and trade. However, available information indicates that breeding and rearing in captivity have been carried out successfully.

Studies on Mangrove ecosystem are limited concurrent with the limited extent of their distribution. Some of the studies related to mangrove plants are on using mangrove leaves for extracting Bioactive compounds. Literature on seagrass ecosystem is also limited.

Studies on socioeconomic aspects of fishermen communities in the Gulf of Mannar
region include utilization of coastal resources such as seaweeds, shell collection and trade, and selling fish in local markets by fisherwomen. Some of the studies indicate the financial problems encountered by fishermen especially due to middlemen exploiting their catch.

Although separate publications on destructive fishing practices are limited, a number of papers give information about such practices, mainly about trawl net fishing near coral reef areas, trap laying for ornamental fish collection on coral reefs, overexploitation of chanks, seacucumbers and pearl oysters by skin diving and seaweed collection in coral reef areas which are blamed for the destruction of fishery resources.

A number of publications of the fisheries institutions include information on crafts and gears used in fishing. The gears include trawl nets, purse seines, cast nets, long lines, shore seines, crab nets and ornamental fish traps. The crafts used are mechanized and non-mechanized types. The non-mechanized ones are small canoes used by smalltime fishermen in the lagoon area. The mechanized vessels are either canoes fitted with in-board engines or motor boats (launches) used for trawl nets.

**Remote Sensing and GIS**

There are only a limited number of publications on application of remote sensing in either assessing the resources of the Gulf of Mannar or in monitoring coastal water pollution status. The Department of Ocean Development through its Integrated Coastal and Marine Area Management Project (DOD-ICMAM) has brought out a Resource Information System for Gulf of Mannar using GIS that gives baseline data on the distribution of marine living resources such as mangroves, coral reefs, seaweeds, seagrasses, finfish, shellfish and other marine organisms. Pollution studies in the Gulf of Mannar area are only limited and the areas studied include only large towns such as Tuticorin and the pilgrim town Rameswaram.

**Scientific Gap Areas**

1. Although information on the existence of various species of corals are available, the extent of their distribution needs to be assessed as done in the case of forests. Long term monitoring of the corals is essential.
2. Research on coral reef ecology particularly the interaction of other animal species with corals needs to be carried out, in order to understand their contribution to fishery.
3. Coral biology with particular reference to reproduction, spawning seasons and patterns should be studied.
4. Rehabilitation of corals in reef denuded areas, especially around all the 21 islands, must be done.
5. The impact of Sethu Samudram Ship Canal Project (SSCP) on the coral reef ecosystem needs to be studied especially in the context of the southwest and northeast monsoons influencing the underwater current patterns.
6. The concern raised by a few publications on bio-invasion due to the SSCP and the operation of foreign vessels in future in the region needs to be addressed. Bio-monitoring of invasive and introduced species also should be carried out.
7. Although the endangered dugong has drawn the attention of a number of scientists not much valuable research has been carried out to study *in-situ* the biology, behavior, ecology, reproduction and population structure of this rare and
endangered species and hence needs immediate attention.

8. Exclusive surveys may be conducted to assess the status of endangered and threatened species such as sea turtles, sea horses, dolphins, dugongs, molluscs, corals, etc.

9. Although some information is available on the morphometry of the Dolphins based on their carcasses, more efforts may be spared to study their biology, ecology and behavior in nature.

10. Research on sea turtles especially about their nesting grounds and breeding populations needs to be carried out.

11. Although the technology of sea cucumber culture has been demonstrated it needs to be extended to the field, so that the fisherman can take it up as an alternate livelihood option since it has great export potential.

12. The technology of pearl culture is available but has not penetrated the field very well and hence needs attention.

13. Sea grass ecosystem which is important for the endangered dugongs needs to be studied properly. It is also necessary that the availability, extent of distribution, diversity and biomass potential of sea grass in the Gulf should be assessed. Long term monitoring of the sea grass ecosystem may be considered.

14. Although the extent of distribution of mangroves in the Gulf of Mannar is limited, their ecology in terms of their support to fisheries, land protection and significance as feeding and breeding grounds for sea birds, sea snakes and other organisms needs to be studied.

15. Although a GIS based Resource Information System is available with the DOD to give baseline information, current underwater surveys should be carried out to locate pearl oyster beds, chank beds, seaweed grounds, sea grass beds and coral reef distribution. A resource map should be prepared based on such underwater surveys.

16. The vast majority of scientific information available with us is based on studies carried out in the northern part of the Gulf of Mannar encompassing the chain of 21 islands. Information on the southern part of the Gulf is only limited and hence attempts must be made to cover the southern parts also and identify any new grounds of living resources.

17. Although pollution is known to be a cause for concern in the Gulf of Mannar, a thorough understanding of the situation is lacking. Hence it is necessary to conduct research to find out the impact of pollution and the polluting sources, including domestic, municipal and industrial discharges, on the marine living resources of the Gulf. A thorough coastal survey between Dhanushkodi and Kanyakumari should be conducted to identify and map the pollution sources using GIS.

18. A complete assessment of the destructive fishing practices and the number of fisherfolk involved should be done and rectification measures should be adopted.

19. A thorough understanding and estimates of the fishery resources harvested by various fishing sectors, such as mechanized and non-mechanized vessels, and the people involved are required.

20. Socio-economic status of the Gulf of Mannar based dependent human population should be studied to understand their problems and the...
prospects of using the human resource to protect and conserve the marine resources.

21. Although training programmes are conducted and extension activities carried out periodically by scientific institutions in order to disseminate information and spread aquaculture technology such as pearl culture, seaweed culture, sea cucumber culture etc., to local people including fishermen, not many success stories are reported mainly because of lack of follow up and encouragement both technically and financially. Therefore efforts should be made to develop entrepreneurship training facility.

22. Remote sensing should be used, including Aerial surveys and photography, to assess the current status of the topography, geomorphology, and land and forest cover of the islands in the Gulf of Mannar. The same technique may be used for surveying the coastal area also.

23. Research on the impact of climate change and sea level alterations in the Gulf of Mannar may be initiated.

24. The total number of fauna and flora in the Gulf of Mannar is said to be 3600 which needs to be updated and consolidated.

25. A collection of information based on traditional knowledge may be useful.

26. Commercially viable short term programmes such as crab fattening, lobster fattening, and marine ornamental fish rearing may be introduced as alternate livelihood options.

27. Fishery dynamics land stock assessment are to be done for the Gulf of Mannar.
Introduction

The Gulf of Mannar region (GOM) along the coast line of India bordering Ramanathapuram, Tuticorin, Tirunelveli and Kanyakumari districts in south east Tamilnadu has rich biological and ecological assemblages with very high levels of productivity. About forty percent of recorded marine biodiversity of India is reported to be found here. The area also exhibits high degree of endemism. The Gulf of Mannar region distinguishes itself as the first area not only in India but in entire south and south-east Asia where conservation management in focus and process was introduced [Gulf of Mannar National Park (GOMNP), 10,500 sq.km., 1986 and Gulf of Mannar Biosphere Reserve (GOMBR), 560sq.km., 1989]. Although the conservation mandate and process in the area has traveled through a journey of nearly two decades and has been able to provide enhanced protection to scheduled species and parts of key habitats, yet the change of mind sets of major stakeholders, understanding the carrying and delivery capacities of the area and limiting the resource extraction to those levels have not firmly rooted in a true sense either in practices or in concepts. One of the main reasons for this has been the lack of integrated management of the Reserve where in a consensus in approach for managing the area in active participation, collaboration and co-operation of all stakeholders is genuinely acknowledged and practiced. Moreover, today the conservation management of natural resources is just not mere or absolute protection of the area. Various other concerns - socio-economic, livelihoods, sustainable use and development have immersed into it and a conservation management programme today has to very holistically acknowledge and seriously attempt to develop management plans that includes all these concerns. Without genuine and active support of people, communities and other stakeholders around the natural resource base the orthodox conservation management strategy will not be the accurate and implementable strategy of management.

GEF-UNDP-GOI-GOTN’s New initiative in Gulf of Mannar region

The GOMBR has been selected as an international priority site based on criteria such as biophysical and ecological uniqueness, economic, social, cultural values and scientific importance of national and global significance. The IUCN Commission on National Parks and Protected Areas, with the assistance of UNEP, UNESCO and WWF has identified the Reserve as being an area of “particular concern” given its diversity and special, multiple use management status.

In consonance with the Convention on Biological Diversity (CBD), significance of the area and its growing threats and duly appreciating the initiatives of the Govt. of India and the Govt. of Tamilnadu, the GEF-UNDP stepped into and a new collaborative project
on “Conservation and Sustainable Utilization of Gulf of Mannar Biosphere Reserve’s Coastal Biodiversity” was approved. This is a unique and pioneering initiative of the Govt. of India and Govt. of Tamilnadu in partnership of GEF-UNDP to bring in a truly integrated management of GOMBR. The 7 year project (2002-2009) is a co-funded project wherein of the total project cost of about Rupees one hundred forty crores about Rupees forty crores is from GEF-UNDP and the balance about Rupees one hundred crores is through parallel financing from GOI, GOTN and other partners.

The overall objective of the project is to conserve the Gulf of Mannar Biosphere Reserve’s globally significant assemblage of coastal biodiversity and to demonstrate in a large biosphere reserve with various uses and users, as to how to integrate biodiversity conservation and sustainable coastal zone management and livelihood development. The focus of the project is on empowering local communities to manage the coastal ecosystem and its valuable resources in partnership with government and other stakeholders and making all accountable for the quality of the resulting stewardship. The project will be instrumental to strengthen specific government and local level institutional capacities, to allow stakeholders to apply sustainable livelihoods through an independent statutory Trust to ensure effective intersectoral co-operation for sustainable conservation and utilization of GOMBR’s biodiversity resources.

**Research and Monitoring inputs and outputs**

Research and monitoring inputs to a project initiative which focuses on biodiversity conservation and sustainable use of resources are basically the processes which aim at understanding the parameters of core themes and issues of biological, ecological, environmental and socio-economic realities, current status of richness and problems, resources use and the carrying and delivering capacities of the resource base and remedial measures to curb the threats, over extraction and use of resources beyond the capacities. This information will act as baseline or benchmarks and if the remedial measures are followed up over a time frame both on short and long term period the impacts of such initiatives on the improvements over the current situation with recoveries of habitats, increase in richness of species and optimal use of resources can be understood. Developing the baseline information on biological, ecological, environmental and socio-economic indices is the first step to understand, document and disseminate the current status, practices and happenings. This information later on subjecting to short / long term monitoring will reflect whether the project initiatives are yielding desired results or there is need for mid course corrections on protocols, mechanism and the strategies being followed to better the situation.

In order to prioritize the baseline scenario it is necessary to recognize the broad nature of threats to target species, habitats, present practices of resource use and extraction (species choice, quantum, seasons etc.) and related socio-economic factors propelling these threats, their predicament and implications on the resource base capital over a period of time are meticulously described and documented.

Among the various threats to biodiversity conservation and the practices, efforts and quantity of resource extraction and use at present prevailing in GOM region and their root causes which need to be understood in order to curb and control and which have a direct bearing on the research and monitoring
priorities for the area an be summarized as below:

- habitat destruction, degradation and depletion (coral reefs, sea grass beds, mangroves, sea beaches ...).
- over harvesting of resource (no proper control, improper practices of harvest and utilization ...).
- potential and increasing land based marine pollution through industrial affluents / sewage disposal into the Gulf of Mannar area.
- developmental pressures in the CZM area of GOM (industries, other projects ...).

Some of the common root causes for the above threats are - (not as per priority)
- lack of integrated management of Reserve.
- insufficient enforcement of regulations.
- insufficient management information.
- lack of community support for conservation.
- insufficient public awareness.
- lack of alternative livelihoods.
- lack of community management capacity.
- lack of effective marine resource property regimes.
- insufficient baseline information on species, habitats & resource use.

**Priority research and monitoring concern**

The GEF-UNDP-GOI-GOTN project initiative has an important focus on research and monitoring issues. As is clear from the root causes of various threats to biodiversity conservation and sustainable use of resources the insufficient information on management concerns-lack of sufficient base line information on critical species, habitats, practices and extents of resource extraction has to be given the priority under the research and monitoring components of the project.

Presently there is no established practice of monitoring in the area except some information of resource extraction through landing sampling. There is no concise information on the carrying capacities of resource availability. The scientific information on GOM recently compiled by Gulf of Mannar Biosphere Reserve Trust with active association of Dr. A.K.Kumaraguru et.al, Center for Marine Coastal Studies, Madurai Kamaraj University, Madurai has revealed about 3000 references of works undertaken by individuals, institutions in the area, however, most of the work is based on the needs and priorities of those individuals and institutions. Though the information available is useful, yet the fundamental information’s are missing in many other core themes of biodiversity conservation and its management. Many status survey, done in past have become outdated and the ground realities have much changed since then and as such fresh surveys will be necessary in order to clearly depict the current situation of habitat / species richness, compositions, population dynamics etc.

The priority areas for research which the project will be addressing through direct funding and through collaborative arrangements are -

- **Biological base lines**
  - key species (sea-cow, turtles, dolphins, whales, pearl oysters, present status, population dynamics ...etc.).
  - key indicators (for identifying health of system- protection, harvest ...etc.).

- **ecological baselines**
  - key habitats (coral reefs, sea grass beds, mangroves, sea beaches, present status, extent ...etc.).

- **environmental baselines**
  - water quality (physical, chemical, biological parameters; implication on
health of human and other species….etc ).

- dumping of waste (locations, volumes of disposals….etc ).
- other polluting activities.
- CZR & CZM issues.

✓ socio economic baselines
  - demography.
  - economic status (income patterns)
  - practices of resource use.
  - quantum of resource extraction.

✓ Harvestable species (fish, mollusks……..etc).
  - privileged and under privileged sections…..etc and related issues.

These are some of the themes where baseline data / information will have to be developed, documented and disseminated on priority.

**Monitoring**

The areas where acceptable baseline information’s are available monitoring protocols (methods, frequencies and reporting) can be initiated straight away. Required capacity building for the staffs / individuals who will be engaged in such monitoring should simultaneously take place by resource institutions and the required equipments and facilities will have to be arranged. For the areas where baseline information’s are lacking the same will be subjected to monitoring initiatives both for short and long term durations once the baseline information’s are developed. The field staffs of Forests, Fisheries, Coast Guards etc. can be groomed to take up the task in coming years. Field guides and manuals in local vernacular will be needed.

The project is making serious efforts to elicit local people’s support for conservation through the process of eco-development in the buffer zone of GOM. The concept and practice of participatory monitoring protocols will be required to be developed so that the local communities become partners in monitoring the project out puts and improvements over current situations by themselves in future.

In fact developing a robust monitoring protocol will meet the needs of project implementation and impacts in a short term and that of GOMBR and its management and the local communities and other stakeholders in the long term. The research and monitoring activities will be attempted to be developed through collaborative programmes in active association of scientists, experts from stakeholder institutions already taking up such initiatives in the area. One of the key focus of these initiatives will be to support the informed management of the Park and the Reserve for effective and enhanced monitoring and evaluation efforts in future. Many research activities and studies covering an array of diverse themes and subjects and surveys of some of the important habitats have been taken up in the area by various institutions and individuals and it shall be necessary to ensure that the duplication of similar efforts is avoided.

Efforts are also needed to bring in integration of research and monitoring so as to build synergy between research and management; research and community; management and community and among all the three because such a synergy will make the efforts truly participatory and efficient and then alone it will be driven by need and the findings and recommendations will be mutually acceptable and workable.

**Research priorities for gap areas**

The recently compiled “Scientific Information on GOM” has highlighted certain
gap areas where future research inputs will be needed. The valuable information on the gap areas of research is included in the **executive summary** of the report which is a part of this publication. This will be of much use while deliberating on the future areas of research and monitoring in GOM region.

The Gulf of Mannar Biosphere Reserve Trust has conducted a revised Logical Frame Work Analysis (LFWA) workshop at Madurai during 5th to 7th January 2006, which was attended by many stakeholders. The workshop also recommended some gap areas where future thrust will be necessary. These are

- Impact of exotics
- Impact of tourism
- Community tenure/Management systems
- Evaluation of Fishing Practices of communities (Non-trawlers)
- Policy research to understand impact on fishery resources due to trawling
- Impacts of different type of pollution
- Impacts of collection of mollusks
- See weed collection-socio economic aspects and ecological impacts
- Sea weed as an indicator of coral reef ecosystem health

**Conclusion**

Serious attempts will be needed by experts in the field, renowned institutions to develop the indices in order to apply these to assess the positive trends and changes that may accrue due to project initiatives in the area where conservation and sustainable use of resources is being focused in the mandates and mindsets of all stakeholders and all becoming jointly responsible for a changed scenario wherein the biological, ecological, environmental, managerial and socio-economic concerns of biodiversity conservation and sustainable utilization of resource are understood, and their limitations are respected and negative legacies are not left for our coming generations.

The need of the hour is to bring a sincere and meaningful integration of the stakeholders including the scientists, experts and institutions to facilitate co-operative, and collaborative sharing of roles, responsibility, experience, knowledge, know-how’s, capacities and resources to synergise our efforts to facilitate integrated biodiversity conservation and sustainable utilization and development of resources in GOM region in making it a “model” and front runner in concept, ethos and practice and is followed at other places across the globe in times to come. And that will be our true moment of pride, joy and jubilation.

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Introduction

Coral reefs are distinct and unique habitats. Being lovely and exquisite objects, these are described as the nature’s splendour and wonderful creation of Mother Nature, so also as the planet’s greatest attraction and beautiful presentations. Coral reefs, and their associated systems of mangroves and seagrasses, are the world’s most biologically diverse marine ecosystems. Besides quite a large number of edible species, brilliantly coloured animals. No wonder they have fascinated Man since time immemorial and provided him with food, pleasure and protection from storms and other natural calamities. Constituting an important asset, they contribute much to the national economy through way of fisheries and tourism. In view of these facts, coral reefs are variously described as under water tropical rain forest, fairy land underwater, biologist’s paradise, testament of biodiversity, magnificent repository of resources, genetic garden, submerged meadows, treasure house of wealth and one among the most valuable and spectacular places on earth.

The coral reefs characterize an ecosystem of high biological diversity, having the greatest number of species of any marine ecosystem. Coral reefs are considered as one of the most important critical resources for various ecological, environmental and socio-economic reasons. They play an important role in global biochemical processes and in the reproduction of food resources in the tropical regions. They act as a barrier against wave action along coastal areas thus preventing coastal erosion. In addition, coral reefs protect mangroves and sea grass beds in certain areas, which are the breeding and nursing grounds of various economically important fauna. Coral reefs are also important breeding, spawning, nesting, and feeding areas for many economically important varieties of fishes and other marine organisms.

Some of the most interesting relationships and interactions between organisms can be observed in coral reefs. An example is the clown fish (Amphiprion) which nestsle amongst the stinging tentacles of large anemones. This attractive fish protects itself from the anemones virulent nematocysts by coating itself with anemone mucus, thereby mimicking its host, which cannot recognize it as a potential food source. The vivid colours of the clown fish, however, attract predatory fishes, which are then caught more easily by the anemone. Thus, while helping the anemone to get its food the clown fish itself is given protection by its deadly host.

Fishes such as the clown fish, due to their vibrant colours and strange habits, are popular as aquarium fishes and hence constitute an important commercial resource of coral reefs.

Distribution of Corals

Among the various countries having coral reefs in the world, Indonesia has the largest reef area followed by Australia and Philippines. India holds the tenth place among
the countries blessed with coral reefs. Indonesian archipelago is considered as epicenter of evolution of marine tropical diversity in particular coral diversity. However, precious corals do not live on coral reefs. They live in colder and deeper waters, such as in the Mediterranean Sea and Sea of Japan. Certain Corals grow as far north as the Arctic Circle. Most of the coral reefs in South Asia are in India, Maldives, Sri Lanka and Chagos.

Coral reefs are distributed along the major oceans of the World. The largest network of coral reefs occur, along the southeast Asian region. The Great Barrier Reef off the Queensland coast of Australia is the largest aggregation of reefs in the world. It extends to a long distance of 1,931 km with the width varying from 16 to 322 km. The barrier reef, that lies off New Caledorria, has a total length of 644 km and the enclosed lagoon has a maximum depth of upto 300 feet. The Great Sea Reef, lying north of the two main islands of Fiji, Viti lever and Vanna lever has a length of 265 km. the fringing reef adjoining the shores of the Red sea is the longest stretch of single reef in the World and if straightened into a single line, would exceed 4,023 km (David Kingston & Ramadhas, 2006).

Coral Reefs in India

Indian subcontinent with its coastline extending over 8,100 km and with tropical and subtropical climatic conditions has very few coral reef areas. The reefs are distributed along the east and west coasts at restricted places. The total area of coral reefs in India is estimated to be 2273.8 sq km. There are 4 major coral reef areas in India: Gulf of Mannar; Andaman and Nicobar Islands (length of coastline -1962km); Lakshadweep Islands (length of coastline -132km); and the Gulf of Kachchh.

Almost all the major reef types are represented here. The fringing reefs are found in Gulf of Mannar and Palk Bay (Tamil Nadu) in the east coast, platform reefs are found along the Gulf of Kachchh (Gujarat) and patchy reefs are present near Ratnagiri and Malvan (Maharashtra) coast of West coast. In addition the fringing and barrier reefs are also found in Andaman and Nicobar Islands. Atolls are found in Lakshadweep. The absence of reef in Bay of Bengal (North-East Coast) is attributed to the large quantity of freshwater and silt brought by the rivers such as Ganges (West Bengal), Mahanadi (Orissa), Godavari and Krishana (Andhra Pradesh). Satellite imagery (Space Application Centre, Ahmedabad) shows scattered patches of corals in the intertidal areas and occasionally at subtidal depths along the west coast of India notably at Ratnagiri, Malvan and Red Port (Rajakumar, 2005).

Biological Diversity in Coral Reefs

Reefs are home to more species than any other ecosystem in the sea. The total number of reef species in the world is still unknown, but up to 3,000 species can be found together on a single reef in south-east Asia and over 1,000 species on a single Caribbean reef. Reefs contain a larger number of vertebrates than rainforests.

The richest reefs, with the greatest diversity of plants and animals are in the region bounded by Indonesia, Malaysia, the Philippines and southern Japan. Of the 700 or so coral reefs that are known in the world, 600 are found in this regions; over 400 are found in the Philippines and Japan, and about 350 in Indonesia, although there are probably many more to be discovered in this areas. Up to 200 corals may occur on a single reef in South East Asia. The variety of species on a reef decreases eastwards across the Pacific.
A total of 208 species divided among 71 genera are hitherto recorded from India, including Lakshadweep, the Gulf of Kachchh, Palk Bay, Gulf of Mannar and Andaman and Nicobar Islands. Out of these, 155 species belonging to 50 genera are hermatypes and 44 species divided among 21 genera are ahermatypes. The Indian Ocean as a whole is known to harbour 88 genera of hermatypes, which means 56.8 percent of the total known hermatypic genera of the Indian Ocean, is present in Indian waters.

The hermatypes constitute 77.8% of the coral fauna and the ahermatypes form 22.2%. Among the hermatypes Acropora alone forms 20% and Montipora 13% and these two are numerically rich genera. The members of the suborder Astrocoeniina constitute 34.7%, Fungiina 25.7%, Faviina 22.6%, Caryophylliina 8% and Dendrophylliina 9% of the coral fauna of India (hermatypes and ahermatypes combined). No genus is endemic to India. The coral reefs of southeast India, Andaman and Nicobar Islands and Lakshadweep harbour Acropora community.

The Gulf of Mannar has 21 islands, formed of coral reefs. The largest island is the Musal Tivu, situated in the Pamban-Kilakarai region having an area of 129 ha. The coral reefs in the Gulf of Mannar provide for a very interesting heterogenous group of fauna and flora. The islands have representatives of every animal phylum known except amphibians. About 3600 species of fauna and flora have been identified from this region. There are 137 species of corals, 275 species of sponges, 180 species of marine algae and seaweeds, 190 species of gastropods, 110 species of bivalves, 96 species of Echinoderms, 125 species of teleost fishes, 11 species of whales and 14 species of turtles. Considering the importance of the coral islands in this region, the Gulf of Mannar marine province has been declared as Marine Biosphere Reserve, which was the first Biosphere Reserve in Southeast Asia. It occupies an area of 10,500 sq km. (170 nautical miles). Considering the importance of conservation of diversified fishery resources, a Marine National park has been set up during 1980 in this province (Rajakumar, 2005).

Uses of Coral reefs

Coral reefs benefit fisheries by supplying food for more and wide ranging pelagic or inshore pelagic fishes. Many species of seaweeds are collected from coral reefs. Corals deposit tremendous quantities of limestone.

Large amounts of the coral limestone also contribute to coral rubble and sand, which are used for making building materials and cement. Jewellery and curios produced from corals produce a substantial revenue. Pearls are produced from pearl oysters present in the reefs.

Natural product chemicals are also extracted from Gargonians. A number of Prostaglandins occur in large quantities in the common gargonacean Plexaura homomella. It has a wide range of pharmaceutical applications in humans including one of assisting in the process of child birth, termination of pregnancies and treatment of cardiovascular diseases.

Reefs are known for an enormous diversity of species. As many as 4,000 species of fishes and about 800 species of corals have been identified so far. It is estimated that about 9 million species are associated with the coral reefs, apart from the microbial species. Therefore, reefs constitute a genetic treasure box. They host a number of bioactive substances that are increasingly used in pharmacology and medicine.
Worldwide, reefs yield an income of about US$ 375 billion per year of which US$ 100 billion is through food from reefs or reef environments. In some developing countries, food from reefs provides about 25 per cent of the total food supply and 60 per cent of the total protein intake. 

The benefits of coral reefs are the following:

1) Coral reefs protect the human being from natural calamities, stabilize the shoreline changes and protect soil erosion.
2) They also provide income and employment through tourism, recreation, and export of fishes.
3) Reef environment is an important place for many colourful sea animals such as fishes, starfish, and sea anemones.
4) One square kilometer of healthy coral reef produces 20 to 35 metric tons of fishes each year, enough to feed 400 – 700 people.
5) Coral reefs can also produce substantial revenue through their use in jewellery and as curios. Precious coral is the one valued for jewellery.
6) The hard core (internal skeleton) that can be polished and brought out in beautiful red, rose, or pink colours is used in jewellery.
7) The coral reef ecosystem may also harbour rich bed of seagrasses, on which dugongs, dolphins, etc., feed. They are also enmeshed with symbiotic algae and seaweeds. The coral reef ecosystem is very heterogeneous indeed.

Corals themselves constitute an important source of lime, which is used in cement industries. Coral blocks are used as building blocks and also in road construction. It has been estimated that the world’s reefs precipitate about 600 million tons of calcium carbonate annually.

**Threats to Coral Reefs**

Coral reefs are endangered worldwide. According to a report by the World Resources Institute, almost 60 per cent of all reefs are endangered due to human activities, such as coastal development, overexploitation, destructive fishing methods, increasing sedimentation and eutrophication, and pollution from domestic and industrial sewage.

**Coral mining or dredging**

Reefs in Gulf of Mannar region were recorded as rapidly deteriorating as early as in 1971, due to high levels of siltation and rapid removal of coral combined with cyclone impacts. One island in the Tuticorin region has disappeared below the surface due to coral mining. Most of the other reefs in the Tuticorin group are also mined. The fishing pressure is also enormous including harvesting of sacred chunks (*Turbinella pyrum*), sea cucumber, pipefishes, and sea horses.

As demographic pressures continue to increase coral reefs are continuously being degraded in the absence of integrated coastal management plan.

**Over exploitation**

The reef fishes are also caught in huge quantities which will affect the system in many ways. The overexploitation of shells and corals for ornamental trade and industrial use is another serious hazard. The over exploitation of reef fishery beyond the sustainable level has started and it is proceeding at an alarming rate. Some species have disappeared from certain reefs, or are very rare.

**Dynamite and cyanide fishing**

Due to lack of awareness and poverty, the fishermen are forced to indulge in destructive fishing practices such as dynamite fishing, using gelatin sticks to blow up the reef and kill shoaling fishes. Thus huge quantities
of a variety of untargeted marine organisms are thrown on the shore as debris. That way there will be serious threat to the biodiversity, which directly and indirectly affect the livelihood of the people depending on it. However, ironically those who depend on the coral reefs for their livelihood do much damage.

**Pollution**

Human and animal wastes, industrial wastes, fertilizers, and other chemicals are finding their way into the oceans and poison coral reefs and also cause harmful algal overgrowth. Increasing human populations in coastal regions is also harming coral reefs by introducing infectious microorganisms through sewage contamination that cause coral diseases such as white band and black band diseases leading to widespread destruction of reefs.

**Sedimentation**

Increasing sediment in coastal areas from rivers created by erosion blocks the penetration of sunlight needed for photosynthesis of algae, which is essential for the corals to survive. Worldwide degradation of estuaries, salt marshes, and mangrove forests that usually filter sediment coming from upland and by erosion has also greatly increased the amount of sediment delivered to marine habitats including reefs. Heavy terrigenous sedimentation coming from rivers due to bad land management, is suffocating corals.

**Cutting of mangrove trees**

Mangrove play important role in alleviation of stressors to coral reef ecosystems. The stressors are sedimentation, storm and wave energy, atmospheric temperature, CO$_2$ level, ultraviolet and solar radiations. Mangrove forests act as filters between the land and coral reef. They prevent soil erosion and also trap soil particles. Further, mangrove forests may help to protect coast and nearby reefs from the fiery effects of storm, typhoons and tsunami. Cutting down mangroves may damage nearby coral reefs by permitting mud or silt to settle on corals and freshwater to spread onto the reef.

**Anchoring of boats**

Fishing and tourist boats frequently anchor on coral reefs while they carry out their daily activities. Dropping anchors, dragging them across the coral and the movement of anchor chains of bigger boats destroy coral colonies.

**Bleaching of corals**

Coral bleaching is the whitening of coral colonies due to the loss of symbiotic algae *zooxanthallae* from the tissues of polyps. This loss exposes the white calcium carbonate skeletons of the coral colony. Corals naturally lose less than 0.1% of their *zooxanthallae* during processes of regulation and replacement. However, adverse changes in a coral’s environment can cause an increase in the number of *zooxanthallae* lost.

**Ocean warming**

Corals are adapted to a moderate range of temperatures. When the water becomes too warm, the corals bleach as the Zooxanthellae leave the corals. The coral’s growth will slow down or it will die if the bleaching is too prolonged.

**Crown-of-Thorn star fish**

*Acanthaster planci* is a carnivorous asteroid spiny starfish that eats quite a lot of corals. Normally it occurs at low density and consumes the coral during night time (nocturnal). It sticks out its stomach and wraps it around a piece of living coral and digests the live coral. At times there are plagues of (hundreds or thousands of) crown-of-thorns
starfishes and these may devastate the entire coral reefs.

**Tourism**

Tourism is the largest industry in coral reef rich countries attracting visitors. Tourism can damage reefs in many ways. Tourist related activities in the coral reef areas include surfing, jet skiing, cruises, yatching and fishing.

**Tsunami**

The tsunami, however, has been kinder on the fragile Gulf of Mannar biosphere, shadowed by Sri Lanka. Though the change in coastal morphology was striking, with the ecosphere showing “geomorphic changes,” the reefs have been only “partly affected by the breakage of some of the branching corals and uprooting of table corals.” The hardier “boulder corals,” which also act as wave-brakes, have suffered less damage.

**Remote sensing application of Coral Reef**

In Gulf of Mannar, the coral reefs have been used as a source of calcium carbonate and building blocks. In general, coral reefs in Gulf of Mannar can be categorised as “degrading”, and hence, monitoring and management of these valuable marine resources are of prime importance. IRS LISS-II (1988), IRS LISS-III (1998) satellite data and ARC-INFO and ARC-VIEW GIS software have been used for coastal geomorphology, seafloor, shoreline, coastal land use/land cover and coral reef mapping of Gulf of Mannar.

High resolution sensor data of IRS LISS -II has been used to map the coral reefs in the Gulf of Mannar on an much larger scale (upto 1:25000) under the DOD programme on Critical habitat Information system. Supervised classification of LISS -III digital data is used to identify the different species of coral reefs apart from the classification odd patch reef, fringing reef and atolls. Due to high spectral resolution (23m) LISS-III data were found to be more useful for coral reef mapping and monitoring. Digital image processing is widely used for coral reef mapping (Ramachandran, 2005).

**Monitoring methods for Coral Reefs**

Monitoring is the gathering of data and information on coral reef ecosystems or on those people who dwell coral reef resources. Monitoring should be repeated on a regular basis, preferably over an extended period of time. Ideally a coral reef manager will perform a detailed baseline survey that includes many measures or parameters that may or may not change over time. These include:

- Mapping the extent and location of major habitats, particularly coral reefs;
- Understanding the status of coral communities, fish populations and fishing practices;
- Measuring the size and structure of the human population using these resources;
- Understanding government rules and regulations on coral reefs and conservation; and
- Determining the decision making process in local communities.

The coral reef manager has to select which variables (things to measure) to be included into a monitoring program.

A major goal of a coral reef monitoring program is to provide the data to support effective management. As more Marine Protected Areas (MPAs) are established, it is becoming increasingly important to monitor whether they are achieving their management goals. Monitoring can assist with the effective management of coral reefs through the following tasks:
1. Resource assessment and mapping in the coral reef area should be managed;
2. Resource status and long-term trends of the resources and changing pattern over time to be monitored.
3. Status and long-term trends of user groups especially the stakeholders of the coral reefs, and the use towards the management to be monitored,
4. Impacts of large-scale disturbances like coral bleaching, crown-of-thorns starfish (Acanthaster planci or commonly known as COTS) outbreaks and tropical storms that affect the coral reefs,
5. Impacts of human activities especially utilization of coral reef resources. This includes fishing, land use practices, coastal developments, and tourism.
6. Performance evaluation & adaptive management based on the success of management goals and assist in adaptive management.
7. Education and awareness must be given to the user communities, government, other stakeholders and management staff about monitoring and the effective control of blast fishing
8. Building resilience into MPAs - how to design MPAs so they are more resilient to large scale disturbances such as coral bleaching or outbreaks of COTS;
9. Contributing to regional and global networks through establishment of linking with other coral reef managers around the world and assist others to manage their coral reefs.

Types of monitorings

There are two main types of monitoring:

- Ecological monitoring; and
- Socio-economic monitoring.

Ecological monitoring

Ecological and socio-economic parameters are often closely linked; therefore ecological monitoring and socioeconomic monitoring should be done in the same place at the same time. For example, monitoring of fish populations should be directly linked to surveys of fish markets, fishermen and their catches. Similarly ecological parameters describe the natural state of the coral reef, which will have impacts on socio-economic factors such as income and employment.

Biological parameters measure the status and trends in the organisms on coral reefs and focus on the major resources. These parameters can be used to assess the extent of damage to coral reefs from natural and human disturbances. The most frequently measured ecological parameters include:

1. Percentage cover of corals (both live and dead) and sponges, algae and non-living material;
2. Species or genus composition and size structure of coral communities;
3. Presence of newly settled corals and juveniles;
4. Numbers, species composition, size (biomass) and structure of fish populations;
5. Juvenile fishes, especially target species; populations of organisms of special interest such as giant clams, COTS, sea urchins etc.;
6. Extent and nature of coral bleaching; and
7. Extent and type of coral disease.

Physical parameters to be measured on and around the reefs. This provides a physical description of the environment surrounding reefs which assists in making maps, as well as measuring the change in the environment. Parameters include:
1. Depth, bathymetry and reef profiles;
2. Currents;
3. Temperature;
4. Water quality;
5. Visibility; and
6. Salinity

Socio-economic monitoring
This aims to understand how people use and interact with coral reefs. It is not possible to separate human activities and ecosystem health, especially when coral reefs are important to the livelihoods of local community members. Socio-economic monitoring can measure the motivations of resource users as well as the social, cultural, and economic conditions in communities near coral reefs. Socio-economic data can help the managers to determine which stakeholder and community attributes provide the basis for successful management.

The most frequently used socio-economic parameters include:
1. Community populations, employment levels and incomes;
2. Proportion of fishers, and where and how they fish;
3. Catch and price statistics for reef fisheries;
4. Decision making structures in communities;
5. Community perceptions of reef management;
6. Tourist perceptions of the value of MPAs and willingness to pay for management etc.

Sensitive Habitats and Resources of Gulf of Mannar
The Gulf of Mannar marine Biosphere Reserve (GMMBR) is a predominantly coral reef ecosystem. The so called Mannar Barrier in this Gulf is composed of 21 small Islands (each of 0.95 ha to 130 ha located between 8°46’ – 9°14’ N lat. And 78°9’ – 79°14’ E long.), which extend to a distance of 140 km from Tuticorin to Mandapam. The biosphere includes the microecosystems of coral reefs, rocks, seaweeds and seagrasses, each supporting its own characteristic community structures and zonations. The area of the Gulf of Mannar under the Indian EEZ is about 15,000 sq.km., where commercial fishing takes place in about 5500 sq. km. (upto 50 m depth).

The Gulf of Mannar is highly productive with an estimated average benthic gross production of 7.3 g c/m²/day. Phytoplankton production in surface waters is 89-91 g c/m³/year. Out of 365 species of phytoplankton catalogued from India, more than 42 species contribute from India, more than 42 species contribute to the major phytoplankton production in the Gulf of Mannar. Occasional blooms of Noctiluca, Ceratium, Trichodesmium, Gymnodinium and rare occurrence of Goyaulax (Alexandrium) have been reported. There are 180 species of benthic algae in the gulf. Thirty three species of seaweeds comprising 16 green algae, 10 red algae and 7 brown algae and their associated fauna occur in dense concentration. The estimated annual seaweed yield from an area of 17,125 ha in the gulf is 22,000 t. The average zooplankton biomass is 16.12 cc in 10 minute haul.

A large number of taxonomic, biological and ecological studies on coral reefs, mangroves, seaweeds, seagrasses, sponges, corals, gorgonids, polychaetes, crustaceans, bivalves, gastropods, echinoderms and fishes of the Gulf of Mannar have been made by the Central Marine Fisheries Research Institute (CMFRI) (Devaraj, 1998).
Conservation and sustainable management of the marine living resource of the Gulf of Mannar Biosphere Reserve

Conservation and development issues in respect of the Gulf of Mannar Marine Biosphere Reserve study is limited. Fishing and other anthropogenic activities are posing considerable threats to many coastal and sensitive habitats along the Gulf of Mannar. The 1991 CRZ notification and the proposed Biodiversity Act are expected to intervene in the free access to coastal resources. The declaration of the Gulf of Mannar as a Marine Biosphere Reserve requires a new set of governance of this ecosystem, while at the same time, ensuring sustainable livelihood opportunities to the coastal communities (Devaraj, 1998).

Management of Coral reef ecosystems

The following measures could be taken to protect the coral reefs.

1. Legislation must be enacted to protect the coral reefs from the anthropogenic activities.
2. Over exploitation of reef resources for the ornamental trade needs to be controlled.
3. Reef mining should be controlled and sufficient time be given for the corals to grow and build up.
4. Fishing using dynamite, cyanide poison and other explosives in the reef environment should be banned.
5. A thorough survey should be done to select healthy reefs for setting up protected areas and discharge of pollutants to such areas should be restricted.
6. Stringent action should be taken to save this fragile ecosystem. Remote sensing of coral reef is also becoming an increasingly useful technique to monitor the changes in reef and it can be used extensively.
7. Anchoring of boats in the coral reef area should be prohibited.
8. Banning reef walking, untreated sewage disposal, dredging and anchoring of boats on the coral Islands—setting up of permanent anchors to minimize damage.
9. Removal of mangrove plants from the reef area should be banned thereby preventing massive siltation. Planting of mangroves in the appropriate places with the involvement of local community in the reef area should be undertaken.
10. Collection of schedule animals from the reef area should be banned.
11. Ministry of Environment and Forests should create awareness among the fisherman and the public not to overexploit the coral reef resources and also not to catch the banned marine organisms. The importance and benefits of the coral reefs should be taught to them.
12. Environmental education programs in schools and villages are also extremely important to help local people to understand the importance of reef resources.

About 100 countries are bordered by coral reefs; almost all developing countries are faced with management problems including increasing demographic pressures. Half a billion people live close to the corals and half a billion people live within 100 km of a coral reef, and some 100 thousand take all they need for life from coral reef resources.

In India there is lack of awareness about the value and importance of coral reefs among government agencies and local communities, although some academic institutions have conducted reef research. Thus, there is a need for more coordinated approach to coral reef management.
1. To provide complete protection to the breeding and feeding grounds of the endangered and vulnerable fauna and flora and to gradually eliminate the disruptive and destructive factors, adversely affecting the system.

2. To maintain the National Park habitat as gene pool reserve for marine aquatic species.

3. To restore and protect natural vegetation and to stabilize the island by promoting natural regeneration or by resorting to artificial regeneration.

4. To create awareness on the need for conservation and management of the marine ecosystem on scientific lines for proper socio-economic development of the region.

5. To promote judicious and optimal utilisation of the landscape in the islands and the sea waters within the National Park Zone for research, education and recreation purposes consistent with ecological principles of habitat management.

Approximately 20% of the shrimp catch of Tamil Nadu is constituted by the shrimp caught from GOM region. However, such a precious natural marine fishery resource is presently facing problems due to anthropogenic activities. In Thoothukkudi, the annual exploitation of ramose coral is approximately to the tune of 0.55 lakh tones and 1.07 lakh tones for massive corals. Also, due to the impact of shore based Industries, thermal power plants and sewage discharge, Thoothukkudi coral resources are in peril. Suitable measures have to be implemented and adopted to safeguard such unique ecosystem which supports a diversity of marine fisheries flora and fauna.

Apart from such local problems, the possibility of gradual dissolution of corals due to the enhanced level of carbon dioxide warrants global level monitoring and timely effort at international level to safeguard such a precious and unique ecosystem of the world (Kingston & Ramadhas, 2006).

**Integrated Coastal Reef Area Management**

Many reefs have been destroyed because of bad land management, such as deforestation for agriculture or urbanization. As for the reef area itself, the best solution is to define zoning for activities (e.g. snorkelling, diving, jet skiing, navigation, fishing) or allow no activities at all (e.g. strict reserves). Marine protected areas (parks and reserves) are interesting ecologically and also for tourism development. Regulations preserve the reefs but parks are also one way to sensitize and educate interested tourists.

Replanting inland forests and riverside vegetation, agroforestry (mixed planting of crops and trees) and replanting coastal mangroves and shoreline vegetations are of help in preventing erosion and subsequent siltation of coral reefs. Schools, environmental groups and community organizations can undertake replanting.

Tourism can damage reefs in many ways. Long coastal stretches are plastered with hotels and the sewage is discharged straight into the sea. Fortunately the number of marine parks and marine protected areas has increased worldwide including in developing countries. Large international programs like the international year of the Reef (IYOR) or the international year of the ocean (IYO 1998) have contributed largely in increasing the awareness of these issues among the local populations (Rajakumar, 2005).

**Legislations and Action Plans for Protecting Coral Reef Ecosystem**

- The Coastal Regulation Zone Notification
1991 of Government of India regulates onshore development activities, which affect coastal environments and strictly prohibits the collection and trade of corals.

- Wildlife (Protection) Act 1972 takes care of protected areas and certain marine species including corals.
- Coral reef conservation is also included in the Environmental (Protection) Act 1986.

**Conclusion**

Coral reef ecosystems are of great importance and of immense value to mankind in the present and in the future. They are being degraded at an alarming rate by various preventable activities including human interference. Such valuable ecosystems are to be monitored periodically for the better management plans either ecological assessment or with the help of remote sensing data for better assessment and management of coral reef ecosystem.

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Introduction

The Gulf of Mannar (GOM) is situated between Lat. 8° 47’ - 9° 15’ N and Long. 78° 12’ - 79° 14’ E along the south east coast of India. The coral reefs of Gulf of Mannar are distributed on the shelves of 21 islands, lying between Rameswaram and Kanyakumari. The Gulf of Mannar is one of the Marine Biosphere Reserves (GOMMBRE) in India covering an area of 10,500 sq. km. This area is commonly known as “Biological Paradise” because of their rich biodiversity. They play an important role by providing habitats for seaweeds, seagrasses, corals, pearl oysters, sacred chank, fin and shell fishes, mangroves so also endemic and endangered species. Nearly 3,600 species of flora and fauna are reported so far here. The 21 islands of Gulf of Mannar were declared as Marine National Park in 1986 for the purpose of protecting marine wildlife and its environment by Government of India and State Government of Tamil Nadu (Upreti and Shanmugaraj, 1997).

Many early studies have concentrated on corals and the distribution of reefs in this area (Foote, 1888; Brook, 1893; Thurston, 1895; Matthai, 1924; Gravely, 1927a,b; Sewell, 1932, 1935). Extensive study and research on the corals and their distribution have also been carried out from 1960s onwards. As a result, the occurrence of 94 scleractinian coral species belonging to 37 genera have come to light in the Gulf of Mannar and Palk Bay (Gopinadha Pillai, 1971, 1973). Also it was found that the southern side of the Gulf of Mannar island is covered with dense and diversified corals than the northern side.

Biodiversity and Productivity of Gulf of Mannar

The Gulf of Mannar has diverse habitats that support many species which are ecologically and economically significant. About 117 corals, 641 crustaceans, 731 molluscs, 441 finfishes and 147 seaweed species have been reported apart from the migratory marine mammals and reptiles (Kumaraguru et al., 2006).

Forty nine species of diatoms out of 51 species of phytoplankton were observed to be common in the plankton samples of the Gulf of Mannar and Palk Bay. The data suggested that the Palk Bay is having a larger stock of autochthonous diatoms which are mostly neritic, whereas the Gulf of Mannar has more oceanic diatoms (Raghu Prasad and Ramachandran Nair, 1960). According to Kannan et al. (1998) a total of 126 species of phytoplankton occur here among which diatoms constituted the major component followed by the Dinoflagellates which constituted the second largest group with 16 species. Though the blue-greens formed the third dominant group, they were represented by only 7 species. All the other groups were represented by one species each.

It is believed that the Gulf of Mannar was once covered with thick mangrove forest. Due to the manmade activities the forest cover has declined rapidly. According to the recent reports 10 species of mangroves occur in the islands of Gulf of Mannar
including the endemic species of the coralline sand namely *Pemphis acidula* (Kathiresan and Rajendran, 1998).

A total number of 35 species of heterotrophic bacteria (THB) belonging to 11 genera were identified. They included 22 species of ammonifying bacteria, 16 species of nitrate-reducing bacteria, 2 species of free living \( \text{N}_2 \)-fixing bacteria (*Azotobacter*), 24 species of phosphate-solubilizing bacteria and 26 species of phosphatase-producing bacteria. Among the 35 species of THB tested, 16 species showed proteolytic activity, 10 species displayed lipolytic activity and 9 species exhibited amyolitic activity (Table 20) (Kannan *et al*., 1998). According to Kannapiran *et al*.(1999) 37 microbial strains from the three biota were isolated with predominance of *Bacillus* spp. followed by *Pseudomonas* spp., *Spirillium* spp., and *Vibrio* spp. Of the three biota studied, the coral reef harbours higher percentage of magnetotactic bacteria followed by the mangroves and estuaries.

Burton (1937) recorded more than 90 species of sponges from the Gulf of Mannar and most of them were found on the reef flats. Fauvel (1930) recorded 119 species of annelid fauna with a good number of polychaetes. Sathyamurthy (1952) recorded 450 species of molluscs. Boring bivalves were identified as one of the dominant reef dwellers causing considerable destruction to the reef systems. A total of 22 species of boring bivalves belonging to 11 genera and 6 families viz. *Mytilidae*, *Veneridae*, *Petricolidae*, *Aloidae*, *Gastrochaenidae* and *Pholadidae* were reported from the Indian coast (Appukuttan, 1973).

A variety of beautifully coloured fishes inhabit the reef corals. The fishes belong to the genera *Holocentrus*, *Lutjanus*, *Pomacanthoides*, *Chaetodontopsis*, *Chaetodon*, *Linophora*, *Abudelfuf*, *Thallasoma* and *Zanclus*. Two species of eels *Gymnothorax undulatur* and *G. punctatur* were found densely populated around the reef flat (Reddiah, 1970).

The monthly average productivity in the Gulf of Mannar was 74.460 gC/m\(^3\) (surface and bottom samples). There were two peaks of primary productivity, one in April – May and another in October. Monthly average of the standing crop of phytoplankton in terms of plant pigment units (Harvey Units) ranged from 9,000 H U/m\(^3\) (October) to 58,000 H U/m\(^3\) (April) (Raghu Prasad and Ramachandran Nair, 1963). Primary productivity of coral reefs in Manauli (Manoli) island, was estimated by the diurnal changes of oxygen in the sea water flowing over the reefs. Manauli reefs are autotrophic with annual net production of 2500 gC/m\(^2\) (Gopinadha Pillai and Ramachandran Nair, 1969).

The mean density of zooplankton in the Gulf of Mannar was 71 ind./l. The copepods, nauplii and tintinnids generally formed the bulk of the zooplankton standing crop with a mean value of 23.4%, 24.8% and 28.0% respectively. Gastropod larvae, polychaetes etc. were found to occur commonly but not in large numbers (Raghu Prasad and Ramachandran Nair, 1963).

Standing crop of the macroalgae from the total area of 17,125 ha was 22,044 tonnes (wet weight), consisting of 1,709 tonnes of agarophytes, 10,266 tonnes of alginophytes and 10,069 tonnes of other seaweeds. The commercially important species viz. *Gelidiella acerosa* contributed 74 tonnes; *Gracilaria* sp., 974 tonnes; *Hypnea* sp., 798 tonnes; *Sargassum* sp. 9,381 tonnes and *Turbinaria* sp., 714 tonnes (Kalimuthu *et al*., 1990).
What is to be done in Gulf of Mannar Biosphere Reserve?

Even though the research work in the Gulf of Mannar are limited and it has to be studied well in all the aspects and find out the present status of the ecosystem for the better management and conservation. Hence, the following aspects have to be given top priority under the management programmes for the Gulf of Mannar.

1. Gulf of Mannar Biosphere Reserve Information System

The exact number of organisms occurring in the Gulf of Mannar should be given in the information system. The number of organisms living here as per the published information varies from 1000 species to 3600 species. List of organisms available here with their IUCN status should be given. In keeping with the international trend, all the species should be digitized and put in the portal so that the information will be available to any researcher with the click of the mouse. Besides all the research work done in the area so also major initiatives should be available in the system (A to Z of the biosphere).

a) After the sixties, greater proportion of research made was only on commercially important organisms. As all the organism play an important role in the food chain and commercially important organisms can not thrive in the absence of other organisms, research should be done on all the groups of organisms occurring in the GOM (Gulf of Mannar). In particular all the minor phyla should be given more importance. Associated marine life with corals (corallicolous besides corallophilous organisms) should be completely mapped in the biosphere area.

2. Bar-coding of species occurring in Gulf of Mannar Biosphere

The value of bar-coding as a tool in taxonomy is very well appreciated in the international arena. While the usefulness of this is beginning to be perceived with terrestrial faunal groups like birds, it is only now that we have begun even to appreciate its value in taxonomy of marine phyla. Much of the identification of the biota now depends on morphological characters and meristic counts. Moreover the taxonomic expertise is collapsing now- d-day. The limitations inherent in morphology based identification system and the fast dwindling pool of taxonomists signal the need for new approach the document the diversity of organisms occurring in the Gulf of Mannar. DNA based approaches to taxon diagnoses which exploit diversity among DNA sequences can be used to identify marine organisms and resolve taxonomic ambiguities including discovery of new/cryptic species. A workshop conducted in Munich, Germany by April 2002 advocated the use of DNA markers for taxonomic identification of biological species, where a gene fragment of desired variability can be sequenced and analyzed for all species. Working on species specific markers, so many investigators proposed and initiated DNA bar-coding based on mitochondrial cytochrome c oxidase (COI) on global scale. Now by barcoding is being employed in large variety of organisms ranging from yeasts to human beings. Several workers have validated the effectiveness of DNA bar-codes in fish identification. That way it is a must for a precious place as GOM.

3. Biodiversity of sea weed and sea grass associated fauna so also corals and mangroves besides assessing the change in associated fauna due to introduction of Kappaphycus alvarezii

The major international initiative on biodiversity as Census of Marine Life (CoML) has recognized the sea grass and sea weeds as
key stone habitats. These give protection, shelter and food to quite a large number of organism. These should be carefully studied and recorded as they provide food for quite a large number of organisms. Information on phytal fauna in the Gulf of Mannar is woefully meagre and therefore this aspect should be studied in depth. Extensive cultivation of *Kappaphycus alvarezhi* may change the diversity of associated fauna. It should be carefully assessed.

4. **Taxonomic sufficiency for Gulf of Mannar Biosphere Reserve**

This study assumes significance in the backdrop of Sethusamudram Ship Canal Project. To find out the impact of dredging in the Gulf of Mannar, base line data have to be collected before large scale dredging is undertaken. Moreover to find out the impact of dredging very quickly and at the shortest possible time, Taxonomic sufficiency (TS) has to be done.

Taxonomic sufficiency (TS) has gained prominence in biodiversity research and Environmental Impact Assessments. TS is the identification of animal taxa to taxonomic levels higher than species without significant loss of information in detecting changes in faunal assemblages which are exposed to environmental perturbations (Ellis, 1985). In the recent past, TS has been advocated for conservation issues as a tool to estimate the diversity in larger areas and in poorly explored environments. TS, therefore, is a convenient and easy way to assess the effects of perturbation on community structure thereby reducing costs involved in precise taxonomic analyses while allowing voluminous data for spatial and temporal replication of samplings. (Williams and Gaston, 1994; Balmford et al., 2000). The need of TS (Boero, 2001) stems from the widespread demise of taxonomic expertise in marine biodiversity studies, even groups which are widely used in EIA studies are far from being taxonomically well-known. TS, hence, has been proposed not only to detect the community stress but also to estimate the biodiversity in conservation biology, when detailed routine surveys are unfeasible (Vane-Wright et al., 1991; Harper and Hawksworth, 1994 and Cabeza and Moilanen, 2001). In this backdrop, taking into account the utility of TS in biodiversity research and taxonomy and lacunae existing in India with respect to this aspect and its relevance in the GOM in the light of Sethusamudram Ship Canal Project, the present suggestion is made. The outcome of this study will be valuable information on the diversity of organisms associated with corals, mangroves, sea grasses and sea weeds besides information on taxonomic level (TS) which will be useful in finding out the impact on diversity of organisms in due to dredging for deepening the Sethusamudram Ship Canal.

5. **Research on biodiversity and utilisation of stomatopods in GOM and preparation of value added products as additional livelihood options for women empowerment**

Man is showing growing interest in the sea and its inhabitants for varied reasons, the most important one being to meet his animal protein requirements. The sea with vast conventional and non-conventional food organisms hold enough raw materials to do away with proteino-amino deficiency that is afflicting the great majority of people.

Stomatopods constitute an important non-conventional resource in the whole of India, GOM not withstanding. The uses of stomatopods are manifolded. They are very good protein supplements and used as an important ingredient in compounded feeds of prawns. Fish meal plants also manufacture squilla meal which serves as an important raw
material for the manufacture of poultry feed. When landed in large quantities, mantis shrimps are used as a manure. Mantis shrimps contain about 35% flesh and the protein content of flesh is high (45% of dry weight). Now it has been appreciated as a very good food item and relished world over. In India also it is utilised for food purpose in many places. Apart from all these, mantis shrimps can also form a rich source of chitin, chitosan and their derivatives which have a wide range of applications in various fields as photography, Chromatography, paper, film, fibres, food and agriculture and also as textile coagulant, medical adhesive and coatings. At present chitosan which is used in photography is being imported at a cost of 115 US$ per pound, while the raw material available in India is not being properly used.

Inspite of the availability in very large numbers and the versatile manifold uses, mantis shrimps have not received the attention they deserve. Therefore this resource should be utilized properly in GOM. The biodiversity should be studied in depth besides the resource position. It should be popularized in the GOM area and training could be imparted to the fisherwomen on the preparation of value added products for empowering them.

6. Investigations on the stock size of mollusks for rational utilization in shell-craft industry

The use of mollusks in shell-craft industry is in vogue since so many years. Souvenirs prepared here are sent to various markets in India. Whether the exploitation of these organisms for use in shell-craft industry is sustainable should be pondered over very carefully. What is the way out? The stock position of various molluscs should be studied very carefully and the exploitation should be in live with the results of such studies. Also based on biological investigations, minimum size to be exploited should be determined for the entire mollusk species used now.

7. Stock enhancement programmes on endangered organisms in GOM

Some of the organisms as sea horses and sea cucumbers are protected by the Wildlife Protection Act, 1972. As some of the laboratories have developed the technology for mass scale production of these organisms, stock enhancement programmes should be undertaken in GOM. Its utility should be carefully evaluated as GOM can show the way for other protected sites. For developing viable technology for other endangered organisms also these laboratories should be encouraged through way of funding support.

8. Investigation on mangroves

Extensive survey has to be made on the coverage and species diversity of mangrove vegetation in 21 islands. Endangered mangrove species to be identified and restore the species in the natural system. Mangrove plantation to be done in the places which are suitable in 21 islands. The endemic species of coral sand *Pemphis acidula* to be cultivated extensively.

9. Investigations on coral monitoring using remote sensing

Extensive survey of coral reefs has to be made in the 20 islands with special emphasis on the coverage and diversity. Endangered coral species to be identified and research to be done on the rehabilitation of the species. Technology for coral transplantation has to be developed for species level besides the reproductive behaviour of coral species has also to be studied. Remote sensing technology can be applied for quantifying the area of coral reefs and associate ecosystem and for regular monitoring.
10. Global warming/ sea-level rise on Gulf of Mannar Biosphere

Global warming is a very serious problem threatening the biodiversity in the marine realm in general and GOM in particular. Sea level changes in the GOM and their influence on biodiversity should be studied.

11. Starting of diving school to train researchers on underwater studies on corals and other organisms and local youngsters for gainful employment

This is the need of the year. While this will help the researchers effectively in their investigations, younger in the local area can also be taught diving with modern gadgets to undertake investigations and analysis of data with computer aided tools. Now youngsters in Philippines are hired throughout the world to undertake studies on corals. Why not Indians in particular youngsters in Gulf of Mannar Biosphere are where there is a very good need to suggest alternate employment for them.

Conclusion

Gulf of Mannar is a gift of God to Man in particular Indians. It is a veritable environment and a paradise. This wonderful environment we have inherited from our forefathers and we have the solemn and sincere duties to pass on the same to the grandchildren of our children. With respect to research and studies on this beautiful environment, we can remain in isolation. Internationally the studies on corals have progressed far ahead than us. We must also carry out world class studies to remain on par with others countries with respect to protection and conservation of biodiversity and resources in the Gulf of Mannar. For our won good let us do it.

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Research need for Gulf of Mannar


Status of Gulf of Mannar Coral Reefs, India

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ABSTRACT
The Gulf of Mannar Biosphere Reserve (GoMBR) is located between 8° 49’ to 9° 15’ N latitude and 78° 11’ to 79° 15’ E longitude on the southeast coast of India. The status surveys on coral reefs were initiated in 1998 in GoMBR. In the present study (2002-2003) among the three groups viz. Mandapam, Keelakarai and Tuticorin, Keelakarai group showed higher percentage of live coral cover than Mandapam and Tuticorin. The results of the present study showed the following order of dominance of live coral in the coral reefs: coral massive (CM) > coral branching (CB) > coral foliose (CF) > coral encrusting (CE) > Acropora branching (ACB) and > Acropora tabular (ACT). Massive corals (CM) dominated the coral reefs of all the islands with 15.2% and 13.7% cover in 2002 and 2003 respectively. In GoMBR, five species of genus Acropora, one species of Montipora and Pocillopora were recorded. In addition to the above study, the status and diversity of branching corals in the GoMBR were also analyzed from the results. The Line Intercept Transect showed 1.9% and 1.7% of acropora coral branching (ACB); 10.7% and 9.1% coral branching (CB) in 2002 and 2003 respectively. In the present study, genera such as Acropora, Montipora and Pocillopora were found to be severely affected probably due to illegal coral mining, destructive fishing practices and induced sediment settlement caused by seaweed plucking. Selective mining of Pocillopora damicornis has depleted their population.

Keywords: Status Survey, coral reefs, branching corals, Gulf of Mannar, India.

Methods
Depending on the proximity to a major town, the 21 islands of GoMBR were categorized into three groups namely Mandapam, Keelakarai and Tuticorin, each consisting of seven islands (Fig. 1). An average of seven to ten, random 20 m line intercept transects (LIT) were laid at the permanent monitoring sites of each island of GoMBR (English et al 1997). A total of 170 transects were laid each year. Surveys were
not conducted in Velanguchalli and Poovarasampatti islands which are submerged and Kasuwar and Van Islands where the shallow reefs are completely eroded and devoid of any life form. The percentages life form categories were calculated following the method of English et al (1997).

Results

The results of the surveys conducted in three island groups such as Mandapam, Keelakarai and Tuticorin during 2002 and 2003 are given in Fig 2. The transect results on Mandapam group of islands showed 2.5% acropora branching (ACB), 7% coral branching (CB), 5.5% coral foliose (CF), 14% coral massive (CM), 20% dead coral (DC), 2.5% macro algae (MA) and 10% sand in 2002 whereas, in 2003, 3.6% ACB, 7% CB, 11.3% CM, 25% DC and 8% Sand. However, the Keelakarai group of island showed 3.3% ACB, 10.2% CB, 18.7% CM, 19.7% DC and 7.5% Sand in 2002 survey, and in 2003 transect survey showed 1.7% ACB, 10.3% CB, 5.3% CE, 18.9% CM, 20.4% DCA and 5.4% S. The survey on Tuticorin group of islands showed 15.2% CB, 5% CF, 13% CM, 25% DCA and 19.3% S in 2002 and in 2003, 10.25% CB, 3.5% CF, 11% CM 27% DCA and 22% sand (Fig 2).

The average percentage of the life form categories of total survey conducted in the Gulf of Mannar islands in 2002 showed: 1.9% ACB, 10.8% CB, 7.06% CF, 15.2% CM, 16.1% DC and 12.7% S and during 2003 1.76% ACB, 9.2% CB, 7% CF, 14% CM and 17.4% DC (Fig 3).

The survey results of the percentage of live coral cover for all the islands of GoMBR studied was as follows: 47% and 20% in shingle; 24% and 37% in Krusadai; 34% and 45% in Pullivasal; 28% and 34% in Poomarichan; 40% and 37% in Manouliputti; 33.5% and 28% in Manouli; 26% and 26.5% in Hare; 58% and 62.6% in Mulli; 55% and 60.4% in Valai; 41% and 46% in Thalayar; 55% and 38.2% in Appa; 40% and 44.4% in Palliyarmunai; 45% and 46.8% in Anaipar; 39.8% and 39% in Nallathanni; 38.15% and
Fig. 2. Comparison of life form categories of three different groups of GoMBR in 2002 and 2003

Fig. 3. Average life form categories in 21 islands of GoMBR during 2002 and 2003
29% in Puzhuvinichalli; 54.5% and 33% in Upputhanni and 2% and 3.5% in Karaichalli Islands in the years 2002 and 2003 respectively.

During the present study branching coral species such as Acropora, Montiopora and Pocillopora were found to be rare when compared to massive corals (Venkataraman, 2004 a). Branching corals such as Acropora formosa, A. rudis, A. austera, A. florida, A. samoensis, Montipora digitata and Pocillopora damicornis were recorded in the present study (Table 1).

Discussion

The mean percentage of live coral cover of Mandapam, Keelakarai and Tuticorin groups was 33.2%, 49% and 33.8% in 2002 and the percentage was 32.5%, 49.7% and 25.8% in 2003 respectively. The variation of live coral cover for 2002 and 2003 was not prominent. However, during 1998-2002, mean live coral cover in Mandapam group was 36% followed by 16% in Keelakarai and 11% in Tuticorin group of islands (Venkataraman et al 2004 a). From the results of the present study it is apparent that there is an increase in percentage of live coral cover in Keelakarai and Tuticorin group of islands when compared to the results of 1998-2000. The present study included four islands from Tuticorin group such as Nallathanni, Puzhiuvainichalli, Upputhannionly and Karaichalli, where the live coral cover was present. The reason for increased percentage of live coral cover in Keelakarai group in 2002 and 2003 may be attributed to the regeneration of corals. Comparison of 2002 and 2003 live cover studies showed a slight decrease in branching forms in all the islands. This may be due to selective illegal mining of corals such as Pocillopora damicornis (Fig. 4). Branching


<table>
<thead>
<tr>
<th>S.No</th>
<th>Species</th>
<th>Family: Acroporidae</th>
<th>Genus: Montipora de Blainville,1830</th>
<th>MANDAPAM GROUP OF ISLANDS</th>
<th>KEELAKARAI GROUP OF ISLANDS</th>
<th>TUTICORIN GROUP OF ISLANDS</th>
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<tbody>
<tr>
<td>1</td>
<td>M. digitata</td>
<td>(Dana, 1846)</td>
<td>[X]</td>
<td>[X]</td>
<td>[X]</td>
<td>[X]</td>
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<tr>
<td>2</td>
<td>A. formosa</td>
<td>(Linnaeus, 1758)</td>
<td>[X]</td>
<td>[X]</td>
<td>[X]</td>
<td>[X]</td>
</tr>
<tr>
<td>3</td>
<td>A. rudis</td>
<td>(Rehberg, 1892)</td>
<td>[X]</td>
<td>[X]</td>
<td>[X]</td>
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<td>A. austera</td>
<td>(Dana, 1846)</td>
<td>[X]</td>
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<tr>
<td>5</td>
<td>A. florida</td>
<td>(Dana, 1846)</td>
<td>[X]</td>
<td>[X]</td>
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<td>6</td>
<td>A. samoensis</td>
<td>(Brook, 1891)</td>
<td>[X]</td>
<td>[X]</td>
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<tr>
<td>7</td>
<td>P. damicornis</td>
<td>(Linnaeus, 1758)</td>
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corals were meagerly observed in Tuticorin group of islands. This may be due to intense human pressure on the coral reefs such as shore seine operation and trap fishing, which were visually observed during the study period. The reefs of Kasuwar and Van Islands have turned into rubble and dead corals (Venkatarman et al., 2004a) due to intensive illegal coral mining by the locals for commercial purposes. During the present study only massive corals (CM) dominated all the islands of GOMBR reefs with 15.2% and 13.7% cover in 2002 and 2003 respectively.

The following are the live cover of branching forms observed: 1.9% and 1.7% ACB; 10.7% and 9.1% CB in 2002 and 2003 respectively. From the results it is apparent that coral branching (CB) such as Montipora digitata and Pocillopora damicornis were found more as live coral cover than Acropora species (ACB). This may be due to various reasons such as coral mining, siltation due to seaweed plucking, breakage due to walking on the reefs by locals for harvest of marine resources, wave action and trap fishing. Yet another reason for less live cover of branching corals may be due to blast fishing in the Gulf of Mannar reefs (personal observation made from 1998-2003). Pillai (1971) observed most of the shallow reefs of Mandapam group of islands densely covered with massive, foliuse and branching forms. During northeast monsoon, due to wave action most of the shallow reefs are filled with silt and sand, which also kills many of the shallow reef live corals. Coral genera such as Favia, Favites, Goniastrea and Platygyra with large polyps, are capable of removing sand particles deposited on them (Pillai, 1971). Corals with tiny polyps such as Acropora and Montipora require clear water for better survival (Pillai 1971, 1975). Species such as Montipora digitata and Pocillopora damicornis were observed most common in all the islands of Gulf of Mannar.

**Management of the Biosphere Reserve**

The Tamil Nadu State Forest Department implements the management action plan for GoMBR through its wildlife wing. An office of Wildlife warden is functioning at Ramanathapuram (district headquarters and major town close to GoMBR) to manage this area, to protect the reserve and to reduce the pressure from the coastal population depending on the resources of this reserve by implementing a GOI/UNDP/GEF project through the Gulf of Mannar Trust formed by the Tamilnadu State. In order to maximize the benefits to the local community, to generate a sense of stewardship in the
fishing industry, to achieve effective enforcement and to minimize habitat damage, the state fisheries act is also in the process of amendment. Other gaps in the management of GoMBR area are lack of awareness among the local public, limited scope for reducing the ever-increasing population pressure and lack of trained work force for marine protected area management which are expected to be culminated using GoMBR Trust out puts.

Conclusions and Recommendations

There was no status study prior to 1998 of the GoMBR. These studies were initiated by GCRMN South Asia node only during 1997, which helped Zoological Survey of India, Marine Biological Station and Madurai Kamaraj University, Madurai to carry out status studies in GoMBR and the first status studies on the coral reefs of GoMBR was conducted during 1998-2000 (Venkataraman 2000, Venkataraman et al 2003, Venkataraman et al 2004 a). Present studies on status survey (2002-2003) revealed GoMBR reefs showing slight increase in live coral cover especially in Keelakarai group of islands and on the other hand Tuticorin reefs facing permanent damages. Indiscriminate illegal coral mining, sedimentation, erosion and other major threats such as land based pollution (sewage discharge near reef, domestic waste disposal) thermal power plant releases heat, ash etc., may be the direct cause for the less live coral cover. Though there are government initiatives to conserve and manage the GoMBR coral reefs through UNDP-GEF funded Gulf of Mannar Trust and other research projects funded by Ministry of Environment and Forests, Government of India to study the coral reefs of Gulf of Mannar, there seems to be very little awareness among the local community 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 GOMBR. However, the problems of GoMBR coral reefs are more critical than ever before. The following recommendations such as implementation of long-term monitoring programme on coral reefs, capacity building programmes for scientists and managers, education and awareness for local communities, database on coral reef for management, promotion of reef restoration and improvement of socioeconomic status of the coastal population may improve the situation in GoMBR in the future.

Before 1960, the reefs of GoMBR were reported to be in pristine condition due to low level of exploitation of reef resources. The studies conducted during 1998 revealed most of the coral reefs as degraded may be due to over exploitation as well as mortality due to 1998 bleaching. During the present study (2003-2004) the reefs of Keelakari group were observed to be recovering from 1998 bleaching and Mandapam and Tuticorin groups are still to recover from the 1998 bleaching. Tuticorin Islands (Karaichalli, Kasuwar and Van) are suffering due to siltation, erosion and illegal coral mining.

Coral reefs in the GOM Islands are under increasing pressure. Factors such as urbanization, coastal population growth, industrial development, export of coastal resources, lack of trained persons and awareness, habitat degradation, and over exploitation of resources due to mechanized and non mechanized fishing are the known threats to the survival of life support system of the GoMBR. There is less effective implementation of the management plan to mitigate the threats to this ecosystem. Networking among the scientific, government and non-governmental personnel in GoMBR is essential to execute what is really needed. Long-term monitoring of the status of the coral
reefs and socioeconomic status of the people depending on the reefs are the need of the hour. The data gathered on the above lines should form the basis of the management action plan. Collaboration with International organizations on reef and resource management should be taken up on priority basis.

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Coral mining - A bygone threat to Gulf of Mannar

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Introduction

Gulf of Mannar, a unique marine ecosystem often referred to as ecological paradise, extends from Rameswaram in the north to Tuticorin in the south. According to a government survey, there are 21 uninhabited islands, from Mandapam to Tuticorin covering 682.76 hactares. The Gulf of Mannar falls in the Indo-Pacific region, considered the world’s richest in marine biological resources. Nearly 1.03 lakhs tonnes of different types of fishes, prawn, crap and tiger prawn are caught in this Gulf yearly. This fetches annual revenue of rupees 80 crores. Forty four villages containing 1.5 lakhs fishermen families rely on productivity of these marine resources (MSSRF document). The fish production is more in this region than any other coasts in India only because of the presence of complex biological communities coral reefs, seaweeds, sea grasses and mangroves. The Gulf has been chosen as a biosphere reserve primarily because of its biological and ecological uniqueness. The region has a distinctive socio-economic and cultural profile shaped by its geography. It has an ancient maritime history and was famous for the production of pearls, an important item of trade with the Roman Empire as early as the first century A.D.

Fishing has historically been the primary livelihood of the coastal communities here and continues to sustain them, although the damage to the coral reefs constitutes a serious threat to this particular livelihood resource. The region has been and continues to be famous for its production of chank (Indian conch). The Gulf of Mannar thus constitutes a live scientific laboratory of national and international value. It has 3,600 species of plants and animals that make it the biologically richest coastal region in India. It is, course, specially known for corals, of which there are 117 species belonging to 37 genera (Frontline dated 28.03.2000).

Coral reefs, the rain forests of ocean

Coral reefs are a distinctive shoreline habitat of stunning visual appeal found only between latitudes 30?N and 30?S. A unique combination of conditions allows them to support an extremely complex biological community. The myriad shapes and crevices of the hard coral structure offer a shelter to animals. Corals grow only where sea surface temperatures are above 20?C, the seabed is kept silt-free by prevailing currents and waves, and there is intense surface sunlight. Corals do not survive in sediment-laden water, such as near the river discharge. Most living corals do not grow at depths of more that 50m, although some grow at depths of 100m. The Indian and Pacific Oceans have the most extensive corals reefs.

The true reef – building corals are animals that collectively deposit calcium carbonate to build ornate and sometimes large colonies. The polyps of most species remain retracted by day, but at night they protrude their tentacles and sweep the sea for the passing plankton on which they feed with their polyps all protracted corals have a markedly floral appearance. The uniqueness of shapes and colours and the variety of life on a coral reef make the reef an experience that is hard to match on land or elsewhere in the sea.
reefs are considered the most biologically productive and diverse of all natural ecosystems, sometimes supporting as many as 3,000 species. The great number of holes and crevices in a reef provide abundant shelters for fishes and invertebrates, and are important fish nurseries. In addition, highly specialized creatures have become dependent for their survival on the reef environment. It provides a solid substrate for many bottom-living organisms (clams, sponges, tunicates, sea fans, anemones and algae) to settle and grow.

Coral reefs are the most productive marine ecosystems with annual gross production rates in the range of 200 – 5000 g c / m2 / year. Pelagic fish production from coral reefs can be quite high, up to 20 tonnes / km2 / year and heavily fished coraline shelves are able to produce sustained harvests of 4-6 tonnes / km / year. This ecosystem thus deserves to be protected and judicious exploitation of the resources is the need of the hour. Coral reefs are fast degrading due to their commercial viability and hence a thorough understanding of the ecological process and eco-structure is required before any practical management options could be adopted.

Coral reef ecosystem contains a number of specialized species representing the most of the marine organisms and is considered as most diverse in nature. Generally they are grouped into fringing reefs, barrier reefs and atolls. The great number of holes and cervices in the reef provide abundant shelter for fishes and invertebrates. These sites are specific to particular organisms and sometimes, same site may be shared by nocturnal and diurnal species. The reefs corals with their symbiotic algae are the main procedures of organic matter.

The coral reef show their luxuriant growth in shallow clear water where the turbidity is low and sunlight is abundant. Hence their occurrence is confined is confined to the 30?C either side of the equator. These coral reefs play vital role in coastal area protection, in mitigating the effect of cyclones and serve as nursery grounds for fish and other economic species. The most exploited species for ornamental limestone are Porites, Favia, Favites, Goniasteria, Symphillia. The human impact on coral reefs is through dredging, reclamation, mining and sedimentation. These activities reduce illumination, physically interface with feeding and respiration and finally destroy the whole system. In India about 33 genera and 120 species of corals belonging to Acroporidae, Portidae and Faviidae, Acroporous, Seiatopora, Stylopora, Alnepora, Herpolitha, Fungia, Podabassia, Cabophilla, Diploastera have been recorded (MSSRF research document extract).

Coral mining in Tuticorin

In Gulf of Mannar, there are 21 Islands bordered by fringing coral reefs extending from Rameshwaram in the north and Tuticorin in the south. The coral reefs provide shelter to numerous marine organisms. Coral reefs hold the highest number of species in the ocean (Kudla, 1995) and the highest number of families, orders or any higher classification on the entire planet (Throne-Milter & Catena, 1991). This diversity benefits us directly through harvestable food, medicines, raw materials and coastline protection, and indirectly by sustaining the ecological process that provides these resources. Coral reefs are also high productive ecosystem and support large population of organisms, whether measured in numbers or biomass (Williams & Hatchar, 1993; Poulin & Roberts, 1994). For these reasons, coral reefs are considered of great economic importance. Developing tropical countries,
especially small island states, depend heavily on coral reef resources for food from reef fisheries. Environmental degradation from increasing worldwide exploitation of coral reefs has provoked international concern over the fate of reefs as a global resource (Roberts, 1993; Ginsburg, 1994; Sebens, 1994).

Today resource harvest from Indian reefs is it fish food, mining of coral blocks, collection of debris or collection of seashells is only for sustenance of the reef dependent population. In Tuticorin, southern end of the Gulf of Mannar, coral mining in several villages operates severely when wildlife protection act, 1972 is in operation. Before this enactment, the rate of coral mining was slow. At present, the rate of coral mining in Tuticorin coast is on peak. Here in the Tuticorin coast, there are 5 islands which have been under severe threat economically, ecologically and environmentally. Nearly 12 villages are fishing dependent in the Tuticorin coast of the Gulf of Mannar. Among which three villages were involved in coral reef mining activities for their livelihood. Ecosystem dependence for survival is a universal phenomenon, in which ecosystems like coral reefs rank high among coastal populations. Traditional fishermen without much access to modern facilities solely depend on such ecosystem for survival. Corals play a vital part in maintaining the productivity of coastal areas acting as breeding ground, nursery and as habitat for many economically important species. They prevent coastal erosion and control the violent, whirling wind which causes severe damage to fishermen's property. Nearly 3000 population from seven villages depend on coral reefs for their sustenance. Their main livelihood was only coral mining.

History of coral reef mining

Earlier coral reefs were mined extensively along the Tuticorin coast of the Gulf of Mannar to extract coral blocks for house construction. This is evident that some of the old, decaying two storied houses with their plaster worn off revealing the coral blocks with which they are built are a common enough sight on the Gulf of Mannar coast. Even the roads were paved with bleached coral blocks. During 1970, the industrial development was set in Tuticorin, leading to high demand for coral reefs that can be utilized for lime production, acetylene gas production and cem production. With the advent of industrial revolution in Tuticorin, coral reef mining started progressing at an immeasurable rate. After smelling the utilization of coral reefs, several industries plunged in to this business. About 200 years ago, coral mining was stared with tortoise pace without knowing its tangible and intangible benefits. But now the market demand and the price of the reefs have raised the pace of coral mining in the Gulf of Mannar at unpredictable rate. Knowing the ecological value and economic value of the coral reefs, people started thinking of this activity as their main livelihood to earn their regular income as other profession like fishing would fetch uneven income due to seasonality, fluctuation in market demand and unpredictable low fish catch. This is why coral mining is severe in southern part of the Gulf of Mannar than northern part. For the time being fortunately by the stay order issued by Hon’ble Supreme Court, New Delhi vide Item No.32, Court No.2, case No.892636 dt.17.08.05, the coral mining activity has been legally restricted and the mining activity is also totally stopped in Tuticorin coast.

Ecological impact of coral mining

The coral miners know that coral mining is an illegal and it would definitely affect the reef ecosystem and finally the livelihood of fishing communities. This
ecosystem is an important coastal habitat in tropical regions, directly or indirectly supporting subsistence and commercial fisheries. However, they are under threat in developing countries where they are being disturbed by a variety of human activities. The distribution of this ecosystem world invariably affect the coastal productivity and in turn the livelihood of those who depend on it for survival. With most coral reefs situated in the developing world, their importance as a resource is tremendous. The lack of knowledge among fishermen about the role of corals in coastal productivity will make them insensitive to the fragile ecosystem and unknowingly they are using destructive fishing methods to accelerate fish catch efficiently and to save time and effort. Earlier, dynamite fishing was very popular in this region and this method was adopted to blow away coral reef areas, and fish population in this coral reef areas get trapped due to its unconsciousness after dynamite blasting. Due to dynamite blasting, not only coral reef ecosystem gets affected but also the nurseries, breeding grounds as well as the fish productivity get reduced. Coral miners say “the reduction in fish production is not due to coral extraction but the entry of modernized fishing methods like trawler method which are equipped with devices that can smash impediments in their path like corals or rocks and have very fine nets that trawl the sea floor, causing severe damage to the marine ecosystems. Added to this, they say “according to the 1993 Marine Fishing Regulation Act, trawlers can only fish beyond a distance of three nautical miles from the shore. The allegations from the traditional fishing sector are that trawlers routinely violate this rule as the best fish catch is found within that range”. Another group of fishermen opines that the drop in fish production year by year is under the influence of vagaries of monsoon. But in reality, due to coral mining, the extend and circumference of the coral reef fringed island wean away day by day. Fifteen years ago, the Vaan Thivu which was 50 m circumference now is reduced to 6 m only because of coral mining being done by near by villagers. With in five years, this island wuld disappear in the Gulf of Mannar map leaving no sign of its presence in the sea.

Method of coral mining

People from Tharuvaikulam, Tirespuram and Vellpatti assemble in the early morning in the seashore where vallams are anchored. The people who have “vallams” engage five members as their crew to mining operation. All should bring their fork, crow-bar and basket. They leave at 6am in the morning and reach the island where they do mining operation, depending upon the selection of island. People from Tharuvaikulam and vellapatti go to “Vann” and “Karaishalli” islands which have easy access to these villagers. Sometimes they may go to “Pandian” islands which is far off from their villages. If they select those islands which have easy access to their villages, they will reach with in one hour. The select the plee where coral reefs are abundant and there is low tide level. After identifying the coral reefs, they jump into the sea and scrap the sea bed with the help of fork and scoop off the finger corals to the basket that is kept between their legs. This method is continued till they fill the central portion of the vallam which loads about seven gejams (One-half gejam – One tonne). Earlier dynamite blasting was adopted for coral reef mining especially for extraction of coral blocks that were used for house construction. But this method has been dropped out due to low demand of coral blocks and enforcement of Wildlife protection Act, 1972. After declaration of the Gulf of Mannar as National Park and as biosphere reserve, the
act of doing coral mining is an illegal and an offense as punishable under the Act. But the coral miners do continuing their operations without any respect and obedience to the WPA, 1972. **Coral mining gaas a livelihood and sustenance**  
Nearly 100 vallams from Thirespuram go to near by islands for extraction of corals. They collect nearly 4 ½ tonnes in a single vallam. On an average they collect 4 tonnes which fetch around Rs.800 for a single crew. Every member in the crew gets Rs.100 as daily wage. A single crew consists of five members including vallam owner. Every week they have to work for six days and Sunday is off. Out of Rs.800/−, the vallam owner takes Rs.200 plus 100 as diesel charges. Remaining money would be shared between four members. So, every single member gets nearly Rs.100-125/ day as his wage. His monthly income comes around Rs.2600-6000. This income makes him satisfying his needs and wants. The Vallam owner earns around Rs.4800 – 6000. The annual income of the coral mining labourers comes around Rs.31,000 – 36,000. The vallam owner earns around Rs.56,000 – 72,000. But in my perception, the labourers will get around Rs.200-500 per day the vallam owner Rs.500 /day. That is why they were involved in coral mining activities without any thinking of conservation to dome other profession like fishing as it is ingrained and infused into their blood that this would be the better option to lead their life. The vallam owner gets advance money from the agent and does coral mining for six days. In the last day of every week the agents will settle the money based on their collections to some other agents, they would be severely beaten up. Every crew in the vallam collects corals and dumps in the sea shore as heaps. These collections will be collected and transported to Sunnambu kalavai for processing where it is burnt using charcoal, and after burning, they are polished and made into small cubes. Then it is packed in to the containers and transported to big industries of Madurai and Chennai where it is utilized to produce acetylene gas as well as cem production.  
Nearly 220 vallams were operating in these three village were doing coral mining operations. Every vallam was collecting about 4 ½ tones per day. For one week, a single vallam collected about 26 tonnes and 104 tonnes of corals were collected in a single
month. On an average, 1248 tonnes of corals were collected every year in single vallam. In toto, 2,74,560 tonnes of corals were removed from the southern part of the Gulf of Mannar. The agents involved in coral mining incur small investment as wages to the miners and sold the coral reefs at the rate of Rs.1000/- tonnes. So he gained more margin as he has no need of incurring storage cost, and no raw material cost involved as it was illegally exploited through coral miners.

As this business involves no production cost risk, he encouraged these three villagers to do coral reef collection and made them accustomed to this livelihood as it sustained their life through regular earning i.e. Rs.100-125 with in four hours of work. Trapped in the net of indebtedness, they have no second thought of changing their livelihood despite the illegality of their present livelihood.

**Economy of Coral Extraction**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of the Village</th>
<th>Number of Vallam</th>
<th>Quantity of extraction / Day (tonnes) (approximate)</th>
<th>Rate Per ton (approximate)</th>
<th>Revenue (Rs.) (approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Vellapatti</td>
<td>20</td>
<td>90</td>
<td>1,000</td>
<td>90,000</td>
</tr>
<tr>
<td>2.</td>
<td>Thirespuram</td>
<td>100</td>
<td>4500</td>
<td>—</td>
<td>45,00,000</td>
</tr>
<tr>
<td>3.</td>
<td>Tharuvaikulam</td>
<td>100</td>
<td>4500</td>
<td>—</td>
<td>45,00,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>220</td>
<td>9090</td>
<td>1,000</td>
<td>90,90,000</td>
</tr>
</tbody>
</table>

**Conclusions**

As far as coral mining is enclosed, the rate of coral mining increases day by day. As per the survey made in the three prominent villages, people from Vellapatti have reduced the rate of coral mining as they have switched over to crab fishing due to awareness about corals and its role on fish productivity and marine ecosystems. Now people are not continuing with coral mining activities because of the learning from recent Tsunami as well as due to the existence of stay on coral mining by the Honourable Supreme Court vide Item No.32, Court No.2, case No.892636 dt.17.08.05.

Even then the agents involved in coral mining are forcing the fishermen involved in coral mining to indulge in mining and also attempting to get legal clearance to continue with destructive coral mining in future. If this situation continues and the agents get some order favouring their industrial activity, it would be really devastating for the coral eco-system existing in and around Tuticorin. To ensure non-involvement of fisherfolk in destruction of nursery eco-system of fish resources in Gulf of Mannar Biosphere Reserve Trust should take encouraging efforts in providing necessary infrastructural support to fishermen in converting their vocation to deep sea fishing. Intensive awareness programmes have to be organized to fisherfolk to educate them about the importance of coral eco-system as well as the role in protecting the coral bio-diversity in addition feasible alternative livelihood opportunities for the affected group should be supported and the pressure on coral mining has to be totally
removed for ever. In addition district administration has to take special efforts in directing the lime industry to change their raw material to lime forms found in terrestrial area. Providing soft loans for purchase of boats and nets to the affected fishermen will act as effective remedy for switching their vocation to harmless legally permitted fishing practices. Unless the concern for conservation is ploughed and nurtured in the minds of fisherfolk involved in various destructive activities in Gulf of Mannar, achieving the goal of conservation and sustainable use of marine resources in Gulf of Mannar will only be a dream. In the recent times the initiatives taken by Trust in organizing Gulf of Mannar dependent fishing villages as responsible conservation groups through formation of eco-development committees is a viable action towards establishing better conservation network at village level in the Gulf of Mannar coastal areas. It is hoped that this effort will convince fisher public in understanding their marine bio-diversity, its biological and ecological importance and their duties and responsibilities in conserving this resource.

References cited
8. MSSRF Research document extract
Role of mangroves in coastal protection, fishery productivity and resilience of reefs in the Gulf of Mannar Marine Biosphere Reserve

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ABSTRACT
Mangrove forests are biologically diverse, ecologically vigorous and exceedingly valuable systems. Many efforts have been made in the last 2-decades for conservation and management of the Gulf of Mannar Marine Biosphere Reserve. However, there is no adequate scientific data available on biodiversity status, merits and demerits of the action taken on conservation of mangrove resources of the area. Hence, it is necessary to assess the current situation for taking action in identified gap areas of mangrove ecology, biodiversity, restoration and coastal protection.

Introduction
Mangroves are trees and shrub species that grow at the interface between land and sea in tropical, subtropical latitudes where the plants exist in conditions of salinity, tidal water flow and muddy soil. The vegetation creates unique ecological environments that host rich assemblages of species. The mangrove ecosystems in Tamil Nadu alone comprise 893 biological species (Kathiresan, 2004). This biological diversity is due to its structural complexities of the mangrove habitats that provide ecological niches for a variety of organisms. The mangroves are critical for sustaining biodiversity. As a detritus-based ecosystem, leaf litter from the mangroves provides the basis for adjacent aquatic and terrestrial food webs. It also serves as breeding, feeding and nurseries grounds for most of the commercial fishes and crustaceans on which thousands of people depend for their livelihood. Besides supporting coastal fishing stock, the mangroves also benefit human economic development by stabilizing shorelines affected by tropical storms, hurricanes and natural calamities. The mangrove system plays a major role in the global cycle of carbon, nitrogen as well as sulphur and acts as reservoirs of waste materials (Kathiresan and Bingham, 2001; Kathiresan and Rajendran 2005; Kathiresan and Qasim 2005). Considering the importance, status of mangrove resources in the Gulf of Mannar islands is discussed here.

1. Mangroves in Gulf of Mannar
It is believed that the Gulf of Mannar was once covered with thick mangrove forests. Their remnants as relics are seen even now (Krishnamurthy et al., 1987). Iyengar (1927, see Krishnamurthy, 1987) also observed a luxuriant and diversified vegetation on Krusadai island with Avicennia officinalis, Excoecaria agallocha, Bruguiera cylindrica, Ceriops tagal and Lumnitzera recemosa. Rao et al. (1963 a, b) noticed only small patches of mangrove on Pamban, Rameswaram and other islands in the Gulf of Mannar. Later records also registered only stunted stands of Avicennia marina, Excoecaria agallocha Rhizophora conjucata (R. apiculata), C. tagal, A. alba, Bruguiera conjucata (B. cylindrica) etc. (Blasco 1975; Krishnamoothy et al, 1987). Gopal and Krishnamoorthy (1993) have mentioned only four mangrove species, which
Mangroves occur in the Gulf of Mannar: *R. conjucata, A.alba, C. tagal* and *E. agallocha*. According to Perichiappan et al. (1995) there are 13 species of mangrove and other halophytes recorded from 8 islands of Mandapam group. Daniel of Botanical survey of India (1997) recorded mangrove plants to be present in all islands of the Gulf of Mannar, except Annaipar, Appa, Karaichalli, Nallathanni, Puluvinchalli, Valimunai and Van islands. The Mandapam group of islands showed that maximum number of species viz., *Aegiceras corniculatum, Avicennia marina, Bruguiera cylindrica, Excoecaria agallocha Lumnitzera racemosa, Rhizophora apiculata*. *Excoecaria agallocha* occurs only in the Mandapam groups of islands; *Avicennia marina* is luxuriant in the Mandapam group of islands and is only shrubby in other islands (Daniel, 1997).

### 1.1. Extent of mangroves

Of the 21 islands, 11 are colonized with luxuriant mangrove ecosystems with total area of 1095.94 hectares. Area wise extent of mangroves is given in Table 1.

Table 1. Natural mangrove vegetation along the coast of the Gulf of Mannar islands

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of the area</th>
<th>Island area (in hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kurusadai island</td>
<td>65.80</td>
</tr>
<tr>
<td>2</td>
<td>Pullivasal island</td>
<td>29.95</td>
</tr>
<tr>
<td>3</td>
<td>Pommarichan island</td>
<td>16.58</td>
</tr>
<tr>
<td>4</td>
<td>Manoliputti island</td>
<td>2.34</td>
</tr>
<tr>
<td>5</td>
<td>Manoli island</td>
<td>16.58</td>
</tr>
<tr>
<td>6</td>
<td>Hare island I</td>
<td>29.04</td>
</tr>
<tr>
<td>7</td>
<td>Mullai island</td>
<td>10.20</td>
</tr>
<tr>
<td>8</td>
<td>Valai island</td>
<td>10.15</td>
</tr>
<tr>
<td>9</td>
<td>Talaiari island</td>
<td>75.15</td>
</tr>
<tr>
<td>10</td>
<td>Appa island</td>
<td>28.63</td>
</tr>
<tr>
<td>11</td>
<td>Nalla Thanni island</td>
<td>110.00</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>1095.94</strong></td>
</tr>
</tbody>
</table>

### 1.2. Biodiversity of mangroves:

About 11 species of mangroves are widely distributed in the islands of Gulf of Mannar (Daniel, 1997; Kathiresan and Rajendran, 1998). Most of the mangrove species are under threat (Table 2). Other biological species reported so far are only incomplete (Table 3).

Table 2. Describes the status of Mangroves of Gulf of Mannar (Kathiresan and Rajendran, 1998)

<table>
<thead>
<tr>
<th>No</th>
<th>Name of mangroves</th>
<th>Status (based on IUCN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Aegiceras corniculatum</em></td>
<td>Critically endangered, exist only in Kurusadai island</td>
</tr>
<tr>
<td>2</td>
<td><em>Avicennia marina</em></td>
<td>Vulnerable, stunted growth in all islands except in Mandapam groups of islands and Kundukal island</td>
</tr>
<tr>
<td>3</td>
<td><em>Bruguiera cylindrica</em></td>
<td>Endangered</td>
</tr>
<tr>
<td>4</td>
<td><em>Excoecaria agallocha</em></td>
<td>Critically endangered, exist only in the Mandapam groups of islands</td>
</tr>
<tr>
<td>5</td>
<td><em>Lumnitzera racemosa</em></td>
<td>Endangered</td>
</tr>
<tr>
<td>6</td>
<td><em>Rhizophora apiculata</em></td>
<td>Critically endangered, exist only in Kurusadai island</td>
</tr>
<tr>
<td>7</td>
<td><em>R. mucronata</em></td>
<td>Critically endangered, exist only in Kurusadai and Mandapam groups of islands</td>
</tr>
</tbody>
</table>

Table 3. Biodiversity status of the region

<table>
<thead>
<tr>
<th>Biological group</th>
<th>No. of species</th>
<th>Author, year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total heterotrophic bacteria</td>
<td>35</td>
<td>Kannan et al., 1998</td>
</tr>
<tr>
<td>Phytoplankton</td>
<td>126</td>
<td>-do-</td>
</tr>
<tr>
<td>Seaweeds</td>
<td>36</td>
<td>Kathiresan and Rajendran, 1998</td>
</tr>
<tr>
<td>Mangroves</td>
<td>8</td>
<td>-do-</td>
</tr>
<tr>
<td>Annelides</td>
<td>6</td>
<td>Ramaiyan et al., 1996</td>
</tr>
<tr>
<td>Gastropods</td>
<td>60</td>
<td>-do-</td>
</tr>
<tr>
<td>Bivalves</td>
<td>20</td>
<td>-do-</td>
</tr>
<tr>
<td>Crabs</td>
<td>38</td>
<td>-do-</td>
</tr>
<tr>
<td>Shrimp</td>
<td>4</td>
<td>-do-</td>
</tr>
<tr>
<td>Finfish</td>
<td>60</td>
<td>-do-</td>
</tr>
</tbody>
</table>
1.3. Gap area to be focused:

Proper survey of mangrove resources in the islands is not yet carried out. Data are not at all adequate on the vegetation characteristics such as species composition, distribution, height and density; biodiversity status of each species, their habitat characteristics such as soil texture, composition, salinity, pH, nutrients and trace elements; their environmental characteristics such as rainfall, wind speed, evapo-transpiration, tidal characteristics etc; and, threat factors in those mangrove-colonized islands. In absence of these data, conservation and management of the mangrove resources is difficult.

2. Mangrove restoration

The forestry sector has taken up mangrove regeneration work in the areas from 1994 onwards in Manoli, Manoliputti, Hare Island and Thalayari Island.

2.1. Gap area to be focused:

There is a need to evaluate the restoration activity to bring out the reasons for success and failure of the work carried out so far. Impact of the mangrove plantation to adjacent territorial trees such as coconut, palmyra and other trees in islands requires to be understood.

3. Biodiversity conservation

The Gulf of Mannar Marine Biosphere Reserve is unique to have very rare mangrove species. One such is Pemphis acidula which is endemic to Peninsular India and restricted to coral sand of open sea-face of Manauli, Manauliputti, Poomarichan islands, Hare islands etc.

3.1. Gap area to be focused:

Pemphis acidula grows only in coral sand soil. This unique habitat specificity requires research on its physiology. The rare species has to be studied for their floral biology, reproduction and vegetative propagation.

4. Fishery resources

Mangroves support coastal fish resources. There is possibly an interaction among the fishes of mangroves, coral reefs and seagrass communities. A recent study reveals that mangroves enhance the biomass of coral reef fish in the Caribbean. Current rate of mangrove deforestation are likely to have severe deleterious consequences for fishery productivity and resilience of reefs (Mumbe et al., 2004).

4.1. Gap area to be focused:

The function of island mangroves on coral reef fishes has to be understood.

5. Coastal protection functions of mangroves

The mangroves do function as a ‘bio-shield’ against sea waves, coastal erosion and natural calamities (Kathiresan and Rajendran, 2005). They help in island building and in protecting the coral reefs and seagrass systems from turbidization of coastal waters. The absence and/or deforestation of mangroves causes erosion of island periphery that enhances the water turbidity, attenuates the light penetration and photosynthetic process and that negatively affects the seagrass and coral reef system.

5.1. Gap area to be focused:

The vital functions on coastal protection have not been properly understood for the Gulf of Mannar Marine Biosphere Reserve. This is highly warranted in the context of a prediction that another giant wave is likely to strike off the Indian Ocean region within 30 years (Borrero, 2006).

Suggestions

The following suggestions are made for mangrove resources and their conservation
in the Gulf of Mannar areas:
1. To collect data on the ecological and biological aspects of mangrove resources;
2. To understand the functions of the mangroves on island building, protection and fishery enrichment;
3. To assess the mangrove restoration activities;
4. To propose techniques for restoration and rehabilitation of mangroves especially for *Pemphis acidula* in potential and/or degraded areas;
5. To impart education, awareness creation, technology transfer through training for conservation and management of mangrove resources; and,
6. To provide guidelines on further improvement of mangrove ecosystems.

**Acknowledgements**

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**References cited**

15. Hindustan Publishing Corporation (India), New Delhi, 251 pp.


Introduction

The mangrove ecosystem being the interphase between terrestrial forests and aquatic marine ecosystems it includes diversified macro habitats such as mangrove dominant forests, litter laden forest floors, mudflats, adjacent coral reefs and contiguous water courses which may be rivers estuaries, bays, inter-tidal waters and channels and backwaters. Thus, this ecosystem offers innumerable microhabitats for large number of species. In recent years nature conservation of mangrove reserves and habitats has assumed great significance in developing countries in the context of the role of conservation in socio-economic development and the recognition of its functional role. The other values attached to this aesthetic and cultural.

Mangroves are the salt tolerant forest ecosystems distributed mainly in tropical and sub-tropical inter-tidal regions of the world. They consist of coastal wetlands; swamps, forestland within and water spread areas. In the mangroves along the coastline various species of marine organisms get themselves adapted to grow under the influence of both salt and brackish water. Mangrove resources/areas are used as a breeding and nursery grounds for many aquatic organisms. The importance of mangrove resources which provides high potential for fisheries and collection of seeds of cultivable and economically important fin fishes and shellfishes for aquaculture in addition for reducing coastal erosion.

The mangroves grow luxuriantly in alluvial soil substrates, which are fine textured, loose mud or silt, rich in humus and sulphides and they develop in low lying and broad coastal plains where the topographic gradients are very small and tidal amplitude is large. Their distribution is limited by temperature and they prefer moist atmosphere and freshwater inflow, which brings in abundance nutrients and silts from terrestrial source. The mangroves occur in sheltered shores as waves and currents damage the mangrove seedlings. Repeatedly flooded but well drained soils support good growth of mangroves, but impeded drainage is detrimental.

In India mangroves are distributed in about 6,470 sq.km that constituted 7% of the world mangroves and 8% of total Indian Coastline. The area-wise distribution of mangrove forests in India has been reviewed. Status of mangroves along the Arabian Sea has been reviewed. There are three different types of mangroves in India viz., deltaic, backwater-estuarine and insular categories. The deltaic mangroves occur on east coast (Bay of Bengal) where the mighty rivers make deltas. The backwater-estuarine type of mangroves exist in the west coast (Arabian sea) which is characterized by typical funnel shaped estuaries of major rivers (Indus, Narmada and Tapti) or backwaters, creeks and neritic inlets. The insular mangroves are present in Andaman and Nicobar Islands where many tidal estuaries, small rivers, neritic islets and lagoons which support a rich mangrove flora.
Of the Country’s total area under the mangrove vegetation 70% was recorded on the east coast, and on the west coast 12%. The bay islands (Anadaman and Nicobars) account for 18% of the Country’s total mangrove area. The mangroves have a vast existence on the east coast of India due to nutrient rich alluvial soil formed by rivers- Ganga, Brahmaputra, Mahanadhi, Godavari, Krishna and Cauvery and perennial supply of freshwater along the deltaic coast. But, the deltas with alluvial deposits are almost absent on the west coast of India, only funnel shaped estuaries or backwaters are present.

In India mangroves comprise approximately 59 species of higher plants from 41 genera belonging to 29 families. Of these, 32 species belonging to 24 genera and 20 families are present along the west coast. The species viz., Sonneratia caseolaris, Suaeda fruticosa, Urochondra setulosa have been reported only from west coast. The east coast of India and Andaman and Nicobar islands show high species diversity. There are 45 species in 27 genera of mangroves in the bay islands. The species like Ceriops decandra, Xylocarpus spp., Lumnitzera littorea and Nypa fruticans, Phoenix paludosa, Cerbera manghas are limited to east coast. The common species in India coastline are Rizophora mucronata, Ceriops tagal, Bruguiera gymnorrhiza, Lumnitzera racemosa, Sonneratia apetala, acanthus ilicifolius, Avicennia marina, A.officinalis, Excoecaria agallocha and Acrostichum aureum. Totally 37 species of exclusive mangroves and about 25 associated species occur in the coastal and inland regions.

In Tamilnadu mangroves exist on the Cauvery deltaic areas. Pichavaram has well-developed mangrove forest dominant with Rizophora spp., Avicennia marina, Excoecaria agallocha, Brugaiera cylindrica, Lumnitzera racemosa, Ceriops decandra and Aegiceras corniculatum. Mangroves also occur near Vedaranyam, Kodaikarai (Point Calimere), Muthupet, Chathram and Tuticorin.

Depletion of mangrove covers in some of the islands of Gulf of Mannar by the onslaught of other interest groups might not only threaten the habitat for many species of fisheries and birds but would result in ecological imbalance. Hence taking proper steps on that people’s participation support, which is very essential for the conservation and management of mangroves, should mitigate the pressure on the mangrove cover. Due to the conflicts, use with the coastal zone related island ecosystems of Gulf of Mannar and surrounding habitats are being increasingly tampered with on behalf of activities such as commercial fishing, navigation, energy exploitation, national defense, recreation and quarrying for industrial needs. Thus conservation of habitats will thus turnout to be the most biologically non-destructive means of reaching “Zero habitat loss”. Public opinion, participation in protecting nature and endangered species run high. Hence, the status on mangrove habitats in the island ecosystem of Gulf of Mannar region will help in the formation of future suitable monitoring strategies for conservation and management.

**Distribution of mangroves in India**

The world’s total mangrove area which spans over 30 countries including those for the various island nations is about 1,00,000 sq.km. The total area of the Indian mangroves estimated at 6,81,976 hectares of which nearly 45% occurs in Sunderbans and the islands in the Bay of Bengal. Other important mangroves are killai and Pichavaram and Gulf of Mannar islands in Tamil Nadu, state of Kerala, Karnataka, Gulf of Kutch and Andaman and Nicobar islands. The Andaman – Nicobar islands contain some of the least distributed
and best preserved mangroves. The Andaman-Nicobar islands have about 1,190 sq.km. area of mangroves. Here, the forests are gregarious type, dominated by single species. The Sunderbans formed in the vast delta complex of the Ganga and Brahmaputra river systems are usually described as the largest single natural mangrove block having an area of 4,170 sq.km. in W.Bengal. It is noteworthy that today, in Kerala, there is no dense mangrove forest in spite of its generally very heavy rainfall as compared to other states of the west coast of India. It is contrary to general rule that the maximum development of mangroves is in the regions with heavy rainfall. Tidal currents and freshwater supply influence the physio-chemical factors in the mangrove estuarine systems to govern the distribution and zonation of mangrove species, of which temperature and salinity of the ecosystem appear to be important factors.

On the basis of the height of the vegetation, 3 categories of forest stratification can be observed in a normal mangrove ecosystem. The widest trunk with spreading crown is found in species of *Sonneratia* and *Avicennia* and less spreading crown found in species of *Bruguiera* and *Rizophora*, which constitute the top canopy of the forest. The Second category is contributed by shrubs and small trees represented by species of *Agecero*, *Exoecaria* and *Ceriops*. Small shrubs and ferns such as of *Acanthus*, *Aegiolitis* and *Acrostichum* occupy the third one. Globally, mangrove ecosystems are thought to contain about sixty species of true mangrove trees and shrubs and more than 20 additional species frequently associated with the mangrove flora. They exhibit a remarkable capacity for salt tolerance and hence they are physiological halophytes. The leaves possess halophilous properties with thick cuticle, large mucilage cells etc. The formation of buttress and stilt roots and vertical pneumatophores are characteristic adaptations. The composition of the mangrove species changes with depth, salinity, wave action, intertidal exposure etc. Diversity in the structural formation and zonation of mangrove forests can be witnessed along the latitudinal gradients and probably also along the longitudinal gradients that reflect climatic, especially rainfall gradients. Across the latitudinal gradients, air temperature and across the longitudinal gradients, water, soil fertility appears to be the most important factors in determining the growth patterns of mangrove populations.

**Influence of mangroves on flora and fauna assemblage**

Mangrove systems are among the most productive natural ecosystems on the earth. The sources primary productivity are the mangrove vegetation themselves, algal colonies associated with the mangrove root surfaces and the moist forest floor and the phytoplankton communities in the associated bay and lagoons. Algae observed in the inter-tidal regions of mangroves are very rich and diverse in both quality and quantity. The benthic algae of the mud surface are represented by the green filamentous species of *Entromorpha*, *Rizocolonium*, *Monostroma* and *ulva*. The mangrove environment provides living space for a dependent biota of more than two thousand species of flora and fauna of resident, semi-resident or migratory mode of life. The mangrove associated fauna, being a composite of terrestrial, estuarine and marine organisms constituting representatives of almost all invertebrates phyla and fishes have to face numerous interactions between animals of terrestrial and aquatic biotopes. As such, the mangrove fauna with its lower species diversity but relatively large number of individuals is highly characteristic in nature. The primary food source for aquatic organisms
in most mangrove-dominated estuaries occurs in the form of particulate organic matter (detritus) derived chiefly from decomposition of mangrove litter fall. The annual litter fall normally ranges from 10,000 to 14,000 kg dry weight per hectare. Dissolved organic compounds of mangrove region provide an additional source of nutrition. The predators feed on the detritus feeders and form important food source for both aquatic as well as terrestrial wild life in addition to forming food resource for human beings.

Mangrove support rich faunal resources. Among invertebrates, more than 500 species of insects and Arachnida, 229 species of crustacea, 21 species of mollusces, 50 species of nematodes, and 150 species of planktonic and benthic organisms are known from Indian mangroves. Vertebrate fauna are represented by 300 species of fish, 177 species of birds, 36 species of mammals and 22 species of reptiles. Recently, 41 species of invertebrates and 52 species of fishes of Indian mangroves have been assessed and four species of invertebrates and only one species of fish have been categorized as endangered. It has been estimated that yield of mangrove-cum-estuarine dependent fisheries of India to the tune of 30,000 tonnes of crustaceans per annum. Roughly about 60% of Indian coastal marine fish species are dependent on the mangrove estuarine complex. Some of the most common fishes of mangroves are species of *Liza*, *Mugil*, *Polynemus*, *Ilisha* and *Etropus*. Prawns are represented by species of *Penaeus* and *Metapenaeus* while mollusk resource are species of *Crassostrea*, *Meretrix*, *Telescopium* and *Cerethedia*.

**Environmental characteristics in the mangrove habitats**

There are five important factors that influence mangroves, namely, temperature, salinity, tides, rainfall and winds; each having its own effect. Temperature influences the development and survival of the mangroves in the early stages. Salinity determines the distribution and zonation of the species within the ecosystem since each species has got its salinity tolerance. Tides act jointly with salinity in the dispersion and zonation; and the tidal amplitude determines the landward extension of the mangroves. Rainfall is important in the zonation of mangroves on flat coasts and the productivity of the mangrove ecosystem is elated to the frequency and volume of fresh-water supply by rainfall. Wind is important in regulating the seasonality of litter fall, which is the major pathway of energy from terrestrial, to aquatic system. Mangrove colonize on variety of substrata that include silty and clayey mud, calcareous mud, quartz sand, calcareous sand or mixture of these. Occasionally they may colonize coastal coral reef as well as cracks and hollows of rocky substrata. They prefer sediments that have been brought by rainwater or transported by tidal currents. The mangrove soils are generally slightly acidic. The anaerobic condition in the soils helps sulphate-reducing bacteria to produce hydrogen sulphide. The characteristic black or grey colour of the soil is due to reduction of ferric compounds to ferrous sulphides.

In general atmospheric mean temperature of most mangrove habitats in the Bay of Bengal varies from 29- 33°C while surface soil temperature ranges from 30- 34°C and surface water temperature from 28-33°C. Salinity of mangroves fluctuates considerably ranging from 3 to 33 ppt. The pH of the water fluctuates from 6.5 to 8.0 and dissolved oxygen content usually very low ranging from 1.7 to 3.8 mg/l. However in the seaside, it may reach even 10mg/l. The primary productivity of the mangrove water is very high. The
productivity rates from 0.2 to 0.8g C/ml/day in northern Andaman, slightly higher values from 0.5 to 1.0g C/m$^3$/day in the shallow mud flats and mangroves of Car Nicobar and higher productivity rates from 2.0 to 3.6mg C/m$^3$/day in and around the mangroves of Port Blair. In recent years, the mangrove environment is getting polluted with different kind of effluents and other contaminants from the factories and industrial wastes. Heavy metals pose a serious problem due to their environmental persistence and toxicity to aquatic organisms even at lower concentration. Hence, it is very important to monitor heavy metal pollution by taking suitable managerial measures to protect the valuable mangrove resources: Increase human pressure for domestic needs and development of industries are virtually destroyed large areas of virgin mangroves all over world. Reclamation of mangroves for housing, agriculture and salt evaporation site, grazing of cattle, removal for fuel, sewage discharge with high BOD, discharge of industrial effluents an excessive release of pesticides and aquaculture practices have threatened most of the mangroves and some are in h verge of extinction. The degraded area need to be restocked and fresh mud-flats need to be afforested with suitable mangroves. Silvicultural techniques like regeneration, restoration and afforestation of mangroves can be the only answer to these problems.

Like any other types of forests, mangroves form the national wealth of a nation. Timber produced from mangrove is of great value. Wood *Rhizophora* is used for boat building, which is resistance to termites and boring animals. Mangrove trees are used as wood or for charcoal. Mangroves are main source of tannin industry once but now gradually replaced by synthetic tannin. A black dye is also extracted from the bark of mangrove trees. Seeds of *Cerebra odlin* are poisonous and fish poisons are extracted from it. Mangroves are good breeding and feeding ground for variety of fishes and prawns. It provides nutrition for various aquatic organisms through recycling of plant and animal remains.

Aquaculture practices in the mangrove sites of many countries are flourishing even now. Protection of birds sanctuaries and endangered species of wild life (crocodiles and tigers) is the other important aspects of mangroves. Mangrove ecosystems, with their variety of subhabitats, offer range of recreational opportunities such as boating, hunting, bird watching, wild life observation, education trips for specimen collections, photography etc. A part from these, fishery activities (culture and capture) in many coastal regions of the tropics are highly dependent upon the mangrove-dominated estuaries. Aquaculture in mangroves signifies a case of necessity rather than suitability. In specific cases of aquaculture in the mangrove ecosystem economic and social benefits may outweigh management problems. A major part of primary production enters the mangrove food-web a dead organic ecosystem or transported into adjoining water body in a degraded form and the estuaries and backwaters fringed by mangroves have long been used for rearing or flattening of bivalves, prawns and fishes.

**Mangrove ecosystems of Gulf of Mannar islands, Tamil Nadu**

A survey on the distribution of various species of mangroves in Shingle, krushadi, Poomarichan, Manoli-putti, manoli, Here, Muli, Poovarasanpatti, Anaipar, Upputhanni, kasuwar, Valai, appa, Nallathanni, Karaihalli, Vantivu, Talayari, Valimunai, Puluvinichalli, Vilanguchalli and...
Rameswaram islands of Gulf of Mannar was conducted during January 1995- December 1997. The various species of mangroves such as *Avicennia marina*, *Rhizophora mucronata*, *Bruguiera cylindrica*, *Ceriops decandrus*, *Lumnitzera racemosa*, *Exoecaria agallocha* and *Suaeda spp.*, are distributed in these selected islands surveyed. It may be revealed that Krushadai, Manoli and Poomarichan islands are found to be more productive in mangroves vegetation when compared to other islands of Gulf of Mannar. Survey on fish and prawn seed resources was undertaken in the mangrove areas of selected islands and Rameswaram (Pamban) to find out the influence of mangroves on the seed abundance of fish and prawns in the non-mangrove areas i.e., marine habitat of the above islands was carried out for comparative studies.

**Management strategies for conservation of mangroves**

In India mangroves are under pressure due to increasing population, development of ports, saltpan and aquaculture, dumping of industrial wastes and affluent, development of fertilizer plants and exploitation for petrochemical activities. Conservation of mangrove areas for aquaculture and residential purposes is also leading to loss of his important ecosystem. Based on the above observations, a concentrated and co-coordinated effort is necessary to undertake management measures to conserve these natural resources. With view to prevent further destruction of mangrove forest, it s felt that an integrated the first step towards achieving this goal. The conservation of mangrove habitats has attained great significance in developing countries in context of its functional role in ecological and socio-economical sustainable development.

i. Need for rapid expansion in taxonomy in order to interpret, manage, conserve and use biodiversity/mangrove sustainability and the need to pool together the existing data from all sources by farming an information network of all agencies in the country.

ii. Priority for the mangrove conservation/biodiversity to be given to the important genes, species and habitats.

iii. Improve the methodologies for different programme, evolve more effective policy and target with priority.

iv. Practice of the conservation/biodiversity programme with precise definition and clear targets.

v. Recognition of the traditional rights of coastal communities to use the natural resources in their surrounding natural habitats for their livelihood while formulating and implementing regulations and conservation measures on priority basis.

vi. Application of anthropogenic objectives of maintaining biodiversity of mangroves so that it is possible value to the mankind.

vii. Integration of all elements of management, from planning and design to implementation, that is, construction and installation, operation and maintenance, monitoring and feedback and evaluation over time.

viii. Integration of management resources of the agencies and entities involved.

**Recommendations**

1. Priority should be given to the little known species of mangroves for propagation.

2. Preparation of distributional maps of each species could be considered.

3. Preparation of a list of endangered and threatened genera and species of genetic, ecological, economical and social significance with their status and perceived threats to them with a view to make them target species for conservation.
Present status on conservation and management of mangrove habitats in the islands of Gulf of Mannar region

5. Identification of suitable sites to pave the way for planting green mangrove coverage/ Propagation.
6. Environmental monitoring in existing mangrove areas of the islands of Gulf of Mannar should be considered.
7. Conservation efforts to be prioritized based on the available expertise and information depending on species representation, richness, uniqueness, endemism and threat to a gene pool.
8. Mangrove species of global significance both in ecological and economic value need to be identified in the region and threat such species need to be looked into.
9. Threats to the mangrove resources and the root causes for it need to be identified for each level both at micro and macro level. This should include both anthropogenic and natural factors.
10. The impact of environmental and human interference (Pollution, Sea erosion, over exploitation and pathogenic conditions) on marine flora and fauna of Biosphere of Gulf of Mannar need to be assessed.
11. Institutional mechanisms must be ensured on the management of resources, environmental factors affecting the resources and social obligation and mobilization needed for the conservation and sustainable utilization of resources.
12. The Institutional set up between the government agencies, research institutes, local bodies, non-governmental organization and environmentalists need to be strengthened.

Bibliography


Introduction

It is estimated that there are 15000 species of sponges living in the marine and freshwater habitats worldwide (Hooper and Van Soest, 2002). Among the various orders of sponges, the siliceous sponges constitute the bulk with about 90% of the total number of species. Thus, species belonging to this order are distributed well in the inshore areas of the sea and hence are commonly used for chemical studies world over.

As evidenced in the latest estimates, the Indian sponge fauna is known only at a 40% level. Comparatively very little systematic work has been done on the shallow water marine sponge fauna of peninsular India along the east coast (Madras & Chilka Lake) which were investigated to some extent by Dendy (1887) and Ali (1954, 1956). The major studies dealing with the deep sea sponge fauna of the Bay of Bengal are those of Dendy and Burton (1926) and Burton (1928). The fauna of the Chilka Lake in Orissa state was investigated by Annandale (1914, 1915). A total record of 275 species from 8 orders, 38 families and 136 genera were recorded by Thomas (1985). More effort is needed to enumerate the sponge fauna fully and this is urgently required for all the lower invertebrates as they are not properly studied or documented yet.

The main objective of the present work is to record the distribution of marine sponges available in the southeast Indian coast which was undertaken for three years since October 1999 as a part of the first author’s PhD thesis. The basic data for the present study were collected from the following centres: Kanyakumari, Chinnamuttom, Arokiapuram and Hare, Manauli and Kurusadi islands in Gulf of Mannar.

Materials and Methods

The materials for the present study were collected at a depth of 2-25m by wading, SCUBA diving, dredging and beach combing. Classification and specimen identification were done following Hooper and Van Soest (2002). The specimens were preserved in 70% alcohol and deposited in IERSE museum.

Results

Out of the 13 orders of the class Demospongiae, 6 orders are represented in the present study. It is generally seen from any collection of demosponges from the world oceans that the number of species of the order Poecilosclerida is highest. However in the present collection, a total number of 50 species belonging to 6 orders, 16 families, and 28 genera, were collected out of which orders Dictyoceratida and Haplosclerida dominates with 14 species, followed by Poecilosclerida with 11 species, Halichondrida with 8 species, Dendroceratida with 2 species and Hadromerida with one species. Number of families, genera and species encountered are given in Table 1 and the distribution details in Table 2.

Discussion

This study shows that Gulf of Mannar contains a diverse sponge fauna comprising of more species of the order Dictyoceratida and Haplosclerida along the shallow reef
Table 1. Number of orders, families, genera & species in the present collection

<table>
<thead>
<tr>
<th>S.No</th>
<th>Order</th>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Hadromerida</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Poecilosclerida</td>
<td>4</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>Halichondrida</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Haplosclerida</td>
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<td>4</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>Dictyoceratida</td>
<td>4</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>Dendroceratida</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
<td><strong>28</strong></td>
<td><strong>50</strong></td>
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Table 2. Distribution details of the sponges collected for the study

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<td>Hadromerida: Cliona (Dendy, 1905)</td>
<td>Hare and Kurusadi Island</td>
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<td>Poecilosclerida: Antho (Acarnia) (Carter, 1880)</td>
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<td>3</td>
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</tr>
<tr>
<td>4</td>
<td>“: Clathria (Thalysias) vulpina (Lamarck, 1813)</td>
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</tr>
<tr>
<td>5</td>
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<td>Chinnamuttom, Manauli Island</td>
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<tr>
<td>6</td>
<td>“: Clathria (Thalysias) sp. aff. arborescens (Ridley, 1884)</td>
<td>Kanyakumari, Chinnamuttom, Arokiapuram,</td>
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</tr>
<tr>
<td></td>
<td>“: Clathria (Thalysias) spiculosa (Dendy, 1889)</td>
<td>Arokiapuram</td>
<td>xx</td>
</tr>
<tr>
<td>8</td>
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<td>9</td>
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<td>10</td>
<td>Raspailiidae: Endectyon (Hemectyon) fruticosum (Dendy, 1887)</td>
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<td>Halichondrida: Axinella ceylonensis (Dendy, 1905)</td>
<td>Kanyakumari, Chinnamuttom and Hare Island</td>
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### Table 2. Continued...

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<td><em>Callyspongia (Toxochalina) folioides</em> (Bowerbank, 1875)</td>
<td>Kurusadi Island</td>
<td>xx</td>
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<td>25.</td>
<td>&quot;</td>
<td><em>Callyspongia (Chladochalina) sp</em></td>
<td>Kanyakumari, Chinnamuttom</td>
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<td>26.</td>
<td>&quot;</td>
<td><em>Callyspongia (Callyspongia) sp.2</em></td>
<td>Chinnamuttom</td>
<td>xx</td>
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<td>27.</td>
<td>&quot;</td>
<td><em>Callyspongia (Callyspongia) sp.3</em></td>
<td>Kanyakumari, Hare Island</td>
<td>xx</td>
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<tr>
<td>28.</td>
<td>&quot;</td>
<td><em>Siphonochalina minor</em></td>
<td>Hare and Kurusadi islands</td>
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<tr>
<td>29.</td>
<td>Niphatidae</td>
<td><em>Gelliodes incrustans</em> (Dendy, 1905)</td>
<td>Kanyakumari</td>
<td>-</td>
</tr>
<tr>
<td>30.</td>
<td>&quot;</td>
<td><em>Gelliodes carnosa</em> Dendy, 1889</td>
<td>Kanyakumari, Arokiapuram and Kurusadi island</td>
<td>xx</td>
</tr>
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<td>31.</td>
<td>&quot;</td>
<td><em>Amphimedon sp.1</em> (? obtusispiculifera) (Dendy, 1905)</td>
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<td>32.</td>
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<td><em>Amphimedon sp. 2</em></td>
<td>Chinnamuttom, Kurusadi island</td>
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<tr>
<td>33.</td>
<td>&quot;</td>
<td><em>Amphimedon sp. 3</em></td>
<td>Chinnamuttom</td>
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<td>35.</td>
<td>Dictyoceratida</td>
<td><em>Luffariella sp.</em></td>
<td>Kanyakumari, Chinnamuttom and Arokiapuram</td>
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<td>36.</td>
<td>Thorectidae</td>
<td><em>Hyrtios cf. erectus</em> Keller, 1889</td>
<td>Kanyakumari and Arokiapuram</td>
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<td>37.</td>
<td>&quot;</td>
<td><em>Fascaplysinopsis reticulatus</em> Hentschel, 1912</td>
<td>Manauli island</td>
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<td><em>Semitaspongia sp.</em></td>
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<td>39.</td>
<td>&quot;</td>
<td><em>Smenospongia sp.</em></td>
<td>Kanyakumari, Chinnamuttom, Arokiapuram and Manauli island</td>
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Table 2. Continued...

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<tr>
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<td>Spongiidae: Spongia aff. ceylonensis (Dendy, 1905)</td>
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<td>41</td>
<td>&quot; Spongia sp.</td>
<td>Hare and Manauli island</td>
<td>xx</td>
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<tr>
<td>42</td>
<td>&quot; Leiosella cf. foliacea</td>
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<tr>
<td>43</td>
<td>&quot; Hyattella intestinalis</td>
<td>Kanyakumari,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Lamarck, 1813)</td>
<td>Arockiapuram, Hare island</td>
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<tr>
<td>44</td>
<td>&quot; Hyattella cf. sinuosa (Pallas, 1766)</td>
<td>Arokiapuram</td>
<td>xx</td>
</tr>
<tr>
<td>45</td>
<td>&quot; Hyattella aff. sinuosa (Pallas, 1766)</td>
<td>Arokiapuram, Hare island</td>
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<tr>
<td>46</td>
<td>&quot; Hyattella tubaria</td>
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<td></td>
<td>Lendenfeld, 1889</td>
<td>Arokiapuram, Hare island</td>
<td>xx</td>
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<td>47</td>
<td>Dysideidae: Dysidea cf. crassa (Dendy, 1905)</td>
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<td>&quot; Lamellodysidea herbacea</td>
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<td>49</td>
<td>&quot; Euryspongia sp.</td>
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<td>x</td>
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<tr>
<td>50</td>
<td>Dendroceratida: Spongionella nigra, Dendy, 1905</td>
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</tr>
<tr>
<td></td>
<td>Dictyodendrillida</td>
<td>&amp; Manauli island</td>
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</tbody>
</table>

* x - New record to India; xx-New to the study area

Habitats. The most abundant species in this study are: Clathria, Callyspongia and Hyattella followed by Amphimedon, Dragmacidon and Axinella.

Out of the 50 species collected, 10 sponges such as Myxilla (Ectyomixilla) arenaria, Edendeyton (Hemectyon) fruticosus, Mycale (Zygomycale) parishii, Clathria indica, Clathria procer, Axinella ceylonensis, A. manus, Gellioidea incrustans, Hyrtios erecta [formerly Heteronema erecta] and Spongia ceylonensis [formerly Spongia officinalis] were reported earlier from the Gulf of Mannar and Palk Bay by Dendy (1889), Burton (1937), Thomas (1985) and from the Ceylon coast by Dendy (1905). Of these, Cervicornia, Amphimedon, Fascaplysinopsis, Semitaspongia, Smenospongia, Leiosella, Lamellodysidea and Euryspongia are reported for the first time from the Indian coasts.

Clathria (Thalysias) spiculosa was reported from the northern west coast (Gujarat and Maharashtra) by Dendy (1916) and Clathria (Thalysias) procera was reported from the Gulf of Mannar by Dendy (1889) and Thomas (1985). Dragmacidon agariciformis was reported as Thrinacaphora agariciformis by Dendy (1905) and as Axinella agariciformis by Thomas (1985) from the Gulf of Mannar. Clathria (Clathria) indica was reported by Burton and Rao (1932), Dendy (1905) and Thomas (1985) from the southeast coasts of India (Tamil Nadu and adjacent coasts of Gulf of Mannar). Clathria (Thalysias) vulpina was reported from the southeast coasts of India (Burton 1937, Burton and Rao 1932, Thomas 1985).

Although the present survey lacks data on the sponge diversity in deeper zones, it appears that the rocky beds along the southeast Indian coasts harbours an extensive sponge and other invertebrate fauna. Hence it is hoped that further explorations would bring out new records from these and other adjacent areas.
Acknowledgements

The first author thanks Dr. Kaliaperumal, former Officer-in-Charge, Regional Centre of CMFRI, Mandapam camp for making arrangements to collect samples from the three islands of Gulf of Mannar. Grateful thanks are due to Dr. Rob Van Soest, Zoologiche Museum, Amsterdam for confirming the identification of the species listed here.

References cited


Marine Reptiles

Marine reptiles are belonging to four orders namely 1. Chelonia, 2. Crocodilia 3. Sauria and 4. Serpentes. Of which the crocodilia and Sauria represents each one species namely salt water crocodile (Crocodylus porosus) and Marine Iuguana (Amblyrhynchus crisatus). The order chelonia represents seven species and order serpents represents 60 species.

The salt water crocodile Crocodylus porosus has reported in India however it’s distribution is now restricted up to Andhra pradesh in the east coast in mainland. Sea snakes are found only in tropical and subtropical regions Indian and Pacific Oceans. Out of seven species chelonia only five species are reported in India.

In GOMB, Green turtle and Olive Ridley turtle frequently reported and Hawks bill turtle strays in the coast occasionally. Similarly 20 species of sea snake known from Indian coast only 12 species were reported. To maintain healthy ecosystem and population, it is important to monitor the marine reptiles, associated threats and evolve suitable measures for long-term conservation of reptiles.

Shore Birds

Many species of waterbirds have been visiting the Gulf of Mannar Biosphere Reserve during October to March. Gulf of Mannar Biosphere Reserve is not an exception to habitat loss and other related conservation problems. In some areas, shoreline modifications have reduced sediment supplies that feed natural protective structures such as sand spits and barrier beaches, which in turn threatens coastal wetlands with erosion. Control and regulation of water levels like setting shrimp farms at the coastal areas led to a degree on shoreline modification reduce the extent, diversity, function, and value of wetlands in the near shore. Though policies and programs are in place to prevent large-scale loss, conversion and degradation of coastal wetlands continues, resulting in many wetlands being fragmented and limiting critical habitat for waterbirds. In the Gulf of Mannar Biosphere Region, 21 islands provide most of the significant nesting and dry-land roosting habitat for migratory waterbirds such as gulls, terns, cormorants, pelicans, flamingoes and herons. The islands much distant from the mainland but relatively close to good sources of prey, waterbirds experience lower risks of predation, less competition and fewer impacts from human disturbance. In the Gulf of Mannar, however, islands most protected from disturbance and predators are often remote and vulnerable to storm-driven waves and climate-induced water level changes. Another possible threat is invasion by exotic species is a major concern for island ecosystems, particularly invasion of exotic plant species that have the potential to change the character and composition of islands over a short period of time. Hence it is important to conserve bird
diversity of Gulf of Mannar through regular monitoring of population and identifying threats and prepare long-term conservation strategies.

**Evolving sustainable Tourism strategy and livelihood options for community based marine resources management in and around the Gulf of Mannar Marine Biosphere Region**

Tourism activities were prevailing in the Gulf of Mannar Marine Biosphere (GOMBR) region much before this area was declared as India’s first Marine Biosphere Reserve. Even after the declaration nothing has changed to regulate the tourism activities in order to reduce the negative impacts of tourism on the biodiversity and livelihood concerns of this region. Market demand for coastal tourism, improvements in transportation, popularity about the tourism attractions of GOMBR brings more and more domestic as well as foreign tourists every year. Their presence has definite impacts on the biodiversity, livelihoods, socio-cultural settings of this region. Tourist’s capacities to spend, attitude towards local culture, knowledge on ecological sensitivity of the dynamic ecosystem are determining the levels of impacts in the destination areas. Over-fishing and poor resource management in the GOMBR have led to a drastic decline in the fishery, forcing many communities in the region to turn to new sources of livelihood. Policy makers and the Government hope that community based tourism will generate revenue and employment while also protecting the natural areas upon which local people depend. Unfortunately, little is known at this time about the ability of tourism to live up to this promise. In the above context the major aim of this research is to determine the potential of tourism to act as a measurable force in promoting biodiversity conservation as well as sustainable economic development in the GOMBR region. This research will provide a case study for outlining the networks, institutional supports, and stakeholder relationships that act as the basis for developing a more sustainable, small-scale community owned tourism ventures around the GOMBR. This will generate a theoretical framework, which examines the linkages, networks, and changing relationships among Protected Areas, local communities, and the tourism industry. The framework will assist in evaluating the degree of local control and participation in the tourism policy process.
Introduction

Ornamental fishes are the most fascinating creatures of the aquatic environment. These fishes occur in a variety of shapes, sizes and extraordinary combination of colours and aptly named as ‘living jewels’ or ‘delicate darlings’. It is anybody’s dream to encompass them in an aquarium for adding beauty and appearance to the households. Watching ornamental fishes is reported to relieve the tensions, worries and calms the mind of the observer.

Ornamental trade is a multi-billion dollar industry. The total world ornamental trade is estimated as US$4.5 billion with an annual growth rate of 8% (Mohanta and Subramanian, 1999) involving 2% coldwater and 98% tropical fishes. The marine ornamental trade is valued as US$ 200-330 million per year. Ornamental fishes are collected and transported mainly from Southeast Asia and from several island nations in Indian and Pacific Oceans. The United States, United Kingdom, Netherlands, France and Germany were the most important countries of destination comprising 99% of all imports of marine ornamental fish. Among the fish groups Pomacentridae dominated the trade followed by Pomacanthidae, Acanthuridae, Labridae, Gobiidae, Chaetodontidae, Callionymidae, Microdesmidae, Serranidae and Blennidae (Wabnitz et al., 2003).

India is blessed with rich biodiversity of ornamental fishes both in freshwater and marine habitats. The domestic market is worth of Rs.25 crores with an annual growth rate of 20%. There are 4 regular large size farms, 300 full time breeders and 600 part time breeders and more than 200 species of freshwater ornamental fishes are bred in the country (Ramachandran, 2002).

The marine ornamental fishes are still unexplored in India and their market is in its infancy. With considerable resources distributed over the coral islands of Lakshadweep, Andaman and Nicobar Islands, Gulf of Kutch, Maharashtra, Cochin to Vizhinjam in Kerala, Gulf of Mannar and Palk Bay in Tamilnadu, there is enormous scope for developing marine ornamental fish trade as a major industry. Unlike freshwater fishes, marine ornamental industry is solely reliant on wild caught fishes and a very small proportion of 1-10% of the fishes and 1% coral species are being captively bred in commercial quantities all over the world.

Status of ornamental fish resource along Gulf of Mannar

Few reports are available on the resources of ornamental fishes in the Gulf of Mannar area. Mahadevan and Nayar (1965) listed about 100 species of ornamental fishes belonging to 30 families from Gulf of Mannar and Palk Bay. Muralitharan (1999) recorded 129 reef fishes coming under 73 genera and 34 families caught in fish traps from Gulf of Mannar. Venkataramani et al. (2004) reported

**Threats to ornamental fish resources in Gulf of Mannar**

Marine ornamental fishes along Gulf of Mannar are mainly caught by shore seines, trawl nets and traps (koodu). Target fishing is also done for certain groups of fishes. Apart from these methods, destructive fishing methods like blast fishing and poisoning are practiced. These methods not only stupefy the fishes but render them vulnerable to diseases. Moreover, the above practices also lead to habitat destruction and mortality of other inhabitants.

Decimation of seagrass beds and coral cover all over the world has caused great concern among the ecologists. Coral reefs support vast diversity of fishes which depend on reefs for their survival, food and living space. Of the 538 species belonging to twenty reef fish families of Indo-Pacific, approximately 11% of the species possess an

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Group</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Pomacentridae</td>
<td><em>Amphiprion sebae</em>, <em>Pomacentrus caeruleus</em>, <em>Neopomacentrus nemurus</em>, N. pavo, <em>Dascyllus trimaculatus</em>, <em>Abudefdu vaigiensis</em></td>
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<tr>
<td>2.</td>
<td>Chaetodontidae</td>
<td><em>Chaetodon collare</em>, <em>C. vagabundus</em>, <em>C. octofasciatus</em>, <em>C. linula</em>, <em>C. lineolatus</em>, <em>C. auriga</em>, <em>Heniochus acuminatus</em></td>
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<td>3.</td>
<td>Pomacanthidae</td>
<td><em>Pomacanthus annularis</em>, <em>Pomacanthus semicirculatus</em></td>
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<td>4.</td>
<td>Labridae</td>
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<td>Acanthuridae</td>
<td><em>Acanthurus mata</em>, <em>A. leucosternon</em>, <em>Acanthurus triostegus</em>, <em>Zebrasoma viliferum</em></td>
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<tr>
<td>6.</td>
<td>Gobiidae</td>
<td><em>Istigobius ornatus</em></td>
</tr>
<tr>
<td>7.</td>
<td>Pseudochromidae</td>
<td><em>Pseudochromis fuscus</em></td>
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<td>9.</td>
<td>Balistidae</td>
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<td>Scaridae</td>
<td><em>Scarus gobban</em>, <em>S. ferrugineus</em></td>
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<td>Tetradontidae</td>
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<td>12.</td>
<td>Haemulidae</td>
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<td>Zanclidae</td>
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<td>Lutjanidae</td>
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<td>Holocentridae</td>
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<td>Muraenidae</td>
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<td>17.</td>
<td>Scorpaenidae</td>
<td><em>Pterois russelli</em></td>
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<tr>
<td>18.</td>
<td>Siganidae</td>
<td><em>Siganus javus</em></td>
</tr>
</tbody>
</table>

List of commonly available ornamental fishes in Gulf of Mannar
obligate association with the living corals (Jones et al., 2004). Trawlers operating in the coral reefs break the corals during fishing. Seagrasses also exhibit high production and biodiversity of associated fauna (Heck and Thoman, 1984; Bostrom and Bonsdorff, 1997). Shore seines operated along the shallow coastal waters uproot and drag seagrasses to the shore. Thus destruction of suitable habitats which offer shelter, food and breeding grounds for majority of the marine ornamental fishes results in gradual decrease of natural fish stocks.

The entire marine ornamental trade, both domestic and international, is purely from natural waters. All size groups of these fishes are targeted for trade which includes brooders and juveniles. Continuous removal of fishes from the natural habitats leads to depletion of wild stocks. A typical example of such a group is the syngnathids comprising of pipefishes and seahorses. Five species of seahorses (Balasubramanian, 2002; Murugan, 2004) and pipefishes (Dhanya, 2003) are reported from Gulf of Mannar of which all species of seahorses and one species of pipefish is exploited deliberately for ornamental as well as medicinal purposes. Indiscriminate fishing combined with habitat destruction has jeopardized them in the wild. In view of the drastic decline of wild populations, syngnathids are listed under Schedule I and protected by the Indian Wildlife Act, 1972.

**Role of aquaculture in biodiversity conservation**

Aquaculture is the farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated. Aquaculture is the fastest growing food-production sector in the world, providing a significant supplement to, and substitute for, wild aquatic organisms. Aquaculture of marine, brackish and freshwater species has grown steadily at ~9% per year during recent decades, resulting in global aquaculture production exceeding 45 million tones, worth more than US$ 63 billion, in 2004 (FAO 2006).

In the case of marine and brackish water species, the number of taxa farmed increased from 150 in 1984 to more than 260 in 2004.

Marine and coastal habitats are the richest storehouse of biodiversity. Human beings are dependent on biodiversity for their sustenance, health, well-being and enjoyment of life. Humans derives food, medicines and industrial products from biological diversity. Aquaculture has vast potential for conserving natural resources.

1. The increased production of species through aquaculture reducing the fishing pressure.
2. The cultured organisms can also be used to reseed the depleted natural stocks in aquatic systems as a means of biodiversity conservation.

**Role of aquaculture in augmenting ornamental fishes for trade**

Aquaculture provides a scenario in which species can be completely cultured in captivity. In-captive breeding and mass scale rearing of marine ornamental fishes is an alternative to limit the dependence on the wild for these fishes. Breeding programs ensure a constant year round supply of marine ornamental fishes meeting the market demand. About 100 marine species (including invertebrates) traded are routinely bred in captivity all over the world (Dawes, 1998) including 21 species of fishes being commercially produced (Schiemer, 2001). Currently clown fishes, gobies and dotty backs are captively cultured (Schiemer, 2001) and other species like basslets, comets, jawfishes,
blennies and seahorses are on the verge of being commercialized (Tucker, 1998).

Successful breeding of marine ornamental fishes is complicated compared to freshwater fishes. Two major bottlenecks preventing captive production of ornamentals are reliable and foolproof technology for in-captive breeding and identification of suitable live feed organisms for the growing larva. Moreover marine ornamental fishes exhibit a variety of breeding and spawning strategies such as egg scatterers (butterfly fishes and angel fishes), egg depositors (clowns and damsels), mouth brooders (cardinal fishes) and pouch brooders (pipefishes and seahorses). Utmost care should

<table>
<thead>
<tr>
<th>S.No</th>
<th>Group</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Clown fishes</td>
<td><em>Amphiprion sebae, A. ocellaris, A. percula, Premnas biaculeatus</em></td>
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<tr>
<td></td>
<td>(Pomacentridae)</td>
<td></td>
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<tr>
<td>2.</td>
<td>Damsel (Pomacentridae)</td>
<td><em>Pomacentrus caeruleus, Neopomacentrus nemurus, Dascyllus trimaculatus</em></td>
</tr>
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<td>3.</td>
<td>Chromis (Pomacentridae)</td>
<td><em>Chromis caerulea</em></td>
</tr>
<tr>
<td>4.</td>
<td>Sergeant (Pomacentridae)</td>
<td><em>Abudefduf vaigiensis</em></td>
</tr>
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<td>5.</td>
<td>Butterfly fishes</td>
<td><em>Chaetodon collare, C. octofasciatus</em></td>
</tr>
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<td></td>
<td>(Chaetodontidae)</td>
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<td>6.</td>
<td>Angel fishes</td>
<td><em>Centropyge multispinus</em></td>
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<td></td>
<td>(Pomacanthidae)</td>
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<td>7.</td>
<td>Cardinal fishes</td>
<td><em>Apogon nigripinnis, A. multitaeniatus, A. aureus, A. quadrifasciatus</em></td>
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<td>(Apogonidae)</td>
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<td>8.</td>
<td>Wrasses (Labridae)</td>
<td><em>Labroides dimidiatus, Halichoeres marginatus, Thalassoma lunare</em></td>
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<td>Gobies (Gobiidae)</td>
<td><em>Istigobius ornatos, Valenciennes sp.</em></td>
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<td>10.</td>
<td>Dottybacks (Pseudochromidae)</td>
<td><em>Pseudochromis fuscus</em></td>
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<td>11.</td>
<td>Triggers (Balistidae)</td>
<td><em>Balistapus undulatus, Odonus niger</em></td>
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<td>12.</td>
<td>Tangs (Acanthuridae)</td>
<td><em>Acanthurus mata, Zebrasoma viliferum</em></td>
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<tr>
<td>13.</td>
<td>Puffers (Tetraodontidae)</td>
<td><em>Canthigaster margaritata</em></td>
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<td>14.</td>
<td>Catfish (Plotosidae)</td>
<td><em>Plotosus lineatus</em></td>
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<td>15.</td>
<td>Snappers (Lutjanidae)</td>
<td><em>Lutjanus sebae, L. fulviflammus, L. quinquelineatus, L. decussates</em></td>
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<td>16.</td>
<td>Finger fish (Monodactylidae)</td>
<td><em>Monodactylus argenteus</em></td>
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<td>17.</td>
<td>Batfish (Ephippidae)</td>
<td><em>Platax teira</em></td>
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<td>18.</td>
<td>Butterfish (Scatophagidae)</td>
<td><em>Scatophagus argus</em></td>
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<td>19.</td>
<td>Rabbit fish (Siganidae)</td>
<td><em>Siganus javus</em></td>
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<td>20.</td>
<td>Orange chromide (Cichlidae)</td>
<td><em>Etroplus suratensis</em></td>
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<td>21.</td>
<td>Pipefishes (Syngnathidae)</td>
<td><em>Syngnathoides biaculeatus, Trachyrhamphus serratums, Hippichthys</em></td>
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<td></td>
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<td>cyanospilos, Ichthyocampus carce</td>
</tr>
<tr>
<td>22.</td>
<td>Seahorses (Syngnathidae)</td>
<td><em>Hippocampus kuda, H. trimaculatus, H. kelloggi, H. spinosissimus</em></td>
</tr>
</tbody>
</table>
be taken in every step from maintaining of brooders till grow out of the larvae. Marine ornamental breeding presents a challenge. But successful breeding programs will be a boon to ornamental fish industry and biodiversity conservation. The following fishes have been identified for undertaking breeding programme.

**Repopulating the endangered species through stock enhancement programme**

Aquaculture has proved to be an important tool for the biodiversity conservation. The application of aquaculture technology through responsible restocking, stock enhancement and sea ranching programs (Blankenship and Leber, 1995) are being employed in various countries to increase production of capture fisheries (Bell et al., 2005). Sea-ranching implies releasing eggs, larvae or juveniles into the natural environment to increase recruitment of marine fish. In fact it was initiates as early as in 17th century with transplanting fish and construction of fish reefs in Japan (Honma, 1993). Sea ranching programmes have been performed to rebuild or restore depleted stocks, support recreational fishery, and support commercial fishery. Releasing of hatchery-reared juveniles have been carried out for a variety of species, and in many countries, to bring back a stock that is locally extinct, to rebuild a stock that has collapsed as a viable fishery or to augment a natural population for a “put and take” fishery (Travis et al., 1998).

In 1994, Japan released a total of 70.7 million juveniles of 33 different marine fish species (Anon., 1995), and an additional 357.5 million crustaceans, 17,827.6 million shellfish and 72.9 million others, such as sea-urchin (Echinoidea). Hatchery reared *Penaeus chinensis* seeds were ranced in China for 20 years within and outside the natural distribution of the species. The number of released prawns reached a peak of 5.213 billion in 1991 and remains at about 600 million per annum, providing annual landings of around 720 t. Catches of released prawns have contributed more than 90% to total landings in the Haiyangdao Fishing Ground in the north Yellow Sea (Wang et al., 2006).

The golden arowana, bala shark, pygmy loach and tiger barb are examples of species conserved through aquaculture (Ng and Tan, 1997). Though most of the ranching programs pertain to food fishes, ‘live rocks’ and many conch species (*Trochus* spp.) are produced in hatcheries and seeded out to reefs (Baquero, 1999; Watson, 2000).

Aquaculture appears to be the best method for conserving and replenishing the endangered marine ornamental fishes like pipefishes and seahorses. The life history of these fishes makes them vulnerable to overexploitation. They are pouch brooders with limited brood size. Unlike other fishes, capturing a brooder not only kills the animal but the whole brood it carries. Though capture has been restricted by law, repopulation of wild stock takes much time. In captive breeding and sea ranching programs constitute an alternative method for enhancing the wild stocks. Though few brooders have to be collected initially from the wild, a portion of the captively reared young ones can be developed as brooders in due course.

**Role of ornamental fish breeding in rural development**

Aquaculture has an important role in the development of many national economies and plays a key role in rural development. It provides livelihood options in rural areas of the developing world. The term “rural aquaculture” has recently been used to distinguish the farming of aquatic organisms...
by small-scale households using mainly extensive type husbandry for household consumption and or income (Edwards and Demaine, 1997).

Cultivation of mussels by self help groups along Kerala Coast is well established. Similarly small self help groups of women folk living along coastal fishing villages can be formed with the involvement of Gulf of Mannar Biosphere Reserve Trust and they can be trained to produce some marine ornamental fishes which can be bred easily. With a small set up for live feed culture, mass scale rearing of ornamental fish is feasible if they are properly trained and encouraged. A part of the income generated from fish culture can be used by them for their living and the rest for further investments. This will be an alternate employment opportunity for the fisherfolk which will uplift their economic status. During each culture few numbers of the produce can also be sea ranched as restocking for future.

**Conclusion**

Aquaculture has successfully proved over the last few decades as an alternate means of fish production and supplements the capture fisheries in fish supply. Aquaculture has also emerged as a vital tool for conservation of biodiversity by means of captive breeding, culturing and sea ranching programs. In fact it is the best way to conserve marine ornamental fishes. Through captive breeding programs complete dependence on wild for ornamental fish supply can be reduced. Apart from preventing the capture of endangered organisms by law, captive breeding and sea reaching help in replenishing the wild populations. Moreover women fisherfolk self help groups can be trained and encouraged to pursue marine ornamental fish culture as an alternate source of employment in the coming years.

**Acknowledgement**

The authors are thankful to the authorities of Annamalai University for the facilities provided and Dr. T. Balasubramanian, Director and Dr. S. Ajmal Khan, Professor for their encouragement and support.

**References cited**

Conservation of marine ornamental fishery resources along Gulf of Mannar through aquaculture


Coastal Ecosystem restoration and bio-resource conservation

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Introduction
The coastal areas consist of 20% of the earth’s surface. Half of the world’s population live within a distance of less than 200 km from the coast, and 37 percent live no more than 60 km away from the coast. Coastal areas have got rich biological importance as they support various life forms. They have an important role of nutrient cycling in the marine environment. They also support the most productive ecosystems of the world such as coral reefs, mangroves, seagrasses, and estuaries, which provide opportunities for a considerable part of the world’s population to find food and livelihood.

Coastal ecosystems

Coral reefs
Reefs are the most diverse and beautiful of all marine habitats with rich biodiversity. These large wave resistant structures are formed through millions of years by slow growing corals. The coral reefs not only provide a sanctuary to a myriad of marine life but also play a key role in protecting the coastline from erosion and other natural calamities. Millions of people depend on the reef areas for fishery and recreational activities for their livelihood.

Mangroves
Mangroves are having both ecological and economic importance and are one among the most productive ecosystems. They act as breeding, feeding and nursery ground for many estuarine and marine organisms. Mangroves protect the shore against cyclones and ingress of seawater during tidal surge. Mangroves also play a major role in the protection of the beaches from erosion. The relevance of mangroves is in the limelight at present after the Indian Ocean tsunami.

Seagrasses
Seagrasses are true marine flowing plants with roots and stem. They are adapted to marine environment and submerged growth with well developed anchoring system to withstand the severe wave action. The seagrasses remain a harbour for epiphytes and acts as a nursery for fish, gastropods, worms and crustaceans. They also form a favourite feeding ground for the endangered marine mammal Dugong dugon and the green turtles.

Estuaries
Estuaries play an important role in the productivity of nearshore coastal environments. They are the transition zones between rivers and the sea and provide habitat for a unique assortment of flora and fauna. These brackish water ecosystems are critical for the survival of many species of birds, mammals, fishes and other wild life.

Threats to coastal ecosystems
The present scenario for many of these coastal ecosystems and resources are of great concern as their status is declining due to various human activities. Modern human civilization and coastal zones make poor companions. Most activities of people (e.g., fishing, deforestation, nutrient enrichment, burning of fossil fuels, and use of toxic chemicals) damage coastal ecosystems either
directly or indirectly (Knowlton, 2001). In addition to direct human interferences, global climate change and natural disasters such as storms, cyclones and tsunamis pose serious threat. The impacts of disasters, whether natural or man-made, not only have human dimensions, but also environmental ones as well. The coastal ecosystems are already experiencing multiple problems and many coastal resources are in highly stressed conditions due to threats mainly from human and nature.

*Anthropogenic stresses*

Unsustainable and destructive fishing practices, land based domestic and industrial pollution, sedimentation, coral mining, physical damage due to boat anchors and uncontrolled tourism and aquaculture are some of the threats, which vastly damage the coastal ecosystems.

*Natural stresses*

Global warming, coastal erosion, fresh water run off, predators, diseases, natural disasters such as cyclones, storms and tsunamis are causing stress to coastal ecosystem. At the present level of industrial revolution, it is expected that the global warming would cause greater damage in the near future.

**Need for restoration and conservation of coastal ecosystem**

There is worldwide concern over the damage caused to the coastal ecosystems by both man made and natural changes. The various human activities in and around the seas have led to serious degradation of the coral reefs, mangroves, seagrasses, and estuarine ecosystems. This huge stress on the marine and coastal environment has led to the concept of biosphere reserve, which was put forward by UNESCO as early as 1971, in its Man and Biosphere (MAB) Programme.

India has about 7860 km coastline and the various coastal ecosystems act as habitats for millions of life forms. The damage / stress to these ecosystems would lead to the decline / extinction of many valuable resources. The coastal zone is the vital ecological bridge between the terrestrial and aquatic ecosystems, and restoration and conservation are essential to maintain the biodiversity and ecological balance.

Proper long-term action plan with an integrated approach in restoration and conservation of coastal ecosystems would not only help in the promotion of sustained livelihood but also in the effective coastal protection. An accurate and objective assessment of the true status of coastal resources is not possible, because of a serious lack of long-term monitoring data (Pearson 1981, and Robertson 1992). It is stated that 70% of the world’s coral reef will be functionally lost within 40 years, unless effective management is implemented (Wilkinson and Buddemeier, 1994). A number of lessons were learnt from the 2004 Indian Ocean Tsunami with respect to coastal ecosystems and its resources.

**Gulf of Mannar**

The coastal areas of Gulf of Mannar include all major ecosystems such as coral reefs, mangroves, seagrasses and estuaries. Thousands of people depend on these ecosystems for livelihood. The population growth has resulted in more crowded fishing grounds with less catch, which ultimately force the people into destructive fishing and other illegal practices. The present average live coral cover in Gulf of Mannar is 35.47% (Mandapam Group – 36.97%, Keezhakkarai Group – 43.58%, Vembar Group – 31.99% and Tuticorin Group – 29.34%). About 32 sq.km reef area has been damaged because of mining and destructive fishing. Considering
Coastal Ecosystem restoration and bio-resource conservation

the dependence of local people on this ecosystem, it is important and need of the hour to restore the damaged reef areas which would help in sustained fishery production and enhanced coastal protection. The erosion in island shores would also be minimized.

Research priorities in Gulf of Mannar

It is essential to consider an integrated approach when considering coastal ecosystem restoration and bio-resource conservation.

Baseline information

At present, the baseline information on the status of coral reefs around the 21 islands is available, but the data is lacking for mangroves and seagrasses. Further, information on the present status of all fishery resources is lacking. All endangered species and commercially important fishery resources should be given priority in the collection of baseline information.

Restoration

The restoration of 32 sq.km degraded reef areas around the 21 islands with native coral species would help to enhance the reef diversity and biomass and also to increase the fishery production. This could be achieved in 4-5 years time in phases. The Indian Ocean tsunami made aware the local people the value of reefs. By building positive experiences from tsunami, it is time to initiate reef restoration for the benefit of coast and people.

Long term monitoring

A long term action plan should be drawn up to monitor all critical habitats such as coral reefs, seagrasses, and mangroves in Gulf of Mannar, which would be much helpful for effective conservation and management practices. Involvement of local research institutions with necessary scientific capacity in monitoring would help in long term sustainability.

Impact of climate change

The climate change would be the most serious threat to coastal ecosystem and species in the near future. Studies should be initiated to assess the impact of climate change on habitats and fisheries in Gulf of Mannar. Steps to mitigate the impacts should also be considered.

Acknowledgements

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References cited

Five species of sea turtles, olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) are distributed along the Indian coast. Except the loggerhead, all other species have been reported to nest along the Indian coast. Olive ridley is the most common and abundant and is unique for its mass nesting along the Orissa coast. All five species have been reported along the Tamil Nadu coast and are listed under Schedule I of the Indian Wildlife (Protection) Act 1972.

The Gulf of Mannar is unique for coral reef, sea grass and seaweed ecosystem. In 1960s, exclusive sea turtle fishing was carried out in Gulf of Mannar and Palk Bay region and live turtle trade existed with Sri Lanka. An estimated 3000 to 4000 turtles were landed annually between Rameswaram and Mimisal during that period and green turtle represented three fourth of the catch (Rajagobalan, 1984). A survey in 1977 by Central Marine Fisheries Research Institute (CMFRI) mentioned about turtle nesting in Puluvinichalli, Nallathani, Anaipar, Valiamunai, Appa, Valai, Mulli, Hare, Manoli, Manoli-Putti and Pullivasal Islands (CMFRI, 1977). In the Kanyakumari to Trichendur stretch, the core nesting area existed between Manapad and Periathalai (Bastian Fernando, 1983).

The turtles migrating to Indian waters are on the decline in recent years owing to many threatening factors. The main detrimental factor is the incidental catch. Exploitation for meat and eggs by humans, developmental activities on the beach including artificial illumination, Casuarina plantation, predation by wild animals and beach erosion are the other factors affecting the sea turtles.

But, no detailed study has been carried out so far on sea turtles in Gulf of Mannar area especially on distribution, nesting beaches, foraging grounds and their migratory behaviour except the works carried out in 1980s. These aspects are considered vital for the efforts to conserve turtle resources. The once reported sea turtle nesting in the beaches of Gulf of Mannar islands have become a foregone era. The nesting and foraging habitats are to be given top priority in the conservation agenda. The existing nesting beaches have to be identified and protected through community conservation measures. Also, local community participation in the conservation of sea turtles is considered very important. The use of Turtle Excluder Device (TED) is to be encouraged. The mythical belief among the coastal folk that sea turtles cure many ailments needs to be neutralized through effective propaganda, awareness programmes and by involving them in the conservation activities.

**References cited**


Sea Turtles in Gulf of Mannar


Seahorses are teleosts or bony fishes and are classified as members of the class Osteichthyes, order Syngnathiformes and family Syngnathidae. The family Syngnathidae includes seahorses, pipefishes, pipehorses and seadragons and consists of about 215 species included in 52 genera. The seahorse taxonomy is complicated and many discrepancies still exist. However, the morphometric and genetic analysis indicated the existence of 32 species of seahorses worldwide.

Seahorses are exploited in millions for medicines, aphrodisiacs, tonic foods, aquarium fishes and curios. It is mainly used in Traditional Chinese Medicines (TCM). The largest known importing countries are China, Hong Kong and Taiwan. The total global consumption in 1995 alone has been estimated at more than 56 metric tonnes i.e. 20 million seahorses. The seahorse fishery is global and destructive. The 1996 and 2000 IUCN Red List of Threatened Animals includes most of the Indo-pacific seahorse species. The characteristic feature of the seahorses like sparse distribution, low mobility, site specificity, low fecundity and mate fidelity make it vulnerable and may result in the recovery of the exploited population difficult.

India is one among the largest exporters of seahorses along with the Philippines, Thailand and Vietnam. They are exploited for the lucrative export market value. The seahorse, distributed in Gulf of Mannar Marine Biosphere Reserve along Southeast coast of India, has been exploited both as by-catch and target fishing. Target fishing got reduced after its inclusion in Indian Wildlife (Protection) Act. But, due to increase in international demand, it is said to be exploited illegally. The distribution, biology and taxonomy of seahorses in Gulf of Mannar are not yet clear completely and a wide information gap on the fundamental aspect of seahorses still exists in this region. Also, the extent of exploitation and the trade in Gulf of Mannar are not well documented and the available information is scattered. The field survey in 1995 indicated that Tamil Nadu fisher’s annual sales involved at least 1.3 million seahorses or 3,040 Kg (Vincent, 1996). In the adjacent Palk Bay, the specific fishing of seahorse, *Hippocampus kuda* has commenced in June 1992 and about 300 to 400 Kg of dried seahorses were exported to Singapore through unknown channels. Along Ramnad coast, the dried seahorse is used as a medicine to arrest whooping cough in children (Marichamy et al., 1993).

As such, the baseline data on seahorses, which is fundamental for planning any successful conservation programmes, does not exist for Gulf of Mannar area. Hence, detailed study on seahorse taxonomy, biology, trade, distribution and abundance, which are very much lacking in Gulf of Mannar, are essential considering the importance given to the conservation and management of biological diversity of Gulf of Mannar.

**References cited**

Seahorses in Gulf of Mannar


Introduction

The Gulf of Mannar is one of the coral reefs rich areas of India situated in the southeast coast of India. The reefs are present around a chain of 21 islands. These islands form a 140 km stretch from Rameswaram to Tuticorin. These islands are protected under wild life act and come under the Gulf of Mannar Marine Biosphere Reserve. The coral reefs need the following for their perfect growth. They are constant salinity, warm water between 27 and 30 °C, clear and clean water and sufficient nutrient levels. There have been a lot of developmental activities all along the coast of Gulf of Mannar in the last few decades causing coastal seawater contamination. Therefore a preliminary pilot study regarding the quantitative estimation of physical and chemical components of Gulf of Mannar waters was considered necessary. In connection with this analysis, microbial count in terms of Total Viable Count (TVC) and estimation of Heavy metals in marine waters and their accumulation in the value added marine product such as fish were also considered essential.

Material and Methods

Study sites

A complete list of locations and sample sites and the distance at which samples were taken are given in Table-1.

The samples were taken all along the Gulf of Mannar coast including the southern part which has not been studied very well extensively by earlier workers because of which there is only limited information available for this region.

The water, sediment and animal samples were collected from the sites given in Table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Location along the coastline</th>
<th>Sample collection site</th>
<th>Distance from Shore in meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rameswaram</td>
<td>Agni theertham</td>
<td>250</td>
</tr>
<tr>
<td>2</td>
<td>Pudhumadam</td>
<td>MKU Marine Study Centre</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td>Keelakkarai</td>
<td>Fish Landing Centre</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>Erwadi</td>
<td>Fish Landing Centre</td>
<td>250</td>
</tr>
<tr>
<td>5</td>
<td>Tuticorin 1</td>
<td>Thirespuram Boat Yard</td>
<td>300</td>
</tr>
<tr>
<td>6</td>
<td>Tuticorin 2</td>
<td>Beyond Thermal Power Station</td>
<td>500</td>
</tr>
<tr>
<td>7</td>
<td>Tuticorin 3</td>
<td>Beyond SPIC</td>
<td>500</td>
</tr>
<tr>
<td>8</td>
<td>Arumuganeri</td>
<td>Beyond DCW</td>
<td>500</td>
</tr>
<tr>
<td>9</td>
<td>Tiruchendur</td>
<td>Off Temple Complex</td>
<td>400</td>
</tr>
<tr>
<td>10</td>
<td>Koodankulam</td>
<td>Off Residential Campus</td>
<td>350</td>
</tr>
<tr>
<td>11</td>
<td>Kanyakumari</td>
<td>Off Gandhi Mandapam</td>
<td>500</td>
</tr>
</tbody>
</table>

Table 1. Locations and Sampling sites in the Gulf of Mannar
in Table-1. The physical and chemical nature of these Gulf of Mannar waters such as atmospheric and surface water temperature, Salinity, Dissolved oxygen, Alkalinity and pH, and nutrient parameters such as Calcium, Magnesium, Nitrate, Nitrite, Phosphate and Silicate were analyzed using Standard methods (Grasshoff et al.,1999).

**Results**

**Physico-Chemical Parameters**

The observed physical parameters of the Gulf of Mannar waters are listed in Table-2.

![Table 2. Physico-chemical parameters of Gulf of Mannar waters](image)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Temperature (°C)</th>
<th>Salinity (%)</th>
<th>pH</th>
<th>Alkalinity (ppm)</th>
<th>DO (mg/l)</th>
<th>BOD (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ATM</td>
<td>SWT</td>
<td>CO₃</td>
<td>HCO₃</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Rameswaram</td>
<td>30</td>
<td>28</td>
<td>8.6</td>
<td>12</td>
<td>94</td>
<td>5.44</td>
</tr>
<tr>
<td>2</td>
<td>Pudhumadam</td>
<td>30</td>
<td>29</td>
<td>8.8</td>
<td>18</td>
<td>86</td>
<td>5.94</td>
</tr>
<tr>
<td>3</td>
<td>Keelakarai</td>
<td>32</td>
<td>29</td>
<td><strong>8.9</strong></td>
<td>22</td>
<td>80</td>
<td>5.56</td>
</tr>
<tr>
<td>4</td>
<td>Erwadi</td>
<td>31</td>
<td>30</td>
<td>8.9</td>
<td>14</td>
<td>98</td>
<td><strong>6.01</strong></td>
</tr>
<tr>
<td>5</td>
<td>Tuticorin 1 Thirespuram</td>
<td>30</td>
<td>30</td>
<td>32</td>
<td>8.7</td>
<td>14</td>
<td><strong>100</strong></td>
</tr>
<tr>
<td>6</td>
<td>Tuticorin 2 TPP</td>
<td>32</td>
<td>31</td>
<td>8.5</td>
<td>16</td>
<td>96</td>
<td>5.60</td>
</tr>
<tr>
<td>7</td>
<td>Tuticorin 3 SPIC</td>
<td>32</td>
<td>30</td>
<td><strong>34</strong></td>
<td><strong>8.1</strong></td>
<td>20</td>
<td>95</td>
</tr>
<tr>
<td>8</td>
<td>Arumuganeri</td>
<td>32</td>
<td>30</td>
<td>33</td>
<td>8.1</td>
<td>19</td>
<td>98</td>
</tr>
<tr>
<td>9</td>
<td>Tiruchendur</td>
<td>30</td>
<td>29</td>
<td>8.6</td>
<td>16</td>
<td>98</td>
<td>5.62</td>
</tr>
<tr>
<td>10</td>
<td>Kudankulam</td>
<td>32</td>
<td>29</td>
<td>33</td>
<td>8.1</td>
<td>14</td>
<td>95</td>
</tr>
<tr>
<td>11</td>
<td>Kanyakumari</td>
<td>32</td>
<td>29</td>
<td>33</td>
<td>8.2</td>
<td>15</td>
<td>90</td>
</tr>
</tbody>
</table>

Bold faced numbers indicate minimum and maximum values.

The highest atmospheric temperature recorded was 32°C and the lowest was 30°C. Due to rains, land run-off and sewage input, salinity level at Rameswaram showed the lowest level of 28 %. The highest level of salinity was observed in places where land drainage was limited. The pH level was similar in all the selected locations except in Erwadi and Keelakkarai. The concentration of alkalinity due to Carbonate and Bicarbonate are listed in Table-2. All the study sites showed similar levels of Dissolved oxygen. However, Biochemical Oxygen Demand was high in Tuticorin waters.

**Nutrient parameters**

The calcium concentration in the selected locations did not vary much (Table 3) and the highest level of magnesium concentration was observed in Keelakkarai (1,277 mg/l) whereas the lowest level was found in Rameswaram waters (1,008 mg/l). The nitrate level was more in Keelakkarai (32.3 µg/l). This may be due to the mass bathing of pilgrims in this water and the contribution from nearby domestic and municipal sewage discharge. Nitrate level was low in Kanyakumari waters (20.2 µg/l). The nitrite values were low in all the locations (Table-3). The silicate level was high in Tuticorin waters and low in Erwadi waters. The phosphate concentration was recorded as high in Keelakkarai station (Table-3). Compared to the reference levels all nutrient parameters were well within limits.
Table 3. Nutrient levels in Gulf of Mannar waters

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Ca (mg/l)</th>
<th>Mg (mg/l)</th>
<th>Nitrite (µg/l)</th>
<th>Nitrate (µg/l)</th>
<th>Silicate (µg/l)</th>
<th>Inorganic Phosphate (µg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rameswaram</td>
<td>460</td>
<td>1008</td>
<td>0.02</td>
<td>24.8</td>
<td>12.8</td>
<td>12.2</td>
</tr>
<tr>
<td>2</td>
<td>Pudhumadam</td>
<td>1075</td>
<td>1277</td>
<td>0.01</td>
<td>25.6</td>
<td>10.6</td>
<td>22.5</td>
</tr>
<tr>
<td>3</td>
<td>Keelakarai</td>
<td>440</td>
<td>410</td>
<td>0.02</td>
<td>24.6</td>
<td>10.2</td>
<td>21.1</td>
</tr>
<tr>
<td>4</td>
<td>Erwadi</td>
<td>425</td>
<td>430</td>
<td>0.02</td>
<td>21.9</td>
<td>16.5</td>
<td>13.7</td>
</tr>
<tr>
<td>5</td>
<td>Tuticorin 1 Thirespuram</td>
<td>430</td>
<td>425</td>
<td>0.03</td>
<td>21.0</td>
<td>17.0</td>
<td>16.0</td>
</tr>
<tr>
<td>6</td>
<td>Tuticorin 2 TPP</td>
<td>1137</td>
<td>1130</td>
<td>0.02</td>
<td>21.0</td>
<td>17.0</td>
<td>16.0</td>
</tr>
<tr>
<td>7</td>
<td>Tuticorin 3 SPIC</td>
<td>1195</td>
<td>1117</td>
<td>0.02</td>
<td>20.6</td>
<td>17.4</td>
<td>22.0</td>
</tr>
<tr>
<td>8</td>
<td>Arumuganeri</td>
<td>446</td>
<td>420</td>
<td>0.03</td>
<td>22.3</td>
<td>10.5</td>
<td>25.3</td>
</tr>
<tr>
<td>9</td>
<td>Tiruchendur</td>
<td>432</td>
<td>420</td>
<td>0.01</td>
<td>21.1</td>
<td>18.5</td>
<td>20.0</td>
</tr>
<tr>
<td>10</td>
<td>Kudankulam</td>
<td>428</td>
<td>1165</td>
<td>0.01</td>
<td>20.2</td>
<td>18.3</td>
<td>22.0</td>
</tr>
</tbody>
</table>

Reference levels: 400 mg/l, 1350 mg/l, 0.5 mg/l, 3 mg/L, 0.07 mg/l

Bold faced numbers indicate minimum and maximum values.

**Microbial status**

Total Viable Counts (TVC) of bacteria are listed in Table 4. Rameswaram (Agnitheertham) sediments showed high amounts of total viable count (TVC) of 2.29 X 10^4 cfu/g and Tuticorin (Thirespuram) sediments showed colonies that were too numerous to count. In water samples, Tuticorin (Thirespuram) had high TVC count of 17.00 X 10^4 cfu/ml followed by Rameswaram (Agnitheertham) 2.08 X 10^4 cfu/ml. The reason for this high TVC is the heavy inflow of sewage into the marine environment in these locations.

_Vibrio cholerae_ and _Vibrio parahaemolyticus_ were also isolated from the marine waters and sediment samples by using Himedia TCBS agar. The viable Counts of _Vibrio spp._, are listed in Table 5. Tuticorin (Thirespuram) waters recorded high counts of _Vibrio cholerae_ (2.84 X 10^3 cfu/ml) followed by Tiruchendur waters (4.6 X 10 cfu/ml). Higher TVC of _Vibrio parahaemolyticus_ in

**Table 4. Microbial Status (Total Viable Count - TVC) in the Gulf of Mannar**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Location</th>
<th>Sediment (cfu/g)</th>
<th>Water (cfu/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rameswaram</td>
<td>2.29 X 10^4</td>
<td>2.08 X 10^4</td>
</tr>
<tr>
<td>2</td>
<td>Pudhumadam</td>
<td>1.67 X 10^3</td>
<td>1.20 X 10^3</td>
</tr>
<tr>
<td>3</td>
<td>Keelakarai</td>
<td>2.05 X 10^4</td>
<td>1.97 X 10^4</td>
</tr>
<tr>
<td>4</td>
<td>Erwadi</td>
<td>1.35 X 10^4</td>
<td>1.13 X 10^4</td>
</tr>
<tr>
<td>5</td>
<td>Tuticorin 1 (Thirespuram)</td>
<td>TNTC</td>
<td>17.00 X 10^4</td>
</tr>
<tr>
<td>6</td>
<td>Tuticorin 2 TPP</td>
<td>3.40 X 10^3</td>
<td>3.40 X 10^2</td>
</tr>
<tr>
<td>7</td>
<td>Tuticorin 3 SPIC</td>
<td>1.20 x 10^2</td>
<td>1.50 x 10^2</td>
</tr>
<tr>
<td>8</td>
<td>Arumuganeri</td>
<td>1.00 x 10^2</td>
<td>1.20 x 10^2</td>
</tr>
<tr>
<td>9</td>
<td>Tiruchendur</td>
<td>1.13 X 10^3</td>
<td>1.45 X 10^3</td>
</tr>
<tr>
<td>10</td>
<td>Kudankulam</td>
<td>1.20 x 10^2</td>
<td>1.50 x 10^2</td>
</tr>
<tr>
<td>11</td>
<td>Kanyakumari</td>
<td>1.10 x 10^3</td>
<td>1.25 x 10^3</td>
</tr>
</tbody>
</table>

cfu- Colony forming Unit; TNTC- Too numerous to count (Highly Polluted!).

Bold faced numbers indicate minimum and maximum values.
Environmental quality assessment of Gulf of Mannar coast

Table 5. Microbial status, *Vibrio* spp., in the Gulf of Mannar

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Sediment <em>Vibrio</em> cfu/g</th>
<th>Sediment <em>Vibrio parahaemolyticus</em> cfu/g</th>
<th>Water <em>Vibrio cholerae</em> cfu/ml</th>
<th>Water <em>Vibrio parahaemolyticus</em> cfu/ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rameswaram</td>
<td>2.5 X 10^2</td>
<td>2.9 x 10</td>
<td>2.2 X 10</td>
<td>2.1 X 10</td>
</tr>
<tr>
<td>2</td>
<td>Pudhumadam</td>
<td>1.5 x 10</td>
<td>2.2 x 10</td>
<td>1.6 x 10</td>
<td>1.5 x 10</td>
</tr>
<tr>
<td>3</td>
<td>Keelakarai</td>
<td>1.5 X 10^2</td>
<td>2.9 x 10</td>
<td>2.6 X10</td>
<td>2.8 x 10</td>
</tr>
<tr>
<td>4</td>
<td>Erwadi</td>
<td>1.8 x 10</td>
<td>2.5 x 10</td>
<td>2.2 x 10</td>
<td>2.1 x 10</td>
</tr>
<tr>
<td>5</td>
<td>Tuticorin 1 (Thirespuram)</td>
<td>3.2 X 10^2</td>
<td>2.9 x 10</td>
<td>2.84 X 10^2</td>
<td>3.9 x 10</td>
</tr>
<tr>
<td>6</td>
<td>Tuticorin 2 TPP</td>
<td>3.3 X 10</td>
<td>2.1 x 10</td>
<td>2.0 x 10</td>
<td>2.1 x 10</td>
</tr>
<tr>
<td>7</td>
<td>Tuticorin 3 SPIC</td>
<td>3.0 x 10</td>
<td>2.0 x 10</td>
<td>2.1 x 10</td>
<td>2.0 x 10</td>
</tr>
<tr>
<td>8</td>
<td>Arumuganeri</td>
<td>1.9 x 10</td>
<td>2.2 x 10</td>
<td>2.0 x 10</td>
<td>2.1 x 10</td>
</tr>
<tr>
<td>9</td>
<td>Tiruchendur</td>
<td>1.2 X 10^2</td>
<td>2.8 x 10</td>
<td>2.6 X 10</td>
<td>2.8 X 10</td>
</tr>
<tr>
<td>10</td>
<td>Kudankulam</td>
<td>1.0 x 10</td>
<td>1.5 x 10</td>
<td>1.0 x 10</td>
<td>1.0 x 10</td>
</tr>
<tr>
<td>11</td>
<td>Kanyakumari</td>
<td>1.0 x 10^2</td>
<td>1.8 x 10</td>
<td>3.6 x 10</td>
<td>1.8 x 10</td>
</tr>
</tbody>
</table>

Bold faced numbers indicate minimum and maximum values.

A range of 4.8 X 10 cfu/ml was found in Tiruchendur waters. In sediment samples, 3.3 X 10^2 cfu/g was recorded as *Vibrio cholerae* in Tuticorin.

**Heavy metals in seawater, marine sediments and in fish**

The concentration of Heavy metals in seawater, sediment and whole fish tissue samples analyzed are listed in Tables 6,7 and 8 respectively. The detectable limits of these metals are given in Table-9. The level of Cadmium observed in seawater and fish tissue samples were maximum at Tuticorin as 0.051 ppm and 0.012 ppm respectively whereas in the sediments the maximum observed was near Tuticorin TPP as 0.062 ppm. The maximum levels of Chromium were observed in Tuticorin sediments and tissue samples as 0.871 and 12.82 ppm respectively whereas the seawater of Erwadi showed the maximum level as 0.009 ppm. Similarly, the level of copper in marine sediments and fish tissue samples observed as maximum were at Tuticorin (4.226 and 0.219 ppm respectively) and in the seawater also it was at Tuticorin (0.084 ppm).

Accumulation of Manganese in fish tissue samples indicated maximum level of 0.795 ppm at Tuticorin and its maximum level in the seawater was recorded at Erwadi as 0.061 ppm. The fish tissue sample collected at Tuticorin and the sediment sample collected at Tiruchendur showed maximum Nickel concentration as 0.287 ppm and 0.302 ppm respectively. Maximum level of Lead and Zinc in sediment and tissue samples were recorded at Tuticorin and Similarly the maximum level in seawater was also observed at Tuticorin.

Accumulation level of mercury in fish tissues and sediment samples observed in Tuticorin were 0.020 and 0.094 ppm. Lower level of the metal in sediments were recorded at Tiruchendur and Erwadi as 0.005 ppm.
Table 6. Heavy metals in the seawater of Gulf of Mannar

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Mn</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
<th>Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rameswaram</td>
<td>0.001</td>
<td>0.003</td>
<td>0.013</td>
<td>0.051</td>
<td>0.025</td>
<td>0.225</td>
<td>0.260</td>
<td>BDL</td>
</tr>
<tr>
<td>2</td>
<td>Pudhumadam</td>
<td>0.002</td>
<td>0.002</td>
<td>0.012</td>
<td>0.050</td>
<td>0.025</td>
<td>0.300</td>
<td>0.225</td>
<td>BDL</td>
</tr>
<tr>
<td>3</td>
<td>Keelakkarai</td>
<td>0.001</td>
<td>0.004</td>
<td>0.033</td>
<td>0.014</td>
<td>0.025</td>
<td>0.348</td>
<td>0.260</td>
<td>BDL</td>
</tr>
<tr>
<td>4</td>
<td>Erwadi</td>
<td>0.008</td>
<td>0.009</td>
<td>0.064</td>
<td>0.061</td>
<td>0.171</td>
<td>0.226</td>
<td>0.690</td>
<td>BDL</td>
</tr>
<tr>
<td>5</td>
<td>Tuticorin 1 Thirespuram</td>
<td>0.051</td>
<td>0.003</td>
<td>0.084</td>
<td>0.061</td>
<td>0.156</td>
<td>0.803</td>
<td>1.202</td>
<td>BDL</td>
</tr>
<tr>
<td>6</td>
<td>Tuticorin 2 TPP</td>
<td>0.031</td>
<td>0.003</td>
<td>0.065</td>
<td>0.055</td>
<td>0.175</td>
<td>0.506</td>
<td>0.750</td>
<td>BDL</td>
</tr>
<tr>
<td>7</td>
<td>Tuticorin 3 SPIC</td>
<td>0.025</td>
<td>0.002</td>
<td>0.062</td>
<td>0.050</td>
<td>0.155</td>
<td>0.515</td>
<td>0.650</td>
<td>BDL</td>
</tr>
<tr>
<td>8</td>
<td>Arumuganeri</td>
<td>0.031</td>
<td>0.003</td>
<td>0.040</td>
<td>0.055</td>
<td>0.170</td>
<td>0.505</td>
<td>0.575</td>
<td>BDL</td>
</tr>
<tr>
<td>9</td>
<td>Tiruchendur</td>
<td>0.018</td>
<td>0.004</td>
<td>0.022</td>
<td>0.003</td>
<td>0.094</td>
<td>0.778</td>
<td>0.952</td>
<td>BDL</td>
</tr>
<tr>
<td>10</td>
<td>Kudankulam</td>
<td>0.001</td>
<td>0.001</td>
<td>0.015</td>
<td>0.002</td>
<td>0.010</td>
<td>0.200</td>
<td>0.200</td>
<td>BDL</td>
</tr>
<tr>
<td>11</td>
<td>Kanyakumari</td>
<td>0.001</td>
<td>0.001</td>
<td>0.015</td>
<td>0.002</td>
<td>0.010</td>
<td>0.200</td>
<td>0.200</td>
<td>BDL</td>
</tr>
</tbody>
</table>

Reference Level
0.00011 0.00005 0.003 0.002 0.002 0.00003 0.01 0.00003

BDL = Mercury was in Below Detectable Limit. Bold faced numbers indicate minimum and maximum values.

Table 7. Heavy metals in marine sediments of Gulf of Mannar.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Location</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Mn</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
<th>Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rameswaram</td>
<td>0.013</td>
<td>0.325</td>
<td>0.650</td>
<td>2.550</td>
<td>0.070</td>
<td>0.250</td>
<td>0.850</td>
<td>BDL</td>
</tr>
<tr>
<td>2</td>
<td>Pudhumadam</td>
<td>0.015</td>
<td>0.350</td>
<td>0.725</td>
<td>2.550</td>
<td>0.060</td>
<td>0.275</td>
<td>0.750</td>
<td>BDL</td>
</tr>
<tr>
<td>3</td>
<td>Keelakkarai</td>
<td>0.014</td>
<td>0.582</td>
<td>1.124</td>
<td>2.551</td>
<td>0.074</td>
<td>0.519</td>
<td>0.959</td>
<td>BDL</td>
</tr>
<tr>
<td>4</td>
<td>Erwadi</td>
<td>0.059</td>
<td>0.627</td>
<td>1.273</td>
<td>2.144</td>
<td>0.098</td>
<td>0.302</td>
<td>1.062</td>
<td>0.005</td>
</tr>
<tr>
<td>5</td>
<td>Tuticorin 1 Thirespuram</td>
<td>0.028</td>
<td>0.871</td>
<td>4.226</td>
<td>7.227</td>
<td>0.293</td>
<td>0.580</td>
<td>1.160</td>
<td>0.094</td>
</tr>
<tr>
<td>6</td>
<td>Tuticorin 2 TPP</td>
<td>0.062</td>
<td>0.725</td>
<td>0.581</td>
<td>6.560</td>
<td>0.215</td>
<td>0.480</td>
<td>1.420</td>
<td>BDL</td>
</tr>
<tr>
<td>7</td>
<td>Tuticorin 3 SPIC</td>
<td>0.056</td>
<td>0.650</td>
<td>0.421</td>
<td>6.320</td>
<td>0.201</td>
<td>0.420</td>
<td>1.050</td>
<td>BDL</td>
</tr>
<tr>
<td>8</td>
<td>Arumuganeri</td>
<td>0.058</td>
<td>0.560</td>
<td>0.386</td>
<td>6.315</td>
<td>0.295</td>
<td>0.475</td>
<td>1.420</td>
<td>0.005</td>
</tr>
<tr>
<td>9</td>
<td>Tiruchendur</td>
<td>0.027</td>
<td>0.858</td>
<td>0.381</td>
<td>7.110</td>
<td>0.302</td>
<td>0.424</td>
<td>1.130</td>
<td>0.005</td>
</tr>
<tr>
<td>10</td>
<td>Kudankulam</td>
<td>0.012</td>
<td>0.075</td>
<td>0.105</td>
<td>2.515</td>
<td>0.060</td>
<td>0.215</td>
<td>0.700</td>
<td>BDL</td>
</tr>
<tr>
<td>11</td>
<td>Kanyakumari</td>
<td>0.014</td>
<td>0.090</td>
<td>0.125</td>
<td>2.250</td>
<td>0.055</td>
<td>0.275</td>
<td>0.750</td>
<td>BDL</td>
</tr>
</tbody>
</table>

BDL - Below Detectable Limit. Bold faced numbers indicate minimum and maximum values.

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### Environmental quality assessment of Gulf of Mannar coast

#### Table 8. Heavy metals accumulation in Fish samples of Gulf of Mannar

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Site</th>
<th>Heavy metal concentration in fish (ppm)</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Mn</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
<th>Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rameswaram</td>
<td></td>
<td>0.003</td>
<td>0.354</td>
<td>0.025</td>
<td>0.030</td>
<td>0.054</td>
<td>0.010</td>
<td>0.350</td>
<td>BDL</td>
</tr>
<tr>
<td>2</td>
<td>Pudhumadam</td>
<td></td>
<td>0.002</td>
<td>0.350</td>
<td>0.030</td>
<td>0.025</td>
<td>0.050</td>
<td>0.025</td>
<td>0.215</td>
<td>BDL</td>
</tr>
<tr>
<td>3</td>
<td>Keelakkarai</td>
<td></td>
<td>0.005</td>
<td>0.530</td>
<td>0.085</td>
<td>0.050</td>
<td>0.110</td>
<td>0.060</td>
<td>0.415</td>
<td>BDL</td>
</tr>
<tr>
<td>4</td>
<td>Erwadi</td>
<td></td>
<td>0.006</td>
<td>0.610</td>
<td>0.090</td>
<td>0.040</td>
<td>0.150</td>
<td>0.070</td>
<td>0.450</td>
<td>BDL</td>
</tr>
<tr>
<td>5</td>
<td>Tuticorin 1 Thirespuram</td>
<td></td>
<td>0.012</td>
<td>12.82</td>
<td>0.219</td>
<td>0.795</td>
<td>0.287</td>
<td>0.135</td>
<td>0.875</td>
<td>0.020</td>
</tr>
<tr>
<td>6</td>
<td>Tuticorin 2 TPP</td>
<td></td>
<td>0.005</td>
<td>6.50</td>
<td>0.210</td>
<td>0.600</td>
<td>0.300</td>
<td>0.125</td>
<td>0.800</td>
<td>0.015</td>
</tr>
<tr>
<td>7</td>
<td>Tuticorin 3 SPIC</td>
<td></td>
<td>0.005</td>
<td>5.05</td>
<td>0.215</td>
<td>0.590</td>
<td>0.290</td>
<td>0.120</td>
<td>0.750</td>
<td>0.010</td>
</tr>
<tr>
<td>8</td>
<td>Arumuganeri</td>
<td></td>
<td>0.006</td>
<td>6.50</td>
<td>0.200</td>
<td>0.550</td>
<td>0.295</td>
<td>0.125</td>
<td>0.650</td>
<td>0.015</td>
</tr>
<tr>
<td>9</td>
<td>Tiruchendur</td>
<td></td>
<td>0.007</td>
<td>0.760</td>
<td>0.107</td>
<td>0.054</td>
<td>0.257</td>
<td>0.071</td>
<td>0.508</td>
<td>BDL</td>
</tr>
<tr>
<td>10</td>
<td>Kudankulam</td>
<td></td>
<td>0.002</td>
<td>0.350</td>
<td>0.025</td>
<td>0.025</td>
<td>0.050</td>
<td>0.020</td>
<td>0.190</td>
<td>BDL</td>
</tr>
<tr>
<td>11</td>
<td>Kanyakumari</td>
<td></td>
<td>0.002</td>
<td>0.550</td>
<td>0.030</td>
<td>0.050</td>
<td>0.025</td>
<td>0.198</td>
<td>BDL</td>
<td></td>
</tr>
</tbody>
</table>

*Fish = Mugil cephalus; BDL- Below Detectable Limit*

><br>**Table 9. Detectable limits of Heavy metals in the study**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Types of Heavy metal</th>
<th>Detectable limit (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cadmium (Cd)</td>
<td>0.003</td>
</tr>
<tr>
<td>2</td>
<td>Chromium (Cr)</td>
<td>0.006</td>
</tr>
<tr>
<td>3</td>
<td>Copper (Cu)</td>
<td>0.006</td>
</tr>
<tr>
<td>4</td>
<td>Manganese (Mn)</td>
<td>0.002</td>
</tr>
<tr>
<td>5</td>
<td>Nickel (Ni)</td>
<td>0.010</td>
</tr>
<tr>
<td>6</td>
<td>Lead (Pb)</td>
<td>0.042</td>
</tr>
<tr>
<td>7</td>
<td>Zinc (Zn)</td>
<td>0.002</td>
</tr>
<tr>
<td>8</td>
<td>Mercury (Hg)</td>
<td>0.005</td>
</tr>
</tbody>
</table>

**Conclusion & Recommendations for further studies**

This pilot study revealed:

1. Heavy metals load increased from Rameswaram coast towards Tuticorin coast.
2. Microbial contamination was found to be high at Tuticorin and Rameswaram.
3. Polluted sites were identified in 2 regions – One between Erwadi and Tuticorin and the other between Tuticorin and Tiruchendur.
4. All samples in the study were collected 250 to 500 meters from the shore and hence might indicate only diluted levels of materials from the point of discharge into the sea. Therefore all the physico-chemical and nutrient parameters appear to be normal.
5. A complete survey of the coastline of Gulf of Mannar, from Dhanushkodi to Kanyakumari, should be done to find out the discharge points of land runoff and sewage/industrial effluents.
6. Seasonal variations in physico-chemical parameters, microbial status, and heavy metals load need to be analyzed extensively in both polluted and unpolluted sites.
7. An in-depth study is essential to understand regional and seasonal variations in marine water quality in the Gulf of Mannar. This should include monitoring the pollution load from the point of entry to a distance inside the sea so as to find out how dilution plays a role in dissipating the contaminants. Based on such a study remedial measures can be taken or suggested to different agencies/authorities.
Introduction

The Indian coastline supports almost 30% of its human population, dependent on the rich exploitable coastal and marine resources. The Bay of Bengal and the Arabian Sea have rich fishing grounds in the South Asian region and contribute to rank as the 7th largest marine fishing nation in the world. The marine biodiversity of India is represented by diverse fish species including medicinal species. The Gulf of Mannar in Tamil Nadu adds further values to the marine habitat and rich biodiversity. The reliance of increasing population on the ocean for food, pharmacological products, recreation, transport and mineral extraction/oil exploration has subjected marine biodiversity to pressures that are changing the structure of marine communities.

Seaweeds

Seaweeds are reported to have multi-faceted medicinal and pharmaceutical properties. More than 14 different seaweeds are reported in Indian Traditional medicine mostly for intestinal disorders. They are used as vermicides and prepared in the form of salad, extract or porridge. Recent experiments in the author’s lab indicated the immune enhancing ability of seaweeds such as Ulva fasciata and Hypnea musciformis. Survey of sea weeds along the Gulf of Mannar is accomplished by the CMFR Institute. A harvesting time-table was also prepared by the Institute for sustained utilization.

Corals

Corals find place in siddha medicine for treating cough, nervous disorders and tuberculosis. Coral reefs are biologically productive & diverse of all natural ecosystems. Reefs are equivalent to tropical rain forests for their rich biodiversity and are objects of beauty and utility. In the Gulf of Mannar and Palk Bay about 96 species in 26 Genera are reported. Coral mining, siltation and other factors like coral bleaching and human interventions (Dynamites) have reduced the coral resources to a greater extent.

R & D Needs

- Need for data on coral beds
- Biodiversity of reef and its associated flora and fauna are to be studied in detail
- Documentation
- Culture of corals
- Studies on coral bleaching and possible remedies

Gorgonids

Gorgonids, being objects of attraction are collected as curios. They are of medicinal importance Prostaglandin was initially extracted from gorgonids. In Traditional medical practice, gorgonids are used for painless child birth – as water extract. In India, commercial exploitation of gorgonids started in 1975. They were exported as bulk quantities to other countries. The Gorgonids are represented by about 22 species belonging to seven families and 15 genera. A detailed survey conducted by CMFRI along
the Gulf of Mannar area indicated that the catch of gorgonids declined due to over exploitation.

**Problems**

Some research information indicates very low growths of sea fans (~2cm/year). While harvesting the gorgonids (‘targeted exploitation), they are removed totally from the substratum – meaning total destruction of the colony. The present status of our information on the growth, regeneration and reproduction of gorgonids is scanty. As they have non-isometric growth pattern, it difficult to get the estimations of growth. Conservative pruning of gorgonids could be a better replenishment strategy and much work is still needed in this aspect.

**R&D Needs**

- Urgent need to assess the availability of different species of gorgonids (space & time)
- Multidisciplinary work on useful chemicals and their bioactivity

**Marine Sponges**

The sponges find attention in traditional medicine to treat goiters. Ashes of sponges are mixed with vegetable oil for such treatments. In living sponges, the secondary metabolites are synthesized to protect themselves and to maintain homeostasis. The wider biosynthetic capability of sponges could be attributed to their biological association with other symbionts and about 38% of the sponge body comprised of microorganisms. Sponge extracts has shown multi various bioactivities ranging from simple anti-biotic activity to complex cytoplastic and anti-cancer activities. Sponges are dislodged by trawling operations. There also need to culture sponges and to detect the bioactivity profiles.

**Molluscs**

The molluscs belonging to gastropods, bivalves, cephalopods are represented by about 3270 species belonging to 591 genera. The bivalves are known to be used as medicines such as antacid, to treat loss of appetite, liver and spleen disorder, skin disorders. The gastropods such as sacred chanks *Xancus pyrum*, are commercially exploited. Declining chank population is noted in the Gulf of Mannar, Palk Bay and Kerala coasts. The recent demand for chank shells, flesh and operculum led to the increased exploitation. Chank flesh is rich in protein and minerals and the values compared favorably with those of fishes. Although, there are restrictions, exploitations by modified trawl nets along Rameswaram coasts in Tamil Nadu have been reported. Such intense bottom trawl activities also led to depletion of population of chanks in the traditional chank bed areas. Apart from the two well distinguished sub-species of the chank viz., *Xancus pyrum* var. *acuta* and *Xancus pyrum* var. *obtusa*, *Xancus pyrum* var. *comorinensis* and *Xancus pyrum* var. *irupiravi* were also noted. The fecundity of the sacred chanks ranges from 99 to 275 (average 222) per chank/ year. The sacred chank, *Xancus pyrum* is a slow growing species with an MSD-wise growth is about 8.0 mm/year. It is possible to breed them in laboratory conditions, grow the babies to the suitable size for sea ranching.

**Sea cucumbers, starfishes, sea urchins and related organisms**

About 12 species of sea cucumbers are commercially exploited. The falling catch per unit effort and the size reduction indicate over fishing of sea cucumbers and needs further research in breeding and sea ranching. The sea urchin gonads are in high demand as source for carotenoid pigments. However, systematic account on the availability of sea
urchins and their gonadal ß-carotene content are to be evaluated.

The sea grass ecosystem

The sea grass ecosystem and the major role in nutrient dynamics are yet to be assessed. The first documented identification of a bioactive marine bacterial metabolite was the highly brominated pyrrole antibiotic, isolated by Burkholder and co-workers from a bacterium obtained from the surface of the Caribbean Sea grass. Till now much research attention is not given for sea grass ecosystem.

Seahorses

Seahorses are sought in great numbers, for use in traditional medicines, as aquarium fishes and as curios. The results of the investigations by the author’s team revealed seven species of seahorse compared to the earlier Hippocampus kuda complex. These include: Hippocampus fuscus, H. histrix, H. kelloggi, H. kuda, H. mohnikei, H. spinosissimus, and H. trimaculatus. The mean number of juveniles per brood was 262.33± 59.49 (range 162 to 317). Juveniles attained a length of 101.10 mm and wet weight of 1.94±0.25g in 90 days of rearing. In the captive conditions, stocking at the rate of 3 juveniles /L was found to be better for nursery rearing along with the combined diet of Artemia and Mysids. The tagging and recapture studies highlighted that the natural growth rate of seahorse (H. kuda) in their normal habitat is 4.15 mm/month.

Urgent R&D needs

• Biodiversity inventory of marine medicinal fishes along the Gulf of Mannar coast of India is essential.
• Biodiversity inventory of Marine microbes and their propagation and new culture methods.
• Seasonal productivity and its relationship to biodiversity.

The effect of anthropogenic influences in coastal waters.
Introduction

The coastal wetlands (lagoons, saltpans, islands, estuaries) along the Gulf of Mannar (GOM) provide feeding grounds for hundred thousands of migratory waterbirds consist of waders, ducks, terns, gulls and flamingos migrating from high arctic regions, west and central Asia. These coastal habitats and the neighbouring inland wetlands including paddy fields not only form the major wintering grounds for the migratory birds but also provide nesting and breeding sites for thousands of heronry birds such as storks, ibises, egrets, herons and pelicans. The threatened Spotbilled Pelican *Pelecanus philippensis* which nests at nearby heronries (Chitrangudi, Big Tank and Sakkarakottai Tank) also frequents the coastal habitats of GOM to collect fishes for their chicks. Some coastal birds of GOM also utilize the surrounding inland wetlands for various activities. Hence, the importance of GOM in maintaining the global population of migratory and resident waterbirds is not dubitable. This paper describes the current status of the coastal birds of GOM and compares with the past status documented through the bird migration studies carried out by the Bombay Natural History Society at GOM between 1985 and 1989.

Materials and Methods

The fortnightly migratory waterbird population documented during the three migratory seasons between 1985 and 1989 at the Manali and Hare islands of Gulf of Mannar, Kundugal Point of Pampan, Pillaimadam and Dhanuskodi lagoons, under the Bird Migration Project of the BNHS were taken as the baseline data to assess the size of the populations during the 1980s. Similarly, the data generated through rapid surveys undertaken between 1990 and 1992 under the same project at various wetlands in and around GOM were used to determine the bird population of 1990s. These baseline data are compared with the current estimates made through the ongoing field project in the GOM.

Past and current status of coastal birds at Dhanushkodi and Mandapam group of islands

Past status

Biddulph (1957) made the annotated checklist of birds of Rameswaram. The bird migration studies carried out by the Bombay Natural History Society has updated the checklist and well documented the status of coastal birds of the Rameswaram and the other Mandapam group of islands during the late 1980’s. Over 70,000 coastal birds migrated to this area from the high arctic and temperate zones of the central Russia and Persian Gulf. Over 7,000 waders and terns were ringed during three migratory seasons between 1985 and 1988. The highest number of Greater Flamingo *Phoenicopterus ruber* recorded during the late 1980’s was around 14,000 (Balachandran, 1990 & 1995). The other species found in over ten thousands were the Lesser Crested Tern *Stern bengalensis*, Lesser Sand Plover *Charadrius leschenaultii* and Curlew Sandpiper *Calidris ferruginea*. The Little Stint *Calidris minuta* was the other...
common species for which the number recorded was around 8,000. The numbers counted for Redshank *Tringa totanus* and Greenshank *Tringa nebularia* and Grey Plover exceeded one thousand. The uncommon waders to India such as Red Knot, Great Knot, Sanderling, Crab Plover *Dromas ardeola* Large Sand Plover *Pluvialis squatarola*, Pacific Golden Plover *Pluvialis fulva*, Terek Sandpiper *Xenus cinereus*, Ruddy Turnstone *Arenaria interpres* and Bar-tailed Godwit *Limosa lapponica* were recorded in several hundreds. The other widespread uncommon species recorded in few hundreds were Eurasian Curlew *Numenius arquata* and Whimbrel *Numenius phaeopus*. A maximum 42 Pied Oystercatchers *Haemotopus ostralegus* were recorded in October 1985.

**Present Status**

Now the total population of coastal never exceeded 15,000 during the present study. The only species seen above 5,000 was the Greater Flamingo. Besides Greater Flamingo, the numbers exceeded over thousand in only three species namely Lesser Crested Tern, Lesser Sand Plover and Brown-headed Gull.

**Greater Flamingo**

The numbers counted for this species during 2005-2006 season was 5500 during January and February at Dhanushkodi Lagoon. When the Dhanuskodi Lagoon was dry this species was seen in few thousands at the neighbouring inland wetlands Chakarakottai Tank and Big Tank in Ramanathapuram town.

**Terns**

Among the tern species recorded from the Gulf of Mannar, the maximum number counted for the most common species the Lesser Crested Tern was 2800 during January 2006 around Manali and Hare islands. At Dhanuskodi Lagoon maximum numbers seen were 650 during February. Over 70% decline was noticed for this species during the last two decades. The variations in numbers counted for two other common species Caspian and *Sterna caspia*, Indian Whiskered *Chlidonias hybrida* terns were not pronounced. However, the species which were regularly sighted in hundreds during the 1980’s such as Gullbilled *Gelochelidon nilotica* and Sandwich *Sterna sandvicensis* terns are rarely seen as is in the case of Large-crested Tern.

**Smaller Waders**

The three common small waders to the GOM during the 1980s namely Lesser Sand Plover, Curlew Sandpiper and Little Stint had shown drastic decline during the last 20 years. During 1985-1988, in three seasons each of these three species were caught and ringed over two thousand. But the total number of this species wintering in this region is not exceeding the ringing totals of 1985-1988. Out of them the most affected was the Little Stint for which the numbers never crossed 300 during the current season. The maximum number counted for the Lesser Sand Plover was 3200 and for Curlew Sandpiper was 850. The Greater Sand Plover number was also too less when compared to the number (700) recorded in the 1980’s as it is now around 50.

**Medium sized waders**

Among the Tringa Sandpipers, the decline in Greenshank was so evident. Though the number of Greenshank never crossed thousand during 1980’s once during a bird census at Dhanushkodi in December 1992, this species was sighted in unusual numbers of around 3000. But this time its numbers not crossed even one hundred. The other species declined heavily was the Terek Sandpiper, for which the maximum number seen was 32. Manali Island was one of the best habitats for this species which used to be seen in several
hundreds during 1980s. Even this species oversummered on this island in small numbers. Though Common Redshank’s number has also gone down heavily still they are seen in a few hundreds in all the habitats of GOM. Marsh Sandpiper being a mudflat preferring species its numbers were low during earlier and now also.

### Larger Waders

The larger waders such as Eurasian Curlew, Grey Plover were now seen around one hundred, which were recorded in several hundreds during the previous study in the 1980’s. The number of Whimbrel seen was less than 20, for which the numbers during 1980’s was slightly over one hundred.

### Uncommon Waders to India

The uncommon waders to India such as Red Knot, Great Knot which were found to occur regularly in three to five hundreds in several hundreds. Now during this study period the numbers recorded for these two species were less than 50. Similarly Sanderling *Calidris alba* numbers never crossed 70, which was much less than the ringing total of 130 during 1985-1988 and the population of around 1000, Though the numbers counted for Bar-tailed Godwit and Ruddy Turnstone were around one hundred still the numbers were far behind that of 20 years back. The Pied Oystercatcher number recorded was 12, for which the maximum counted was 42 in the previous study.

### Resident Waders

Out of the five resident wader species around the GOM, the Yellow-wattled Lapwing *Vanellus malabaricus* was not recorded during this study. The Greater Stone Plover *Esacus magnirostris* which was regularly seen in a few pairs in all the habitats, has become so rare only one pair was seen in Manali Island. The Stone Curlew *Burhinus oedicnemus* used to be heard quite often during night has become rare. The breeding subspecies of the Kentish Plover *Charadrius alexandrinus seebohmi* numbers is also no exception for the heavy decline.

### Ducks

The numbers of the three migratory ducks (Northern Pintail *Anas acuta*, Garganey *Anas querquedula* and Common Teal *Anas crecca*) recorded which normally seen in a few thousands at Pillaimadam Lagoon (near Mandapam) during the 1980’s have become in hundreds. Earlier only Pintail frequented the Manali Island in a few occasions. However, now they frequent the island mostly for resting in hundreds (up to 800) from December to February.

### Gulls

Among the three species of common Gulls of the GOM, the decline was more pronounced in Brown-headed *Larus brunnicephalus* gull. In the other two species namely Pallas Gull *Larus ichthyaetus* and Hueglin Gull *Larus heuglenei* the decline was 15%.

### Other coastal bird habitats

#### Saltpans along the Gulf of Mannar

The saltpans at Valinokkam located between Dhanushkodi and Tuticorin also supported over 1500 Greater Flamingos and the other waders 5000 each during early 1990s. The Greater Flamingo occurring at Dhanushkodi can also frequent the Valinokkam saltpans when the water level in the lagoon is not conducive for them to forage. It is possible because, the aerial distance between the lagoon and the saltpan is c. 60 km. At Tuticorin, a shallow salt marsh found inside the major fertilizer factory premises at Spic Nagar, regularly supported Greater Flamingos in several hundreds. The
salt pans in and around Tuticorin also supported large population of migrant shorebirds during till early 1990s. The present status of coastal birds at these saltpans are not known as no surveys were undertaken after 1992.

From October 2005 onwards, the three relatively small saltpans around Kanyakumari, the southernmost tip of India have started attracting Greater Flamingos in several hundreds. It is interesting to mention that the Greater Flamingos stayed in these wetlands throughout the year except July and August. These salt pans also attract several thousands of migratory waders, terns, ducks.

**Inland wetlands**

*Sakkarakottai Tank and Big Tank*

These two twin irrigation tanks together identified as an Important Bird Area are located in the Ramanathapuram town. Greater Flamingo frequents these tanks up to 2000 in numbers in certain periods generally from October to February subject to the water level. The other coastal birds which utilize both Gulf of Mannar and these tanks are Black-tailed Godwit, Greenshank, Marsh Sandpiper, Black-winged Stilt *Himantopus himantopus*, and Common Redshank

**Threats to the coastal bird habitats**

The decline in of population in the last two decades at Dhanushkodi Lagoon was probably due to habitat degradation. Due to silitation the flooding of this lagoon is not happening regularly and most of the period it is dry. As the lagoon is flooded for a shorter period between November and January it is habitable for the flamingos and coastal waders only during this period. Now, the major bird congregation area of Dhanuskodi lagoon, which falls in the Coastal Regulation Zone (CRZ) is proposed to construct the administrative block and being used as the dumping sites for the dug out sand during dredging for the massive ‘SethuSamuthram Shipping Canal’ project.

**Recommendation**

- Awareness about the migratory birds
- Role of migratory birds in the coastal ecosystem and especially in maintaining the local fishery
- Long-term monitoring of bird population along with their feeding ecology
- Documentation of macrobenthic organisms, the major food components of the coastal waders

**Conclusion**

Among the coastal bird habitats of the east coast of India, the Manali and Hare islands, and the Dhanuskodi lagoon are the most favoured habitats of sand-flat preferring waders such as Crab Plover, Oystercatcher, Bar-tailed Godwit, Sanderling, Red Knot, Great Knot. Similarly this area also supported the larger congregation of marine terns namely Lesser Crested and Sandwich terns. Overall all the coastal waders at GOM are on the decline, it is necessary to investigate the local causes for the decline, for undertaking conservation measures. Occurrence of larger congregation of coastal birds will help to maintain the biodiversity of GOM as they play important role in recycling the nutrients back to the ecosystem.

**References cited**


Introduction

The coastal zone is a unique geological, physical, and biological area of vital economic and environmental value. India has a peninsular coast of 3554 nautical miles and has had maritime trade with various countries of the world since time immemorial. India is one of the 12 mega-centers of biological diversity. Two of the major realms and three basic biomes including 10 biographic regions are represented in our country. The Gulf of Mannar biosphere Reserve is one of the six areas chosen on the basis of the significance and diversity of threats, on the one hand and the richness of biological wealth on the other. Coastal and marine areas contain some of the world’s most diverse and productive biological systems. They include extensive area of complex and specialized ecosystems, such as enclosed seas and tidal systems, estuaries, salt marshes, coral reefs, seagrass beds and mangroves that are sensitive to human activities, impacts and interventions. As rapid development and population growth continue in coastal areas, increasing demands are placed on the natural resources and on the remaining natural habitats along the coasts.

The Gulf of Mannar is currently under serious threats the study is aimed to design a database to help the decision-makers & stakeholders in effective monitoring and managing the biological wealth of this area.

Coral ecosystem

Coral reefs are among the most diverse and productive of all ecosystems in the marine environment. They are among the most complex, biologically diverse, and beautiful of all marine ecosystems. Coral reefs are beautiful vibrant underwater cities, home to over a hundred thousand different species of sea creatures. There are about 128 species of corals (42 endemic) were reported (Pillai, 1986, CMFRI,1998) The dominant genera were Pocillopora, Acropora, Montipora, Favia, Favites, Gonipora Gonisatrea, Platygyra, Echinopora, Glaxea, Porites, Turbinaria, Leptoria, Pavona and Pachyseris.

Mangrove ecosystem

Mangroves are a group of woody salt tolerant trees that are adapted to grow in the intertidal zone. In contrast with other trees that grow on land, mangroves grow in saline / salty waters. They grow closest to the ocean and have prop roots which are submerged under water during high tide but are exposed during low tide, sticking out of the muddy substrate. It is believed that the Gulf of Mannar was once covered with thick mangrove forests. Their remnants as relics are seen even now (Krishnamurthy et al., 1987). Iyengar (1927) also observed luxuriant and diversified vegetation on Krusadai island. They are highly productive ecosystems which provide essential nursery grounds for a variety of marine organisms They provide food and shelter for many organisms both above and below the water (Odum and Odum, 1955). They also serve as protection against soil erosion and storm damage and act as a buffer.
zone that filters pollutants and prevents them from reaching the sea.

**Seagrass ecosystem**

Seagrasses are marine angiosperms (flowering plants) which resemble grasses in growth and form (as most have ribbon-like, grassy leaves), but none is a true grass. They are unique as they are the only marine flowering plants. Like terrestrial angiosperms, they have leaves, stems and flowers, as well as roots. Seagrasses growing in large areas are called seagrass beds. Seagrass beds are valuable and overlooked habitats, providing important ecological and economic components of coastal ecosystems worldwide. These underwater plants trap sediment and hold them in their roots and thus help to stabilize coastal sediments and shorelines. Seagrass beds also serve as spawning and nursery grounds for various species of fish and invertebrates. (McRoy and Mc Millan 1977). The list of seagrass species of Gulf of Mannar Biosphere Reserve is as follows: Enhalus acoroides, Thalassia hemprichii, Halophila ovata, Halophila ovalis, Halophila stipulacea, Halophila decipiens, Halophila beccarii, Potomogetonaceae, Halodule uninervis, Halodule uninervis(broad leaved form), Cymodocea serrulata, Cymodocea rotundata, Syringodium isoetifolium

**Seaweed ecosystem**

Seaweeds or marine algae form one of the important marine living resources. They are primitive plants without any true root, stem and leaves. They come under the Division of Thallophyta of plant Kingdom. Seaweeds belong to four groups of algae namely Chlorophyceae (green algae), Phaeophyceae (brown algae), Rhodophyceae (red algae) and Cyanophyceae (blue-green algae) based on the type of pigments present in them and other morphological and anatomical characters. They occur in the intertidal and subtidal regions of the sea and also in brackish backwater environment. They grow on dead corals, rocks, stones, pebbles, other substrates and as epiphytes on seagrasses.

Studies were made by several workers on marine algal flora, their distribution and resources from some of Gulf of Mannar islands. (Chacko et al., 1995; Varma and Krishna Rao, 1962; Desai, 1967; Uma Maheswara Rao, 1972; Krishnamurthy and Joshi, 1970). A total number of 147 species of algae comprising 42 species of green algae, 31 species of brown algae; 69 species of red algae and 5 species of blue-green algae occurred in the Gulf of Mannar islands.

**Gulf of Mannar as a critical habitat**

Gulf of Mannar is now facing severe threats due to destruction of critical habitats like corals, seaweeds and seagrass through indiscriminate and intensive trawling, coral mining, dynamite fishing, commercialized fishing of specific fauna such as sea fans, chucks, sea cucumber and sea horses, poaching of threatened and endangered species like dugongs and turtles and discharge of effluents from various industrial activities. Under such grave circumstance the Gulf of Mannar was aptly chosen as a critical habitat on the basis of the serious threats on one hand and its richness of biological wealth on the other.

**Methodology**

The major objective of the study is to create an Information System on the resources of Gulf of Mannar in order to help the decision – makers in effective monitoring and managing the biological wealth of this area. Remote sensing, GIS and RDBMS along with the field surveys have been used in developing the Critical Habitat Information system for this region. Satellite data and GPS
data were used as primary sources of information, GIS and RDBMS were used to analyze and develop complete information system with their capabilities.

The water quality parameters will be analyzed by using the methods in APHA

**Previous studies in remote sensing and GIS**

The significance of need-based-research, the important of accurate planning and the necessity to take fast and objective decisions stimulated researchers, scientist, planners and academicians to use the latest technologies. Remote Sensing (RS) and GIS being relatively new on the scientific horizon that have been used in a number of studies for a variety of purposes. The sheer number of studies that are being carried out using RS and GIS is an ample guidance for the potential of RS and GIS techniques.

In the previous study (2000) the Digital data IRS 1D LISS –III of June 1998 was used to map the coral reefs, seaweeds and seagrass in Gulf of Mannar. The Digital data was enhanced spatially to get accurate classification of coral reefs. The digital data were classified using Isodata classifier with 70 classes initially. After ground truth verification the digital data was again classified using supervised classification with 100 training sites. The classified out puts are shown in Table 1. The areas of coral reefs, Mangroves and seagrasses around the islands of Gulf of Mannar calculated using remote sensing data

Among Mandapam group of islands, Musal island has 18.0 sq.km of coral reefs in which 52% are alive. Seagrasses cover an area about 9.5 km. Next to that Manoli and Manoliputti islands have 15.0 sq.km of corals, in that 25% of coral are alive. Seagrasses cove an area about 5.0 sq.km. Pulivisal and Poomarichan islands have 4.0 sq.km and 5.0 sq. km of coral reefs and sea grasses respectively and here 14% of corals are alive. Shingle island has 2.0 sq.km of coral reefs and 0.21 sq.km of seagrasses, in which 46% coral are alive. Krusadai islands has 1.5 sq.Km of coral reefs and 3.0 sq.km of seagrasses in which 33% of corals are live.

Among Keelakarai group of islands, Valai and Talayari islands have 14.0 sq.km of corals in which 16% are alive. Seagrasses cover an area of about 8.0 sq.km. Next to that Mulli island has 7.0 sq.km of corals, in that 25% of coral are alive. Seagrasses cover an area about 2.0 sq.km. Poovarasanpatti and Valimunai islands have 6.0 sq.km and 11.5 sq.km of corals are alive. Anaipar islands have 5.0 sq.km of coral reefs and 14.0 sq.km of seagrasses. In this islands 37% of coral are alive. Appa islands has 5.0 sq.km of coral reefs with only 2% of live corals and 8.0 sq.km of seagrasses.

Among Vembar group of islands, Pulivinchari islands has 7.0 sq.km corals of which 38% are alive. Seagrasses cover an area about 1.5 ssq.km . Next to that Upputhanni island has 3.0 sq.km of corals, in that 26% of corals are alive. Seagrasses cover an area about 2.5 sq.km. Nallathanni island has an area of 2.0 sq.km and 5.0 sq.km. Nallathanni island has an area of 2.0 sq.km and 5.0 sq.km of coral reefs and seagrasses respectively. Here 38% of the corals are alive.

Among Tuticorin group of islands, Kasuwar islands has 6.0 sq.km of corals in which 5% are alive. Seagrasses covers an area about 3.0 sq.km in this islands. Next to that Van island has 2.5 sq.km of corals, in that 7% of corals are alive. Seagrasses covers an area about 5.0 sq.km. Villanguchalli island has 1.0 sq.km of coral reefs and 1.5 sq.km of seagrasses respectively. In this island 8% of corals are alive. Karaichalli island has 0.31 sq.km of coral in which 4% are alive. This island has 1.0 sq.km of seagrasses cover.
Table 1. Coral reef and seagrass area around the island

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<th>Coral reef area (sq.km)</th>
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Future plan to improve the status of the previous works by using higher resolution satellite data

- In the previous survey in 2001 the IRS – 1D data was used for mapping of the floral ecosystem. But currently are available of the higher resolution data from IRS-P6 (Resource sat) with the two sensors such as
  AWiFS data – which has a higher resolution (56m) than the earlier WiFS data, with additional two bands covering green to shortwave infrared region.
  LISS – IV which has the resolution of 5.8 m in multispectral mode.
- Since LISS–IV data has higher resolution; a species level diversity of coastal ecosystem could be achieved using digital image processing techniques.
- A higher scale map of coastal ecosystem could be produced using LISS-IV data, which can used to identify small scale degraded areas. Those areas can be considered for implantation in future.
- Since the water quality parameters is an important parameter for the future plan to save the ecosystem of Gulf of Mannar the water quality parameters must be analyzed and the spatial display must be in GIS use.
- In the Gulf of Mannar the sediment deposits will be identified by using the Bathymetry mapping. And we can also do a comparative analyses of sediment deposit in past 1970’s using the Naval Hydrograph cart with the present chart. This is an important process because if the sediment is deposited in the corals it will affect the whole ecosystem.
- The demarcation of the Potential Fishing Zone, which is the most important future to the fisherfolk. We can mark the fishing zone in the deeper area, and the information will be given to the fishing folk about the details where the fishing
Monitoring Gulf of Mannar coastal ecosystem through remote sensing and GIS with higher resolution satellite data

Site is located. It will also help the fisherfolk not to disturb the ecosystem of Gulf of Mannar in reserve.

- A GIS based Coastal Zone Information System can be developed using the higher resolution data.

**Recommendations**

- The Gulf of Manner Biosphere must be protected from the human interference in order to save the unique ecosystem.
- The mining of the coral in and around the reefs of tuticorin group of islands have already banned by Wild Life Act 2002
- Use of the GIS based information system for sensitive ecosystem is essential
- Regular updating of the water quality parameter gives us an idea about the level of pollution in the water of Gulf of Mannar
- Continuous updating of the database is recommended, in order to help the decision makers in effective monitoring and managing the biological wealth of the islands.

**Conclusion**

Current sectoral approach to the management of marine and coastal resources have generally not proven capable of conserving the marine and coastal biological diversity. New models are needed to move planners towards multiple use, systems oriented and community based management approach. Such a management plan should take into account the threats to the ecosystems, root causes of threat, cost-effective interventions to address the root-causes. The implementation plan should be more strategic to enhance capacity building, sustainable multiple use of biodiversity and develop protection strategies for priority habitats and species. We can no longer continue to take mangrove forests, seagrasses and seaweeds for granted, or assume that they can support unlimited resource exploitation or unmanaged global trade. Even under ideal conditions, it would take more than a lifetime for some of the World's mangrove forests, seagrass beds and seaweeds to recover. Unless immediate effective measures are taken to protect them, they may disappear from the face of the Gulf of Mannar forever.

**References cited**

India has a long coast line of as much as 8000 km of which nearly 1050 km long coast is found in Tamil Nadu of the many coral reef rich environments found in Indian waters. Tamil Nadu coast also possess a coral rich marine environment in its south eastern marine space. Such distinct area is called by name Gulf of Mannar which is acclaimed to be the first marine biosphere reserve not only in the country but also in south and south east Asia.

Gulf of Mannar with all the 21 islands along the 140 km stretch between Tuticorin and Rameswaram (Lat.8 55 – 9 15’ N and Long.78 0’-79 16’ E) has been rightly considered as a Marine Biosphere Reserve. Biosphere Reserve are being very important subject of concern in the Global waters. Gulf of Mannar harbors a unique diversity of more than 3600 spp. of marine organisms. Coral reefs are considered as one of the most productive and diverse eco-systems on earth. This rich bio-diversity is found threatened in most part of the world due to environmental pollution, coral mining, over fishing in reefs, dynamiting, trawling, boat anchoring and also due to natural forces such as floods, cyclones etc.

Gulf of Mannar is also known for its sea grass diversity which amounts to 12 spp. Of which Enhalus acuroidus is considered to be endemic to this area. Sea grass ecosystems being a diverse habitat inhabiting hundreds of organisms right from invertebrates to sea anemones, sea horses, sea turtles and finger links of various fish spp. Sea grass is a marine angiosperm and is unique and the only flowering plant in marine eco-system. Sea grasses grow in continuous patches called sea grass beds or meadows. The sea grass beds are valuable and overlook habitats providing important ecological and economic components of coastal eco-system worldwide. These under water plants trap sediments and hold them in their roots and also help in stabilizing the coastal sediments and shore lines. This rich bio-diversity is facing serious threat due to bottom trawling and over harvesting.

Gulf of Mannar is found in the tropical region of the world and also provides space for existence of unique halophytic mangrove eco-system. Nearly 13 spp. of mangroves are found to be existing in Gulf of Mannar. Of which Pemphis acidula is identified to be endemic to this area. Mangrove hesitation are specialize to growing hostile saline conditions that to in estuaries, creeks, salty coast. Mangrove support an eco-system that is comprised of plants, animals and microorganisms that have adapted to life in the dynamic environment of the tropical inter-tidal zone. This eco-system is responsible for adding organic nutrients into the marine eco-system to facilitate better primary productivity in the areas nearby. This eco-system is also under severe threat due to indiscriminate felling, clearing for salt pan activity etc.

Gulf of Mannar marine biosphere reserve harbors various other eco-system such as island, rocky shore, sandy shore, sand tunes, coastal etc. which adds richness to its diversity. It also provides space for many endangered marine organisms for their survival feeding, breeding and existence. But
it is fact that all the richness existing in the area are entering in to history because of unscientific harvesting methods, over harvesting than the production potential of the area, destruction of breeding and feeding habitat of marine organisms and also due to severe localized pollution. The conservation of Gulf of Mannar biodiversity through holistic management will only be possible through attempting various efforts through various agencies and departments simultaneously. Forest department, Fisheries department, Customs department, Coast Guard, Coastal security and Navy are some of the enforcing departments involved in law enforcement to ensure legal way of exploitation of marine resources from the area. But simple law enforcement will not bring holistic scientific management possibility in place in Gulf of Mannar area without the support of local fisher population.

Gulf of Mannar Biosphere Reserve is extending to a distance of 320 miles along the coast starting from Dhanuskodi to Kanyakumari. The more productive zone of Gulf of Mannar which harbors 21 islands and surrounding shallow water habitat is extending up to Tuticorin coast. This coastal length itself is inhabited by around 3 lakhs fishermen who are on day to day basis dependent on Gulf of Mannar for earning their livelihood. The coastal zonation is peculiar in vocation categorization, communal variation and in other factors. Hence it is necessary to understand the complexity in handling the Gulf of Mannar dependent fisher scientific marine resource management. This would be possible only when the concerned fisher population is made aware of the importance of the marine bio-diversity existing in their area. It is also important to educate the illiterate fisherfolk in appreciating the bio-diversity boundary of the area as well as provide responsibility of managing the marine resources in their area to the fisher population of the area. This proposition would look less imperative as the coastal length is vast and the fisher population is diversified in nature. But this option is achievable if the task of creation of fisher village level local organization with the whole hearted support of residents of village. Such village level organization with Government support and sincere efforts to bring back the richness of Gulf of Mannar can make it possible to manage the marine resources of their area in a more effective way.

The Gulf of Mannar Biosphere Reserve Trust is a unique and pioneering initiative taken by GoI and GoTN in collaboration with GEF-UNDP to establish integrative people based marine resource management in Gulf of Mannar. Trust methodology is a new strategy adopted by Government to facilitate better functioning and liberty to the implementing agency. The Trust is chaired by the Chief Secretary and strengthened by various partner department secretaries to make this body a more effective co-ordinating agency to ensure conservation of Gulf of Mannar Marine bio-resources. The Mission of this Trust is “To build and nurture the Trust as a vibrant organization of international repute with a key role and focus on facilitating improved coordination, concern and care among other and often conflicting agencies and organizations for sustained conservation, preservation, protection and sustainable utilization of the ecosystem services and resources from the rich, unique and fragile coastal and marine ecosystems of the Gulf of Mannar Biosphere Reserve in order to ensure sustainable coastal zone development in the area which is compatible with the ethos of biodiversity conservation” and livelihood.
security of coastal people of Gulf of Mannar for all times to come.

The Trust has taken four factors as the important pillars for strengthening conservation possibilities in Gulf of Mannar. They are

1. Protection of Gulf of Mannar National park and endangered marine organisms found in Gulf of Mannar through strengthening law enforcement departments.
2. Systematic research in areas related to ecology, biology, environment, management and socio-economy to ensure better understanding in the above mentioned areas to evolve feasible strategies and mechanisms for improvement as well as for monitoring.
3. Awareness and education to fisher population and all other stakeholders to ensure better understanding of the resources of Gulf of Mannar as well as to convince them about the immediate need for restricting unscientific, destructive practices carried out in Gulf of Mannar. It is also necessary to promote eco-friendly and scientific non-destructive practices in all activities carried out in Gulf of Mannar.
4. Eco Development in all the Gulf of Mannar dependent coastal villages located in 10 km impact zone from shore inland. The attempt is to establish fisher village level local organization specially built on the interest of Gulf of Mannar conservation by taking support from the members from all the families of the fisher village.

All the above factors can be address through various agents, departments, organizations and others. But it would be more effective if all the above mentioned factors people participation at the village level.

1. Participatory protection.
2. The inhabitants of coastal village are well aware of the sources of damaging factors which causes severe threat to the Gulf of Mannar marine bio-resources. They are well aware of the list of fishermen involved in dynamiting, destructive netting practices, bottom trawling, seaweed cultivation, illegal collection of endangered organisms etc.

The local level Eco-development committee if strengthened and empowered in use of law enforcement machinery existing with various departments, the damaging factors can be totally removed from the area with ease. It would be possible only by the support from the Government made special authority to the local level Eco-development Committees. The first attempt of engagement of forty anti-poaching watchers from the fishermen villages through Eco-development committee is fetching considerable result in getting information regarding the illegal activities happening in an area. If the information network is strengthening and law enforcement is activated the protection machinery will be effective. Each EDC may be entrusted with protection of a defined space of Gulf of Mannar with available natural boundaries to ensure better protection.

Participatory Research

The fisher population existing in the coast of Gulf of Mannar are well aware of the marine resources found in their area of operation much better than the scientific institutions studying the area. Their field knowledge about the availability of certain organisms, eco-systems, whether and other
marine factors is exemplary. They are well aware of the distribution of coral reef, distribution of sea grass, availability of chunk beds, and availability of pearl beds in their area of movement. They are also well informed about the migration pattern of sea turtles, sea cow, dolphins, whales and other mega organisms found in marine area. There field knowledge about the area can be utilized for better planned research in the area for quicker results. The Gulf of Mannar Biosphere Reserve Trust initiative in training fisher youth in Scuba diving is very useful in utilizing the services of fisher population in underwater studies. For periodical studies in the identified quadrates, intercept lines, blocks can be carried out in the required routine manner with the skilled scuba diving team available with the fishing villages. The educated youth from fishermen villages can be trained to the requirement of the research organization as well as to the requirement of Trust to undertake regular monitoring research programmes in Gulf of Mannar area. This will provide monitory support to the fisher population and will also help in getting better co-operation in conservation of marine resources through people participation.

**Participatory Awareness and Education**

The coastal village fisher population is less illiterate and most of them do not cross 5th standard in their studies. But even in this situation few fisher youth are overcoming the family based poverty threats and getting educated up to SSLC and more. Their education and capability can be utilized for convincing the local people in understanding the importance of Gulf of Mannar marine bio-diversity and also getting their support in taking immediate action for ensuring conservation of the degrading resources of their area. The GOMBRT attempts to engage 60 field project workers for undertaking people mobilization, awareness creation and field co-ordination is an attempt to tap and utilize the locally available manpower to create awareness among the fisher public and also to educate them with their own people. Children in fisher villages can also be educated with regard to the destructive fishing practices through the identified capable local fisher youth to spread the message of immediate need for restricting destructive fishing practices to achieve the role of conservation.

**Participatory Eco-development**

The coastal villages were having better local organization in the last century. The village head and the village regulations were respected by the local public. Later, the local level organization and its powers got eroded. Now no such local level empowered organization is existing to ensure co-ordination among various groups in the society. It is high time to activate local level organization set up through Eco-development to enable better control system at village level to ensure regulated activities in marine space to avoid destructive measures taken by few vested interest groups. The GOMBRT’s effort to create Village Marine Conservation and Eco Development Committees (VMC & EDCs) in all the 222 coastal villages Gulf of Mannar. Two members in each family of project village are enrolled as members in VMC & EDC. Among the members seven representatives are elected by the VMC & EDC to act as executive committee members. The sub-zonal officer of the concerned village is the ex-officio Member-secretary for the Committee. The financial transactions are handled by member-secretary and the president of VMC & EDC. The GOMBRT provides an initial support to VMC & EDC based on the threat category to which the village belongs to. The threat
categories are classified based on the criteria’s given below:

1. High Threat (HT) – poaching of Sea Turtles, mining of Corals, Chanks & Sea Cucumbers collection, Sea Weeds collection, Destructive Netting practices, Dynamiting, Destructive Fishing, Island dependents, Other Illegal Activities.

2. Medium Threat (MT) - Increased crafts & gears, Increased fishers, Increased fishing coolie, Increased immigration, Supporting illegal activities.

3. Low Threat (LT) - Non fishing shore villages, Seasonal fishing.

This local organization can help the co-ordinating various activities which are required for addressing the factors which are damaging the Gulf of Mannar marine environment. The financial support extended by GOMBRT can also be effectively utilized by VMC & EDC to create alternative livelihood option to reduce pressure on Gulf of Mannar resources. In addition VMC & EDC can very well be groomed to act as the empowered local organization to take full responsibility of scientific management and monitoring of marine resources in the jurisdiction of VMC & EDC.

Without the whole hearted support of people, conservation and sustainable use of any natural resources will only exist as a dream. The systematic organization of people who are stakeholders for marine resources, in VMC & EDC with enough inputs on the importance of conservation measures will only help in ensuring real scientific management of marine resources in Gulf of Mannar. GOMBRT initiative in building local level conservation organization will really help in achieving the goal of Gulf of Mannar conservation for sure.
Participatory management of biological resources for conservation and livelihood security of coastal fishers in the Gulf of Mannar Biosphere Reserve

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National Institute of Ocean Technology, Pallikaranai, Chennai - 601 302

Introduction

Gulf of Mannar Biosphere Reserve (GOMBR) is one of the world’s richest regions of marine biodiversity covering an area of 1,050,000 hectares (78°11' to 79°15' E longitude and from 8°49' to 9°15' N latitude). GOMBR has 21 islands with estuaries, beaches, forests of the near shore environment, including a marine component. Its core area is surrounded by a 10-km buffer zone, which further extends inland and offshore for approximately 10 km. 47 villages along the coastal part of the biosphere reserve gives livelihood support to about 200,000 people.

Fishing is the primary livelihood of the coastal communities here. However, there is a declining trend in the fish production in the area with reduced catch/effort ratio due to over-exploitation and habitat degradation caused by destructive fishing practices like bottom trawling, exploitation of berried females and juveniles etc. Coral mining and pollution are some of the other major reasons for the degradation of fish habitats.

To protect and preserve the pristine biodiversity of the region with unique endemic species, the Global Environmental Facility (GEF) provided support to the establishment of the biosphere reserve. The Gulf of Mannar Biosphere Reserve Trust was formed for the coordination of the management plan for the biosphere reserve in consultation with government agencies, private entrepreneurs, and local people’s representatives. Priority is being given to encouraging community-based management.

The declaration of the area as biosphere reserve has introduced strict restrictions and monitoring on fishing activities like ban on bottom trawling and use of other destructive gears. Many fishers were involved in mining of dead corals for lime production which is now banned. Animals like sea cucumber, sea horse and many moluscs whose shells were used for shell craft industry were being exploited traditionally in the area. The collection, possession and trading of these animals or their products (live or dead) are banned under the Wild Life (Protection) Act 1972. This has added more stress to the livelihood support of the fishers who are otherwise affected by decline in fish production.

Any attempt to effectively preserve the biodiversity should involve the people who are traditionally exploiting the resources for centuries for their livelihood. Sustainable exploitation and conservation of biodiversity in the region require participatory management by traditional users of the resources. This approach requires a concerted approach to create awareness among the coastal community on the need to protect the unique habitats and biodiversity. Alternate livelihood support programmes should be evolved for exploiting the fishery resources without harming the long term goal of protecting the biodiversity and sustainable exploitation of resources. Few such productive programmes
that can be taken up by the coastal fishers with the technical support of Government research Institutions and NGOs are described below.

**Seaweed farming**

Farming of the exotic seaweed, *Kappaphycus alverezii* is successfully being done by self help groups including women self help groups in the Palk Bay and at many places along the south east coast of India. The department of Ocean Development, under the Ministry of Earth Sciences, Government of India has elaborate plan to spread farming of this species all along the Indian coast with participation from state governments, NGOs and industry.

As the GOMBRT has decided not to introduce farming of this species in the region it can take up farming of indigenous seaweeds like *Gracillaria* sp. for which technology for farming and exploitation has already been developed by the Regional Centre of the Central Marine Fisheries Research Institute, Mandapam camp. It can take the help of technology development institutes like the National Institute of Ocean Technology (NIOT) for developing cost effective and rafts with long durability for deployment in the sea and effective mooring systems for the same.

Selected SHGs could be trained and assisted in undertaking seaweed farming, with subsidized infrastructure in the beginning and continuous monitoring by govt. institutes and trained NGOs. Necessary agar making plants also can be planned by other SHGs in the area.

**Lobster farming and fattening**

Spiny lobsters are one of the most sought after commodities in the export market and live lobsters command a high price. GOMBRT is an important lobster fishing region along the south east coast of India and as in all other regions in the country, a large number of juvenile lobsters are caught in the fishery. These juveniles cannot be exported as there are size limitations for export of different species of lobsters from India. These undersized lobsters can be grown to market size when its value would be more than doubled depending on size, species and season. The technology for growing lobsters in sea cages have been perfected by the NIOT and has been successfully transferred to coastal fishers at many places along the Tamil Nadu coast including Erwadi, which falls under the GOMBR area. NIOT could provide all the technical back up for the programme to be funded by the GOMBRT.

Extreme caution should be exercised when taking up this programme as it should not encourage fishers to target juvenile lobsters for fattening in cages. Only those undersized lobsters in their regular catch should be grown in cages. Just moulted lobsters which would not fetch any price also could be kept in cages for about two weeks to make it ready for live transport.

In all places where NIOT has initiated sea cage culture of lobsters, large numbers of small juvenile lobsters have been attracted to the cage site, sometimes even entering the cages. This stock has been utilized for stocking by the fishers. The scope of this project is limited as large number numbers of juveniles are not available for stocking. Though research is going on in India as well as in other countries to produce spiny lobster seeds, it may take a long time before hatchery reared seeds could be made available for lobster farming.

In a study in Western Australia, it was estimated that up to 40 million puerulii (just metamorphosed baby lobsters) could be collected for aquaculture without affecting the fishery as more than 95% of the settled puerulii die before recruitment to the fishery. By utilizing the data on puerulus settlement,
accurate prediction of the ensuing lobster fishery is being done in Western Australia for more than 12 years. The quota for lobster fishing is decided based on this prediction and the Western Australian lobster fishery is being described as the best managed fishery in the world.

A similar could be initiated in the GOMBR to study the settlement of puerulii and collection of puerulii for lobster farming. The puerulii collected could be used as seed bank for lobster farming in the area. This involves extensive oceanographic studies like ocean currents, water mixing, temperature gradients and appropriate fabrication and deployment of puerulus collectors. Expertise from Western Australia could be sought for this programme and NIOT can coordinate and manage this project if approved by GOMBRT.

The fishers should be taught on the necessity to avoid catching egg bearing lobsters. Even though the export of egg bearing lobsters is banned, those caught with eggs are being exported by removing the eggs from the pleopods. As a conservation measure, along with lobster fattening programme, few cages could be utilized for keeping egg bearing lobsters in cages till they release phyllosoma larvae. The GOMBRT could initially buy the egg bearing lobsters from the fishers and release it back after marking. The fishers should be asked to release such lobsters back into the sea if they catch it a second time. Such conservation measures are successfully being adopted in U.K. and Canada.

**Mud crab farming and fattening**

Like lobster farming, mud crab farming and fattening have good scope to be taken up as a livelihood security programme for coastal fishers in the GOMBR. Two species of mud crabs, *Scylla serrata* and *Scylla tranquibarica* are predominant in the crab fishery in the GOMBR and both these are being exported live to south East Asian countries from India. Crabs weighing 500g and above and fully mature female crabs (300-350g) fetch good price when exported alive. Crabs weighing 150 to 250g can be used for soft shell crab production which too has great export potential.

About 20 to 30% of the crabs caught are just moulted “water crabs” (crabs whose shell is soft) and do not fetch good price as it its flesh content is low. Such crabs can be held in earthen enclosures or in pens in mangrove as well as in brackish water bodies till their shell hardens. This process would take 20 to 30 days depending on the condition of the crab at the time of catch. Value addition up to 3 times can be obtained by such fattening of water crabs.

Farming of crabs below the prime size of 500g in earthen enclosures, pens in brackish water or in mangrove enclosures also can be a very good programme for improving the livelihood security of coastal fishers. Appropriate areas in the GOMBR have to be selected and the farming system for the area should be identifies. Till now the farming and fattening of mud crabs was completely dependant on natural collection. But the Rajiv Gandhi Centre for Aquaculture (RGCA), Thirumullaivasal and a private hatchery in Chennai are now producing mud crab seeds in hatchery. Hence the scope of mud crab farming has increased.

NIOT has successfully introduced mud crab farming and fattening in brackish water pens and mangrove enclosures in the mainland as well as in the Andamans. The NOIOT technology involves a two tier culture system where farming of juvenile crabs are done in pen/mangrove enclosure while fattening is done in floating FRP cages with
cell type individual compartments in the same pen or enclosure. Organizations like the Central Institute of Brackish water Aquaculture (CIBA), the RGCA and private farmers in Andhra Pradesh and Kerala (in paddy cum prawn fields) also have demonstrated crab farming/fattening in many places. GOMBRT can introduce this programme with the technical back up from any one of the agencies mentioned above.

**Sea cage culture of fin fish**

Cage culture of marine fin fish is yet to take up in India as policy has yet been framed for leasing of sea for fish culture. Further, cage culture requires large scale production of the required fin fish seeds in hatcheries. The only marine finfish whose seed has been produced in hatchery is the sea bass, *Lates calcarifer*. The technology for the production of seeds of this fish was developed by CIBA and later transferred to RGCA. Both these central Government Institutes are now capable of producing sea bass seeds after initial set back suffered due to tsunami damage to their hatcheries. The RGCA has also taken up grouper seed production in Andamans is expected to come out with hatchery produced grouper seeds in the near future.

Sea cage culture of fishes can be taken up involving coastal fishers in GOMBR. The first step should be selecting suitable sites for cage farming which involves many oceanographic assessments. The GOMBRT can initiate this programme with technical support from the institutions like NIOT, CIBA, RGCA and the Department of Fisheries, Tamil Nadu.

**Deployment of artificial reefs**

Artificial reefs (AR) are devices installed at the sea bottom to provide habitat for marine organisms. The extent of ARs may vary from a few square meters to over 20 square km. Artificial Reefs help to increase coastal productivity in the long run by providing hard bottom habitat for the growth of sessile organisms and establishing food chains. They increase the chance of post larval settlement of many invertebrates and fish larvae and also the survival of juveniles. ARs have been found to be effective in aggregating a variety of fish species and in holding them by providing suitable habitats. While a majority of the fish shoals around the ARs for shelter and/or feed, a few moving stocks of high value fishes are attracted by the rich benthic fauna, crustaceans, mollusces, echinoderms, etc. Aggregation of fishes depends upon the complexity of reef structures like its size and density and bigger modules are found to be more effective. The holes, crevices, vertical relief, and ledges of the artificial reef structures increase habitat space for marine organisms.

Apart from providing new fishing grounds for small scale artesian fisheries and sport fishing, AR could play an important role in conservation of biodiversity and fishery resources in near shore areas severely affected by destructive fishing activities like trawling and use of other destructive gears. It will be a deterrent for trawling and would help in reducing fishing pressure. Studies have indicated that a properly designed and managed AR would considerably increase the income of coastal fishers through enhancement of marine living resources.

As the fishing activities are being restricted and coral mining has been banned, installation of ARs at selected locations along GOMBR could be an appropriate method to increase fish production as well as value addition to the catch as it would increase production of targeted, high value fish by using non-destructive fishing gears. ARs can
Participatory management of biological resources for conservation and livelihood security of coastal fishers

be installed even in areas where fishing (trawling) ban is in existence as it will not involve any destructive fishing methods and would enhance the livelihood security of the coastal artesian fishers who are affected by the ban.

Installation of ARs can be thought off in buffer zone also to increase fish production as well as to transplant reef building corals.

**Conclusion**

Conservation of biodiversity in GOMBR assumes top priority as it is one of the rare ecological zones with many endemic species of plants and animals. At the same time it gives livelihood support to more than 200000 coastal poor people around it. Any successful measure to protect the biosphere reserve should involve the traditional users of the reserve and should provide alternate livelihood support to the people who could be affected by enforcement of strict regulatory measures.
Biodiversity studies by IERSE using underwater equipments

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The marine environment harbors a variety of flora and fauna far exceeding that of the terrestrial environment, in certain cases. Although scientists have documented some of them systematically many are yet to be explored and identified properly. The taxonomic studies so far made on marine flora and fauna were mainly based on commercial catches, stranded materials and some collected through exploratory cruises in certain selected areas. The reasons for the inadequacy of study materials have been the non-availability of suitable equipments and technologies for the observation and collection of study materials by scientists underwater.

The invention of Self Contained Underwater Breathing Apparatus (SCUBA) in the 1950s has solved this problem to some extent and the biodiversity of marine environment has been studied in detail in many parts of the world where SCUBA diving is popular. Although it was originally invented for exploring the oceans, now it is mainly in the hands of ecotourists who use it as a recreational tool to enjoy the beauty of the marine underwater.

For conserving the nature and its plant and animal life one should have an idea about the various categories of plants and animals living in an ecosystem. For this purpose cataloging becomes necessary and this is possible only by direct observation in the natural environment without making any disturbance to the fauna and flora and damage to their living environment. For this, SCUBA diving is the best method and it should be made known to all who are interested in the study of marine biodiversity.

In India, SCUBA diving is not very popular and the studies made so far using SCUBA equipments are limited to Tuticorin and the Andaman seas by the Central Marine Fisheries Research Institute and by some NGOs. In order to solve this problem, the Institute for Environmental Research and Social Education (IERSE) a scientific NGO based at Nagercoil has formed a Reef Research Team (RRT) by appointing Post Graduate and Doctorate degree holders holding International Diving Certificates. It has a “SCUBA Cell” with all modern types of SCUBA diving equipments. So far IERSE has done a number of underwater studies in south India including Gulf of Mannar and Lakshadweep as detailed below. Through these studies IERSE could record a number of fishes and invertebrates which are new to Indian waters and describe the sea bottom and its biodiversity in a scientific manner so as to help conservation. In addition to this the IERSE could publish the following 10 research papers in national and international journals of repute within a period of 5 years.
Underwater studies conducted by IERSE using SCUBA

<table>
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<tr>
<th>Sl. No</th>
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<th>Study Area</th>
<th>Period of Study</th>
<th>Outcome</th>
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<tr>
<td>1</td>
<td>Community development through diving based tourism at Kovalam beach</td>
<td>Kovalam-Vizhinjam southwest coast of India</td>
<td>July 2001-January 2002</td>
<td>Identified the areas suitable for diving and snorkeling and documented the invertebrate and ornamental fish fauna of the area and published a snorkelers guide to Kovalam beach.</td>
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<td>2</td>
<td>Monitoring of the shallow water fauna of Gulf of Mannar</td>
<td>Gulf of Mannar including Hare, Kurusadi and Manauli islands</td>
<td>August-October 2001</td>
<td>Studied the underwater habitats of the Gulf of Mannar and reported the sponge and gorgonid biodiversity</td>
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<td>3</td>
<td>Ecology and biodiversity of Indian coral-reef fishes</td>
<td>Gulf of Mannar and Southwest coast of India from Kanyakumari to Goa</td>
<td>February 2002 - April 2003</td>
<td>Observations were made at Tuticorin, Tirunelveli and Kanyakumari coasts in Tamil Nadu, Vizhinjam and Kovalam in Kerala; Natrani and Grand islands off Murdeshwar in Karnataka and off Panaji in Goa. Recorded 182 fish species representing 32 families of which 18 species are new records to Indian waters.</td>
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<td>4</td>
<td>Reef-fish monitoring off Goa</td>
<td>St.George Island</td>
<td>May-July 2003</td>
<td>Underwater studies using SCUBA were made and the reef fish behaviour was studied and documented.</td>
</tr>
<tr>
<td>5</td>
<td>Underwater survey of the rock reefs off Muttom, Tamil Nadu: Possible Tsunami impacts</td>
<td>Muttom, Tamil Nadu</td>
<td>May-June 2005</td>
<td>Studied the rocky reef fauna of Muttom and reported the tsunami impact found on the sessile invertebrates.</td>
</tr>
<tr>
<td>6</td>
<td>Capacity building for Environmental assessment</td>
<td>Goa and Lakshadweep islands</td>
<td>August to December 2005</td>
<td>Trained five Indian young scientists in underwater research using SCUBA and studied the impact of tsunami on the sponges, corals and octocorals of Goa area and Lakshadweep islands</td>
</tr>
</tbody>
</table>
Diving / Snorkeling based publications by IERSE


*Not based on diving

Research and Management Protocol

Indian coral reefs are subjected to numerous threats, both natural and anthropological. Coastal fishermen are dependent upon these reefs for their livelihood. Despite the importance of these reefs, little is known about the abundance and distribution of many prominent reef taxa. Amazingly, there has been no underwater exploration in most of our coastal habitats. Previously everything that was known about the biodiversity of most of our study region was gleaned through bycatch of fishing vessels. Comprehensive studies on the fauna and flora in relation to the various habitats of the coral reefs of Gulf of Mannar is still lacking. Almost all research in this region have been conducted in the shallow-water habitats. So, gather information that has never before been collected following transect and other suitable methodologies using SCUBA and other underwater study equipments by engaging scientists trained in diving. The application of the collected data to conservation will be quite straightforward though by no means easy. It has to be done with the full support of the stake-holders. So communicate the results and potential benefits of non-destructive use of these resources to the local community through culturally relevant media.
Introduction

General description

The Gulf of Mannar Biosphere Reserve covers an area of 10,500 Km² on the south-east coast of India across from Sri Lanka. It is one of the world’s richest regions from a marine biodiversity perspective. The biosphere reserve comprises 21 islands with estuaries, mudflats, beaches, forests of the near shore environment, including marine components like algal communities, sea grasses, coral reefs, salt marshes and mangroves. Among the Gulf’s 4,000 plants and animal species, there are the globally endangered species sea cow and six mangrove species endemic to peninsular India. The inhabitants are mainly Marakeyars, a local Community principally engaged in fisheries. There are about 125 villages along the coastal part of the biosphere reserve which support some 100,000 people (200,000 seasonally as of 2001). Major ecosystem type Major ecosystem types available are Coral reefs, mudflats, beach, island, shallow water, mangrove etc. of coastal / marine component.

Major habitats & land cover types

Sea grass beds dominated by family like Hydrocharitaceae and Potamogetonaceae etc., and species Halodule uninervis Cymodocea rotunda, C.serrulata etc.: coral reefs; mangroves including Rhizophora muctunata Avicennia alba, Bruguiera gymnorrhiza, Ceriops tagal, Lumnitzara racemosa etc., also common in the stretch. Location 08°47' to 09° IS’N; n° 12' to 79° 14’E is the location of Gulf of Mannar.

II. Objectives

This survey is a sequel to the report of Tamil Nadu Forest Department on “Avifaunal diversity of Gulf of Mannar (GoM) by V.Naganathan, IFS, Wildlife Warden, GOM with an intention to:

a. Update and finalize a checklist on birds as on 2005
b. Identify the potential habitats preferred by birds
c. Identify red spots (highly disturbed/ poached)
d. Collect details on supplementary foraging and nesting areas around the declared sanctuaries in Ramanathapuram district
e. Survey of declared sanctuaries as on 2005 and assess the impact on them due to anthropogenic and climatic factors.
f. Suggest measures to protect areas of importance! potential habitats and
g. Look into any other aspects that may go to help in preserving the avifauna of this belt.

III. Study Area

The study area encompassed two districts namely Tuticorin and Ramnad and included the islands lying in that area viz., Nallathanni, Appa, Vazahai, Talayari, Kurudasai, Pullivasal, Poomarichan, Manoli and Hare (Musal) islands.

Team 1 surveyed the islands around Mandapam and the declared sanctuaries in Ramnad districts.

Team 2 surveyed the coastline between Ramnad and Kilakarai and the islands of Appa, Vazahai and Talayari.
Team 3 surveyed the areas around Tuticorin and coastline between Tuticorin and Kilakarai and islands of Nalatanni.

Wherever required, a detour was taken to survey adjacent lakes and water bodies lying in the line of travel by the team. The list of surveyed sites are given below:

1. Thermal Power station - Tuticorin
2. Coast Guard Land near Mandaparn Range office
3. Munaikadu Backwaters - Mandapam
4. Kothandaram temple Lagoon
5. Mandapam Camp to Keelakarai - Roadside
6. Keelakarai to Melasel vanoor - Roadside
7. Appa island - Keelakarai
8. Thirespuram, Mottakopuram, Siluvaipatti - Tuticorin
9. Sippikulam, Keelavaippar. Melmaanthai-South Ramnad district
10. SPIC -Tuticorin
11. Kurusadai island -Mandapam
12. PillivasaJ & Poomaricaan island - Mandapam
13. Manoli island - Mandapam
14. Thalayari, Valai island - KeeJakarai
15. Naripaiyur Taravai Tank-Ramnad District
16. Sathangudi diversion, Mariyur Alam, Valinokkam salt area & Idampadal tank
17. Nallathanni island - Tuticorin group
18. Hare island - Mandapam
19. Kadugusanthai Kanmoi - Ramnad District
20. Vinayakar Koil tank - Rammd
21. Big Tank - Ramnad
22. Mallal tank - Ramnad
23. UttiragosamangaiTank
24. Thaliyenthal Tank
25. Kadambodai Tank
26. Chitrangudi tank

IV. Survey Methodology

Since this national park comprised of different terrain due to the presence of water bodies, coastal strips, villages and towns, the encounter method was followed with suitable modifications as and when required. Traditional method like transect count or point count could not be employed due to the unique topography and inability to apply these methods under such conditions.

The modifications resorted to were:

a. Wherever big group or congregation of birds was seen, block count as suggested in Asian Waterfowl Count (AWC), was resorted to and

b. At traditional nesting sites quadrant method was used to estimate nests

The survey group was divided into three teams of two each, to facilitate a comprehensive survey covering the entire stretch of GoM and ensure coverage of different habitats lying in the biosphere reserve. Also, the importance of buffer zones and peripheral areas closer to habitations was also covered under the survey, which was one of the main objectives.

Team 1 surveyed islands of Kursadi, Pullivasal, Poomarichan, Manoli and Hare; Kothandarramar lagoon; sanctuaries of chitrangudi and kaanjirankulam; adjacent 6 villages where water bodies were present like Kadambodai, Mallal; Taliyarinendal.

Team 2 covered the coastal strip of Ramnad to Kilakarai and islands of Appa, Vazhai and Talyari from Kilakarai and the Melselvanooor sanctuary.

Team 3 covered the thermal station, SPIC factory at Tuticorin and the coastal strip from Tuticorin to Kilakarai including waterbodies in this area like Sippikulam, Melmandhai, Kilavaipar Lagoon, Kadugusandhai, etc. and the Island of Nallathanni.
v. Findings and Observations

1. The notable aspect of this survey was the addition of 10 new species of birds’ to the already existing 217 species reported in the book (Avifaunal diversity of GoM published by Tamil Nadu Forest Department) as listed below:

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Location at which seen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chestnutbittern</td>
<td>Ixobrychus pillayar Koil Cinnamomeus</td>
<td>Pillayar Koil tank, Ramnad,</td>
</tr>
<tr>
<td>Nakta or Comb duck</td>
<td>Sarkidiornis meluotos</td>
<td>Kadugusandhai</td>
</tr>
<tr>
<td>Lesser black backed</td>
<td>Larus fuscus</td>
<td>Manoli island</td>
</tr>
<tr>
<td>Slender-billed gull</td>
<td>Larus genei</td>
<td>Kothandaramar Lagoon</td>
</tr>
<tr>
<td>Rufous tailed finch lark</td>
<td>Ammomanus phoenicus</td>
<td>Tuticorin thermal plant</td>
</tr>
<tr>
<td>Southern grey shrike</td>
<td>Lanius meridionalis</td>
<td>Sippikulam</td>
</tr>
<tr>
<td>Yellow-fronted pied woodpecker</td>
<td>Dendrocopos mahrattensis</td>
<td>Chittarangudi, and Kanjirankulam</td>
</tr>
<tr>
<td>Indian courser</td>
<td>Cursorious coramandellus,</td>
<td>Sippikulam</td>
</tr>
<tr>
<td>Long-legged buzzard</td>
<td>Buteo rutinus</td>
<td>Ayakudi – Melselvanu</td>
</tr>
<tr>
<td>Black-throated diver’</td>
<td>Gavia arctica</td>
<td>Near kilakarai</td>
</tr>
</tbody>
</table>

2. The following areas seem to hold high potential for birds.

<table>
<thead>
<tr>
<th>Area</th>
<th>Species seen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal power station, Tuticorin</td>
<td>Flamingoes. Gulls and Waders</td>
</tr>
<tr>
<td>Kilavaipar grasslands</td>
<td>Indian courser &amp; Harriers</td>
</tr>
<tr>
<td>Kadugusandhai Kammai</td>
<td>Comb ducks &amp; other duck species</td>
</tr>
<tr>
<td>Mariyur alam</td>
<td>Waders and Gulls</td>
</tr>
<tr>
<td>Kothandaramar Lagoon</td>
<td>Flamingoes, Gulls, Terns and Waders</td>
</tr>
<tr>
<td>Muniakaadu</td>
<td>Birds of Prey and Waders</td>
</tr>
<tr>
<td>Manoli and Hare islands</td>
<td>Gulls, Terns and Waders</td>
</tr>
<tr>
<td>Periyakanmai, Ramnad</td>
<td>Breeding of Pelicans and waterfowls</td>
</tr>
<tr>
<td>Mallal Tank</td>
<td>Bareheaded geese and other ducks</td>
</tr>
<tr>
<td>Talayariendal</td>
<td>Breeding colonies of grey herons and egrets</td>
</tr>
</tbody>
</table>

At thermal power station, Tuticorin, Mariyur alam, Kothandaramar lagoon, Manoli and Hare Islands, the congregation of birds was seen in thousands. Places like Kilavaipar lagoon, Muniakaadu were important in view of backwater ecosystem facilitating bird habitation. Ringing method has to be tried to find out the migratory pattern of visiting bird nesting and roosting birds of the established sanctuaries seem to have moved to more greener pastures around. That could be the reason for sudden increase in bird population and species at place of well-watered tracts like Uthiragosamangai, Mallal, Kadambodai, Theriruveli, Ramnad Big Tank etc., and population. The Melselvanoor are becoming heronry in the last few years.
3. The survey identified the following hot spots

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Area</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Kilavaipar Lgoon</td>
<td>Expansion of salt units – Threat to grasslands species</td>
</tr>
<tr>
<td></td>
<td>Kadugu Santhai</td>
<td>Poaching</td>
</tr>
<tr>
<td></td>
<td>Kothandaramar Lagoon</td>
<td>Poaching</td>
</tr>
<tr>
<td></td>
<td>Manoli, Hare (Musal), Pullivasal, Poomaricechan, Kurusadai Island</td>
<td>Disturbance due to fishing and fishermen, collection of seaweed etc.</td>
</tr>
<tr>
<td></td>
<td>Mallal Tank</td>
<td>Poaching by nomads</td>
</tr>
<tr>
<td></td>
<td>Thalyarinenthal Tank</td>
<td>Poaching by nomads</td>
</tr>
<tr>
<td></td>
<td>Kilakkarai Islands</td>
<td>Disturbance due to fishing and fishermen,</td>
</tr>
<tr>
<td></td>
<td>Tuticorin Islands</td>
<td>Disturbance due to fishing and fishermen,</td>
</tr>
</tbody>
</table>

4. Survey of the declared sanctuaries at Chitrangudi and Kanjirakulam

These sanctuaries are completely dried due to failure of monsoon specifically at theses places whereas, in other parts of Ramnad, there was copious rainfall. Even the small quantity of water collected during scanty rains in the sanctuary had evaporated soon. There has been no nesting or roosting activity of waterfowl in both these sanctuaries for last four years due to successive failure of monsoon. The water from the Vaigai channel is not reaching these villages though they reach up to 15 km upstream. However both these sanctuaries abound in wood land birds. The only concern was the over spread of *Prosopis juliflora*, which has started smothering native vegetation and undergrowth. However, the yellow-fronted pied woodpecker an addition to list of birds was seen here.

5. Other observations

Surprisingly throughout the four-day survey, there was no sighting of lesser flamingo (*Phoenicopterus minor*).

Osprey was seen at Munaikaadu and Manoli island. Similarly Peregrine falcon was also seen at the same spot. Osprey was also sighted at Thermal Station, Tuticorin.

Lesser known areas like Kadambodai and Theriruveli had good number of ducks, especially garganeys and common teals, which were not seen elsewhere. At Theriruveli, a huge roost of fruit-bats was seen in the Acacia trees of the lake. Similarly, at the Vinayagar Koil tank in Ramnad city on a mist filled day big group of large egret, chestnut bittern, grey herons and median egrets were seen.

In the areas around Ramnad, the team encountered an unusually high number of rosy pastors and pied crested Cuckoo is the bird known as the harbinger of monsoon.

6. Discussion

The additions to the existing list indicate the true potential of the biosphere and also the habitat potential of the unprotected areas since many are reported from such areas. In fact, the sighting of chestnut bittern on a mist-filled day at 8:00 am was a revelation into the behavioral pattern of the crepuscular species. Not only the bittern, but also the median and large egrets along with white-breasted water hen were seen foraging under the extended cover of the mist until 9:00 a.m, which was not a usual phenomenon in this area. Similarly in a salt pan on the way
to Kilakarai, we encountered a big group of exclusively large egrets at around 11:00 a.m.

The sighting of comb duck with juveniles by Christopher & Sasikumar at Kadugusandhai corroborates the earlier observation of Wildlife warden Mr. Naganathan in the same area. Also, this goes to explain the fruitful result one could achieve by sustained observation of an area over a period of time.

Sighting of lesser black backed gull (Larusfuscus) may be of importance only to a few as this is most widely seen species in coastal areas of South. The suspicion over its presence as well its identity: as expressed in Grimmette al in their handbook, need not be taken too seriously as even literatures of RSPB (Slightly smaller than a herring gull, the lesser black backed gull has a dark grey to black back and wings, yellow bill and yellow legs) tend to distinguish them from Herring gull as Salim Ali does.

The slender billed gull with pale pinkish under parts was immediately recognized in spite of being among a huge congregation of gulls at Kothandaramar lagoon. In fact, 12 Kothandaramar lagoon is an ideal spot to watch the different species of gulls and terns apart from a huge flock of greater flamingoes. The team reported around 5000+ flamingoes. The sighting of woodland birds such as rufous tailed lark, southern grey shrike and yellow-fronted pied woodpecker emphasizes the potential of dry scrub land which are considered as waste land. The meticulous observation of the team at Melmandhai has resulted in sighting of Indian courser, an unobtrusive bird. Its presence along with that of harriers in the nearby grasslands explains the importance of such an ecosystem.

Another interesting observation by the team from Tuticorin to Kilakarai was the formation of ideal habitat by the collection of fly ash from the Thermal power station. The shallow pools thus formed, seem to attract more foraging waterfowl. However, the optimum level of accumulation of fly ash has to be ascertained to retain this spot as a regular habitat. Otherwise, this area will be lost with huge collection of fly ash over a period of time. The team from Ramnad to Kilakarai has encountered a long legged buzzard at a village called Ayakudi near Melselvanur and the other team that went around Uthrakoshamangai also encountered Kestrels and few buzzards. Thus the un-spoilt countryside alternating with cultivation and scrub-grass land ecosystem offers a beautiful habitat for such birds of prey. The importance of inter tidal zone and mudflats created due to the influence of tides, was witnessed at the islands near Mandapam. In between, Manoli and Hare islands, the vast stretch of mudflats exposed during low tides attracted a huge congregation of gulls and terns. At this spot, lesser black backed gulls, caspian terns, and black headed gulls were seen in thousands along with a biggest flock of crab plovers, numbering around 300. The lesser sized gulls and terns viz. brown headed gulls, gull billed terns, and whiskered terns were seen again in thousands but as a separate group elsewhere in the same locality. The associating patterns of these waterfowls offer an interesting study for the future. A solitary Peregrine falcon seemed to have taken a refuge at Manoli like its counter part at Munaikaadu. The islands around Mandapam have a quite a number of woodland species of birds like sun birds, blue tailed bee eaters, warblers, shrikes, etc. In Manoli, grey herons were nesting and juveniles were seen in good numbers. These islands are being used as resting places by local fisher-folk at times and areas around the shallow reef where corals are found; the local people indulge in collection of sea grass and algae.
The sighting of seventeen bar headed geese, a Himalayan migrant, is from Mallal tank near Ramnad along with pintails and shovellers. The nearby Thaliverandal village has a huge Peepal tree in which grey herons and egrets were breeding and the total number of nests was around 30. Similarly the villages like Kadambodai, Uthtrakoshamangai and Theriruveli where small tanks exist; ducks and waterfowls were seen in good numbers. However, sporadic poaching by nomads as well as others seems to be common.

The established heronries of Chitrangudi and Kanjirankulam were bereft of water and totally devoid of waterfowl as a result. This is the state of affairs for the last four years. Both the sanctuaries have witnessed a wild growth of *Prosopis juliflora* suppressing under growth and endemic 14 flora. The villagers, who do not have any gainful vocation, expressed their desire to weed out this species, which can be used as fuel supplement or sold to earn livelihood. However, their zeal to protect the birds remains intact in spite of the continuous drought conditions but unless some remedial measures from the socio-economic angle are taken, the conditions may not be same in the future.

However, the sanctuaries abound in woodland birds and it is not surprising that one can declare this a woodland bird sanctuary! To be correct, the addition of yellow fronted pied woodpecker was seen in both the sanctuaries. If the water from Vaigai, which is reaching up to 15 km from here, could be diverted to these sanctuaries, probably, they will once again regain their splendor. The non-sighting of lesser flamingo anywhere is a question to be answered. Since algal bloom is common and at some places it is abundant. Probably a site fidelity test may prove the answer to this. The sighting of almost 13 species of raptors (birds of prey), including the elusive Peregrine falcon (*P. calidus*), clearly underlines the fact that this biotope is very rich and to confront them at frequent intervals in a four day survey is remarkable.

**VII. Suggestions**

The following suggestions are specific to protection of potential habitats.

1. Areas which may not fall under national park, also hold quite a good number of waterfowl or resident species and as such these areas require frequent monitoring; protection; creation of watch and ward staff, etc, such areas are:
   a. Mallal tank
   b. Talaiyariendal tank
   c. Kadugusandhai
   d. Melmandhai
   e. Kothandaramar lagoon
   f. Kilavaipar
   g. Thermal Plant areas

2. A complete hydrological study at Kothandaramar lagoon may be carried out to ascertain the site fidelity as flamingoes congregate in this area only.

3. Grasslands and scrub jungle habitats at Kilavaipar and Sippikulam to be ear marked for effective protection in view of the presence of certain highly endangered species like Indian courser.

The suggestions given below are to reduce the anthropogenic factors responsible for disturbances

1. Traditional sites like Chitirankudi and Kanjirankulam are totally dry and no activity of waterfowl seen for the last four years. To maintain their position and also enlist the support of villagers who are otherwise favorably disposed, rehabilitation and reclamation measures are to be taken/thought of before it is too late.
2. Patrolling the islands around Mandapal1l at regular frequencies to be introduced to save the fragile ecosystem around them. Also, providing alternate vocational activities to local people to wean them from collection of sea produces is required to maintain the health of marine flora and fauna. Measures to improve the overall efficiency and level of knowledge are listed below:

1. Education to lower level staff who matter most (As they are at the site most of the time)
2. To remunerate the mat fixed intervals (to avoid arrears in salaries) so that one may avoid dropouts; lack of interest; inaction; and falling a prey to poachers.
3. To provide with regular census format for effective monitoring of wildlife movement and occurrence.
4. To provide an effective communication network for patrols in remote areas and high seas.
5. Reporting violation of Wildlife / wildlife traffic act as and when encountered and to popularize such acts among staff and public.

Suggestions for more scientific studies

1. Similar surveys to be conducted at determined intervals to have meaningful database – 17
2. Ringing of birds at known sites of congregation like, Kothandaramar Lagoon, Manoli islands. Even ringing of birds like Rosy Pastor, bar headed geese may help to know more about migration datapattern.
3. The format for day-to-day monitoring of birds in the GoM may be the one used for AWC and supplied by BNHS. This can be conveniently filled up by any staff with a little working knowledge. The data can be collated later and tabulated.
4. The regular census format for further surveys may be as detailed below:

<table>
<thead>
<tr>
<th>Species seen</th>
<th>Time</th>
<th>Activity</th>
<th>Co-inhabitants</th>
<th>Habitat type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

This form can be combined with AWC form.

5. Committed and interested NGO’s may be enlisted to participate in surveys and studies so that unbiased and independent observations/suggestions could be mustered for implementation in the management plan.

VIII. Acknowledgements

This survey was made possible because of the enthusiasm and the wholehearted initiatives from all the participants and field staff at various places in Gulf of Mannar. The results are the compilations of independent observations of each team. We wish that the findings and observations are taken as part of the work and not as anyone’s personal view. We also hope that suitable measures are taken to redress shortcomings and efforts taken to make this unique biome still richer in avifauna.
For more information

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