Biodiversity Conservation in Gulf of Mannar Biosphere Reserve

SACEP

सत्यमेव जयते

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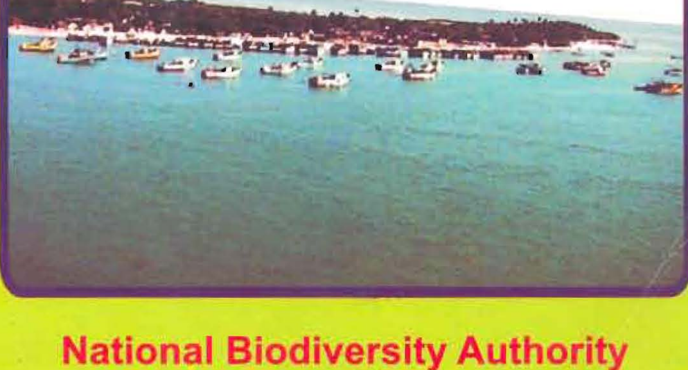

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FOREWORD

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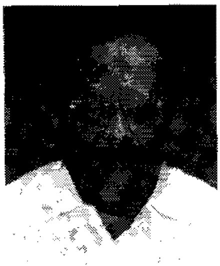

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FOREWORD

Tamil Nadu is situated on the southeastern part of the Indian peninsula and it has a conglomeration of different types of ecosystems rather than a particular type as in some other states of India. Though most of the ecosystem types are represented in Tamil Nadu as found in other States, yet much of the thorn forests and scrublands of India are confined to Tamil Nadu, comprising a major part of this state. The whole eastern side of the state is protected by 1000 km of sea coast, which has all major types of habitats and major ecosystems such as pelagic and benthic, estuarine, seaweed and sea grass, mangrove and coral reef ecosystem of Gulf of Mannar Islands, peculiar to the State of Tamil Nadu. The km stretch between Tuticorin and Rameswaram. These islands are located between the latitudes 8° 47' N and 9° 15' N and longitudes 78° 12'E and 79° 14' E. The islands lie at an average distance of 8 Km from the main land. All these 21 islands have been notified as reserve lands under section 26 of the Tamil Nadu Forest Act, 1882. This was reinforced by a re-notification of the State Government on 10, September, 1986 as Gulf of Mannar Marine National Park. Under the Man and Biosphere Reserve Programme of UNESCO, Government of India set up in 1989, The Gulf of Mannar Marine Biosphere Reserve, the first of its kind in the country and probably, in Southeast Asia. Different types of reef forms such as shore, platform, patch and fringing type are observed in the Gulf of Mannar. Narrow fringing reefs are located mostly at a distance of 50 to 100 m from the islands. On the other hand, patch reefs rise from depths of 2 to 9 m and extend 1 to 2 km in length with width as much as 50 m. Reef flat is extensive in almost all the reefs in the Gulf of Mannar. Reef vegetation is richly distributed on these reefs. The total area occupied by reefs and their

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associated features is 94 sq km. Reef flats and reefs vegetation including algae occupy 65 and 14 sq km. respectively. Usually, monsoons and high sedimentation loads affect the visibility. These reefs are more luxurious and richer than the reefs of the adjacent Palk Bay.

The present International Workshop on "Gulf of Mannar Biosphere Reserve: an ecological model for Biodiversity Conservation, livelihood and sustainability" is organized by the National Biodiversity Authority, UNESCO and SACEP mainly to find more elucidation to conservation and Management of Biological resources and open the opportunity for the livelihood options for the coastal villagers along the coast of Gulf of Mannar Biosphere Reserve. I appreciate and congratulate the efforts taken by Prof. S. Kannaiayan, Chairman, National Biodiversity Authority and Dr. K. Venkataraman, Secretary, National Biodiversity Authority for their effort in preparing the conference Proceedings as book form. I am sure that the book will be useful to the scientists working in Marine biology and also to the students, scholars, NGO's. The book will be an excellent reference volume.

4/4/08

(S. REGUPATHY)

Date: 02.04.2008

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INAUGURAL ADDRESS

Hon'ble Thiru. Regupathy

Hon'ble Minister of State for Environment and Forest, CGO Complex, New Delhi

Introduction

The Gulf of Mannar is one of the three coastal Biosphere Reserves designated by Government of India. This Reserve has 47 villages with a total population of around 50,000, largely consisting of fishing communities. This population depends on fishing and other marine related activities for their sustenance. In order to mitigate hardship to the local inhabitants, the idea of "Biosphere Reserve" was formulated by UNESCO for which UNESCO prescribed certain criteria. I am glad to mention here that India has so far designated 14 Biosphere Reserves based on UNESCO criteria developed by its Man and Biosphere Programme.

As many of you might be aware, the Man and Biosphere (MAB) Programme initiated by UNESCO in 1972 is broad based ecological programme aimed at improvement of the relationship between man and the environment; and to predict the consequences of today's actions on tomorrow's world and thereby to increase man's ability to manage efficiently the natural resources of the biosphere. The approach emphasizes research and training and seeks scientific information to find solution of concrete practical problems of management and conservation.

Biosphere Reserves are special ecosystem for both people and nature and are living examples of how human beings and nature can co-exist while respecting each other's needs. These reserves contain genetic elements evolved over millions of years that hold the key to future adaptations and survival. The high degree of diversity and endemism and associated traditional farming systems and knowledge held by the people in these reserves are the product of centuries of human innovation and experimentation. These sites have Global importance having tremendous potential for future economic development, specially as a result of emerging new trends in Biotechnology.

This is primarily a programme of research and training and seeks scientific information to find solution to practical problems regarding management and conservation. It is, therefore, necessary that a comprehensive work plan is available to the Stakeholders for better understanding of the issues and ensuring long-term protection for sustainable use.

Let me mention here that UNESCO is playing an important role in linking globally designated biosphere reserves through an international network that is known as **"International Network of Biosphere"** under its Man and Biosphere (MAB) Programme. As of today, there are 507 Biosphere Reserves on World Network in 102 countries recognized by the UNESCO which include The Nilgiris, Sunderbans, Gulf of Mannar and Nanda Devi Biosphere Reserves from India. I am happy to mention here that my Ministry has recently forwarded proposals in respect of Kanchanjanga (Sikkim), Manas (Assam), Similipal (Orissa) and Pachmarhi (Madhya Pradesh) to UNESCO for inclusion in the world network.

It is a matter of great pride that the ecological diversity of India makes it one of the megadiversity regions on the globe. Many of you might be aware that the Wildlife Institute of India has demarcated 10 bio-geographic regions, namely, trans-Himalaya, Himalaya, Desert, Semi-arid, Western Ghats, Deccan Peninsula, Gangetic Plain, Coastal Areas, North-East, and Islands in the country, which are further divided into 25 bio-geographic provinces. Our efforts will be to have one Biosphere Reserve in each bio-geographic province.

The Biosphere Reserves present a beautiful paradigm of protection for an ecosystem through an integrated approach of benign regulation and promotion of alternative livelihood for the inhabitants. One of the unique and notable features of this programme is the multi-disciplinarity and multi-sectoral approach which lay great emphasis on alternative livelihoods which span the whole gamut of down-to-earth occupations ranging from cattle-rearing, horticulture, api-culture, sericulture, poultry, pisciculture, handicrafts, and production of agro-based products.

Today, the world is very much concerned towards the global environmental and social consequences of the policies of countries like India and China, which have large population and also fast growing economies. The National Environmental Policy (NEP) 2006 is our attempt to successfully address these concerns. While defining the basic principles of environmental conservation and management, the NEP emphasizes the need for priority allocation of societal resources for conservation of Entities of Incomparable Value (EIV), both natural and man-made, which may have impact on the well-being, broadly conceived, of large number of persons. The NEP underscores that **'the most secure basis of conservation is to ensure that people dependent on particular resources obtain better livelihoods from the act of conservation, than from degradation of resource'.**

The Gulf of Mannar Biosphere Reserves has been designated by the Government of India **"to promote conservation, development and logistics support with emphasis on alternate livelihood options for local communities".** The Gulf of Mannar is unique and encompasses a mosaic of ecological systems which consist of combinations of terrestrial, coastal, and marine ecosystems. This is one of the largest biosphere reserves in India covering an area of 10,500 square kilometers. The Gulf of Mannar is known to harbour varieties of marine flora and fauna which include more than 100 species of coral and thousands of sea turtles which are frequent visitors to the Gulf. The reserve is also known for sacred chunks, sharks, dugongs, dolphins, etc. The local population is largely dependent on the

Gulf of Mannar Biosphere Reserve for their day-to-day livelihood. The species that figure in the endangered list include dolphins, Dugongs *(Dugong Dugon)*, whales and sea cucumbers.

As you are aware, many national and international research institutions are conducting research on conservation, management and sustainable use of the marine resources of the Gulf of Mannar. I am happy to mention that a 'Gulf of Mannar Biosphere Reserve Trust' has already been formed to facilitate implementation of a GEFF funded project in the reserve. It is a seven-year project, funded under the Global Environment Facility (GEF), United Nations Development Programme (UNDP) with co-financing by the State and Central governments for conservation and sustainable use of the biodiversity of the Gulf of Mannar Biosphere Reserve.

As you are aware, some of the ecologically rich and sensitive areas in the communities are currently covered through the Protected Areas (PA) network, deriving power under diverse legal instruments and/or regulatory frameworks but the provisions of extant legal instruments have not been translated into regulatory frameworks and guidelines, and they do not fully cover certain entities such as biosphere reserves, natural heritage sites and man-made monuments wetlands, mangroves, and sacred groves. In consideration of this situation, it is proposed to set up a harmonized system for identification, constitution, rationalization and management of the diverse entities under a unified Regulatory Framework within the ambit of existing Environment Protection Act (EPA), 1986.

I am happy to mention that the project managers of Biosphere Reserves in India are successfully developing and conserving these sites despite several odds faced by them due to remoteness, difficult topography and sensitivity involved in dealing with local inhabitants, which mainly constitute of traditional communities.

I greatly appreciate the initiatives taken by the National Biodiversity Authority, Chennai and the UNESCO, New Delhi in organizing this International Workshop on **"Gulf of Mannar Biosphere Reserve: An Ecological Model for Biodiversity Conservation, Livelihood and Sustainability."** I am sure, this workshop will provide a great opportunity for various stakeholders for exchange of information and knowledge related to various complex issues pertaining to management of this reserve.

It is my privilege to inaugurate this International Workshop and I take this opportunity to wish this Workshop a grand success and hope that the people of this country benefit out of the natural resources available for the future generation. The Scientists participating in the Workshop should bring out practical recommendations for conservation and protection of this Reserve.

Let me remind you of our great cultural heritage that respected not only humans; not only animals and Plant systems but also inanimate beings, passed on to us in the words of the Tamil poet Varakavi Bharathi:

"Kaakkai Kuruvi Engal Jaadhi; Neel Kadalum Malayum Engal Koottam."

Thank you,

Vanakkam.

PRESIDENTIAL ADDRESS

S. Kannaiyan

Chairman, National Biodiversity Authority, Chennai

India is very rich in Biodiversity and associated traditional knowledge. India with only 2.4% the world's area, it is the Home for over 8% of its Biological Diversity and is also one of the 17 mega-diversity countries of the world. It has been well recognized that valuable and productive biological resources are crucial for sustainable economic development. The rural populations of India always believe that biodiversity is important for their livelihood and survival. Protecting and conserving biodiversity is our own interest and industries such as pharmaceuticals, cosmetics, pulp and paper, construction, Agriculture and agro industries, between 70-80% of the population in India relies on plants as the only source of medicine. To conserve and sustainably use the biodiversity of India, the Government has established The National Biodiversity Authority (NBA) in 2003 at Chennai in accordance with Biological Diversity Act, 2002, with the following objectives:

i. ***To regulate access to biological resources, of' the country with the purpose of securing equitable share in benefits arising out of the use of biological resources, and associated knowledge relating to biological resources.***

ii. ***To conserve and sustainable use of biological diversity.***

iii. ***To respect and protect knowledge of local communities related to biodiversity.***

iv. ***To secure sharing of benefits with local people as conservers of biological resources and holders of knowledge and information relating to the use of biological resources.***

v. ***Conservation and development of areas of importance from the standpoint of biological diversity declaring them as biological diversity heritage site.***

vi. Protection and rehabilitation of threatened species and

vii. Involvement of institutions of State Governments in the broad scheme of the implementation of the Biological Diversity Act through constitution of committees.

A three tiered structure at the national, state and local level is established under the Biological Diversity Act, 2002. All matters relating to requests for access by foreign individuals, institutions or companies, and all matters relating to transfer of results of research to any foreigner will be dealt with by the **National Biodiversity Authority (NBA)**. All matters relating to access by Indians for commercial purposes will be under the purview of the **State Biodiversity Boards (SBB).** The Indian industry will be required to provide prior intimation to the concerned *SBB* about the use of biological resource. The State Board will have the power to restrict any such activity, which violates the objectives of conservation, sustainable use and equitable sharing of benefits. Institutions of local government (Panchayat, District and Municipalities) will be required to set up **Biodiversity Management Committees (BMC)** in their respective areas for conservation, sustainable use, documentation of biodiversity and chronicling of knowledge relating to biodiversity. NBA and SBBs are required to consult the concerned BMCs on matters related to use of biological resources and associated knowledge within their jurisdiction.

The present International workshop on "Gulf of Mannar Biosphere Reserve: an ecological model for Biodiversity Conservation, livelihood and sustainability" is organized mainly to find more elucidation to conservation and Management of Biological resources and open the opportunity for the livelihood options for the coastal villagers along the coast of Gulf of Mannar Biosphere Reserve.

The Gulf of Mannar (GoM) Biosphere Reserve was established by the Government of India and the State of Tamil Nadu as the first marine protected area to be declared in South and South East Asia. The GoM 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. All the 21 islands (only 19 islands are above surface waters) have been notified as reserve lands under section 26 of the Tamil Nadu Forest Act, 1882. This was reinforced by a renotification of the State Government on 10, September, 1986 as Gulf of Mannar Marine National Park under section 35(1) of the Wildlife (Protection) Act 1972. Under the Man and Biosphere Reserve Programme of UNESCO, Government of India *set* up in February 1989, The Gulf of Mannar Marine Biosphere Reserve, the first of its kind in the country and probably, in Southeast Asia. The Gulf of Mannar biosphere reserve has an area of about 10,500 km^2 running along the mainland coast for about 170 nautical miles including the 21 islands in the gulf. The Gulf of Mannar is considered as "Biologists Paradise" for it has 3600 species of flora and fauna.

In recent decades, however, the coral reef ecosystems in Gulf of Mannar region have come under increasing pressure from environmental stress, unsustainable fisheries and harvesting methods, climate related coral bleaching and diseases, land-based sources of pollution, sedimentation, dredging and coral mining, and from inappropriate coastal development caused by insufficient planning, management, and policy decisions. These negative impacts erode the livelihoods provided by healthy coral reefs to local people. The impacts vary among stakeholder groups, but in general the poorest stakeholders are finding that their livelihoods are declining more than other coastal stakeholders and they are the least able to respond to this change. If coral reef management is to be successful on the longer-term, it has to effectively address the needs and aspirations of the poor people depending on reefs, ensuring the benefits are equitably distributed among all stakeholder groups. Almost any form of resource management will affect the way people interact with reef resources, and dramatic changes in their access to reefs are likely to influence their livelihoods. And where people's livelihoods are marginal and subjected to stress and conflict, this will likely seriously affect their ability to pursue a sustainable livelihood. To avoid this situation, informed and holistic reef management that address the concerns of local reef users is vital.

The present International workshop on "Gulf of Mannar Biosphere Reserve: an ecological model for Biodiversity Conservation, livelihood and sustainability" has identified the following priority themes for workshop:

- Biological diversity of Gulf of Mannar Biosphere Reserve;
- Biodiversity conservation into sustainable development interventions.
- Integrated management of marine resources for food security;
- Assessing Gulf of Mannar ecosystem dynamics for poverty alleviation.
- Coastal livelihoods and policy options for the benefit of coastal population (such as seaweed culture, ecotourism);
- Scenarios and policy options for good governance in the context of global change;
- Aquaculture for sustainable use;
- Management of natural and man-made disasters- natural ecosystem recovery models using GoM as case;
- Sustainable development and knowledge sharing;
- Environmental degradation and promoting rehabilitation;
- Protecting and safeguarding the corals in Gulf of Mannar.

It is envisaged that he final outcome of this workshop direct the efforts towards an integrated approach to the conservation. Socio-economic and biological monitoring will be viewed as an integrated activity. Developing the capacity of different institutions working on Gulf of Mannar to provide in-house training and guidance can assist or fulfill the long-term training requirements of a constantly changing workforce. Using locally-based institutions with a pre- existing *role* and relationship with the community will assist establishing a monitoring programme and help ensure that information feeds into the policy process or management efforts more effectively. The more precisely the socioeconomic and biological monitoring meets the information requirements at the local and national levels, the more likely it is used and it will receive long-term national support. Formal and informal networking and sharing of expertise among network partners, government departments, NGO's, private sector and stakeholders at both local and national level is required for effectively producing and disseminating socioeconomic and ecological information into management and policy processes.

It is my privilege to preside over the International workshop and I take this opportunity to welcome all the delegates to this International workshop who have come to make this function and workshop a grand success. I am sure that the workshop will bring out implementable recommendations for conservation and protection of Marine Biodiversity in Gulf of Mannar Biosphere Reserve.

SPECIAL ADDRESS

Minja Yang

Director, UNESCO New Delhi Office and UNESCO Representative to India

UNESCO is at the forefront of international efforts to conserve biodiversity. The World Network of Biosphere Reserves and the World Natural Heritage Sites offer great potential for the conservation of biodiversity, especially in areas that are of outstanding universal value. They also present great opportunities for development as models of how humanity can cope with the threats posed by climate change and natural disasters.

Biosphere reserves are areas of terrestrial and coastal ecosystems recognized within the framework of UNESCO's Man and the Biosphere (MAB) Programme which innovate and demonstrate approaches to conservation and sustainable development. They are of course under national sovereign jurisdiction, yet share their experience and ideas nationally, regionally and internationally within the World Network of Biosphere Reserves. The world's major ecosystem types and landscapes are represented in this network, which is devoted to conserving biological diversity, promoting research and monitoring as well as seeking to provide models of sustainable development in the service of human kind. There are 529 Biosphere Reserves worldwide in 105 countries, and they are required to meet a minimal set of criteria and adhere to a minimal set of conditions before being admitted to the Network.

In India four Biosphere Reserves have been designated by UNESCO: Nilgiri (2000), Gulf of Mannar (2001) Sunderban (2001) and Nanda Devi (2004). Sunderban is also a World Natural Heritage Site (Sunderbans National Park, designated 1987), as are Nanda Devi (Nanda Devi and Valley of Flowers National Parks, 1987 and 2005), along with Manas Wildlife Sanctuary (1985), Kaziranga National Park (1985) and Keoladeo National Park (1985). Sites on the World Heritage List are natural properties recognized by the World Heritage Committee has being of outstanding universal value.

In July 2007 UNESCO launched an ambitious project for biodiversity conservation in four of the World Natural Heritage sites – Nanda Devi, Manas, Kaziranga and Keoladeo – with the support of the United Nations Foundation, the Government of India, the relevant State Governments and donors. The project will focus mainly on community participation in the management of the protected areas and capacity building of park management. Such a comprehensive programme in biodiversity preservation will help in building replicable models for law enforcement, scientific management and community participation at other sites. We are grateful to the Honorable Minister of State for Environment and Forests, who took time to be with us for the launch of this project.

The Gulf of Mannar Biosphere Reserve covers an area of 1,050,000 hectares 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, beaches and forests of the nearshore environment, including a marine component with algal communities, sea grasses, coral reefs, salt marshes and mangroves.

Among the Gulf's 3,600 plant and animal species are the globally endangered sea cow (*Dugong dugon*) and six mangrove species endemic to peninsular India. The inhabitants of the Gulf are mainly Marakeyars, local people principally engaged in fisheries. There are about 47 villages along the coastal part of the biosphere reserve which support some 100,000 people (200,000 seasonally as of 2001).

The Global Environmental Facility (GEF) provided support to the establishment of the Biosphere Reserve, including the setting up and functioning of the Gulf of Mannar Biosphere Reserve Trust, which is responsible for the coordination of the management plan for the Biosphere Reserve in association with Government agencies, private entrepreneurs, and local people's representatives. As with the UNESCO World Natural Heritage sites in India, priority is being given to encouraging community based management.

The Gulf of Mannar has the distinction of being the only marine Biosphere Reserve in India. UNESCO is working with the Government of Sri Lanka to have the Sri Lankan part of the area also designated as a biosphere reserve. The success of this undertaking will provide a fine example of a transboundary biosphere reserve, with the possibility of joint conservation efforts leading to a peace park. Considering the unique features of the area, the Gulf of Mannar has the potential to become a World Heritage Site as well.

I thank the National Biodiversity Authority and the SACEP for taking the initiative to organize this important conference with UNESCO to bring together various stakeholders to discuss and devise suitable strategies for the conservation of this valuable heritage of humankind.

SPECIAL ADDRESS

T. Balasubramanian

Director, CAS in Marine Biology, Annamalai University, Parangipettai

Coral Reefs are the world's rich storehouses of biological diversity. They are one among the most productive and dynamic ecosystems on the earth. They provide shelter and food to thousands of marine fishes which form the basis of livelihoods of many coastal communities. Conservation and management of the coral reef is an urgent need in the present context of their fast disappearance at the global scale.

India is blessed with all the major types namely atoll, fringing and barrier enriched with marine biodiversity. Among the corals of India, Gulf of Mannar is unique for its recognition as the first Marine Biosphere Reserve in the Southeast Asia. There are 117 species of corals belonging to 40 genera, predominantly with Acropora, Mantipora and Porites. However, it is not known about the actual number of marine species associated with coral reef ecosystems in the country. There are only a few experts available to study the marine organisms in the coral ecosystem. Taxonomists are really 'endangered' species of this country. Encouraging the young taxonomists with assured job opportunities and handsome financial support will promote the marine studies. In this regard, our Centre is grooming faculty members supported with student force to study about the taxonomy and biology in 20 groups of marine organisms.

In the Gulf of Mannar, there are about 25 marine species at threat and these species are strictly protected under Wildlife Act from human pressure, allowing the species to breed in the natural habitat. There is a need to monitor the species continuously for spatial and temporal changes in their wild populations. This study will help to identify the species which decline in population, in spite of all the protection measures. These specific species can be bred under the lab conditions and released in large numbers to the natural stock. Such 'Sea-ranching' efforts, if practiced for marine fish species of commercial importance and those at threat, may increase the population of the species thereby conserving the endangered species as well promoting livelihood of the local people.

In this regard, our Centre has developed techniques for successful breeding of ornamental fishes such as pipe fish, clown fish and seahorses under lab conditions. Our centre has also released millions of commercial tiger prawns, developed in hatcheries, to the natural environment.

KEYNOTE ADDRESS

Arvind Boaz

Director, South Asian Co-operative Environment Programme,
Colombo Srilanka

- **Hon'ble Thirumigu S. Regupathy, Union Minister of State for Environment & Forests, Government of India**
- **Ms Minja Yang, Director of the UNESCO-New Delhi Office**
- **Prof. S. Kannaiyan, Chairman, National Biodiversity Board, India**
- **Shri G. Balachandhar, (Jt. Secretary, Ministry of Environment and Forests, New Delhi)**
- **Dr. K. Venkatraman, Secretary, NBA, India**
- **Dr. Ram Boojh, UNESCO New Delhi office**
- **Ladies and Gentlemen**

It is indeed a great honour for me to be present here today and to been asked to deliver the Key Note Address at this International Workshop on Gulf of Mannar Biosphere Reserve: an ecological model for Biodiversity Conservation, Livelihood and Sustainability.

SACEP has had a very long association with UNESCO especially in its formative years through the Man and Biosphere Programme and latterly through the programme activities of the South Asian Regional Seas Programme.

It is noted that UNESCO's Man and the Biosphere (MAB) Programme has a long tradition of promoting marine ecosystem studies within and among its Member States, in particular through its MAB coastal and marine

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It is noted that UNESCO's Man and the Biosphere (MAB) Programme has a long tradition of promoting marine ecosystem studies within and among its Member States, in particular through its MAB coastal and marine resources programme. The MAB programme's main focus is to promote environmental sustainability through the World Network of Biosphere Reserves (WNBR) where emphasis is placed on linkages between biodiversity conservation and socio-economic development in specific biosphere reserve contexts.

South Asia is one of the most diverse regions in the world. Being in a unique geographical location, bordered to the north by the Himalayas and to the south by the Indian Ocean, the region covers a diversity of ecosystems from lush tropical forest to harsh, dry desert and the vast Indian ocean. It is also one of the most populous regions, with over 1 billion people living in India alone. The region covers almost one twentieth of the earth's surface and provides a home for about one fifth of the world population. South Asia is home to 14 percent of the world's remaining mangrove forests and the Sundarbans between Bangladesh and India is one of the largest continuous mangrove stretch in the world. About 6 percent of the world's coral reefs are in the South Asian seas. The atolls of Maldives and Lakshadweep islands of the region, are biodiversity rich marine habitats. Himalayan region is home to over 25,000 major plant species, comprising 10 percent of the world's flora. The region is prone to natural disasters such as cyclones, floods and landslides. From 1990-1999, the region accounted for over 60 percent of disaster-related deaths worldwide.

There have been exchanges and movements across the region since time immemorial resulting into strong commonalities between cultures. Yet there remains a huge diversity of languages, religions and outlooks across the sub-continent. . Most of the South Asian nations share many similar environmental problems, stemming from poverty and its consequences on natural resources. According to the World Bank, during the past decade, South Asia has been the second fastest economically growing region in the world, and their efforts at increased production have put increasing pressure on natural resources and the environment. Significant natural resource concerns of the region include depletion of water quality and quantity, dwindling forests and coastal resources, and soil degradation resulting from nutrient depletion and salinization.

Many countries of the region have taken actions for the protection and management of the environment. They are also party to many multilateral environmental agreements requiring them to work cooperatively for the mitigation of concern issues. SACEP supports national government's efforts for environmental protection and sustainable development.

SACEP as the Secretariat for the implementation of the South Asia Seas Programme of the United Nations Environment Programme, have and are conducting several related programme activities concerning Biodiversity in the region. These are particularly important not only for the Gulf of Mannar Biosphere Reserve but also for the Conservation, Livelihood and Sustainability of the abundant Biodiversity that our seas and oceans support.

One of our major projects under implementation is a European Union funded project titled "Institutional Strengthening and Capacity development for the Long-term Management of Marine and Coastal Protected Areas encompassing Coral Reefs in South Asia" with technical collaboration and support of UNEP. Under this project, regional initiative gives priority to the management and conservation of exploited marine and coastal resources. The improvement of management outputs from existing Marine and Coastal Protected Areas (MCPAs) will be targeted through the development of human and technical expertise, improvement of information and networking services, and the allocation of technical equipment to sites. Training and management processes across the region will be reviewed and rationalised to ensure greater consistency and aptitude for management and conservation, and to formulate a transferable resource base capable of accommodating future MCPA network developments in line with countries Multilateral Environmental

Agreement (MEA) commitments. Institutional strengthening will be undertaken in parallel to mainstream environmental considerations into development policy and readdress the unique situations of poor coastal communities. The creation of advisory and coordination capacity through the establishment of the South Asia Coastal Resource Task Force, will develop linkages between all levels of management, and will harness and focus existing regional expertise, facilitating coordinated responses to transboundary management issues and improving the representation of South Asian marine and coastal resource management challenges within global discussion fora.

Its objectives is to contribute to the reduction in the rates of marine and coastal biodiversity loss at the global, regional and national level and protect the natural resources on which the economic and social development of future generations is based, through the establishment of regionally representative networks of marine and coastal protected areas (MCPAs) encompassing coral reefs. One of the major outcomes of the project will be the establishment of an advisory team of regional experts and stakeholders called the South Asia Coral reef Task Force, to review policy, guide future interventions and encourage governments to urgently address all threats, including those arising from the land and shipping, in order to maximise the effectiveness of marine and coastal protected areas in achieving their objectives for marine and coastal biodiversity. This will improve the integration and inter-agency cooperation of the maritime countries of the region and increase the potential for transboundary management and coordinated responses to shared environmental issues, and generate greater disaster response capabilities within the South Asia maritime nations.

Another major activity of the SACEP and South Asian Seas programme is connected to the Global Marine Litter Programme.

Marine Litter is considered as one of the marine pollution source categories of the GPA. Within this context, UNEP/RSP has committed to supporting SACEP and the South Asian Seas programme in the survey and assess the sources, types and levels of contaminants in their marine environment, and to enable them to prepare priority action programmes and supporting measures to reduce pollution loads and mitigate potential risks to the marine and coastal environments.

With assistance of the 5 marine member states SACEP has prepared a Review Document on Marine Litter in the South Asian Seas Region and also a framework document "Regional Activity on Marine Litter in the South Asian Seas" which spells out proposed activities on a short term and long term basis, which also includes a setting up of Task Force for the implementation of the activities identified by the countries.

SACEP has with assistance of the Government of Sri Lanka and UNEP is implementing a project titled Strategic Planning and Developing Market Based Instruments for the Medium to Long Term Strategic Planning of the Implementation of the Sri Lanka National Program of Action (MBI/NPA) Under this project there is assistance provided *to evaluate the potential of market based instruments for the medium to long-term implementation of the Sri Lanka NPA and the Strategic planning for the implementation of the short, medium and long term implementation of the Sri Lanka National Programme of Action on Land based Sources.*

SACEP has also prepared a Draft Regional Oil Spill Contingency Plan for the South Asian Seas region with technical assistance of IMO and UNEP.

South Asia not only imports much of its own consumption of oil, but India, Maldives, Pakistan and Sri Lanka lie close to the main shipping route from the Middle East to the Far East. A total of some 525 million tonnes a year of crude oil pass into or through the Region – about 25 per cent of total world movement of crude oil by sea. Additional maritime oil spill risks arise from non-tanker shipping, carriage of refined products, offshore exploration and production operations, and the transfer of oil cargoes at sea.

Although there is some capacity within the Region to respond to oil spills in harbour and at sea, and the five countries continue to develop or enlarge their capabilities, the response to a major spill at sea would probably require the co-operation of the other States in the Region, or assistance from further field. A Regional Plan is an important first step towards supplementing individual States' response capabilities.

The purpose of this Contingency Plan is to establish a mechanism for mutual assistance, under which the competent national Authorities of Bangladesh, India, Maldives, Pakistan and Sri Lanka will co-operate in order to co-ordinate and integrate their response to marine pollution incidents either affecting or likely to affect the territorial sea, coasts and related interests of one or more of these countries, or to incidents surpassing the available response capacity of each of these countries alone.

The general objective of the Plan is to organise a prompt and effective response to oil spills affecting or likely to affect the area of responsibility of one or more of the countries concerned and to facilitate their co-operation in the field of oil and chemical pollution preparedness and response. It is envisaged that this Plan will be operational before the middle of 2008.

SACEP has also entered into a Memorandum of Understanding with Traffic International and the efforts to establish the South Asia Wildlife Enforcement Network in response to the decisions of it's Governing Council. During the 10th Governing Council of South Asia Co-operative Environment Programme a decision was taken to incorporate special work programme for combating illegal trade in wildlife and its products in South Asian Region with a view to strengthen CITES enforcement and in controlling illegal trade in wild flora and fauna.

To take this decision forward, SACEP has signed a Memorandum of Understanding with TRAFFIC International to establish a Wildlife Enforcement Network for the South Asian Region and a draft South Asian Regional Strategic Plan on Wildlife Trade has been drafted for the implementation of the initiative.

It is evident from the above that SACEP is a vital and viable organisation in the region playing a pivotal role and enhancing regional co-operation in the South Asian Region.

Recognizing the need to develop partnership and synergy in the region in the filed of environment and related areas both the UNESCO and SACEP have signed an MoU to contribute to sustainable human development and create conditions for dialogue, based upon respect for commonly shared values and the dignity of each civilization and culture, through programmes and projects in their fields of competence and to work closely to develop and reinforce their respective competencies and strengths through a range of partnerships, alliances and other cooperative mechanisms in the region, so as to foster impact of their programme at both regional and national levels. This is the first activity under this ambitious MoU and I am confident together we will be able to develop extensive networking strategies for the benefit of the environment in the region which will help our member countries to identify opportunities for sharing and strengthening the knowledge and innovation based on already ongoing eco-networking and network of biosphere reserves and world heritage sites that are the mutual strengths of our organisations.

I wish the deliberations of this workshop all success and we at SACEP will look forward to the outcome and will continue to work very closely with UNESCO and the member countries.

BIOLOGICAL DIVERSITY OF GULF OF MANNAR BIOSPHERE RESERVE

OVER VIEW OF MARINE BIODIVERSITY CONSERVATION IN TAMIL NADU AND IMPORTANCE OF GULF OF MANNAR BIOSPHERE RESERVE

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Introduction

Tamil Nadu is situated on the southeastern part of the Indian peninsula. It is bounded in the east by Bay of Bengal, in the south by the Indian Ocean, in the west by the states of Kerala and Karnataka and in the North by the Karnataka and Andhra Pradesh. Tamil Nadu has a total geographical area of 13 m ha which amounts to 4% of the India's land surface. It lies between 8° 04′ N and 13° 34′ N and 76° 14′ E and 80° 21′ E. Tamil Nadu can be divided in to four major geographical divisions such as the eastern and coastal plains, central uplands, western Karnataka plateau and the central Eastern Ghats.

The general climate is moderately hot and dry in the plains of the State. However, temperature dips close to 0° C in the Western Ghats during winter. The average rainfall varies between 900 and 1200 mm/y. Rainfall in the range of 3000-5000 mm/y occurs in the Western Ghats while the rain shadow region of Coimbatore and adjacent areas receive less than 600 mm annually. Whereas the southwest monsoon is the major source of rain, the northeast monsoon hydrates the east coast during the colder part of the year. Tamil Nadu has a human population of 62.11 m (2001 Census) and a livestock population of 26 m. 17.4% of the land area (2.26 m ha) is classified as forests of which 86 % are reserve forests, 11 % reserve lands and 2.71% unclassified forests.

Tamil Nadu has a conglomeration of different types of ecosystems rather than a particular type as in some other states of India. The geographical location of the state has bestowed it with major representative ecosystems. It has within its confines, areas representing different types of ecosystems like dry deciduous forests, moist deciduous forests, degraded shrub lands, dry evergreen forests or thorn shrub and small pockets of semi evergreen forests, besides certain wetland ecosystems and freshwater bodies. Though most of the ecosystem types represented here is found in some of the other states, yet much of the thorn forests and scrublands of India are confined to Tamil Nadu, comprising a major part of this state. The whole eastern side of the state is protected by 1000 km of seacoast, which has all major types of habitats and major ecosystems such as pelagic and benthic, estuarine, seaweed and sea grass, mangrove and coral reef ecosystem, peculiar to the state of Tamil Nadu (Fig 1).

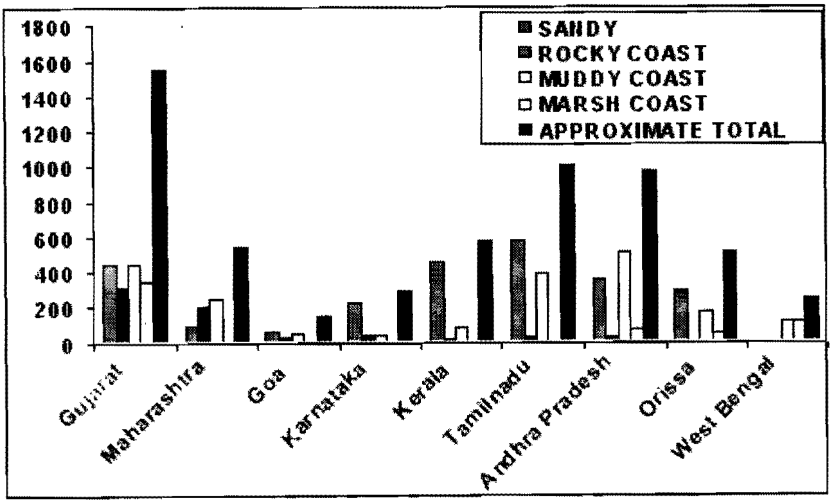

Fig 1. The description of habitats (in sq km) of coastline in Tamil Nadu and other coastal states in India

COASTAL AND MARINE ECOSYSTEMS IN TAMIL NADU

Among coastal wetlands, estuaries, mangroves and coastal lagoons are biodiversity-rich areas, whereas the other brackish water habitats have only a few specialized species. It is well known that there is a reduction in the number of species is greater in estuaries when compared to adjacent seas and in-flowing river system. However, as far as estuaries of Tamil Nadu are concerned, this statement is only partly true. There is lesser number of species in the adjacent seas when compared to the estuaries, but the upper riverine ecosystem does not harbor as many species as its estuary. It has been observed that as the distance increases from the sea the number of species decreases. Salinity becomes an important regulating factor. However, much study is to be conducted in the estuaries, mangroves and coastal lagoons of Tamil Nadu.

Mangrove Ecosystem: Tamil Nadu has two major mangrove forests. Pitchavaram mangrove is located 200 km south of Chennai City covering an area of 1100 ha. The whole mangrove consists of 51 small and large islands and is bathed with seawater during high tide and freshwater from irrigation channels during low tide. The Muthupet mangrove forest which spreads over an area of approximately 6,800 ha of which only 77.20 ha (4%) is occupied by well grown mangrove and the remaining 96% of the area is covered by poorly grown mangrove vegetation, is situated near Point Calimere on the southeast coast of the Peninsular India (10^0 25′ N; 79^0 39′ E). It is situated at the southern end of the Kaveri Delta. At the tail end, it forms a lagoon before meeting the Palk Strait. Dense mangroves occupy the northern and western borders of the lagoon and the southern part is occupied by sand spit, which is devoid of mangrove vegetation (Kathiresan, 2000).

Sea Grass and Seaweed Ecosystem: Sea grasses occur in the infratidal and midtidal zones of shallow and sheltered localities of sea, gulf, bays, backwaters and lagoons. They are submerged monocotyledonous plants and are adapted to the marine environment for completion of their life cycle under water. They form a dense meadow on sandy and coral rubble bottoms and sometimes in the crevices under water. Earlier studies have revealed that 14 species are found along the India coast (Kannan, *et al.,* 1999). Thirteen species of sea grasses under six genera occur in the Gulf of Mannar Biosphere Reserve (Kannan, *et al.,* 1999). The unique ecological importance of the sea grasses in the conservation of rare and endangered animals such as marine turtles, dugongs, some common echinoderms, juvenile prawns and fishes. Other than these the ecology and diversity of sea grass associated invertebrate fauna from Tamil Nadu is still not known.

Marine algae or seaweeds are important reef resource in India. Maximum number of species has been recorded from Gulf of Mannar (302) (Oza and Zaidi, 2000). In Tamil Nadu, seaweeds are exploited and used as raw material for the production of agar, alginates and seaweed liquid fertilizer. A little over 25 agar industries and 10 algin industries are situated at different places in the maritime states of Tamil Nadu, Kerala, Karnataka, Andra Pradesh and Gujarat. Red algae such as *Gelidiella acerosa, Gracilaria delis, G. crassa, G. foliifera* and *G. verrucosa* are being used for agar manufacture and brown algae *Sargassum* spp., *Turbinaria* spp. and *Cystoseira trinodis* for alginates and liquid seaweed fertilizer. The agar yielding seaweeds are being harvested since 1966 from the natural seaweed beds of Gulf of Mannar Islands, along the coastline from Rameswaram to Tuticorin in Gulf of Mannar area and Sethubava Chatram area in Palk Bay, Tamil Nadu. Data collected by the Central Marine Fisheries Research Institute (CMFRI) on seaweed landings in Tamil Nadu from 1978 to 2000 reveal that the quantity (dry wt) exploited in a year during this period varied from 102 – 541 t for *Gelidiella acerosa,* 108 – 982 t for *Gracilaria edulis,* 2-96 t from *G. crassa,* 3- 110 t for *G. foliifera* and 129-830 t for *G. verrucosa.*

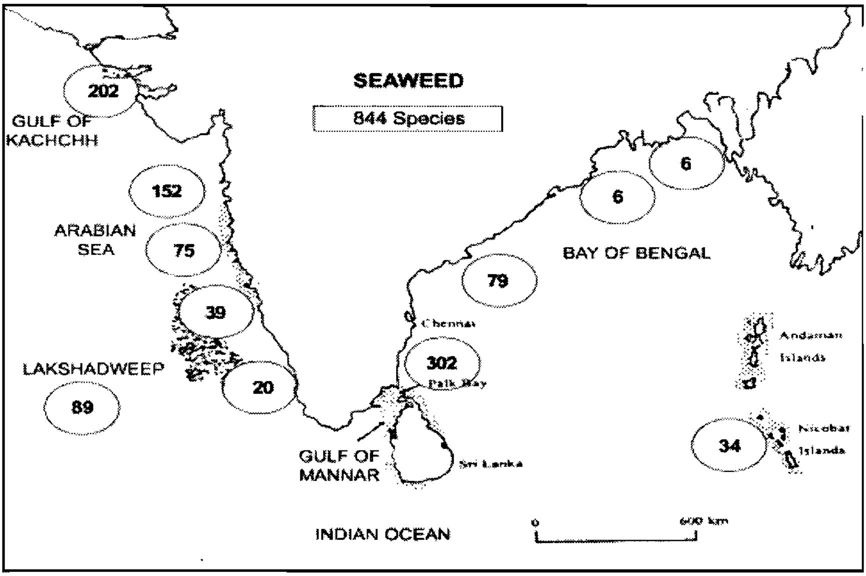

Fig. 2. Seaweed diversity in Gulf of Mannar and other regions in India

Coral Reef Ecosystem: Coral reefs form the most dynamic ecosystem providing shelter and nourishment to thousands of marine flora and fauna. They are the protectors of the coastlines of the state. A few genera of corals are supposed to be older than prairies. This unique ecosystem is most productive because of its symbiotic association with algae called Zooxanthellae. Though they are the builders of the most massive structures ever created by living beings on earth, they are very fragile and vulnerable to natural disturbances and human activities. Maritime states and their coastal population mostly depend upon the coral reef ecosystem for their day-to-day life.

In Tamil Nadu, the reefs are distributed along the southeast coast especially at Gulf of Mannar and Palk Bay region and at restricted places in Chennai, Pondicherry and Cuddalore coasts. Among the other areas, Gulf of Mannar is supposed to be one of the hot spots for marine biodiversity in India and falls in the world's biologically richest Indo-Pacific realm (Fig. 3). Coral reefs along with the mangrove and seaweed/sea grass ecosystems support nearly 3,600 biological species in this reserve (Venkataraman *et. al.,* 2002). The Gulf is not only the first marine biosphere

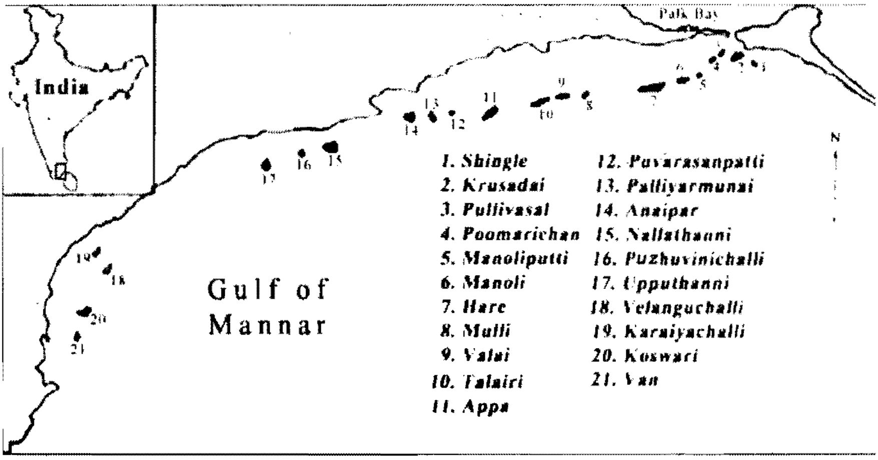

Fig. 3. Map of Gulf of Mannar showing 21 islands.

reserve in India, but also the first in south and Southeast Asia. The area falling between longitudes 78° 08'E to 79° 30'E and latitudes 08° 35' N to 09° 25' N was declared as marine biosphere Reserve by the Government of India on February 18, 1989 to conserve this unique ecosystem. The Gulf of Mannar Biosphere Reserve (GoMBR) encompasses 21 islands.

These are uninhabited islands, ranging in size from 0.25 ha to 130 ha, spreading along the coast for 170 km, with the closest being 500 m and the farthest, over 4 km from shore. The reef flat area occupies 67% in Gulf of Mannar with reef vegetation, 15%, vegetation over sand 4% and sand over reef is 13% (D.O.D. and S.A.C., 1997) (Fig. 4).

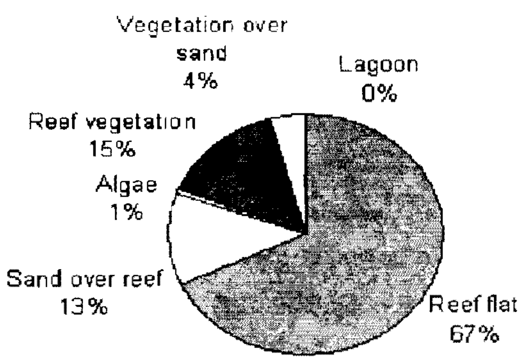

Fig. 4. Area estimates of coral reefs in Gulf of Mannar (Adapted from D.O.D. and S.A.C., 1997).

The Gulf of Mannar, which is globally significant because of its unique biological diversity, came to lime light mostly due to extensive scientific research activities (Table 1). Some of the unique fauna occurring in the Gulf are at present commercially threatened due to over exploitation (Venkataraman *et al.,* 2004). Nearly 47 fishing villages dot the 180 km long reserve coastline. More than 50,000 people inhabiting the coastal villages depend on the marine resources of the Gulf for their livelihood. A little over 650 mechanized vessels and nearly 2500 non-mechanized vessels are being operated from 47 fishing villages. Methods used to exploit the seaweeds cause severe damage to coral reefs. Rapid industrialization around the reserve, usage of dynamite and trap fishing methods, poaching and commercial aquaculture are other major threats to coral reefs in these areas (Venkataraman, 2006).

Table 1. Coral Reef Resources of Tamil Nadu especially Gulf of Mannar and Palk Bay.

Groups	Palk Bay and Gulf of Mannar
Sea weed	**302**
Sponge	**275**
Scleratinia	**92**
Crustacea	**641**
Mollusca	**428**
Echinodermata	**112**
Fishes	**762+**

The first study in India on marine fauna was on *Aplysia* and its purple colour by Ensign W. Francklin 1786-87 (Bengal to Persia in Pinkerton's Voyages And Travels, 1811) Bombay followed by Wallich's Marine algae on Herbarium (1822) (In Prodromus Florae Peninsulae Indiae Orientalis, 1834) along the coast of Hindustan and Madras.

However, major marine faunal studies in Tamil Nadu were consequent to the setting up of Madras Museum. The Madras Literary Society mooted the proposal for a museum in Chennai in 1846 and Sir Henry Pottinger, the then Governor, obtained the sanction of the Court of Directors of the East India Company in London. In January 1851, Dr. Edward Balfour, Medical Officer of the Governor's Body guard was appointed as the First Officer in charge of the Government Museum. The setting up of a marine aquarium in Chennai in the Marina Beach in 1909 followed this. Dr. E. Thurston the then Superintendent of the Museum first drew up the plans for the Madras Aquarium during 1905-1906. The aquarium was opened to the public on October 21, 1909 AD. Today many famous collections available in the museum, starting from Great Indian Baleen Whale to molluscan shells, starfishes, sea urchins, insects and several hundreds of dry preserved specimens in boxes and cabinets are important for research.

The golden period of the study of marine fauna of Tamil Nadu is 1885 to 1978 when Dr. Edgar Thurston (1885 – 1908) was holding the charges of Superintendent of the Madras museum followed by Dr. J. R. Henderson (1908 – 1919), Dr. F. H. Gravely (1920 – 1940), Dr. A. Aiyappan (1940 – 1960) and Dr. S. T. Satyamurthi (1961 – 1978). During this period many surveys and publications were made on the marine fauna of Chennai and the adjacent areas of Tamil Nadu. When Dr. Frederic Henry Gravely took charge as Superintendent in 1920, the investigation of the littoral fauna of Krusadai Island in the Gulf of Mannar was undertaken. This investigation led to the revival of the Bulletin of the Madras Government Museum for the publication of the results of the researches. The collections were scientifically preserved, studied and interpreted by publishing research bulletins during the tenure of Dr. Gravely (1920 – 1940). Dr. Gravely's work on Mollusca helped in completing the gallery and the reserve collection in these two large Zoological groups (Gravely, 1927- 1942). In 1940, Dr. S. T. Satyamurti who joined as Curator, Zoology Section was promoted as Superintendent of the Museum. During the tenure of Dr. Satyamurti, the displayed collections in the galleries were interpreted and published as Guide Books. His noteworthy publications are on the Mollusca of Krusadai Island in the Gulf of Mannar "Amphineura and Gastropoda" Vol. I, "Scaphopoda, Pelecypoda and Cephalopoda" Vol. II and Echinodermata (Satyamoorthy, 1952, 1956, 1976).

The Phylum Chaetognatha was studied by many workers of which, John (1933, 1937), Menon (1931), Srinivasan (1977, 1980) and Subramaniam (1940) are important. Except Ali (1945, 1956, 1960) and Dendy (1887) no other worker has directly dealt with the sponges of Tamil Nadu. Other important works on sponges from Tamil Nadu are of Burton, (1930, 1937), Burton and Rao (1932) Pattanayak and Buddhadeb (2001) and many publications of Thomas (1968-1985) from Gulf of Mannar. The hydromedusa forms the major part of the zooplankton of Tamil Nadu Coast. Menon's (1931) publication is the only major work on this group and Annandale (1907 a, b; 1915) published mainly on the brackish water medusa. The diversity of scyphomedusae was investigated by many researchers (Sundara Raj, 1927; Menon, 1931) of which, Chakrapany (1984) made elaborate inventory on the Madras (= Chennai) Coast. Sundara Raj (1927) and Leloup (1934) were the pioneer workers on the siphonophores of Tamil Nadu and it was followed by Daniel and Daniel (1963a, b). Diversity of hard corals is well studies by Pillai (1967-1986 *cited elsewhere*) and Venkataraman *et. al.* (2003). Nayar (1950, 1959) and Sivaprakasam (1969 a, b,) were the major workers on the amphipods. The study on barnacle was first started in India by Anandale (1905, 1906, 1909, 1910, 1911, 1913) followed by many publications on the diversity by Daniel (1952, 1953, 1956, 1958, 1959, 1962) and Daniel and Ghoush. (1963). Alcock (1894, 1895, 1896, 1898, 1899, 1900, 1901) was the first person to work on the crabs of India and neighboring seas. This was followed by many publications of Chopra (1933a, b) and Chopra and Das (1937). Except the above, no major work on the marine crabs of Tamil Nadu is available. Also the credit of working on the macruran fauna of India goes to Alcock (1901, 1905). The pioneering work on gastropod molluscs of Tamil Nadu was by Melvill and Standen (1878) and Preston (1911), which was followed by Crichton (1940, 1941) and Gravely (1942). Recent work by Subba Rao (2003) and Subba Rao and Dey (2000) deal with distribution of most of the molluscan fauna occurring in Indian coast including Tamil Nadu. The only major investigation on the bivalves is by Crichton (1941), Gravely (1941) and Preston (1916). Bell (1888) investigated the echinoderm fauna collected by Thurston from Tuticorin Coast followed by Thurston (1890) mainly from the Gulf of Mannar Coast. Satyamoorthy (1976) is the only major worker dealing with the echinoderm fauna of Chennai coast. The major studies on fishes from India Which includes Tamail Nadu as a part are of Alcock (1993), Day (1865, 1875-78, 1898), Murthy (1982a, b), Talwar and Kacker (1984) and Talwar and Jhingran (1991) deal with the fishes of Indian seas, which have reference to the distribution of fishes in the Chennai Coast. The next major vertebrate group occurring in the Chennai Coast is sea snakes and turtles, which has been investigated only by Murthy (1977). Smith (1933, 1935, 1943) published a series on the reptiles of India and Srilanka. Other studies on reptiles of Chennai Coast are by Sharma (1998), Tikader and Sharma (1985) and Tikader and Sharma (1992).

Floral diversity

Seaweeds are marine plants, belonging to lower Cryptogams. These are large and diversified groups with size ranging from single cell, such as *Chlamydomonas* to several meters in length (*Macrocystis*). The four classes of seaweeds are Chlorophyta (green algae), Phaecophyta (brown algae), Rhodophyta (red algae) and Cyanophyta (blue-green algae). In India so far 844 species of seaweeds (including blue-green algae) with a maximum of 434 species of Rhodophyta followed by 216 species of Chloriophyta and

191 species of Pheaophyta have been recorded (Oza and Zaidi, 2000). Out of these Tamil Nadu (302) has the maximum (Fig. 2), followed by Gujarat (202), Maharashtra (159), Lakshadweep group of Islands (89) and Goa (82).

Studies on sea grasses started only during 1980s and some of the first reports are available from Tamil Nadu. Distribution of sea grasses along the Tamil Nadu coast varied with varying species diversity. Kannan *et al.* (1999) reported 13 species from Gulf of Mannar (Kannan *et al.*, 1999) (Fig. 5). All the 6 Indian genera of sea grasses with 11 species are recorded from the Palk bay region. Of the 11 species *C. serrulata, H. ovalis* sub sp. *ovalis, K. pinifolia* and *S. isoetifolium* are predominantly distributed. *H. wrightii* is present only in Akkalmadam of Rameswaram area. Thirteen species of seagrasses under six genera occur in the Gulf of Mannar Biosphere Reserve. Of these, *Halophila, Halodule, Enhalus* and *Cymodocea* are common. *Thalassia* and *Syringodium* are dominant in the areas of coral reefs and coral rubbles where as the others are distributed in muddy and fine sandy soils.

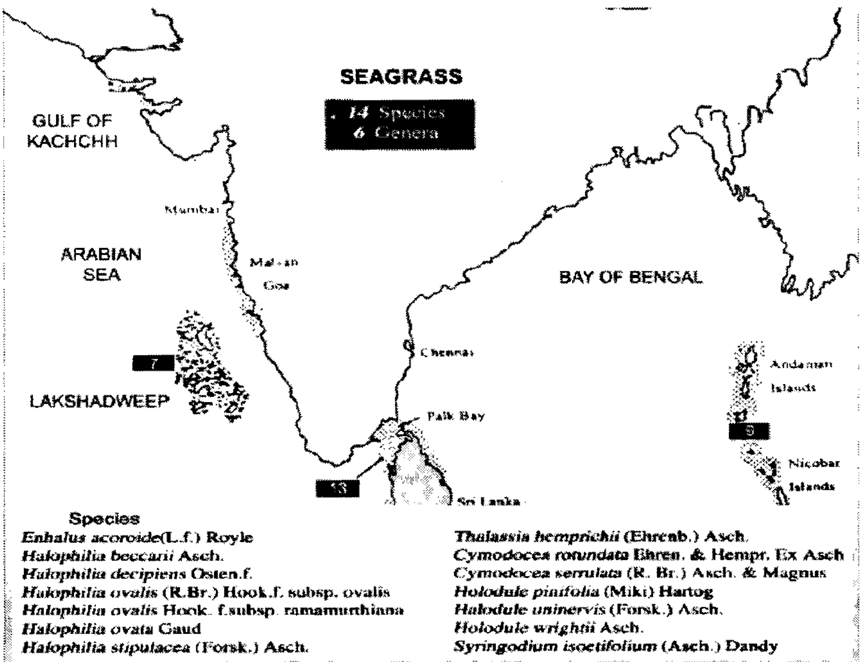

Fig. 5. Seagrass and seaweed resources of India.

The area under mangrove ecosystem in Tamil Nadu is about 225 km^2 (Kathiresan, 1995-2003 *cited elsewhere*). One of the largest and most unspoiled mangrove forests in Tamil Nadu is at Pitchavaram in Cuddalore District, extending over an area of 1100 ha. The Pitchavaram and Muthupet mangrove ecosystems embrace a heterogeneous mixture of both plants and animals. The aquatic fauna comprises of juveniles and adults of finfish, shrimps, molluscs, crabs and benthic invertebrates (Kathiresan, 2000). Finfishes constitute major portion of the total fish catch in the mangrove area. *Mugil cephalus, Liza dumerili, Chanos sp., Leiognathus sp., Siganus sp.* and *Etroplus sp.* are common. The prawn fishery is dominated by *Penaus indicus, P. monodon, Metapenaeus sobsoni, M. monoceros and Macrobrachium sp.* and the crab fishery is dominated by *Scylla serrata* and *Portunus pelagicus.* Oyster (*Crassostrea madrasensis*) and clams (*Meretrix meretrix* and *M. casta*) are commercially important molluscs and herons, egrets, kingfishers, myna, plovers and sand pipers are the important avifauna of this region (Kathiresan, 2000).

Faunal diversity

The marine fauna of Tamil Nadu is rich and varied (Table 2). The coastline encompasses almost all types of intertidal habitat, from hypersaline and brackish lagoons, estuaries, and coastal marsh and mudflats, to sandy and rocky shores with varying degree of exposure and widely varying profile. Subtidal habitats are equally diverse. Each local habitat reflects prevailing environmental factors and is further characterized by its biota (Venkataraman *et al.,* 2002). Thus, the marine fauna itself demonstrates gradients of change throughout the Tamil Nadu coast.

The major contributions of marine biodiversity studies came from Central Marine Fisheries Research Institute, Mandapam and Marine Biological Station, Zoological Survey of India. There are also other institutions such as Integrated Coastal and Marine Area Management, Department of Ocean Development, Chennai, Madurai Kamaraj University, Madurai, Suganthi Devadasan Marine Research Institute, Tuticorin, Tamil Nadu Fisheries College, Tuticorin contributed a lot on the other aspects of marine studies.

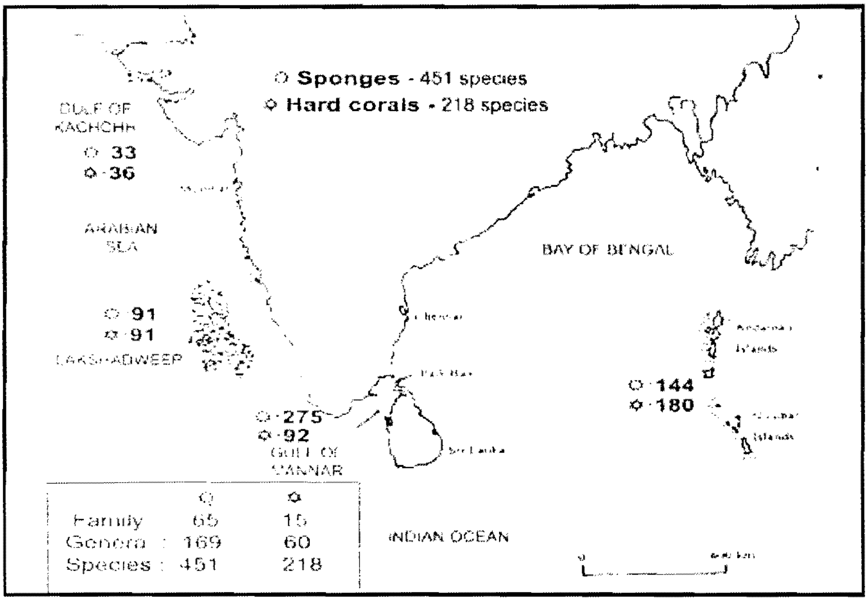

Fig. 6. Sponges and hard coral diversity in Gulf of Mannar and other regions in India.

Out of the total 34 animal phyla in the world, 15 are represented by the taxa in the marine ecosystem (Venkataraman and Wafar, 2005). They may constitute either migratory or resident species. The former includes pelagic crustaceans, coelentrates (medusae), cephalopod molluscs, fishes, reptiles, birds and mammals. The benthic macro fauna comprises resident species of polychaetes, molluscs, sipunculas and mud-burrowing fishes.

So far, 451 species under 3 classes, 17 orders, 65 families and 169 genera have been described on marine sponges in India (Pattanayak and Buddhadeb, 2001). The sponge fauna of India is dominated by Desmospongia species followed by Hyalospongiae and Calciospongiae. A total of 275 species has been recorded from Gulf of Mannar and Palk Bay (Thomas, 1968-1985 *cited else where*) (Fig. 6). Recent studies have revealed that sponges contain several peculiar chemical compounds that are not found in any other animals. Arabinose nucleosides isolated from *Tethya crypta* have proven cancer inhibiting properties and this discovery has triggered off a worldwide interest in the biochemistry of this group. In India too, several institutions have taken up the extraction and characterization of several pharmacologically active compounds from sponges. So far, no species of sponges are exploited commercially in India.

Pillai (1967 – 1986 *cited else where*) the first Indian worker on corals submitted his Ph D thesis on the "Studies on Corals" from Mandapam group of Islands of Gulf of Mannar and Chetlet and Minicoy group of islands from Lakshadweep. This thesis is considered to be first of its kind in India on corals, dealing with 125 species of corals belonging to 34 genera and one subgenus in detail. During 1969, Pillai published a series of papers on the coral species of Gulf of Mannar followed by distribution of corals in Minicoy Atoll, Lakshadweep contributed on composition, distribution, coral resources, and human effects on corals of Gulf of Mannar.

Table 2. Comparison of marine faunal diversity in the world, India an Tamil Nadu.

Group	World	India		
		Total aquatic	Marine	TamilNadu
Protista	31250	2577	750	?
Mesozoa	71	10	10	?
Porifera	4562	519	486	275
Cnidaria	**9916**	**817**	**790**	**224**
Hydromedusae				27
Sea Anemones				9
Gorgonids				3
Scyphozoa				32
Siphanophore				29
Scleractinia				92
Soft corals				32
Ctenophora	100	12	12	?
Gastrotricha	3000	88	88	?
Kinorhyncha	100	99	99	?
Platyhelminthes	17500	4920	550	?
Annelida	12700	842	440	4
Mollusca	66535	5050	3370	428
Bryozoa	4000	194	184	?
Crustacea	35534	2994	2440	641
Meristomata	4	2	2	?
Pycnogonidae	600	16	16	?
Sipuncula	145	38	38	19
Echiura	127	33	33	?
Tardigrada	514	30	10	?
Chaetognatha	111	30	30	10
Echinodermata	6223	765	765	112
Hemichordata	120	12	12	1
Protochordata	2106	116	116	88
Pisces	21723	2546	1800	762
Amphibia	5150	204	3	?
Reptilia	5817	446	26	15
Aves	9026	1228	145	141
Mammalia	4629	372	29	29
Total =	**241563**	**23960**	**12244+**	**2749+**

? = Data not available/not studied

Excepting the taxonomic studies of Pillai, there is no other contribution on corals till 1997 due to reasons unknown. In 1998, Scientists of Marine Biological Station, Zoological Survey of India started coral reef research both in the biophysical as well as in the taxonomy studies. This resulted in a delegation from India participating and presenting papers on the status of Gulf of Mannar Coral reefs (Venkataraman, 2002, Venkataraman and Raghuram, 2006) and all the four major coral reefs of India in 9^{th} and 10^{th} International Coral Reef Symposium in Bali, 2000 and in Okinawa 2004 after a gap of 30 years. A major break through in coral reef studies in India was the signing of an agreement by governments of India and Australia in 2000 to build the capacity on coral reefs in the name of "India Australia Capacity Building and Training Project" under which scientists were trained on coral taxonomy in Museum of Tropical Queensland, Townsville (2001-2002) and the out come of this training is this publication of a hand book on "Hard Corals of India" by Zoological Survey of India, recently (Venkataraman *et al.,* 2003).

Status studies on coral reefs carried out by the Zoological Survey of India on Gulf of Mannar shows 25% of live cover of coral reefs in 1998 has increased to 45% in 2003, revealing the regeneration of these reefs after 1998 unprecedented coral bleaching which occurred throughout the world (Venkataraman and Raghuram, 2006). The main component of the coral reefs, the Scleractinian fauna is represented by 92 species (Fig. 6). The dominant genera include *Acropora, Montipora* and *Pocillopora* among the ramose forms and *Porites, Favia, Favites, Goniastrea, Platygyra* and *Symphyllia* among the massive forms.

Among the three groups of islands, Mandapam had a higher percentage of live coral cover (37.03%) than the other two groups (17.29% Keelakarai and 18.69% Tuticorin group; year 2000 survey). Among the life form categories, massive corals dominated the GoMBR (7.67 $\pm$ 2.23%). The reason for the dominance of massive corals over the other groups of corals in GoMBR may be explained as a consequence to the 1998-bleaching event (Venkataraman *et al.,* 2004). The fragile and most sensitive branching coral was the most affected life form category due to the rampant 1998 bleaching event (Venkataraman, 2002). The destruction of reefs started from early sixties to a tune of 80,000 tons per year at Tuticorin and 250 m^3/day at Mandapam (Pillai, 1996). Probably, removal of corals has resulted in the submergence of Poovarasanpatti and Villangu Challi Islands (Venkataraman *et al.,* 2004). The removal of sea weeds, operation of shore nets, gill nets, modified trawl nets and "*Paari kudus*" to catch reef fish, anchoring of boats in the reef areas and stampeding of live corals in the process of picking seaweeds, siltation, and microbial contamination due to sewage are the major threats posing on the coral reef ecosystem of Gulf of Mannar today (Venkataraman, 2006).

There are 765 species under 332 genera and 90 families of echinoderms so far recorded from the Indian subcontinent of which 15% are reported from Gulf of Mannar (112 species) (James, 1978, 1988, 1995a, b). In the seas around India, nearly 200 species of holothurians are known, of which about 75 are from the shallow waters within twenty-meter depth of which, only 12 species belonging to two families Holothuridae and Stichopodidae are of high economic value (James, 2001). Of the 12 species *Holothuria (Microthele) nobilis* is the most valuable species yielding high quality *beche-de-mer*. They are *Holothuria (Metriatyla) scabra, Actinopyga mauritiana, A. miliaris and A. echinites* and all of them occur in Gulf of Mannar region. Sea cucumbers are priceless echinoderm species, which have been overexploited for several decades without any proper regulation. This has caused a severe damage to the resources in Gulf of Mannar and Palk bay. Data regarding population dynamics and status of the available stock is very scanty. As an act of conservation, in 1982 Government of India banned the export of *Beche- de- mer* less than 75 mm in length (James, 1998). Growing coastal population and export demand for *beche- de- mer* have led to the indiscriminate exploitation of resources. With the aim of conserving sea cucumbers in 2001, Ministry of Environment and Forests, Government of India imposed a total ban on fishing holothurians under the Wild life Protection Act, 1972. This one strong legislation is aimed in the direction of rejuvenating the damaged stocks especially in Tamil Nadu.

Free swimmers or nekton are important components of marine biodiversity and constitute important fisheries of the world. Coral reef fisheries in India are not important in national statistics, however, they are important as a subsistence fishery for local people taking snappers, groupers, emperors, breams, barracuda, jacks and other commercial inshore fisheries such as sprats, herrings and flying fish. There are reef fisheries for sea horse, sea cucumber and some aquarium species but they are banned from collection as per the amended Wildlife Act, 1972. There is no specific information on reef fisheries of Gulf of Mannar is available, but the annual catch of demersal fish is about 45,000 tons per year. In recent years, however, the use of reef resources has increased dramatically with the growth of the tourist industry, the development of new export markets for reef fishery products and the growth of the island population. But today reef fish are also exported chilled, frozen and also alive. Unlike earlier practice, fisheries are now targeted at particular species; for example the shark fishery, grouper and snapper fishery, sea cucumber fishery, lobster fishery and molluscan fishery. The dominant taxa in the nekton of Tamil Nadu are fish (762 species, Fig. 7) others being crustaceans (641 species) and molluscs (428 species, Fig. 7). Majority of the nektonic species is found in the coastal waters.

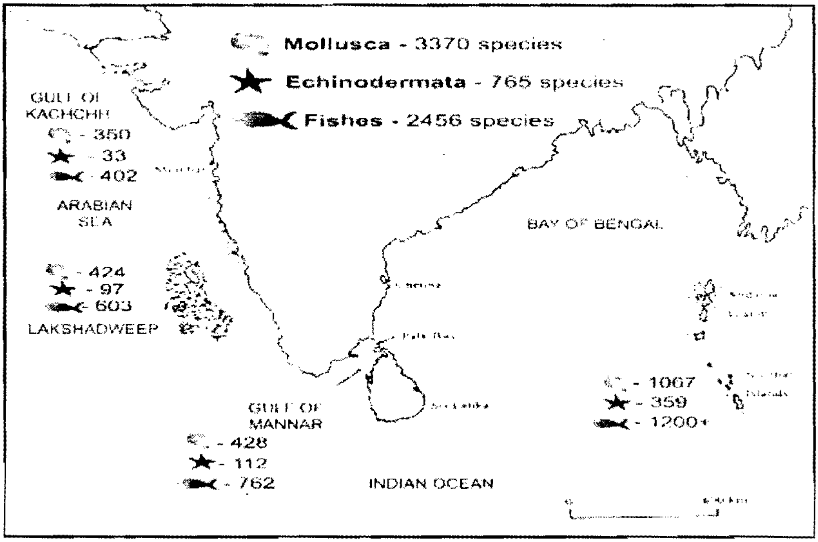

Fig. 7. Diversity of Mollusca, Echinodermata and marine Fishes in Tamil Nadu and other regions of India.

Among reptiles, sea snakes and turtles are important and represented worldwide by 50 and seven species respectively. These are generally oceanic forms but a majority of these often swim near to the shore and visit the shore at some part of their life. About 26 species of sea snakes belonging to one family, Hydrophiidae and five species of sea turtles were reported from seas around India. In Tamil Nadu nine sea snakes and five species of turtles have been reported till today. All the five species of turtles in their marine environment are known from Tamil Nadu (Venkataraman and John Milton, 2003). Turtles visit the shore of Tamil Nadu especially Chennai coast and some islands of Gulf of Mannar during breeding time (November to February) to lay their eggs. The shore visit of these turtles especially the Olive Ridley is a spectacular sight on the beaches of Chennai and near by areas. The Gulf of Mannar and Palk Bay have best nesting beaches for the leatherback, the hawksbill and the green turtle and also the Olive Ridley.

The seashore offers a variable feeding and breeding ground for a number of birds. It is difficult to define precisely the avian component of marine biodiversity. There are some special species, which are exclusively dependent on marine ecosystem while a few are generalists without much dependence on it. From the available data it has been inferred that 141 species occur in the coastal ecosystem.

Marine mammals belong to three orders, Sirenia, Cetacea and Carnivora. About 120 species are estimated to occur in World seas and of these 25 are reported from seas around India of which 16 are reported from Tamil Nadu (Venkataramn, 2005). But majority of these are oceanic forms and occasionally a few individuals may get stranded on the shore. The endangered sea cow occurring in near shore waters of Gulf of Mannar is an added beauty to the seas of Tamil Nadu.

INTRODUCED DIVERSITY

The invasive species of marine is yet to be ascertained excepting some of the known introductions such as an algae *Euchema cottonii* into the Palk Bay area to extract gelatin. Other important invasive species such as *Eichhornia crassipes* (water hyacinth) and *Prosopis juliflora* can be found competing with mangroves in Pitchavaram and Muthupet mangrove forests. A lot of studies have to be conducted in this area.

VALUES

Marine and coastal ecosystems and the diversity of species provide a wide range of important resources and services. Food from the sea in particular, fish, crustaceans and molluscs is a major source for human consumption. Marine fish provided about 84 million tons of human food and livestock supplements in 1993 (FAO, 1995). The fishery producing this catch is a major source of employment for many of the world's coastal States. Small-scale fisheries harvest a large proportion of the world's catch. Fish accounts for about 25 % of the average individual's intake of animal protein worldwide (FAO, 1995), and the proportion is higher in many developing countries (WRI, 1996). Marine and coastal ecosystems also provide many critically important services for humanity such as a) storing and cycling nutrients, b) regulating water balances, c) buffering land and protecting it against erosion from storms and waves, d) filtering pollutants, e) playing an essential role in regulating planetary balances in hydrology and climate, and f) through the ocean's photosynthetic pump, removing the primary greenhouse gas, carbon dioxide from the atmosphere and producing one third to one half of the global oxygen supply. Coral reefs, estuaries, lagoons and shallow coastal waters are particularly valuable for human population because of the goods and services they provide. They are among the most biologically productive systems on the earth. Some like reefs and mangroves provide sea defenses and buffer the impacts of tropical storms, mitigating the erosive effects of waves, storm surges and

Tsunami (Venkataraman, 2006 a). All these systems provide nurseries and feeding grounds for many coastal and pelagic species of fish. Marine species provide many other products as well, including edible seaweed, ingredients for food and cosmetics, industrial chemicals and dyes and a host of other products. Medical researches have already identified a number of marine organisms that produce previously unknown bioactive compounds, including antiviral and anti tumor agents, which may soon have medical applications.

This diversity of species and ecosystem in the marine and coastal environment is the foundation for the production of goods and services valuable to human communities. While we tend to measure the ocean's value in terms of harvests of particular species used for food or other purposes, marine and coastal ecosystems provide important ecological services that are rarely perceived until they are lost. Species do not live in isolation, but are part of, and dependent upon, vast ecological communities and systems. Thus exploitation of even a single stock of living marine resources is a biodiversity issue. The conservation of biodiversity is therefore an important part of managing economically valuable living resources.

THREATS

Though human impact on marine and coastal biodiversity are less understood and publicized than those on its terrestrial counterpart, their potential effects are no less threatening. The major direct threat to marine and coastal biodiversity can be divided into five interrelated categories: pollution (from land based and other sources), over exploitation of marine living resources, introduction of alien species, habitat degradation caused by coastal development, and global climatic change and ozone depletion. Some of the harmful human impacts on marine biodiversity stem from ignorance and lack of understanding of the importance of marine biodiversity and how it gets affected. Marine resources and biodiversity have traditionally been undervalued, which puts marine resources on a lower priority level, than land biodiversity. Unregulated use of resources, increase demand for the resources and rapidly expanding coastal development has put the marine resources at considerable risk.

Sedimentation: The construction of Ennore Port and dredging operations deposit large quantities of silt, which increase the turbidity in water causing damage to marine life. There are also reports available on the erosion of some areas in the North Chennai due to the construction of Ennore Port. Sedimentation is the major cause for the reduction in live coral cover of Gulf of Mannar Biosphere Reserve. Sedimentation reduces the sunlight reaching the bottom of the sea thereby decreasing the productivity of the ecosystem. In general, siltation and sedimentation due to erosion reduces the productivity in the shallow areas.

Disposal of Domestic Sewage: Demographic pressure in Chennai city has resulted in the production of enormous amount of domestic waste materials. These materials reach the marine environment directly through Coovum and Adyar River. These domestic wastes are discharged mostly in partially treated and untreated conditions. The capacity of the sewage treatment plants is to be increased to treat the total waste generated in Chennai and other major cities and towns of Tamil Nadu. The sewage also causes diseases to many organisms living in the coastal areas. This results in reduced growth rate and reproduction, which in turn affects the biodiversity.

Industrial waste: Tamil Nadu is one of the largest industrial States in India. The enactment of Water Pollution Act in 1974 and Environment Protection Act, 1986 have helped in regulating the disposal of industrial wastes. Most of the major industries treat their effluents and comply with the standards set for each type of industry. However, the problem of wastes generated by medium and small-scale industries is not dealt with effectively. Common treatment plants for small and medium scale industries have been set up in Tamil Nadu. These measures have resulted in reduction of pollution loads in the coastal waters to certain extent. Major industries like fertilizer, petro and agrochemical and chemicals are mainly located at Chennai, Ennore, Cuddalore and other areas of Tamil Nadu. Besides industrial and municipal wastes, port related operations such as continuous movement of marine vessels at Chennai and Tuticorin including oil transport as also the wastes of aquaculture and agriculture farms (near Thanjavour) are increasingly posing threats to the coastal water quality and to the biodiversity.

Over fishing: The variation in the production of marine fisheries in the past 50 years and in particular the drop in production after 1997 onwards indicates a series of crisis this sector is facing today. The status of fishing industry cannot be assessed based on catches alone. During 2002-2003, Tamil Nadu exported 61,612 metric tons of marine products. To achieve the above target 10,278 mechanized fishing boats and about 49000 traditional crafts of which 20,000 crafts motorized with outboard motors were engaged in marine fishing. Fishing operations with latest technologies are causing damage to the marine living resources. Along with increase in the targeted catch, a number of untargeted fish and other biota are removed from their habitat and discarded as waste (Venkataraman, 2006). It is estimated that worldwide, shrimp fishermen discard up to 15 million tones and other fishermen up to five million tones per year. Shrimp trawlers probably have the highest rate of by catch bringing in up to 90% more of "**trash fish**". Random capture techniques destroy immature fish and other non-targeted marine species. Gill nets used to catch fish bring in a host of other animals such as dolphins, turtles *etc.*

Tourism: Sandy beaches are the main attraction for tourists. Trampling of the beach sand and litter has changed the complexion of the Marina and other beaches along Chennai Coast. The beaches along the Chennai Coast have been attracting more and more number of tourists as well as locals. Other than the major beach Marina, many new beaches are being used for recreation, which include some of the amusement parks and private beaches with hotels along the East Coast Road up to Mahabalipuram. Other coastal pilgrimage centers such as Rameswaram, Kanyakumari, Thiruchendur, Velankanni, Nagoor, Nagapatinam and many other smaller areas attract large number of tourists and generate unimaginable amount of waste material, which finally reach the coastal waters. The beaches along the Tamil Nadu Coast are under tremendous pressure from tourism and garbage accumulation. Many of these areas previously ear marked for turtle nesting grounds now accumulate a lot of garbage and waste materials discarded by the visitors.

Tamil Nadu Coast is known for its rich biodiversity. It is also the zone of maximum human concentration. The problems in the zone are due to conflicting sectoral interests. There are several stakeholders representing both, the Government Departments and NGOs. The traditional fishermen and trawler operators exploit the living resources along the Chennai Coast to the maximum. There is no proof to show that the existing catches have exceeded the maximum sustainable yield. Nevertheless, one thing is certain, coastal biodiversity is threatened by pollution especially from domestic sewage and run off from agricultural land. Destruction of habitat is another serious problem along the Tamil Nadu Coast. Many fishermen living along the Tamil Nadu Coast are ignorant of the Wildlife (Protection) Act 1972 and Coastal Regulation Zone Notification. Socioeconomic evaluation of coastal resources and Public involvement in the management are the two aspects, which ought to be considered for conservation and management of faunal resources of Chennai Coast.

CONSERVATION ACTION SO FAR

There are only two laws which deal with aquatic ecosystem (freshwater and marine) as a habitat, the Wildlife (Protection) Act, 1972 and the Environment Protection Act, 1986. The Wildlife Act designates areas as Wildlife Sanctuaries, National Parks and Closed Areas. Under the Environment Protection Act, the Central Government can declare ecologically sensitive areas as Protected Areas. The existing legal mechanism involved in demarcating/protecting wetland habitats as a Sanctuary, National Park or Protected Areas and it biodiversity is The Wildlife (Protection) Act, 1972, The Environment Protection Act, 1986, Water (Prevention and Control of Pollution) Act, 1974, The Land Acquisition Act, 1894, The Indian Fisheries Act, 1857, The Tamil Nadu Marine Fisheries Regulation Act 1983, The Forest Conservation Act, 1980, Tamil Nadu State Forest Act 1882, and Constitutional mandate for wetland protection through Articles 31A of the Constitution of India.

The Union Government has signed and ratified several international conventions relating to oceans and other conservation and management of natural resources related activities in India. The important ones are the following: MARPOL 1973/1978; London Dumping Convention 1972; Convention on Civil Liability for Oil Pollution Damages (CLC 1969) and its Protocol 1976; Fund 1971 and its Protocol 1979, Ramsar Convention, 1971 and Convention on Biological Diversity (1992). Many acts and rules related to coastal and marine activities existing in the country are being implemented in the State. The following are the important ones. Indian Fisheries Act 1897 and its Amendments 1920 and 1980; Indian Ports Act 1902; Merchant Shipping Act 1974; Wildlife Protection Act 1972; Water (Prevention and Control of Pollution) Act 1974; Indian Coast Guard Act 1974; and Marine Zones of India (Regulation of Fishing by Foreign Vessels) Act 1981 and Environment Protection Act 1986.

The Wildlife (Protection) Act 1972 provides legal protection to the Wild species no matter where they are found. The Act also provides provision to establish legally protected areas. After the enactment of this Act there has been quantum rise both in numbers and extent of coverage of protected areas in the country since early 1970. The coastal marine areas started receiving grater attention since 1980s.

As per IUCN, "any area of inter-tidal or sub-tidal terrain, together with its overlaying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" is defined as a Marine Protected Area (MPA). MPA's are vital in conserving marine biodiversity. Closure of certain areas for fishing and other uses is now recognized as an option for rebuilding degraded fish stocks and other marine biological resource and an essential component to control over exploitation of resources.

In India some of the National Parks and Wildlife Sanctuaries were declared as MPA's between 1980s and 1990s. There are substantial numbers of Protected Areas in the region that includes marine and / or coastal elements. It is not easy to prepare a list of MPA's as per IUCN criteria. However, as per IUCN definition a total of 31 MPA's have been established in addition to over 100 PA's in coastal zone and Andman and Nioicobar islands which have some part of marine environment / ecosystem or they form boundaries with sea. In Tamilnadu there are 3 Protected Areas in the marine environment *viz.* Gulf of Mannar Marine National Park, Point Calimere Sanctuary and Pulicat Lake Bird Sanctuary. The first Marine Biosphere Reserve in Gulf of Mannar is one of the three marine biosphere reserves in India. Although marine ecosystems have a larger coverage than the other ecosystems these are poorly represented among world's protected areas.

World over the pressures on conservation management are on rise. The conflicts between conservation efforts and livelihood and developmental needs of the coastal communities are equally on rise. The growing population in the coastal areas which have always been densely populated and lack of proper and meaningful co-ordination among various agencies make the task of the conservation manager more complex. Habitat destruction, improper and over harvesting of resources, marine pollution from coastal towns and industries, lack of integrated management of MPA's and Biosphere Reserves, insufficient enforcement of various regulations, lack of local communities support for conservation action, insufficient public awareness, lack of clarity in MPA's boundaries and last but not the least lack of alternative livelihood options are some of the major factors which affect conservation management and have to be seriously recognized and remedied with equal focus and initiatives urgently.

There has been a dramatic paradigm shift in conservation management and philosophy in action, meaning and scope over the past little more than two decades. With 1980's new thinking and initiative transforming the old preservation and protection focus of conservation to mutuality in conservation has taken grounds. The National Forest Policy 1988 and National Environment Policy, 2006 provided a new thrust and meaning to ethos and values of forests, wildlife and natural resource management in the country. Participatory approaches for managing conservation, regeneration and protection of forests and wildlife came into active consideration and various programs and projects like the Joint Forest Management in forest areas and Eco-development in protected areas were undertaken in various parts of the country. Today conservation is not mere protection of natural resources because the concept of sustainable utilization has immersed into it. Today a conservation program has to be socially acceptable and it has to secure co-operation, co-ordination and support from multi-sectoral agencies and organizations residing / working in and around the resource rich area and whose action and activity in one way or the other affects and will affect the objectives of the conservation management. Without the active and meaningful support from these critical stake holders the management actions will never produce desired results.

SOME AREAS FOR PRIORITY ACTION

As per the Coastal Regulation Zone (CRZ) notification, Tamil Nadu had to prepare a Coastal Zone Management Plan identifying and classifying the CRZ areas within a year from the date of CRZ notification (Ministry of Environment and Forests Notification, August, 1994). The CRZ notification also states that during the interim period till the coastal zone management plans are prepared and approved, all developments and activities within CRZ should not violate the provisions of this notification. As per the Environmental Protection Act, 1986 and Coastal Regulation Zone Notification 1991, the following activities are banned in the land part of the country including Tamil Nadu State viz. 1. Setting up and expansion of new industries, fish processing units except those, which require waterfront. 2. Manufacture or handling or storage of disposal of hazardous substances and discharge of untreated waste and effluents from industries, cities or towns and other human settlements. 3. Dumping of fly ash from thermal power stations and other solid waste dumping. 4. Land reclamation, bund raising or disturbing the natural course of seawater. 5. Mining of sand, rocks and other substrate materials other than raw minerals. 6. Drawal of ground water within 200 m of high tide level. 7. Any construction activity between the low and high tide line, and 8. Altering of sand dunes and other natural features including landscape changes. In the ecologically sensitive areas, construction of civil and other man made structures like breakwaters for harbour, floating industries, laying of pipelines, reclamation of sea and its bed, sea bed mining and ship breaking activities are prohibited. However, they can be permitted at a no-impact distance from the outer limit of environmentally sensitive areas. Discharge of untreated and treated domestic, industrial, aquaculture wastes, nuclear and thermal power plants, dredged materials and operational discharges are prohibited in environmentally sensitive areas.

Consequently, effective research and extension programs, which are critical to the conservation and management of marine ecosystem, have to be given priority. Other than Fisheries Department of Tamil Nadu, Department of Environment and Forest, the following institutions in Tamil Nadu are actively engaged in the research and extension as well as conservation and management of the Marine and Coastal Ecosystems: Central Marine Fisheries Research Institute (Ministry of Agriculture), Central Salt and Marine Chemical Research Institute, National Institute of Ocean Technology (Department of Ocean Development) Fisheries Survey of India, Marine Product Export Development Authority, Central Brackish water Aquaculture Research Institute, Aquaculture Authority of India, National Biodiversity Authority, Zoological Survey of India, Geological Survey of India, Botanical Survey of India, National Environmental Engineering Research Institute, Universities such as Anna University, Alagappa University, Annamalai University, Madurai Kamaraj University, Manonmaniam Sundaranar University, Tamil Nadu Veterinary and Animal Science University and important Non-Governmental Organizations such M.S. Swaminathan Research Foundation, Suganthi Devadhasan Marine Research Institute, and East Coast Research and Development.

Despite the above-mentioned acts, regulations and research institutes in Tamil Nadu the marine ecosystems are being subject to over-exploitation of their resources and degradation of marine ecosystems. Besides over-exploitation, pollution from land-based sources is another major threat to marine resources. The population influx and increased tourism in some coastal places are responsible for indiscriminate destruction of marine resources. Recent spurt in aquaculture activities have increased the demographic pressure and the related environmental manipulation. All the above mentioned reasons lead to biodiversity conservation problems in Tamil Nadu which may be reduced by taking experience from better examples from other regions of the country and world where the marine ecosystem is conserved at a larger scale successfully.

FUTURE PERSPECTIVES

The marine biodiversity of Tamil Nadu cannot be accurately estimated due to inadequate exploration as well as lack of expertise in many invertebrate groups. The situation is worst in case of microfauna and meiofauna that occur in marine ecosystems. Furthermore, there are few expert taxonomists and taxonomic institutions in Tamil Nadu. All these make the estimation of species very difficult, even though there is a surge of interests on marine biodiversity studies in Tamil Nadu. Despite the growing importance of bio-monitoring the status of all different ecosystems, hardly any effort is being devoted to the preparation of identification manuals and assessment of their diversity.

It is important to point out that a large number of fauna are known from their original collection and description only. In the absence of regular surveys and suitable identification keys, these have not been reported from the State. This does not necessarily imply a restricted distribution of these species but is definitely a great bottleneck in evaluation of true biodiversity in different habitats and in different parts of the State.

Protected Areas are being managed for protection and conservation of the ecosystem and environmental protection, recreation and aesthetics and for the sustenance of all diverse renewable resources is important aspect of management. The important and extensive however productive ecotone zone and dependence of a diversity of flora and fauna on this and other zones, make ecosystem management more of a system management rather than species management. The following are some of the suggestion for conservation of faunal diversity in Tamil Nadu. 1. Core, buffer, controlled use area, wildlife refuges, intensive use areas, and multiple use area should be designated in different ecosystems. 2. A set of rules and regulations should be developed prescribing the activities that are allowed, restricted or prohibited and these should be clearly displayed and/or explained to all the visitors of the protected areas. 3. A well designed and equipped information and interpretation center at each park is an essential part of the management. The center should have adequate and detailed information about the layout, ecological, aesthetic, cultural and historical values. Life cycles of the plants and animals of the area, socio-economic benefits from the park ecosystem to the local communities and the importance of the park to key species should be explained graphically as well as in the form of pamphlets and other literature. Enhanced attention and better facilities will heighten people's awareness of the value of the park and in turn instill the desire to preserve the area.

Survey and inventory of marine ecosystems in Tamil Nadu and their habitat needs must be documented before a proper management plan is made. Survey and inventorisation of the fauna, capacity building and training are the need of the hour. A long term monitoring and status of fauna and the marine ecosystem is important for conservation of faunal diversity of Tamil Nadu. With a well-developed database on biodiversity of Tamil Nadu the field managers can better conserve the marine biodiversity and the marine ecosystems.

A NEW INITIATIVE TOWARDS INTEGRATED CONSERVATION MANAGEMENT IN GULF OF MANNAR.

The Gulf of Mannar (GOM) part of Indian coast distinguishes itself for receiving recognition for its conservation ahead of many other parts along the Indian coast line. The GOM is located on the southeastern tip of India in the state of Tamil Nadu. The Gulf is known to harbour marine biodiversity of global significance, falling within the Indo-Malayan realm, the world's richest region from marine biodiversity perspective. The GOM deserves the status of being the jewel in the crown of the marine and coastal wealth of India.

Established in 1989, the Gulf of Mannar Biosphere Reserve (GOMBR) is the first marine Biosphere Reserve not only in India but also in all of south and south East Asia. It extends over 10,500 sq km with a core area of 560 sq km which has a status of a National Park and includes 21 small Islands which are endowed with the variety of eco systems including mangroves, sea grass habitats and coral reefs harboring rich marine bio-diversity of global significance and falls within Indo-Malayan realm, the world's richest region from marine bio-diversity perspective. The reserve has about 300 km long coastline and 10 km wide buffer zone. The Gulf of Mannar area along Ramanathapuram and Tuticorin Districts covers about 160 km of coastline. About 2 lakhs people live in coastal buffer zone and out of them about 1.5 lakh are directly depending upon the Marine Resources for their livelihood. The IUCN Commission on National Parks and Protected Areas with assistances of UNEP, UNESCO and WWF has identified this Reserve as being an area of particular concern given its diversity and special multiple-use management status (Rajivi Gandhi Foundation, 1995).

Anthropogenic pressures and biotic interference on the rich marine wealth of the reserve has started leading to great loss of marine bio-diversity. Over the years erratic monsoon consistently had forced even the marginal farmers from the buffer zone area to take over to fishing and this is on the increase. Further, fisher folk from far off places also venture into fishing in the Reserve which adds fuel to the existing pressure. About 1,200 mechanized and 11,000 non-mechanized boats enter in to the sea for exploitation of marine resources almost on daily basis. The multiplication of mechanized boats is not thoroughly regulated and the strict enforcement of fishing methodology is also lacking and this together adds to over exploitation of natural resources. Illegal coral mining, indiscriminate collection of seaweeds has caused and will continue to cause gradual collapse and break down of this sensitive and fragile marine ecosystem. The local fishers will further loose their livelihood security if this damage and degradation of the unique eco-system continues.

Keeping the obligations on part of various signatory states of the Convention on Biological Diversity (CBD), in order to support the primary objective of the Conservation of biodiversity and sustainable use of its component and the equitable sharing of the benefits arising out of the utilization of these components by integrating conservation and sustainable use of bio-diversity into relevant plans and policies, and duly appreciating the endeavor of Tamil Nadu in India GEF and UNDP intervened and the project **"Conservation and Sustainable use of Gulf of Mannar Biosphere Reserve's coastal bio-diversity"** was approved during 2002. The project aims to "Conserve and sustainably utilize the globally significant bio-diversity in the multiple use are of the GOMBR through establishment and effective participatory management of the GOMBR through application of the strengthened conservation programme in the core area and economically feasible and socially acceptable sustainable livelihood development in Biosphere reserve as a whole"

This GEF-UNDP supported project is designed to demonstrate how to integrate bio-diversity conservation into coastal marine management plan and implement the same in a large Biosphere Reserve with various multiple uses. The project also aims at committed and innovative approach to develop a long term multisectoral conservation programme in the Gulf of Mannar Biosphere Reserve area. Gulf of Mannar Biosphere Reserve Trust (GOMBRT) has been established as an independent governmental statutory body to holistically implement the activities and to play more than an advisory role as a flexible transparent system to facilitate appropriate integrated coastal development actions in the Reserve (Sreedharan and Melkani, 2006).

The Trust also works to achieve effective inter-sectoral, co-ordination and facilitate monitoring of bio-diversity conservation issue in to the protective sector and policy sector. The action of Government of Tamil Nadu in establishing the Trust is as an independent Governmental statutory body as the implementing agency for the project is indeed unique and pioneering. This innovative approach to the development of the long term multi-sectoral bio-diversity conservation program will open new vistas of conservation, development and sustainable use of resources.

CONCLUSION

Coastal and marine areas are much vast in extents and complex to manage for conservation per say as the areas have an open access to harvest and use a variety of products and as such selective harvest of resource is practically a difficult proposition for the user who is interested in maximizing his effort and catch and for the conservation manager who has to control harvest of prohibited resources. The coastal and marine conservation, therefore, has to very seriously focus on the realistic integrated management coastal zone management where the availability, carrying capacity of the resources and its sustainable use is understood clearly and practiced sincerely, where the stake holder groups mutually own their role and responsibility in the over all initiative of conservation of biodiversity and where desired results can be achieved jointly.

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DIVERSITY OF BRACHYURAN CRABS IN GULF OF MANNAR(SOUTHEAST COAST OF INDIA)

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Introduction

Coral reefs protect the coastline against waves and erosion and constitute one of the most diverse marine ecosystems in the world. Coral reefs provide subsistence, security and cultural utility to the inhabitants of coastal areas in all the tropical nations. Nevertheless, reef degradation is widespread, due to their manifold uses and importance to the people of developing countries. Therefore the International Union for Conservation of Nature and Natural resources (IUCN) considers maintenance of reef fisheries as a global priority. Collection of data about thè coral reef resources is the most basic information in a coral reef ecological study. Management could be done only on the basis of such information.

The main objective of any management scheme will be to maintain the 'ecological health' of a coral reef. The purpose of monitoring is to detect significant deviations in reef and associated organisms. Such deviations are generally considered to be signs of stress. One of the most important limitations in assessing the effects of stress on coral reefs is the general lack of quantitative data. Such data indicate 'normal' or 'stressed conditions' of a reef. Coming specifically to the environment where this study was made, even though ecological studies on coral reef of Polk Bay and Gulf of Mannar Mandapam group of islands were done by Pillai (1967), quantitative studies on coral reef communities are yet to be undertaken. In this backdrop the present study was undertaken to assess the diversity of brachyuran crabs in the Gulf of Mannar. Quantitative data on brachyuran crabs of Gulf of Mannar coral reefs have been collected for a period of one year. Compared to other reef organisms, brachyuran crabs have been grossly neglected here and elsewhere in quantitative studies. This lacuna necessitated the present study.

Complete qualitative faunistic inventories of coral reef communities have been made only in the recent past elsewhere (Stephenson *et al.*, 1958; MacNae and Kalk, 1962; Thomassin, 1973; Gibbs, 1975). However these are few in number and generally few systematic groups were covered e.g. crustaceans (Garth, 1964; Thomassin, 1974) and mollusks (Maes, 1967; Salvat, 1967, 1970, 1972; Taylor, 1968, 1971; Salvat and Renaud-Mornand, 1969; Renaud-Mornand *et al.*, 1971) besides fishes. Quantitative studies either by enumerating individuals of various species by surface area or volume, or by calculation of biomass are just beginning.

Brachyuran crabs contribute considerably to the biomass and species diversity of coral reef ecosystems as they attain large standing crops. Therefore presently the diversity of brachyuran crabs in coral reefs of Gulf of Mannar islands was made for a period of one year (January – December, 1994).

Materials and methods

Samples were collected at inner reef flats of four dominant islands, one each from the four groups of islands namely (a) Manauli island, (b) Appa island, (c) Nallathanni island and (d) Karaichalli island. Samples were collected every month during low tide at a depth of 0.5 m and below during the study period. Sampling was done following the quadrate method along transects. Along the 200 metres long transect lying perpendicular to the shore, 50 x 50 cm quadrate was used for sampling at the interval of 5 m. Number of animals was counted and distribution is expressed as individuals/m^2. Animals were wet weighed and the biomass expressed as gm/m^2. The method used presently is basically the same as that of Reys (1964, 1968) who made a comprehensive review of methods used for biomass studies on a worldwide basis (Reys and Salvat, 1971) and also by Holme and McIntyre (1971).

The species diversity index was calculated using by Shannon and Wiener (1949). The species richness was calculated using formula give by Simpson's index (D). The Evenness index (J) or equitability was calculated using the formula of Pielou (1966).

All these three indices were calculated using the computer programme (BASIC) written by Bakus (1989).

The Gulf of Mannar environment is very much influenced by the Northeast monsoon and during this period (October-November) profound changes take place in the hydrographical conditions and other parameters. Therefore for the sake of convenience the study period was divided into four distinct seasons namely postmonsoon (January – March), summer (April – June), premonsoon (July – September) and monsoon (October – December) and the results are discussed in relation to these four seasons.

Results

Species composition

As many as 32 species of brachyuran crabs were recorded in the Manauli island during the postmonsoon, summer and premonsoon seasons (Table 1). During the monsoon season, only 28 species were recorded. In Appa island 26 species were collected during the postmonsoon and summer seasons, while during premonsoon season 23 species and during monsoon season 22 species were recorded (Table 2). In the Nallathanni island 22 species were collected during postmonsoon and summer seasons which decreased to 20 species during premonsoon and to 18 species during monsoon seasons (Table 3). In Karaichalli island, 18 species were recorded during postmonsoon, summer and premonsoon seasons and 17 species during monsoon season (Table 4). Thus the number of species recorded varied in relation to season. With respect to abundance of species, islands sampled can be given in the following order:

Manauli island > Appa island > Nallathanni island > Karaichalli island.

Mean density

Mean density of brachyuran crabs per m^2 fluctuated from 31.0 to 42.5 in Manauli island, from 31.2 to 43.4 in Appa island, from 24.4 to 35.4 in Nallathanni island and from 20.2 to 29.7 in Karaichalli island (Tables 1-4). Seasonal variations in mean density of brachyuran crabs in of all these islands may be placed in the following order:

Postmonsoon > Summer > Premonsoon > Monsoon.

Mean biomass

Mean biomass of brachyuran crabs per m^2 varied between 576.9g and 1029.8g in Manauli island, 561.9g and 1052.1g in Appa island, 474.5g and 859.6g in Nallathanni island and between 444.4g and 722.29g in Karaichalli island. Seasonal variations in mean biomass of brachyuran crabs per m^2 of all these islands may be placed in the following order:

Postmonsoon > Summer > Premonsoon > Monsoon

Species diversity

Species diversity index in the Manauli island varied between 4.023 and 4.277, between 3.893 and 4.127 in Appa island, between 3.686 and 3.993 in Nallathanni island and between 2.736 and 3.894 in Karaichalli island (Tables 5-7). Postmonsoon season witnessed higher species diversity in the first three islands and in the Karaichalli island high species diversity was witnessed during the premonsoon season. Seasonal variations in species diversity indices of first three islands may be placed in the following order:

Postmonsoon > Summer > Premonsoon > Monsoon

For the Karaichalli island, it was in the order of

Premonsoon > Summer > Monsoon > Postmonsoon

Species richness

Species richness index in the Manauli island fluctuated from 0.943 to 0.949, from 0.946 to 0.948 in Appa island, from 0.946 to 0.951 in Nallathanni island and from 0.706 to 0.966 in Karaichalli island (Tables 5-7). The trend with respect to seasonal variation was more or less similar to that of species diversity as could be seen from the following:

Manauli island	:	Postmonsoon > Summer > Premonsoon > Monsoon
Appa island	:	Postmonsoon > Summer > Monsoon > Premonsoon
Nallathanni island	:	Postmonsoon > Summer > Premonsoon > Monsoon
Karaichalli island	:	Monsoon > Premonsoon > Summer > Postmonsoon

Species evenness

Species evenness values varied between 0.837 and 0.855 in Manauli island, 0.869 and 0.878 in Appa island, 0.876 and 0.895 in Nallathanni island and 0.656 and 0.935 in Karaichalli island (Tables 5-7). Seasonal variations in species evenness were in the following order:

Manauli island	: Postmonsoon > Summer > Premonsoon > Monsoon
Appa island	: Postmonsoon > Premonsoon > Monsoon > Summer
Nallathanni island	: Postmonsoon > Monsoon > Summer > Premonsoon
Karaichalli island	: Monsoon > Premonsoon > Summer > Postmonsoon

Discussion

The biological composition of organisms living in and on the surface of coral reefs depends on many factors most of which are still not well understood. Littler *et al.*, (1987) proposed a model, based on prevailing nutrient concentration, wave energy and grazing pressure to describe predominant organisms living on coral reefs. With the passage of time, it has become clear that the distribution and abundance of coral associated animals are more directly linked with the availability of habitat and food. Coral reefs provide brachyuran crabs with food, protection from predators and wave action, and constantly exchanged freshly aerated water medium to live in. The spatial distribution of species varies in relation to the degree of availability of the above requirements. Most of the brachyuran crabs inhabiting coral reefs are xanthid crabs which are essentially herbivorous, normally grazing on algae growing near their niche or on fronds which get drifted into their hiding place. They also have the ability either to catch or dislodge the prey organisms. Knudson (1967) estimated that 90% of the total food consumed by these crabs consists of algae and the remaining 10% of animal matter. Availability of seaweeds and algae are one of the important factors determining the species composition and diversity of brachyuran crabs in the coral dominated environments. Seaweeds and algae protect coral reefs by dampening wave action and slowing currents thereby the associated organisms also. They protect coral reefs by trapping sediments

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Karaichalli island	: Monsoon > Premonsoon > Summer > Postmonsoon

Discussion

The biological composition of organisms living in and on the surface of coral reefs depends on many factors most of which are still not well understood. Littler *et al.*, (1987) proposed a model, based on prevailing nutrient concentration, wave energy and grazing pressure to describe predominant organisms living on coral reefs. With the passage of time, it has become clear that the distribution and abundance of coral associated animals are more directly linked with the availability of habitat and food. Coral reefs provide brachyuran crabs with food, protection from predators and wave action, and constantly exchanged freshly aerated water medium to live in. The spatial distribution of species varies in relation to the degree of availability of the above requirements. Most of the brachyuran crabs inhabiting coral reefs are xanthid crabs which are essentially herbivorous, normally grazing on algae growing near their niche or on fronds which get drifted into their hiding place. They also have the ability either to catch or dislodge the prey organisms. Knudson (1967) estimated that 90% of the total food consumed by these crabs consists of algae and the remaining 10% of animal matter. Availability of seaweeds and algae are one of the important factors determining the species composition and diversity of brachyuran crabs in the coral dominated environments. Seaweeds and algae protect coral reefs by dampening wave action and slowing currents thereby the associated organisms also. They protect coral reefs by trapping sediments and reducing the possibility of resuspension of the same. In tropical areas high species diversity and abundance of various groups are associated with the presence of seaweeds and seagrass meadows (Fonseca *et al.*, 1992). In the present study species composition and species diversity were very high in the Manauli island and decreased in the following order in other islands:

Manauli island > Appa island > Nallathanni island > Karaichalli island

As discussed above, one of the reasons for the high species composition and species diversity is the high cover of seaweeds and algal distribution in the Manauli island. During summer and premonsoon seasons the sea is very rough in Gulf of Mannar and the water is more turbid. In such a situation the seaweeds and algae protect the coral reefs and the associated organisms.

When compared to other islands, live coral colonies were very high in the Manauli island. The number of live coral colonies was less in other islands situated in the southern region. Dredging of live coral colonies is being done in Karaichalli island situated in the Tuticorin area. Apart from dredging, the coral reefs are also heavily damaged due to anchoring of boats during low tides. Dredging leads to damage and death of corals through three means namely i. mechanical damage, resulting in breakage of corals which subsequently die ii. sediment loading or siltation resulting in the burial and death of colonies and iii. increased turbidity resulting in bleaching, excessive mucus secretion and death of corals. Also, waters over dredged areas have significantly more bacteria than neighboring seawater (Galzin, 1981) which can cause damage to corals. The removal of live coral colonies can be viewed as habitat destruction. Habitat loss produces significant reduction in the fauna. For example the total number of fish species present in an area, and the population density of each are markedly affected by changes in the live coral cover. Even small changes (< 5%) in live coral cover produced significant changes in the total number of individuals in an area of 250 m^2 (Bell and Galzin, 1984). The seaweeds and algal cover vouch for the high species composition and diversity in the Manauli island. Such cover was less in other islands explaining comparatively less abundance and diversity in these islands. The species composition and diversity in Karaichalli island were low when compared to other islands. It indicated that the habitat loss is higher in this island. If the present trend continues, the condition of the coral reefs will become bad to worse.

Another major factor controlling the species composition is pollution. The pollution load is high towards the southern side islands from the Manauli island (Dhandapani, 1995). The Karaichalli island is highly polluted due to industrial discharges from the Tuticorin area. Dumping of the fly ash from the thermal power plant also adds to the woe. Diversity indices are also helpful in detecting and evaluating pollution status (Wilhm, 1967). The species diversity of brachyuran crabs in Karaichalli island was lower than in all the other islands. .

The species richness index of brachyuran crabs showed a trend parallel to that of species diversity index in the present study.

Species evenness index is a measure of the uniformity in the distribution of individuals among species. With lesser number of species, the distribution of individuals was even in the Karaichalli Island and therefore high evenness indices were recorded during most of the time. Evenness values were less in other three islands, compared to the Karaichalli Island.

The base-line data collected through the present study on species composition, species diversity, richness and evenness will definitely serve as a ready reference to find out the changes that may happen in this very important and fertile at the same time fragile marine ecosystem.

Table 1. Mean density of brachyuran crabs in Manauli island

Sl. No.	Species	Mean density / m^2			
		Post-monsoon	Summer	Pre-Monsoon	mon-soon
1	*Portunus (Monomia) petreus*	0.2	0.2	0.2	0.0
2	*Charybdis (Charybdis) helleri*	0.25	0.25	0.2	0.0
3	*Thalamita danae*	0.4	0.2	0.2	0.2
4	*T. prymna*	0.6	0.5	0.4	0.2
5	*T. integra*	0.5	0.5	0.4	0.4
6	*T. admete*	0.4	0.4	0.2	0.0
7	*Leptodius euglyptus*	0.4	0.4	0.2	0.2
8	*L. gracilis*	0.8	0.6	0.6	0.2
9	*L. exaratus*	1.4	1.4	1.2	0.6
10	*Atergatis floridus*	0.3	0.2	0.2	0.2
11	*A. roseus*	0.2	0.2	0.2	0.0
12	*Platypodia cristata*	2.4	2.2	2.2	1.8
13	*Etisus laevimanus*	6.0	5.6	5.2	4.4
14	*Pilodius areolatus*	2.0	2.0	2.0	1.8
15	*Phymodius monticulosus*	2.2	2.4	2.4	2.0
16	*P. granulosus*	1.2	1.2	1.0	0.8
17	*P. ungulatus*	2.4	2.6	2.6	2.2
18	*P. nitidus*	1.0	1.2	0.8	0.8
19	*Chlorodiella nigra*	6.8	6.6	6.4	6.0
20	*Cymo melanodactylus*	1.2	1.0	1.0	0.8
21	*C. andreossyi*	2.4	2.2	1.8	1.8
22	*Pilumnus vespertilio*	3.0	3.0	2.4	2.0
23	*P. tomentosus*	0.4	0.2	0.2	0.2
24	*Tetralia cavimana*	0.2	0.2	0.2	0.2
25	*Trapezia cymodoce*	0.2	0.2	0.2	0.2
26	*T. areolata*	0.3	0.3	0.25	0.2
27	*T. ferruginea*	0.2	0.2	0.2	0.2
28	*Composcia retusa*	0.4	0.6	0.4	0.4
29	*Tylocarcinus styx*	1.0	0.8	0.8	0.6
30	*Hyastenus oryx*	0.6	0.4	0.4	0.2
31	*Schizophrys aspera*	1.2	1.0	1.0	1.0
32	*Percnon planissimum*	1.6	1.8	1.4	1.4
	Total mean	**42.5**	**40.55**	**36.85**	**31.0**

Table 2. Mean density of brachyuran crabs in Appa island

Sl. No.	Species	Mean density / m²			
		Post-monsoon	Summer	Pre-Monsoon	mon-soon
1	*Thalamita prymna*	0.8	0.8	0.6	0.6
2	*T. integra*	0.4	0.5	0.4	0.2
3	*T. admete*	0.2	0.2	0.0	0.0
4	*Leptodius exaratus*	1.8	1.8	1.2	1.2
5	*Platypodia cristata*	2.8	2.6	2.4	2.0
6	*Etisus laevimanus*	4.6	4.2	3.8	3.2
7	*Phymodius monticulosus*	3.4	3.2	2.8	3.0
8	*P. granulosus*	0.6	0.2	0.2	0.0
9	*P. ungulatus*	1.2	1.0	0.8	0.8
10	*P. nitidus*	0.4	0.2	0.0	0.0
11	*Chlorodiella nigra*	5.2	4.6	4.0	4.2
12	*Cymo melanodactylus*	0.8	0.4	0.2	0.2
13	*C. andreossyi*	1.2	1.2	1.0	1.2
14	*Pilumnus vespertilio*	2.2	2.0	2.0	2.2
15	*Trapezia cymodoce*	0.4	0.3	0.2	0.2
16	*T. areolata*	0.2	0.2	0.0	0.0
17	*T. ferruginea*	0.2	0.2	0.2	0.2
18	*Composcia retusa*	0.8	0.6	0.6	0.4
19	*Tylocarcinus styx*	1.6	1.2	1.0	1.0
20	*Hyastenus orxy*	1.0	1.2	1.2	0.8
21	*Schizophrys aspera*	1.2	1.0	0.8	0.6
22	*Cyclax suborbicularis*	0.8	1.0	0.8	0.4
23	*Metopograpsus messor*	0.4	0.6	0.2	0.2
24	*Grapsus albolineatus*	6.2	6.4	5.4	4.6
25	*Plagusia depressa tuberculata*	3.2	3.0	2.6	2.2
26	*Percnon planissimum*	1.8	2.0	1.6	1.6
	Total mean	**43.4**	**40.6**	**34.0**	**31.2**

Table 3. Mean density of brachyuran crabs in Nallathanni island

Sl. No.	Species	Mean density / m²			
		Post-monsoon	Summer	Pre-Monsoon	mon-soon
1	*Portunus (Monomia) petreus*	0.2	0.2	0.0	0.0
2	*Charybdis (Charybdis) helleri*	0.3	0.2	0.2	0.0
3	*Thalamita prymna*	1.2	1.2	0.8	0.4
4	*T. integra*	0.8	0.6	0.2	0.2
5	*Carpilius maculatus*	0.4	0.2	0.0	0.0
6	*Leptodius exaratus*	2.8	2.8	2.4	2.4
7	*L. euglyptus*	0.6	0.4	0.4	0.2
8	*Atergatis integerrimus*	1.0	0.6	0.4	0.6
9	*Platypodia cristata*	3.8	2.6	2.2	1.8
10	*Etisus laevimanus*	4.2	3.8	3.6	3.2
11	*Phymodius monticulosus*	2.8	2.8	2.8	2.4
12	*Chloridiella nigra*	4.6	4.8	4.2	3.8
13	*Cymo andreossyi*	2.0	1.2	1.4	1.4
14	*Pilumnus vespertilio*	2.2	2.0	2.0	1.8
15	*Trapezia cymodoce*	0.2	0.2	0.2	0.0
16	*T. ferruginea*	0.3	0.2	0.2	0.2
17	*Composcia retusa*	0.6	0.6	0.4	0.2
18	*Tylocarcinus styx*	1.4	1.2	1.0	0.8
19	*Hyastenus oryx*	0.8	1.0	0.4	0.4
20	*Schizophrys aspera*	1.0	1.2	0.8	0.8
21	*Grapsus albolineatus*	3.4	3.6	3.2	2.6
22	*Percnon planissimum*	1.4	1.2	1.8	1.2
	Total mean	**35.4**	**32.6**	**28.6**	**24.4**

Table 4. Mean density of brachyuran crabs in Karaichalli island

Sl. No.	Species	Mean density / m^2			
		Post-monsoon	Summer	Pre-Monsoon	mon-soon
1	*Thalamita danae*	0.8	0.8	0.6	0.4
2	*T. prymna*	1.0	1.0	0.8	0.8
3	*Leptodius exaratus*	2.0	1.6	1.8	1.4
4	*Atergatis integerrimus*	0.6	0.6	0.8	0.6
5	*Platypodia cristata*	1.8	1.2	1.2	0.8
6	*Etisus laevimanus*	3.6	3.2	3.0	2.6
7	*Pilodius areolatus*	2.2	2.0	1.6	1.4
8	*Phymodius monticulosus*	2.4	2.2	2.0	1.8
9	*Chlorodiella nigra*	4.2	3.8	3.4	3.0
10	*Cymo andreossyi*	1.6	1.6	1.2	1.0
11	*Pilumnus vespertilio*	2.4	2.2	1.8	1.6
12	*Trapezia ferruginea*	0.2	0.2	0.2	0.2
13	*T. cymodoce*	0.3	0.2	0.2	0.0
14	*Composcia retusa*	0.6	0.6	0.8	0.4
15	*Hyastenus oryx*	1.0	1.0	1.2	0.8
16	*Schizophrys aspera*	1.2	1.0	1.0	1.0
17	*Grapsus albolineatus*	2.8	2.4	2.0	1.6
18	*Percnon planissimum*	1.0	1.0	0.8	0.8
	Total mean	**29.7**	**26.6**	**24.4**	**20.2**

Table 5. Species diversity of brachyuran crabs

Station	Post monsoon	Summer	Pre monsoon	Monsoon
Manauli island	4.277	4.241	4.186	4.023
Appa island	4.127	4.084	3.957	3.893
Nallathanni island	3.993	3.918	3.784	3.686
Karaichalli island	2.736	3.863	3.894	3.821

Table 6. Species richness of brachyuran crabs

Station	Post monsoon	Summer	Pre monsoon	Monsoon
Manauli island	0.049	0.949	0.946	0.943
Appa island	0.948	0.947	0.946	0.947
Nallathanni island	0.951	0.948	0.946	0.946
Karaichalli island	0.706	0.957	0.962	0.966

Table 7. Species evenness of brachyuran crabs

Station	Post monsoon	Summer	Pre monsoon	Monsoon
Manauli island	0.855	0.848	0.837	0.837
Appa island	0.878	0.869	0.875	0.873
Nallathanni island	0.895	0.879	0.876	0.884
Karaichalli island	0.656	0.927	0.934	0.935

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SYNGNATHID RESOURCES IN GULF OF MANNAR AND THEIR CONSERVATION THROUGH AQUACULTURE

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Introduction

The family Syngnathidae is unique and includes fishes like the seahorses, pipefishes, pipehorses and seadragons, known for their peculiarity. There are about 215 species in the family classified in 52 genera (Dawson, 1985). Syngnathids can be distinguished from other bony fishes by the presence of fused jaws, pore-like opening of the gill chamber, bony plates encasing the whole body and the absence of teeth and pelvic fins. The unusual shape and interesting habits of these fishes gained the attraction of marine aquarium keepers and traders. Bulk of the syngnathids except seadragons are traded in dried condition for their use in Traditional Chinese Medicine. Syngnathids are credited with curing a wide range of ailments from asthma, skin allergies, arteriosclerosis, lymph node disorders and goiter to impotence. Seahorses and pipefishes are also embedded in plastics and sold as curios.

India has a long history of syngnathid trade and was positioned among five major exporters of the world. Majority of the syngnathid trade was concentrated in and around the Gulf of Mannar region. In 20u1, 12,173 kg of pipefishes were exported to Hong Kong (Martin-Smith *et al.*, 2003) and 2,560 kg of dried seahorses were exported to Singapore in the year 2002 (Anonymous, 2003). Indiscriminate fishing, incidental capture in various gears and habitat destruction collective resulted in the decrease of syngnathid populations. Presently, all syngnathids are protected legally from the capture and trade by keeping them under Schedule I of the Indian Wildlife Protection Act, 1972. Aquaculture has proved to be an important tool for biodiversity conservation. The application of aquaculture technology through restocking, stock enhancement and sea ranching programs are being employed in various countries to increase production of capture fisheries (Bell *et al.*, 2005). Similar techniques can be applied for conservation of fishes threatened by anthropogenic activities like the syngnathids.

Though syngnathids had been the target of international trade before the implementation of this act, they were poorly studied in Indian context. In this backdrop, the species composition of syngnathids along Gulf of Mannar was assessed and the technology for in captive breeding and rearing of seahorses and pipefishes was developed and perfected for biodiversity conservation.

Materials and methods

Survey was undertaken along Gulf of Mannar area covering five landing centres viż. Mandapam, Keelakarai, Ervadi, Valinokkam and Tuticorin for a period of one year from October 200 to September 2001. Syngnathids are landed as by catch through various fishing gears operated along this area like country trawls, shrimp trawl nets and shore seines were alone considered for this study. Seahorses and pipefishes were segregated from the by catches and identified following Lourie *et al.*, 1999 and Dawson (1985) respectively.

For perfecting the technology of mass scale production, live seahorses, *Hippocampus spinosissimus* and the pipefishes, *Syngnathoides biaculeatus* collected from the by catch were transported in oxygenated polythene bags to the breeding facility available at our centre. The fishes were acclimatized to the laboratory conditions and maintained in 0.5 ton capacity fiber glass tanks filled with filtered and UV treated seawater. Dead coral bits and nylon ropes were provided as hold fasts in the brooder tanks. The fishes were fed twice daily with *Acetes* sp. Optimum water quality was maintained and a 12 L: 12D photoperiod was provided. The water was exchanged as per the requirement for maintaining the water quality. The fishes were allowed to form pairs and breed naturally. The young ones were fed with rotifers, copepods, *Artemia* nauplii and small sized *Acetes* sp. depending upon the feed preference during growth stages.

Results

Syngnathid resources

Four species of seahorses viz. *Hippocampus kuda, H. spinosissimus, H. trimaculatus, H. fuscus* and five species of pipefishes viz., *Syngnathoides biaculeatus, Hippichthys cyanospilos, H. spicifer, Trachyrhamphus serratus, T. longirostris* were recorded from the Gulf of Mannar area. *H. trimaculatus* was the most abundant species constituting 53 ± 2.8% of total seahorse landing followed by *H. kuda* (23 ± 0.9%), *H. spinosissimus* (14 ± 1.3%) and *H. fuscus* (10 ± 1.4 %) (Fig. 1).

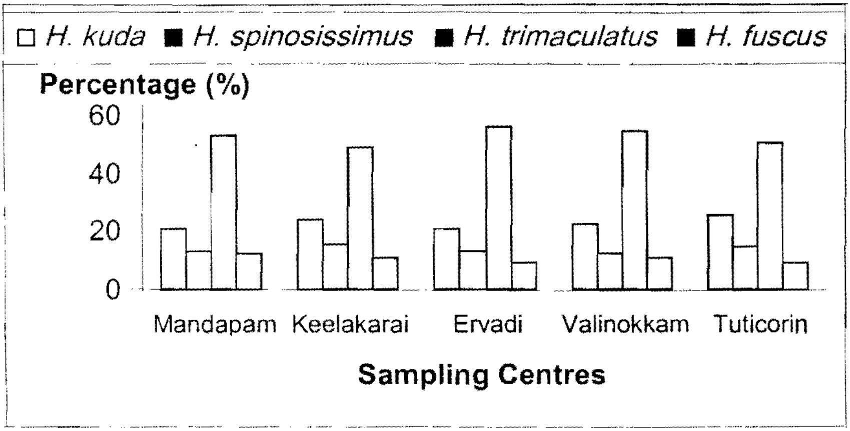

Figure.1. Percentage composition of seahorses at different landing centres along the Gulf of Mannar

H. fuscus, H. trimaculatus and *H. spinosissimus* were more often recorded at depths ranging from 2 to 5 m. However, *H. kuda* was recorded at greater depths (3-10 m) than others along the Gulf of Mannar. Dead corals and seagrasses were the preferred habitat of *H. fuscus*, whereas *H. kuda* was found among sponges also. *H. trimaculatus* and *H. spinosissimus* were common among seagrasses and seaweeds.

Syngnathoides biaculeatus was the commonest pipefish in the shallow coastal areas at 2 to 5 m depth (Fig. 2). They mimic the seagrass blades and coil around with their prehensile. *H. cyanospilos* and *H. spicifer* occured in few numbers amidst the seaweeds and seagrasses. However *Trachyrhamphus* spp were captured by trawlers operated only at depths above 20 m.

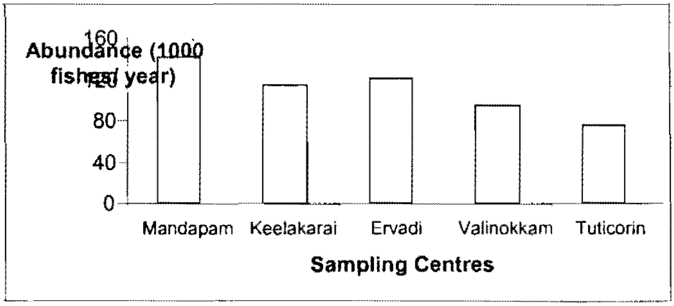

Figure.2. Abundance of the alligator pipefish, *Syngnathoides biaculeatus* in Gulf of Mannar

Brooder Maintenance

The water quality was maintained at optimum levels in the brooder and larval rearing tanks (temperature 27° to 32°C, salinity 28 to 32ppt, pH 8 to 8.5 and DO 4.0 to 6.5 mg/l) by monitoring the water quality regularly and carrying out water exchanges.

Hippocampus spinosissimus measuring 12 cm SL were stocked at the rate of 1:5 (M: F) ratio. Dead and washed out coral bits were provided as hold fasts. After 20 days of stocking the accepted pair showed courtship behaviour.

Syngnathoides biaculeatus of 19 cm SL were stocked in the brooder tanks in the ratio 2:1(male: female). Nylon ropes and artificial plants were provided as holdfasts in the tanks. Fishes were fed with live moving prey such as *Acetes* sp. After about one month from stocking, the fishes showed pair formation and courtship displays.

Courtship, mating and hatching

Accepted seahorse pair showed courtship behaviour early in the morning. The paired seahorses remained in the same hold fast. The male changed its colour to create a contrast to the surrounding. The female which responded also changed its colour and tucked the head as a positive response. Male seahorse inflated and deflated its brood pouch and quivered. The accepted pair got away from the hold fast, swam around the tank and then towards the water surface pointing their snout upwards. The female deposited her eggs into the male's brood pouch with the help of genital papillae. The number of eggs deposited by the female can be assessed only by sacrificing the brooding male. The male seahorse took care of the embryos during incubation period in their brood pouch. The wall of brood pouch was thick initially just after egg transfer and in course of time became thin, expanded and rounded. The gestation period was found to be 10 to 14 days.

The release of young ones occurred in the early hours. The male seahorse showed rapid bending of the body forward before releasing the young ones. The number of youngones ranged between 153 and 620 during this study. The newborn seahorse measured 9.5 ± 1.3 mm in standard length

Female pipefishes showed colour intensification from light green to dark green with the lateral edges becoming whitish along the lateral ridges. The colour pattern along the ventral side of the trunk intensifies and dermal appendages can be seen along the body. Responding males showed similar colour changes initially. Fishes forming pairs showed quivering very often. The pair was transferred to 500 litres capacity circular tanks. Courtship behaviour was observed early in the morning. The fishes showed colour intensification and female started quivering. The male fish responded by quivering with the ventral surface facing the female. The pair later swam upwards in the water column, entwined and the female deposited her eggs on ventral surface of the trunk of male fish. About 72 to 187 eggs were deposited in the brood pouch of male of 19 to 22 cm SL length. The eggs were whitish initially and turned brownish as incubation progressed. After 18 to 22 days of incubation, the eggs hatched out and the young ones were released.

Hatching usually took place in the early hours and extended till noon. The male pipefish swam horizontally along the tank with short bending movements forward and backward. The fish shook its body vigorously just before releasing young ones. One to six young ones were released at a time. All the eggs hatched out with no egg loss and during this experiment the males released 72 to 180 babies. The size of the new born ranged from 1.8 to 2.0cm. The young ones were found clinging to the parent's body or to the hold fast provided or to other baby fishes in the tank soon after the release. They resembled the parents in body form except for a cylindrical body and brown colour.

Larval rearing

Seahorse babies were carefully transferred to 35 liter fiber glass tanks and stocked at the rate of 75 numbers per tank. During the first week, rotifers and copepods were given in two different feeding experiments. The survival rate was higher in copepod fed tank (85%) than in the rotifer fed tank (74%). From the second week onwards copepods and *Artemia* nauplii were given shifting completely to *Artemia* nauplii from the 20th day. After two months the young ones were fed with *Chironomus* larvae and amphipods. After 90 days, small sized *Acetes* sp. was given as feed. During the laboratory culture for a period of 297 days, *H. spinosissimus* attained a mean length of 137.2 ± 4.6 mm (Fig. 3)

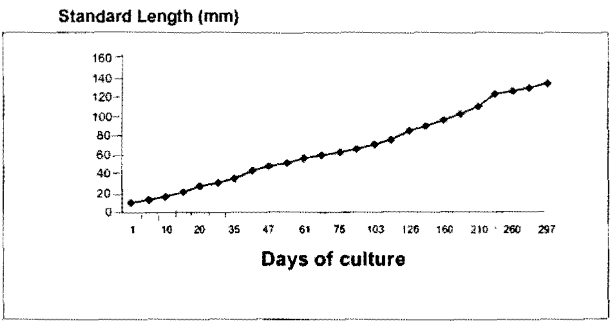

Figure.3. Growth in terms of standard length (mm) in *H. spinosissimus* during culture

Pipefish young ones were transferred to 150 litres capacity tanks at the rate of 100 numbers per tank. They started feeding soon after birth. Initially they were fed with mixed copepods for five days, after which they were divided into two batches. For the first batch, copepods were continued and the second batch was fed with newly hatched *Artemia nauplii.*

The survival rate of young ones fed with *Artemia* was less (82%) than those fed with mixed copepods (90%). After 40 days, Cyclop-Eeze was tried but the acceptability was found to be very low. From forty fifth day, small sized live *Acetes* sp. were provided.

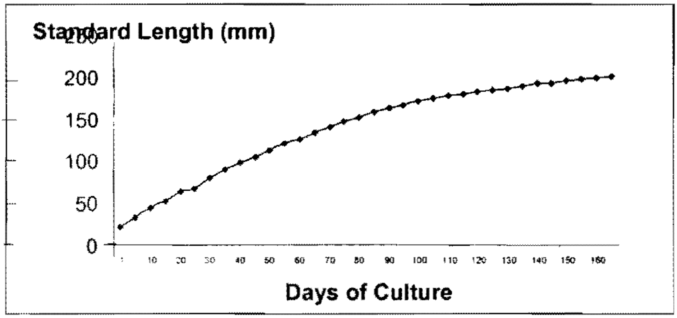

Figure. 4. Growth in terms of standard length (mm) in the pipefish Syngnathoides biaculeatus during culture

Pipefishes attained a length of 12 to 16cm in three months and 17 to 20 cm in five months. The average standard length (mm) attained by *S. biaculeatus* during culture is shown in Figure.4.

Discussion

Pipefishes and seahorses (Family Syngnathidae) are a group of fishes whose life histories render them vulnerable to over fishing and habitat destruction. They show sparse distribution, low mobility, small home ranges, low fecundity, lengthy parental care and mate fidelity (Vincent, 1996). Species with low rates of natural reproduction, small geographic range, complex social behaviour and distribution in vulnerable habitats is likely to be overfished (Sadovy, 2001). Syngnathids are exploited either in dried form for traditional medicines, tonic foods and curiosities or as live for ornamental display. The global trade of seahorses alone for Traditional Chinese Medicines exceeds 20 million dried animals annually. This has lead to drastic decline in wild catches between 15 and 50% over a 5 year period (Vincent, 1996). The alarming rate in reduction in wild stock led to the inclusion of a few pipefishes and all seahorses in the IUCN Red List of Threatened animals as vulnerable or endangered (IUCN, 2003). Seahorse trade worldwide is also restricted by listing them in Appendix II of CITES (Convention on International Trade in Endangered Species) (CITES, 2003).

Aquaculture has proved to be an important vocation and became the fastest growing food-production sector in the world. In spite of this, aquaculture has vast potential for conserving natural resources. Aquaculture provides a scenario in which the entire life cycle of a species can be completed under captive conditions. With minimal dependence for brooders from the wild, sufficient numbers of young ones can be produced through successful rearing and management practices. Releasing of hatchery reared juveniles have helped in many countries to bring back a stock that is locally extinct, to rebuild a stock that has collapsed as a viable fishery and to augment a natural population for a "put and take' fishery (Travis *et al.*, 1998). Hatchery reared *Penaeus chinensis* seeds were ranched 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 remained 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 (Watson, 2000). In 1973, the American alligator (*Alligator mississipiensis*) was put on endangered list but reclassified to threatened in 1978 with the assistance from captive rearing programs (Landau, 1992).

The present study indicates that culture of syngnathids is feasible under laboratory conditions with appreciable survival rate. Since, natural replenishment of population is time taking, sea ranching programs will help in the establishment of lost population at a faster pace. This is imperative since syngnathids are still caught as bycatch in various gears and traded through clandestine means. However, one of the main arguments against aquacultural production of seahorses is that captive culture relies heavily on repeated removals of wild animals and thus provides no net benefit to wild seahorses (Project Seahorse, 1999). But this problem can be solved if aquaculture is coupled with sea ranching. Incaptive bred and reared seahorses can be maintained in the laboratory and used for further production cycle as soon as they attain maturity. Though initial dependence on wild stocks exists for any breeding program, few animals from captive-bred generation can be developed as brood stock for future breeding programs. Thus the continual removal of adults from the wild can be eliminated. Aquaculture and sea ranching of syngnathids should thus be promoted to replenish the wild stocks and conserve these protected organisms from extinction in the near future.

Acknowledgements

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GROUPER FISH BIODIVERSITY IN GULF OF MANNAR BIOSPHERE RESERVE

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Introduction

Even though *E.malabaricus* supports a fishery in the Palk Bay and Gulf of Mannar in the vicinity of Mandapam, the magnitude of the fishery has not been recorded in any of the earlier reports. The existence of this fishery has been recorded as early as in James (1996). Muralitheran (1997) recorded this species from the trap catches around Mandapam, but did not indicate the magnitude of the fishery in the area.

Three species of grouper fishes occur in Palk Bay and the Gulf of Mannar in the Vicinity of Mandapam, of which, *Epinephelus tauvina* is the most common species occurring thorought the year in Palk bay and Gulf of Mannar of the other two species, the occurrence *of E.malabaricus* is only seasonal and *E.polyphekadion* occurs sporadically however, occasional shoals of the latter species are also reported from this region. A general survey of the fishing centers along Palk Bay and the Gulf of Mannar was made with a view to gather information about the fishing methods with special reference to the grouper fish fishery in the area. Grouper diversity was studies for 2years (2000-2002).

Description of study area

The Gulf of Mannar is designated as a National Biosphere Reserve and its 3,600 species of plants and animals constitute a biologically rich coastal region one of the richest in the whole mainland of India. (Jagannatha Rao et al., 1998). There are about 47 fishing villages along the coast, of which 38 are in the Ramanathapuram district and 9 in Tuticorin district bordering the Gulf of Mannar Park area (Vineetha 1997). Mandapam is one the dynamic center of fishing in Ramanathapuram district with annual fish landing of about 3,500 tonnes Mandapam fishery plays a significant role in providing jobs for 8000 persons out of fisherman population of 25,000 present in these fishing villages.

Review

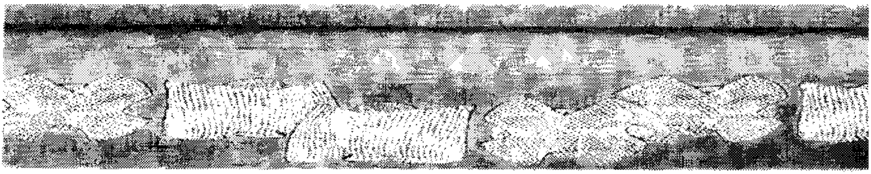
Muralithran (1997) has reported that the grouper fishery of Mandapam consisted of 8 species (including Epinehlus spp) caught were about 1, 54,103 tonnes in 1998. 1, 55,008 tonnes in1999. Total landings of *Epinephelus spp.* in India during 1997 to 1998 was 18,580 tonnes and about 15,158 tonnes 1998 to 1999. In Tamil Nadu, *Epinephelus spp.* Landings during 1998 and 1999 was estimated to be about 5, 20,693 tonnes in 1998 5, 90,099 tones in 1999 year. (Karup et al., 1999).There is no detailed study especially on grouper diversity.

Craft & Gear

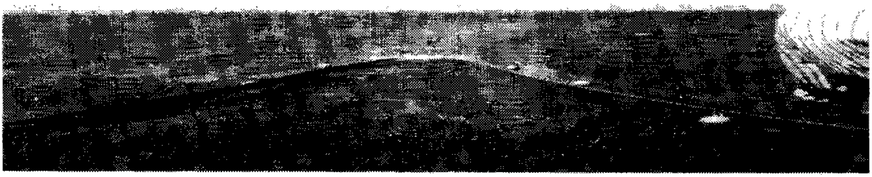
In Mandapam region they are used in trap net and Plank –built boats. Plank –built boats, provided with Sail, called 'Kalava vellam, are engaged in this fishery, each boat is about 13m long and 1.5m wide. Eight to fifteen fishermen go in a boat at a time currying food materials, salt and ice for preserving the fishes. About 50 such boat goes for this fishery from this region.

The gear used traditionally is hook and line. Hooks of sizes 6 and 7 one to five on each line are used up to 40m depth, but after reaching deeper water, single are used. Length of the line varies from 50-20m, for which good quality nylon thred (mono filament) is used . One fisherman operates a single line during fishing and the number of lines in a boat depends on the number of fisherman engaged in a boat.

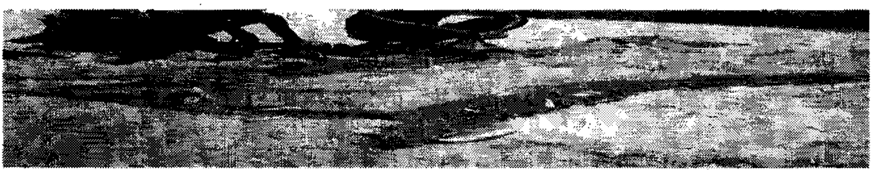
Trap nets (fig. in page 3) have been traditionally used in the shallow reef coastal marine waters of Gulf of Mannar and Palk Bay region for catching grouper fishes, which around in localities with hard bottom formed of rocks and corals. Fishing with the help of trap is very common along the Ramanathapuram district, especially Mandapam and Kilakarai localities.



A view of double entrance and four trap net



A view of Trawl net



A view of gill net ([illegible])

Fishery:

Total landings of grouper fish 20,000 tonnes in Tamil nadu while the landing at Gulf of snout to Mannar Maximum was 21 tonnes during the study period,i.e.2000-02. This fishing season was found to be during - October – November, and second peak was during March – April. The fishes were caught with depth 2 to 3 fathom , by trap net , 30 to 80 fathom by trawl net. Generally the fishing grounds are rocky with sand – 5 to 50 km from the shore.

BIODIVERSITY OF GROUPERS

Morphometric characters like length width etc are also very useful in identifying and separating the genera, species and even population with in a species. Studies by Ramaiyan (1977), Venkataramani (1979) and Siva Kumar (1981) Srinivasan (1992) have stressed the importance of Morphometric in taxonomical studies of food fish is of Parangipettai and Cuddalore costal waters. Measurements were made according to the method followed by Berry(1968)and Venkataramani(1979).Total length, standard length, fork length, head length, snout length, eye diameter, body depth at caudal peduncle, post orbital length,inter orbital length ,upper jaw length, lower jaw length , length of straight lateral line, dorsal fin base, snout to dorsal fin, snout to anal fin, pectoral fin length, base of anal fin, anal fin height,porsal fin height, pelvic fin length. 23 morph metric characters and 9 meristic counts were made and the details are given below.

Meristics characters:

Countable body characters are highly helpful taxonomically in separating different species (MC Hugh, 1951) and it is useful for systematic analysis of different species. Number of dorsal fin rays, Number of anal fin rays, Number of pectoral fin rays, Number pelvic fin rays, Number scales, Number of rakers were counted and confirmed the indentificaion to species level.

The description of the fishes were given below:

1. *Cephalopholis argus* (Schneider)

Family:Scrranidae

Common name:Peacock grouper

Description :Based on 22 specimens (225-322mm S.I) From gulf of manner and Palk Bay region south east coast of India DIX 15 -17 :A111 ,8-9 : P16-18. In percentages of standard length : Body depth 27.57 -30.22,head length 33.78-36.44, snout length 6,83 -7-11 eye diameter 4.88-5.59. predorsal distance 33.41,36.13, prepelvic distance 34.78-37.44, prepeotoral distance 35.09-36.18 and preanal distance 62.59-65.77

1. Head, body depth 2.7-3.2 times in standard length, distinctly less than head length
2. Maxillary extends beyond margin of eye ,auxillary scales present on body.
3. Pectoral fin shorter than poster orbital head ,about 1.3 times in head length

Colour: Head, body and fins dark brown, covered with small, blackish blue spots 5 or 6 broad pale vertical bars often present on rear half of body

Distribution: distributed in the Red sea and western Indian Ocean to the central pacific. Also in the south china sea.

Remarks : This species closely resembled Cephalopholis cynostigma but different in having 9 anal soft rays (8 in C.cyanostigma) and cycloid scales ventrally on abdomen (ctenoid in C. cyanostigma).

2. *Cephalopholis formosa* (Shaw)

Family: Serranidae

Common name: Blue lined hind grouper

Description : Based on 13 specimens (133-246mm S.L)from Gulf of Manner and palk Bay regions ,south east coast of India .DIX 17: A111,8:P17. In percentage of standard length : 34-98 -37-39, head length 42.1-45.52, snout length 12.03-13.01 ,eye diameter 6.76-7.31, predorsal distance 42.1-45.52, prepelvic distance 42.1-46, 52 prepecteral distance 40.6-47.15 and peranal distance 69.17-74.79.

1. Body robust or somewhat compressed ,oblong oval to rather elongate . Mouth large with small slender in wardly depressible teeth on jaws.
2. Middle opercular spine much closer to lower than to upper sprine: preopercle very finely serrate ,the lower edge fleshy. Of maxillan ear distal end.
3. A small knob on lower edge of maxilla near distal end.

Colour: Head and body usually dark brown with longitudinal blue lines . Some specimens with ground colour yellowish brown on ventral half of head and body.

Distribution: Northern part of the Western Indian Ocean but notm in the Red sea and the "Gulf" also present in the Eastern Indian Ocean and the Western Central Pacific to China and Southern India.

Remarks: This species closely resembles *Gracila polleni,* but differs in having rounded caudal fin truncate in Gracila polleni and no blue lines on dark brown back round of head and body.

3. *Epinephelus bleekeri* (Vaillant)

Family: Serranidae

Common name: Dusky tail grouper

Description: Based in 35 specimens (160-280mm S.L)from Gulf of Mannar and Palk Bay region ,south east cost of India. DX1 16-17; A111.8:P 17-18. In percentage of standard length:Body depth 31.12-33.36,head length 35.37-37.98 snout length 6.64-7.23, eye diameter 6.12-6.38, predorsal distance 34.92-38.13,pre pelvic 35.72-39.63,and preanal distance 56.82-60.63.

1. Medium sized serranid with body depth 3.2 times in standard length.
2. Preopercle finely serrate at angle
3. Sides of lower jaw with 2rows of sub equal teeth.

Colur : Body, dorsal fin and upper third of caudal fin brownish grey ,covered with gold spots distal half of anal fin and lower 2/3 of caudal fin dark purplish grey; pectoral fins pale.

Distribution : Tropical water of the Indo west pacific from the west coast of India and Srilanka east ward to China and Philippines.

Remarks: This species distinactly differ from other species of Epinephelus in having a truncle caudal fin . Head ,Body, dorsal fin and upper third of caudal fin with small orange –yellow spots . The lower two –thirds of caudal fin dark brown.

4. Epinephelus caeruleopunctus (Bloch)

Family: Serranidae

Common name: White spotted grouper

Description: Based on 22 specimens (176.322mm S.L)Manner Palk Bay Region, South east of India. DX1, 15-16:A111, 8:P 17-19. In percentages of standard length : Body depth 29.12-30.11, head length 35,93-37.91 snout length 5-45-6.25,eye diameter 5.91-6.84,predorsal distance 36.81-39.5, prepelvic distance 28.49-32.68 prepeotoral distance 37.72-40.06 and preanal distance 55.81-62.84.

1. Body depth distinctly less then head length 35.93-37.91 snout length 5.45-6.25, diameter eye diameter 5.91-6.84, pradorsal distance.
2. Opercular flap actue, the upper edge nearly straight.
3. Teeth in lower jaw in attest 3 series . A pair of canine teeth on symphasis in each jaw.

Colour : Head, body and fins dark brown or block; head and body with many small and medium sized , white or yellow spots : dorsal , anal and pectoral fins spotted like body, also proximal part of caudal fin :pelvic dark Adark "moustache "streak along maxillary grove.

Distibution : Wide spread in the Western India Ocean , Eastern India Ocean and Western Central Pacific to Japan and Australia.

Remarks: This species differs from other species of Epinephelus in having small and large white spots on body and streak on upper edge of maxillary grove. Its occurrence is rare in Mandapam group of Islands.

5. *Epinephelus longispinis* (Kner)

Family: Serranidae

Common name: Long spine grouper

Description: Based on 20 specimens (128-322m**mS.L)** From Gulf of Mannar and palk Bay region south east coast of India Dx1, 16-17: A 111, 8; P17 - 19

In percentage of standard length : Body depth 29.62- 31.63 head length 36.43-39.64 snout length 7.38-7.92, eye diameter 6.39-6.86, predosal distance 36.52-39.92 prepelvic distance 36.14-38.74 ,prepectoral distance 37.12-40.96 and preanal distance 67.17-71.92.

1. Body depth contained 2.8 -3.3times in standard length.
2. Interorbital area to slightly convex, the dorsal head profile convex.
3. Preoperucle corner with enlarged serrae and a shallow indentation just above the corner.

Colour: head and body pale ; grayish brown covered with small , dark reddish brown spots that are round and widely spaced on head and front half of body , but obliquely

Ditribution: Wide spread in the continental and insular localities in the Indian Ocean including Mauritius, Reunio, Maldives, Lakshadweep Islands, India, Srilanka , Nicobars and the Nazarath Bank.

Remarks: E*pinephelus longisspinis* is similar to E. maculates in counts of fin rays scales, gill rakers and also in morphometeric features but differs in having the dark spots, obliquely elongated closer together and darker posteriorly (none elongated in to oblique streaks in E.maculatus). Regarding the occurrence, this species is found in small numbers and its is recorded and for the first five from the Indian side of Gulf Manner Palk Bay costal water.

6. *Epinephelus malabaricus* (Schneider)

Family: Serranidae

Common name: Malabar grouper

Description: Based 501 specimens (60-759mm S.L) from Gulf of Mannar and Palk Bay region, South east cost of India. DX1, 14-16; A111, 8; p18-20.

In percentage of standard length : Body depth 14.53-58.74, head length 18.37-74.42 snout length 3.89-14.14, eye diameter 3.13-12.78, predorsal distance 17.7-76.63, prepelvic distance 16.62-74.35, prepeotoral distance 17.52-76.43, and preanal distance 33.08-138.7.

1. Body depth contained 3.0-3.6 times in standard length.
2. Preoperde finely serrate, with a shallow notch, the serrae enlarged

at the angle near nostrils not more than twice the size of anterior nostrils.

3. Midlateral body scales distinctly ctenoid with minute auxillary scales.

Colour: Head and body generally pale grayish brown covered with small organs, golden brown or dark spots. Five more or less distinct slightly oblique, irregular, broad; usually 3dark blotches on interopercde.

Distribution: Wide spread in the Western Indian Ocean and Eastern Indian Ocean

Remarks:This species closely resembles Epinephelus cocides but differs in having blackish brown spots on head, and body chain. It differs from E.tauvina in having a slightly conviex interorbital (Slightly concave in E.tauvina) and less lateral line scales 55-62 (in E.tauvina 65-74).

7. *Epinephelus quoyans* (Valenciennes)

Family: Serranidae

Common name: Barred –chest grouper

Description: Based on 17 specimens (151-283mmS.L)from Gulf of Mannar and Palk Bay region, South east cost of India. DX1, 16-18; A111, 8; p17-19. In percentage of standard length: Body depth28.47-30.38, head length 39.73-42.15snout length5.96-6.36, eye diameter8.60-9.18, predorsal distance31.78-33.56, prepelvic distance38.78-37.8, prepeotoral distance33.77-36.39, and preanal distance62.25-86.78.

1. Body depth contained 3.0-3.6 times in standard length inter orbital cover concave its least width contained 1.4-1.7 times in eye diameter. Body roubst or somewhat compresed oblong, oval to rather elongate, maxilla exposed with or without paper maxilla. Preoperacle serrate mostly covered by skin pectoral fins 1-2 -1.5 times in head length caudal fin rounded .Head and body pale with numerous round, dark brown spots about pupil sizes some spots at dorsal fin base.

Colour: Head and body pale with numerous rounds, dark brown spots about pupil sizes some spots at dorsal fin base. Larges and darked than others or body chest pale with 2 vague diagonal dark bands.

Distribution : The Distribution of the species is not it is clear because of confusion with other species wide spread in the Western Pacific from southern Japan to Australia including Taiwan, China, Hong, Philippines, and Vietnam.

Remarks: This species differ from other species Epinephelus in having 2 irregular oblique dark brown bands on thorax and a large semicircular dark brown spot on pectoral fin base.

It is recorded for the first time in the Gulf of Mannar & PalkBay region.

8. *Epinephelus lanciolatus* (Bloch)

Family: Serranidae

Common name: Giant grouper

Description : Based on 5 specimens (29.5-99.05cmS.L) from Gulf of Mannar and Palk Bay region, South east cost of India. DX1, 14-16; A111, 8; p18-20. In percentage of standard length: Body depth29.99-59.09, head length 33.41-49.09snout length7.03-7.99, eye diameter6.33-6.99, predorsal distance39.71-59.14, prepelvic distance39.79-59.99, prepeotoral distance69.09-79.99

1. Body depth contained 2.4 -3.4 times in standard length.
2. Inteorbital area flat to slightly.
3. Midlateral part of lower jaw 2 or 3rows of teeth.

Colour : Small juveniles (12cm standard length) yellow with irregular broad block bars on body the first from spinous dorsal fin to belly and chest ands extending onto head the second from base of soft dorsal to anal the last at base of caudal fin, small about (20-50cm standard length) with irregular white or yellow spots on block areas and fins ,with irregular block spots ,adult (80-150 cm standard length) dark brown with faint motting ,the fins with numerous small block spots ,large adults (160-230 cm standard length) dark brown, the darker.

Distribution: This species is widely distributed grouper in the world. It occurs throughout Indo-Pacific region from the sea and South Africa eastwarc to Hawaiian and Pitcarin Islands.

Remarks : *E. lanciolatus and E. itajara* are closely related ,both grow to enormous size and have a similar body shape, small eye, wide international area, numerous platelets on the gill arches, short dorsal –line scales with branches tubules. E.itajara differ from E. Lanciolatus in having ctenoid scales of the body and small block spots on the head and dorsal part of the body. It is recorded for the first time in the Gulf of Manner & PalkBay region.

9. *Epinephelus coioides* (Hamilton)

Family: Serranidae

Common name: Orange spots grouper

Description: Based on 15 specimens (13.5-59.0cmS.L) from Gulf of Mannar and Palk Bay region, South east cost of India. DX1, 14-16; A111, 8; p18-20. In percentage of standard length : Body depth29.09-33.29, head length 33.91-39.09snout length7.09-7.99, eye diameter6.33-6.99, predorsal distance33.79-39.13, prepelvic distance35.79-39.99, prepeotoral distance65.09-70.99

1. Body depth contained 2.9 -3.7 times in standard length
2. Interorbital flat or slightly convex.
3. Upper edge of operculum straight or somewhat convex, nostrils sub equal, maxilla reaches to slightly past a rear edge of eye.

Colour : Head and body tan dorsally, shading to whitish ventrally , numerous small brownish orange or reddish brown spots on head ,body, and median fins body with 5 faint, irregular ,oblique ,dark bars which on interopercle. Orange spots turn brown on exposure to and become fainter (more diffuse) in preservative.

Distribution : This species is widely distributed in the sub tropical Indo – Pacific west Pacific region from the Red Sea and South to at least Durban and east to the Western Pacific

Remarks : As implied by the numerous misidentified mentioned above, E. coioides is often mistaken for *E.malabaricus and E.tauvina* the valid name for the species that most recent it is misidentied as E.mictodon. This species has often been confused with *E.fuscoguttatus.* Similar colour pattern of irregular dark blotches superimposed on numerous small dark brown spots and a black saddle block on peduncle.

It is recorded for the first time in the Gulf of Manner & PalkBay region

10. *Epinephelus tukula* (Margans)

Family: Serranidae

Common name:Potato grouper

Description:Based on 3 specimens (59.0-75.5cmS.L) from Gulf of mannar and Palk Bay region ,South east cost of India. DX1, 14-15;A111 ,8;p18-20. In percentage of standard length : Body depth29.3-53.29, head length 33.03-39.03snout length7.05-7.99, eye diameter5.90-7.05, predorsal distance35.99-59.03, prepelvic distance33.05-38.99, prepeotoral distance65.33-73.99.

1. Body depth contained 2.9 -3.5 times in standard length
2. Interorbital area slightly convex.
3. Midlateral part of lower jaw 2or6 rows of teeth.

Colour: Body pale brownish grey with several dark brown to block widely spaced blotches, mostly large than eye and varying in shape from round to oval or dumbbell-shaped, head with smaller dark brown spots and streaks(many radiating from eye, especially posteriory), dark spots on fins, smaller distally. Large adults may be nearly block.

Distribution : This species is widely distributed in the Western Ocean and Red Sea to the Western Pacific.

Remarks : The absence of *E. tukula* at most of the Indian Ocean is puzzling .The distinctive colour pattern makes E. tukula easy to identify and difficult to confuse with other species of groupers. The name "potato grouper" refers to the potato shaped dark blotches on the body. It is recorded for the first time in the Gulf of Manner&PalkBay region.

11. *Epinephelus tauvina* (Forsskal)

Family: Serranidae

Common name: Greasy grouper

Description: Based on 104 specimens (112-309mmS.L) from Gulf of Mannar and Palk Bay region, South east cost of India. DX1, 15-16; A111, 8; p18-19. In percentage of standard length: Body depth28.57-30.74, head length 35.71-38.83snout length7.14-7.76, eye diameter 6.25-6.79, predorsal distance35.71-39.15, prepelvic distance35.71-38.83, and protectoral distance36.6-39.48 preanal distance 66.07-70.87.

1. Large serranied with an elongated and thickset body, preoperculam with a slightly convex serrated upper edge and several strong spinals at lower angle.
2. Teeth is narrow bands in the young in broad bands in adults in 3 rows on sides of lower jaw in adult canines small disappearing with age.
3. Pectoral fins moderate, slightly shorter than postorbital part of head, scales ctenoid in young, cycloid in adults.

Colour: Ground Colour light brown, with darker vertical or oblique bands upper parts of head and body, and base of pectoral fins with red brown spots; very variables most marking last with age.

Distribution: Wide spread in the tropical Indo –Pacific.

Remarks: This species is closely resembling Epinephelus malabaricus and E.coioides but differ in having slightly concave Interorbital ,more lateral line scales (65-74) and 3-4 rows of teeth on midside of lower jaw and a large dark spot at the base of last four dorsal spines . Compared to the occurrence of its compatriot genus Epinephelus, this species is found in large numbers.

12. *Epinephelus merra* (Bloch)

Family: Serranidae

Common name :Honey comb grouper

Description:Based on 12 specimens (129-339mmS.L) from Gulf of mannar and Palk Bay region ,South east cost of India . DX1, 15-17;A111 ,8;p16-18. In percentage of standard length : Body depth28.63-33.99, head length 35.99-39.09snout length5.39-7.99, eye diameter4.99-6.51, predorsal distance35.52-40.01, prepelvic distance26.14-38.24, protectoral distance27.12-40.99 preanal distance 49.17-71.49.

1. Body depth contained 2.8-3.3 times in standard length.
2. Interorbital area flat ,the dorsal head profile convex.
3. Preopercle rounded or sub angular, the sèrrate at angle enlarged.

Colour : Head, body and fins pale, covered with close –set, dark brown or reddish brown spots dark spots on median fins become smaller towards the fins margin . Pectoral fins covered with district small black spots.

Distribution: This species is widely distributed in the Indo- Pacific region South Africa to French Polynesia in the Central Pacific.

Remarks: This is species is one of the reticulated groupers. Its pectoral pattern of conspicuous black dots that are largely confined to the rays of the fins

13. *Epinephelus undulosus* (Quoy and Gaimard, 1824)

Family: Serranidae

Common name:Wavy lined hind grouper

Description:Based on 13 specimens (133-440mmS.L) from Gulf of Mannar and Palk Bay region, South east cost of India. DX1, 17-19;A111 ,8;p18-19. In percentage of standard length : Body depth33.99-34.39, head length 42.1-45.59snout length13.03-13.09, eye diameter6.79-7.33, predorsal distance41.1-43.52, prepelvic distance43.1-46.52, protectoral distance 41.6-49.15 preanal distance69.13-74.79.

1. Body depth contained 2.7-3.1 times in standard length
2. Upper edge of operculum straight or slightly concave.
3. Midlateral part of lower jaw with 2 rows of teeth.

Colour: Head and body and fins purplish grey to brownish grey, with golden –brown dots on head and wavy longitudinal lines of same colour on dorsal part (lines faint or large specimens) margins of spinous dorsal fin narrowly blackish.

Distribution: *E. undulosus* occurs in the northern Indian Ocean and it is also known from Indonesia.

Remarks: This species are more numerous and longer than the gill rakers of any other species of Epinephelus, its diet is not different from that of other species of groupers. It is a generalized predator that usually feeds on a Varity of fishes and crustaceans that live on or near the bottom. Like other groupers, it will take macro zooplankton (e.g., pelagic tunicates) if such prey are available.

14. *Epinephelus polyphekadion* (Bleeker)

Family: Serranidae

Common name:Camouflage grouper

Description :Based on 15 specimens (115-305mmS.L) from Gulf of mannar and Palk Bay region ,South east cost of India. DX1, 14-15;A111 ,8;p16-18. In percentage of standard length : Body depth28.97-31.29, head length 35.41-38.91snout length7.11-7.99, eye diameter6.26-6.90, predorsal distance35.71-39.14, prepelvic distance35.79-38.99, protectoral distance 66.01-70.99.

1. Body depth contained 2.7-3.1 times in standard length.
2. Interorbital area flat the dorsal head profile evenly convex.
3. Midlateral part of lower jaw with 2 or 3 rows of teeth.

Colour: Head body and fins pale brown covered with numerous small dark spots numerous small white spots on fins. Juveniles with a pair of blackish spots on each side of snout and a black spots at margins of second and third interspinous dorsal –fin membranes.

Distribution: This species is widely distributed in the tropical and sub tropical Indo- Pacific West Pacific region from the Red Sea and east cost of Africa to French Polynesia.

Remarks: *E. polyphekadion* is the valid name for the species that most recent it is misidentied as E.microdon .This species has often been confused with *E. fuscoguttatus*. Similar colour pattern of irregular dark blotches superimposed on numerous small dark brown spots and a black saddle blotch on the peduncle.

15. *Epinephelus diacanthus* (Valenciennes)

Family: Serranidae

Common name:Spiny cheek grouper

Discription:Based on 16 specimens (140-290mmS.L) from Gulf of mannar and Palk Bay region ,South east cost of India. DX1, 15-17;A111 ,8;p17-120. In percentage of standard length : Body depth20.80-36.50, head length 20.23-26.42snout length4.64-7.99, eye diameter4.33-7.02, predorsal distance24.92-38.33, prepelvic distance17.91-31.01, protectoral distance26.72-39.09.and preanal distance 49.81-61.09.

1. Medium - sized serranied with body depth 2.8-3.5 times in standard length.
2. Numerous bony pates on of gill arches.
3. Midlateral part of lower with 2 rows of short ,sub equal teeth.

Color: Body pale grayish brown ,usually with 5 dark vertical bars broader than interspaces 4 below dorsal fin and fifth (faintest) on peduncle ;ventral part of head and body often pink or reddish fins dusky grey without spots.

Description: Continental shelf of the Northern India Ocean from the Gulf of Aden to Srilanka and Madras India.

Remarks: This species records on misidentifications of E.striatus , E.fusciatomaculos. This species distinctly differs from other species of Epinephelus in having black spots on the median fins, fewer scales ,a smaller head and deeper caudal peduncle.

Discussion

Hussain and Abdulla (1974)studied the biometry of E.tauvina and stated that standard length showed maximum growth in relation to total weight Premalatha (1989) studied the biometry of *E.aerolatu E. cholorostigma* and *E.diacanthus* and stated that length and weight showed perfect correlation for males and females. Taxonomical studies are very important for further conservation and management. During the study period 15 different species were identified. Out of fifteen species Epinephelus tukula was found to be a new record in the study area. Further studies can be in taxonomy area of all the food fishes from the Gulf of mannar area for better conservation and management.

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BIODIVERSITY OF SHRIMPS, LOBSTERS, CRABS AND STOMATOPODS OF GULF OF MANNAR BIOSPHERE RESERVE

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INTRODUCTION

The reported fauna of macro crustaceans from the Gulf of Mannar Biosphere Reserve (GoMBR) include penaeid shrimps (Wood-Mason, 1891; Henderson, 1893; Alcock, 1901 & 1906; Hansen, 1919; Gravely, 1927; Thomas, 1969, 1979 & 1986; Miquel, 1983; CMFRI, 2006), non-penaeid shrimps (Wood-Mason, 1891; Henderson, 1893; Alcock, 1901; Kemp, 1922; Gravely, 1927; Sankarankutty, 1962; George *et al.*, 1972; Thomas, 1979 & 1986), lobsters (Henderson, 1893; Alcock, 1901; De Man, 1916; Gravely, 1927; Nair *et al.*, 1973; Thomas, 1979; Kathirvel *et al.*, 1989; Radhakrishnan *et al.*, 1995) anomuran crabs (Henderson, 1893; Alcock, 1905 a & b, Gravely, 1927; Sundararaj, 1927; Sankarankutty, 1961a, 1961b, & 1963a; Thomas, 1986), brachyuran crabs (Henderson, 1893; Thurston, 1894; Alcock, 1895, 1896, 1898, 1899a, 1899b & 1900; Kemp, 1919; Gravely, 1927; Chopra, 1931; Balss, 1935; Sankarankutty, 1963b & 1967; Jeyabaskaran *et al.*, 2000; CMFRI, 2006; Gokul, 2006; Kathirvel and Gokul, 2006), and stomatopods (Henderson, 1893; Kemp, 1913; Gravely, 1927; Chopra, 1939; Manning, 1969 & 1978; Shanbhogue, 1970 & 1986). The present paper deals with the record of these six groups and their richness, habitat and distributional pattern and suggestions for their conservation.

STUDY AREA

The extent of Gulf of Mannar Biosphere Reserve in the Indian Exclusive Economic Zone measures about 10,500 square kilometers. The boundaries of GoMBR are the coast line between Mandapam and Kanyakumari on the western side, the coast line along Mandapam and Rameswaram Island on the northern side, the Sri Lankan side of Gulf of Mannar on the eastern side and the Indian Ocean on the southern side. There are 21 islands from Mandapam in the north to Tuticorin in the south covering a distance of 140 km and are located closer to the coast bordering Ramanathapuram, Tirunelveli, Tuticorin and Kanyakumari districts of Tamil Nadu. The extent of the islands range from 0.95 to 1.30 ha. These islands which are having rich coral reef environment are part of the Mannar Barrier reef (Venkataraman, 2003). The different habitats in GoMBR are sandy seashore, mud flats, mangroves, pelagic, sea grass/sea weed beds, sand/ mud bottom with fragmented shells in littoral region, sand/mud bottom with fragmented shells in deep sea, coral reefs, pearl banks, rocky patches and commensal (co-existence of two different animals).

GROUP-WISE NUMERICAL ABUNDANCE

The group-wise numerical abundance of six groups of crustaceans is presented in Table 1.

Table 1. Number of families, genera and species in each group.

Group	Family	Genus	Species
Penaeid shrimps	8	22	46 (11%)
Non-penaeid shrimps	7	19	24 (6%)
Lobsters	3	9	14(4%)
Anomuran crabs	3	14	45(11%)
Brachyuran crabs	22	117	248(62%)
Stomatopods	5	11	25(6%)
Total: 6	**48**	**192**	**402**

A total of 48 families, 192 genera and 402 species in six groups of crustaceans, namely, penaeid shrimps, non-penaeid shrimps, lobsters, anomuran crabs, brachyuran crabs, and stomatopods are recorded during 1893-2006 from GoMBR. The brachyuran crabs stood first by larger number of families, genera and species, accounting 62 %, followed by penaeid shrimps (11 %), anomuran crabs (11 %), non-penaeid shrimps (6 %), stomatopods (6 %), and lobsters (4 %).

SPECIES RICHNESS

Penaeid shrimps: A total of 46 species belonging to 8 families (Aristaeidae-4 species; Benthesicymidae-1; Luciferidae-1; Pasipaeidae-2; Penaeidae-28; Sergestidae-5; Sicyonidae-2; Solenoceridae-3) were represented in GoMBR. Alcock (1901 & 1906) reported 23 species, while Wood-Mason (1891), Henderson (1893), Hansen (1919), Gravely (1927), Thomas (1969, 1979 & 1986), Miquel (1983) and CMFRI (2006) added 2, 1, 1, 2, 12, 4 and 1 species respectively.

Non-penaeid shrimps: 24 species belonging to 7 families (Alpeidae-6 species; Hippolytidae-6; Nematocarcinidae-1; Palemonidae-6; Pandalidae-2, Rhynchocinetidae-1 and Stenopidae-1) were reported from this study area. The number of species reported by Wood-Mason (1891), Henderson (1893), Alcock (1901) and Sankarankutty (1962) was 1 each, while Gravely (1927), Kemp (1922), George *et al.* (1972) and Thomas (1979 & 1986) added 8, 2, 4 and 6 species respectively.

Lobsters: 14 species belonging to 3 families (Nephropidae-1 species; Palinuridae-8; Scyllaridae-5) were recoded. Henderson (1893), Alcock (1901), Gravely (1927), Kathirvel *et al.* (1989) and Thomas (1979) reported 1 species each, while De Man (1916), Nair *et al.* (1973) and Radhakrishnan *et al.* (1999) recorded 2, 5 and 2 respectively.

Anomuran crabs:

a) Hermit crabs: 30 species under two families, namely, Diogenidae (28 species) and Coenobitidae (2 species) were reported. Henderson (1893) recorded 14 species, while Alcock (1905b) added 10 more species. Later, Sundararaj (1927) and Thomas (1989) reported 3 species each.

b) Porcellanid crabs: 15 species belonging to family Porcellanidae were recorded in the study area. Henderson (1893) reported 2 species, while Gravely (1927) recorded 9 species. Later, Sankarankutty (1961a, 1961b, & 1963a) reported 4 species, of which, 2 are new to science.

***Brachyuran crabs*:** A total of 248 species belonging to 22 families (Dromiidae-7; Homolidae-3; Dorippidae-4; Calappidae-10; Portunidae-35; Carpiliidae-11; Menippidae-1; Xanthidae-60; Panopeidae-3; Pilumnidae-7; Trapeziidae-6; Tetraliidae-5; Leucosiidae-19; Majidae-28; Parthenopidae-13; Hymenosomatidae-2; Goneplacidae-1; Gecarcinidae-1; Pinnotheridae-3; Ocypodidae-13; Grapsidae-16) were known to occur. Henderson (1893) recorded 93 species, while Thurston (1897), Alcock (1895-1900), Kemp (1919), Gravely (1927), Balss (1935), Sankarankutty (1963b & 1966), Thomas (1969), Jeyabaskaran *et al.* (2000), Gokul (2006), CMFRI (2006) and Kathirvel and Gokul (2006) added 10, 17, 3, 18, 2, 39, 5, 53, 4, 3 and 1 respectively. According to Kathirvel *et al.* (2007), 362 species belonging to 25 families and 154 genera were recorded from Tamil Nadu coast, thus the representation of species richness from GoMBR being 68.5 %.

Stomatopods: 25 species belonging to 5 families (Gonodactylidae-4 species; Protosquillidae-1; Nanosquillidae-1; Lysiosquillidae-2; Squillidae-17). While Kemp (1913) reported 17 species, Gravely (1927), Chopra (1939), Manning (1969), Shanbhogue (1970) recorded 1 species each. Further, Henderson (1893) and Manning (1978) added 2 species each. Those 3 species reported by Manning (1969 & 1978) were new to science.

HABITAT-WISE DIVERSITY

The habitat-wise diversity of species of six groups of crustaceans are presented in Table 2.

Table 2. Group-wise diversity of macro-crustaceans in different habitats

HABITAT	Penaeid Shrimps	Non Penaeid Shrimps	Lobsters	Anomuran Crabs	Brachyuran Crabs	Stomato-pods	Total
Sandy sea shore	0	0	0	2	4	0	6
Mud flats	0	0	0	0	16	0	16
Mangroves	0	0	0	0	6	0	6
Pelagic	6	0	0	0	0	0	6
Sea grass/weed	1	2	0	0	4	0	7
Sand/mud-littoral	26	3	3	26	67	20	145
Sand/mud-deep sea	13	2	3	2	2	0	22
Coral reefs	0	10	8	0	94	5	117
Pearl banks	0	4	0	0	23	0	27
Rocky patches	0	0	0	12	9	0	21
Commensal	0	3	0	3	23	0	29
Total	46	24	14	45	248	25	402

1. *SANDY SEASHORE*

***Anomuran crabs*:** 2 species of hermit crabs belonging to family Coenobitidae wander all over the beach and seldom visit water area.

***Brachyuran crabs*:** The sandy seashore between the high and low water mark is inhabited by 4 species of Ocypodidae. These crabs remain in burrows during day and the come out of burrows during night for biological activities.

2. *MUD FLATS*

***Brachyuran crabs*:** 16 (1 Gecarcinidae, 10 Ocypodidae and 5 Grapsidae) crabs make burrows in the substratum and come for feeding and breeding.

3. *MANGROVES*

***Brachyuran crabs*:** 6 (1 Goneplacidae and 5 Grapsidae) crabs are found among the mangroves.

4. *PELAGIC*

***Penaeid shrimps*:** 1 Luciferidae and 5 Sergestidae shrimps are pelagic in habit. Hence, their rich occurrence has been noticed in plankton collections.

5. *SEA GRASS/SEA WEED BEDS*

Penaeid shrimp: One species of Penaeidae, namely, *Penaeus semisulcatus* (green tiger shrimp) prefers the sea grass/sea weed beds and hence the shrimp has acquired the green colour. Generally, the sea grass beds are situated in sandy areas, where the shrimp remains buried under the substratum.

Non-penaeid shrimps: Two (Hipploytidae) shrimps are known to cling to the sea grass/weed.

Brachyuran crabs: 4 crabs (1 each of Calappidae, Portunidae, Majidae and Parthenopidae) take refuge among sea grass/sea weed.

6. *SAND/MUD BOTTOM WITH FRAGMENTED SHELLS IN LITTORAL REGION*

Penaeid shrimps: Out of 46 species, 6 are pelagic and 40 are demersal in habit. 26 (1 Solenoceridae, 23 Penaeidae and 2 Sicyonidae) are littoral forms (2 to 70 metres depth) and they prefer sandy/muddy bottom with shell fragments. Most of them remain bury under the substratum, mostly during the day and emerge during night for biological activities, with exception of few non-burying species such as Indian white shrimp (*Fenneropenaeus indicus*) and tiger shrimp (*Penaeus monodon*).

Non-penaeid shrimps: Three shrimps (1 Hipploytidae and 2 Palaemonidae) are found in the littoral region.

Lobsters: One species each of Palinuridae and Scyllaridae are reported from 10-30 m depth in the littoral region.

Anomuran crabs: 26 littoral species of Diogenidae (hermit crabs) are recorded in the dpth range of 2-20 m.

Brachyuran crabs: 69 crabs (1 Raninidae, 4 Dorippidae, 3 Calappidae, 22 Portunidae, 17 Leucosiidae, 11 Majidae, 8 Parthenopidae and 2 Hymenostomatidae) inhabit sandy/muddy littoral region.

Stomatopods: 20 stomatopods (1 Nanosquillidae, 2 Lysiosquillidae and 17 Squillidae) have been recorded from sand/mud bottom.

7. *SAND/MUD BOTTOM WITH FRAGMENTED SHELLS IN DEEP SEA REGION*

***Penaeid shrimps*:** 13 shrimps (1Benthescymidae, 2 each of Pasiphaeidae & Solenoceridae and 4 each of Aristaeidae & Penaeidae) are known to inhabit deep sea region (200-350 m).

***Non-penaeid shrimps*:** 2 species of Pandalidae are recorded in the depth range of 200-350 m in the deep sea.

***Lobsters*:** 3 (1 Nephropidae and 2 Palinuridae) lobsters are known to occur in deep sea (200-350 m depth).

***Anomuran crabs*:** 2 deep sea species of Diogenidae (hermit crabs) have been recorded from 200-350 m depth.

***Brachyuran crabs*:** 2 crabs (1 Homolidae and 1 Portunidae) are found in the deep waters.

8. *CORAL REEFS*

***Non-penaeid shrimps*:** 10 shrimps (4 Alphiedae, 3 Hippolytidae and 1 each of Palaemonidae, Rhynchocinetidae and Stenopidae) are recorded.

***Lobsters*:** 7 lobsters (5 Palinuridae and 2 Scyllaridae) are known to occur among the coral reefs/boulders/crevices.

***Brachyuran crabs*:** 94 crabs (6 Dromiidae, 1 Raninidae, 2 Calappidae, 10 Portunidae, 10 Carpiliidae, 1 Menippidae, 47 Xanthidae, 3 Panopeidae, 6 Ppilumnidae, 2 Leucosiidae, 4 Majidae and 2 Grapsidae) are found among corals.

***Stomatopods*:** 5 species of Gonodactylidae have been recorded among corals.

9. *PEARL BANKS*

***Non-penaeid shrimps*:** 1 Alpheidae and 2 Palaemonidae shrimps are reported from crevices and pits.

***Brachyurn crabs*:** 23 crabs (4 Calappidae, 6 Xanthidae, 1 Pilumnidae and 12 Majidae) are reported from pearl banks.

10. *ROCKY PATCHES*

***Anomuran crabs*:** 12 species of Porcellanidae are found beneath stones and boulders.

***Brachyuran crabs*:** 9 crabs (2 Portunidae, 1 Carpliidae, 3 Parthenopidae and 3 Grapsidae) are known to inhabit the rocky areas.

11. *COMMENSAL*

***Non-penaeid shrimps*:** One species of Alpheidae has been recorded as a commensal in the sea urchin (*Stomopneutes* sp.), while the bivalve mollusc (*Pinna bicolor*) and the giant sea anemone (*Stoicactus* sp.) found as host for 2 shrimps belonging to Palaemonidae.

***Anomuran crabs*:** The sea pen and giant sea anemone are recorded as host for 3 species of Porcellanidae.

***Brachyuran crabs*:** 23 crabs (7 Xanthidae and 5 each of Trapeizidae and Tetralidae) are commensal on live/dead corals, while 1 species of Trapeizidae has been recorded from sea fan, 1 species of Dromiidae from ascidian, 1 species of Parthenopidae from crinoid, 3 species of Pinnotheridae (one from sea cucumber -*Holothuria scabra* and 2 from bivalve mollusc - *Pinna* sp.) are commensals.

GENERAL REMARKS

The Gulf of Mannar Biosphere Reserve is an unique marine environment wherein 11 types of habitats are existing, thus facilitating for a greater biodiversity in penaeid & non-penaeid shrimps, lobsters, anomuran & brachyuran crabs and stomatopods. Among the penaeid shrimps, majority of them preferred sand/mud bottom both in littoral and deep sea regions (Wood-Mason, 1891; Henderson, 1893; Alcock, 1901 & 1906; Hansen, 1919; Gravely, 1927; Thomas, 1969, 1979 & 1986; Miquel, 1983; CMFRI, 2006). Whereas, 42 % of the non-penaeid shrimps were found among the coral reefs (Wood-Mason, 1891; Henderson, 1893; Alcock, 1901; Kemp, 1922; Gravely, 1927; Sankarankutty, 1962; George *et al.*, 1972; Thomas, 1979 & 1986). The majority of lobsters were also found among the coral boulders/crevices/live or dead corals (Henderson, 1893; Alcock, 1901; De Man, 1916; Gravely, 1927; Nair *et al.*, 1973; Thomas, 1979; Kathirvel *et al.*, 1989; Radhakrishnan *et al.*, 1995). Among the anomuran crabs, the hermit crabs were mostly occurred in sand/mud bottom in littoral region (Henderson, 1893; Alcock, 1905 a & b; Sundararaj, 1927; Thomas, 1986), while porcellanid crabs were found below pieces of rocks (Gravely, 1927; Sankarankutty, 1961a, 1961b & 1963a). The brachyuran crabs were found recorded in all the eleven habitats (Henderson, 1893; Thurston, 1894; Alcock, 1895, 1896, 1898, 1899a, 1899b & 1900; Kemp, 1919; Gravely, 1927; Chopra, 1931; Balss, 1935; Sankarankutty, 1963b & 1967; Jeyabaskaran *et al.*, 2000; Gokul, 2006). However, 38 % of them were among coral reefs, while 27 % were in sand/mud bottom. According Serene (1972), 25 % of brachyuran crabs are known to inhabit the coral reefs of the tropical Indo-West Pacific region. Among the stomatopods, 80 % were in sand/mud bottom in littoral region and 20 % among corals (Henderson, 1893; Kemp, 1913; Gravely, 1927; Chopra, 1939; Manning, 1969 & 1978; Shanbhogue, 1970 & 1986). Some of the non-penaeid shrimps, anomuran and brachyuran crabs recorded from GoMBR are commensals with sea anemone, sea fan, sea cucumber, sea urchin and bivalve mollusc, which agreed with the observation by Patton (1967).

FUTURE STRATEGIES FOR BIODIVERSITY CONSERVATION

In order to sustain the biodiversity of macro-crustaceans, the following conservations measures are suggested.

Pilot survey: In order to take stock of the current status of biodiversity of macro-crustaceans in GoMBR, a pilot survey may be conducted by a) scuba diving in those coral reef environment for a visual observation without disturbing the habitat of these crustaceans and b) an enumeration of crustaceans caught in indigenous and mechnaised crafts and gears. Further, a field guide on these crustaceans may be prepared to facilitate the identification of these crustaceans during such pilot surveys.

***Fishing*:** To reduce the damage on coral reefs and adjoining sea grass beds, a ban on the operation of traps on coral reefs and trawling over sea grass beds should be enforced. Further, a ban on trawling within 5 kilometres from the shore and the operation of indigenous net fishing for juvenile penaeid shrimps from the sea grass beds also should be strictly enforced.

***Sea grass*:** Survey on the extent and ecology of sea grass beds including biodiversity of fauna and flora.

***Mangroves*:** Nurseries should be established to replenish the green belt around each island, which will ensure the colonization of all mangrove-dependent organisms including shrimps and crabs.

***Corals*:** Strict enforcement of amended laws of Wild Life Act of 1972 to curb further illegal mining, so as to protect the remaining coral reefs and coral ref-dependent shrimps, crabs, lobsters and stomatopods.

***Penaeid shrimps*:** Sea ranching of hatchery raised seeds of most common species may help to replenish the natural stock.

***Brachyuran crabs*:** A ban on capture of berried female crabs from the littoral region may increase the production of fresh broods and subsequently the density of population.

***Lobsters*:** Berried female lobsters should be released back into the sea. The legal size for capture announced by Govt. of India should be enforced strictly.

***Industrial pollution*:** Systematic studies to understand the actual effect of industrial pollution on littoral crustacean fauna may be undertaken.

***Public awareness*:** Posters may be prepared in local language depicting the marine crustaceans, their importance in the context of biodiversity conservation and distribution of the same among the coastal folks. Regular meeting with fishing communities and poachers of corals and other rare animals and creating an awareness on the important of different habitats and value of such habitat dependant species diversity and their conservation.

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POLICY OPTIONS
AND
LIVELIHOOD SECURITY
FOR COASTAL POPULATIONS

SEAWEED CULTIVATION - A PROFITABLE VENTURE FOR THE ECONOMIC REHABILITATION OF COASTAL POOR

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Seaweeds are wonder plants of the Sea and considered as medical food of the 21st century. They have innumerous applications in food, pharmaceutical, textile and chemical industries and world demand is increasing every year. The world production has gone up to 10 million tonnes worth of US $8.0 billion and China is the world leader followed by Japan, South Korea, Philippines, Indonesia etc. Seaweeds are also found to provide a strong base for growth promoters of several plants because of their properties such as cytokinine, auxin and gibberellines. Therefore seaweeds will be the major source of raw material for biofertilizer to start organic agriculture revolution in the country.

The vast sea with rich nutrients around mainland and islands and with plenty of sunlight throughout the year in tropical climatic conditions are natural gifts to India to produce atleast 1.0 million tonnes of seaweeds (dried) and employ nearly 200,000 families with an annual earning of about Rs.1.0 lakh per family. The annual turnover through Kappaphycus seaweed cultivation alone can be safely estimated to be Rs.2,000 crores. Dr. Abdul Kalam, Former President of India, supported seaweed cultivation for employment generation and development of bio-products.

Annexure - I

Seaweeds provide shelter to a variety of organisms and enhance biodiversity. They absorb CO_2 and reduce global warming. They are also efficient in controlling organic pollution including heavy metals in the inshore waters. Thus, seaweed cultivation is cent percent eco-friendly with sustainable income to the coastal poor.

Tamil Nadu is rich in seaweed resources. Wild seaweeds are harvested for agar agar and algin production especially in the area of Gulf of Mannar. Several hundred women depend on wild seaweed collection just to earn their daily bread and they were victims of recent tsunami with loss of life and properties. If this coastal community could be rehabilitated from wild seaweed collection to scientific farming it is possible to generate atleast Rs.10,000/- per month for a family. Economics of seaweed cultivation, in bamboo rafts, is given in the **Annexure - II**. Seaweed cultivation can also be done in monoline net bags where waves are fairly high with good water motion. Pilot scale operation on seaweed cultivation started for the welfare of fisherwomen in Mandapam, Pampan, Tuticorin and Kanyakumari, has shown remarkable results proving it to be a profitable venture. All inputs such as seed plant, raft material for cultivation, bank loan and buyback are available. SBI and Pandyan Grama Bank have started financing this project to SHGs. If the cultivation is taken up in Gulf of Mannar, permission is required from the Chief Wildlife Warden.

Characteristics of Kappaphycus seaweed and its geographical distribution:

Kappaphycus is a red alga under Rhodophyceae with excellent source of carrageenan. Kappaphycus alvarezii has cylindrical axis with branches that are commonly enlarged maximally beyond basal structure towards the light. The branches are irregular. Pigmentation is more or less at brighter light levels. Thalli may be dark brown in intense light and relatively more reddish in the shade or in deeper water due to relative abundance of phycoerythrin. Pale yellow thalli are found in some bright light conditions. *Kappaphycus alvarezii* becomes phototrophic in intense light. Its growth generally increases as water motion increases. If wave action is high, excessive damage occurs to plants.

Kappaphycus seaweed grows profusely in the sea where the bottom is sandy and salinity is ranging from 29 to 34 ppt. A seed plant of 150 gram grows to >600 gram in 45 days in calmer waters like Palk Bay area. It requires only sunlight, transparent seawater with mild wave action for replenishing bottom nutrients. It has also been proved that Kappaphycus seaweed grows >10 times in the open sea where wave action is fairly high through monoline net-bag culture method.

Advantages of Kappaphycus (Eucheuma) for cultivation:

- They are autotrophic plants and grow by absorbing nutrients (nitrogen, phosphorus and other minerals) present in the sea water under sunlight. Cycling of nutrients means cycling of wealth, and Kappaphycus cultivation is ideal to generate such wealth from the seas.
- A major source of Kappa carrageenan.
- Kappaphycus is a versatile plant growing almost everywhere in marine environment.
- Propagates vegetatively by "cloning" from buds cuttings without a sexual phase. It is easy to multiply.
- Grow fast and can be regenerated fast after harvesting.
- Can be eaten raw or used in salad.
- Does not involve application of fertilizer, growth hormones, pesticides, insecticides, herbicides etc and is totally organic.
- Cultivation technology is simple and eco-friendly.
- Seeding of plant in the raft/bag, harvesting of plant by pulling the raft/bag to the shore and sun drying are shore-based activities.
- Two to three persons of a family can handle this with an income of Rs.12,000-15,000/per month. The techno-economic viability has been well established in Tamil Nadu.
- Beneficial to the environment since it controls pollution, absorbs CO_2 and enhances biodiversity.
- Does not generate any hazardous or solid waste.
- Farming, harvesting and processing generate new cottage scale industries, employing thousands of men and women among the coastal poor. Nationalized banks are willing to provide loans to Self Help Groups (SHGs) even without collateral security upto Rs. 5.0lakh/ SHG. The State Bank of India and PepsiCo have entered into an agreement for assured buy-back of the produce.

- An excellent rehabilitation programme for fisher folk from hunting to seafarming. Which will pave way to reduce fishing pressure and arrest over-exploitation of fish resources.
- Refined carrageenan extracted from Kappaphycus fetches a high price ranging from US$ 7,000 to 10,000/mt depending upon grade, quality and functionality. Raw weeds around 33% moisture get a price of US$ 250-600/mt. Since Kappaphycus is a high value seaweed with persistent demand and innumerable applications in various industries, the world market is expanding fast.
- Above all, it is going to be instrumental in creating an organic agricultural revolution in India because of its strength in growth promoting substances. Experiments have proved a growth enhancement of 18 to 40% in several plants such as rice, sugarcane, ground nuts, corn, wheat, etc.

Marketing of seaweed:

As on date M/s. PEPSICO is the only company executing agreements with Banks for an assured buyback of the produce. They have already executed such agreement with the State Bank of India. A few more seaweed processing Indian companies are showing interest to execute similar agreements like PEPSICO which has long term interest in utilizing Kappaphycus seaweed for manufacturing carrageenan and biofertilizer.

A strong demand for carrageenan has increased the price of seaweed from P10 per kilo to P20-P30/kilo in Philippines. Of course, the price varies according to the quality grades. PepsiCo is paying now Rs.12.0/Kg for dried Kappaphycus without any rejection on quality and quantity grounds. They are also increasing the price every year. When the returns per month are upto Rs.15,000/family with the prevailing price, it will go up further when the price increases especially when it is applied for biofertilizer. This kind of guaranteed price with assured buy-back is not available for other seaweeds. Therefore, cultivators are getting higher income from Kappaphycus cultivation. It is encouraging further that USFDA and Codex Alimentarious

Commission have approved carrageenan as a food additive. Therefore, the demand in the world market for carrageenan will go up in the coming years.

It is understood from the Customs Department that India is importing nearly 400 tonnes of carrageenan powder and the demand in the domestic market is going up. Therefore, our demand alone is expected to be around 2000 tonnes per annum.

Procedure followed in the demonstration, training and rehabilitation programme:

Formation of SHGs and bank loan for cultivators:

SHG of women/men has to be formed with 12-20 members to avail a bank loan upto Rs.5.0 lakhs without collateral security. If it is an individual, collateral security has to be produced. Commercial banks such as State Bank of India have studied the techno-economic viability of Kappaphycus seaweed cultivation and have come forward with a budget to encourage seaweed cultivation. Each family may need 150 rafts to have a daily harvest and earn a daily income ranging from Rs. 600-700 according to the amount of labour and growth of seaweed.

Subsidy for motivation:

Promotion for motivation of entrepreneurs through partial financial assistance in the form of a grant up to 50% of the capital cost per family could be very useful. It can be given to the families who are below the poverty line. This grant can form margin money so that the bank will get encouraged to finance seaweed cultivation. The grant can always be linked to bank loan.

Survey, awareness creation campaign, pilot scale demonstration and training:

It should start with a survey to identify the suitable areas for cultivation. Since seaweed cultivation is totally a new activity to the coastal communities it is necessary to start with an awareness creation campaign to explain the potential and prospects.

Though Kappaphycus seaweed cultivation is invariably successful, location specific trials are needed in the form of pilot scale demonstration to ensure the economic viability, which depends purely on rate of growth depending on the local environmental conditions. Socio-economic issues are also important in terms of fishermen cooperation, and protection of properties at sea during cultivation, shore facilities for sun drying and access to the cultivation sites in the remote coastal areas.

Pilot scale demonstration starts with hand on training of 30 entrepreneurs (one each from 30 families) at a time in one site. It is possible to give training for 30 candidates in 2 days (i.e. theory one day and practical one day) with field observation for 2 months. During these 60 days training and trial culture each candidate is given a stipend of Rs.1500/- per month to meet their travel cost and subsistence. Each candidate is given a raft for hand-on training on seaweed cultivation. Field observation including growth, cleaning of undesirable foreign objects and maintenance of rafts in good condition against wave action in the sea is carried out by him/her for 45-50 days till the plant attains harvestable size. Practical training in harvest, sun drying and packing is given to complete one programme.

The Government of Tamil Nadu has issued a Government Order supporting seaweed cultivation. DRDA is encouraging seaweed cultivation under tsunami relief programme in all coastal districts of Tamil Nadu. Aquaculture Foundation of India (AFI), Chennai has organised a series of demonstration and training in several parts of Tami Nadu coast. Local NGOs have been involved to coordinate the programme on day to day basis with all stakeholders.

ANNEXURE - I

Address by Dr. A. P. J. Abdul Kalam, Former President of India at the Bicentennial Celebration of the State Bank of India on 30th May 2006 Bio-products from Seaweed: Coastal PURA employment generator:

Scientists of Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar have developed an important thickening agent Carrageenan using seaweed called *Kappaphycus alvarezii* that bestows useful properties to many commercial products such as toothpaste, ice cream, pet food and soft capsules. I am happy that SBI is providing loan upto Rs.5.0 lakh without collateral security to the women self-help groups in Mandapam region of Tamil Nadu for cultivation of seaweed. The scientists have developed a unique technology of liquefying seaweed without adding any water and thereafter they have separated the solid from the liquid to obtain two products. The solid is the source of carrageenan and the liquid has been found to be a very useful plant nutrient rich in potassium and organic growth promoting hormones. This sap has been used in a variety of crops such as sugarcane, paddy, maize, pulses and several fruits and vegetables. The productivity increase has been in the range of 20% to 40% in different regions for different plant varieties as per studies conducted by regional institutions. This highly innovative process of producing to useful products from the fresh harvest of the seaweed is being done for the first time in the world.

I would suggest seaweed cultivation and value addition should be taken up as a mission mode project of fishermen co-operatives and self-help groups of the coastal areas particularly in the PURA (Providing Urban Amenities in Rural Areas) complexes in partnership with scientists, industrialist and SBI. This will enable creation of industries for producing Carrageenan and bio-fertilizers in the coastal PURA itself resulting in substantial amount of revenue increase to the fishermen and farmers.

ANNEXURE - II

Seaweed Cultivation in Bamboo Rafts – Unit Cost per Raft

Infrastructure Cost

No.	Particulars / Description	Qty Reqd.	Rate (Rs)	Cost per Raft (Rs)
1.	3-4" dia Hallow bamboos of 12'x4 for main frame + 4'x4 for diagonals (without any natural holes, crakes etc.	64'	3.10/ft	200.00
2.	Five-Toothed Iron Anchor of 15kg each (@ Rs. 35 per kg) – One anchor can hold a cluster of 10 rafts.	1.5 kg	40/kg	50.00
3.	3mm PP twisted rope for plantation – 20 bits of 4.5m each	0.45 kg	110/kg	50.00
4.	Cost of HDPE braider pieces (20 pcs x 20 ropes = 400 pcs of 25cm each)	0.165 kg	120/kg	50.00
5.	Braider twining charges @ Rs. 1.0/20 ties. For one raft 400 ties = Rs. 20	20 ropes	1/rope	20.00
6.	Raft framing rope 6mX12 ties per raft i.e. 36mts of 6mm rope	0.65 kg	110/kg	75.00
7.	HDPE Fishing Net to protect the raft bottom (4m x 4m size) + labour charges Rs. 10	1.13 kg	75/kg	85.00
8.	2mm rope to tie the HDPE net (28mts)	0.09 kg	110/kg	10.00
9.	Anchoring rope of 10mm thickness (17m per cluster of 10 rafts)	0.09 kg	110/kg	10.00
10.	Raft linking ropes per cluster 10 rafts – 6mm thick – 2 ties x 3m x 9pairs = 54m length	0.1 kg	110/kg	11.00
11.	Transport cost for seed material			25.00
12.	Seed material 150gm x 400 ties	60 kg	0.85/kg	51.00
13.	Raft laying + maintenance cost	-	-	75.00
14.	Miscellaneous	-	-	3.00
	Total raft cost Rs. 700 (Rounded off)			**690.00**

Ref. State Bank of India

For SHG having 20 members		
Rs.690 x 900 rafts	=	Rs. 6,21,000
Less subsidy	=	Rs. 1,25,000
Net Bank Loan	**=**	**Rs. 4,96,000**

Economics of seaweed culture:

i.	Total yield of seaweed per raft in 45 raft days	- 260 kg
ii.	After retaining 60 kg as seed for the next crop, balance available for drying	- 200 kg
iii.	Dry seaweed available for sale, after 2 days of solar drying (10%)	- 20 kg
iv.	Estimated yield of dried seaweed available for sale after wastage	- 18 kg

Income:

a.	For one cycle – 18x12x900	- Rs. 1,94,400
	For 4 cycles in the I year	- Rs. 7,77,600
	For 6 cycles in the II and III year	- Rs. 11,66,400

Interest Rate:

7 % per annum for tsunami affected people (otherwise 8.5 %)

Repayment: - 3 years including 3 months grace period

- Repayment at monthly intervals except October, November
  1 year – 4 cycles; II year and III year – 6 cycles each

ALTERNATIVE LIVELIHOOD OPTIONS FOR COASTAL COMMUNITY IN THE GULF OF MANNAR BIOSPHERE RESERVE

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Preamble

Gulf of Mannar supports luxuriant growth of corals and sea grass meadows in the shallow sea and mangroves in their shores and swampy regions. About 3600 species of flora and fauna have been known to occur in this area in the past. There are 49 villages along the coast, bordering the Marine Biosphere area. Altogether, there are 53,880 fisher-folk, of whom 13,500 are active fishermen. The literacy rate is about 38% in this area. There are about 1110 mechanized fishing boats, 5800 country craft and various kinds of nets. The average catch per day per boat varies from 10 to 20 kg. The average income is about Rupees 500 to 5000 per month per person.

Several thousands of coastal community including the fisher folk are dependent on the marine resources of Gulf of Mannar for their livelihoods. Almost all sections and particularly those from the traditional fishing sector, are experiencing decline in fish catch due to a number of reasons and the introduction of fishing ban in the Marine Biosphere reserves and National Marine Parks, has further eroded their livelihood security. Loss of the only source of income and livelihood through fishing and collection of seaweed by the local community (fishermen and women), has also led to resentment among the fishing community as they have been pushed to acute poverty.

Improvements in coastal resource management and the development of alternative income opportunities are being successfully introduced as a package in many countries. They provide opportunities for income generation and provide a safety net for the poor by diversifying the use of labour.

Alternative livelihood opportunities and affordable credit are key factors that can reduce the dependence of poor fishermen on over-fished waters and allow time for regeneration of overexploited marine resources through conservation. Any alternative livelihood options identified for rehabilitating the fishermen affected because of the introduction of biosphere reserve in the Gulf of Mannar should match the ground realities and should be based on the needs/skills of the coastal fishing community.

Overexploitation of coral reefs and associated resources has led to their severe degradation in the Gulf of Mannar region. Alternative livelihoods need to be promoted as a means to alleviate pressure on these limited resources.

While most of the environmentalists and environmental organisations like Greenpeace are advocating conservation and protection of the marine biosphere resources, none of them have initiated any meaningful action for providing alternate sources of employment and income to the traditional fishers and the coastal community including women who have been impacted adversely owing to the declaration of these areas as protected areas for fishing, sea weed collection and other related activities in the vicinity of these reserves.

A number of stakeholders, particularly traditional fisherfolk who were interviewed on various occasions along Orissa coast where "No fishing zone" is imposed for over 150 km stretch of the 480 km long coastline have one thing to say i.e., *"Help us Survive"*. The fishermen openly convey:

"It is not possible for us to stop fishing, because if we do not catch fish how will we survive? If fishermen are directly responsible for turtle mortality, is the Government not also indirectly responsible? Is it a crime for a hungry man to fill his stomach? We fish because this is our only livelihood. We agree that if the turtle is saved, but if this means we cannot fish, then what will we do in this season? If we do not fish our stomachs will remain empty and our families hungry and cold. So, if the Government can do something for us then the call to save the turtle will be more credible and valuable." " If the government is thinking that we fishermen are responsible for turtle mortality and wants to do something to stop it, they should also understand that this is our traditional profession and we do not know any other. Besides, we do not intentionally kill turtles. If the government therefore wishes to save the turtles and wants us to stop fishing it should provide us money or some compensation during the 4 months of the turtle season, so that we wouldn't depend on fishing during this period." (I Witness: Turtle Witness Camp, 2006, GREENPEACE, 2006).

This statement calls for a clear understanding of the needs and capabilities of the coastal fishers and community with respect to their livelihood options in the coastal and marine areas which are protected for the sake of conservation of the resources. There are a number of alternative employment opportunities, such as Animal Husbandry (Rearing of milk cow, goat rearing; poultry rearing); making garments; net making; lace making; Betel Leaf cultivation; Vegetable Cultivation; selling home made food including sweets; mud crab fattening; fish selling; fish processing (dry fish); etc., some of which could be considered for introduction for the benefit of the affected fishers.

Relief and rehabilitation to/of fisherfolk

Relief and rehabilitation should be recognised as a right of affected fishers and coastal community and should be delivered on a humanitarian basis, irrespective of gender, legal status, ethnicity, etc., and with a particular focus on vulnerable groups. Protection of the fishermen's livelihood security must be within the framework of sustainable and responsible fisheries and should promote "employment-intensive" fisheries operations that contribute directly to poverty alleviation and food security of the affected people.,

The right of fishing communities to occupy coastal lands traditionally inhabited by them must be recognised and protected. Where safety considerations require the rehabilitation of communities, this should be in consultation with them and with their prior informed consent. Land identified for rehabilitation should be close enough to the sea, to maintain the organic link with their livelihoods. Legal measures should be adopted to ensure that the priority use rights to coastal and beach spaces continue to rest with fishing communities, and that vacated coastal lands are not taken over by tourist, aquaculture, housing/real estate and other industrial interests.

Compensation packages for the mechanised fleet should be suitably designed to ensure that the problems of over-fishing and social conflict that their operations are eliminated. Coastal zone management programmes that reduce the near-shore fishing pressure should be supported by the creation of alternative livelihoods in the areas of:

- Ecologically sustainable marine tourism projects;
- Diverting and spreading excess near-shore fishing capacity to waters further ashore, with the proviso that any new fishery is conducted within safe ecological limits.

Diversification of livelihood options

In order to avoid overexploitation of bioresources and reduce pressure on marine biodiversity in the Gulf of Mannar Biosphere Reserve, attempts have been made in the last four years to demonstrate alternative livelihood options for poor fishing families, by establishing various marine resource based and community owned business enterprises. In the Mandapam region, an agar plant and a pearl culture farm have been established in Kunjarvalasai and Mundalmunai respectively, while in the Tuticorin region, a modern fish pickle unit run by women has been started in Vellapatti village. A village level society owns the enterprises. Demonstration of artificial reef as a tool to enhance fishery resources has also been initiated in Therespuram village.

Experience with the fishermen affected by tsunami has shown that the fishers considered it below their dignity to do any work other than fisheries related and they apprehend that if they showed any inclination for engaged in non-fishery activities, they would be implicitly accepting that there were alternatives to fishing and thus risk a reduction in the flow of funds into the sector. The fishermen also have expressed their unwillingness to take up sewing and they did not want to be trained in activities like sewing. Obviously, any alternative income generation programme would have to content with such factors and come up with some meaningful responses, but it is clear that for many fishers, working in the fish production and marketing chains still remained the only option to meet their livelihood needs.

The potential to shift to new livelihood activities and the human and financial capital required for such shifts should also be understood and this may necessitate not only the skill development, but also the provision of market links, building up the required management capacities and assistance in terms of financial capital. Other livelihood issues relate to skill development, strengthening community organisations, rehabilitation of the natural environment, resettlement problems, etc. Hence, Identification of livelihood strategies and supporting structures and processes are of paramount importance.

Conservation of resources and rehabilitation of fisherfolk must be undertaken in consultation with the respective communities, as only this will lead to activities that are in harmony with the local environment and the livelihoods of local communities.

Cash-for-work programme provide only short-term assistance, and there exists a need to ensure sustainable livelihoods. Gaps still remain between the long-term needs of the people and the assistance actually provided. Assistance to fisherwomen should be considered a priority. Due to the seasonal and highly fluctuating nature of fishing, many fisherwomen supplement their incomes with other activities like fish processing, farming and livestock breeding. Many of these self-employment opportunities are no longer available. The women now need to develop new opportunities, skills and capacities.

There are a number of alternative employment opportunities as listed below, some of which could be considered for introduction for the benefit of the affected fishers. The quality of education and opportunities for skill development should be enhanced to enable diversification of the livelihood options of the fishing communities.

Job Alternatives: Animal Husbandry (Rearing of milk cow, goat rearing; poultry rearing); making garments; net making; lace making; Betel Leaf cultivation; Vegetable Cultivation; selling home made food including sweets; home gardening; freshwater ornamental fish breeding and rearing; mud crab and lobster fattening; fish selling; fish processing (dry fish); coir industry (rope-making, etc); weaving mats; packing condiments; candle making; etc.

Aquaculture

Aquaculture is playing an increasingly important role in supplying food fish and a source of trade to the rapidly increasing populations of Asia (Kongkeo and Phillips, 2002). As an alternative livelihood to destructive fishing, although promising, aquaculture has specific issues that must be addressed before implementing any new activities. These issues vary for each type of aquaculture activity planned and must be considered case by case. However, they typically include:

- The often high capital cost and skill levels required.
- Correct focusing of projects to answer the needs of specific tiers, genders and ages of the population and to integrate with other aspects of coastal management.
- The willingness and ability of fishermen to change occupation.
- The ability of farmed products to replace wild-caught counterparts (marketing).
- The footprint of the aquaculture operation (including such things as environmental pollution, land-use conflicts, requirements for fishery products and waste treatment facilities).
- Seed and broodstock source and supply, and
- Often unproven economic, technical and environmental sustainability factors.

Mariculture

Sea farming or mariculture is relatively new to India. Although certain age old practices of traditional farming of fish and shrimp in saline coastal areas are being followed even today, commercial farming of finfishes is yet to become a viable industry. This is mainly because of the absence of proven technology for production and culture of these species on commercial scale. However, in the Gulf of Mannar Region, there is a potential for seaweed culture along the peripheral areas of Palk Bay and the Gulf region, which needs to be encouraged with adequate post-harvest facilities for processing of different sea weed species of commercial importance.

Seaweed culture

Sea weeds belonging to four groups namely green, brown, red and blue-green algae are one among the commercially important marine living resources of the country. Over 806 species of marine algae have been reported from India of which 428 species are reported from Tamil Nadu, 79 species from Andhra Pradesh, 64 species from A&N islands and 6 species each from West Bengal and Orissa. The annual production of seaweed in India is estimated at 77,000 tonnes (fresh weight).

The seaweeds contain more than 60 trace elements, minerals, protein, iodine, bromine, vitamins and several bio-active substances. Various technologies have already been developed for extraction of chemicals such as agar, agaroids, algin and carrageenan from seaweeds.

Viable technology is available for the extraction of agar and algin for industrial production. However, commercial scale production units for demonstration and training is a priority requirement in this sector. All these activities will help in augmenting the supply of the raw materials for seaweed industry, in providing employment to coastal population and thereby increasing their income and socio-economic upliftment.

Of the seaweed species which can be cultured on commercial scale, the red algae viz. *Gracilaria* (agar producing alga) and *Kappaphycus* which yields carrageenan are found to be suitable for cultivation by the coastal community of the Gulf of Mannar region. These by-products are used in the manufacture of several food products, drugs, cosmetics, etc.

At present, industries are producing agar from the algae collected from the wild. This has led to depletion of seaweed resources in our coastal waters. To prevent this loss, fishermen's groups have been encouraged to take up algal culture in certain parts of the country. Growing these red algae would benefit industries, fetch good economic returns for the farmers and at the same time save the natural resources from being exploited indiscriminately.

In one year about six harvests can be made and from one raft about 90 kg of seaweed can be harvested. The harvested produce can then be dried in the sun and sold. When planted in the summer season, the first harvest can be done in about 60 days and during winter in about 45 days. The dried produce can be sold at the rate of Rs. 8.50 per kg and if fresh it is sold at 85 paise.

Alternative Fishing Methods

The lack of knowledge on alternative employment opportunities and their impact on existing fishery may become a serious problem in the near future. Such activities may lead to the destructive use of aquatic resources or the destruction of coastal habitats, which are the main grounds for small-scale fishing.

There are possibilities to replace cyanide and blast fishing with traditional non-destructive methods, e.g., hook and line and fish traps *(bubu),* with sufficient training, incentives, regulation and enforcement. Hook and line fishing can be effective, especially in unexploited reefs.

Other, non-traditional livelihood possibilities include catching organisms for the aquarium trade using certified, non-destructive methods, fish attracting devices (FADs) aimed at the hook and line harvest of marine pelagic fish and the setting up of Marine Protected Areas for conservation and tourism-related livelihood generation.

Fish processing and marketing

The realms of fish processing and marketing in which the role of women is very significant also needs some fresh thinking. The opportunity to introduce low-cost, hygienic fish processing techniques for the domestic market must be seized. This will require coastal space, financial and physical investments, demonstrations and training.

Fish drying (solar fish driers) and curing yards; mobile flake ice vans, ice plants, fish marketing kiosks, etc., will have to be provided under a special programme to the fishers.

Artificial reefs

Artificial Reefs are man-made structures deployed in the sea, 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. The holes, crevices, vertical relief, and ledges of the artificial reef structures increase habitat space for marine organisms. Artificial reefs are generally created for the following purposes:

- To provide habitat or shelter for fish and other marine organisms
- To serve as a nesting, feeding, breeding, spawning and nursery ground
- To act as a deterrent to bottom-trawling and other destructive gear
- To help create fishing grounds
- To create recreational fishing areas.

About 45 countries are at present engaged in establishing artificial reefs in their coastal waters. In the past, scrap materials, wooden and bamboo structures, used tyres, broken ships, etc were used in the fabrication of artificial reefs. However, due to environmental pollution from some of these materials such as tyres and decay of some materials such as wooden and bamboo structures, many countries now use ferro-cement and high density polythene materials for the construction of artificial reefs.

Similar initiatives could be introduced in the Gulf of Mannar islands particularly near the Tuticorin group of islands for resource enhancement.

Coastal Bio-village for Livelihood Rehabilitation

The economy of coastal villages can be strengthened through the bio-village model of rural development. The Coastal Bio-village movement relies on the sustainable use of natural resources and the introduction of market-driven, non-farm livelihood options as well as value addition to primary products. It also involves a paradigm shift from unskilled to skilled work, resulting in the addition of economic value to the time and labour of the coastal community. One of the important components of this programme is the establishment of aquaculture estates, that can help confer the power of scale to fishermen communities in the production, processing and marketing. Seawater farming is another potential area which could support enhanced livelihood sources if the technology and services are right. Starting of traditional micro-enterprises particularly for fish vending by women, is very vital to market the landed fish.

Tourism

Tourism presents an increasingly important opportunity for alternative livelihood generation, while sustaining the natural resources.

Reef-related tourism is becoming increasingly important in many parts of the world. Tourism, especially related to dive tourism, is incompatible with destructive fishing since the larger, more spectacular species such as the groupers and wrasses targeted by cyanide fishermen are exactly the species that most divers will pay to see, and the incompatibility of blast fishing and diving hardly needs to be explained.

Often, dive resorts set up their own "house reefs" or MPAs, which are well preserved, with the resorts often providing fast boats and fuel to local agencies to improve surveillance. This then goes to ensure the financial self-sufficiency of the protected area. Dive tourism can thus play a direct and active role in conservation of resources, as well as providing jobs and foreign exchange earnings for the host country (Chou, 2000; Djohani, 1996).

Experience in the Philippines has shown substantial increases in dive-related tourism, in addition to improved fish catches, after the establishment and management of MPAs, such as in Apo Island in Visayas Province (White, 1997). Additionally, it was shown that the financial benefits of selling souvenirs and transporting tourists to resort islands were substantial even to fishers using only their outrigger boats. Fishers' benefits exceeded losses due to reduced catches and the presence of tourists made it harder for fishers to continue blasting with concomitant improvements in resources (Pet-Soede et al., 1999).

Non-fishing livelihoods

Some of the non-fishing livelihoods that could be considered for restoration of the fishers' livelihood are as follows: agriculture, poultry keeping, milk production, salt and lime production, basket making, mat weaving, etc., by providing technical support and a revolving fund to the interested fishers for venturing into these alternative activities.

Conclusion

For every affected fisherman there are 3-4 non-fishing members of the community whose livelihood is severely affected due to the ban imposed on the fishing and related activities in the marine biosphere reserves and National Marine Parks/Sanctuaries. There are many dependants including women and others who take up ancillary economic activities such as sea weed collection, catching, drying, loading, unloading, transporting, vending, and marketing fish; boat and net making; boat/motor repair, supply of nets and fishing accessories. All these people have also suffered loss of livelihoods.

Instead of subjecting the communities to undue hardship and misery, these communities should be assisted to form their own collectives, provided with seed capital and matching grants and other inputs through revolving funds which will enable them to choose alternative livelihood options and help them become economically more resilient.

Alternative livelihood generation can form only a part of an integrated coastal management plan, but, as such, is of critical importance in maintaining or enhancing the lives of coastal fisherfolk deprived of their current livelihoods. The type of alternative livelihoods suitable will vary depending on the socio-economic and cultural character of the fishing community and on other factors such as the available natural resources and infrastructure (Pet-Soede et al., 1999).

- Alternative employment opportunities can be created for poor fishermen in the GoM region, by establishing commercial production units, utilising locally available resources.

- The local people are more interested in a wage rather than managing commercial units because of the risk involved in terms of investment, marketing and maintenance of sophisticated machinery.

- Artificial reefs can be utilised to address the issue of depleting fish resources, which seriously affects the conservation and management of the marine biodiversity of the GoM. Multi-cluster artificial reef can be established at appropriate distances from natural coral reefs as alternative fishing grounds for poor fishermen to avoid fishing in the reef area, which is another major problem in the management of the GoM.

- Any proposed income generating activity should not just be developed to absorb the potential labour redundancies in fisheries or other related activities, but also to absorb increasing populations of working age.

- Non-governmental agencies and community-based organisations such as fisher folk organisations and women's groups can play a vital role in the mobilisation of community interest and support, it is important to identify and strengthen such groups before any alternative livelihood programme is introduced.

- A thorough understanding of the demographic and social dynamics of coastal communities is needed before introduction of a new employment venture.

- Rather than trying to introduce new concepts, promoting employment activities that already exist within that area is more likely to be successful.

- Law enforcement and public awareness programmes should also go hand in hand with the implementation of alternative livelihood options to ensure success of the programme.

- Directly improving the livelihoods of reef dependent communities can help to reduce their dependency on the coral reef.

- The concept of turning "poacher into a gamekeeper" in resource protection should be explored. the possibility of employing fishermen in coral reef areas to protect the reefs needs to be considered.

- Time scale issues – projects are often short-term and have failed as they have not been able to offer full community support, such as the development of markets for the produce of alternative livelihoods.

- All Community Based Management and alternative livelihood/ employment schemes must be enforced and supported by the appropriate agencies in order to succeed.

- Extensive education and sharing of information on the ecological issues (illegal fishing, sustainable development etc.) with the fisher-folk is needed. This should be started by training the chosen local leaders who will conduct the information campaigns.

- If there are no multi-purpose cooperatives in the area, the cooperative or private foundation composed of fisher-folk who will implement the action programme itself should be formed.

- Sea farming be introduced as an alternative livelihood. People will eventually realise that fish-cages or fish-pens along the coastal areas, and seaweed farming (for carageenan) which is a sunrise industry here, are truly profitable.

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BIODIVERSITY IN MANGROVE ECOSYSTEM OF THE GULF OF MANNAR

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1. Introduction

Mangrove forests along the coastlines are among the world's most productive ecosystems. These are often called as 'tidal forests', 'coastal woodlands' or 'oceanic rainforests'. Living along the interface between land and sea, the mangrove ecosystems support genetically diverse groups of aquatic and terrestrial organisms. They include diversified habitats such as core forests, litter forest floors, mudflats, and adjacent coral reefs and seagrass ecosystems. The contiguous water bodies consist of the rivers, bays, inter tidal creeks, channels and backwaters. The mangroves can exist under wide ranges of salinities, tidal amplitudes, winds, and temperatures, even in muddy and anaerobic soil conditions. The highly variable habitat conditions make them profusely rich in biodiversity. 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 (Kathiresan and Qasim, 2005).

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 nursery 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 protect coastal populations and 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).

The mangrove forests are biologically diverse, ecologically vigorous and exceedingly valuable systems (Ngoile and Shunula, 1992; Kathiresan and Bingham, 2001; Kathiresan and Rajendran, 2005). This paper deals with the status of mangrove resources in the Gulf of Mannar Islands, in order to develop update inventories on their current status, extent, prevailing threats and recommending management prescriptions in the Gulf of Mannar, the first Marine Biosphere Reserve in the South and South East Asia.

2. Mangrove forests in Gulf of Mannar

There is no previous survey of mangroves for the whole of the Gulf of Mannar nor are there any bench mark studies on the flora. There are indications that there was over-exploitation that led to degradation and shrinkage of mangroves and vanishing of species as a result. Species such as *Bruguiera gymnorrizha* and *Acanthus ilicifolius* earlier collected in Rameswaram, and *Pemphis acidula* in Pamban have not been re-collected in recent years. Likewise *Acanthus ilicifolius* and *Excoecaria agallocha* earlier collected on Krusadai Island have not been re-collected (Daniel and Uma Maheswari, 2001). Destruction of mangroves on Muyal and Pullivasal Islands for firewood is obvious. Effects of rapid industrialization all along the mainland coast particularly around Tuticorin and pollution from existing industries on the ecosystems particularly on the Islands do not seem to have been quantified. The increase in the extent of salt pan is yet another factor leading to the shrinkage of mangroves particularly around Tuticorin area (Daniel and Uma Maheswari, 2001). In spite of all these clear changes, the available information on physico-chemical aspects of the mangrove habitats in the Gulf of Mannar is highly inadequate (Subramanian and Kannan, 1998; Bhagan *et al.,* l996; Balasubramanian and Kannan, 2005; Kumaraguru *et al.,* 2006).

2.1. Occurrence and distribution of mangroves:

The Gulf of Mannar Biosphere Reserve is the only region in far south of Tamil Nadu State, harbouring mangrove vegetation. It is believed that the Gulf of Mannar was once covered with thick mangrove forests all along the coastal Tamil Nadu. Their remnants as relics are seen even now

(Krishnamurthy *et al.,* 1987). Of the 21 Islands, 11 are colonized with luxuriant mangrove ecosystems and these Islands are Kurusadai, Pullivasal, Poomarichan, Manoliputti, Manoli, Hare, Mullai, Valai, Thalaiyari, Appa and Nallathanni (Table 1).

On the mainland coast the total area under mangroves is 187 ha with 40 ha at Kundhukal, 10 ha around Tuticorin and 137 ha at Punnakayal (Neelakantan, 1994). There are large shrubs of *Avicennia marina* at Veppalodai where this large stream meets the sea. There are also large areas of small shrubby *A. marina* in the vicinity of the Tuticorin. However, those at Punnakayal in the Tamirabarani delta are extremely stunted. The Islands of the Mandapam group have mangroves with multiple species. Krusadai, Poomarichan, Pullivasal, Manoli and Manoliputti Islands have large areas of mangroves of *Aegiceras corniculatum, Avicennia marina, Bruguiera cylindrica, Ceriops tagal, Lumnitzera racemosa, Rhizophora apiculata* and *R. mucronata.* Muyal and Shingle Islands, nevertheless, have only *Avicennia marina* and *Lumnitzera racemosa* is extremely rare whereas that of *Excoecaria agallocha* is a little frequent. In the Keelakarai group only have good patches of mangroves with *A. marina* and *Lumnitzera racemosa* in Thalaiyari Islands and, *A. marina* and *Pemphis acidula* in Valai Islands. The Tuticorin group of Islands is very poor in mangroves. Upputhanni Island has only *A. marina.* Kaswari Island had a small patch with *A. marina* and *P. acidula* which appears to be getting stabilized. Other associated are *Aeluropus lagopoides, Arthrocnemum glaucum, Atriplex repens, Clerodendrum inerme, Fimbristylis ferruginea, F. polytrichoides, Halosarcia indica, Ipomoea violacea, Pandanus fascicularis, Salicornia brachiata, Salvadora persica, Sesuvium portulacastrum, Sporobolus tremulus, Suaeda maritima, S. monoica, S. nudiflora* and *Thespesia populnea* (Daniel and Umamaheswari, 2001).

Table 1. Mangrove species that exist in different groups of Islands of the Gulf of Mannar

No.	Name of Island Group	Name of Island	No. of mangrove species	Name of mangrove species
1	Mandapam group	Shingle	4	*Avicennia marina, Excoecaria agallocha, Lumnitzera racemosa, Pemphis acidula*
2		Krusadai	8	*Aegiceras corniculatum, Avicennia marina, Bruguiera cylindrica, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Pemphis acidula, Rhizophora mucronata*
3		Pullivasal	9	*Aegiceras corniculatum, Avicennia marina, Bruguiera cylindrica, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Pemphis acidula, Rhizophora mucronata, R. apiculata*
4		Poomarichan	7	*Avicennia marina, Bruguiera cylindrica, Ceriops tagal, Excoecaria agallocha, Pemphis acidula, Rhizophora mucronata, R. apiculata*
5		Manoliputti	5	*Avicennia marina, Bruguiera cylindrica, Ceriops tagal, Excoecaria agallocha, Pemphis acidula*
6		Manoli	8	*Avicennia marina, Bruguiera cylindrica, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Pemphis acidula, Rhizophora mucronata, R. apiculata*

No.	Name of Island Group	Name of Island	No. of mangrove species	Name of mangrove species
7		Muyal	6	*Avicennia marina, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Pemphis acidula, Rhizophora mucronata*
8	Keelakarai group	Mulli	2	*Avicennia marina, Pemphis acidula*
9		Valai	1	*Pemphis acidula*
10		Thalaiyari	2	*Avicennia marina, Pemphis acidula*
11		Appa	3	*Avicennia marina,, Excoecaria agallocha, Pemphis acidula*
12		Pulliarmuni	1	*Pemphis acidula*
13		Anaipar	2	*Avicennia marina, Pemphis acidula*
14	Vembar group	Nallathanni	1	*Avicennia marina*
15		Puluvinichalli	0	
16		Upputhanni	1	*Avicennia marina*
17	Tuticorin group	Karaichalli	0	
18		Kaswari	0	
19		Van	1	*Avicennia marina*

2.2. Mangrove species diversity:

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, notably at Manoli, Manoliputti, Poomarichan and Hare Islands. In Tamil Nadu, *Cerips tagal* is found to be present only in the Gulf of Mannar region. This species has high percentage of tannin in its bark. Medicinally it is used to cure malaria and also prevents haemorrhage.The whole plant has antidiabetic property and is also used in treatment of malignant ulcers. The species contains flavonoids, tannins, alkaloids, diterpenoids as well sugars such as rhamnose and ribose, but sugar alcohols are absent (Albert *et al.,* 2005). Nothing is known about floral biology and pollinators of those rare species in the Gulf of Mannar, although such information is a prerequisite for restoration process (Tomlinson, 1979). Thanks to Andhra Pradesh for publishing a recent work on pollination biology of *Ceriops decandra* (Solomon Raju *et al.*, 2006).

Iyengar (1927) was perhaps the first to record about vegetation of Krusadai Island with *Avicennia officinalis, Excoecaria agallocha, Bruguiera cylindrica, Ceriops tagal* and *Lumnitzera recemosa.*

Rao and his co-workers of Botanical Survey of India were the earlier workers to give account of plant ecology with description of soil and other related feature of the Krusadai group of Islands and Rameswaram Islands situated in the Gulf of Mannar (Rao *et al.*, l963a, b). The workers 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), Ceriops tagal, A. alba,* and *Bruguiera conjucata (B. cylindrica)* (Blasco, 1975; Krishnamurthy *et al.*, 1987). According to Perichiappan *et al.* (1995) there are 13 species of mangrove and other halophytes recorded from eight Islands of Mandapam group.

In l997, the Botanical survey of India recorded the presence of mangrove plants in the Islands of the Gulf of Mannar, except Annaipar, Appa, Karaichalli, Nallathanni, Puluvinichalli, Valimunai and Van Islands. The Mandapam group of Islands has maximum number of species with *Aegiceras corniculatum, Avicennia marina, Bruguiera cylindrica, Excoecaria agallocha, Lumnitzera racemosa,* and *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, 1998).

Recently the Wildlife Institute of India has recorded 10 species of mangroves namely *Aegiceras corniculatum, Avicennia marina, Bruguiera cylindrica, B. gymnorrhiza, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Pemphis acidula, Rhizophora apiculata* and *R. mucronata* (WII, 2007).

Kathiresan and Rajendran (l998) observed that most of the mangrove species in the Gulf of Mannar area are under threat (Table 2). No sustainable effort has been made to study the mangroves in a comprehensive manner (Nammalwar and Muniyandi, 2000). Hence, a need for proper management of mangrove vegetation in the Krusadi group of Islands was emphasized some 23 years before (Lakshmanan *et al.*, l984).

Table 2. Status of mangroves of Gulf of Mannar (Kathiresan and Rajendran, 1998)

No.	Name of mangroves	Status (based on IUCN)
1	*Aegiceras corniculatum*	Critically endangered, exist only in Kurusadai Island
2	*Avicennia marina*	Vulnerable, stunted growth in all Islands except in Mandapam groups of Islands and Kundhukal Island
3	*Bruguiera cylindrica*	Endangered
4	*Excoecaria agallocha*	Critically endangered, exist only in the Mandapam groups of Islands
5	*Lumnitzera racemosa*	Endangered
6	*Rhizophora apiculata*	Critically endangered, exist only in Kurusadai Island
7	*R. mucronata*	Critically endangered, exist only in Kurusadai and Mandapam groups of Islands

2.3. Biodiversity of mangrove ecosystems:

There are only a few studies on flora and fauna associated with mangrove systems of the Gulf of Mannar, as shown in Table 3. Thanks to the Central Fisheries Research Institute at Mandapam for a pioneer effort in preparation of a field guide for identification of species of Krusadai Islands, some 5-decade before (Chacko *et al.*, 1955).

Table 3. Biodiversity status of the region

Biological Group	No. of species recorded	Authors, Year
Total heterotrophic bacteria	35	Kannan *et al.*, 1998
Phytoplankton	126	-do-
Seaweeds Rajendran,1998	36	Kathiresan and
Mangroves	8	-do-
-do-	10	WII, 2007
Associated littoral plant species	17	Daniel, 1998
Annelides	6	Ramaiyan *et al.*,1996
Gastropods	60	-do-
Bivalves	20	-do-
Crabs 38	-do-	
Shrimp	4	-do-
Finfish	60	-do-

2.4. Mangrove restoration work:

The forestry sector has taken up some mangrove regeneration work in the Gulf of Mannar areas from 1994 onwards using *Avicennia marina* and *Ceriops tagal* in Thalaiyari and Muyal Islands. But, the performance of the plantation is in general poor due to lower growth rate and survival. This can be attributed to lack of proper sedimentation and poor freshwater source. 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. The establishment of mangrove seedlings depends on many factors such as canopy cover, substratum topography and crab mounds (Minchinton, 2001). For example, in a temperate forest in New South Wales, Australia the propagules and new seedlings of *Avicennia marina* are more abundant under the canopy than in gaps and on flat areas than on mounds. Four times as many propagules are dispersed away from mounds as from flats and this difference is greater under the canopy than in gaps, suggesting that this is an important microhabitat for recruitment. Seedlings survival to nine months is independent of habitat structure. The influence of mounds on dispersal is, however, much greater than establishment, so that densities of new seedlings nine months after establishment are greater on flats. Patterns of seedling abundance in the mangrove forest are thus primarily driven by the influence of habitat structure on the supply of propagules. In contrast, saplings are most abundant on mounds in gaps. Long–term survival of seedlings and their development into saplings is dependent both on light availability in gaps and on sediment disturbance resulting from the creation of mounds. The causative agent, crabs, may therefore be critical for regeneration of mangrove forests (Minchinton, 2001).

Management plan for the Gulf of Mannar Marine National Park and Biosphere Reserve has been prepared for the year 2007 – 2016 by Wildlife Institute of India. According to this plan, of the 19 existing Islands, only five Islands have enough area for further development of mangroves. In the Mandapam group of Islands, natural regeneration is observed in places where they were found degraded previously. Natural regeneration is found irregular because of no proper zonation in the colonization of the propagules. *Avicennia marina*, *Rhizophora mucronata* and *Ceriops tagal* are suggested to be the most suitable species for plantation (WII, 2007). A serious effort for restoration of mangroves in the Gulf of Mannar is highly warranted (Murugan, 2001).

3. Major Causes of Destruction and Degradation

3.1. Causes of degradation of mangroves

Degradations of mangroves are caused by nature-induced changes. Tropical storms are common in the Bay of Bengal and the Caribbean respectively. To cite an example, a cyclone has destroyed about 8.5 million trees in Bangladesh, which is equivalent to 66.3 million m^3 of sawed timber in the year 1988 (Hussain and Acharya, I994). The damaged forests take a very long time to recover.

Diseases also cause devastating damages to mangroves. For example, top dying disease has damaged about 45 million *Heritiera fomes* (Sundari) trees. This is about 20% of the entire forests in Bangladesh (Hussain and Acharya, 1994). The top dying disease is believed to be caused by an array of factors - increased soil salinity due to reduced water flow, reduction in periodic inundation, excessive flooding, sedimentation, nutrient imbalances, pathogenic gall cankers and cyclone – induced stress.

Biological pests and parasites also have serious impacts on mangroves. Significant damage is caused by grazing of buffaloes, sheeps, goats and camels in dry coastal areas of Asia and the Middle East. Young plants are damaged by barnacles and leaf eating crabs of the sesarmid family. Some caterpillars are parasites of the fruits of *Rhizophora,* and these inhibit seed germination (Kathiresan and Qasim, 2005).

3.2. Causes of man-made destruction

3.2.1. Cutting for timber, fuel and charcoal: Mangroves are cleared for timber, charcoal and firewood. Because of higher calorific value, the mangrove twigs are used as firewood. The mangrove wood is rich in phenols, and hence is highly resistant to deterioration, and it is widely used as timber for construction purpose.

Prevention of freshwater flow and tidal flow: Mangroves are best developed in areas that receive freshwater run-off and tidal water flushing. Embankment construction or siltation at the river mouths restricts the inflow of tidal water in mangrove swamps. Dam and barricade constructions in upstream areas for diverting water for irrigation purposes have resulted in poor flow of freshwater into mangrove swamps. The poor flows of tidal and freshwater result in high salinity of mangrove swamps and thus reduce the growth of mangroves.

Oil pollution: Oil or gas exploration, petroleum production, and accidents by large oil tankers cause significant damage to mangrove ecosystems. To cite an example, Nigeria's richest oil wells are situated close to inshore where rich mangroves once existed. Similarly oil tanker accidents in the Gulf of Mexico and in the Caribbean areas resulted in oil spillage that severely damages the coastal systems. As a result, the entire mangrove ecosystem gets affected, causing defoliation of trees, mortality of all sessile and benthic organisms and contamination of many water fowls. Once the mangrove forest is affected by oil pollution, it will take a long time of at least 10 years for recovery of the forest (Lamparelli *et al.*, 1997). Tuticorin area is vulnerable to such oil pollution issues.

Pollution issues: Mangrove habitats serve as a dumping ground for solid wastes and for discharging the effluents from various sources. The best examples of this are from Brazil and Singapore. In India as well, the mangroves that existed in major coastal cities like Kolkata and Mumbai are adversely affected by pollution, so as in Tuticorin.

Overfishing: The scientists from SDMRI reported destructive fishing in reef and mangrove areas of Tuticorin coastal waters (Deepak Samuel and Patterson, 2002). The coral mining and denuding of mangroves along Tuticorin coastal waters reduced the breeding grounds of shell and finfishes substantially. Adding to these losses, the illegal fishing and lapse on the part of government in implementing strict regulations also increased the destruction rate. The use of harmful nets such as Karai valai, Roller madi, and Sippi valai and dynamite fishing in coral and mangrove areas of Tuticorin coast, Tamil Nadu, India were assessed and their impacts are described with the list of species targeted (Deepak Samuel and Patterson, 2002).

4. Mangroves and climate changes

A growing threat to mangrove ecosystem is the climate change, associated with increasing temperature, changing hydrologic regimes, rising sea level, and increasing magnitude and frequency of tropical storms & natural calamities like tsunami (Field, 1995). Most mangrove habitats in the world experience increasing temperature, changing hydrologic regimes (*e.g.* changes in rainfall, evapo-transpiration, run-off and salinity), rising sea level and increasing magnitude and frequency of tropical storms and natural calamities like tsunami. Each decade would bring out a 0.3°C rise of atmospheric temperature and a 6 cm rise of the global sea level (Gregory and Oerlemans, 1998). If temperatures exceed 35°C, root structures, seedling establishment and photosynthesis will all be negatively affected. The mangrove-associated fauna would be affected both directly by climatic changes and indirectly by changes in the mangroves.

To these changes, mangroves are likely to be one of the first ecosystems to be affected because of their location at the interface between land and sea. A large part of the coastal area will be vulnerable to cyclonic storms and surges. It is likely that intensity of tropical storms would increase in the event of global warming (Knutson *et al.*, 1998). A possible increase in cyclone intensity of 10-20% is expected for a rise in sea surface temperature of 2 to 4 °C (Offshore Eco, 2003). The impacts of any increase in the frequency or intensity of cyclones due to global warming and consequent sea level rise would highly be devastative in heavily populated areas.

Mangroves especially of low-lying Islands as in the Gulf of Mannar are likely prone to sea level rise. Recently the Gulf of Mannar area has experienced submergence of two Islands. Similarly, in Indian Sundarbans, two Islands namely Suparibhanga and Lohacharra have recently submerged, rendering over 10,000 people homeless and a dozen other Islands on the western end of the inner estuary delta are under the threat of submergence which may evacuate nearly 100,000 people from the Islands in the next decade. The sea level will rise about 45 cm by the year 2050 along the Bangladesh coast and Indian coast. While estimating potential threat of sea level rise (SLR) on the mangrove ecosystem of Bangladesh, the World Bank has projected that 10 cm SLR inundates 15%, 25 cm SLR inundates 40%, and 45 cm SLR inundates 75% of the Sundarbans. At 1 m SLR the Sundarbans would completely disappear (World Bank, 1999).

As the sea level rises, mangroves would tend to shift landward. Human encroachment at the landward boundary, however, makes this impossible. Consequently, the width of mangrove systems would be likely to decrease with the sea level rise. Once the mangroves degraded, it may require fairly long periods to recover from even minor disturbances. This habitat loss might cause a gradual depletion of rich biodiversity of the forest flora and fauna of the mangrove ecosystems. The tsunami-induced damage to coastal ecosystems in four Nicobar Islands, *viz.* Camorta, Katchal, Nancowry and Trinkat reveals the extent of damages ranged from 51 to 100% for mangrove ecosystems, 41 to 100% for coral reef ecosystems and 6.5 to 27% for forest ecosystems. The severity of damages and their consequences suggest the need for a definite restoration ecology programme (Ramachandran *et al.*, 2005).

However, in the mangrove ecosystems, there are a few genetically superior organisms, which can overcome any climatic change. Species that are tolerant of increasing temperatures (*e.g.* fish, gastropods, mangrove crabs and other crustaceans) may adjust rapidly to the changes. In contrast, soft-bodied invertebrates would be very sensitive to higher temperatures. Desiccation that would accompany increasing temperatures would harm many marine species associated with mangroves (Kathiresan and Bingham, 2001). It is therefore, suggested as a long term plan (i) to identify the mangrove genotypes and fauna which are tolerant to temperature and flooding, (ii) to propagate those genotypes, (iii) to create new hybrid species from those genotypes, for biodiversity enrichment and coastal protection against the climate change (Rajendran and Kathiresan, 2006).

Results of a study in 10 countries and territories of Pacific Islands sponsored by the UNEP highlight the following seven technical and institutional capacity-building priorities (Gilman *et al.*, 2006):

- Strengthen management frameworks regulating coastal activities to develop a plan for adaptation to mangrove responses to climate change effects. This will require developing local capacity (i) to conduct site-specific mangrove vulnerability assessments and to incorporate this information into land-use and master planning, and (ii) reduce and eliminate stresses that affect mangroves, in part, to increase resistance and resilience to climate change effects;
- Determine projections of trends in mean relative sea level and frequency and elevation of extreme high water events (a minimum of a 20 year local tide gauge record is required to obtain an accurate trend in relative sea level);

- Measure trends in changes in the elevation of mangrove surfaces to determine how mean sea level is changing relative to the elevation of mangrove surface;

- Assess how the position of mangrove margins have changed over past decades through observations of a time series of historical remotely sensed imagery and use this information to predict the future mangrove position;

- Provide training opportunities for in-country staff;

- Establish mangrove baselines and monitor gradual changes through regional networks using standardized techniques; and,

- Produce maps showing mangrove boundaries, topographic information and locations of coastal roads and developments, and use these products to assess site-specific mangrove vulnerability to projected sea level rise.

5. Conclusion & suggestions

There is no previous survey of mangroves for the whole of the Gulf of Mannar nor are there any bench mark studies on the flora. Data are not at all adequate on the following five aspects. In absence of these data, conservation and management of the mangrove resources is very difficult.

(i) vegetation characteristics such as species composition, distribution, height and density;

(ii) biodiversity status of each species;

(iii) habitat characteristics such as soil texture, composition, salinity, *p*H, nutrients and trace elements;

(iv) environmental characteristics such as rainfall, wind speed, evapo-transpiration, tidal characteristics; and,

(v) threat factors in those mangrove-colonized Islands.

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 marine organisms needs to be studied (Kumaraguru *et al.*, 2006).

Sea level rise is a serious threat especially to the low-lying Islands of the Gulf of Mannar in the context of a prediction that another giant wave is likely to strike off the Indian Ocean region within 30 years (Borrero, 2006).

The following suggestions are made for assessment of 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.

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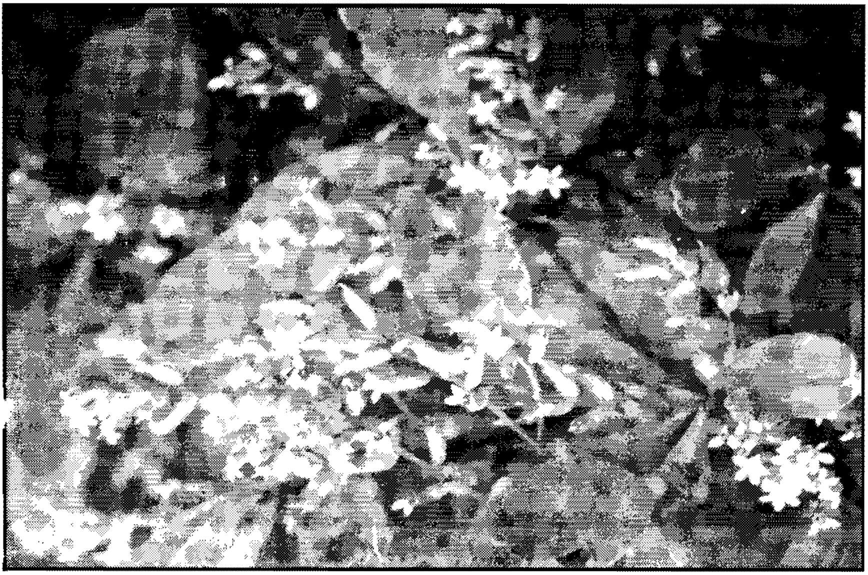
***Aegiceras corniculatum* (L.) Blanco (with curved fruits)**

Avicennia marina (Forsk.) Vierh.
(with pneumatophores and Inflorescence)

***Bruguiera cylindrica* (L.) Bl. (with flowers)**

Ceriops tagal (Perr.) C.B. Robinson
(with viviparous hypocotyls)

Excoecaria agallocha L. (with inflorescence and fruits)



Lumnitzera racemosa **Willd. (with flowers)**

Pemphis acidula **Forst. (with flowers)**

Rhizophora apiculata **Bl. (with flowers)**

***Rhizophora mucronata* Poir.**
(with viviparous hypocotyls and stilt roots)

SEAWEED FARMING - ALTERNATIVE LIVELIHOOD

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Introduction

Seaweeds are one of the commercially important marine renewable resources. They are non vascular, cryptogamic plants. Seaweeds are belong to three groups namely Chlorophyta (green algae), Phaeophyta and Rhodophyta (red algae) (brown algae) based on the pigments, morphological and anatomical characters were present in them. Seaweeds are distributed with in various ecosystems (intertidal, shallow and deep water, mangroves, estuaries, coral reefs and lagoons).

Seaweeds are one of the commercially important renewable resources of our country. They contain more than 60 trace elements, minerals, protein, iodine, bromine, vitamins and several bioactive substances of economic value and they also serve as both feeding and breeding grounds for invertebrates and fishes (Patricia Burtin, 2003;Krisnamurthy,2005).Of 20,000 species in the world, 844 species are in India with total standing crop of 91,339 tons (wet weight) consisting of 6,000 tons of agar yielding seaweeds, 16,000 tons of algin yielding seaweeds and remaining edible and other seaweeds (Kaliaperumal, 2000).

Seaweeds are used as food, animal fodder, meal and manure. Antitumor activity, antimicrobial activity, anti hypercholesterolemic activity, anti coagulant substance, immunomodulating activity, immunosuppressive activity and anti ulcer activity are mentioned bv (Anantharaman *et al,* 2006).

Seaweed cultivation and value addition should be taken up as a mission mode project of fishermen co-operatives and self-help groups of the coastal areas, particularly in the PURA (Providing Urban Amenities in Rural Areas) complexes in partnership with scientists and industrialists. This will enable creation of industries for producing carrageenan and bio-fertilizer in coastal PURA itself resulting in substantial amount of revenue increase to fishermen and farmers (Honorable Former President of India Dr. A.B.J. Abdulkalam speech on Science and Technology Day, 11 May, 2006).

"Seaweed farming helps protect our remaining coastal resources by building up other marine life and providing alternative livelihood for coastal fishermen, who might have otherwise have resorted to cyanide and dynamite fishing."

Commercial exploitation

Agar - agar

Agar is a major constituent of cell walls of certain red algae, especially members of Gelidiaceae and Gracilariaceae. The term agar is now generally applied to those algal galactans which have agarose, the disaccharide agarobiose, as their repeating unit. Until about 1900 agar was commercially exploited for mainly used as food item. As a significant quantity began to be used for microbiological plating media, it became the first seaweed polymer extract to achieve commercial status for purposes other than food use. It is excellent gelling property use in bakery products, confectionery making and in puddings, creams and gelled products. It is also used in the preparation of canned meats and fish as a clarifying agent in wines and beers (Levring *et al.* 1969).

Algin

Algin or alginic acid is a major constituent of all brown algae. It is a polymer of D-mannuronic acid and L-guluronic acids; the various salts of alginic acid are termed 'alginates'. Alginic acid and its salts with divalent and trivalent metal irons are generally insoluble in water, while alkali metal salts are water soluble. Algin products are used as binders, stabilizers, emulsifiers, and moulding materials in the pharmaceutical industry, in cosmetics and sops, in dental and food technology, in bakery and candy products, in dairy products, and in fish, meat, sausage and beverage processing. They are also used in a wide range of industrial products including dyes, paints and other coatings, in binding briquettes and explosives, in producing paper and cardboard products, in filters and absorbents, in textile production, in pesticides, polishes and lubricants, in fire retardants and extinguishers, in enameling and ceramics and in other miscellaneous applications(Levring *et al.*1969).

Seaweeds are commercially exploited due its uses. Since 1956 the commercial exploitation of seaweeds started in India (Silas and Kalimuthu, 1987). Detailed account on the distribution, potential areas for commercial exploitation of seaweeds, their standing crop in different maritime states of India and the seaweed resources in estuaries and backwaters of Tamil Nadu and Pondicherry was given by Kaliaperumal *et. al.* (1995), Kaliaperumal *et. al.* (1987), Kaliaperumal and Kalimuthu (1997), However, the need for commercial cultivation of agar yielding red algae was also stressed by Kalimuthu and Kaliaperumal (1996) due to increasing utilization of agar. Knowledge on the availability and exploitation of seaweeds in the previous years will help for rationales exploitation and for the sustainable utilization in the future. Information on the total quantity of agarophytes viz. *Gelidiella acerosa, Gracilaria edulis, G. Crassa* and *G. folifera* and the alginophytes Sargassum spp., Turbinaria spp., is also available (Kalimuthu *et. al.*, 1990; Kalimuthu and Kaliaperumal, 1996; Kaliaperumal and Kalimuthu, 1997). The seaweed exploited localities in Tamil Nadu is Rameswaram, Pamban, Vedalai, Seeniappa Darga, Pudumadam, Periapattnam, Kalimankundu, Kilakarai, Ervadi, Valinokkam, Mundal and Kanyakumari area.

Carrageenan

Carrageenan is a family of sulphated polymers obtained from various red algae *Chondrus* from Gigartinaceae, *Eucheuma* of the Solieriaceae and *Hypnea* of the Hypneaceae. Until the 1930's, commercial harvest of carrageenophytes went to supply home uses of carrageenan in cooking, cough syrups, and so forth. Numerous applications have been developed for carrageenan in food products and processing, in pharmaceutical applications, in cosmetics, in coatings, such as paints and inks, and other products and processes. Several other carrageenan like polymers, especially furcellaran and funoran find similar uses (Levring *et al.* 1969; Whistler 1973).

Threats

Trawl net operation over the seaweed beds, siltation and sedimentation by erosion, accretion process and deepening the harbour areas are the major threats to the seaweed distributions. Alteration of the major ecosystems like estuaries, mangroves, coral reefs are also affecting the seaweed distribution. As the demand for raw material of seaweed based industries leads to extensive and unrestricted commercial harvest of seaweed through the year, there is depletion in the natural stock of the red algae. Loss of vegetation in the upstream, enhance siltation on coastal ecosystem. Suspended sediments harm algal thallus and reduce population density and diversity. Construction of structures along the coast which cause erosion and accretion also affects the distribution of seaweeds.

The use of seaweed in medicine is not wide spread, the use of seaweed polymer extract in pharmacy, biochemistry is well established. All these and many other uses of seaweeds will demand continuously supply of good quality of raw material. To meet this challenges, it is necessary to develop an appropriate cultivation technology (Anantharaman, 2006).

Seaweed Industry in India

A status report of the Indian seaweed industry was given by Kaladharan and Kaliaperumal (1999). The over exploitation of agar yielding seaweeds has led to the scarcity of raw material to agar industries. To overcome the paucity of raw material *Gracilaria edulis* for agar production. *Gracilaria crassa* and *G.folifera* from Kattumavadi area in Palk Bay are harvested since 1990 (Kalimuthu and Kaliaperumal, 1991).

Agar is produced in the forms of mats, shreads and powder. The bacteriological grade agar with a gel strength of 600 g/cm^{2}is manufactured from the red algae *Gelidiella acerosa* spp. yield food grade with a gel strength range of 120 to 150 g/cm^2. The annual production of agar in India ranges from 110 to 120 tonnes utilizing about 880 to 1100 tonnes of dry agarophytes. The present cost of 1 tonne of raw material varies from Rs.12000 to 15000 for *Gracilaria crassa* and Rs.4000 to 5000 for *Gracilaria edulis* and other *Gracilaria* spp. The market rate for food grade and Rs.200 to 300 per kg for food grade and Rs.450 to 600 per kg for bacteriological grade depending on the quality.

At present, resource of alginophytes is quite adequate. The brown algae viz., *Sargassum* spp. and *Turbinaria* spp. are mainly used for the production of alginates in India. Alternately trails were made using *Cystoseira trinodis* during 1996-1998. *Sargassum* spp. are preferred over *Turbinaria* spp. since the yield and quality of alginates are high in the former. The total annual production of alginates in India ranges from 360 to 540 tonnes utilizing 3600 to 5400 tonnes of dry alginophytes. Alginates are produced either as granules or powder and marketed at the rate of Rs.100 to 150 depending on their quality.

The annual requirements of raw materials for Indian seaweed industries is about 2000 tonnes (dry weight) of agarophytes and 12,000 tonnes (dry weight) of alginophytes. The available resource of agarophytes is inadequate to meet the demand of agar industries. Hence there is an immediate need to start commercial scale cultivation of agarophytes in order to augment the supply of raw material to the Indian agar industries for their successful running throughout the year. The large scale cultivation of the agarophyte, carrageenophyte and alginophyte which is alternate employment opportunity to the coastal dwellers.

Seaweed culture is a good economic activity for the rural poor in view of the following merits:1. It requires only less capital, 2. it does not need inputs that are potentially harmful to the environment, 3. seaweed farms are not labor – intensive and 4. The market for seaweed extracts – agar, algin and carrageenan, are diversified and are valued in food, pharmaceutical and other industrial sectors.

Seaweed culture/ Commercial success

Success is defined as being socially, economically and environmentally sustainable production. Crop factors critical to commercial success in production systems includes 1. The population – which is the natural population or cultivated seed stocks that is used as the basis of commercial seaweed culture for production. 2. The method – which includes agronomic and processing protocols followed to achieve commercial culture for production within the economic goals. 3. The location – which must be chosen carefully because good site selection will make or break any commercial seaweed farming.

Recommendations for Seaweed cultivation

1. National Academy of Agricultural Sciences of India in their policy paper 22 has recommended that "Commercial cultivation of macroalgae should be a national priority and taken up as a mission mode project. A new model cell for promotion of commercial cultivation, processing and marketing of macro algae should be set up in the ministry of Agriculture. It will be responsible for coordinating with other concerned Ministries and departments such as Environment and Forest, Ocean Development, Biotechnology, Industry, Commerce, Coast guard, port Authorities, Co-Operatives, Customs & Excise as well as the State Government".

2. Since "cultivation is done below the low tide mark, CRZ regulations should not be applicable to seaweed farming".

3. "Cultivation of macro algae and the dried macro algae so produced shall be treated as agricultural cultivation and agricultural produce for the purposes of fiscal as sales tax, income tax, excise, octroi etc".

4. Integrated cultivation of shrimp and seaweeds should be encouraged in aquaculture as seaweeds act as scrubbers in reducing and cleaning the environment".

5. "Seaweed cultivation should be encouraged all over the Indian Coasts including Chilka Lake, Palk Bay, Andaman Islands as well as Lakshadweep Islands. Seaweed cultivation is ecologically safe and does not damage the marine ecosystem".

6. "To ensure dependant supply of raw material high priority should be accorded to cultivation of agarophytes and carrageenophytes".

7. Seaweed farming should be treated on par with sea-related activity such as fishing with all incentives. Seaweed cultivators should be exempted from taxation/fees in the form of lease rent. The Government should create the basic infrastructure such as road, drinking water, drying yards and storage.

Alternative Livelihood as a Policy Option

There are many examples of the promotion of alternative livelihoods for coastal communities and small-scale fishers, especially the introduction of various forms of mariculture. There are two main objectives for the promotion of alternative livelihood. The first is to raise the economic standard of living of fishers and coastal communities, and the second is to reduce fishing effort. Alternative livelihood as a solution to overfishing has been proposed for more than two decades. Smith (1979) recommended alternative income sources such as seaweed farming as one type of incentive to reduce fishing pressure as long as they are attractive enough to reduce full-time fishing. However, he also reported that only 50% of fishers are willing to change their occupation, with households more dependent on fishing more receptive to occupational change. Willingness to change was also higher in more geographically isolated locations, among poorer, younger, less educated and less successful fishermen, groups less likely to accept the risks of a new activity. Therefore, he recommended an emphasis on supplemental rather than alternative employment, encouraging a shift from full-time to part-time fishing.

Training Programme

The entire farming community of the area where seaweed cultivation is feasible will be educated about the significance and the benefits of the of the seaweed culture in their villages. The training programmes which will be organized in local languages will be of short term duration and will be phased in a manner that they do not interrupt the normal activities of the trainees. The technology and financial assistance will be made available to them. The seaweed culture will be demonstrated to the fishermen, marginal agricultural farmers, landless laborers and women folk. The progress of work will be closely monitored in the culture site periodically.

Rationale

The demand for seaweed is immense. This program on seaweed culture will help to revolutionise the rural economy along the coastal region. Through training and demonstration they can be motivated to undertake seaweed culture. The training part includes an initial orientation training, subsequent training at the appropriate time for the different phases of culture operations, post harvest technology and final refresher training.

The second programme is for the interested parties and entrepreneurs who can afford to invest money for purchasing the inputs required and for engaging the people to carry out culture operations. For them, the training will be given at the institute itself, so that they can put to practice the technology learnt by them in a place of their choice that is suitable for seaweed culture.

The transfer of technology programme also includes printing of handouts and pamphlets in regional languages and distribution among the public. The message and methods of science and technology could be spread by conducting farm fairs inviting fishermen, landless labour and other interested public to witness the various aspects of technology being demonstrated. Mobile exhibition to reach the coastal sector and participation of the concerned scientists in the rural programmes of All India Radio and organizing public lectures in the coastal areas will be helpful for popularizing seaweed cultivation in the coastal areas.

Rehabilitation programmes

Formation of SHGs and bank loan for cultivators

SHGs of women/men have to be formed with 12-20 members to avail a bank loan upto Rs. 5.0 lakhs without collateral security. If it is an individual, collateral security to be produced. Commercial banks such as State Bank of India have studied the economic viability of *Kappaphycus* seaweed cultivation and have come forward to lend to a loan upto Rs. 1.0 lakh per family. Each family may need 150-200 rafts to have a daily harvest and earn a daily income ranging from Rs. 300-500 according to the amount of labour and growth of seaweeds (Sakthivel, 2006).

Economic viability

A group of fisherfolk was involved in the seaweed cultivation. They adopted raft technology, which was developed by CSMCRI, to grow seaweed on shallow water they become experts under the guidance of Pepsico team after initial hiccups. Now, even an illiterate woman, who took the initiative with much hesitation, can earn Rs. 4000 to Rs. 5000 a month. If two persons, preferably a male and female, engage in the work, they can earn a minimum of Rs. 12,000 a month. It involves only seven to eight hours of work a day. There is no need for pesticide or chemical. It needs only maintenance. If two persons handle three rafts a day, they can harvest 540 to 600 kg a day. In turn, they can earn Rs. 375 to Rs. 420 a day.

The Central Salt Marine Chemical Research Institute and Pepsico India Holdings LTD initiated the seaweed *Kappaphycus* on one km shallow seawater stretch of Munaikadu near Mandapam. CAS in Marine Biology (Annamalai University) in collaborated with Pepsico India Holdings LTD and Aquaculture Foundation of India initiated the raft culture method of seaweed (*Kappaphycus)* and they trained up more than 100 coastal poor at Parangipettai coastal regions. CAS in Marine Biology also involved seaweed cultivation training programme for tsunami affected self help groups and coastal poor, in collaboration with PepsiCo-Private holding Ltd and Aquaculture Foundation of India (Sponsored by Govt. of Tamil Nadu, Swarnajeyanthi scheme).They provide workshop on seaweed *Kappaphycus* culture for NGOs, coastal poor and students (Self-funded project). *Kappaphycus* culture (Anantharaman *et al.,*2006) and seaweed culture management (Anantharaman and Thirumaran, 2006).

Assumptions

1. One SHG has max. of 20 members; each members to have 45 rafts
2. Culture period 45 days
3. Hence total no. of rafts to be financed – 900 per group
4. Total cost (900 x Rs.690/-) = Rs.621,000
5. Subsidy from Project Officer, DRDA = Rs. 125,000
6. Net Bank loan = Rs.496,000
7. Dried seaweed@ Rs.8.50/kgm,
8. Supply input materials, rafts etc as per cost indicated above
9. Sale proceeds through the bank
10. There will be no culture in October, November, December on account of North East Monsoon in the East coast and June-August in the West coast. Hence no repayment is fixed during the 3 months.

11. 900 rafts per SHG has been arrived @ 45 rafts/member. In case the SHG has less than 20 members, and the number of members in a particular group to take up seaweed culture is less than 20, the total number of rafts to be financed will be calculated on the basis of 45 rafts per member.

Economics of Seaweed culture (Sakthivel, 2006)

1. Total yield of seaweed per raft in 45 raft days – 260kg
2. After retaining 60kg as seed for the next crop, balance available for drying – 200kg
3. Dry seaweed available for sale, after two days of solar drying (10%) – 20kg
4. Estimated yield of dried seaweed available for sale after wastage – 18kg

Income

1. For one cycle – 18kg x Rs. 8.50 x 900 rafts	: Rs.137,000
For 4 cycles in the 1 year	: Rs.550,000
For 6 cycles in the II and III year	: Rs.826,200/year
2. EMI (for 24 months)	: Rs.22,385
3. DSCR	: 1:4:1
4. Interest Rate	: 7% pa

Conclusion

Seaweed farming tends to be a good fit to the supplemental livelihood model. Since seaweed farming and other "alternative" or "supplemental" livelihoods do not always result in reductions in fishing, this goal needs to be carefully reassessed and perhaps abandoned altogether. Where fishing effort reduction is a strategy, more careful investigation and tailoring of livelihood development programs will be needed to ensure exit objectives are met. More specifically, unless livelihood strategies are combined with resources management strategies that address that open access nature of coastal fisheries, progress towards improved fisheries management will be limited. However, it seems that livelihood development and economic improvements in the welfare of coastal communities can be achieved through programmatic initiatives.

Providing alternative livelihood to fishers that simultaneously improves their economic condition and reduces fishing pressure can be achieved in some instances. However, in cases where fishers do not fully exit the fioishery and a shift from full to part time fishing is likely, a limited degree of effort reduction can result, at least temporarily. Whether seaweed cultivation leads to entry or exit from fishing depends to some extent on world market and prices for seaweed. However, non-economic factors often keep fishers in the occupation of fishing. The viewpoint of supplemental livelihood rather than alternative livelihood makes better sense as this strategy attempts to reduce household dependence on fishing but acknowledges that some fishers may still like to engage in fishing. However, with population growth and low employment, exit from fishing does not prevent entry as well, so even if some fishers leave to take up alternative employment, there will be new entrants. These new entrants will still be faced with the same dilemma of previous fishers, too many fishers and not enough fish, exacerbating the overfishing problem and driving down earnings per fisher. Without some form of limited entry, the fishery will tend to move to the economic equilibrium point of opportunity wages. As previously noted, there may be several reasons why the fishery moves below the open access equilibrium point as predicted by classic bioeconomic model of a fishery. In addition, while some fishers may do well, others will do poorly as some degree of income variability and non-equity will always exist. Only if regional employment and wages increase can overall wages of fishers increase.

Alternative livelihoods to some extent can contribute in this regard but economic overfishing will still occur with an open access regime. Rather than emphasizing alternative and supplemental livelihoods, development programs should learn from the traditional economic strategies demonstrated by the coastal communities and households. Economic diversification may be a better goal than alternative or supplemental livelihood. Diversification is a common business strategy, and rural households can in fact be considered as small-scale businesses. Diversification provides stability to families and the ability to ameliorate and survive through periods of large-scale ecological and global market changes. This may be a better means of promoting sustainable coastal communities and making progress on our journey towards sustainable development.

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TRAWL BYCATCH RESOURCES: SUSTAINABLE UTILIZATION FOR MARINE BIODIVERSITY CONSERVATION AND ALTERNATE LIVELIHOOD

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"States should improve the use of bycatch to the extent that this is consistent with responsible fisheries management practices"

(clause 8.4.5) ***FAO Code of Conduct for Responsible Fisheries***

Introduction

The Indian marine fisheries sector plays a very vital role in supplying protein rich food to the exploding population, employment generation and foreign exchange earnings. From the economic point of view, fish and fisheries contribute a lot to national economy and foreign exchange earning for any developing maritime countries. India is bestowed with an extensive coastline of over 8129 km, 0.5 million sq.km. of continental shelf and 2.018 million sq. km. of exclusive economic zone (EEZ), with an estimated annual marine fishery potential of 3.9 million tons

Commercial extinction of target fish species?

The 21st century marine fisheries scenario is facing a pathetic situation in recent years due to declining yield of the target species in terms of catch per unit effort. This might be due to irrational overexploitation, indiscriminate fishing practices like capturing of juveniles and brooders, coupled with other hazardous anthropogenic activities like habitat destruction and pollution that further decimate the population. Unregulated exploitation of fishery resources so as to cater their increased demand made the fishery resources especially the target fish species at considerable risk.

For instance, the Indian marine fisheries statistics evinced nearly a six fold increase in fish catch from 1950 (0.38 m tones) to 2003 (2.6 million tons).This might be attributed to the tremendous developments in the field of fisheries such as modernization of fishing craft, gear & processing technologies. Further, government subsidies allotted from the fourth quarter of last century, for the fisher folk, also lead to the fabulous increase of fishing boats (trawlers) in the entire coastal belt. It has to be said that with the improved technology, the number of crafts and gears boosted up, the fishing effort doubled; but not the stock in the wild which got dwindled. An alarming condition like this will surely pave way to the commercial extinction of target fish species in near future.

In ecological perspective, overexploitation or disappearance of any one species may lead to, in due course, to a biodiversity crisis; as it is well understood that species in the ecosystem are dependant upon each other as vast ecological communities and systems. Thus, management of economically valuable living resources is therefore an important part in conservation of biodiversity.

Understanding this distressing state, the FAO Code of Conduct for Responsible Fisheries (Clucas, 1997) advised the maritime nations "to establish principles and criteria for the elaboration and implementation of national policies for responsible conservation of fisheries resources and fisheries management". This situation warrants rational management; hence focus should be directed on all aspects of fisheries with special emphasis on the effective utilization of bycatch resources so as to minimize the fishing pressure exerted on target fish groups

Plate 1. Discarding of bycatch

Sustainable utilisation of bycatch resources - A better alternative for fisheries management and alternate livelihood

FAO Code of Conduct for Responsible Fisheries (Clucas, 1997) emphasised that "states should improve the use of bycatch to the extent that this is consistent with responsible fisheries management practices" (clause 8.4.5).Utilization of bycatch resources is strictly necessary, as they constitute significant proportion in marine landings.

The term 'bycatch' is defined as the catch which is retained and sold but which is not of the target species for the fishery (Clucas, 1997). Estimated marine fish landings for the year 2003 revealed that bycatch species were caught to the tune of 56696t as miscellaneous among pelagic finfish captured, about 25248t among demersal finfish, followed by 37341t of stomatopods (crustaceans) and 1734t of molluscs apart from cephalopods (CMFRI, 2004). Besides, a considerable proportion of the target fish species population captured were discarded as waste as they were undersized or damaged due to mishandling and poor preservation facilities on board. It has been estimated that 23% of total fisheries catch around the world is discarded. This amounts to nearly 20 million tonnes of unwanted catch being thrown back into the sea each year. Discard of bycatch organisms back to sea create lot of problems as majority of them die after capture or in such a moribund state that they will not survive. Moreover, discard of bycatch species has adverse impacts either biologically, ecologically or economically. One of the options that are apparent for overcoming the problems of discard in fisheries is that more quanta of fish should be used for human consumption, assuming that it is consistent with responsible fisheries management practices. Thus, there is an imperative need to exploit these resources effectively than merely discard them at sea, so as to cater the protein requirements of exploding populace. In this backdrop, it is imperative to sketch out all possibilities so as to achieve the goals of effective utilisation of bycatch, either directly or indirectly.

1. Bycatch / Non-target species as alternative food species

Fish accounts for about 16 % of the average per capita consumption of animal protein worldwide, and the proportion is still higher in many developing countries (WRI, 1996). As the population of target fish species is declining in a faster pace, it is inevitable to promote alternate species as food species so as to satisfy the demand. Investigations on bycatch constituents proved that there exist quite a lot of species that are viable round the year in higher quantities, with significant proximate composition. These species can be considered or converted as edible ones. For example, stomatopods (*Squilla*), which are landed in bulk quantities forms a chief bycatch component of shrimp fisheries. Majority of the species of these groups are highly rich with regard to it biochemical composition (Paul, 2002). But people are reluctant to use stomatopods due to sheer ignorance and several false beliefs. Presence of spines on their exoskeleton is a major constraint that hampers the easy removal of meat. Boiling the organisms along with certain chemicals is a solution to this. Steps should be directed to popularize stomatopod resources as a table dish will provide a sigh of relief to the already stressed shrimp fisheries. Similarly, crab fishery in mangroves for mud crabs of Scylla spp. can also be diverted to another species, namely, *Metapograpsus messor* owing to its positive traits such as bigger size, high number in mangroves and ease in procure. The populace is reluctant to use these species as edible ones either due to shear ignorance or due to some minor reasons or false belief and their mindset has to be changed. This will create a sigh of relief to the already overexploited target fish species groups

2. Bycatch resources as Export items

Fish and fisheries contribute much to our national economy and foreign exchange earning. There are species which we considered as trash has immense demand in other countries. For instance, processed jelly fish is one among the most palatable dish of Japan and China. Similarly, puffer fishes (Family: Tetrodontiformes) are the esteemed choice of Japanese. Roe (gonad) of sea urchin has great demand in Canada. But in our country these are considered as trash fish which are landed in considerable proportions during certain seasons. By investing less money and by using indigenous technology, these products can be treated and converted to export grade items. Immense care should be directed on proper methods of processing of these resources which will definitely pave way to the effective conversion of them as valuable export items.

3. Value Added Products from bycatch resources

Value addition is a buzzword in the fish processing industry because of the increased realization of foreign exchange and high unit value for such products. Value added products means addition of value to the fish either by changing or concentrating its consistency or by enrichment or extraction of proximate or bioactive compounds from its crude state (Malcolm and Barlow, 1981). The bycatch resources can be effectively utilised and converted for the production of a vast array of value added products like Fish Protein Concentrate (FPC), Silage, Collagen Chitin, Chitosan, Fish pickles, Sausages, Surimi, breaded or battered products etc.

3.1. Fish Protein Concentrate (FPC)

Fish Protein Concentrate is defined as any stable fish preparation, intended for human consumption, in which the protein is more concentrated than in the original fish. These are typically made by hydrolysing fish protein by means of enzymes or other chemicals and then concentrating the product into a paste or extract. FPC are superior to any other protein source as the quality of the protein is high because the amino acids present in it are at right proportion for human nutrition. Untreated and unprocessed foods do not generally contain more than about 20 % protein, whereas FPC contains about 80 % that makes it more pronounced.

The Food and Agriculture Organization (FAO) classifies fish protein concentrate into three types, namely, *Type A*- a virtually odourless and tasteless powder having a maximum total lipid content of 0·75 percent; *Type B* - a powder having no specific limits as to odour or flavour, but definitely having a fishy flavour and a maximum fat content of 3 per cent; *Type C* - Normal fish meal produced under satisfactorily hygienic conditions.

Type B, the dehydrated fish powder, is found to be highly acceptable (Stillings, 1967; Gopakumar, 1979). Type A, which is a bland powder is incorporated in bread, biscuit and beverage production. Extensive studies conducted showed a remarkable response to FPC evidenced by improved weight gain, haemoglobin content and increase in mid-arm circumference (Helge Moller, 1983).

Special emphasis should be directed to the commercial level manufacturing of FPC from bycatch fishes which will solve the problem of malnutrition to a greater extent.

3.2. Fish Silage

Fish silage is a liquid product made from whole fish or parts of fish to which no other material has been added other than an acid. The liquefaction of the fish mass is brought about by enzymes already present in the fish. The product is a stable liquid with a malty odour which has very good storage characteristics, but which contains all of the water present in the original material. Fish silage production is a simple process that requires only less capital equipment and any bycatch fish species can be utilised.

3.3. Fish body oil & liver oil

Finfishes from the bycatch can be effectively employed for the extraction of fish body oils and liver oils. Fish oil mainly composed of triglycerides and a unique combination of compounds which are strictly necessary for human health and longevity. Fish oil is enriched with unsaturated fatty acids which are capable of reducing blood cholesterol level and also aid in the production of prostaglandins. Fish liver oil is mainly sold for medicinal or veterinary purposes and is highly priced for its vitamin A and D content.

3.4. Fish pickles, surimi, sausages, breaded & battered products

Bycatch fishes can be effectively utilised by converting them into more palatable items like pickles, sausages, Surimi, breaded or battered products etc. Fish pickle is a value added item whose bulk is contributed by low value items like ginger, chilly, acetic acid etc. Surimi is a Japanese term for mechanically deboned fish mince from white-fleshed fish that has been washed, redefined and mixed with cryoprotectants for good frozen shelf life. For fish sausage, surimi is the base material which is homogenized after mixing with several other ingredients. The homogenized mass is stuffed in synthetic casings like Ryphan (Rubber hydrochloride). The casing is closed using metal rings after which it is heated in water at 85-90^{0}C and then slowly cooled. After drying the surface the sausage is wrapped in cellophane laminated with polythene. Women self help groups can take this as a better choice of income generation as the raw materials are of low-cost or free of cost. As a prelude to this, it is to keep in mind that, stuffs which are produced in hygienic conditions should have a good shelf life and high market demand. The packaging materials employed should be sufficiently strong and durable to withstand stress during handling, storage and distribution.

3.5. Fish scale collagen peptide

Collagen is another important nutrient needed for body metabolism. Fish Collagen is made from fish scale by enzyme engineering technology. As fish collagen is devoid of fat, it is a suitable food additive apart from its health, pharmaceutical and cosmetic applications.

3.6. Chitin and chitosan

Chitin is a polysaccharide found in the exoskeleton of decapod crustaceans like shrimp or crabs. Chitosan is a natural product derived from chitin. Undersized and non-target species of shrimp as well as crab species can be used for the extraction of these valuable compounds. The importance of chitin and chitosan has increased significantly because of the potentials of these products and their applications to a large number of scientific, industrial, cosmetic and medicinal applications. New forms and derivatives of chitin and chitosan are being reported, many of which have tremendous applications in commercial products. The existing technology for the isolation of chitin from shrimp shell waste has to be standardised for bycatch crustacean resources, which will be a boon for its sustainable utilisation. Proper vigil should be directed on every step of its extraction and production as the suppliers and users are specifying strict standards for different forms chitin and chitosan for various end uses.

4. Commercially viable products

Bycatch organisms having tremendous prospects for the production of diversified products like pearl essence, isinglass, fish leather, glue and gelatine etc. which are having immense industrial and market value. The existing technologies for the production of these products are to be modernized to get more fruitful results.

5. Augment the utilisation of bycatch as fish meal

Fish meal produced throughout the world is a very cheap potential FPC, but is not intended for human consumption. Presently they are used as the chief ingredient for cattle, pig, chicken and shrimp feeds. Steps should be taken to enhance the present level of exploitation of bycatch resources for the preparation of fodder, poultry and shrimp feed by giving stress to its value addition.

6. Ornamental purpose

Substantial quantities of molluscan forms (gastropods & bivalve' landed as bycatch along with trawl catch is having aesthetic value a: ornamental articles. Shells of the species, *Conus, Oliva* etc. have excellent demand in international market. Sacred chank *Xancus pyrum,* matter of veneration for Hindus is also a trawl bycatch Special emphasis should be directed on this line to augment the proper exploitation of these resources.

Juveniles or undersized animals of target species are also thrown as trash as it does not have market demand. These are carefully segregated from trash onboard and should be returned to sea itself, which will aid in the proliferation of natural stock. For instance, live, undersized and soft shelled (freshly moulted) crabs of desired species like *Scylla, Portunus* etc.; baby lobsters of *Palinurus* spp. are to be taken and subjected to culture in confined grow outs (cages or ponds). This acts as an alternate source of income for the fisher folk during lean months of fishing.

Conclusion

The aforementioned steps are to be imparted for the sustainable utilisation of bycatch resources. Though bycatch will not solve the world's food problem, but it provides a significant contribution to satisfy the protein requirements of the burgeoning population, if utilised in a proper manner. Apart from that, expanding bycatch utilisation as a management step can also help in achieving certain goals of conservation strategy as these movements aid in protecting our target fish population to a greater extent. The role of fishery research institutes is imperative for popularizing bycatch resources by implementing proper methodologies for its sustainable utilisation. Moreover, the techniques should be economically affordable to fisher folk with less capital investment. The fisher-folk should be encouraged to avail the technology so as to improve their earnings and also contributing to the countries income through export. The lacunae between the fishery scientists and fisher commune are to be nullified so as to form of a strong beneficial commitment, is found wanting. Considering the vast potential of effective utilisation of bycatch resources, there is an urgent and imperative need for enhancing research on this perspective, which will go a long way in safeguarding our fishery resources from the clutches of commercial extinction and opening new vistas of alternate livelihood and thereby augmenting biodiversity conservation.

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INTEGRATED MANAGEMENT OF MARINE RESOURCES FOR FOOD SECURITY

BIODIVERSITY CONSERVATION THROUGH UNESCOS MAN AND THE BIOSPHERE (MAB) AND WORLD HERITAGE PROGRAMMES

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Background

UNESCO's Man and the Biosphere (MAB) and World Heritage (WH) programmes, play an important role in biodiversity conservation through linking nature and culture and ensuring sustainable development. The aim of the MAB programme, which is UNESCO's flagship environmental research and conservation activity, is to study and improve the relationship between people and their environment and to conserve the environment through sustainable use of natural resources. The programme involves both natural and social sciences and was the first international programme to take a holistic view of the ecosystem based on interdisciplinary approach. The programme includes studies concerning structure, function and dynamics of different ecosystems and bioclimatic zones and human environment relationships. MAB programme was initiated in 14 Project areas covering different ecosystem types from mountains to the sea, from rural to urban systems, as well more social aspects such as environmental perception. The programme promotes research , training and demonstration in natural resource management and contributes not only to a better understanding of the environment including global change but also to greater involvement of science and scientists in policy development concerning the wise and rational use of natural resources and their conservation (http://www.unesco.org/mab).

The world heritage convention 1972, concerning the protection of the world cultural and natural heritage, seeks to encourage the identification, protection and preservation of cultural and natural heritage around the world considered to be of outstanding value to humanity. Education and public awareness-building activities and conservation and participation of the local population in the preservation of their cultural and natural heritage are encouraged under the convention. The Convention ratified by 184 Parties, recognizes a set of places that are of *outstanding universal value* and their deterioration or destruction constitutes a loss to the heritage of *all humanity*, not just to the country in which it is located. These cultural and natural places make up the *world's heritage.* To-date, the World Heritage Committee has inscribed 851 properties on the World Heritage List, of which 660 are cultural sites, 166 natural sites and 25 mixed properties.

The MAB programme works in close coordination with the World Heritage Centre of the UNESCO to enhance linkages between cultural and biological diversity. The natural sites as well as ccultural landscapes and sacred sites play an important role in the conservation of biological and cultural diversity. There are many sites which are designated both as biosphere reserves and world heritage sites. Both the sites are being promoted as learning laboratories for sustainable development and can play a vital role not only in conserving some of the world's unique ecosystems and species but also in helping the humanity to cope up with challenges of the climate change and disasters.

MAB and Biodiversity conservation

MAB programme was conceived in the "Biosphere Conference" organized by UNESCO, FAO, WHO, IUCN and ICSU in 1968 at UNESCO headquarters, Paris. The conference provided the conceptual basis for the programme which was officially approved by UNESCO General Conference in 1971.The first governing body, the International Co-coordinating Council, usually referred to as the MAB Council or ICC, consists of 34 Member States elected by UNESCO's biennial General Conference. In between meetings, the authority of the ICC is delegated to its Bureau, whose members are nominated from each of UNESCO's geopolitical regions. The member countries constitute a MAB National Committee under the relevant government ministries for the management of the national MAB programmes including biosphere reserves.

MAB programme consists of an interdisciplinary research agenda with a focus on capacity building to improve the relationship of people with their environment. The programme mainly focuses on the ecological, social and economic dimensions of biodiversity loss and the reduction of this loss. The emphasis is on the application of research results in appropriate conservation and sustainable development programmes.

The programme activities contribute significantly in minimizing biodiversity loss through the use of scientific research in policy- and decision-making, promoting environmental sustainability through the World Network of Biosphere Reserves; and enhance the linkages between cultural and biological diversity. The Network of Biosphere Reserves serves as vehicles for knowledge-sharing, research and monitoring, education and training, and participatory decision-making under the MAB programme.

MAB also helps in capacity building in the area of biodiversity conservation particularly of the concerned stakeholders in biodiversity rich countries in the tropics and subtropics. The support in terms of scientific database and capacity building is necessary for these countries to fulfill their commitments under various conventions such as Convention on Biodiversity (CBD). The capacity building activities focus on broad-based interdisciplinary research agenda with respect to the ecological, social and economic dimensions of biodiversity loss and its reduction. This helps in equipping the concerned stakeholders to take informed decisions related to biodiversity conservation including sustainable use of natural resources. The programme also promotes the development of a network of learning centres for integrated ecosystem management and through South-South cooperation. Particular emphasis is placed on specific ecosystems such as arid zones, mountains, coastal areas etc.

Biosphere reserves

One of the significant initiatives of the MAB programme is the development of the World Network of Biosphere Reserves (WNBR) as representative samples of biodiversity conservation with a variety of natural and human managed ecosystems as part of a larger ecological landscape unit. The concept of these unique conservation areas, evolved during the 1st Intergovernmental "Biosphere Conference" in 1968. One of the original MAB projects consisted in establishing a coordinated World Network of sites representing the main ecosystems of the planet in which genetic resources would be protected, and where research on ecosystems as well as monitoring and training work could be carried out. These sites were named as "Biosphere Reserves", in reference to the MAB programme itself.

The Biosphere reserves are expected to perform the following three functions, which are complementary and mutually reinforcing:

- a conservation function - to contribute to the conservation of landscapes, ecosystems, species and genetic variation;
- a development function - to foster economic and human development which is socio-culturally and ecologically sustainable;
- a logistic function - to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

The Biosphere reserves are organized into 3 interrelated zones:

1. the core area
2. the buffer zone
3. the transition area

The core area is the *sanctum sanctorum,* the strictly protected area that requires legal protection. This can form part of an existing protected area such as nature reserve or a national park. The buffer zone and the transition zones are in the periphery extending up to the human habitation. The zonation pattern is applied in many different ways in the real world to accommodate geographical conditions, socio-cultural settings, available legal protection measures and local constraints. This flexibility can be used creatively and is one of the strongest points of the biosphere reserve concept, facilitating the integration of protected areas into the wider landscape.

The concept of biosphere reserve provides a useful framework to guide and reinforce projects to enhance people's livelihoods and ensure environmental sustainability. The international recognition by UNESCO helps in raising the profile of the site and attracting resources for better management and in the improvement of socioeconomic status of the people living around these sites. The designation of a site as a biosphere reserve also helps in creating environmental awareness about the conservation of biodiversity and linked development issues among the people of the area and the visitors. Biosphere reserves are governed through a soft statutory framework which allows flexibility in their management and establishment. They are not governed by any binding international convention or treaty but by a "soft law" — the Statutory Framework for Biosphere Reserves — adopted by the UNESCO General Conference and which provide ample flexibility to the countries to manage them as per the local situation based on basic framework. UESCO does not perform a regulatory or "policing role" and national governments through their MAB National Committee or Focal Point, manage these reserves as per the basic guidelines. It is not necessary to enact special national legislation for biosphere reserves but rather to use the existing legal frameworks for nature protection and land/water management. However, many countries have given biosphere reserves a special legal status in order to reinforce their application.

UNESCO does not require any change in law or ownership. Each biosphere reserve has its own system of governance to ensure its meets its functions and objectives. The management system of a biosphere reserve needs to be open, evolving and adaptive in order for the local community to better respond to external political, economic and social pressures, which would affect the ecological and cultural values of the area. Hence it is necessary to set up an appropriate governance mechanism, for instance a committee or board, to plan and co-ordinate all the activities of all the actors concerned, each within their own mandate and competence. Usually a biosphere reserve coordinator is named as the contact person for all matters dealing with the biosphere reserve. Biosphere reserves are sites to innovate and demonstrate approaches to **conservation and sustainable development**. Although these globally recognized sites are under national sovereign jurisdiction, they share a common management principle evolved through scientific research on a variety of ecosystems combined with experience and ideas generated nationally, regionally and internationally within the World Network of Biosphere Reserves.

Biosphere reserves can serve as learning and demonstration sites in the framework of the United Nations Decade of Education (DESD). They provide the opportunity to link biodiversity conservation issues and socio-economic development in specific contexts. The WNBR and the regional networks b can be used as vehicles for knowledge-sharing and exchange of experience, research and monitoring, education and training, and testing of participatory decision-making, thereby contributing to the emergence of "quality economies" and to conflict prevention.

Biosphere reserves play a very important role in the MAB goal of minimizing biodiversity loss through the use of ecological and biodiversity sciences in policy- and decision-making and promoting environmental sustainability. Biosphere reserves represent areas of representative terrestrial and coastal ecosystems promoting solutions to reconcile the conservation of biodiversity through its equitable and sustainable use. They serve as 'living laboratories' for testing and demonstrating integrated management of land, water and biodiversity.

The world network of biosphere reserves and regional and sub-regional MAB networks are playing a very important role in the exchanges of information, experience and expertise.

From a historical concept to a tool

Rapid population growth and unsustainable consumption pattern are putting tremendous pressures on planet's life support system. The concept of sustainable development to meet the needs of the present without compromising that of future generations is the key to the future of humans on the earth. This should be coupled with a holistic and interdisciplinary approach as well as a long term vision. The natural heritage sites and biosphere reserves are the laboratories where new and optimal practices to manage nature and human activities can be tested and demonstrated. They are the answer to many of the ecological and development conflicts arising from the traditional confined conservation zones. Biosphere reserves particularly combine core protected areas with zones where sustainable development is fostered by local communities. Their governance systems are inclusive and flexible which allows locale specific innovative approaches of management. The knowledge and experience of the management of these sites from a variety of ecological and geographical locations representing varied ecosystem types can be used in the wider land and seascape. They are tools to help countries implement the international commitments under the millennium development goals (MDGs), World Summit on Sustainable development (WSSD), Convention on Biological Diversity (CBD) and UN Decade on Education for Sustainable Development (DESD) as well as adaptation to climate change. They represent living laboratories for experimenting ecological impacts of humans on nature and culture, thus shaping the future of the human civilization.

Biodiversity conservation through enhanced linkages between culture and nature

Biosphere reserves and World Heritage sites as well as similarly managed other sites (Protected areas) offer unique venues and opportunities for raising awareness about the issues linked with cultural diversity and biodiversity. There is a need to fully explore and use the potential of these sites as learning laboratories for environmental education and education for sustainable development. Biosphere reserves World heritage sites can showcase best conservation and management case studies and facilitate education. These sites can also serve as learning and demonstration venues in the framework of the United Nations Decade of Education for Sustainable Development (DESD) offering opportunities to share the experiences of best ESD practices from across the world of these or similarly managed sites.

One of UNESCO's mandates is to pay special attention to new global threats of climate change that may affect natural and cultural heritage and ensure that the conservation of sites and monuments contributes to social cohesion. Our natural heritage belongs to all of humanity, and biosphere reserves and world heritage sites constitute crucial landmarks on the planet. They symbolize our common consciousness and inheritance. We are duty bound to conserve these valuable heritage of humanity for our future generations. Efforts to enhance local development and to promote scientific understanding are means to ensure the protection of the natural heritage values.

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INTEGRATED MANAGEMENT PLAN FOR THE GULF OF MANNAR MARINE NATIONAL PARK AND BIOSPHERE RESERVE (2007-2016): PROCESS AND METHODOLOGY

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INTRODUCTION

The Gulf of Mannar, the first Marine Biosphere Reserve in the South and South East Asia, running down south from Rameswaram to Kanyakumari in Tamilnadu, India is situated between Longitudes 78^{0}08'E to 79^{0}30'E and along Latitudes from 8^{0}35'N to 9^{0}25'N with a total area of 10,500 Km^2. This marine Biosphere Reserve encompasses a chain of 19 islands and adjoining coral reefs off the coasts of the Ramanathapuram and the Tuticorin districts forming the core zone; the Marine National Park. The surrounding seascape of the Marine National Park and a 10 km strip of the coastal landscape covering a total area 10,500 sq. km., in the Ramanathapuram, Tuticorin, Tirunelveli and Kanyakumari Districts form the Gulf of Mannar Biosphere Reserve. The importance of the Gulf of Mannar region dates back to the 2nd Century AD because of its highly productive pearl banks and other religious significance.

The South and South-east Asia region in the southern hemisphere is one of the richest coastal and marine biodiversity areas in the World with the maximum diversity of coral reef systems. In India, in addition to the Gulf of Mannar region in Tamilnadu, the Gulf of Kutch in Gujarat, the Lakhsadweep and Andaman & Nicobar Islands are the other important coral reef regions. With its rich biodiversity of 3600 species of various flora and fauna, part of the Gulf of Mannar was declared as a Marine National Park in 1986 by the Government of Tamil Nadu and later the larger seascape was declared in 1989 by the Government of India as the first Marine Biosphere Reserve of the country.

Organizations like Central Marine Fisheries Research Institute (CMFRI), Zoological Survey of India (ZSI), Tuticorin Fisheries and Research College, ICMAM project of Department of Ocean Development, Government of India, Anna University, Madurai Kamaraj University, Annamalai University, Suganthi Devadasan Marine Research Institute (SDMRI), Wildlife Institute of India (WII) and others have conducted biodiversity assessment studies in the Gulf of Mannar Protected Areas and their studies have confirmed the richness of the marine biodiversity in the Gulf of Mannar region with 104 species of hard corals, more than 450 species of fishes, 4 species of sea turtles, 38 species of crabs, 2 species of lobsters, 12 species of sea grasses, 147 species of marine algae, 160 species of birds, 79 species of crustaceans, 108 species of sponges, 260 species of molluscs, 99 species of echinoderms, 5 species of sea horses, 12 species of sea snakes besides the critically endangered Dugong (sea cow) and the endemic balanoglosses. The Gulf of Mannar Marine National Park also supports 12 mangrove species.

For centuries, the exploitation of fishery resources in the in-shore waters has been the sole occupation for several thousand families living along the coast of Mannar. They have been in such close intimacy with the coastal and marine environment that their life-style, culture and social life all centre around the sea. In this background, it was considered important to develop an adaptive management plan for the Gulf of Mannar Marine National Park and Biosphere Reserve with community based participatory approaches for sustainable use and management of coastal and marine resources of this region.

THRUST AREAS OF THE MANAGEMENT PLAN

The primary objective of the Management plan is to safeguard and manage the biodiversity of the Gulf regions in general and the declared Marine National Park in particular, so that the Protected Marine Park will serve as a marine resource generation area and the renewable marine resources will spread out in to the Biosphere Reserve Landscape, where controlled and sustainable utilization by coastal communities can be worked out. If this plan is followed properly then this will serve as a model for other marine parks in the country.

The key thrust Areas visualized in the Management Plan are:

A) Protection of the islands and the Associated Marine Environment.

B) Restoration of the Protected Ecosystem

C) Development of Protection and Restoration infrastructure.

D) Monitoring of the Protected and Restored Ecosystems health functions.

E) Development of Recovery Plans for the threatened Species

F) Development of an 'Education and Awareness' programme for stakeholders on the function and role of the Marine Protected Area as a resource generation base.

METHODS

Initiation

'The Wildlife Institute of India, after setting in place a process for Management Plan Development, initiated the management plan development exercise during January 2006. A team of field researchers lead by experienced WII faculty inventoried the ecological, socio-economic, developmental and threat assessment settings for the region. Based on this information, the management plan has been developed through a consultative process. This has been shared with the GOMBRT, GOMMNP and other stakeholder agencies. Analyzing the feed back from these agencies, the WII finalized the Integrated Management Plan and presented it to the Management Plan Development Steering/Advisory Committee on 20th April 2007. After incorporating the final suggestions, the WII submitted the Plan to the Gulf of Mannar Biosphere Reserve Trust in the month of September 2007 for obtaining the approval of the Concerned Competent Authority and subsequent implementation.

Management Plan Development Framework and Guidelines

The Wildlife Institute of India has followed the IUCN-WCPA, Marine Protected Area Planning Process and Planning Guidelines for the broad general principles in developing the Marine Protected Area Management Plan. The Management Plan Development Guidelines for Protected Areas developed by the Wildlife Institute of India provided the general guidelines for developing the plan for the Marine National Park. The Biosphere Reserve Management Plan Development Guidelines by the Man and Biosphere Programme of the UNESCO and the new guidelines for regulatory regimes in the Biosphere Reserve by the Ministry of Environment and Forests, Government of India have also been followed in developing the Integrated Management Plan for the Gulf of Mannar Biosphere Reserve and Marine National Park.

The Process of Management Plan Development

After having discussion with Park Authorities, the format and the process of the Management Plan of GOMMNP were as under:

1. First formed a management plan development team with representatives of the GOMMNP, GOMBRT and WII as a Core Team.
2. Formed a GOMMNP&BR Management Plan development Steering/ Advisory Body.
3. Set up of a GOMMNP Management Plan development cell by WII at the National Institute of Coastal and Marine Biodiversity, Kanayakumari with Project Personnel and logistic support.
4. Collected all available information through literature search and visited several organizations which have worked in the GOMMNP region and landscape.
5. Conducted a Management Plan development launch workshop with all stakeholders and organizations and found out gap areas in research.

6. Rapid fieldwork was carried out for the period of one year for collection of information for the identified gap areas.

7. Meetings of the Advisory/Steering Committee were conducted to review the suggested thrust areas of the Management Plan and adoption of guidelines.

8. Development of a Management Plan as per the guidelines of the a) IUCN-Marine Park Management, b) GOI-MOEF wetland Division guidelines c) MAB Biosphere Reserve Guidelines and d) A Guide for Planning wildlife management in Protected Areas and Managed landscape – keeping in mind the close linkages and relationship of the National Park and the Biosphere Reserve.

Management Plan Development Core Team and Steering/Advisory Committee met several times during the period of the Management Plan development exercise. Apart from the input provided by the committee, various stakeholders meetings also contributed a lot for preparation of this Integrated Management Plan. We also consulted other well known organizations/Experts in India and abroad and also reviewed global model case studies from Marine Protected Areas for this plan.

The present Management Plan has two important parts, one is addressing the need and importance of the Management Plan and the other provides the management prescriptions for both the Gulf of Mannar National Park and the Biosphere Reserve.

RESULT & DISCUSSION

Geographic scope of the Management Plan

The geographic scope of the Management Plan encompasses the Gulf of Mannar Biosphere Reserve (GOMBR) as buffer area and the Marine National Park within the GOMBR as the core area. The GOMBR also encompasses terrestrial area up to 10 km from the coast line from Dhanuskodi Island on the north-east (Ramanathapuram District) to Cape Comorin in

South (Kanyakumari District) covering all along the four coastal districts of Ramanathapuram, Tuticorin, Tirunelveli and Kanyakumari of Tamilnadu, India.

Administrative structure

The Management Plan prescribes that the GOMBRT to be made into 'Gulf of Mannar Biosphere Reserve Management Authority' (GOMBRA) not only for unified control and management of all activities of the core area of the Biosphere Reserve i.e., the Marine National Park and the buffer and multiple use area i.e., Biosphere Reserve, but also for better coordination and synergy with all other stakeholders agencies who are expected to play an important role in the management of Reserve. The new Authority in such a situation will have better co-ordination between the management of the Marine National Park as well as the Biosphere Reserve through its own staff i.e. the Wildlife Warden, the Eco-development Officer and the suggested sociologist, biologist, fisheries and tourism officials to deal with human dimensions, research and monitoring unit, fisheries and eco-tourism aspects as well as eco-compatible and sustainable marine resource utilization activities.

Zonation

Selective control of activities at different zones is proposed here, including both strict protection and various levels of use.

The Core zone (Gulf of Mannar Marine National Park)

All the 19 islands and 2 submerged islands and the sea portions surrounding the islands up to 6.405 m (3.5 fathoms) on the bayside and 9.5m (5 fathoms) depth toward the seaward side, form the National Park, which is the Core Zone and the rest of the area of the seascape i.e. up to 20 m depth and the coastal terrestrial areas (10 km from the high tide mark to landward side) form the Biosphere Reserve, which is the buffer zone.

It is observed that by hindsight, the boundary of the Tuticorin cluster of islands based on quadrates mentioned in the Notification has omitted Karaichalli Island, which has been included into the Marine National Park, accordingly the boundary line was redrawn. Except research, monitoring and restoration of biodiversity, no other activities are proposed to be permitted in the core zone. The strict protection given to the core zone will result in spillover and migration of the faunal wealth to the buffer zone and will be available and can be harvested in sustainable manner by people who directly depend on these resources for their livelihood especially those who live in the buffer zone. It will also help in the economic development of the coastal districts.

The Buffer zone - Gulf of Mannar Biosphere Reserve (The Utilization / Manipulation / Experimental zone)

This zone is proposed to be permitted for local people's use such as fishing and fisheries related activities. The seascape surroundings and the islands beyond the limits of the National Park will form the buffer zone of the biosphere reserve i.e. up to 20 m depth in seascape around the National Park and the coastal areas (10 km from the high tide mark to landward side). As per the Notification of the Gulf of Mannar Biosphere Reserve, the total area of the Reserve is reported to be 10500 sq. km which extends from Dhanuskodi Island to Cape Comorin. However, based on the 20 m depth south-eastern boundary of the Biosphere Reserve the actual size of the Reserve is to be calculated.

Eco-developmental Zone (Terrestrial)

10 km stretch of coastal land starts from sea shore all along the Biosphere Reserve are identified as the Eco-developmental (terrestrial) zone. This zone is also utilised for multiple use like the Utilization zone.

Restoration zone

Restoration zone will enable damaged areas to be set aside for recovery. Both core zone and buffer zone can be used for restoration of habitat/species. All the islands are infested with invasive species. These islands need to be restored to their original state by eradicating invasive species from these islands. Northern group of islands such as Mandapam and Kilakarai groups are proposed to be used for restoration of mangrove habitat during this Management Plan period. Coral reefs in the Southern group of islands need to be restored. Detailed prescriptions are available in the concerned chapters.

Tourism zone

Tourism zone is proposed to be used for various recreational activities (bird watching, snorkeling, coral watching etc.) to increase the enjoyment and safety of each pursuit. Eco-tourism is proposed to be allowed in the Biosphere Reserve. As a part of the value addition to the Eco-tourism in the Gulf of Mannar Biosphere Reserve, around 50 km stretch of land and sea areas around the Biosphere Reserve has also been identified and proposed as 'Tourism Zone for Value Addition' with community participation. All the tourist centers in this area have been assessed and included as potential tourism resources in the Eco-tourism sub plan in this Management Plan.

Delineation of boundaries

The boundary demarcation of the Biosphere Reserve, especially towards the seascape side needs to be reviewed at five years interval as the bathymetry of the sea tends to change. The boundaries of the National Park and of the different zones will have to be suitably demarcated with different colour buoys or markers so as to be easily visible to the users of the coastal waters as per the Notification. Coloured buoys in every 250 m to 500 m distance for the National Park boundary and buoys with automatic illumination system to alert the vessels along the boundary of Biosphere Reserve needs to be installed in every five kilometers. Registered fishermen who use trawlers and are not supposed to fish inside the Biosphere Reserve need to be assisted by the Government to install required equipments such as GPS etc to receive the alarm signal if they approach the Biosphere Reserve boundary.

Protection measures

The core zone of the Biosphere Reserve i.e. the Marine National Park and its biodiversity need to be protected strictly from any kind of anthropogenic activities except the activities related to habitat & species restoration, and research & monitoring. Therefore, it is important to strengthen the protection force of the Biosphere Authority by having 'Forest Watchers Hut' in each island, which is in addition to existing protection facility. A minimum of two forest watchers should be posted in each island with a motorboat and communication systems. People who are posted on the island need to be paid special incentives and their stay on the islands should not harm the biodiversity at any level. Minimum accommodation facilities (eco-friendly patrolling hut) may be created in each larger island. Responsibilities of the proposed protection force under the control of the Wildlife Warden need to be extended to other zones of the Biosphere Reserve too. Any violation of the Indian Wildlife (Protection) Act, 1972 and the Management Plan of GOMBR, any where in the Biosphere Reserve should not be allowed and this would be the responsibility of the protection force under the WLW and also of the other staff of the Biosphere Authority.

Restoration of habitat and recovery of certain species

Gulf of Mannar harbours diverse life forms. If not all, most creatures still experience severe threats like illegal extraction, poaching etc. Dugongs, Dolphins, Turtles, Hard Coral species, and several other organisms require significant conservation measures. A list of fauna and flora of Gulf of Mannar Marine Biosphere Reserve has been given in the Management Plan. This list in detail depicts their scheduled status under the Indian Wildlife (Protection) Act 1972. Their status as per the IUCN Red Data Book and CITES Appendix is also given in the Plan.

Stock enhancement of certain commercially important marine fauna within the National Park is prescribed in the Plan. Spill-over of the enhanced stock from core zone to the buffer zone of the Biosphere Reserve will be harvested rationally and in a sustainable manner, which ultimately will improve the livelihood of coastal fishermen and the economy of the coastal districts of the Gulf of Mannar Biosphere Reserve. During current Management Plan period, the following species of conservation importance and sustainable utilization are required to be given special management attention.

The two categories of species requiring conservation and management actions are:

A. Species recovery/restoration programme to improve their threat status.

Even though, several species of invertebrates and vertebrates within the Gulf of Mannar Biosphere Reserve and Marine National Park are in the Red Data Book of the IUCN and schedules of the Indian Wildlife (Protection) Act, 1972, it is proposed to initiate active species recovery and restoration of a few prioritized species. It is important to realize that such species recovery programmes require highly specialized and professional help. The small number of species recovery programme suggested below will also provide opportunities for capacity building of GOMMNP and GOMBR staff, educated youth, local NGOs and other institutions to formulate and initiate similar actions for a range of other species. The species requiring recovery/ restoration programme are: Dugong, Sea turtles, Sea horses & pipe fishes, Holothurians, Balanoglossus, Reef fishes, Lobsters and economically important crabs.

B. Stock enhancement of species important to dependent communities for subsistence and commercial reasons.

Commensurate with the traditional dietary spectrum of the local inhabitants and the increasing evidence of a large number of marine fauna entering into the local, regional and global commercial market, there has been an over exploitation of many such resources. The current status of many marine resources is vulnerable and an increasing number of species are being considered to be taken into the threatened and endangered category and provided strict protection. In a situation like this there is drastic decline in the number of species that can be harvested without any legal hindrance. It is, therefore, important that the 'stock enhancement option' for select group of harvestable resources is initiated. Such programmes are proposed to be taken up in the National Park limits where no fishing is permitted. This will provide the replenished stock to grow in a sheltered and protected situation and spill over into the Biosphere Reserve limits where controlled and sustainable harvest by users is permitted. The community at large will view this activity as a positive and supportive effort by the Biosphere Reserve Authority rather than as a ban on resource use. Fortunately, for a range of economically important and subsistence level use resources, the technology has been developed with fair degree of extension and technology transfer mechanisms in place. The few species suggested to be included under this programme can be enhanced after the success of the pilot programmes. A range of species for which such programmes can be initiated is appended in the plan. A similar approach of creating livelihood opportunities involving propagation of indigenous marine flora and fauna that are not in the threatened and endangered category have also been suggested in the Eco-development plan chapter.

Eco-tourism Plan

The coastal landscape and seascape in the Gulf of Mannar Biosphere Reserve historically has been a major tourist destination in Tamilnadu as well as South India. Of the four coastal districts in which the Biosphere Reserve is located, the northern district of Ramanathapuram and southern district of Kanyakumari attract the largest number of tourists, the majority being religious tourists. Most of the tourists visiting Kanyakumari are interested in the 'tri-sea confluence' at the Cape Comorin and the tourists visiting Rameswaram are interested in the Ramanathaswamy Temple and nearby temples.

The coastal and marine habitats of the Gulf of Mannar and Palk Bay have also been favourite visiting sites for academic purposes by students, researchers and scientists studying biology, marine sciences, ecology, oceanography, geography and coastal geomorphology. After the creation of the GOMMNP which encompasses the offshore islands and surrounding coral reef systems, there has been a restriction on tourism. However, all eco-tourism prospect assessments have recommended reef based tourism as the highest opportunity in the Gulf of Mannar (MSSRF-UNDP-GEF study, 1988).

It is in this context, that a **World Class State of Art Aquarium** is suggested to be established in the Rameswaram Island perhaps in Pamban. This way the new aquarium will not pose any competition with the Heritage Museum and aquarium of the CMFRI and the new small scale aquarium of the TNFDC. It is suggested that the Tamilnadu Government through a Global Tender seek 'Expression of Interest' of interested and experienced corporate sectors and or global consortium to invest and construct a world class aquarium on a 'Build, Operate and Transfer (BOT)' basis.

As a part of the value addition to the Eco-tourism in the Gulf of Mannar Biosphere Reserve, a 50 km stretch of land and sea area around the Biosphere Reserve has been identified as 'Value added tourism zone'. All the tourist centers in this area have been assessed and included in the Management Plan. Visitors/Tourists need to be guided to all the available tourism resources in the Biosphere Reserve as well as in the 'Value added tourism zone' of the Biosphere Reserve.

The proposed state of the art **Marine Conservation Interpretation cum Education Center (MARCONI)** and small information centers are required to be established at important entry points as well as at urban sites that will provide the visitors and other users a safe, visually coherent, appropriately sequenced and enjoyable experience with a focus on conservation education through exhibits and self guided activities

Eco-development Plan

The term "eco-development" seeks to reflect the interdependency between environmental problems and those connected with economic growth, demography and poverty. This leads to the principle of a trade-off between development and ecology or "eco-swap", according to which the project undertakes to support activities meeting the community's immediate needs in exchange for the latter's commitment to environmental restoration or conservation activities, in the spirit of a "social contract for long term concerted development" The notion of participation brings the human development dimension into the eco-development concept, by introducing the idea of local control over decision-making.

With the setting up of Gulf of Mannar Marine National Park in Tamilnadu, under the provisions of Wildlife (Protection) Act 1972, covering the 21 offshore islands along the Ramanathapuram and Tuticorin Districts, fisher folk have lost livelihood access to the common property resources from the coral reef-based fisheries operations. However, to eek out a subsistence of livelihood option, they still resort to some level of marine resource harvesting from the protected area. By setting up the Gulf of Mannar Biosphere, a large buffer zone of seascape surrounding the Marine National Park as well as a coastal terrestrial landscape have been earmarked as a multiple-user area where a diversity of alternate livelihood options are to be facilitated by the Gulf of Mannar Biosphere Reserve management agencies in an attempt to wean away the dependency of coastal communities from a multitude of marine resources. This major marine protected area management objective has been met with only to some extent by initiating some "eco-development measures" by the GOMBRT in the year 2002 following the India Eco-development Program (IEP) model. In this present plan, it is proposed to enhance the eco-developmental activity in a planned manner within the GOMBR limits following the guidelines set forth by Wildlife Institute of India (WII, 2004). This is proposed to be achieved by a proper assessment of the socio-economic dependency levels of dependent communities on coastal and marine biodiversity, identifying alternate livelihood options, enhancing community empowerment and setting in place proper inter-sectoral institutional mechanisms for the sustainability of such eco-developmental initiatives. The plan therefore examines the cultural, socio-economic and the socio-political situation to suggest a practical eco-development plan.

After a review of the existing eco-development programs implemented by the GOMBRT under the supervision of the Eco-Development Officer (EDO), the present eco-development plan proposes the need to continue and enhance the eco-developmental activities with certain modifications in all the identified villages during the 10 year plan period.

The objective of the eco-development plan is to combine guaranteed ecological balance with economic and socio-political dynamism at local level. More specifically, the Eco-development plan of the Gulf of Mannar Biosphere Reserve aims:

1. To ameliorate the hardships faced by the fishing villagers living in Biosphere Reserve, due to the curtailment of their access to fishing in the National Park, with a view to reducing their dependence on the protected area
2. Planning for resource substitution
3. Socio-economic uplift of the target population especially fisher folk
4. Involving local communities in conservation by adopting a "Community participatory" system of management, so as to elicit public support for conservation
5. Creating organised community institutions at the village level, and assuring benefits and rights to usufruct by developing viable partnerships with the village communities, subject to successful protection and conditions laid by the park management
6. Developing micro-institutional and technical functions in the community management organisations, so as to make them self-sustaining in the long run with minimum dependence on the Park Management
7. Formulation of utilisation rules and their enforcement, so that the contemplated welfare actions are not nipped in their infancy

The planned activities of eco-development program forms an integral part of the Buffer Zone (Biosphere Reserve) Management objectives, for it is this Zone that is expected to absorb the biotic pressures and insulate the Core Zone (Marine National Park). Community activities of "Social buffering" are expected to support "Extension buffering" that involves providing a habitat for the spillover population of fish and other marine resources for sustainable use. The eco-development activities area not restricted only to the presently prioritized 222 Buffer villages of the Gulf of Mannar Biosphere Reserve region but are expected to be carried out in other coastal villages in Tirunelveli and Kanyakumari districts during the plan period of 2007-2016.

Conclusion

The Integrated Management Plan of the Gulf of Mannar National Park and Biosphere Reserve is an adaptive management plan, which will undergo periodic review based on evaluation of management activities and its outputs. This plan has also prescribed various policy level decisions which need to be taken up by the Government of Tamilnadu. These policy level decisions are important for the successful implementation of the Management Plan. This adaptive management plan for the Gulf of Mannar Marine National Park and Biosphere Reserve strongly emphasizes the importance of community based participatory approaches for sustainable use and management of coastal and marine resources of this region.

BEGINNING OF A NEW ERA IN CONSERVATION MANAGEMENT IN GULF OF MANNAR.

V. K. Melkani

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PRELUDE:

A wide range of natural ecosystems with variety of resources and services bestowed on the earth and the role they play in shaping the very destiny of the earth need to be very critically understood in order to use the benefits in a sustainable manner in today's context. The natural resources are finite and even the renewable resources have limits / capabilities and need time intervals to recoupe, regenerate and renew, therefore, how the needs and demands from us can keep growing indefinitely without compromising with the earth? Conservation and management of natural ecosystems and resources available in the form of wilderness, mountains, forests, deserts, rivers, lakes, coasts, seas and oceans, the repository of biodiversity is precisely for maintaining the balance where the future of human welfare, security and socio-economic development and the fate of natural resources is endured safely for both.

Conservation of natural resources has been inbuilt in our socio-cultural traditions and worked significantly well till we started overgrowing in numbers, needs and demands which started making the resource base shrink and that if it goes beyond control will not it endanger the very existence of ours in this earth? Conservation of wild biodiversity in practice started with setting apart forests and other areas as protected / reserved areas with prime aim to protect and regulate these systems to sustain the flow of its services and goods for the overall benefit of the society. Establishment of network of Protected Areas (PA's) was a key step in preserving the biodiversity of India's forests. Today there are 604 PA's covering about 4.7% of geographical area of the country. However, many of the PA's are not very large, or contiguous enough to serve as a requisite base for conservation. In a highly fragmented landscape most of the PA's have remained small inlands of repository of biodiversity and its in situ conservation and management. Integrating PA's and surrounding areas as a larger landscape management unit for biodiversity conservation is being attempted recently. The Conservation of marine biodiversity was also brought into the folds of Wildlife Protection Act and over a period of time many species have been listed in the schedules. While the conservation effects were initiated in 1980's the PA coverage in coastal and marine areas however, remains meager in contrast to terrestrial areas.

The conservation management philosophy and practice in earlier period remained under tight control of the government agencies and the surrounding communities never felt themselves as part of it and gradually alienated themselves from its care considering that it is only a government property and responsibility for its protection and sustainable use is of the governments alone. The dependence for sustenance and for other needs, however, remained and this was considered illegal and gave rise to many occasions where the conflicts between government agencies and local communities were unavoidable. Management being a dynamic process has taken due note of the happening and the ever-increasing pressures on resources and slowly adopted new mechanisms acknowledging the fact that conservation can not remain mere protection and preservation and the concept of sustainable utilization started becoming an integral part of the conservation programmes to make them able to become socially acceptable and receive co-operation, co-ordination and support from communities and other stakeholders so that these are workable and successful.

The National Forest Policy, 1988 provided a dramatic shift to the ethos of forest, wildlife and natural resource management in the country. Participatory practices for conservation, regeneration and protection of forest & wildlife became operational and various projects under joint forest management of forest areas and eco-development in PA's were implemented in various parts of the country. New learnings that have emerged paved way to redesign strategies for future.

GULF OF MANNAR – ITS RICHNESS AND PROBLEM PROFILE:

Gulf of Mannar (GOM) in the southeastern coast of Tamil Nadu falling within the Indo-Malayan realm, the world's richest region from marine biodiversity perspective with its estimated 3600 species of flora and fauna makes it one of the richest coastal region in India. Gulf of Mannar Marine National Park (GOMNP – 1986) and Gulf of Mannar Biosphere Reserve (GOMBR – 1989) are the first Marine National Park and Biosphere Reserve not only in India but in whole of South and South East Asia. The Reserve has been an international priority site based on its biophysical and ecological uniqueness, economic, socio-cultural and scientific importance. The IUCN Commission on National Parks and Protected Areas, with the assistance of UNDP, UNESCO and WWF have identified GOMBR as being an area of "*particular concern*" given its diversity and special multiple use management status.

Though the GOMNP and its management is now more than twenty years old and has been a significant step to protect the Park areas to some extent but the plethora of problems affecting the Park and the Reserve and its cohesive management remained existing and increasing. The objectives of first blue revolution with focus on mechanized fishing, export potential beginning simultaneously in the eightees have risen conflicts between park management local communities and business interest groups and started posing threats to conservation. The primary threats to the globally significant biodiversity of the Reserve, in order of importance, are-

- Habitat destruction.
- Over-harvesting of marine resources; and
- Potential, localized land-based marine pollution from a low number of civic point sources.

Habitat destruction (coral reefs, sea grass beds, mangroves) has been the most serious threat for the long-term viability of the Park's globally significant resources. Coral mining, though it is illegal, has stripped most of coral in past. Sea grass beds are harmed by inappropriate bottom trawling practices. The root causes of habitat destruction are -

- ❖ Lack of integrated management of the Reserve (Park and its buffer zone).
- ❖ Insufficient enforcement of protected area laws.
- ❖ Inadequate level of proactive management / insufficient management information
- ❖ Lack of clarity in the demarcation of protected area boundaries.
- ❖ Lack of alternative livelihood options.

The waters in the buffer zone around the Park currently suffer from the growing cumulative impacts of over-harvesting of marine resources which threaten to disrupt of ecological balance supporting globally significant biological resources in the Park and the Reserve as a whole. In a situation where there is no control exerted over who takes how much, the result has been the larger mechanized boats are catching most of the fish, precluding the smaller, traditional crafts from catching their share. This in turn forces traditional craft to take up destructive practices, such as mangrove cutting and coral mining in and around the Park. The root causes of the threat of over-harvesting are-

- ❖ Lack of effective, marine resource property regimes.
- ❖ Lack of community management capacity.
- ❖ Insufficient enforcement of existing marine resource use rules and regulations.
- ❖ Lack of alternative livelihood options.
- ❖ Lack of adequate and fair credit arrangements.

❖ Lack of management information to drive good management decisions.

Localized pollution outside of the southern tip of the buffer zone represents a potential threat to the Reserve's biological diversity. Development underway in the southern part of the Tuticorin district is of concern to the long-term management of the Reserve, however no discernible impact upon the Park's biodiversity has been detected from any resulting pollution. The potential threat of pollution to the Reserve has been caused by –

❖ Lack of management information to drive good management decisions.

❖ Inadequate enforcement of existing laws and policies.

❖ Lack of awareness of the importance of the Reserve.

Therefore, whereas on one hand the National Park and the Reserve being managed on adhoc basis the conflicting interests of stakeholders, their perception and level of understanding of problems and its link with the future security and availability of resources and failure to acknowledge the value and need for conservation of rich biodiversity clubbed with conflicting roles of various agencies makes it harder to focus on attempts for sustainable and mutually helpful practices and protocols to reverse the situation and improve the management.

THE NEW BEGINNING:

Keeping the obligations on part of various signatory states of the Convention of Biological Diversity (CBD), in order to support the primary objective of the Conservation of biodiversity and sustainable use of its component and the equitable sharing of the benefits arising out of the utilization of these components by integrating conservation and sustainable use of biodiversity into relevant plans and policies, and duly appreciating the endeavour of Tamil Nadu in India GEF and UNDP intervened and the genesis of a project **"Conservation and sustainable use of Gulf of Mannar Biosphere Reserve's Coastal Biodiversity"** took shape during

2002. The seven year project is a co-funded project with a total outlay of 26,735,000 US$ and counterparts contribution in cash and rind from GOI, GOTN, NGO, Banks & Private is 18,085,000 US$. The project aims to *"conserve and sustainably utilize the globally significant biodiversity in the multiple use area of the GOMBR through establishment and effective participatory management of the GOMBR through application of the strengthened conservation programme in the core area and economically feasible and socially acceptable sustainable livelihood development in Biosphere Reserve as a whole"*.

The overall Objective of this 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 multiple uses, 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 wild resources in partnership with Government and other stakeholders and making all accountable for the quality of the resulting stewardship. Specific Government and village level institutional capacities will be strengthened, stakeholders will apply sustainable livelihoods, and an independent, statutory Trust will ensure effective inter-sectoral co-operation in the sustainable conservation and utilization of the GOMBR's biodiversity resources.

GULF OF MANNAR BIOSPHERE RESERVE TRUST:

In tune with the mutuality in conservation philosophy which has taken ground in the country, the Gulf of Mannar Biosphere Reserve Trust was established as a new institution and preausor to oversee and coordinate implementation of GEF-UNDP project in 2000 by the Government of Tamilnadu. The Trust is an independent governmental statutory body to holistically coordinate and implement various activities as envisaged in the project and to play more than an advisory role as a flexible and transparent system in order to genuinely facilitate appropriate integrated coastal developmental action in GOMBR area leading to a changed focus and practice of conservation management through active involvement of all stakeholders in Gulf of Mannar region.

MISSION:

"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".

VISION:

- To coordinate the implementation of GEF-UNDP assisted Project on "Conservation and Sustainable Use of Gulf of Manner Biosphere Reserve's coastal Biodiversity" with the highest standard of professional and ethical competence and integrity during the project period ensuring that the implementation is globally acknowledged and appreciated and it is taken as a model to be replicated in various other parts of the country and in the world.

- To actively advocate incorporation of biodiversity conservation principles and practices into sustainable development interventions in the programmes and projects of all the stakeholders in the area.

- To develop and put in place working mechanisms for long term funding to sustain the Trust and associated conservation activities within the Biosphere Reserve area even after the project period.

- To support strengthening of the Gulf of Manner National Park through improved infrastructure and facilities, management planning, law and policy frameworks, law enforcement, capacity building and skill development of park staffs.

- To develop and implement a systematic research, monitoring and information management programme for the Park and the Reserve.

- To develop and implement programmes on environmental education and awareness for all stake holders.

- To develop and implement programmes to enhance the biodiversity conservation capacity of various agencies and organizations.

- To elicit local people's active and meaningful support and involvement towards conservation through establishing and empowered village level committed marine conservation and eco-development committees to plan and implement various alternate livelihood and livelihood enhancement mechanisms through site specific and conservation friendly strategies in order to reduce over harvest, destructive harvest, damage and degradation of marine and coastal resources.

- To gather support and assistance from other agencies and departments to improve basic amenities and infrastructure facilities in the villages to improve the quality of life and to develop better marketing and rise in income levels of villagers.

- To peruse with the policy makers and planners for required changes, reviews and needful interventations.

- To network with various national, regional and international agencies, experts and institutions for broader support base.

MANDATE:

- The Trust has been established as a special purpose vehicle to facilitate project implementation to ensure inter-sectoral co-ordination and to bring about main streaming of biodiversity conservation issues into the productive sector and policy development.

- The Trust will allow for project methodologies and results to be replicated in the rest of the coastal belt of Tamilnadu and serve as an institutional model for India and other parts of the globe as a whole.

- The Trust will work towards providing institutional frameworks and working with the Government to support, advocate and strengthen the over all policy initiatives to enable various agencies working in the area for enhanced and meaningful co-ordination and collaboration in the enforcement of coastal zone regulations and biodiversity conservation.

- The Trust will sincerely and seriously perusue innovative and improved ways and means to elicit support of local communities of the area for biodiversity conservation by organizing and empowering the communities at grassroots level and assist them in enhancing awareness and skill development and creating opportunities through alternate / enhanced livelihood security.

WORKING MECHANISM

The Project Co-ordination Unit of the Trust is headed by the Trust Director. The Trust Director supported by a team of technical staff which include an Eco Development Officer, Biodiversity Programme Officer and Monitoring and Evaluation Officer and required support staff. In the field to implementing the Eco Development process and activities the 10km vide zone of influence along 160 km coat line in Ramanathapuram and Tuticorin districts a few field staff from departments of Forest / Fisheries are in place.

The Board of Trustees (BOT) is the apex body for management of various activities and initiatives of the Trust and is presided by the Chief Secretary to the Government of Tamilnadu; The Secretary to Government, Environment & Forests is the Vice-Chairman of the Trust. The members include the Secretaries to Government, Finance; Animal Husbandry; Fisheries; Rural Development; Information and Tourism; the Principal Chief Conservator of Forests; the Chief Wildlife Warden; the Chairman Pollution Control Board; the Representative of the Ministry of Environment & Forests, Government of India; the District Collectors, Ramanathapuram & Tuticorin; the representative of M.S.Swaminathan Research Foundation; the Executive Director, DHAN foundation; one member of Legislative Assembly and one Panchayat President from the project area on nomination by the Government.

The UNDP representative in the BOT as special invitee. The Trust Director, GOMBRT is the Member Secretary of the Trust.

With the above composition of the BOT there is full scope and potential to make the Trust to play a model role in shaping the future conservation priorities and protocols where the ethos of bio-diversity conservation are truly knitted with sustainable development not only in the coastal and marine scapes but in variety of other areas of natural resource management in times to come. A sincere beginning has been made and with focused steering the Trust will emerge as an acclaimed and alternate institution of repute and credibility world over where conservation of resources goes hand in hand with development and economic growth and in time secure mutuality in conservation strengthens.

The major responsibilities of the BOT include review of legal, policy and procedural issues and recommending solutions and initiating the process of change is consonance with the memorandum of association of the Trust and with the obligations as stipulated in the project. The BOT also reviews coordination between departments and other agencies, priority allocation of programmes, schemes and other interventions as needed in the project area in addition to reviewing external monitoring exports and progress of approved work plans of the project.

In addition to the Board of Trustees the government has constituted an Empowered Sub Committee (ESC). The Principal Chief Conservator of Forests and Chief Wild Life Warden is the chairperson of the ESC. The members include local Forest and Fisheries department officials, UNDP representative and representatives from the villages in project area. The Trust Director is the Member Secretary of ESC. The establishment of ESC is to insure easy and efficient implementation of the project activities. The important responsibilities of the ESC include of annual work plans its review. It also takes decision on staff requirements, remuneration, and approval of completed tasks and guides the Trust Director for time bound implementation of project activities.

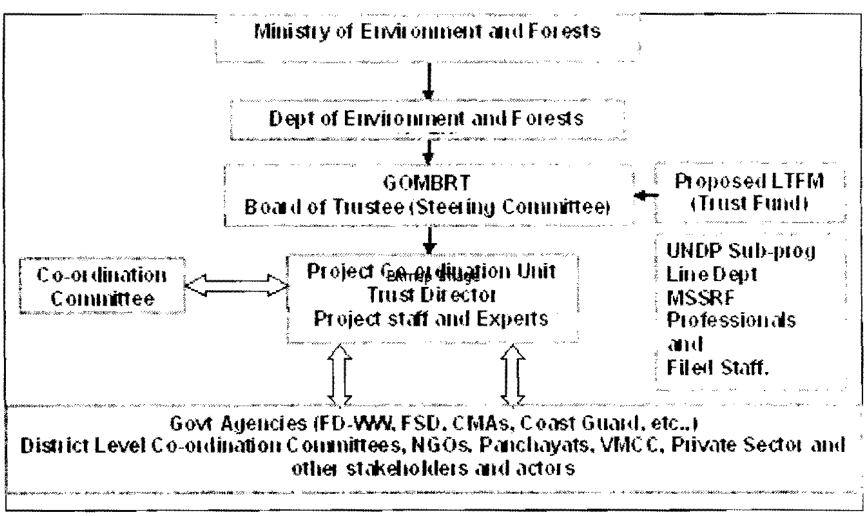
The Secretary to Government, Environment & Forests Department is the Chairman of the State Level Co-ordination committee (SLCC) and the members include the Heads of Departments of Forest, Fisheries, Rural Development, Environment, Agriculture, Elementary Education, Public Health, the UNDP representative and two NGO's (MSSRF and DHAN). The SLCC helps in identifying issues related to various departments which can be better coordinated by the Trust. The issues related to co-funding and requirement of different departments where the Trust can initiate some works are identified and approved by the State Level Committee.

District Level Co-ordination Committees (DLCC) under the Chairmanship of the District Collectors of Ramnathapuram and Tuticorin districts where the project focus is now on, these committees which includes line department officials of the district, prominent NGO's and representatives of local communities as members are in place. The Eco Development Officer is Member Secretary of DLCC. These committees have been established for proper coordination among various line departments and other agencies in the districts in order to secure support and access to developmental programmes and schemes towards facilitating and providing felt priority needs of the communities in project villages falling within 10 km. zone of influence along the coast line of about 160 km. in these two districts. These committees also assist the Trust and the communities in dealing with offenders with reference to biodiversity resources and the environment by various enforcement departments and agencies. These committees also share information regarding operations of non governmental agencies in the project area and to tie up various ongoing activities in the project villages.

The Research Advisory Group (RAG) is constituted to assist the Trust on research, monitoring and demonstration activity planed to be implemented in the project area. The Trust Director is the convener of RAG and member includes senior officials from Forest and Fisheries departments, senior scientist working in the project area and the representative of UNDP.

Taking into consideration the physical location and geographical area of work, experience and past performance in marine bio-diversity conservation projects, experience in community based work, experience in natural resources based livelihood work, mandates of the NGOs, technical capacity, cost effectiveness and sustainability and the organization's willingness and commitment to work with the project, the Trust has identified - M.S. Swaminathan Research Foundation (MSSRF), Mugavai Kalanjia Mahalir Vattara Sangam (MKMVS), Sangamam Vattara Kalanjiam (SVK), Neithal Vattara Kalanjiam (NVK), Tamilnadu Rural Reconstruction Movement (TRRM), Syed Hameeda All Women Development Organization (SHAWDO), People's Action for Development (PAD), Tuticorin Mulipurpose Social Services Society (TMSSS), Arumbugal Trust, Chevaliar Roche Society (DeRose), Small Industries Product Promotion Organization (SIPPO) as partner NGO's of the Trust. There experience and services are utilized for project implementation based on the core capacities and rapport available in the project area villages.

The working mechanism and project implementation arrangements are shown in Table (1).



MAJOR PROJECT INPUTS AND ACHEIVEMENTS SO FAR:

The project initiatives presently focus on

1. The management of the Trust which includes developing relationships among stakeholder organizations through consultations, workshops etc., in order to extent the network. The BOT, ESC, DLCC, RAG are actively contributing to project implementation The Project has envisaged and carved an unique feature to conceptualize and develop a Long Term Funding Mechanism (LTFM) to support the Trust and its associated conservation activities within the Biosphere Reserve even after the closure the project period. The LTFM will also ensure sustainability of the Trust activities and the recurring costs of managing the Trust continuously.

2. Providing support to strengthen the management of the Gulf of Mannar National Park in terms of infrastructure, capacity of fields staffs and developing participatory management plan for National Park and the Biosphere Reserve. The infrastructure support in the form of field & office equipments & capacity of PA staff in marine biodiversity issues have been initiated and ongoing. The management plan for Gulf of Mannar Marine National Park & Gulf of Mannar Biosphere Reserve has been completed through Wildlife Institute of India. The procurement of patrolling boats and demarcation of Park area through floating buoys is under progress through UNDP joint patrolling in National Park / Biosphere Reserve areas by Park, Fisheries Department and coastal security police staff has been introduced. 40 able bodied youth from project site have been provided to Park as anti-poaching watches to assist the Park staff in improving protection works.

3. Undertaking target research on key species, habitats and environmental baseline and developing monitoring protocols for short term and long term monitoring of these Baselines. The compilation of research work done in Gulf of Mannar over last 100 years by various institutions, scholars in the form of Bibliography has been completed. Taking clue from the compilation about gap areas the Trust also organized a National Research & Monitoring Moderation Workshop which paved way to identify priority and nine research and monitoring projects are now commissioned. The projects are basically aiming at developing base line informations which unfortunately were missing for resource availability, current use patterns and future management protocols for key ecosystems and species (corals, sea grass, sea weeds, mangroves, fisheries including chanks, water quality parameters, etc.,) and six premier institutions have undertaken in these projects.

4. Imparting training, education and awareness programmes for various categories of stakeholders including government and non government agencies their staff, local communities including skill development of local communities is on ongoing effort. Training manuals in English and Tamil have been developed to enhance capacities of different stakeholders viz Government officials & staff, NGO's, teachers & students, panchayats, village community members, SHG members etc., on themes of values, needs & threats on marine biodiversity conservation in Gulf of Mannar. Awareness among local communities, students is being attempted through folk, print, electronic media. Training programmes are regularly organized for various stakeholders. The services of experienced partner NGO's and recognized institutions are being utilized for these efforts.

5. Innovate protocols and develop sustainable enhanced alternate livelihood options to reduce negative and over use or resources from the area and to win the support of local communities for bio-diversity conservation. The process of Eco-development, hitherto, practiced in terrestrial PA's in the country has been adopted to elicit local people's support towards biodiversity conservations in a coastal and marine PA for the first time in the country. 222 grass root level statutory organizations with commitment to conservation in the form of Village Marine Conservation and Eco-Development Committees (VMC & EDC's) have been formed in the 10 km. wide zone of influence along the 160 km long coastline of Ramanathepuram and Tuticorin districts. One male & one female member from each house hold can become, a member in VMC & EDC and also gives an annual subscription towards membership fees. The general body of the VMC & EDC selects / elects an executive committee as its chairperson. Further these committees have been categories based on the threats to conservation they pose into high, medium and low threat category. This primarily helps in developing site specific plans to curb and reduce the emerging threats. PRA based site specific micro planes have been developed for all 222 VMC & EDC's through active involvement of local communities, partner NGO's and Trust staff. The micro plans address the issues of conservation and weaning away communities from destructive practices of fishing and other resource use and providing them sustainable, socially acceptable and economically feasible alternate / enhanced livelihoods options. The VMC & EDC's support Self Help Groups (Men & Women) through the funds received from the Trust and manage these as revolving fund of the VMC & EDC. A provision of sample interest of 12% per annum provides scope for growth of revolving fund. A field officer (Forester / Sub Inspector of Fisheries) functions as the Member

secretary of VMC & EDC and is a joint signatory bank account of VMC & EDC. The VMC & EDC's have fifty percent or more women. Sixty educated youth from VMC & EDC's have been engaged as field project workers who link the Trust and VMC & EDC's and 3-4 VMC & EDC's are looked after by one worker and efforts to enhance their skills and knowledge are on going.

Another very unique started the Trust has initiated under the project has been the focus on vocational trainings in variety of skills ranging from computers hard & soft ware, printing technology, AC mechanics, repainting equipments, cell phones, electrical appliances, driving (JCB, light & heavy motor vehicles), tailoring embroidery, nursing, health care, Ornamental fish culture, and many more to educated youth (male & female) from the VMC & EDC's from recognized institutions in order to equip them in the skills that shall lead them to an alternate livelihood. The response to this initiative of the Trust is highly encouraging. Investment in nurturing and developing young human resource of the project area will open up new vistas in effective conservation and livelihood linkages.

CONCLUSION:

Marine PA's are one of the components of the conservation management strategy. Convincing and facilitating community for the cause of conservation of marine biodiversity through enhanced co-ordination, co-operation and collaboration with multiple stakeholders in Gulf of Mannar Biosphere Reserve has sincerely began. The truly integrated coastal area management where the sustainable resource use is decided by stakeholders through active involvement and clearly defining and restricting it to carrying / delivering capacities of the resources is acknowledged and practiced will alone help the conservation of the PA and its resources. This unique initiative of the Trust and implementation of project activities is a larger canvas of a participatory model involving many departments, agencies, NGO's and local communities vis-à-vis the earlier attempts where the canvas was smaller. The task is challenging and securing co-ordination, co-operation of multiple agencies which often have conflicting mandates and to bring a change in their mindset for giving due space for conservation oriented thinking and action is painfully slow process. However, it's the slow and steady who wins and together we all in Gulf of Mannar can make it possible to achieve the goals where both Gulf of Mannar with its bounty of resources and the aspirations of the stakeholders of now and future generations mutually coexist, benefit and flourish.

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BIODIVERSITY CONSERVATION
SUSTAINABLE DEVELOPMENT
INTERVENTIONS

CONSERVATION AND MANAGEMENT OF SEA CUCUMBERS FROM GULF OF MANNAR BIOSPHERE RESERVE

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INTRODUCTION

The processed product of sea cucumber is called as *beche-de-mer*, which is a delicacy for the Chinese, Japanese and Koreans. The sea cucumbers are consumed in the fresh, chilled, frozen and processed forms. A grade *beche-de-mer* from *Holothuria scabra* commands a price at US $ 110 per kg in the International market. *Isostichopus japonicus* distributed in the temperate regions like China and Japan costs US $ 400 per kg. The Chinese visited all the reefs of the Indian and Pacific Oceans in search of sea cucumbers. They came to the Gulf of Mannar more than 1000 years ago in search of pearls and *beche-de-mer*. They took pearls and *beche-de-mer* in exchange for silks and porasc skin. They taught the local persons the processing methods and personally supervised them. The Chinese were stayed in Ramanathapuram till early twentieth century.

Sea cucumbers are slow moving animals and offer no resistance at the time of capture, which subjected them to heavy exploitation. For example, the fishing for sea cucumbers started only in the Maldives in 1988 and within a few years the resource was already is need of management (Joseph and Shakeel, 1991; Joseph 1992). On the positive side, no specified gear is devised for their capture. The chief method of collection is by skin diving. The diver has to hold his breath, go down the sea and search for the sea cucumbers. Hence, only few specimens could be collected during each dive. Other points in favour of the sea cucumbers are the high fecundity (1.5-2.0 million eggs in a single spawning) and the younger sages are cryptic and hide in the coral reefs. Though the fishing is going on for more than

1000 years, the population still thrives. Another important point in favour of the sea cucumbers is the spawning populations are beyond the reach of the skin divers, as they move out of usual sea cucumber beds. Hence, the fished population consists mostly of adolescent stage.

Silas *et al.* (1988) stated that the populations of *Holothuria scàbra* and *H. spinifera* are endangered in the Gulf of Mannar and Palk Bay due to over exploitation. James (1991, 1996 & 2005) emphasized on research & development, conservation and management programmes for commercially important sea cucumbers. James and James (1994a & 1994b) highlighted the importance of conservation of commercially important sea cucumbers and the management of *beche-de-mer* industry. The fishing is unregulated and the industry is unorganized which have brought in all the present day problems. Nithyanandan (2003) pointed out the danger to which, *Holothuria scabra* is subjected to-day due to over exploitation. Surprisingly, after the total ban imposed by the Government of India in 2001, Asha and Diwaker (2006) have stated that at Tuticorin and Kalavasal, huge quantities of *Stichopus hermanni* were processed since 2004. The fishery extended from May to July every year and daily two lakhs of animals were fished for processing.

MEASURES TAKEN BY GOVERNMENT

As a result of indiscriminate fishing over the years, the average size of the sea cucumbers have been reduced and the catch per unit of effort has also decreased. These are clear signs of over fishing. In order to conserve the sea cucumbers to certain extent, the Government of India banned the export of processed *beche-de-mer* less than 75 mm (in length) in 1982. Since there is no local market for this product in India, this ban should have proved effective but in practice it was not so. Under-sized processed forms were taken out of the country clandestinely as hand baggage in air travels. There was also a demand for the under-sized forms. Hence, they were sent into the interior parts of China to cater to the needs of the poor people. To implement the sea cucumber conservation programme strictly, the Ministry of Forests and Environment banned the fishing of all species of sea cucumbers throughout the India in 2001 by making an amendment in the Wild Life Act of 1972. Further, sea cucumbers have been recommended for inclusion under Appendix II list of the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) to conserve the declining populations all over the world. The present move has proved to be effective, though some illegal fishing is going on here and there. In addition to these laws, the Government of India insisted for regulation in fishing to sustain the yield right from the middle of nineteenth century and has promulgated the following Legislative Acts to protect the environment and biodiversity of this region and other parts of India (Parikh and Parikh, 1999).

1. The Indian Fisheries Act, 1857.
2. The Wild Life Protection Act, 1972.
3. Water (Prevention and Control of Pollution) Act, 1974.
4. Territorial Water, continental Shelf, Exclusive Economic Zone and other Marine Zones Act, 1976.
5. Maritime Zone of India (Regulation and Fishing by foreign vessels) Act, 1980.
6. Environmental (Protection) Act, 1986.
7. Coastal Zone Regulation Notification, 1991.
8. Wild Life (Protection) Amendment Act, 1991.
9. National Conservation Strategy and Policy Statement on Environment and Development, 1992.
10. National Policy and Macro Level Action Strategy on Biodiversity, 1999.

The objective of introduction of size restriction was to give the sea cucumbers to breed at least once in their life time, which would go in a long way to replenish the natural stock. The divers, processors and exporters made agitations to lift the ban on the under-sized processed product. They opined that such size restriction was not imposed in other countries and also argued that it was not possible to judge the size under water. Nevertheless, their stand was not correct as it was always possible to identify adult from that of juveniles under water.

The Ministry of Agriculture of Government of India constituted three Committees consisting of Hon'ble Ministers, Members of Parliament, Directors of Research Institutes and Professors from Universities to examine and study the justification in imposing the ban on the export of processed material. This author was co-opted as Member-Secretary. The Committees examined the issue in details and suggested that more scientific data had to be collected before a decision could be taken to lift the ban.

AWARENESS PROGRAMMES

To allow the divers to collect the under-sized sea cucumbers will be just like killing the proverbial goose which laid golden eggs. It was decided to educate the fishermen, processors, and exporters of sea cucumbers, for which, a First National Workshop on *Beche-de-mer* was conducted at Mandapam Camp in 1989. In the three-day Workshop, an exhibition was also conducted and the deliberations were conducted in Tamil for the benefit of the fishermen/divers/processors/exporters. The participants were advised on the ill-effect of capture of under-sized material. Conservation measures and management policies were also explained to them to sustain the resource. The recommendations were sent to various maritime states and to the Directorate of Fisheries in Port Blair (Andamans) and Kavarati (Lakshadweep) for implementation. To make this programme successful, co-operation from the fishermen was absolutely essential. A Hand book prepared in Tamil was distributed to the fishermen to understand the conservation and management policies of the Government of India.

NEED FOR A RELIEF TO AFFECTED FISHERMEN

The total ban imposed by the Government of India in 2001 has created some problems for the sea cucumber fishing communities. They have been collecting the sea cucumbers, processing them and selling the material to the exporters from time immemorial. The lives of a few thousand fishermen families have been affected due to the total ban as there was neither immediate financial relief nor useful alternative avocation made available to them. Further, a total ban on the collection of sea cucumber was not justified since this living resource would perish after a few years. As a self replenishing resource, the population of sea cucumbers could multiply themselves, provided no fishing during the breeding season and no disturbance of juveniles population.

Recently the Wild Life Institute of India, Dehradun is reviewing the scheduled species under the existing Wild Life act of 1972 with the advice of experts in the concerned fields. It is hoped that some relief may be given for those fishermen engaged in sea cucumber fishing, keeping in mind the conservation and management policies of the Government of India. When the ban is partially modified, the following conservation measures will become relevant.

Size regulation: Size regulation is the most important measure for conservation. Durairaj *et al.* (1984) stated that the percentage of shrinkage ranged from 56 to 60 % for dried *beche-de-mer*. Therefore, the *beche-de-mer* of 75 mm corresponds to nearly 190 mm in total length in the fresh condition. At this length, *Holothuria scabra* is immature. It is essential to allow the animals to spawn at least once in their life time to replenish the stocks. The *beche-de-mer* exported from East Africa, Indonesia and Singapore is also subjected to size regulation. Baskar and James (1989) also studied the size and weight reduction in *H. scabra* during processing.

Catch limits: This is also an important conservation measure which is followed in other countries. Different areas should be demarcated and catch limits can be worked out for each specified area. Such measures are in force and successfully implemented for many years for the shell fisheries (*Trochus* and *Turbo*) in the Andaman and Nicobar Islands.

Closed seasons: Sea cucumbers should not be allowed to be collected during the breeding season. So far as the Gulf of Mannar is concerned, *Holothuria scabra* breeds twice, first a major peak during March-April and a minor peak during September-October. During these months, *H. scabra* should not be collected from the Gulf of Mannar.

Sea ranching programme: One of the ways to replenish the stocks in the sea is to sea ranch the juveniles in large numbers on sea cucumber beds. Such work is being done in Japan for *Isostichopus japonicus*. In India, a breakthrough was achieved for the first time when James *et al.* (1988) successfully induced *H. scabra* to spawn in the laboratory. They were able to produce 20,000-30,000 juveniles. Such successful hatchery technology may be utilized for large scale juvenile production and their ranching. The same technology was used in the Solomon Islands. Giraspy (2006) has stated that in Queensland, Australia annually 5-7 lakhs of juveniles are produced which are used for sea ranching.

Lifting of the ban: Before lifting the ban, a sample survey should be done in the Gulf of Mannar at different places to record the average size and the weight of *H. scabra* since there was no fishing of this species for the last six years. It is hope that the average size and weight of the species could have increased during the last six years and these figures could be compared with those of James and Baskar (1994). If the average size and weight has increased considerably, then the ban may be partially lifted subjected to some conditions.

RECOMMENDAIONS

1. Stock assessment of sea cucumbers should be taken up on priority basis since no such studies are conducted in India. Total stock, standing crop and maximum sustainable yield have to to be worked out to avoid overfishing.

2. Species like *Holothuria nobilis* and *H. fuscogilva* should not be allowed to be collected as they occur in small numbers.

3. Collection of sea cucumbers should be banned during the months of March-April and again during September-October which is breeding season in the Gulf of Mannar.

4. There should be a total ban on the collection of sea cucumbers from the Gulf of Mannar Biosphere Reserve.

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SUSTAINABLE MANAGEMENT OF MARINE BIODIVERSITY AND KNOWLEDGE SHARING THROUGH INFORMATION TECHNOLOGY

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INTRODUCTION

Definition of Biodiversity:

Biodiversity is the outcome of interactions between the phylogenetic history of life on earth and ecological processes. As such, biodiversity is the sum of life on earth and includes genetic, species and functional diversity. The status and trends in biodiversity reflect the health of the ecosystems that support and enrich human life. The most straightforward definition is " variation of life at all levels of biological organization". A second definition holds that biodiversity is "a measure of the relative diversity among organisms present in different ecosystems". "Diversity" in this definition includes diversity within a species and comparative diversity among ecosystems. A third definition that is often used by ecologists is the "totality of genes, species and ecosystems of a region". An advantage of this definition is that it seems to describe most circumstances and present a unified view of the traditional three levels at which biodiversity has been identified:

- **Genetic Diversity** – diversity of genes within a species. There is genetic variability among the populations and the individuals of the same species. For geneticists, biodiversity is the diversity of genes and organisms. They study processes such as mutations, gene exchanges and genome dynamics that occur at the DNA level and generate evolution. To understand many ecological and evolutionary processes, one must understand something of the genetic diversity of the species, population, or individual of interest. Further, it is desirable to understand the mechanisms for creating and maintaining the observed patterns of diversity. Thus, studies of genetic diversity have the potential to provide insight in many fields including conservation biology, population and community ecology, and evolutionary biology.

- **Species Diversity** – diversity among species in an ecosystem. For biologists it is the gamut of organisms and species and their interactions. Organisms appear and become extinct; sites are colonized and some species develop social organizations to improve their varied strategies of reproduction."Biodiversity Hotspots" are excellent examples of species diversity (*A biodiversity hotspot is a region with high level of endemic species).* Species diversity is the variation in the number and frequency of species in a biological assemblage or community. Species diversity is the most commonly used synonym for biodiversity, where species richness (number of species in a given habitat) is the main index used for its measurement.

- **Ecosystem Diversity** – diversity at a higher level of organization, the ecosystem. For ecologists, it is also the diversity of durable interactions among species. It not only applies to species, but also to their immediate environment ("biotope") and their larger eco-region. In each ecosystem, living organisms are part of whole, interacting with not only other organisms, but also with the air, water and soil that surround them. Ecosystem diversity is the variation in the collection of assemblages, communities, and habitats within a region. Currently, there is no universal classification or unique definition of ecosystems at a global scale, however, this area of research is evolving quickly. Inherent in ecosystem diversity are both biotic (living) and abiotic (non-living) components, which differs from both genetic and species diversity. There are a number of habitats that continue to be discovered at an alarming rate and there may be more ecosystems of this nature waiting to be revealed. In the ocean, hydrothermal vents were discovered less than 30 years ago! They are known to be extremely unique habitats with many endemic species .

- **Other Diversities**: It is evident from the above that the biodiversity encompasses many levels including genes, species, ecosystems and habitats. Although these are the main components of biodiversity, there are two other kinds of biological diversity that have been suggested. They are: (i) higher taxonomic diversity and (ii) functional diversity.

Phyletic or taxonomic diversity involves the variation and variability of the working body plans (phyla) of organisms. An example of a phylum includes Arthropoda of which the class Insecta is part. Phyletic diversity can result in a higher diversity of phyla without requiring a high diversity of species. For example, in the marine environment there are 32 out of the 33 animal phyla present and this is considered a high phyletic or taxonomic diversity.

Functional diversity is a grouping of species on the basis of how similar their functions are. For example, in the ocean. all organisms that deposit feed may be amalgamated into one functional group just like all filter feeders would compose another group based on that particular function. This can also extend to reproduction methods or biochemical diversity. In 1992 United Nations Earth Summit in Rio de Janeiro defined "biodiversity" as "the variability among living organisms from all sources, including, 'inter alia' , terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystem". This is, in fact, the closest thing to a single legally accepted definition of biodiversity, since it is the definition adopted by the United Nations Convention on Biological Diversity (CBD).

Measurement of Biodiversity:

Measurement of biodiversity is a complex and more challenging job. Each measure of biodiversity relates to a particular use of the data. Biodiversity is usually plotted as taxonomic richness of a geographic area, with some reference to temporal scale (e.g. Species richness, Simpson index and Shannon index etc.).Ecologists use other indices such as **Alpha diversity** (diversity within a particular area, community or ecosystem and is measured by counting the number of taxa within the ecosystem-usually species), **Beta diversity** (diversity between ecosystems; this involves comparing the number of taxa that are unique to each of the ecosystems) and **Gamma diversity** (measure of overall diversity for different ecosystems within a region).

Benefits of Biodiversity:

There are three main reasons commonly cited in the literature for the benefits of biodiversity :

(1) Ecological role of biodiversity,

(2) Economic role of biodiversity and

(3) Scientific role of biodiversity.

In simple terms, for all humans, biodiversity is a resource for daily life.

Challenges:

This valuable biodiversity currently faces two major challenges that are highly relevant to sustainable management:

- **Loss of biodiversity** – During the last century, erosion of biodiversity has been increasingly observed. Some studies show that about one of eight known plant species is threatened with extinction. Some estimates put the loss at up to 140,000 species per year. This indicates unsustainable ecological practices, because only a small number of new species are recorded each year. Most of the species extinctions from 1000 AD to 2000 AD are due to human activities, in particular destruction of plant and animal habitats. Almost all scientists acknowledge that the rate of species loss is greater now than at any other time in human history, with extinctions occurring at rates hundreds of times higher than background extinction rates.

- **Introduction of exotic species** –When exotic species are introduced, often by humans, to ecosystems, they may establish themselves as self-sustaining populations often replacing the endemic species in that ecosystem. These introductions cause major changes in biodiversity of that ecosystem on a long run often affecting the economic out puts.

Managing the growing pressures placed by the world's surging population and industrial and technology driven development on the planet's natural resources has become an urgent global priority. UNEP seeks to catalyze regional and global efforts to address emerging environmental challenges and chart a new course for resource consumption that would not jeopardize the earth's life support systems in the long-term.

Sustainable use of Biodiversity:

Sustainable use of biological diversity, one of the three objectives of the CBD, is essential to achieving the broader goal of sustainable development and is a cross-cutting issue relevant to all biological and natural resources. Sustainable simply means "the ability to continue a defined behaviour indefinitely". Sustainable use entails the introduction of and application of methods and processes for the utilization of biodiversity to prevent its long-term decline, thereby maintaining its potential to meet current and future human needs and aspirations. The concept of sustainability also embodies social dimensions- including distribution, values, and equity – as well as understanding of the intrinsic limitations on the supply of biological products and ecological services.

Sustainable use of biological diversity is a central objective of the Convention on Biological Diversity (Articles 1 and 10). The Addis Ababa Principles and Guidelines for Sustainable Use of Biological Diversity (an open-ended workshop conducted at Addis Ababa, Ethiopia from 6 to 8, May,2003) were adopted at the 7th meeting of the Conference of the Parties (COP)in 2004 in decision VII/12. They provide a framework for governments to develop and implement policies that will foster sustainable use of biological diversity. They also provide guidance to resource managers on how to enhance the sustainability of their uses of biological diversity. Although the CBD has a clear definition of sustainable use in Article 2, understanding of the concept varies greatly between different institutions and individuals. When we talk about sustainable management, the need to develop suitable **indicators** to monitor the changes is clearly evident. Unfortunately there is no single dataset which has been developed to monitor changes of biodiversity resources subject to use.

However four global scale datasets are broadly available that have relevant data with sufficient temporal depth (geographic scope and taxonomic diversity) to document changes in status over time:

- IUCN-SSC Red List Database
- CITES trade-related data
- The World Database on Protected Areas (WDPA) and
- FAO datasets on fisheries, fish stocks and forest inventories.

It is now realized that in the long term there may be a necessity to collect new data that would be directly applicable to assessing trends in the status of biological diversity in use.

Sustainable use indicators:

The IUCN/SSC Sustainable Use Specialist Group with the UNEP World Conservation Monitoring Centre convened an ***Ad Hoc Working Group on Sustainable Use Indicators*** in Cambridge, UK, on 16-17,January,2006 identified several potential candidate indicators that would measure rates of change in the status of populations, species and communities subject to use. While assessing changes in the impact of the use on the status of populations, species and communities is straight forward, it is not easy to do so at the level of ecosystems. Thus clarification of the scale at which indicators can be applied to monitor the impact of use and definition of the unit of measurement is necessary. At the same time the process of developing, testing and applying indicators to monitor the impact of use will assist broader understanding of the concept of sustainable use as framed in the Addis Ababa Principles and Guidelines for the Sustainable Use of Biological Diversity. Social, economic, and institutional factors can influence sustainability of use. As quantifying these factors is very difficult, our initial focus should be on looking at what is needed to develop indicators that are based on measuring the inherent biological characteristics of resources subject to use.

Qualifications of indicators:

When developing indicators it is important that they be:

- Scientifically defensible
- Readily available
- Resonate with the public
- Policy relevant
- Scalable to the extent practicable between global, regional and national levels and,
- Easy and cost effective to apply

Challenges in the development of Indicators:

There are essentially six challenges that we have to face when we want to develop effective indicators that can be implemented:

- Discriminating the impact of use (trade) on the status of species comparison to other factors (e.g. loss of habitat,pollution).
- Data could be interpreted depending on the scale (local, national, regional,global) at which the data are being applied.
- Determining the parameters for selecting a representative sample of data sources to compromise a "basket" index.
- Within the time frame in which measurements would be taken trade patterns could change (demand change).
- Data on the use of wild and semi-wild resources vs.data on uses of cultivated , farmed or ranched resources will be difficult to discriminate.

- Ideally, data should be readily available for compilation and analysis and should be capable of documenting change (rate of decrease or increase) in the status of biodiversity resources over time.

So the fore most requirement for any development of management system is the availability of data sets on several aspects of biodiversity.

Information system:

A typical biodiversity information system contains information in the form of databases essentially on four core areas:

1. **Taxonomic inventory** – Survey of extant taxa and their systematics.
2. **Spatial pattern of Biodiversity** – Biodiversity data along latitudinal and altitudinal gradients, between-habitats, between disturbed and undisturbed sites and ultimately national, regional and global scales.
3. **Temporal dynamics of biodiversity** – Changes in patterns of biodiversity over time. This is done by comparing baseline information with repeated measurements taken over a period of time – both short time and long time. This will allow analysis of the trends in biodiversity over various temporal scales and relative to both natural variation and anthropogenic causes.
4. **Mechanisms generating biodiversity patterns** – The available data would help to study the evolutionary processes and patterns that contribute to dynamic patterns of biodiversity. Concurrent study of species interactions and how they vary depending on abiotic processes should be

one focus. The opportunity to integrate evolutionary and ecological analyses of pattern and process will help provide a unique and robust understanding of the origin, maintenance, and functioning of biodiversity.

The above information may be available in many data sets that may be either centrally located or distributed with a network system. They include:

- Specimen data (description, voucher details, DNA sequence etc.)
- Offsite conservation data
- Key ecosystem data (field stations and reserves)
- Species inventory data
- Endangered and protected species data
- Taxonomic experts data
- Biotechnological application data
- Ecosystem inventory data
- Major environmental data
- Social and economic data

There are several global databases that contain information on several of the above aspects. For example:

1. **Global Biodiversity Information Facility (GBIF):**

GBIF is an international non-profit organization to provide free and universal access to data regarding the world's biodiversity (www.gbif.org). A number of countries and organizations participate in GBIF and have made their data available here. This portal provides access to two types of data: (i) Taxonomic names (scientific and common) and (ii) Specimens and Observations. This network already provides access to over 40 million records of occurrences of different organisms. Many of these relate to specimens in natural history museums and herbaria around the world, or to living cultures of microorganisms, but at least a third come from observations of wild organisms. Wherever possible these records include information about the locality where the organisms were found and are used to generate maps of the distribution of these occurrences.

Google Earth and GBIF Data(http://ge.gbif.net/) : Google Earth has many potential uses, including environmental planning visualization. It was used at the World Summit for Sustainable Development in 2002 to highlight participating countries. And now, with the addition of GBIF data, it can be used to see not only where in the world a species lives, but also what the terrain is like at the spot, what the elevation is, and so on. Even better, for those who are engaged in digitizing natural history specimen data, GE can help with geo-referencing, measuring distances and describing habitat. With this web enabled capacity to access GIS layers (roads, terrain, latitude and longitude, water bodies, and many others) and combine them with GBIF-mediated species-occurrence data. GBIF users can perform their own GIS analyses and print out their results.

Data Tester (www.gbif.net/datatester/index.jsp): Data quality and errors in data are often neglected because of the time and expense involved in checking data sets for typographical errors, empty or misused fields in a data record etc. Now GBIF is providing open-source software to assist with some of the tasks involved in checking data sets for quality. Tests that can be executed include the following:

- Reporting unrecognized values for data elements (e.g. Country names or basis of record values)
- Checking that coordinates fall within the boundaries of named geographic areas.

- ❖ Finding scientific names that are not known to external lists such as the Catalogue of Life or nomenclatures.
- ❖ Checking that scientific names have an appropriate format.

The software is particularly suited to reporting on **XML data sets**, but can be applied to other data formats or relational databases. It allows programmers to develop new tests and to generalize tests so that they can work against multiple data standards (e.g. Darwin Core and Access to Biological Collections Data(ABCD) Schema).

2. **Species 2000 Catalog of Life Programme(**www.sp2000.org**)**:

A project focusing on enumerating all known species of plants, animals, fungi and microbes on Earth as the baseline data set for studies of global biodiversity. Its goal is to provide a simple access point enabling users to link to other data systems for all groups of organisms using direct species-links.

3. **Integrated Taxonomic Information System (ITIS)(**www.itis.usda.gov):

Here you will find authoritative taxonomic information on plants, animals, fungi, and microbes of North America and the world. ITIS is also a partner of Species 2000 and the Global Biodiversity Information Facility (GBIF).

4. **ETI World Biodiversity Database**(www.eti.uva.nl**):**

The World Biodiversity Database (WBD) is continuously growing taxonomic database and information system that allows you to search and browse a number of online species banks covering a wide variety of organisms. The species bank offer taxonomic information, species names, synonyms, descriptions, illustrations and literature references as well as online identification keys and interactive geographical information systems(GIS).

5. **DIVERSITAS**(www.diversitas-international.org):

A partnersnip of inter-governmental and non-governmental organizations, formred to promote, facilitate, and catalyze scientific research on biodiversity including its origin, composition, ecosystem function, maintenance and conservation. Its goal is to provide accurate scientific information and predictive models of the status of biodiversity and sustainability of the use of the Earth's biotic resources, and to build a worldwide capacity for the science of biodiversity.

6. **FAO Fisheries Data Products**:

ASFIS species - List of species for fishery statistics purposes

DIAS - Database on Introductions of Aquatic Species

FISHERS - Time Series of Number of Fishers

FISHERY FLEET - Time Series of Fishery Fleet

GLOBEFISH - Information on Fish Marketing

IMPORTER - Register of Fish Importer

INFOFISH - Equipment Register (IER)

POPDYN - Population Dynamic Database

SPECIESDAB - Global Species Database for Fishery Purposes

SPATIAL - Space time Dynamics in Marine Fisheries

FAOSTAT - Fisheries Data on Primary and Processed Products

FIGIS - Fisheries Global Information System

7.**FishBASE(**www.fishbase.org**)** :

FishBase 2000 now covers over 25,000 species of fish known to science, has over 70,000 synonyms and 100,000 common names in over 200 languages. The names are the key to accessing knowledge accumulated over time and mobilising scientific and non-scientific knowledge systems. Over 25,000 pictures illustrate these fish and information about them has been extracted from 20,000 references.

8.**LarvalBASE** (www.larvalbase.org) :

LarvalBase is a comprehensive information system on fish larvae that are relevant in the field of fisheries research and finfish aquaculture, combining traditional sources such as primary and "grey" literature. 1,850 species, 2,550 pictures, 2,005 references and 58 Collaborators.

Sustainable management of Biodiversity:

The major difference between the routine biodiversity information system and that for sustainable use and management is the addition of **expert systems** for predictive modeling and powerful **visualization tools**. These are also called **Decision Support Systems(DSS)**.So the ultimate goal of such a system would be to combine:

1. the primary information in various databases
2. the derived theories in the model library, and
3. the expertise of biodiversity conservation

The goal of such a management system is to adopt uses of biodiversity that are sustainable. This may sound simple, but in designing such activities a broad range of issues must be addressed. For example:

- Who are the user groups? What are their patterns of consumption and demand?
- If a species or stock is being used, what is the condition of its habitat? Does it depend on other species? Is its population size changing?
- Is the availability of the resource affected by natural disturbances? By human alteration of ecosystem processes or declines in diversity.
- How are the benefits of resource use distributed? How is this determined?

Because there is such a diversity in resources, uses, and users, **there is no universal formula for sustainability**. The process of biodiversity data collection, integration and conversion into "**information products**" suitable for decision makers can be very time consuming. Just as it is necessary to have water management infrastructue in place to avert floods before they occur, there must be an "**information management infrastructure**" in place before particular instances of decision making are critical. This means having available in advance essential "**core datasets**" likely to be needed for a range of decision making purposes, having information systems in place with the **processing capabilities** to be able to quickly produce the specific information products required, and information exchange agreements and facilities already established. This basic diversity information management infrastructure must be developed to address ranges or classes of biodiversity issues in anticipation of likely decision making scenarios and requirements. The information systems capabilities required will normally be with the specific expert institutions which are the key custodians of the essential core datasets.

Three main classes of data or information are required:

Data or information	Nature	Informatics
1.**Scientific**	Includes observations on the condition and status of biodiversity, Encompassing information on bio-systematics, species, habitats, protected areas, wild life, ecosystems, and biodiversity indicators. It also extends to genetic resources, biotechnology, environmental statistics and scientific methods and procedures for monitoring and modeling.	Includes quantitative and coded tables, time series as well as narrative and descriptive text. A common characteristic is that it is often spatially referenced – i.e. in map form or with reference to point locations. The needed bioinformatics technology includes (i) database management systems(DBMS) (ii)GIS,(iii) image analysis, (iv) statistical analysis (including time series) and (v) modeling (both dynamic and static). Further, there is a need to be able to locate an extract descriptive text – often involving large quantities in disparate locations. This leads to requirements for (i) keywording, (ii)indexing, (iii)hypertext linking,(iv)distributed networking and (v) meta-database technology to assist in locating appropriate data sources.
2.Policy	Includes policies, action plans, strategies, administrative procedures, institutional arrangements and legal instruments- that is responses to issues, as wells as information on the human factors, encompassing population, human health, societal conditions, indigenous knowledge and their relationships to biodiversity.	Such information is dominantly in text form with some statistical tables. Spatial referencing is usually to an administrative framework. Thus text processing requirements dominate – including the use of micromedia and optical storage, along with statistical data bases and associated processing , although tolls like GIS may be required for integration with scientific information.

Data or information	Nature	Informatics
3.Economic	Economic information is essential to the concept of "equitable sharing of benefits" (CBD) to "wise use (Ramsar)", "sustainable use"(CMS) and so on Included are measures of economic productivity as well as the valuation of biodiversity.	Such information is dominantly in statistical tables, and time-series – referenced to administrative areas, social groupings or industrial sectors. Informatics analysis tools needed include time-series analysis, cross sectoral modeling , GIS etc.

The major components serve to transform the raw data held by national custodians (museums, government agencies, Universities etc) into information suitable for decision making.

The World Conservation Union (IUCN) has identified the following main issues that need to be considered when addressing sustainable use of biodiversity components:

1. When using biodiversity components, people should seek to **minimize losses of biological diversity.**

2. Sustainability, as a goal, can lead to constructive change that is underpinned by **continuous monitoring**.

3. Achieving sustainability involves ongoing process of **improved management practices.**

4. Management should be **adaptive**, incorporating monitoring and the ability to modify management practices to take account of risk and uncertainty.

5. Frameworks for developing systems for sustainable use of biodiversity components should be approached holistically by adopting an **interdisciplinary strategy** that incorporates biological, legal, economic and social consideration.

6. **Policy reform**, supported by appropriate economic incentives and innovative programmes, is required to promote the application of adaptive management and vest local communities with the authority to make and implement decisions on resource management.

Decision support systems(DSS):

As pointed out earlier the major difference between a Biodiversity information system and a Biodiversity information system for sustainable management is the requirement of a powerful **"decision support system(DSS)"**. This system may contain a variety of datasets that are necessary to draw meaningful management action plans. The most important components are programmes to construct **predictive models**, tools for **visualization of data** and **integration** of various policies, administrative regulations, social and economic aspects.

Predictive Modeling:

The most important part of any DSS is the availability of predictive models to develop adaptive management practices for sustainable use of the resources. To develop effective models we need information on several key issues:

- Species composition change with physical and biophysical environmental changes
- Information on where species and ecological communities could be expected to occur in the regions.
- Total economic, environmental and social value of biodiversity conservation at a range of scales.
- Impact of threatening processes on ecosystem processes.
- Impact of industrial activities and conservation management practices on the viability of populations within species.

- ❖ Conservation reserve system designs that are efficient in achieving biodiversity goals.
- ❖ The threshold conditions and extent below which further loss of habitat and loss within species and ecological community causes:
    - ❒ - inevitable further decline in ecological community
    - ❒ - unacceptable biodiversity loss in short and long time
- ❖ The extent of loss that can occur from all causes without jeoparadising ecosystem sustainability.
- ❖ The effect of existing and proposed management strategies and practices on biodiversity conservation.
- ❖ Practices that would enhance the ecological sustainability of industries.

Once the predictive models are prepared it is highly essential to verify the accuracy of the predictions ("**audit**") using targeted sampling.

1. **Example:**
2. **Nature Serve, USA (www.natureserve.org) :**

Over the past 30 years, the Nature Serve (a non-profit conservation group) network has collected and recorded detailed information on more than a half-million separate occurrences of at-risk species and natural communities. They have recently released an advanced GIS based software tool (***Biotics-4***) for managing biodiversity information. The use of Biotics-4 promotes interoperability throughout the network, ensuring that data collected at different locations can be compared , exchanged and combined. Through the Nature Serve Explorer website, users can query Nature Serve's central databases by any combination of scientific name, taxonomic group, conservation or legal status and geography. The Nature Serve has also developed a decision support system (DSS) – ***Vista Software*** - that will allow planners, conservation groups and local governments to better integrate biodiversity information into land use and conservation planning. The next major step forward in information technology for Nature Serve will be to implement an open web services architecture for the data resources, using emerging **XML-based Web services protocols.** Specifically organizations can use Vista to:

- ❖ Identify the plants, animals, and habitats that they wish to conserve, using high-quality scientific data from Nature Serve, natural heritage programmes, and other sources , and map the places where they are found.

- ❖ Summarize the conservation value of a particular place, using weighting system that reflects user priorities, and identify the most ecologically sensitive areas to be conserved , along with those places where development presents fewer conflicts.

- ❖ Generate a set of proposed conservation sites that meet agreed-upon conservation goals.

- ❖ Evaluate how well various land use or resource management plans meet the conservation goals. For example, user can access the positive and negative implications for the environment of competing land-use scenarios, such as different routes for highways or housing developments.

- ❖ Develop and implement land use and resource management plans, and monitor the progress of these plans over time.

The Vista introduces a module called "***Site Explorer***", a powerful tool that allow users to identify and understand the species and habitats that contribute to the conservation value of a particular site or set of sites, the land use and policies associated with those sites, and the response of the identified species and habitats to those land uses and policies. Site Explorer also provides the ability to conduct site-level "what if" inquiries that help to evaluate the effect of land use or policy changes on the achievement of conservation goals. Exploring these different scenarios, users can test alternative land use plans and policies for a given site, eventually finding the scenario that best fits their conservation goals.

Another feature of the Vista is interoperability with two popular conservation planning tools, **MARXAN** (see ***Appendix-1*** for more details)and **SPOT**, commonly used by conservation experts around the world. The Vista greatly eases the process of developing the data inputs required to run these tools, and then imports the resulting scenarios back into Vista. This software is a custom desktop GIS application designed an extension of **ESRI's ArcMap** platform with **Spatial Analyst**.

Marine Biodiversity Management:

Even though the general concepts outlined earlier fit very well for managing marine biodiversity, there are special categories and peculiarities of the ocean that require more sophisticated tools and databases. There are several tools with different levels of expertise to manage a variety of ocean resources.

Recently (September,2004), the Nature Serve conducted a survey of all available IT tools for Ecosystem Based Management (EBM)and evaluated their utility, sustainability and opportunities for further development. This report entitled, "**Tools for Coastal Marine Ecosystem Based Management (CMEBM)**" was submitted to the David and Lucile Packard Foundation, USA. According to the Foundation, this survey was conducted as a response to the growing number of scientists, practitioners and environmentalists who believe that existing approaches to coastal-marine conservation are inadequate and who are calling for a new management approach that focuses on entire ecosystems, including the people and communities that live there. They also claim that the ultimate goal of the initiative is to facilitate a shift to such management regimes. Ecosystem-based management (EBM) is a management approach designed to restore and sustain the health, productivity, and biological diversity of ecosystems and the quality of life for humans who depend on them. EBM is as much as a process as a science. It is a science based approach that:

- focuses on all of the organisms living in a given place as well as their interactions with each other and their physical environment, and is committed to understanding ecosystem processes and how ecosystems respond to environmental perturbations;
- integrates ecological, social, and economic goals and recognizes humans as key components of the ecosystem;
- defines the management regime based on ecological boundaries - not political boundaries, and the different spatial and temporal scales that accompany them; addresses the complexity of natural processes and social systems and uses an adaptive management approach in the face of resulting uncertainties;
- engages multiple stakeholders in a collaborative process to define problems and find solutions;
- is concerned with the ecological integrity and sustainability of the coupled human-ecological system, and;
- in coastal-marine systems, incorporates the dynamic interplay between terrestrial, marine, and freshwater systems.

EBM is as much a process as a science. Packard's working assumption is that to successfully establish a robust and durable ecosystem-based adaptive management regime in a particular region, stakeholders and decision-makers must be actively engaged in both understanding the consequences of their action (or inaction) and the process that leads to the adoption and implementation of a preferred management regime. Science and scientists are integral to this process, providing an understanding of the complex dynamics within a given system, helping answer "what if" questions, and identifying real conflicts based on differing values as opposed to perceived differences based on a limited knowledge, ideology, or historic conflicts between stakeholders.

This survey clearly showed that out of the 67 tools short listed 42 are developed for the terrestrial realm. Nine of the tools are designed for freshwater applications. Fewer tools are developed for the marine realm, with 6 tools addressing coastal issues and 6 focused on marine applications.

When we develop a management system or tool for sustainable use natural resources, several important categories have to be included and effective decision support system (DSS) has to be created. From the above survey report the inclusion of the following categories seem to be highly relevant to develop a good management system. The current status of these components in the surveyed tools, as shown below, clearly indicates the absence of a single efficient tool for sustainable management of the marine biodiversity.

Category-1:Information gathering and Management:

This functional category is fairly well covered by current tools but is particularly weak in the areas of ecosystem process models and inclusion of confidence information. The most common functions of these tools were the ability of the user to identify elements (also known as features or targets) of interest and the ecological requirements of those elements (***Note:*** *A new terminology* ***"Element Occurrence (EO)"*** *is used increasingly in planning management strategies for conservation of biodiversity. EO is defined as an area of land and/or water where a species or ecological* *community is or was present and has practical conservation value. An* ***EO Record (EOR)*** *is a data management tool that has both spatial and tabular components including a mappable feature and its supporting database*). There is great variability in the detail of element requirements that can be addressed and the flexibility of how they are expressed. Most tools only utilize presence / occurrence information; few incorporate spatial attributes of viability and confidence in presence. Ecological modeling functions tend to be supported by separate tools that can incorporate a great deal of information about element reactions to temperature and chemical changes, and trophic interaction. However, these single-purpose tools may be difficult to integrate with larger ecosystem planning tools utilizing coarser data. Only two tools are inclusive of information regarding the confidence level of the data, a serious concern of decision makers.

Category-2:Goal Setting and Evaluation:

All but one of the tools allow the user to set conservation goals, but only four of them are capable of setting any type of economic goals or limitations. Stakeholder involvement in goal setting and evaluation is fairly well supported but few tools can allocate goals among separate jurisdictions within a larger ecosystem.

Category-3:Threat Identification and Impact Analysis:

Many tools are able to identify or include information on threats to achieving ecological goals and viability. A few tools claim ability to identify threats to economic goals.

Category-4:Threat Mitigation Analysis:

A single tool (NatureServe **Vista**) is capable of identifying land uses that are compatible with individual elements as opposed to generic compatibility of land-uses to conservation. Several tools can identify areas for restoration and an equal number can generate scenarios for conservation reserves.

Category-5:Conservation Area Selection:

All tools allow some form of scenario comparison and a few conduct cost/ benefit analysis and specifically support stakeholder involvement in the decision process. Functions that support plan implementation are covered partially by only two tools, Index and COSMO. Currently no available tool is able to calculate an implementation budget that sufficiently represents real world economic complexities or can support dynamic decision making and budgeting.

Category-6:Ecosystem Management:

Very few tools are capable of the functions involved with ecosystem management, such as designating indicators for monitoring or creating a plan for monitoring and evaluation. Only one tool (EMDS) has the function of creating a monitoring plan or of supporting the implementation and monitoring of a land-use decision.

Two examples extracted from the above survey report are given in ***Appendix-1*** for better understanding of these tools and their capabilities:

- EwE Ecopath with Ecosim (Marine)
- MARXAN (Marine)

Most tools tend not to be engineered to commercial standards or to be maintained with changing technology. For example, only one tool (NatureServe **Vista**) is currently operating on ArcGIS 9.0 (though some developers of other tools have indicated that they are planning an upgrade to ArcGIS9.0).

Details of four more tools relevant to sustainable management are given in ***Appendix-1***.

As on today, as part of the ongoing Census of Marine Life (CoML) programme, the best information system on global marine biodiversity is the **Ocean Biogeographical Information System** (**OBIS**)(Costello and Berghe,2006). For more details contact their web site (www.iobis.org). It must be mentioned that this database does not cover all aspects necessary for a sustainable management of marine biodiversity but the modules can be developed in the future. The Ocean Biodiversity Informatics is the use of computer technologies to manage marine biodiversity information, including data capture, storage, search, retrieval, visualization, mapping, modeling, analysis and publication. The latest information systems are open-access, making data and/or information publicly available over the Internet. This ranges from primary data on species occurrences to species information pages and identification guides. Using standard data schema and exchange protocols, online systems can become interoperable and, thus, integrate data from different sources. However, insufficient metadata standards, i.e. the terminology to describe data, are available for biology and ecology. Quality assurance needs at least the same rigor as for printed publications including expert oversight (e.g. Editorial Board), quality-control procedures and peer review. Although taxon names are the central, and most unique, element of biodiversity informatics, only about one-third of the names of described marine species are currently available online in authoritative master lists.

Gulf of Mannar GOM) Biosphere Reserve, India:

A biosphere reserve is defined as an area which is set aside for conservation of the resources of the biosphere and for the improvement of the relationship between man and the environment. It is also an area which is identified to serve as sites for long term scientific research as well as education all over the world. Each Biosphere Reserve is intended to fulfill three basic functions which are complementary and mutually reinforcing.

- Conservation of landscapes, ecosystems, species and genetic variation.
- Development of sustainable aeconomic and socio-cultural activities.
- Logistic function to provide support for research, monitoring, education and information exchange (local, national & global)

The Gulf of Mannar (GoM) is located at the southern tip of Tamil Nadu, India extending from Rameswaram in the north and to Kanyakumari in the south. The 140 km GoM stretch extending from Rameswaram to Tuticorin includes 21 uninhabited islands, which are surrounded by coral reefs (Patterson et.al., 2007). In 1980 the Government of Tamilnadu notified the public of the intention of setting up the Marine National Park. After renotification in September,1986 the Gulf of Mannar Marine National Park was declared, including the 21 islands. The islands are located between Lat.80 47' and 90 15'N and Long.780 12' E and 790 14' E.

In 1989 the GoM was declared as "Biosphere Reserve" covering an area of 10,500 sq.km. By the Government of India. The GoM is influenced by seasonal monsoonal patterns, southwest monsoon and northeast monsoon. The islands lie at an average distance of 8-10 km from the mainland. Narrow fringing reefs are mostly located at a distance of 100 to 350 m from the islands and patch reef rise from depths of 2m to 9m and extend up to 1-2 km length with width as much as 50 m. The large areas of reefs along GoM are generally poor in condition due to a number of destructive activities by people who live along the coast and depend on fishery resources of the reef areas for their livelihood. There are over 150,000 people living in the coastal zone of GoM, many of whom depend on reef fishery resources for their livelihood. Nutrient and other pollution loads are significant due to agriculture, deforestation, indusry and urbanization. According to the recent survey (Patterson et.al., 2007) there are 107 species of corals. The present live coral cover in GoM was suggested to be around 35%.The GoM is rich in various other biological resources like seaweeds (147 species), sea grass (13 species), sea cucumbers (17 species), finfishes (510 species), shell fishes (106 species), lobsters (4 species) and sea cows. While main threat to the ecosystem is local – destructive and non-sustainable fishery practices such as trawling, poison fishing, blast fishing etc., the global threat is climate change induced coral bleaching and invasion of alien species. Further, traditional fishers who form the majority of the population living along the GoM have increased in numbers during the last decades.

Considering the unique nature of GoM and realising the need for scientific management a GEF-UNDP project at a total cost of Rs.140 crores for a period of seven years (2003-2010) was initiated with the formation of Gulf of Mannar Biosphere Reserve Trust (GoMBRT). The main objective of his trust is to demonstrate how to integrate biodiversity conservation into coastal marine management plan and implement the same in a large biosphere reserve with various multiple use.

GoMBRT Mission statement: " 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 and sensible coastal zone development in the area which is compatible with the ethos of biodiversity conservation and livelihood security of coastal people of GoM for all the time to come".

The GOMBRT's vision statement also emphasizes the need of sustainable management of the resources of the bioreserve: " Project on "conservation and sutainable use of Gulf of Mannar Biosphere Reserve's coastal Biodiversity" with the highest standard of professional and ethical competence and integrity during the project period ensuring that the implementation is globally acknowledged and appreiated and it is taken as a "model" to be replicated in various other parts of the country and in the world".

So the **major tasks to completed** to achieve these goals are:

- ❖ Inclusion of biodiversity conservation principles and practices into sustainable development interventions.
- ❖ Management planning, law and policy frameworks, law enforcement and capacity building.
- ❖ Environmental education and awareness for all stakeholders.
- ❖ Network with national, regional and international agencies.

If we see the progress made by the project during the last few years, development of adaptive management practices through capacity building and awareness programmes have been their main concern (GoMBRT Annual Report,2006). They also gave sufficient attention to practice conservation strategies(protection of endangered habitats and organisms, prohibited harvest and use of scheduled marine animals and control of illegal use of destructive fishing practices). Their achievements during the last few years are as follows:

- ❖ > 67 Ecodevelopment committees established and trained members.
- ❖ >24 Anti Poaching Watchers appointed and regular patrolling of islands improved.
- ❖ Boundary demarcation for National Park completed (10 buoys).
- ❖ Joint Patrols with State Fisheries and National Park Authorities conducted.

- Long Term Funding Mechanism(LTFM)does not exist – Negotiations with 2 institutions held.
- Training module in biodiversity conservation developed.
- Development of Ecotourism policy and guidelines -***in progress.***
- Trust started negotiating with local communities on habitat zoning.
- 54 microplans to address conservation and sustainable development issues have been developed.
- Small Help Groups(SHGs) formed in 40 villages and trained. This is part of the establishment of village level grass-route organization in the name of Village Marine Conservation and Eco-Development Committees (VMC & EDCs) in all 222 project villages identified in the zone of influence (10 km from shore line) of GoM.
- Compilation of all available information on the ecology and conservation of GoMBR has been commissioned.
- Awareness of GoMBR and marine conservation issues enhanced among school students and teachers.
- 222 coastal villages have been categorized into various threat categories (High Threat, Medium Threat and Low Threat) and are being involved in the project.
- Nine NGOs have been selected to partner.

Possible future activities:

Given the above scenario for the GoM Biosphere Reserve, for effective implementation of sustainable management of resources we may also consider the following three actions:

1. Establish a **Central knowledge portal** for information management (GoMBR Information system). The central part of this system is a Data Management System (DMS) consisting essentially of (i) **Spatial Data** integrating species and habitat information to produce habitat suitability (HS) maps using GIS. (ii) The DMS can use the HS maps to find out **habitat patches** using patch-recognition algorithms, (iii) **Habitat dynamics** and (iv)information on **publications and subject experts** with their contact details. The DMS should have an interactive, user-friendly menu system. There should also be a large set of error and warning messages for checking consistency of different inputs. The DMS also will have visualizaion and output tools. A web server should be the integral part of this system.

2. Prepare **Predictive Models** for sustainable use of resources employing freely available and relevant commercial programmes. Ecological risk assessment is an important component of any biodiversity management strategy. The DMS must have a sensitivity analysis feature that allows multiple simulations with automatically changed input parameters. This will enable the user to compare results from different simulations by superimposing graphs of risk curves, time-to-extinction distributions etc.

3. Develop **Decision Support Systems** (DSS) to formulate Active Adaptive Management strategies. The most important components are programmes to construct predictive models, tools for visualization of data and integration of various policies, administrative regulations, social and economic aspects. We should try to build DSS that can be used by local communities which involves translating several of the outputs in to local language.

Because there is so much diversity in resources, uses and users, we can not have a universal formula for sustainability. As GoMBRT has already completed several sub-sets of this management system it is possible to establish a complete system specifically for the Gulf of Mannar area without much difficulty. It is also advantageous to streamline the various research activities conducted by many institutions and individuals so that their findings would contribute to the development of management practices. If they can identify the gaps and prioritize the areas, special programmes can be initiated, either by themselves or by other government agencies.

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APPENDIX-I:

Tool-1 :

Name : **EwE Ecopath with Ecosim**

URL : http://www.ecopath.org/

Summary: EwE is an ecological software suite with more than 2000 registered users representing 120 countries. More than a hundred ecosystem models applying the software have been published. EwE has three main components: Ecopath – a static, mass-balanced snapshot of the system; Ecosim – a time dynamic simulation module for policy exploration; and Ecospace – a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas.

The Ecopath software package can be used to

- Address ecological questions;
- Evaluate ecosystem effects of fishing;
- Explore management policy options;
- Evaluate impact and placement of marine protected areas;
- Evaluate effect of environmental changes.

The foundation of the EwE suite is an Ecopath model, which creates a static mass-balanced snapshot of the resources in an ecosystem and their interactions, represented by trophically linked biomass 'pools'. The biomass pools consist of a single species,or species groups representing ecological guilds. Pools may be further split into ontogenetic (juvenile/adult) groups that can then be linked together in Ecosim. Ecopath data requirements are relatively simple, and generally already available. Ecosim provides a dynamic simulation capability at the ecosystem level, with key initial parameters inherited from the base Ecopath model. The key computational aspects are in summary form:

- Use of mass-balance results (from Ecopath) for parameter estimation;
- Variable speed splitting enables efficient modeling of the dynamics of both 'fast' (phytoplankton) and 'slow' groups (whales);
- Effects of micro-scale behaviors on macro-scale rates: top-down vs. bottom-up control incorporated explicitly.
- Includes biomass and size structure dynamics for key ecosystem groups, using a mix of differential and difference equations.

An FAO workshop was convened at UBC in July 2000 aimed at exploring 'The Use of Ecosystem Models to Investigate Multispecies Management Strategies for Capture Fisheries'. At the workshop around 40 scientists from throughout the world worked with 15-20 EwE models to investigate the impact of different multispecies harvesting strategies on the community structure and fishery yields with a view to identifying preferred harvesting strategies. A central aim of fisheries management is to regulate fishing mortality rates over time so as to achieve economic, social and ecological sustainability objectives. An important dynamic modeling and assessment objective is thus to provide insight about how high these mortality rates should be, and how they should be varied over time (at least during development or recovery from past overfishing). We cannot expect models to provide very precise estimates of optimum fishing mortality rates, but we should at least be able to define reasonable and prudent ranges for the rates.

The objective function can be thought of as a 'multi-criterion objective', represented as a weighted sum of the four objectives: economic, social, legal, and ecological. Assigning alternative weights to these components is a way to see how they conflict or tradeoff with one another in terms of policy choice. Even if we would not dream of incorporating the results into today's management without very thorough considerations of inherent risks and uncertainties, it is for now very rewarding to be able to participate in a process where the questions addressed are of the sort: "How do we want this ecosystem to look in the future, and what are the implications of our choices?" The goal function for policy optimization is defined by the user in Ecosim, based on an evaluation of four weighted policy objectives:

1. Maximize fisheries rent;
2. Maximize social benefits;
3. Maximize mandated rebuilding of species;
4. Maximize ecosystem structure or 'health'.

EwE is being used for marine calculations in the global Millennium Ecosystem Assessment. EcoSpace adds a spatial component to the model that lends itself well to restoration targets and reserve locations. Scenarios can be run with hypothetical marine protected areas to view their potential effects on the ecosystem and fisheries.

Ecotype	:	**Marine**
Cost	:	**Downloading, registration, user's guide and support is free of charge.**
Usability	:	Used for graduate courses in a number of universities. Basic Ecopath modeling is not very difficult; mainly requires knowledge of the ecosystem to be modeled and reading the User's Guide. However, for advanced use in fisheries management it is as demanding as advanced single-species assessment tools.
Platform	:	Windows 98/2000/ME/NT4/XP
Source Code	:	Available upon request
Support/Training	:	User support is free
Info gathering and management	:	Includes identification of planning boundaries, element selection, and specification of element requirements
Goal setting & evaluation	:	Ability to set ecological goals and incorporate multiple stakeholders
Threat ID & impact	:	Identifies threats to ecological goals, impact analysis on ecosystem viability, and threats to economic goals (expressed as cost to fisheries)
Threat mitigation	:	Identifies potential restoration and reserve sites and allows user to run scenarios with hypothetical protected areas to identify most effective location
Conservation area	:	Allows scenario comparison, and contains a basic fisheries cost/benefit equation

Ecosystem Management	:	Increasingly being incorporated in the management process.
Used for	:	Dynamic simulation of large-scale marine ecosystems for investigating policy decisions
Comment	:	EwE provides a common language for marine and fisheries managers and planners. Although the tool does not explicitly include multiple stakeholders or conflict negotiation aspects, it does act as a powerful visualization for making complex decisions. The inclusion of a basic fisheries economics equation minimally brings socio-political factors into the model that could potentially be expanded to include other factors or developed more fully to incorporate complex cost/benefit analysis. Ecopath/Ecosim are among the most widely used conservation planning tools in the discipline. They have been around for several years and have undergone a number of upgrades and extensions. Ecopath is part of a number of university curricula and has gained widespread mainstream use and application.

Tool-2:

Name	:	**MARXAN**
Category	:	Conservation
URL	:	http://www.ecology.uq.edu.au/marxan.htm
Summary	:	MARXAN is software that delivers decision support for reserve system design. MARXAN finds reasonably efficient solutions to the

problem of selecting a system of spatially cohesive sites that meet a suite of biodiversity targets (goals). Given reasonably uniform data on species, habitats and/or other relevant biodiversity features and surrogates for a number of planning units (as many as 20,000) MARXAN minimizes the cost while meeting user-defined biodiversity targets. The model calculates the portfolio cost for each potential solution and tries to minimize this cost while generating a near-optimal solution. Hundreds of different scenarios can be run and compared to look at different outcomes and patterns in the outcomes to determine which landscape elements are most critical to preserve.

The optimisation algorithm that attempts to find good systems of sites is 'simulated annealing'. The number of possible solutions is vast (for 200 planning units there are over 1.6 x 10^60 solutions) and because the problem is NP-complete there is no possible method for extracting an optimal solution in reasonable time for large problems. Because of this there is no real hope (or indeed incentive) to find an optimal solution: MARXAN will find good solutions using simulated annealing. The user can also invoke a variety of less sophisticated, but often faster, heuristic algorithms. We have found that one of the most useful outputs from the decision support software is the 'summed irreplaceability' output. This output shows how often each planning unit is in one of the good systems. Planning units that are chosen more than 50% of the time can be thought of as being essential for efficiently meeting biodiversity goals. Sites that are rarely selected can be ignored.

MARXAN was developed as a modified version of SPEXAN to meet the needs of the Great Barrier Reef Marine Planning Authority (GBRMPA) in their rezoning plans. GBRMPA provided partial support for the modification.

MARXAN is currently being used by Adam Lewis and Suzanne Slegers to provide decision support for the GBR representative areas program. Along with TheNature Conservancy(TNC) ecoregional planning processes, these represent the largest applications of MARXAN/SPEXAN. MARXAN is extensively used in marine and coastal planning applications, including in the northern Gulf of Mexico coast of the US, the Florida Keys, the Gallapagos Is., British Columbia Canada, the Guld of California, the marine park in the Great Barrier Reef, and in the evaluation of reserve systems in southern Australia.

Ecotype	:	**Marine**
Cost	:	**free download**
Platform	:	A separate graphic user interface is provided for setting up input data and run options for the engine. MARXAN does not provide graphic display of design solutions, but its output data are easily imported into GIS applications such as ArcView 3.2 of ArcGIS 8.x.
Info gathering and management	:	Includes identification of planning boundaries, element selection, and specification of element requirements
Goal setting & evaluation	:	Ability to set ecological and economic goals
Threat ID & impact	:	Identifies threats to ecologic and economic goals
Threat mitigation	:	Creates reserve scenarios
Conservation area	:	Enables scenario comparison and economic cost/biodiversity benefit analysis.
Used fo	:	Reserve system selection
Feedback	:	MARXAN is the most common tool for designing reserve systems.

Tool-3:

Name	:	**EstimateS**
Category	:	Statistical estimations of species richness and shared species from samples.
URL	:	http://viceroy.eeb.uconn.edu/EstimateS
Summary	:	(i)Major features of EstimateS 8.0.0: ● Rarefaction and species accumulation curves ● Species richness estimation & diversity indices ● Shared species estimation and biotic similarity indices with estimators ● Importing data and exporting results ● Biodiversity Database Manager (ii)Major uses : Conservation biology; Biotic inventories ; Nature area assessment & monitoring; Biogeography; Macroecology; Microbial ecology; Molecular biology; Ethanobiology.
Cost	:	**Free**
Operating system	:	Windows 2000 to Windows XP; also available for Mac.

Tool-4:

Name	:	**Open Modeller**
Category	:	Open Modeller is a fundamental niche modelling library, providing a uniform method for modelling distribution patterns using a variety of modelling algorithms.
URL	:	http://openmodeller.sourceforge.net/
Summary	:	Ecological niche modeling and species

richness estimations ,both require coupling biodiversity information – named species occurrence – with geographic and potentially environmental data, geographic information systems (GIS) and statistical approaches. The openModeller project aims to provide a flexible, user friendly, cross platform environment where the entire process of conducting a fundamental niche modeling experiment can be carried out. The software includes facilities for reading species occurrence and environmental data, selection of environmental layers on which the model should be based, creating a fundamental niche model and projecting the model into an environmental scenario. A number of fundamental niche modeling algorithms are provided as plug-ins, including GARP, Climate Space Model, Bioclimatic Envelopes, and others. Additional algorithms are planned for the future.

Cost : **Open source initiative** (current developers include: CRIA,Poli,INPE,FAPESP, IncoFish, BDWorld, KU and individuals).

Operating systems : Windows 2000 to Windows XP

Tool-5 :

Name : **BioMapper**

Category : A GIS Toolkit to model ecological niche and habitat suitability (HS)and maps for any kind of animal or plant. It is centred on the Ecological Niche Factor Analysis (ENFA) that allows to compute HS models without the need of absence data.

URL : http://www2.unil.ch/biomapper/

Summary : More precisely, it can deal with the following

tasks :

* Preparing the ecogeographical maps in order to use them as input for the ENFA (e.g. computing frequency of occurrence map, standardisation, masking, etc.)
* Exploring and comparing them by mean of descriptive statistics (distribution analysis, etc.)
* Computing the Ecological Niche Factor Analysis and exploring its output.
* Computing a Habitat Suitability (HS)map
* Evaluating it Biomapper is designed to be autonomous but as it uses the same file format as the GIS software *Idrisi* they can transparently work in conjunction.

Cost : Downloadable for free.

Operating systems : Windows N.T. or later

Comments : Biomapper does not need absence data (very important and rare property) and it works with presence data only. Eventhough it can use the ***Idrisi*** file formats, it does not require ***Idrisi*** to work.Biomapper was designed with huge files in mind. It was actually tested with up to 30 maps of 32MB each. Infact the only limitation would be the available memory and the hard disk space. A help file gives few information and a step-by-step modus operandi. The Biomapper and its central statistical procedure; ENFA produces high quality accurate results even with poor input data. In fact, it is quite robust to data quality and quantity.

Tool-6:

Name : **BIOTA *v.2.04***

Category : Biodiversity Database Manager

URL : http://viceroy.eeb.uconn.edu/biota

Summary : *Biota* manages specimen-based, spatially and taxonomically referenced data for ecologists, conservation biologists, evolutionary biologists, systematists, museums and herbaria.

Features of Biota ver.2 :

Tabbed input forms; combined Specimen and Collection input option

* External Image files transparently linked to Species, Specimen, Collection, and Locality records (Species only, in *Biota* 1) ; onboard image editing tools
* Literature Reference table (easy import from EndNote) with links to Species, Specimen, Collection, and Locality records
* Improved picklist system with easy import for authority files
* Onboard Web server capability for Internet or intranet publication of your database Fast, scalable application based on an industrial grade engine (www.4d.com)
* Comprehensive, profusely illustrated, cross-referenced Manual.

* Intuitive menus and screens; clear, contextual instruction and error messages
* Powerful import and export tools
* Flexible field customization and unlimited auxiliary fields
* Species Synonymy, Determination History, and Specimen Loan systems
* ...and many other tools and features

Cost	:	**Priced**
Operating system	:	Windows XP or Mac OS X
Comments	:	Users of BIOTA : Ecologists; Conservation Biologists; Reserve Managers; Biogeographers; Taxonomists; Collections Managers. No more struggling through immense spread sheets with repeated (variously mispelled) taxonomic and locality columns. Biota's relational structure means there is exactly one record for each taxon and locality. No more scanning through files or external image management applications to find images of specimens or collecting sites. With Biota we can link any number of external image files (or internal images) to any Species, Specimen, Collection or Locality record in the Biota Data File. Using Biota's image comparison tools, we can ompare thumbnails for likely species quickly to help identify specimens, and see the full, original image at the touch of a zoom button. Biota has

got Specimen Loan Management System, label printing and label text export facilities (for pinned, fluid-preserved, slide-mounted or herbarium specimens), static Web page export and client server readiness (TCP/IP based). It also has onboard web server to offer query based ,dynamic searching and browsing to web visitors.

INDOBIS AND ITS RELEVANCE TO THE GULF OF MANNAR BIOSPHERE RESERVE

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Introduction

The Gulf of Mannar (GoM), which has been given the status of a Biosphere Reserve in 1989 under the Man and Biosphere Reserve Programme of UNESCO. It was declared as the first marine protected area in South and South east Asia, owing to its geographical, ecological and biological features.

IndOBIS (Indian Ocean node of OBIS) is one of the seven regional nodes established by the OBIS (Ocean Biogeographic Information System), which is the data and information component of Census of Marine Life (CoML). It harbors species and related metadata on Indian Ocean region. In the present paper, we are describing the functions and role of these worldwide initiatives and the need to have quality data of species in computerized online databases where it can be accessed by anyone at any time. We also emphasize here the need to have a central data facility for marine biodiversity and the importance of sharing the data in the context of conservation of GoM Biosphere Reserve.

Basic Requirements

Diverse data sets such as species, biogeography, museum specimen, ecology, climate change, traditional knowledge, environment, bathymetry etc. are very critical for making forecast on the species, community and/or the ecosystem.

The question is, with these diverse kind of data can we answer the following three basic questions on any species? How many species lived in the past? How many species are present now? How many species will exist in future?

Need of a Central Data Facility System

Biodiversity is rich in developing countries whereas biodiversity information is concentrated in developed countries. Scientists find it difficult to discover, access and use biodiversity data because of the mismatch between the distribution of biodiversity, and the distribution of the data, and most importantly, the complexity of biodiversity data.

For the sustainable utilization of biodiversity resources mankind must learn how to exploit the massive data sets, how to store and access them for analytic purposes. We must unlock the knowledge and economic power lying dormant in the masses of biodiversity that we have on hand that is stored in static media. All of this informatics capability is needed because, we are losing at an ever-increasing rate both species that we know and ten times as many that we don't know.

IndOBIS (http://www.indobis.org)

IndOBIS is the Indian Ocean node of OBIS (http://www.iobis.org), which is the data and information component of the Census of Marine Life (CoML, http://www.coml.org). It is initiated with the objectives to understand species occurrence (type, census, distribution pattern, biological threat category, bioinvasion), ecological impact on biota, seascape ecology, phylo- and macro-geography evolution of fauna and flora at population and species levels), marine bio-terrorism informatics etc. The National Institute of Oceanography (NIO), Goa and the National Chemical Laboratory (NCL), Pune have been jointly interested to develop this regional node and have been managing it since 2004.

IndOBIS- Mission

Indian Ocean (IO) is the third largest ocean in the world. It is different from other oceans in social, cultural, economic and ethnic aspects. It is a significant contributor to the production of marine living resources. About 10% of world's population lives within 100 km of IO shores, but is the least studied for its biodiversity.

IndOBIS will contribute to the understanding of the past and the present, in order to learn about the future of life in the Indian Ocean. It will become a prime provider of biodiversity information on the Indian Ocean, and make this available in a multi-dimensional geographic context; promote communication and awareness to user groups at all levels, using appropriate information tools; and enable informed decision-making process, leading to sustainable use of natural resources.

IndOBIS - features and status

IndOBIS has administrative tools for online contributions with special quality control, authentication and validation methods. It has various web search modules for data use applications. The database has adopted Cavilier Smith's 8 kingdom classification system.

Features of the database include Scientific names, Common and local names, Locality records,

Mostly faunal species, QA/QC exercise is in progress, Network of distributed taxon editors

Data statistics of the IndOBIS database (as on September 2007) is, 41404-Scientific names, 25698-Synonyms, 10336- Common names, 96955-Locality records with 70905 - Unique localities. Average number of localities per scientific name is 2.34.

IndOBIS database has been developed with the dream mission of making it as a potential data provider on species, biogeography, ecosystem, molecular and sequence data, electronic literatures/articles, experts/ institutions, traditional knowledge of flora and fauna from the Indian Ocean. IndOBIS will serve as a centralised facility holding a treasure-trove of biodiversity data which can be accessed by anybody at anytime (Fig-1).

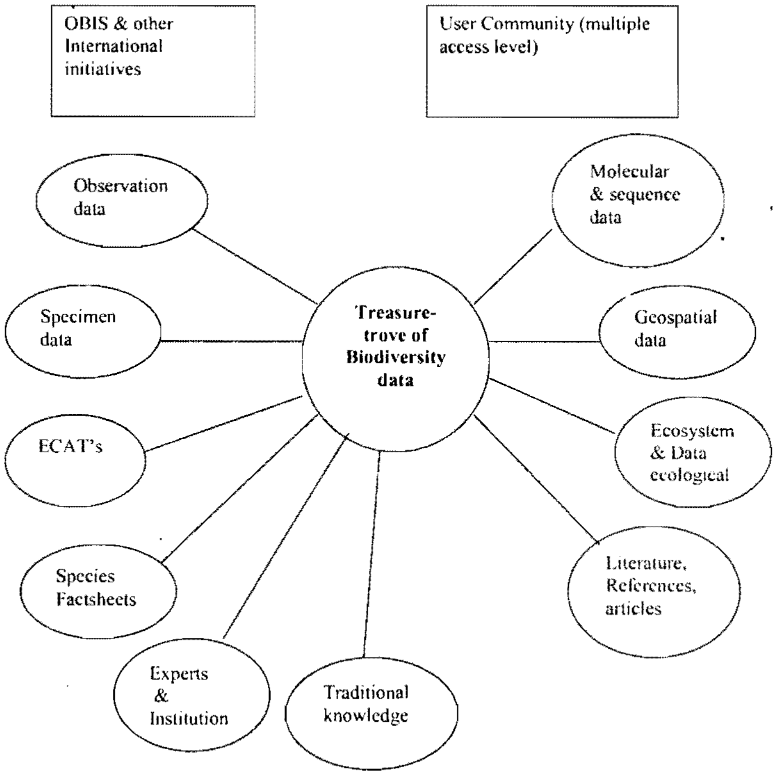

Fig.1. A Diagrammatic representation of future perspectives of IndOBIS.

Gulf of Mannar Biosphere Reserve

The Gulf of Mannar is a large shallow bay lies between the southeastern tip of India and the west coast of Sri Lanka ($8^{O}49'$ to 9^{O} 15' N latitude and $78^{O}11'$ to $79^{O}15'$ E longitude) with widths between 160 and 200 km. It covers an area of 1,050,000 hectares and encompasses 21 coastal islands with estuaries, beaches, forests of the nearshore environment, including a marine component with algal communities, sea grasses, coral reefs, salt marshes and mangroves. It is one of the world's richest regions from a marine biodiversity perspective.

The Government of India, has established the Gulf of Mannar Biosphere Reserve, in 1989, the first of its kind in South and South East Asia, with the basic objectives of conserving *in situ* of biodiversity of natural/ semi-natural ecosystems and landscapes, contributing to sustainable economic development of the human population living within and around the biosphere reserve and providing facilities for long-term ecological studies, environmental education, training, research and monitoring related to local, national and global issues of conservation and sustainable development. It is the first Indian marine national park which is internationally recognized under the UNESCO-MAB (Man And Biosphere) program. It is rich both in species and habitat biodiversity. The reserve has a status of particular concern because of its diversity and special multiple use management status.

Ecological Importance

The Reserve harbours marine biodiversity of global significance and is renowned for its coral reef, sea grass and algal communities. The islands are referred as a "biologist's paradise" and it contains over 3,600 species of flora and fauna most of which are in their virgin form. The sandy shores of the islands provide an excellent foraging habitat for 5 species of marine turtles. Nearly 117 species of hard coral have been recorded from here . The reef is home to sprats, herrings, barracuda, sea horses, dolphins, balanoglossus, sea cucumbers, and pearl oysters. Migratory birds also visit these islands. International Union for Conservation of Nature's Commission of Natural Parks and Protected Areas has identified this reserve as one of the priority sites for treatment on account of its diversity and multiple use status.

The Algae Resources

Seaweed or marine algae are renewable important marine living resources. Gulf of Mannar marine area has more than 147 species of sea weeds, majority are found in the reef regions. *Padina* was observed on the shores and lagoons. *Gracilaria lichenoides* was found more on the shore and lagoon than on reefs. The predominant species on the coral reefs is

Halimeda opuntia. *Sargassum* and *Turbinaria* are found on the shoreward part of the reefs. *Caulerpa, Sargassum, Amphiroa fragilissima* are the other dominant species.

Seagrass Eco-system & Higher plants

Out of the 14 species of seagrasses under six genera known from Indian seas, thirteen species occur in the Gulf of Mannar Biosphere Reserve (Venkataraman & Wafar, 2005), dominated by family like Hydrocharitaceae, Potamogetonaceae and species *Thalassia hemprichi, Halophila ovalis, H.ovata, H.beccari, H.spipulacea, Halodule uninervis, Cymodocea rotunds, C.serulata.* All the 11 sea grasses of India occur here with *Enhalus acoroides* being endemic. The sea grass beds provide feeding grounds for the highly endangered sea-mammal *Dugong dugon* and a suitable habitat for many marine animals for spawning.

The area has all the mangrove species available in India (*Rhizophora muctonata, Avicennia alba, Bruguiera gymnorrhiza, Ceriops tagal, Lumnitzera racemosa),* with *Pemphis acidula* being endemic.

The angiosperm flora of Gulf of Mannar has a total of 784 taxa which includes 764 species and 20 infraspecific taxa (Subspecies /varieties). They belong to 433 genera and 113 families.

Endemic plants

There are 46 endemic taxa including one subspecies and 7 varieties. Species endemic to Gulf of Mannar: *Acrachne henrardiana, Acrachne sundararaji, Ceropegia mannarana, Chloris wightiana, Ipomoea pes-caprae var. perunkulamensi, Iseilema jainiana, Jatropha villosa var. ramnadnesis, Leucas anandaraoana, Perotis indica var. keelkaraiensis.*

The Coral Eco-system and Major Invertebrates

The corals are commonly called "Ever Green Forest of the Sea". Nearly 117 species of Hard coral belonging to 37 genera (Kelleher, 1995) have been recorded from here . The reef is home to sprats, herrings, barracuda, sea horses, dolphins, balanoglossus, sea cucumbers, pearl oysters and turtles. As many as 133 species are found in the Gulf of Mannar region.

The invertebrates are represented by 280 species of sponges, 92 species of corals, 22 species of sea fans, 160 species of polychaetes, 35 species of prawns, 17 species of crabs, 7 species of lobsters, 17 species of cephalopods and 103 species of echinoderms.

Vertebrates

Fishes and Marine Turtle

Of the 2200 fish species distributed in Indian water 450 species have so far been recorded in this area. Five species of marine turtles are known from this area. They are the Hawks bill turtle, Green Turtle, Olive ridley, leatherback turtle and Logger head turtle. All turtles are becoming highly endangered.

Avifauna

The island of Gulf of Mannar with their luxuriant mangrove vegetation, mudflats and coral reefs form an important resting place for the birds migrating to and from other countries. The diversity of eco-system in the area has made in the wintering and mounting ground for many thousands of waders. More than 168 species of birds have been recorded

Mammals

Dolphins, Dugongs and whales represent the marine mammals in the Gulf of Mannar. The sea cow (*Dugong dugon*) and Baleen Whale are critically endangered living in this region.

Reference of IndOBIS to GoMBR Conservation

IndOBIS database currently holds a total of only 111 species records, mostly faunal from Gulf of Mannar region.

The phylum-wise statistics is given below :

Annelida- 4; Arthropoda -12; Chordata -24; Cnidaria-18; Coelenterata-1; Echinodermata-10; Mollusca -13; Porifera-3; Chlorophyta-2; Rhodophyta-6, and Retaria-18.

Potential Gaps

While more than 3600 species of flora and fauna have been recorded from GoM region, only less than 5% of original available information could be added to IndOBIS database. There is a wide gap between the actual information and the available information. How can we fill these gaps?

Here is the need of active data sharing from other organizations, database collaborations, individual data holders, tangible and online resources etc . Unfortunately, species and biodiversity data are possessed by individual scientist/taxonomist or some institutions which cannot be accessed by others. Therefore, these valuable data are not available for developing realistic niche models or ecological models and also for planners/ managers to rely on to take decisions for conservation and sustainable use of these bioresources.

What you can do?

We need your valuable participations in the following ways to make IndOBIS a potential marine data provider.

- Comment on IndOBIS web sites and portal, it is as good as you help make it.
- Assist IndOBIS networking to scientists.
- Promote need for IndOBIS to governments and funding agencies.
- Encourage data publication through IndOBIS new datasets, newly digitized data, and compliment those who have published online databases.

Gulf of Mannar Biosphere Reserve -

An ecological model for Biodiversity conservation, livelihood & sustainability

The GoMBR has a sound resource base. From the biodiversity perspective it is known as "biologist's paradise". Diverse forms of fauna and flora with complex, interdependent fragile ecosystems with high degree of endemism making it one of the potential field area for science related activities. Being renewable resources, presently over 40,000 local fisherman in a population of 1.60 lakhs living in 125 villages directly depend on these marine resource.

Over the years the marine wealth of GoM has been over exploited, leading to drastic loss of resources and diversity. The resources of the region are being overexploited beyond the carrying capacity due to overfishing, destructive fishing practices, lack of awareness etc. Of late, the agriculturists from the main land area are switching over to fishing activities in a big way due to consistent failure of monsoon. This adds a new dimension to the already existing pressure on the marine resources of the area. However, It is estimated that for every 1000 kg of fish collected, 325 kg of variety of marine organisms are discarded and allowed to die outside the sea. Thus huge quantities of a wide variety of untargeted marine organisms are thrown on the shore as debris. Further illegal coral mining for cement industries and indiscriminate collection of sea grass for industrial use collectively cause the collapse and breakdown of variety of sensitive marine eco-system. Presently, it is estimated that 65% of the existing coral reefs in the project area are dead, mostly due to human interference.

Time seems to have exceeded to adopt different strategies for protecting this internationally recognized marine park, which is an ecological model from the biodiversity, socio-economic and renewable resource perspectives. Here we are reviewing the various strategic measures from an informatics point view.

Computational approach to conservation strategy

Project Activities and Databases

Projects regarding the systematics, ecology and biodiversity of GoM will be an analytic tool to know the existence of biota (past, present and future), ecological behavioural pattern, biogeographic pattern , biochemistry, evolutionary aspects etc. Design and creation of comprehensive databases (dedicated to GoM), which can be accessible to each and everybody, including common man, is a major information facility.

Digital Libraries

Museum specimen data are a vital source of ancient history. Since, the biological specimens are getting disintegrated by the time, the digitization of museum collections are gaining momentum. Accessibility and usability at any time makes the digital libraries one of the important tool for taxonomic identification of species. Therefore, there is an urgent need to digitalize all the specimens available from GoM along with all available metadata and make these available online.

Bio- Softwares and Tools

Computational softwares and tools are used to manage the large, complex metadata elements.

A relatively new virtual modeling approach, ecological niche modeling is used to predict the range of a species, bio-invasion etc. GARP (Genetic Algorithm for Rule-set Prediction) software is used for ecological modeling. By predicting the distribution of a species using its current distribution, we can create a virtual distribution containing the predicted occurance. This technique will be significant in the case of biologically threatened species, since it will show whether this species will become extinct or exist in the near future. It can also be effectively used for predicting the movement and settling of bio-invasive species.

This is the era of converging sciences. Every discipline is merging with information technology. The species interactions are the source of emergent properties of ecological systems. Emergent properties then give rise to further interactions. The challenge of incorporating the living nature of natural systems with information technology is increasing as the result of all biotic and abiotic interactions. Informatics approach is needed because we are losing our wealth of biodiversity at a rapid rate, both species that we know and ten times as many, those we do not.

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PROTECTING AND SAFEGUARDING THE CORALS OF GULF OF MANNAR

IMPACT OF HUMAN ACTIVITIES DETRIMENTAL TO THE GULF OF MANNAR BIOSPHERE RESERVE AND THE NEEDED REMEDIAL AND PREVENTIVE MEASURES

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INTRODUCTION

The Curators of the Madras Govt. Museum were the first to study the biological components of marine fauna of the then known Madras Presidency in the year 1885. In the year 1920, Gravely, the Superintendent of Madras Govt. Museum, took special interest to study the littoral fauna of the Krusadai island of the Gulf of Mannar. This was followed by the Dept. of Fisheries of the Govt. of the then Madras Presidency and later by different workers belonging to Scientific Institutions and the University of Madras. Encouraged by the results obtained, and also based on the fishery potentiality of the area, the Govt. of India, soon after Independence, established the Central Marine Fisheries Research Institute (CMFRI) at Mandapam Camp and was first headed by a Superintending Zoologist of the Zoological Survey of India. The CMFRI's contribution to the flora and fauna of the Gulf of Mannar area is a laudable one. Later, the Madras Regional Station of Zoological Survey of India conducted an intensive survey of Appa Island of this area (Reddiah, 1971).

It was in the year 1980 that the Marine Biological Station of Zoological Survey of India, in association with the Centre for Advanced Studies in Marine Biology of Annamalai University conducted a workshop at Parangipettai (Porto Novo) to recommend to the Government of India to declare the Gulf of Mannar area as a Biosphere Reserve. After a series of sittings and useful discussions a project report was prepared (Krishnamoorthy, 1987) and the Govt. of India, in the year 1989, declared the Gulf of Mannar as the First Marine Biosphere Reserve not only for India but to the entire

South-east Asia. As a follow up the Marine Biological Station conducted a survey and submitted a report (Dhandapani, 1986).The Indian part of the Gulf of Mannar Biosphere Reserve covers approximately10,500 sq km. It consists of 21 islands, two of them tending to disappear, and rich flora and fauna. The presence of mangrove ecosystem, sea grass ecosystem, marine algae associated ecosystem, the coral reef ecosystem and ecosystems associated with very large submerged rock formations known as pearl banks form a major constituents of the GoMBR. Apart from the innumerable species of fauna and flora accounted, two unique species, the Hemichordate worm, *Ptychodera flava* and the Sea cow, *Dugong dugon* are noteworthy of mention. Based on the investigations conducted by many Scientific Authoreties, on behalf of the Management Authority, Neelakandan (1993) prepared the first Management Plan for GoMBR.

Enumeration of floristic and faunistic components of Gulf of Mannar Biosphere Reserve (GoMBR) is a continuos process as it holds both endemic and migratory species, the composition of which keeps changing depending on the varying status of the niche. This variation on the niche or the ecosystems at different areas of GoMBR during different periods of a year could be either due to the impact of natural phenomena or as caused by human activities. The out come of natural phenomena like the change of currents and water masses which are of annual recurrence occurring in the sea are naturally expected to have a positive effect for the betterment of the ecosystem. But, natural catastrophes like tsunami, cyclone etc., have such damaging effect that it takes a prolonged period for recovery.

Therefore, it is the responsibility of the community to prevent detrimental human activities taking place all along the shore and in the sea in order to prevent damage to the marine ecosystem of GoMBR. If not, it might result in the loss of valuable bio-resources. Under this pretext, it is also not possible to do away with the developmental activities along the coastal areas; instead, it is imperative on the part of the Management Authority to strike a balance between developmental activities on the shore side and conservation of bio-diversity through regulated measures. The management of the natural phenomena, whether advantageous or not to the ecosystem, is out of human control; but, the management of the human activities can be regulated to prevent detrimental results to the ecosystem. Many remedial measures were suggested by the author in an earlier account about the management of GoMBR (Dhandapani, 1998) but as years rolled on, more problems are being encountered and therefore, new measures are suggested in the present account to take up necessary steps by the Management Authority and the GoMBR Trust.

DETRIMENTAL HUMAN ACTIVITIES in GoMBR

Although it is not absolutely possible to detect and assess every human activity in the GoMBR, efforts were taken to list out whatever has been observed as detrimental to the conservation of the biosphere reserve for discussion and rectification.

1. High intensity trawl fishing over the pearl oyster paars (banks) in the Tuticorin Sector and discharge of flyash from the Thermal Power Station into the sea either directly or through coolant waters.
2. Fishing activity inside the core zone of the biosphere reserve.
3. Harvesting of the algae from the wild along with their holdfasts.
4. Plucking of sea grass along with their roots to pick the associated fauna like sea horses, pipe-fishes etc.
5. Coral mining and dynamite fishing and
6. Hunting for sea-cows (*Dugong dugon*).

Trawl fishing and discharge of fly ash over pearl oyster paars

Pearl oyster Paars or pearl banks are large submerged rock formation off Tuticorin coast in the GoMBR area. The Paars extend from 8 to 9 degree North Lat. and are more concentrated from 78 to 78-20' E Long. covering hundreds of hectors. Although pearl fishing was done traditiónally for thousands of years, the maintenance of proper records was done only from the year1857. Unfortunately, there was no fishing for pearl oysters after 1962 which can be attributed only to the impact of human activity like trawling over the paars and discharge of flyash into the sea.

Trawling, both with non-mechanised boats and mechanised fishing crafts, over the pearl banks have damaged the entire niche thus making it completely unsuitable for pearl oyster spats to settle on them. This has been going on for the past forty-five years. The composition of trawl catch invariably consisted of reef dwelling parrot fish, gravid females of rock cods, uncommon species of elasmobranchs which take shelters among rocks, gorgonids, large pieces of sponges, echinoderms etc. The discharge of the coolant waters of thermal power station mixed with fly-ash into the sea keeps the ash particles as suspended particulate matter. These particles cause death of veliger larvae and spats of pearl oyster by choking the gills and alimentary canal during the process of suspension feeding.The only way to prevent such a catastrophe is to educate the local fishermen not to fish over the pearl oyster paars and to inform the concerned authorities of the Thermal Power Station to see that no fly ash is released in to the sea.

In addition to creating awareness among the stake holders, it becomes imperative to declare the pearl oyster paars as Marine Protected Areas by the Management Authority of GoMBR in order to retrieve whatever has been lost so far in this area.

Fishing activities inside the core zone area:

It is not clear whether fishermen are aware of the concept of the Biosphere Reserve. Although the fishermen are warned not to enter any of the islands, which are actually part of the core zone, it has always been a sight to watch the operation of drag nets from the shelf zone of the islands, particularly of distant islands. As the shelf zone of the islands are covered with dense coral, algae and sea-grass beds, the gravid females of many commercially important fish are attracted to take peaceful shelter to discharge their eggs. It was found on one occasion, that several gravid and large seer fish numbering nearly a dozen were being dragged over the Talayari Tivu, a distant island off Periyapatnam. It is essential to educate fishermen about the usefulness of the core zone of the shelf area of the islands as the area that replenishes the living resources of their livelihood in the utilisation zone. It should also be realised by the fishermen that any fishing activity inside the core zone would surely damage the ecosystem and prevent the chances of recruitment of valuable living resources.

From the year of declaring the Gulf of Mannar area as a Biosphere Reserve, no efforts were made by the Management Authority to demarcate the Core zone and the Buffer zone. Lack of knowledge on the part of fishermen about the delineation of the boundaries of the Core and Buffer zones is the main reason for the fishermen to trespass into these zones. It is suggested that the Management Authority should initiate marking the boundaries of the two zones, the core zone and the buffer zone, with buoys to warn and prevent fisher-folk from trespassing. In addition to this educational process, it is also suggested that a fool-proof policing of the GoMBR could be achieved only if we involve the coast guard, who are duty bound to protect our coastal and island territories, along with the Management Authority. This would surely prevent the fisher-folk from trespassing into the core zone and the buffer zone.

Harvesting of the marine algae from the wild:

Fisher-folk pluck marine algae from the wild that causes loosening of the sandy sea floor. The sea floor with algal-beds actually act as binders of sandy sea floor and also as wave breakers and dampen the striking force of the waves on the island shore. But, with denudation of the sea-floor due to harvesting of marine algae, the sandy sea-floor turns barren and causes loosening of the soil. The periodical currents carry this loosened sand and cover the coral reefs causing their death. Also the impact of heavy wave action over the island shore causes such a damage to cause caving in of the island. Such a damage can be observed in Appa island off Kilakkarai coast. Similar phenomenon was also observed in the Palk Bay area (Jerold Wilson *et al*, 2005)

Prevention of harvesting of marine algae from the wild can be achieved only through bringing in awareness among fisher folk about the disastrous effects it implies both on the coral reefs and on the island ecosystem. Also, the logistic advantages of involving in the mariculture of marine algae would completely divert them towards culturing marine algae with raft and rope culture more at the inter-tidal zone. It is heartening to note that some non-government organisations and the GoMBR Trust are intensively engaged in educating not only men but also women folk about mariculture of marine algae to their betterment. It is suggested that the community of aquaculturists should be aware that it is essential to maintain a constant interaction with the scientific community to update their knowledge periodically to adopt eco-friendly procedures of mariculture that would benefit both the environment and the producers.

Plucking of sea grass to pick associated fauna:

There is a trend among marine products trading circle to pick the hitherto considered 'unimportant' marine fauna to earn quick money. This has lead to the collection of sea horses, pipe fishes and sea cucumbers from the sea grass beds of the GoMBR. While the sea cucumbers live among the sea grass and algae, both the sea horses and the pipe-fishes attach themselves to the branches of sea grass with their tail. In order to save time, and also to have a swift operation, the poachers pluck the entire vegetation of *Cymodacea* spp. and *Halophilla* spp. along with their running roots. This collection is taken in net bags to the shore to pick sea horses and pipe-fishes, thus leaving the vegetation to dry on the shore. Such a para-traditional fishing activity would naturally spoil the entire sea grass ecosystem which might not only take a long time to recoup but also prevent the availability of these two species of sea grass to the dugongs. Therefore, it becomes absolutely necessary to ban the export of the above animal products at least for the sake of saving the sea grass ecosystem.

Coral mining and Dynamite fishing:

Earlier to the enactment of Wild Life Act in 1972, coral mining was a recognised profession; and at once stage there was even a government approved labour union of coral miners in GoMBR area. During earlier years corals were mined in large blocks for construction of small tenements and large sheds as storage facility for fishing community to store their fishing gears and products. This helped them save unnecessary investment towards purchase of expensive building materials like bricks and mortar from distance towns. Pieces of corals were collected by poor fisher folk to prepare lime for painting purposes. The threat to coral reefs from extensive and intensive mining was felt when corals were mined for cement manufacturing industries located near the coastal towns. This solid and pure calcium carbonate was a nature given gift. The reasons for the loss of Puvarasampatti Island and Vilangushalli Island could easily be attributed to the greed of coral miners and the associated industries.

Dynamite fishing is another disastrous method of fishing that leaves the marine ecosystem beyond repair. The methodology is such that certain shrubs from the mainland coast is cut and dragged to a coral associated niche and allowed to decompose. The emanating smell attracts large school fish from all around to feed on this vegetation. A dynamite explosion in this area kill not only the fish but also all the associated fauna and occasionally dugongs too.

It is necessary to educate coastal community that the benefit derived from use of dynamite is only momentary because the damage caused would make the same area unfit for any further fishing for a longer period. It was mentioned by an NGO that dynamite fishing does no longer exist now. Although it is heartwarming information there is always a tinge of doubt about the effectiveness of the monitoring machinery since the Management Authority of the GoMBR could not support the statement. It is, therefore, suggested that legal enforcement with provision for stringent punishment for use of dynamite for fishing should be enacted.

Hunting for sea-cows (*Dugong dugon*)

The dugong, the only marine dwelling animal of the order Sirenia, is facing an ordeal against certain groups of fishermen for its survival. This species, known as sea cow, is distributed in four isolated pockets of Indian coast namely the Gulf of Kutch of Gujarat coast, the Gulf of Mannar and Palk Bay of Tamil Nadu coast and the Andhaman group of islands. The Zoological Survey of India conducted an enumerative survey and could spot only fourteen adults and one calf during a period of three years from 1994 to1997 (Dhandapani, 1997). This does not include ten dead adults and one dead calf recorded by the forest department which included one death due to dynamite fishing.

Sea cows are stealthily hunted for their meat which is relished by certain group of fishermen particularly in the GoMBR area. Although a slow swimmer, the dugong has so far managed to survive in our seas due to its elusive nature to avoid human interference. Being nocturnal feeders, a habit perhaps acquired to avoid intense fishing activity of fisher folk during day time, they approache the feeding pastures located towards the shore by sun set, feed well, and leave the pastures before sun rise. Presently the status of its population in India is not at all appreciable. The dugong does require a special attention to be treated as a threatened species, if not protected in time, would be lost for ever from the GoMBR. It is a pity that the dugong, except for the local community and the marine scientists, is hardly known even to the literate community in India just as the tiger or lion is known. The survival status of dugong is in peril. Therefore, it is essential to declare the dugong as the National Marine Mammal on par with tiger and peacock not only to protect the animal but also to bring in awareness among educated community of India that such a rare gift to the Indian seas is likely to face EXTIRPATION.

COMMUNITY INVOLVEMENT

It has been discussed in this article that the community awareness combined with remedial and preventive measures taken by the Management Authority of GoMBR only could save this valuable ecosystem. In addition, it sounds reasonable that the community benefited by harvesting the marine products from the sea should also help the sea to recoup its bio-resources as discussed below.

Sea ranching of mariculture products:

The Marine Products Export Development Authority of India has been running a vital business by helping exporters of aquaculture products to earn to the tune of millions of dollars for the past several years. It is true that mother nature in the form of ocean is delivering innumerable variety of products for the benefit of human kind. Unfortunately, it has always been a one way traffic in the sense that products are always tapped from the sea indiscriminately. Brood stocks of commercially important fin fish, molluscs, echinoderms and crustaceans are tapped from the sea in order to produce seeds for coastal aquaculture. Presently, the aqua formers are intensively engaged to produce seed out of brood stocks from the cultured population. This inbreeding has reached a stage that it might end up in weakening, the gene pool due to isolation, which in turn would surely affect the quality of products. Continuos fishing for marine products without any concern for size and maturity is also depleting the seasonal fishery and the gene pool. There seem to be only two avenues open to revitalise such gene pools:

1. Ranching of mariculture products through release of 1% of the farm bred products into the sea which would work out to 100kgs./ one tonne through the estuaries. This should be done well before harvesting when the tendency of the juvaniles are to migrate into the sea. Such a population would naturally grow into very healthy animals due to the nutrient rich food they consume from the wild. Brood stocks of these sort of revitalised population, if at all retrieved from the sea, would naturally have the capability to produce stronger and healthy seeds for farming.

2. Inter-breeding of brood stocks of aquaculture farms from areas widely separated might also produce healthy seeds but comparatively their chances growing healthier than the wild catch is expected to be less. There are also cases of muscular dystrophy or Loose shell syndrome" reported from populations reared from inbred farm brooders.

COMMUNITY AUTHORISED MANAGERS

It is felt absolutely essential to bring about the feeling of commitment awareness among the stake holders of the GoMBR area to care for the Bio-sphere Reserve. The Management Authority, the GoMBR Trust, the Revenue

Administration and the Department of Fisheries of Tamil Nadu should collaborate in order to achieve this Commitment Awareness among stake holders. It is mandatory to create involvement of local community of the coastal dwellers so as to enable them to form a committee of their representatives as their COMMUNITY AUTHORISED MANAGERS of the entire GoMBR eco-system.

SUMMARY

The detrimental effects of human activities like trawling for fish over Pearl bank and inside the core area of GoMBR; illegal harvesting of marine algae and sea grass from the wild; involvement in para-traditional fishing activity for sea-horses, pipe fish and sea-cucumbers; coral mining and dynamite fishing; and hunting for Dugongs were elaborated and discussed. Remedial and preventive measures like declaring the Pearl Oyster Paars as Marine Protected Areas; demarcation of Core and Buffer zone by the Management authorities and the need to involve Coast Guard to prevent trespassing; collaboration between scientific community and aqua farmers; ranching of commercially important marine products to re-vitalise the gene pool; stringent punishment for use of Dynamite and coral mining; declaring Dugong as the National Marine Mammal to prevent extirpation of the species; and involvement of Stake Holders as Community Authorised Managers of the GoMBR are suggested.

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ANTHROPOGENIC THREATS TO MARINE BIOIDIVERSITY OF INDIA WITH SPECIAL REFERENCE TO MARINE TURTLES OF GULF OF MANNAR BIOSPHERE RESERVE

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INTRODUCTION

The Gulf of Mannar is a marine National park on the south eastern tip of India which consists of 21 Islands some eight km off the coast of Tamil Nadu. Spreading over an area of 623 hectares (10,500 km^2), the area described as the Pamban-to-Tuticorin barrier reef was declared a National Park in 1986 and later converted into a Biosphere Reserve in 1989. The park has a distinguished marine life, which runs, along the coasts of Ramanathapuram and Tuthukudi (Tuticorin) districts near Mandapam – 150 kms away from Madurai area. The park is a part of the Indian Ocean and lies between India and the west coast of Sri Lanka at a width between 160 and 200 km. A chain of low islands and reefs known as Rama's Bridge (based on the epic Ramayana), also called Adam's Bridge, separates the Gulf of Mannar from the Palk Strait, which lies to the north between India and Sri Lanka. Tambaraparani River from the coast of India and the Aruvi Aru from the coast of Sri Lanka merges with the Indian Ocean on both sides of the park (Venkataraman and Milton, 2003).

Of the 21 islands, seven islands belong to Mandapam group, seven islands to Keelakarai group, three islands to Vembar group and four remaining islands to Tuticorin group. There are beaches, estuaries, and tropical dry broadleaf forests in the park, and three distinct marine ecosystems such as sea grass, coral reefs and mangroves along with algal communities and salt marshes. Around 11 species of seagrass, totally recorded in India are found in the reserve. The Kurusadai Islands, off Manadapam boasts of a vast expanse of shallow waters. Marine National Park, one of the richest coastal regions in Asia, contains over 3,600 species of flora and fauna most of which are in their virgin form. Nearly 117 species of hard corals have been recorded in the Gulf of Mannar. The reef is home to sprats, herrings, barracuda, sea horses, dolphins, Balano-glossus, sea cucumbers, pearl oysters and turtles. The sandy shores of the islands provide a nesting habitat for about 5 species of marine turtles. Migratory birds also visit these islands. But due to destructive fishing and pollution, coral reefs, dolphins, Dugongs (*Dugong dugon*), whales and sea cucumbers are among the species, which figure, in the endangered list (Venkataraman and Milton, 2003).

TURTLE RESOURCES OF INDIA

The following are the sea turtles represented from India;

Class: Reptilia

Sub-class: Anapsida

Super-order: Lepidosauria

Order: Testudina

Suborder: Cryptodira

Family: CHELONIDAE **(Marine Turtles)**

1. *Chelonia mydas* (Linnaeus, 1758) (Green Turtle)
2. *Eretmochelys imbricata* (Linnaeus, 1757) (Hawksbill Turtle)
3. *Caretta caretta* (Linnaeus, 1758) (Loggerhead Turtle)
4. *Lepidochelys olivacea* Eschschlotz, 1829 (Olive Ridley)

Family: DERMOCHELIDAE (Marine Turtles)

5. *Dermochelys coriacea* (Linnaeus, 1766) (Leatherback Turtle)

EAST COAST DISTRIBUTION OF INDIA

Tamil Nadu: Nesting of all the five species of turtles Olive ridley, green, hawksbill, leatherback and loggerhead are reported from this state. The coral and sea grass areas in the Gulf of Mannar and Palk Bay provide rich feeding habitats for turtles. Nesting of olive ridleys are reported from all along the coast of Tamil Nadu (Abraham, 1990).

Andhra Pradesh: The entire coast of Andhra Pradesh has sporadic nesting of olive ridley turtles. The 270 km stretch between Kakinada and Uppada provide nesting grounds for the olive ridleys. Though the aggregations of olive ridleys do not form '*arribada*' as in Orissa, the nesting is in considerable number. The nesting of other species of turtles in Andhra Pradesh is discrete (Rajasekhar, 1998).

Orissa: The nesting of olive ridleys in and around the coasts of Orissa is enormous. The large mass nesting beaches in the Cuttack district, Roorkey, Ganjam, Rishikulia, Gahirmatha and another near Devi river estuary, together host one of the largest aggregations of olive ridleys in the world and certainly the largest in India. These areas receive about 5 lakh olive ridley nestings annually that lay more than 5 crores eggs. Each adult turtle in an average weighs 40 kg and thus about 40 thousand tons of turtle biomass visit the Orissa coast every year (Hemasundararao, 1998).

West Bengal: Nesting of olive ridleys is reported along the coasts of West Bengal. Nesting of other turtle species are remote (Swapankumar, 1996).

Andaman Islands: Olive ridley, green, hawksbill and leatherback turtles nest along the coasts of Andaman Islands.

Nicobar Islands: Olive ridley, green, hawksbill and leatherback turtle nest along the coasts of Nicobar Islands. Hawksbills nest at Pygmalion Poin the southernmost point of India. Great Nicobar Island is the most importa nesting island. The two beaches at the mouth of the Dagmar and Alexandri River on the island's west coast are the main nesting grounds of leatherbacks. Islands of lesser but still appreciable importance as regards nesting are Katchal, Trinkat and Teressa Islands. It is reported that uninhabited Meroe Island is favoured by nesting green turtles.

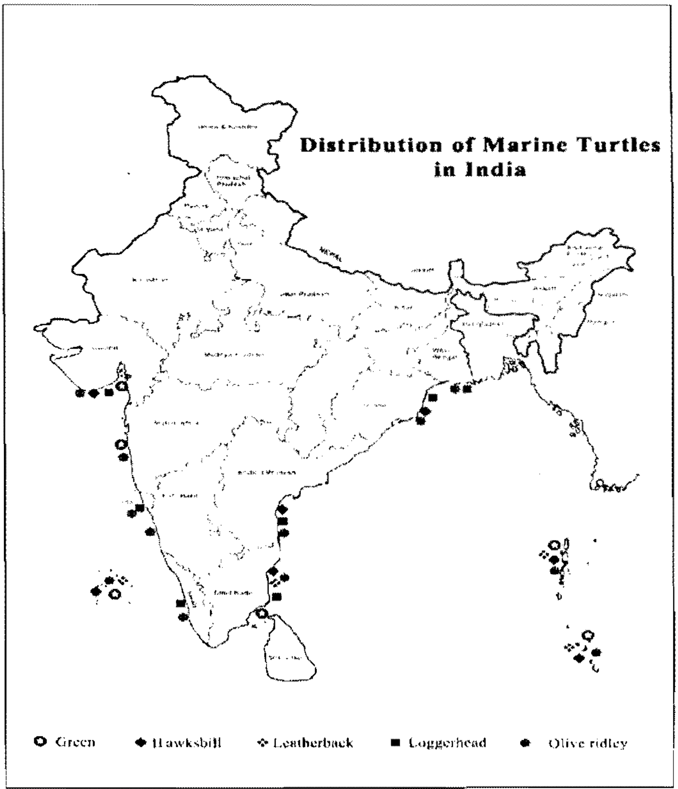


Fig. 1. Distribution of Marine Turtles in India

Table 1. Nesting area and nesting season of marine turtles of India (Venkataraman and Milton, 2003).

SPECIES	NESTING AREA	NESTING SEASON	INTENSITY
Green turtle	Kutch, Sourashtra	-	Moderate
	Maharashtra,	July-January	Sparse
	Tamil Nadu,	July-January	Sparse
	Andaman and Nicobar,	November-January	Moderate
	Lakshadweep	June-September	Moderate
Hawksbill	Tamil Nadu, Andhra,	-	Extremely low
	Orissa, Gujarat	-	Rare
	Andaman and Nicobar	April-January	Moderate
	Lakshadweep	-	Rare
Leatherback	Tamil Nadu	-	Very rare
	Andaman and Nicobar	December-April	Moderate
	Lakshadweep	-	Stray
Loggerhead	Tamil Nadu	-	-
Olive ridley	Gujarat	July-September	Moderate
	Maharashtra, Goa,	July-September	Stray
	Karnataka, Kerala	July-September	Stray
	Tamil Nadu,	December-February	Moderate
	Andhra,	December-February	Moderate
	Orissa,	December-February	Mass Nesting
	West Bengal,	December-February	Moderate
	Andaman and Nicobar	December-February	Stray
	Lakshadweep	June-September	Stray

THREATS TO MARINE TURTLES

In spite of adults being the master predators in the seas, the sea turtles are subjected to various types of biotic and abiotic threats during different stages of their life cycle.

Natural Threats

Predation: The biotic threats can be categorized as threats to the eggs, hatchlings, sub-adults and adults by predators. Non-human predators of eggs include invertebrates such as ants *(Dolyrus sp.),* flies (especially larvae of some species as secondary predators), Scarabidae *(Trox suberosus).* Reptiles such as *Boa sp.* (elapids); and varanid lizards; birds such as black vulture, turkey vulture, ibis, crows; small mammals such as rats *(Rattus sp.),* coatis, racoons, mongooses, genets, feral cats, white lipped peccary, pigs, hogs, jackals, dingoes, foxes, coyotes, hyenas and dogs (Limpus, *et al.,* 1994).

Human impacts

1. Human interference

Some of the examples of ecosystem modifications by human interference adversely affecting sea turtle populations are: beach erosion (for example, Gahirmatha coast); construction of erosion preventive embankments; plantations along the beach as anticyclone measures; fencing of beaches or construction of palisades; sand mining for cement, titanium ore and Indian Rare Earths (I.R.E.); rapid colonisation of coastal areas and beaches for human settlements; temporary settlements by fishermen on nesting beaches; beach resorts and other constructions on shore such as jetties; physical barriers such as beached boats or vehicular traffic on beaches; defence set-up on beaches and experimental demonstration in coastal water in the vicinity of major mass nesting beaches; artificial lighting on beaches; oil drilling operations in river beds and river mouths adjacent to breeding ground of turtles; coral mining; various types of marine and land based pollution, etc. Further, proliferation of non-mechanised and mechanised fishing boats increases the operational range and efficiency of turtle hunters and making beaches, breeding and feeding grounds once remote easily accessible. Activity of large number of fishing boats and use of nets often create artificial barriers temporarily in the coastal waters preventing turtles to emerge on the beaches for nesting (Stancyk, 1982).

2. Human Consumption

Tortoises and sea turtles are both worshipped as God and consumed as food in India. It is worshipped as the *Kurma avatar* of Vishnu, the God of Creation. The poor, irrespective of their caste and community consume the eggs and meat of tortoises and sea turtles all over the country. In West Bengal, the biggest market for turtles and turtle eggs, for example, turtle meat is eaten on *Pausha Sankranti*, a harvest festival dedicated to Laxmi, the Goddess of Harvest and Wealth in the Hindu religion (Andrews, 2000).

3. Industrial Effluents

The following are the harmful substances released into the seawater from the chemical factories,

- Phosphogypsum containing the radioactive substance radium-226, which releases a harmful gas, called radon. Radon has been designated as a human carcinogen by The world Health Organisation (WHO) and US Environmental Protection Agency (EPA).
- Free Sulphuric acid, which is harmful to all living organisms.
- Sulphur dust which is also a poisonous chemical

These industrial discharges have serious effect on the marine ecosystem. The waters of the Atharabanki creek were grayish white in colour due to the continuous discharge of Phosphogypsum. A thick crust of gypsum was reported at the Mahanadi river mouth (Andrews, 2000).

4. Sand mining

Sand mining is an important threat, which affect the nesting population in terms of habitat loss. Loss of nesting beach of leatherback and Hawksbill in Andaman and Nicobar is due to severe sand mining (Andrews, 2000).

5. Sewage pollution and marine debris

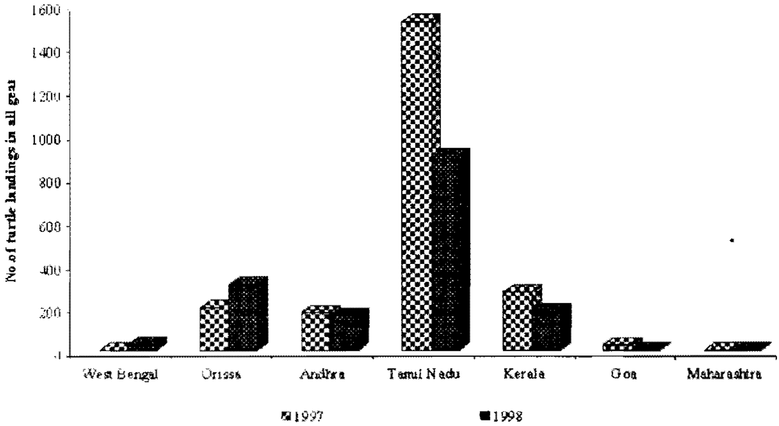
Presence of refineries, oil terminals and rapid increase in export and import of oils and petroleum products are major sources of oil and sewage pollution along the east coast of India (Andrews, 2000).

6. Commercial exploitstion of beaches

Luxury hotels and other commercial developments destroy nesting beaches. In our trash chocked oceans, sea turtles mistake plastic bags for jellyfish, a favourite food and choke to death. Adult sea turtles have been hunted for their meat and to fuel the high-tened apparel market to make eyeglass frames, combs and cigarette lighters. Economic imbalances cause coastal communities to steal eggs from nests to sell to city dwellers as aphrodiscacs (Andrews, 2000).

7. The killer trawlers

In 1990, the US National Academy of Sciences concluded that more sea turtles die from shrimp trawling than from all other humans causes combined in US waters. Sea turtles breathe air like humans and in ideal circumstances can hold their breath for upto 8 hours. When sea turtles are caught up in the huge funnel shaped shrimp nets that scour the ocean floor, they panic, struggling for air. Eventually they drown unable to free themselves from the nets (Andrews, 2000).



2 Turtle landing in all gears

(Source: Venkataraman and Milton, 2003).

IMPACT OF UNSUSTAINABLE FISHING METHODS

In addition to harming sea turtles, unsustainable fishing methods, such as mechanized shrimp trawlers that do not use TEDs also severely impact global food supply and local economies by depleting local fish stocks through unselective fishing techniques. Unsustainable fishing has a much broader impact on social and economic issues than just environmental ones. The UN Food and Agricultural Organization (FAO) estimates that 27 million metric tones of fish bycatch are discarded every year globally, equivalent to about 1/3rd of the total annual catch and that, in India, Malaysia and the United States, 90% of the fish caught is discarded and not consumed.

PRESENT STATUS OF TURTLES

IUCN Red Data Book recognises seven categories such as Extinct (Ex); Endangered (E); Vulnerable (V); Rare (R); Indeterminate (I); Out of danger (O); and Insufficiently known (K) which can be assigned to any particular species of plants and animals for determining its status for conservation purposes. The recent edition of the IUCN Amphibia, Reptilia Red Data Book (1982) compiled by Groombridge has listed 6 of the 7 species of living sea turtles in its various categories, which are as follows:

Species Name	Status
FAMILY: CHELONIIDAE	
Caretta caretta	Vulnerable
Chelonia mydas	Endangered
Eretmochelys imbricata	Endangered
Lepidochelys kempii	Endangered
Lepidochelys olivacea	Endangered
FAMILY: DENNOCHELYIDAE	
Dermochelys coriacea	Endangered

LEGAL MEASURES

In the international context there exists a very strong protective policy for sea turtles (Whitaker and Kar, 1984). At present, there are in force two global conventions of sea turtles.

- All species of the sea turtles including those found in India are included in the Appendix I or II of CITES, 1973, (Convention on International Trade in Endangered Species of Wild Fauna and Flora). Appendix I include species that are threatened with extinction. Appendix II species are those which either may become threatened with extinction if international trade is not regulated, or species which must be subjected to regulation in order that trade in these first species may be controlled. Though not a comprehensive wildlife conservation convention, CITES, since it came into force in 1975, is mainly concerned with international control of trade in endangered and threatened species. India ratified CITES in 1975 and it came into force in India in October 1976.

- The convention on the conservation of migratory species of wild animals was negotiated and signed by 22 nations (except USA) in Bonn, West Germany, in June 1979. In June 1981, India became a party to the Bonn convention on the conservation of Migratory Species of Wild Animals.

- This convention makes all migratory species and regions of the world eligible for consideration and is designed to stimulate as well as to provide direction and guidelines for negotiation of further conservation agreements for migratory animals. It also provides a mechanism for individual states to unilaterally conserve endangered migratory species. *Lepidochelys kempii* and *Dermochelys coriacea* are included in Appendix I and all species of cheloniidae are included in Appendix II of the convention. Appendix I includes endangered species for which immediate and stringent conservation measure by the party states along the range of the listed species ("Range States") are required.

- Appendix II species are those recommended to be the subject of agreements by their range states. The convention is predicted upon the principle that all the states along the range of a migratory species must participate in its conservation and management. Besides, there are other international conventions such as draft law of the sea treaty and the convention concerning protection of world cultural and natural heritage. Several regional conventions which are directly relevant to the conservation of sea turtles include (i) Convention on Nature, Protection and Wildlife Preservation in the Western Hemisphere which came into force in 1940, (ii) African Convention on the Conservation of Nature and Natural Resources, 1968 came into force since 1969 in which all marine turtles have been listed as "Class A " protected species, and are totally protected throughout the entire territory of the parties with taking allowed under special circumstances, (iii) Convention on the Conservation of Nature in the South Pacific and (iv) international fisheries agreements (Venkataraman and Milton, 2003).

- Existing international fisheries agreements do not address the problem of incidental take or the need to conserve sea turtles as a natural resource. However, the following organisations have the potential for supporting sea turtle recovery such as WECAFC, IOCARIBE, GCFI, UNESCO, MAB, etc.

- In India, all the five known species of sea turtles are now fully protected from hunting, killing and other forms of exploitation under the Indian Wildlife (Protection) Act, 1972 by an amendment of the schedules in September 1977. In the above amendment, excluding the flatback sea turtle, rest six species were included in the list of Schedule I animals along with locally unreported kemp's ridley. Changes were made in the revised list of Schedules (Government of India Letter No. 1-28-78-FRY(WL), Dated 12th September 1980, effective from 2nd October 1980). *Lepidochelys kempii* was then removed from the list, as it is not known to occur in Indian waters (Kar and Dash, 1984).

Conservation strategies for sea turtles in India

- Intensified effort on basic research to understand biology, reproductive and nesting cycles and pathways of migration of sea turtles.

- Genetic analysis of turtle groups to determine their behaviour biology.

- Recovery programme should be encouraged to ascertain the pathway and global distribution of sea turtles.

- Incidental catch of turtles may be avoided by regularizing fishing practices.
- Mechanised fishing vessels should not be allowed in the protected areas during the nesting seasons of the turtles.
- Conventional TEDs causing minimal loss to the shrimps should be produced and distributed to the fishermen at affordable rates.
- Fishing jetties and harbours should be constructed far away from the protected areas.
- National policy on the conservation of sea turtles should be developed.
- National coordinated programme for studies on sea turtles.
- Conservation of nature and natural resources should be placed above economic gains.
- Awareness among youth and children should be developed with regard to the conservation of natural wealth of the country.
- Socioeconomic conditions of the people depending on the marine resources should be highlighted. Conservation measures should always take this into account.
- Longterm monitoring of breeding population
- Establishinng hatcheries
- Training on hatchery management
- Survey and monitoring potential nesting grounds
- Periodical status survey
- Establishing Turtle Protected Areas

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PUBLIC MARINE AQUARIUM: A TOOL FOR MARINE BIODIVERSITY CONSERVATION AND EDUCATION

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Introduction

Over half of the world's population occupies a coastal zone 200 kilometers wide. In India however only 10% of the total population are living in the coastal area and therefore majority visit the marine environment only infrequently. The lack of the contact with the marine habitats is a major causal factor in the relatively low status of marine conservation. Generally the achievement of long-term conservation depends mainly on environmental education of the public (Orr, 1990; Caro et al., 1994). Consequently it was believed that public aquariums are important for understanding the marine environment and support to those engaged in marine conservation projects, research and education.

The first aquariums appeared in the middle of 19th century. For around 100 years the main objective of aquariums was to exhibit animals to the public. The focus was on the animals themselves. Little importance was given to the environment they lived in or to education activities. The aquariums were first generated based on small volume aquariums showing mostly fish. In the 1960s and '70s, the second generation aquariums began to appear. Major advances were made in life support systems (water filtration and sterilization), salt production for synthetic seawater and diets. At the same time there was an increase in the knowledge of the life history and behavior of marine animals and their underwater habitats (water current, light spectrum etc.). At the present time aquariums are able to maintain a wide diversity of healthy animals for a long periods. Visitors to public aquariums could now see fishes living together with sensitive invertebrates like corals, anemones and even marine plants in an artificially reproduced but naturalistic setting.

Most significantly, public aquariums have the potential and power to communicate the issues affecting the marine environment. With around 140 public aquariums currently in Europe (and more under development) reaching an audience in the region of 70,000,000 people a year, the EU Maritime Strategy should consider aquariums an integral part of the strategy and a powerful tool to achieve change. At the same time in India there are few aquariums particularly marine aquariums, that are significant. The marine research and public aquarium in Annamalai University and the public aquarium in Zoological Survey of India are the two important marine aquariums in India as they help enhance the scientific knowledge to understand the marine biodiversity and its values to the public. The present study was designed to gather information on the impact of a large marine aquarium on its visitors.

Methods

The maintenance of the marine aquarium for the last three years at Annamalai University helped identify candidate species suitable for such large scale recirculating aquariums. During the present study the aquarium maintained 63 species of fishes and invertebrates of which nearly 50% of the species were purchased from Gulf of Mannar and the rest collected from Parangipettai coastal areas. Lobsters, Crabs, Edible fishes, Bat fish, Lion fish, Squirrel fish, Puffer fish, Surgeon fishes, Star fishes and some estuarine ornamental fishes were mainly collected from Parangipettai coast. The captive bred clownfishes from the Centre of Advanced Study in Marine Biology was also maintained in the aquarium. Species like Butterfly fishes, Sea anemones, Morey eels and Angel fishes were purchased from the Gulf of Mannar. Water quality was regularly monitored during this study. The present survey was made based on discussions with visitors regarding their awareness of marine life and its conservation by posing the following questions.

- Have you visit any other aquariums?
- Do you know where marine ornamental fishes are live in the sea?
- Do you re the marine biosphere reserves in India?
- Do you know the Gulf of Mannar?
- Have you visited any coral reef areas?
- Do you know the common names of animals exhibit?
- Which animal do you find most attractive?
- What are the marine species most vulnerable to extinction?
- Which marine habitats and ecosystems are most disturbed by human activity?
- Which marine habitat is likely to recover to their former state after human disturbance?
- Is the removal of biological resources by fisheries damaging ecosystem function?
- Is biodiversity decreasing in marine ecosystems?

Results and discussion

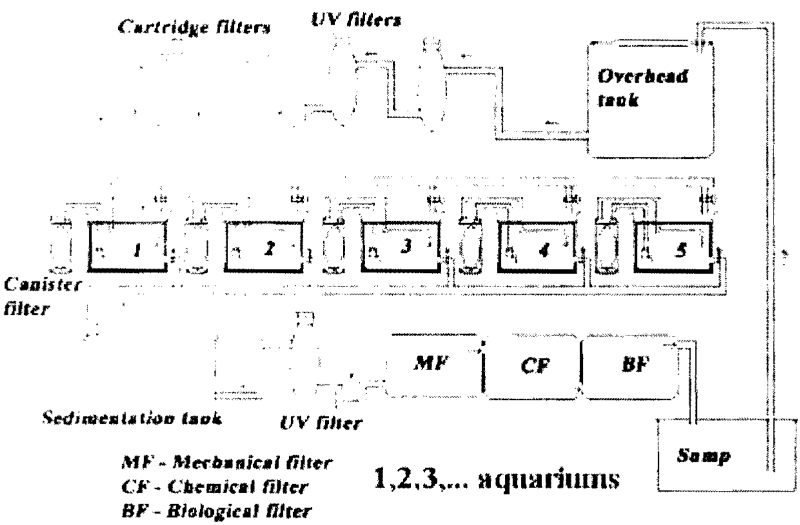
Marine Research Aquarium of the Marine Biology department has 28 tanks of 2,300 liter capacity. The water is recycled every day through UV filters, charcoal filters and biofilters. Each tank has an individual canister filter that is filled with bioballs, charcoal and coir mat. There is no specific aerator in the aquarium however dissolved oxygen content of the water is regulated at 5.8 to 6.9 mg/l with the help of powerheads and canister filters. The pH is balanced from 7.9 to 8.5. The water in the aquarium tanks is continually passed through the bed filter filled with sea shells with the help of two power heads. There are no advanced aquarium equipments like protein skimmer or ozoniser. As a result the research in this aquarium would give useful data to hobbyists who also do not have such advanced equipments.

1. Construction and maintenance of recirculating public aquarium

1.1. System design

The present system has many desirable features for the researcher. Use of expensive equipment like protein skimmer and ozoniser were minimized, and approximately 80% of the materials are available locally. The entire system is housed along with twenty eight 2,300 l experimental aquaria. All tanks are fully accessible and offer a clear view of their contents. The siphons used in the system allow water to enter the tanks at the top and leave at the bottom. Many times more water is circulated than is necessary to achieve the desired turnover rate. Water is kept as homogeneous as possible in terms of water quality. The system was designed for ethological observation studies as well as more attractive style to the visitors.

Technical view of present marine research aquarium



1.2. Lighting

The fluorescent tubes (300watts) used in the present aquarium was placed more than a foot from the water level. Present observation shows that this lighting was suitable for 'fish only' aquariums. However, sea anemones fade considerably due to this type of lighting. Most of the ornamental invertebrates are found in water depths of 10 to 20 m, where light penetrates. Corals, anemones, and other invertebrates which utilize zooxanthellae are almost always more colorful when found at high light penetration level. However in the present lighting system did not enhance the growth of zooxanthellae resulting to loss of color. In addition to affecting the pigmentation of ornamental species, too much light also increases the occurrence of nuisance algae, especially filamentous green algae, and may make temperature control more difficult. The observation of the temperature in aquarium water clearly showed that there was nearly one °C increase by the lighting. There is no individual temperature controller in the aquarium however the entire aquarium was maintained by centralized air-conditioning.

1.3. Water movement

Water movement is often accomplished using air-lifts, air stones, or water returns from filters or degassing devices (Loyless and Malone, 1998). Some species, especially in the fish group, may perform poorly (e.g., slow growth) if the water movement is too strong, especially during breeding. The present aquarium had an undergravel filter with two powerheads at both sides. The bed was filled with seashells for effective filtration. Observations on fish growth and activity showed that the present water movement system would provide suitable environment for growth of the fish. This type of water movement enhances the attraction of the fish movements.

1.4. Control of suspended solids

High levels of suspended solids can present a problem to both the fish and recirculating system components. Problems arise when these organic compounds break down into simpler organic and inorganic compounds as their decomposition process consumes oxygen resulting in the decrease of oxygen available to the fish. The detrimental effects of suspended solids on fish and culture systems include: gill damage, reduced growth rates, mortality, and increased susceptibility to disease, clogging of biological filters, increased biochemical oxygen demand and mineralization to produce ammonia (Chen and Malone, 1991; Chen et al., 1993). They also report that small particles (5-10 mm in diameter) had the most harmful effects. It is, therefore, essential that the amount of small particles in recirculating systems be minimized to prevent the above discussed problems. Filtration methods are generally size and/or density limited. Thus, one filtration method alone is usually inefficient in successfully removing the range of particle sizes found in aquarium systems at a reasonable cost. Therefore the present aquarium is maintained with a multiple treatment method. There are several filters used with water being pumped to and from these filters. Typically, undergravel filter, canister filter and cartridge filter are chosen for controlling this problem. This type of gravel filter successfully controls suspended solids. But these solids deposit at the bottom of the tank and may be solved by cleaning out shells and filter bed.

1.5. Water quality maintenance

The evolution of marine ornamentals has occurred in tropical reef ecosystems, where conditions are relatively stable throughout the year. The present aquarium allowed for easy monitoring and maintenance of water quality. There are several key parameters and design criteria which deserve attention.

1.5.a Temperature

Reliable and adequate temperature control methods are essential in marine ornamental aquaria, as many species are extremely intolerant to even narrow temperature fluctuations. Shallow water species are typically more tolerant, but most economically important species occur in waters of 10–20 m depth where the annual temperature variation ranges from 25 to 28°C. Temperature was maintained at this range during the present study. However, an increase in water temperatures may benefit reproduction in some species (e.g., 28–32°C for the anemone fish *Amphiprion sebae*; Ignatius et al., 2001).

1.5.b. Salinity

The natural seawater used is stored a sump large enough (30,000 liters) for any probable water replacement is incorporated in the design. The water in the aquaria is always well-aerated through filters to ensure temperature control and saturated with dissolved oxygen. The rate of evaporation is high in the aquarium and it results in increased salinity. To balance this, freshwater is added to adjust salinity. As many ground water and municipal water sources may contain unacceptable amounts of dissolved elements, it is recommended that the freshwater replacement be filtered by reverse osmosis. The salinity was maintained consistently between 33 and 35 ppt in the present aquarium.

1.5.c. Nitrogen

Most marine ornamental species have a very low tolerance for ammonia or nitrite compared to freshwater species. Nitrate toxicity is also a concern at levels which would have little to no impact on freshwater species. Nitrogen is the limiting nutrient in most marine systems, and as such presents a challenge for design criteria. Even moderate levels of nitrogenous wastes can result in algae blooms in the system. In the present system with inoculation of nitrogen fixing bacteria in the biological filtration helped maintain total ammonia nitrogen (TAN) and nitrite, at levels near zero (<0.004 mg/l).

1.6. Other elements

Although sodium chloride is predominant (30 ppt of 33 ppt), seawater contains at least 40 other minerals and numerous dissolved gases, some of which are consumed by processes in a recirculating system (e.g., carbonates), and others which are taking up by animals (e.g., calcium, iodine, strontium) (Reynaud et al., 2004). While much research remains to determine optimum levels and ratios for many of these elements, efforts should be made to mimic ratios found in open reef ecosystems. In the present aquarium calcium carbonate reactors are simple units where water moves slowly through a bed of finely crushed limestone, continuously adding carbonates to the system.

1.7. Dissolved gases

Management of gas exchange is an important design criterion for marine ornamental systems. Maintaining high concentrations of dissolved oxygen is necessary for health of cultured organisms and proper functioning of biological filters (i.e., maintenance of aerobic bacteria). In general, dissolved oxygen levels should not fall below 5 mg/l. In the present aquaria it was managed by vigorous aeration of the water flow of canister filter.

1.8. Control of bacteria through sterilizing

There are two most common methods for sterilizing water in aquaculture; ozone and ultraviolet light. Ozone is highly reactive in seawater, and therefore effective as a sterilizing technique. However, it is not used in aquarium and UV sterilization is considered and it a preferable method for marine aquaria.

2. Use as a tool for Marine Biodiversity Conservation and Education

Although still in its infancy, it is believed that development of public aquariums will focus on communication and education strategies. The aquarium industry has the potential to become one of the most powerful tools for relaxation and receiving tension. Public aquariums are .the ideal place to explain and publicize the implementation of the much-needed sustainability policy, making new laws more easily accepted and to create public awareness.

The aquarium exhibits are a 'powerful communication tool. The Marine Research aquarium had nearly 2, 00,000 visitors during the last three years. The visitors are interested, ready to listen and many of them eager to know what their role in preserving the oceans. This shows that the aquariums may be the needed link to make policies understood and allow the general public to participate in their implementation.

The present survey is the outcome of discussion done with 250 visitors (196 male; 54 female) on various occasions from 2006-2007. Children were not included in the discussion as few understood the basics of biodiversity conservation. Their expression and eagerness was observed and noted. Visitors, though aware of the fact that oceans contain fish, were not very knowledge of other marine taxa, e.g. benthic invertebrates, which are often both beautiful and sensitive to environmental change.

Based on discussion with the visitors it is gathered that most are interested in receiving scientific information of the marine animals and are concerned of the threats to marine biodiversity. For 96% of the visitors it was their first visit to a marine aquarium. Only 0.8% of the visitors had previously visited a marine aquarium abroad. Only 3% of the visitors guessed that most of the ornamental fishes live in coral reef environment and 2% of the visitors had previously visited a coral reef environment. Ninety percent of the visitors relate the Gulf of Mannar region to the Sedhu Samuthiram Canal Project and were unaware that it is a biosphere reserve. Most of the visitors (65%) raised question's like 'why should we conserve biodiversity?' On the other hand they were concerned about the threats to marine biodiversity. They believe that the direct discharge of industrial waste into the sea is one of the major threats to biodiversity. All the visitors were familiar with dolphins and sea turtles though 99.2% of them had not had on opportunity to watch these animals.

Majority of the visitors (95%) misidentify a sea anemone as an artificial material; they also misidentify the eel as snakes. Most of the male visitors generally evinced an interest about large animals like Seabass, Lobsters and Moray eels. The female visitors were mostly attracted by the colorful fishes, particularly butterflyfishes, and expressed fear while watching the larger fishes.

Some of the visitors (44%) expressed a desire to maintain the marine aquarium in their homes and requested for more scientific information about marine aquarium keeping. Some children recognize the fish on the basis of the popular film '*Finding Nemo*'. The majority of visitors expressed the desire for establishing public aquaria in their native places and providing environmental education. The visitors were keen in involving themselves in conservation of the marine environment, though several avenues are available for promoting marine conservation, establishing marine aquaria appears to be the most advantages in creating awareness to the masses.

Recommendations & Suggestions

- This study suggests that public aquaria are useful for public education and there is a need for more public aquariums especially in areas far from the coast.

- Aquariums are incorporated with multimedia interactive exhibits including some that do not require actual species on display. For example, Monterey Bay Aquarium (in Monterey Bay, California) and Mystic Marine Life Aquarium (in Mystic, Connecticut) are among aquariums featuring submersibles capable of transmitting data and video imagery from extreme depths.

- Interested people who contact aquarium personnel are likely to need learning material including videotapes and books. The preparation of such information regarding the marine education is therefore essential in an aquarium. The present observation also shows that aquariums are the suitable place for the distribution of books and other materials regarding marine biodiversity.

- Previous research at zoos has shown that developing more naturalistic exhibits increases visitor enjoyment and has considerable benefits for public education in conservation issues (Price et al., 1994). McCormickray (1993) argued for exhibits which 'focus on the role of organisms in ecosystems to encourage better public understanding and support of aquatic conservation'. In the present study also it was observed that the public aquariums are suitable tool for biodiversity conservation.

- In India, collection of marine aquarium species depends mainly on resources of Gulf of Mannar. In the Gulf of Mannar the fishermen and aquarium fish sellers collect live fishes during the regular trap fishery. To reducing the fishing pressure in such sensitive environment, the present aquarium also exhibits fishes that can be collected from Parangipettai coast. Even the 'colorless' fishes interested the visitors. Besides colorful fishes like Lion fishes, Pufferfishes, Surgeon fishes, some colorful estuarine ornamental fishes are also available from the Parangipettai coast. It is suggested that such alternate resources will reduce the pressure of aquarium fish collection in Gulf of Mannar.

- It is suggested that conservationists should form collaborative partnerships with aquaria to develop research initiatives on the links between information provision, visitor numbers and visitor satisfaction. Meanwhile conservation organizations and policy makers should actively contribute to developing educational programmes of commercial aquaria in order to demonstrate their validity on a commercial platform.

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POSTER SESSION

FAUNAL DIVERSITY OF SETHUSAMUDRAM SHIP CHANNEL AND ITS ADJOINING REGION OF GULF OF MANNAR AND PALK BAY, SOUTHEAST COAST OF INDIA

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Introduction

The Gulf of Mannar is an arm of Indian Ocean lying between southern tip of India and the west coast of Sri Lanka at a width of between 160 and 200km. The Gulf of Mannar Biosphere Reserve is one of the world's richest marine biological resources covers an area of 10,500km^2 and it has about 3600 species of fauna and flora making it India's biologically enriched marine ecosystem (GEF, 1999). Besides, the Gulf of Mannar is especially significant for the diversity of 123 species of corals belonging to 54 genera, 400 species of algae, 13 species of sea grasses under six genera and endangered species of dugong (*Dugong dugon)*, dolphins and turtles. The Palk Bay is also considered as one of the five major reef formations in India and it also harbours 61 species of algae belonging to 37 genera (Venkataraman and Wafar, 2005).

The Sethusamudram Ship Channel Project (SSCP) is a 167km long shipping channel envisaged creating a navigational channel across the Palk Strait between India and Sri Lanka and allowing ships to have a straight passage through Indian territorial waters instead of circumnavigating Sri Lanka. The present study describes the existing faunal assemblage with emphasis on their diversity and distribution along the adjoining area of the project site. Though voluminous literature is available on various components of this ecosystem, the studies pertaining to the diversity of faunal resources are scanty. However earlier works by Foote (1988), Thurston (1890 & 1895), Hornell (1917), Gravely, 1927; Horst, 1931; Sewell, 1932; Burton, 1937; Satyamurthy, 1952, 1956; Apurba Ghosh (1963), Jones (1966), Ananthanarayanan (1967), Mahadevan and Nair (1968), Thomas (1969), Pillai (1969, 1973, 1975, 1977, 1986, 1996 & 1997), Appukuttan (1972), Pillai and Stoddart (1972), Nair and Mahadevan (1973), Ameer Hamsa (1974 & 1981), Ameer Hamsa and Gandhi (1978), James and Soundararajan (1979), Venkataramanujam *et al.* (1981), Anderson (1981), Bhatt (1983), Agastheesapillai and Thiagarajan (1984), Thomas (1984), James (1985), Scheer (1985), Wafar (1986), Thomas (1985), Thomas and George (1986), Bakus (1994), Krishnapillai and Kasinathan (1987), Krishnamurthy (1987), Silas and Fernando (1988), James *et al.* (1988), Krishnamurthy (1991), Marichamy *et al.* (1993), Purvaja and Ramesh (1993), Bakus (1994), Deshmukh and Venkata Rámani (1995), Jeyabaskaran *et al.* (1996), Asir Ramesh (1996), Appukuttan (1996), Dorairaj (1998), Venkataraman (2002), Venkatraman and Alfred (2002) Venkatraman *et al.* (2003), Anon (NEERI) (2004), Raghuram and Venkataraman (2005a,b), Venkataraman and Raghuram (2006) and Venkataraman (2006) on this area are worth mentioning.

Material and Methods

The study was conducted along the coast off Kilakarai, Mandapam and Devipatnam in the Gulf of Mananar and Devipatnam, Thondi, Adirmanpatnam, Point Calimere and Nagapattinam in Palk Bay regions of Bay of Bengal where the alignment of SSCP is involved (Fig. 1). The primary data on the faunal resources and diversity the aforesaid regions were collected by undertaking several field surveys during the year 2004-2006. In addition, the secondary and tertiary data were also collected by consulting published literatures and interacting with the fisherfolk of the respective regions for eliciting specific information and seasonal variations. Furthermore, the data collected through the various projects and annual research programmes of work of the Marine Biological Station, Zoological Survey of India conducted over three decades on distribution pattern of faunal elements were one the major sources of this inventory. The collected information has been processed and collated from analysis.

The diversity of species and genera were calculated for entire faunal group at all the station following the Shanon-Weiner formula.

H' = ? Pi log e pi

Where Pi = proportion of the *i*th species in the collection and H′ = diversity of a theoretically infinite population.

Results and Discussion

The Gulf of Mannar and Palk Bay are unique marine ecosystem and Marine National Park, not only harbouring endangered faunal and floral components but also supports conventional and non-conventional fishery. The average primary productivity of these areas is 205 and 223 mg C/m^3/ day respectively. About 126 species of phytoplankton belonging to diatom (97 species and 33 genera), dinoflagellates (10 species and 6 genera) and blue green algae (7 species and 5 genera) were reported in this region. Approximately 360 species of zooplankton were recorded with the numerical density ranging from 8000-65000 No./100 m^3. The present study is confined to the SSCP site and its adjoining area and it reported 1752 species of faunal communities accommodated in 869 genera under 15 groups (Table 1). The species and generic diversities and distribution of these faunal constituents accounted from the study area are depicted in Tables 2-16.

Table 1: Generic and species composition of faunal group in SSCP site along Gulf of Mannar and Palk Bay

Sl.No.	*Faunal group*	*No. of Genera*	*No. of Species*
1.	Protozoa	27	32
2.	Porifera	133	326
3.	Coelenterata	86	164
4.	Platyhelminthes	1	1
5.	Aschelminthes	9	9
6.	Annelida	20	32
7.	Arthropoda	61	152
8.	Mollusca	105	192
9.	Echinodermata	96	145
10.	Hemichordata	2	3
11.	Cephalochordata	1	2
12.	Tunicata	17	42
13.	Pisces	295	632
14.	Reptilia	10	14
15.	Mammalia	6	6
	Total	**869**	**1752**

Protozoans

A total of 32 species of protozoans belonging to 27 genera were recorded from the study area. All these species were found in Mandapam and Kilakarai region of Gulf of Mannar. The species and generic diversities of protozoans were found to be minimum (1.0 & 0.7) at Point Calimere and maximum (1.6 & 1.1) in most of the stations respectively (Table 2). However, mean diversity of these single celled organisms was 1.6 for both species and genera. The species composition of protozoans in the Gulf of Mannar and Palk Bay regions was very low when compared to 2577 species of these organisms reported from Indian seas (Venkataraman and Wafar, 2005).

Table 2. Distribution and diversity of Protozoans at different stations along the SSCP site

Phylum: Protozoa	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
No.of Species	32	32	29	24	26	11	27	32
No.of Genera	25	25	22	20	20	8	19	27
Number of Order	5	5	3	2	2	2	2	5
Species diversity(H')	1.6	1.6	1.3	1.1	1.2	1.0	1.2	1.6
Generic diversity(H')	1.1	1.1	1.0	0.8	0.9	0.7	0.9	1.6

Poriferans

Poriferans have a paleontological significance as they originated about 570 million years ago (Thomas, 1998). Poriferans especially sponges, reported from the present study comprised of 326 species under 133 genera, 50 families and 16 orders (Table 3). It is fascinating to note that 67% of the India's sponge species (486) were only recorded at SSCP site of Gulf of Mannar and Palk Bay regions. The class Desmospongia was the only dominant group of sponges in the study area. The total number of species and genera reported from individual station varied from 132 & 66 to 200 & 92 at Point Calimere and Mandapam respectively. However, the species diversity were ranged from 3.8 at Thondi to 5.9 at Kilakarai with the total of 7.1, while generic diversity varied between 1.5 at Point Calimere and 4.4 at

Devipatnam with the total value of 3.0 respectively. The literature on the species distribution of sponges is also available for Andaman and Nicobar Islands (95 species), Lakshadweep Islands (82 species) and Gulf of Kachchh (25 species), which are quite lower in diversity than Gulf of Mannar and Palk Bay where the optimal concentration of nutrients in seawater coupled with coral reef environment provides the conducive environment for the rich diversity of these organisms.

Table 3. Distribution and diversity of Poriferans at different stations along the SSCP site

Phylum: Porifera	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	200	197	205	171	178	132	135	326
Number of Genera	99	104	111	88	89	66	74	133
Number of Family	45	44	49	41	41	25	27	50
Number of Order	16	16	16	16	16	16	16	16
Species diversity (H')	5.5	5.9	4.4	3.8	5.1	3.9	4.0	7.1
Generic diversity (H')	**2.5**	**2.7**	**4.4**	**2.0**	**2.2**	**1.5**	**1.7**	**3.0**

Coelenterates

The phylum Coelenterata represents the classes Hydrozoa, Zoantharia and Anthozoa in the study area. Among them the diversity of anthozoans was very high in the SSCP site of Gulf of Mannar and Palk Bay. A total of 164 species belonging to 86 genera were recorded from the study area. However the number of species and genera varied from 16 & 15 to 122 & 62 at Point Calimere and Madapam respectively, where as the species and generic diversities varied from 1.0 & 1.0 to 7.8 & 3.5 for the same set of stations respectively (Table 4). In Indian seas 812 species of coelenterates comprising of 212 species of Hydrozoa, 25 species of Scyphozoa, 5 species of Cubozoa and 600 species Anthozoa were reported (Anandale, 1915 &1916; Leloup, 1934; Menon, 1931; Daniel, 1985; Chakrapany, 1984; Pillai, 1991; Venkataramn and Wafar 2005). It is also to note that about 20% of the coelenterate species of India are recorded from the study area. The diversity of corals in the study area was constituted by 123 species belonging to 54 genera during the present investigation which is about 56.42% of the coral species distributed in Indian seas.

Table 4. Distribution and diversity of Coelenterates at different stations along the SSCP site

Phylum: Coelenterata	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	122	111	96	89	50	16	30	164
Number of Genera	62	56	46	43	34	15	26	86
Number of Family (Zoantharia and Anthozoa)	16	16	15	12	9	2	3	17
Number of Order	9	9	9	9	9	8	8	9
Species diversity (H')	7.8	6.3	6.1	2.9	3.2	1.0	1.9	8.1
Generic diversity (H')	**3.5**	**3.1**	**2.9**	**2.7**	**2.2**	**1.0**	**1.7**	**4.0**

Platyhelminthes

Convoluta saliens (Graff) is the only species of the phylum Platyhelminthes belonging to the order Acoela was recorded from the study area (Table 5). However, this species was noticed only in Mandapam and Kilakarai in Gulf of Mannar and Thondi and Adirampatnam in Palk Bay region. Moreover no detailed study has been undertaken on this phylum on taxonomic point of view.

Table 5. Distribution and diversity of Platyhelminthes at different stations along the SSCP site

Phylum: Platyhelminthes	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	1	1	—	1	1	—	—	1
Number of genera	1	1	—	1	1	—	—	1
Number of Order	1	1	—	1	1	—	—	1
Species diversity (H')	0.1	0.1	—	0.1	0.1	—	—	0.1
Generic diversity (H')	**0.1**	**0.1**	—	**0.1**	**0.1**	—	—	**0.1**

Ashelminthes

A total of 9 species belonging to 9 genera in the phylum Asheminthes were encountered in the study area (Table 6). Among them Rotifera has 2 species and Nematoda comprised of 7 species. The order Entoprocta of this phylum is predominantly marine having about 60 species around the world. Earlier studies on Entoprocta are scanty except the brackishwater and marine species reported by Annandale (1908 & 1916) and Harmer (1915). The representatives of Ashelminthes were reported at all the stations of present study and their species and generic diversities ranged from 0.1 in most of the stations to 0.4 for both the variables in Mandapam and Kilakarai respectively.

Table 6. Distribution and diversity of Ashelminthes at different stations along the SSCP site

Phylum: Ashelminthes	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	9	8	4	2	2	2	2	9
Number of Genera	9	8	4	2	2	2	2	9
Number of Order	4	4	3	1	1	1	1	4
Species diversity (H')	0.4	0.4	0.3	0.1	0.1	0.1	0.1	0.6
Generic diversity (H')	**0.4**	**0.4**	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.6**

Annelids

Thirty two species of Annelids belonging to 20 genera were recorded from the study area, which is closely related to the report of Gravely (1927) who has recorded 36 species under 11 families in Krusadai Island of Gulf of Mannar. However, Fauvel (1930) has reported 119 species of polychaetes under 22 families in the same area where as a total of 883 species of annelids were enlisted in India (Venkataraman and Wafar, 2005). The distribution of annelids ranged from 4 species at Point Calimere to 25 species at Mandapam and the similar trend of variation was noticed for their species and generic diversities (Table 7). In the present study area only 3 species class Archiannelid was reported out of 20 species recorded from Indian coast. However their distribution in Indian waters is significant with the worldwide record of 90 species under 18 genera and 5 families.

Table 7. Distribution and diversity of Annelids at different stations along the SSCP site

Phylum: Annelida	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	25	11	14	9	6	4	9	32
Number of Genera	18	10	9	7	4	4	8	20
Number of Order	5	5	5	5	3	3	5	6
Species diversity (H')	1.6	0.7	0.9	0.6	0.4	0.2	0.6	2.0
Generic diversity (H')	**1.6**	**0.6**	**0.6**	**0.6**	**0.3**	**0.2**	**0.5**	**1.5**

Arthropods

The classes Insecta and Crustacea were taken up for this study. *Halobates galatea* was the only species of insect reported form the study area and it found in Mandapam, Adirampatnam and Nagapattinam. A total of 152 species under 61 genera, 23 families and 7 orders of arthropods were reported with the range of 41 species at Thondi to 102 species at Nagapattinam (Table 8). The species diversity of these organisms varied from 3.8 at both Thondi and Point Calimere to 5.5 at Devipatnam with the total of 5.9. Among the arthropods, crustaceans are predominantly marine inhabitants. The global estimate of the described species of crustaceans is 40,000, of which 2934 species have been reported. In India, 139 species of stomatopods, 26 species of lobsters, 162 species of hermit crabs, 705 species of brachyuran crabs, 82 species of shrimps and prawns were recorded (Venkataraman and Krishnamoorthy, 1998). The representatives of the families Balanidae, Penaeidae, Panuliridae, Portunidae, Ocypodidae were distributed at all the station of study.

Table 8. Distribution and diversity of Arthropods at different stations along the SSCP site

Phylum: Arthorpoda	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	95	81	81	47	66	60	102	152
Number of Genera	41	31	32	15	26	25	44	61
Number of Family	19	12	12	8	10	7	18	23
Number of Order	6	5	6	5	5	5	6	7
Species diversity (H')	3.9	5.0	5.5	3.8	4.2	3.8	4.4	5.9
Generic diversity (H')	**1.6**	**1.8**	**2.6**	**1.5**	**1.7**	**2.8**	**1.7**	**2.0**

Molluscs

The Gulf of Mannar and Palk Bay coupled with the coral reef environment attracts the highly diversified molluscan fauna. A total of 192 species of molluscs under 105 genera, 54 families and 9 orders were recorded along the SSCP site (Table 9). The representatives of all Schedule-I molluscs under Wildlife Protection Act, 1972 were also found in this region. The species of gastropod families such as Trochidae, Cerithidae, Strombidae, Littorinidae, Cassidae, Muricidae, Turbinellidae, Melongenidae and Fisrellidae, opisthobranchs and the family Sepiidae of cephalopods were recorded at all the stations. The number of molluscan species encountered at different stations of study area ranged from 61 at Devipatnam to 148 at Mandapam while the genera varied between 42 at Adirampatnam and 86 at Mandapam. Similarly the species and generic diversity also showed minimum (2.4 and 1.4 respectively) at Adirampatnam and maximum (3.6 and 1.8 respectively) at Mandapam. In India, 3370 species of marine molluscs were recorded so far (Subba Rao, 1991 and 1998). Among them 428 species were found in Gulf of Mannar and Palk Bay region (Venkataraman *et al.*, 2004). However, the present study reported that about 45% of molluscs recorded in Gulf of Mannar and Palk Bay region were found exclusively in SSCP site and its adjoining areas. In general, the molluscan diversity of Andaman and Nicobar Islands is higher in order as this archipelago harboured 1000 species (Subba Rao and Dey, 2000). It is also to note that the species of oysters, mussels, clams, pearl oysters, chanks, and cephalopods from the study area are being exploited for various purposes such as food, aphrodisiac substances, perfumes, ornamental value and medical properties.

Table 9. Distribution and diversity of Molluscs at different stations along the SSCP site

Phylum: Mollusca	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	148	123	61	59	59	73	98	192
Number of Genera	86	75	46	38	38	42	52	105
Number of Family	47	41	30	25	25	28	36	54
Number of Order	8	7	7	6	6	7	8	9
Species diversity (H')	3.6	3.0	2.9	2.9	2.4	2.4	2.9	4.0
Generic diversity (H')	**1.8**	**1.7**	**1.8**	**1.7**	**1.5**	**1.4**	**1.7**	**2.6**

Echinoderms

The diversity and distribution of Echinoderm fauna are depicted in Table 10. A total of 145 species under 96 genera, 44 families and 5 classes were noticed in the SSCP area (Table 10). The number of species and genera recorded at individual stations varied from 10 & 9 at Adirampatnam to 108 & 70 at Mandapam respectively. Similar trend of variation was also observed for the species and generic diversities as they ranged between 1.1 & 0.9 at Adirampatnam and 3.3 & 1.9 at Mandapam respectively. Though the considerable diversity of echinoderms were reported in the study area, their distribution was mostly restricted to the Mandapam, Kilakarai and Devipatnam region as these places endowed with luxuriant growth of coral reef formations. In Indian seas, 765 species of echinoderms were recorded, of which the highest diversity of 257 species found at Andaman and Nicobar Islands (Sastry, 1998). Among the Indian echinoderms, 19% of the species were reported from the present study site. The representatives of order Holothuroidea are commercially important and being exploited for *beche-de-mer* industry in larger extent in spite of its ban for fishing and included under Schedule I of the Wildlife Protection Act, 1972. However, the species such as *Holothuria scabra, Holothuria spinifera and Bahadschia marmorata* are highly targeted holothurians for large scale exploitation in Gulf of Mannar and Palk Bay.

Table 10. Distribution and diversity of Echinoderms at different stations along the SSCP site

Phylum: Echinodermata	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	108	83	64	29	21	10	13	145
Number of Genera	70	60	54	23	20	9	13	96
Number of Family	37	25	25	11	10	7	11	44
Species diversity (H')	3.3	2.5	1.8	3.1	2.0	1.8	1.8	2.6
Generic diversity (H')	1.9	1.8	1.4	2.0	1.7	0.9	1.3	1.5

Hemichordates

Three species of hemichordates, *Balanoglossus carnosus, Ptychodera flav* and *Ptychodera viridis* were reported from Krusadai Island of Mandapam region (Table 11). So far 102 species of hemichordates were recorded from the world, of which 12 are known from India (Dandapani, 1988a). The species of *Plychodera, Balanoglossus* and *Glandiceps* have also been reported from Gulf of Kachchh, Andaman and Nicobar Islands, Lakshadweep and Tamil Nadu coasts (Venkataraman and Wafar, 2005).

Table 11. Distribution and diversity of Hemichordates at different stations along the SSCP site

Phylum: Hemichordata	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	3	—	—	—	—	—	—	2
Number of Genera	2	—	—	—	—	—	—	2
Number of Class	1	—	—	—	—	—	—	
Species diversity (H')	0.7	—	—	—	—	—	—	0.7
Generic diversity (H')	0.2	—	—	—	—	—	—	0.2

Cephalochordates

Only two species of cephalopods, *Branchiostoma indica* and *Branchiostoma lancoelatus* were reported in Mandapam region of the study area (Table 12). Globally 24 species of cephalochordates under 2 families and 2 genera were reported and in India 6 species were reported under 2

Table 12. Distribution and diversity of Cephalochordates at different stations along the SSCP site

Sub phylum: Cephalochordata	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	2	—	—	—	—	—	—	2
Number of Genera	1	—	—	—	—	—	—	1
Species diversity (H')	0.1	—	—	—	—	—	—	0.1
Generic diversity (H')	**0.1**	—	—	—	—	—	—	**0.1**

Tunicates

The distribution and diversity of tunicates recorded in the SSCP site is presented in table 13. A total of 42 species belonging to 16 genera under the families Salpidae, Doliolidae and Pyrosomatidae were reported in the study area. The representatives of salpids and doliolids were found at all the places of study. The number of species and genera encountered from individual station ranged from 8 and 5 at Adirampatnam to 25 & 13 at Mandapam respectively. The species diversity of tunicates in the SSCP and adjoining area was calculated as 2.4 while the generic diversity found as 1.8. It is fascinating to note that 113 species tunicates were listed out in India (Dandapani, 1998b and Renganathan, 1986) of which 37% of the species were reported at the present study area.

Table 13. Distribution and diversity of Tunicates at different stations along the SSCP site

Phylum: Tunicata	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	25	23	17	18	12	8	16	42
Number of Genera	13	12	8	10	7	5	8	16
Number of Family	3	3	2	3	3	2	2	3
Species diversity (H')	2.1	2.0	1.9	1.7	1.4	1.3	1.7	2.4
Generic diversity (H')	**1.2**	**1.1**	**0.8**	**0.8**	**0.5**	**0.4**	**0.6**	**1.8**

Pisces

A total of 632 species of fishes under 295 genera and 124 families were reported in the study area (Table 14). However the number of species and genera recorded among the stations varied between 186 & 108 at Thondi and 387 & 199 at Nagapattinam respectively. It is noteworthy to state that the Nagapattinam coast alone harboured the fishes belonging to 120 families out of 124 reported in the study area. The species and generic diversities of the SSCP site were 2.6 and 1.7 respectively. However the diversity at individual station for these variables varied between 2.2 & 1.6 at Mandapam and 3.9 & 2.7 at Nagapattinam respectively. Day (1989) has described 1418 species of fishes under 342 genera from the British India while Talwar (1991) has given a description for 2546 species belonging to 969 genera, 254 families and 40 orders. The distribution and diversity of the fishes reported from the study area revealed that, 25% of fish species enlisted from India is available at SSCP site. Furthermore, over 1000 species of fishes found in Andaman and Nicobar Islands and about 538 species in the Gulf of Mannar Biosphere Reserve (Venkataraman and Wafar, 2005). The presently focused study area in Gulf of Mannar and Palk Bay region also serve as an abode for ornamental species such as damsel fishes, butterfly fishes, sweet lips, angel fishes, parrot fishes, snappers, wrasses and surgeon fishes as they prefers the coral reef ecosystem of this area.

Table 14. Distribution and diversity of Pisces at different stations along the SSCP site

Class : Pisces	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	298	279	237	186	243	188	387	632
Number of Genera	164	142	125	108	143	116	199	295
Number of Family	93	77	71	67	73	67	103	124
Number of Order	14	12	12	11	11	13	14	14
Species diversity (H')	2.2	5.5	4.6	4.3	4.5	3.7	3.9	2.6
Generic diversity (H')	**1.6**	**2.2**	**2.1**	**2.2**	**2.2**	**2.6**	**2.7**	**1.7**

Reptiles

Two families of reptiles, Hydrophiidae and Cheloniidae were recorded in the study area (Table 15). Eleven species of sea snakes under 7 genera were encountered for former while 3 species of turtles under 3 genera for the latter found in the study area. The species and generic diversities of reptiles were calculated as 0.78 and 0.38 respectively. In Indian waters, 26 species of sea snakes and 5 species of sea turtles have been reported. All these species were found to occur in Andaman and Nicobar waters. The observation on the species composition of reptile communities revealed that about 54% of the Indian species belong to this group reported in SSCP site.

Table 15. Distribution and diversity of Reptiles at different stations along the SSCP site

Class : Reptilia	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	5	—	—	—	2	3	9	14
Number of Genera	5	—	—	—	2	3	9	10
Number of Family	2	—	—	—	1	1	1	2
Number of Order	2	—	—	—	1	1	1	2
Species diversity (H')	0.32	—	—	—	0.1	0.2	0.2	0.38
Generic diversity (H')	**0.32**	—	—	—	**0.1**	**0.2**	**0.2**	**0.38**

Mammals

Six species of mammals under 6 genera such as *Grampus griseus, Tursiops tuncatus, Sausa chinensis, Belanoptera edeni, Pseudarca crassidens* and *Dugong dugon* were reported only in Mandapam region of the study site (Table 16). Globally 120 species of marine mammals are reported, of which 40 species are found in Indian Ocean. In India, 25 species belongs to order Cetacean and Sirenia were observed (Kumarn, 2002). Sea cows (Dugong) and dolphin are commonly found in Gulf of Mannar and Palk Bay where the seagrass meadow is abundant.

Table 16. Distribution and diversity of Mammals at different stations along the SSCP site

Class : Mammalia	Mandapam	Kilakarai	Devipatnam	Thondi	Adiram patnam	Point Calimere	Naga pattinam	Total
Number of Species	6	—	1	—	—	—	—	6
Number of Genera	6	—	1	—	—	—	—	6
Number of Order	2	—	1	—	—	—	—	2
Species diversity (H')	0.38	—	0.18	—	—	—	—	0.38
Generic diversity (H')	**0.38**	**—**	**0.18**	**—**	**—**	**—**	**—**	**0.38**

The scrutiny of the data obtained from the present investigation revealed that the species and generic diversities are highly significant throughout the study area. However diversity and distribution of species pattern were gradually reduced from the stations in Gulf of Mannar to the stations in Palk Bay. The higher diversity in Gulf of Mannar is mainly attributed to the reef environment coupled with the optimal primary and secondary productivities. Despite the indiscriminate exploitation of marine resources of this region over the last few decades, the species diversity of poriferans, coelenterates, crustaceans, molluscs, echinoderms and pisces of the study area are still moderately high as their composition is calculated as 20 to 67% of species reported from the other parts of Indian waters. The data provided in this paper will be served as baseline information for the faunal components of Sethusamudram Ship Channel Project site and its adjoining areas in Gulf of Mananr-Plak Bay system for the long-term monitoring of living resources of this fragile ecosystem.

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DISTRIBUTION OF BRACHYURAN CRABS ASSOCIATED WITH POCILLOPORA CORALS FROM SELECTED ISLANDS OF GULF OF MANNAR MARINE BIOSPHERE RESERVE

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ABSTRACT

Coral reefs are considered to be one of the significant resources for various environmental, ecological and socio-economic reasons. In India, Lakshadweep, Andaman and Nicobar Islands, Gulf of Mannar and Gulf of Katchchh are the areas that are rich in coral diversity. The Gulf of Mannar Marine Biosphere Reserve (GoMMBR), consists of 21 uninhabited islands ranging from 0.25 to 130 ha in size and lying between 1 and 4 km offshore, surrounded by shallow waters. GoMMBR is considered to be one of the richest biodiversity regions in India. Morphometry analysis was carried out in all the 21 islands of GoMMBR to study the diversity of corals and the associated brachyuran crabs. The morphometry survey results with the wider distribution of *Pocillopora* corals with the associated crabs were found to be abundant in 12 islands of the biosphere reserve. Results also revealed that the cryptic crabs were associated more in the dead *Pocillopora* colonies covered with algae than the live ones. The brachyuran cryptofauna play a crucial role in the development and maintenance of reef systems. The island area dominates with coral diversity with the associated brachyuran crabs includes Shingle (east), Krusadai (north-east), Pullivasal (south), Poomarichan (east), Manauli Putti (west), Hare (west), Mulli (south-east), Vaalai & Thalayari (North), Appa (north-east), Anaipar (south-west), Nallathanni (north) and Upputhanni (north-west). The coral crabs were found abundant in these specific directions of the islands. Both obligatory and facultative crabs were associated with the dead colonies covered with algae. A total of 26 species of coral crabs were collected. Various natural and anthropogenic threats to the coral reefs have an impact on the coral colonies and the associated

crabs. Basic education is needed to the coastal communities for the conservation and to improve the future corals with its associated faunal communities.

Key words: Morphometry, Brachyuran, Transect

INTRODUCTION

Coral reefs have a set of ecological tuning with respect to physical, chemical, geological and meteorological parameters of an ocean which have been studied by several workers (Pillai, 1971, 1973, 1975; Biswarap, 1994; Venkataraman *et al.*, 2002; Venkataraman, 2003). Coral reefs of the world constitute a shallow water ecosystem, which is largely restricted to the area between the latitudes 30°N and 30°S. A pioneer work on coral reefs was initiated by Pillai (1975) and he stated that coral reefs are one of the most successful marine benthic communities in the tropical waters.

In India coral reefs are distributed along the East and West coasts at restricted places like Lakshadweep, Andaman and Nicobar Islands, Gulf of Mannar and Gulf of Katchchh where the diversity of coral and its associates are more (Arjan *et al.*, 2000; Muley *et al.*, 2000). Coral reef ecosystem acquired extreme biodiversity which includes both commercial and non commercial organisms than any other ecosystems on the land or in the sea. Similarly Jeyabaskaran and Ajmalkhan, 1998; Venkataraman, 2005; Gokul, 2006 declared that coral reefs have a large variety of direct uses that will benefit the human beings. Socio-economic condition of the coastal fishermen population is mainly dependent on the coral-associated organisms (Venkataraman, 2003).

Earlier reports made by Mahadevan and Nayar, (1972), Nair and Nandakumar (1974) the GoMMBR appears to be a unique zone with respect to its biodiversity, general fisheries potential and variety of fishing activities. Based on the nature and ecological conditions various faunal communities are associated with the coral reefs. Many facultative predators are obligatorily associated on the coral hosts for feeding (Robert, 1970). The facultative and obligatory symbiotic faunal communities associated with the coral reefs is mainly to fulfill their basic needs like food and reproduction. The spatial distribution of associated fauna is related to the degree of availability of requirements (Thomas *et al.*, 2002a,b). Cryptofaunal communities play a significant role in all the coral reef ecosystems. According to Hutchings (1983) majority of the cryptofauna was reported to be occurring in reef rock and coral debris. Thus both the dead as well as the live corals serves as a home for several animals.

Venkataraman *et al.* (2002), Nammalwar and Edwin (2002), Venkataraman *et al.* (2003), Kathirvel and Gokul (2006), Gokul (2006) made various studies on the diversity and species richness of the cryptofauna of GoMMBR. Comparitively the cryptic crustaceans play a major role in the reef areas as well in the coral colonies. However both the brachyuran and anomuran crabs were found to be associated more in dead *Pocillopora* coral colonies than in live corals. Extensive studies have been done on the taxonomy and ecology of the coral reef associated brachyuran crabs of GoMMBR (Henderson, 1893; Thurston, 1894; Alcock, 1895, 1896, 1898, 1899a, 1899b & 1900; Kemp, 1919; Gravely, 1927; Chopra, 1931; Balss, 1935; Sankarankutty, 1963 & 1967; Jeyabaskaran *et al.*, 2000; CMFRI, 2006; Gokul, 2006; Kathirvel and Gokul, 2006). Thus the objective of the present paper is to deal with the diversity and distribution of the cryptic brachyuran crabs associated with *Pocillopora* coral colonies covered with algae in GoMMBR.

MATERIALS AND METHODS

A preliminary survey was undertaken around all the islands of GoMMBR from Mandapam to Tuticorin for the availability of brachyuran crabs during post monsoon (Jan-Mar), pre monsoon (April-july) and monsoon (Aug-Dec) periods. All the 21 islands were surveyed for the availability of the brachyuran crabs. Whereas 12 islands were found to have the brachyuran crabs associated with *Pocillopora* coral colonies covered with algae.

Tsuchiya *et al.* (1992) method was followed to collect the brachyuran crabs from dead *Pocillopora* corals. The corals were randomly selected and covered with polythene bags and brought to the shore. They are gently taped with hammer to remove the crabs from coral branches for collection. The collected crabs were preserved in 10% formalin and identified using Alcock, 1895, 1896, 1898, 1899a, 1899b, 1900; Sankarankutty, 1967; Jeyabaskaran *et al* 2000. Similarity percentage of the brachyuran crabs were analyzed by using Sorensen's (1948) index. The index was calculated in each combination of stations according to the following equation:

$$\boxed{\frac{2C}{(a+b)} \times 100}$$

Where '*C*' is the total number of species common to both islands,
a is the total number of species in one island and
b is the total number of species in another island.

RESULTS AND DISCUSSION

Earlier studies made by Thurstan (1894) revealed the density of the corals and its associated fauna. However from the present study it was observed that the brachyuran crabs associated with the *Pocillopora* corals covered with algae were found abundant in 12 islands of GoMMBR. Among the12 islands, the Vaalai and Thalayari Islands were considered as a single island (Thanikachalam and Ramachandran, 2003a; Venkataraman, 2003) based on their landscape and texture. Similar study made by Thomas *et al.* (2002a) indicated that various fluctuating environmental factors influenced the association and diversity of brachyuran crabs in the biosphere reserve. However according to Heil *et al.* (2004) stated that the benthic micro-algal population was potentially nutrient limited. Recently a detailed analysis made by Gokul and Venkataraman (2005); Gokul (2006) argued the status, diversity and richness of the dead *pocillopora* coral associated brachyuran crabs in GoMMBR. Various observations in the present study reflects the concepts of the earlier works in the coral reef ecosystem leads to conclude that the faunal richness is comparatively more in dense branched coral colonies covered with algae.

Whereas the abundance of the brachyuran crabs associated with the coral colonies was higher during the post-monsoon period (1150 individuals). The huge occurrence and diversity of the brachyuran species were restricted during the post-monsoon period (Ajmalkhan, 1999) and a low abundance (66 individuals) was observed during the monsoon period. Abundance was moderate (491 individuals) during the pre-monsoon period. Seasonwise distribution of brachyuran crabs was the least during the monsoon periods (Ramaiyan and Ajmalkhan, 1998; Ajmalkhan, 1999). It was observed from the present study that the brachyuran crabs prefer to associate in the coral colonies during post monsoon period. Van and Done (1997) reported that the associated benthic communities indicate the status of corals in the reef ecosystem.

In post monsoon period maximum number of coral crabs from the islands of the GoMMBR was obtained in the Mulli Island (175 individuals) and minimum number in the Nallathanni Island (33 individuals). Abundance of brachyuran crabs associated with the dead *Pocillopora* coral was not constant during the post-, pre- and monsoon periods. Mulli Island was observed to have maximum number of individuals in all the three seasons comparatively. The results indicate the distribution of the bachyuran crabs were found maximum during post monsoon period. Similarly, Ramaiyan and Ajmalkhan, (1998); Ajmalkhan, (1999) observed the greater number of crabs during post-monsoon period whereas moderate during pre-monsoon period and to a lesser degree in the monsoon period. The abundance of the brachyuran crabs observed in the Mulli Island of Keelakarai group may be due to the lesser anthropogenic disturbances as it is located not nearby the mainland area. According to Husein *et al.* (2003) the distribution of the brachyuran crabs was observed in the undisturbed areas compared with the disturbed areas. However, various factors, including less water contamination and less turbidity, may also enhance the association of brachyuran crabs in the GoMMBR (Murugesan *et al.,* 2000; Kailasm and Sivagami, 2004).

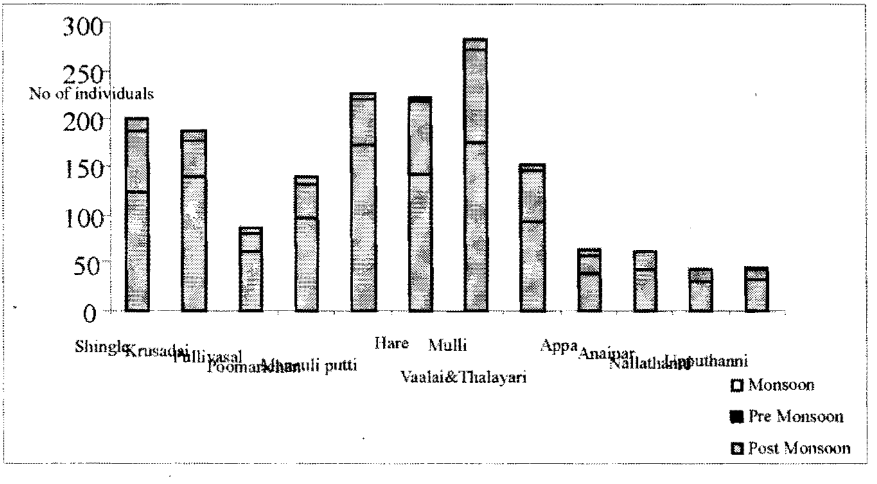
Sorrenson (1948) index of similarity analyzed mainly on the basis of the density of the species occurred. The present study resulted with highly similar species (60-100%) occurred in between a) Shingle and Pullivasal, b) Appa and Pullivasal, c) Nallathanni and Vaalai and Thalayari. Venkataraman and Nandi (1997) stated that the distribution of similar species reflected the higher similarity percentage. Whereas moderately similar species (31-60%) were distributed among a) Krusadai and Shingle, b) Poomarichan, Shingle and Krusadai, c) Pullivasal and Krusadai, d) Manauli Putti, Shingle, Krusadai and Pullivasal, e) Hare, Shingle, Pullivasal and Manauli Putti, f) Mulli, Shingle, Pullivasal, Manauli Putti and Hare, g) Vaalai and Thalayari, Shingle, Krusadai, Pullivasal, Hare and Mulli, h) Appa, Shingle, Krusadai, Poomarichan, Hare, Mulli and Vaalai and Thalayari, i) Anaipar, Pullivasal, Mulli, Vaalai and Thalayari and Appa and j) Nallathanni, Krusadai, Poomarichan, Pullivasal, Manauli Putti, Hare, Mulli and Anaipar. However, lesser similar species (0-30%) was distributed within a) Pullivasal and Poomarichan, b) Manauli Putti and Poomarichan, c) Hare and Poomarichan, d) Mulli, Krusadai and Poomarichan, e) Vaalai and Thalayari, Poomarichan and Manauli Putti, f) Appa and Manauli Putti, g) Anaipar, Shingle, Krusadai, Poomarichan, Manauli Putti and Hare, h) Nallathanni, Shingle and Appa and i) Upputhanni, Shingle, Krusadai, Poomarichan, Pullivasal, Manauli Putti, Hare, Mulli, Vaalai and Thalayari, Appa, Anaipar and Nallathanni.

The percent similarity is not constant in all the islands of GoMMBR. The brachyuran crabs reflect various limiting factors from their similaritry percentage. According to Sergio *et al.* (2003) stress is a major factor for the fluctuating similarity percentage of the brachyuran crabs in the islands of biosphere reserve. Similarly Venkataraman and Nandi (1997) stated that the lower similarity percentage reflects the disturbances in the sampling areas. Further studies also stressed the anthropogenic pressures occurred in the islands of the biosphere reserve alters the reef structure, distribution and growth which shuffled the distribution of coral associated faunal communities (Vineeta, 1997; Arthur, 2000; Venkataraman, 2000, 2003, 2005; Sergio *et al.*, 2003; Thanikachalam and Ramachandran, 2003a,b; Ajmalkhan, 2005; James, 2005). However intensive removal and destruction of the corals disturb the association of brachyuran crabs (Vinith *et al.*, 1996).

Various studies have been suggested some limitations to the diversity and distribution of the coral associated brachyuran crabs in GoMMBR. It was observed from the present study that the crabs prefer dense branched colonies covered with algae and not with the sediments. Anthropogenic pressure including seaweed plucking, anchoring, various traditional fishing practices in the reef area enhance sediments will sure has an impact on the corals and its associated brachyuran crabs (Pillai, 1969, 1971; Roberto *et al.*, 1989; Stefano, 1997; Vineeta, 1997; Van and Done, 1997; Dhandapani, 1998; Arthur, 2000; Venkataraman, 2000, 2003, 2005; Sergio *et al.*, 2003; Thanikachalam and Ramachandran, 2003a,b; Heil *et al.*, 2004; Ajmalkhan, 2005; James, 2005).

However, better monitoring plans have been introduced in India. Seasonal and long term monitoring might help to understand the status of the coral reefs in GoMMBR. Seasonal estimation such as qualitative and quantitative estimation of biodiversity, percentage covers of live and dead corals their associated faunal communities and level of exploitation has to be improved.

Fig 1. Seasonal abundance of the *Pocillopora* coral associated brachyuran crabs of GoMMBR



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8	+	+	+	x	x	+	+		9			
9	+	+	•••	+	x	+	+	+		10		
10	x	x	••	x	x	x	+	+	+		11	
11	x	+	+	+	+	+	+	•••	x	+		12
12	x	X	x	x	x	x	x	x	x	x	x	

••• = 61-100; + = 31-60; x = 0-30

1. Shingle; 2. Krusadai; 3. Pullivasal; 4. Poomarichan; 5. Manauli Putti; 6. Hare; 7. Mulli; 8. Vaalai&Thalayari; 9. Appa; 10. Anaipar; 11. Nallathanni; 12. Upputhanni.

Fig. 2. Similarity percentage of brachyuran coral crabs in GoMMBR

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FOOD WEB ANALYSIS OF A MANGROVE STAND IN SOUTH INDIA: STABLE ISOTOPES AND FATTY ACID BIOMARKER APPROACH

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Abstract

A study was conducted in a mangrove system of the Vellar estuary, South East Coast of India, in order to delineate the food web of the system. Stable isotopes of carbon and nitrogen were analyzed in different components of a mangrove as well as non-mangrove systems. The data reveal that mangrove-associated microbes significantly contribute to the food web in mangrove biotope, whereas in non-mangrove system, phytoplankton's contribution to the food web is significant. The prominent species of microbes in decomposing mangrove leaves are *Aeromonas hydrophila, A. punctata, Azotobacter beijerinckii, A. vinelandii, A. chroococcum, Bacillus cereus, Corynebacterium xerosis, Escherichia coli, Lactobacillus* sp., and *Pseudomonas aeruginosa*. The contribution of microbes to mangrove food web was further substantiated with fatty acids profile of dominant producers and consumers in the mangrove biotope. The fatty acids which are specific to bacteria are 15:0 ISO, 15:0 ANTEISO, 17:0 ISO, 17:0 ANTEISO and 18:1þ7. These were found present significantly in the tissues of prawns and fishes. This reveals that the microbes contribute significantly to the food web of the detritus based mangrove ecosystem. This work has also proved that the stable isotopes together with the fatty acid biomarkers are effective tools for identifying the trophic interactions among dominant producers and consumers in the mangrove ecosystem. This work is extended to different coastal ecosystems with multiple habitats in order to understand their inter-

relationships between critical habitats in the Gulf of Mannar, the first Biosphere Reserve in the South and South East Asia.

Introduction

Mangroves provide an important nutrient base for food webs leading to enhancement of fish resources in estuaries and coastal area (Turner, 1977; Feil and Master, 1981; Kathiresan and Bingham, 2001, Rajendran and kathiresan, 1998, 1999a, 1999b and 2000). The connectivity that exists between mangroves and fishes is in the form of trophic (flow of material from mangroves to adjoining habitats where different stages of life cycle), or physical contacts between the habitats (migration pathways for completion of different life history stages) is still debated (Lee, 2004; Rajendran and kathiresan, 2004 and 2007).

Stable isotopes has been used more specifically to identify food web relationships and interactions among dominant taxa in the estuarine environment (Hernandez et al., 2001; Kharlamenko et al., 2001; Ramos et al., 2003; Persic et al., 2004; Abed-Navandi and Dworschak, 2005). Stable isotope signatures are used to identify the trophic dynamics of a mangrove/ seagrass estuarine food web at Matapouri, northern New Zealand by Alfaro et al., (2006). The role of mangroves as the primary food source of prawns has been proved with the help of stable isotopes of C and N, in the estuaries of the Matang mangrove swamps (Chong et al., 2001). In contrast Stoner and Zimmerman (1988), while studying the mangrove fringed lagoon in Puerto Rico, using stable carbon isotope found that penaeid prawns and their food items derived most of their organic carbon from benthic algae rather than from mangrove detritus. The penaeid prawns in a mangrove–fringed river in the Philippines were more dependent on phytoplankton and epiphytic algae than on mangrove leaves, as suggested by Primavera (1996). While studying stable C and N isotopes in the tissues of prawn species in relation to several sources of primary producers in tropical northeastern Australia, Loneragan et al., (1997) emphasized that the seagrass beds and their epiphytes are a major source of energy supporting the food web of prawns in estuary. The contradictory results of the above-workers are due to the fact that none of them have used stable isotope studies for the microorganisms that are the essential link between primary producers and consumers in the detritus-based mangrove ecosystems. The microbes in the mangrove habitats are known to decompose mangrove litter as well other primary producers and then built up a protein-rich detritus which is consumed by the detritivorous fishes especially their juveniles (Rajendran and Kathiresan 2004, 2007). During this process, the flow of carbon and nitrogen from the primary producers to the consumers through microorganisms is not known yet.

The contribution of mangroves to food web of fishes is often under debate, even when advanced techniques like stable isotopes are used (Canuel et al., 1995; Bouillon et al., 2002). Several studies have successfully used fatty acids to trace the transfer of organic matter in coastal and estuarine food webs (Kharlamenko et al., 1995; Napolitano et al., 1997; Meziane and Tsuchiya, 2000; Bachock et al., 2003; Hall et al., 2006). The fatty acids are transferred from primary producers to higher trophic levels without significant change and hence they are used as biomarkers (Parrish et al., 2000). A few such studies are available for mangrove food web; however, none of them has studied fatty acids in microbes associated with decomposing leaves, prawns and fish. Hence the present study was conducted to find out the contribution of different producers in mangrove system and non-mangrove system to nutrition of the consumers with the help of stable C and N isotopes combined with fatty acids as biomarkers in identifying the trophic interactions in the food web.

Materials and methods

Collection of samples

The present study was conducted at a mangrove forest along the Vellar estuary, Parangipettai (Lat. 11° 29′ N; Long. 79° 47′E) lying in southeast coast of India. The fresh and decomposing leaf samples of *Rhizophora apiculata* and *Avicennia marina* were taken to the laboratory and washed thoroughly in sterilized water in order to remove debris and were shade dried for stable isotope analysis. Besides the mangrove leaves, samples of fishes including prawns, seagrasses, seaweeds and plankton were collected from the mangrove waters as well as non-mangrove waters 1 km away from the experimental site. Seaweed and seagrass samples were hand picked during the low tide and the fish samples were collected by using cast net operation. Samples of plankton were collected by using No.30 net for phytoplankton and No. 12 net for zooplankton. The dominant groups of fish, seagrasses, seaweeds and plankton were transferred to the laboratory and were and were identified.

Stable Isotope Analysis

The samples of fresh and decomposing leaves of mangroves, seagrasses, seaweeds and fishes (whole body by removing the gut) were washed thoroughly in distilled water to remove the surface debris and they were oven-dried for 24 h at 60^{o} C. All the samples were finely ground to a size of <200 mm using a pestle and mortar. Plankton samples were collected on pre-combusted Whatman GF/C fiber filters by using a suction pump. The microbial isotope composition was determined using the modified method of Chloroform-Fumigation-Extraction technique (Murage and Voroney, 2007).

The samples were analyzed for stable carbon and nitrogen isotope composition using a mass spectrometer (ANCA-SL, SerCon Inc.).The stable isotope compositions of carbon and nitrogen are expressed in ä-notation as the deviation from standards in parts per thousand (‰) according to the following equation:

$$äX= [(R_{sample} / R_{standard})-1] \times 1000$$

where, X is ^{13}C or ^{15}N and R = $^{13}C/^{12}C$ or $^{15}N/^{14}N$. Carbon values are expressed relative to the Pee Dee Belemnite standard and nitrogen ratio relative to air.

Enumeration and identification of microbes

The microbial population of the decomposing leaves of mangrove was analyzed for total heterotrophic bacteria (THB). For microbial analysis, the samples were brought to the laboratory immediately after collection and were analyzed for microbial population using the media purchased from HI-media Chemicals, Mumbai, India. Enumeration of the microbes was done by adopting spread plate method by using Zobells marine agar medium. The plates were incubated in an inverted position at 28±2°C. All the determinations were carried out in triplicates. After the incubation period of 2 to 3 days, the prominent groups of isolated microbes were identified (Buchanan and Gibbons, 1984).

Fatty acid analysis

Fatty acid content was analyzed for mangrove leaves of *R. apiculata* and *A. marina*, dominant microbes and fish groups associated with decomposing mangrove leaves. Fatty acid was extracted by using the standard procedures (Bligh and Dyer, 1959; Meziane and Tsuchiya, 2000). The extracts were saponified at 80°C for 90 min with a sodium hydroxide:methanol mixture (1:2, 3 ml,). The fatty acid methyl ester (FAME) was prepared and extracts were analyzed by Hewlett-Packard (Model HP 5890A, USA) Gas Chromatograph (GC). The GC was equipped with a flame ionization detector (FID) and 5% phenyl methyl silicon column. Triplicate samples were used for fatty acid analysis for each group.

Statistical methods

The data were analyzed to find out the significance between the variables for two way analyses of variance.

Results

Stable isotope analysis of producers

The ä^{13}C values in senescent leaves of *R. apiculata* and *A. marina* are -27.07‰ and -28.95‰ respectively. The ä^{15}N values of these species are +2.1‰ and +3.29‰ respectively. Amongst other producers, phytoplankton are dominant with diatoms with the mean values of ä^{13}C and ä^{15}N as -21.01‰ and +6.5‰ respectively. Zooplankton is represented mostly with copepods, exhibiting the mean values of ä^{13}C and ä^{15}N as -

20.46‰ and +6.025‰ respectively. Seagrass beds are dominant with *Halodule pinifolia,* showing ä^{13}C and ä^{15}N values of -10.69 ‰ and +1.91 ‰ respectively. Seaweeds are mostly composed of *Ulva lactuca* and *Enteromorpha compressa* with the mean ä^{13}C and ä^{15}N values of -23.01‰ and +5.19 ‰ respectively. The ä^{13}C values in microbial population exhibit mean values of ä13C and ä^{15}N as -18.04‰ and +8.06‰ respectively.

Stable isotope analysis of the consumers

The predominant consumer species found during the present study were *Metapenaeus monoceros, Macrobrachium* sp., and *Mugil cephalus* that belong respectively to penaeid prawns, non-penaeid prawns and finfish. The mean ä^{13}C values estimated for consumers in the non-mangrove water fell in the range of -19.5.87‰ and -13.33‰ and ä^{15}N values between 8.03‰ and 10.76‰. The mean ä^{13}C values of these consumers collected from the mangrove water fell in the range from -17.9‰ to -22.7‰ and ä^{15}N from +6.6‰ to +9.1‰. The isotope value in each of the consumers is statistically significant ($p < 0.05$) between the samples drawn from mangrove and non-mangrove waters (Table 1).

Table 1. **The δ^{13}C and δ^{15}N values of the consumers collected from mangrove waters (MW) and Non Mangrove waters (NMW). F value and level of Significance *- significant ($p < 0.05$)**

Species	δ^{13}C			δ^{15}N		
	MW	**NMW**	**'F' value**	**MW**	**NMW**	**'F' value**
P indicus	**-21.1**	**-17.58**	**21.8***	**7.0**	**8.89**	**15.7***
P monodon	**-21.7**	**-13.33**	**113.3***	**6.6**	**8.03**	**14.3 ***
M monoceros	**-22.7**	**-19.15**	**13.4***	**8.0**	**10.35**	**18.5***
M affinis	**-17.9**	**-15.87**	**15.8 ***	**8.6**	**9.85**	**33.5***
Mugil cephalus	**-20.5**	**-16.09**	**37.9***	**9.1**	**10.76**	**12.5***

Identification of the microbes

The dominant microbes isolated from the decomposing mangrove leaf were identified based on their morphological and biochemical characters. They are *Aeromonas hydrophila, A. punctata, Azotobacter beijerinckii, A. vinelandii, A. chroococcum, Bacillus cereus, Corynebacterium xerosis, Escherichia coli, Lactobacillus* sp. and *Pseudomonas aeruginosa.* Characteristics of the microbes used for identification are given in Tables 2.

Table 2. Morphological, culture and biochemical characteristics of microbes isolated from decomposing leaves of mangroves

Organism	*Ah*	*Ap*	*Ab*	*Ac*	*Av*	*Bc*	*Cx*	*Ec*	*Lsp*	*Pa*
Gram Stain										
-Rod										
-Rod										
-Rod										
-Rod										
-Rod										
+Rod										
+Rod										
-Rod										
+Rod										
-R od										
Motility			-	+	+					
Lactose	±	±				-	-	AG	+	-
Dextrose	+	+				A	A±	AG		-
Sucrose	±	+				A	A±	A±	+	-
Rhamnose			-	+	-					
Mannitol			+	+	-					
H_2S										
Production	+	+				-	-	-	-	-
NO_3 reduction	+	+	+	+	+	+	+	+		+
Indole production	+	+				-	-	+	-	-
MR Reaction	±	±				-	-	+		-
VP Reaction	+	-				±	-	-		-
Citrate Use	-	-				-	-	-		+
Urease Activity	-	-				-	-	-		-
Catalase Activity	+	+	+	+	+	+	+	+	-	+
Oxidase Activity	+	+				-	-	-		+
Gelatin liquefaction	+	+				+, fast	-	-	-	+
Starch Hydrolysis	+	+	+	-	-	+	-	-	+	-
Lipid Hydrolysis	-	+				±	-	-		+

(A=Acid production, AG= Acid and Gas production, ± = variable)

A h- Aeromonas hydrophila, A p- A. punctata,A b- Azotobacter beijerinckii, A c- A. chroococcum, A v- A. vinelandii, B c- Bacillus cereus, C x - Corynebacterium xerosis, E c -Escherichia coli,L sp- Lactobacillus sp and P a - Pseudomonas aeruginosa

Fatty acid biomarkers

Content of fatty acid biomarkers present in decomposing mangrove leaves microbes, prawns and fishes are shown in table 3. The bacterial biomarkers, namely - 15:0 ISO, 15:0 ANTEISO 17:0 ISO, 17:0 ANTEISO and 18:1þ7 - were more abundantly present in prawns and fish than any other producers biomarkers. However, other biomarkers of seaweeds (18:1 n-9), diatoms (20:5 n-3), and seagrass (18:2 n-6+ 18:3 n-3) are present in minor quantities. Long chain fatty acids the biomarker of vascular plants like mangroves are not found detected in the fishes (Table 3).

Table 3. Concentration of fatty acid biomarkers (% of total) in microbes, prawns, and fish predominantly associated with 40-days decomposed leaves of two mangrove species (*Rhizophora apiculata* and *Avicennia marina*)

Name of biomarker fatty acid	Content of fatty acids (% of total fatty acids)						
	R. apiculata	*A. marina*	*Azotobacter* sp.	*Lactobacillus* sp.	Non-Penaeids	penaeids	Finfish
BACTERIA							
15:ISO	0.6±0.1	0.7±0.14	14.7±1.2	12.5±1.2	10.5±1.3	9.16±1.2	3.03±0.6
15:ANTE-ISO	1.2 ±0.3	0.9±0.2	8.5±0.9	16.5±1.6	9.24±1.2	11.2±1.3	4.5±0.7
17:ISO	0.8±0.1	2.1±0.34	15.4±1.4	10.7±0.9	11.2±1.5	9.6±1.1	6.4±0.9
17:ANTE-ISO	0.3±0.08	1.5±0.2	12.7±1.1	13.6±1.4	2.6±0.5	4.7±0.5	3.2±0.5
18:1(n-7)	nd	nd	6.98±0.8	10.41±1.1	5.7±0.7	4.5±0.5	6.7±0.8
SEAWEED							
18:1(n-9)	nd	nd	nd	nd	1.4±0.2	2.3±0.3	1.7±0.2
DIATOMS							
20:5(n- 3)	0.24±0.02	0.45±0.06	nd	nd	0.23±0.03	0.12±0.0	0.21±0.02
SEAGRASS							
18:2(n-6)	nd	nd	nd	nd	0.18±0.01	0.16±0.0	0.54±0.05
18:3(n-3)	nd	nd	nd	nd	0.14±0.01	0.45±0.0	0.23±0.02

nd- not detected

Discussion

Stable isotopes are used as a reliable tool to investigate trophic ecology and to identify food pathways of ecosystems (Peterson and Fry, 1987; Hemminga and Mateo, 1996; Kwak and Zedler, 1997; Peterson, 1999, Kharlamenko, et al., 2001; Post, 2002; Persic et al., 2004). Combined analysis of carbon and nitrogen stable isotope is a powerful tool for identifying the ultimate organic matter sources and trophic position of consumers (Michener and Schell 1994). The ä ^{15}N can be used to identify the relative trophic position of various organisms within the food web, while ä ^{13}C provides information regarding the source of primary production in the ecosystem, and the flow of carbon from primary producers to consumers (Gu et al. 1996; Vizzini et al. 2002). Peterson and Fry (1987) reported average trophic shifts of carbon and nitrogen is about 0 ‰ and 3.3 ‰ respectively; and, ä ^{13}C value of consumers typically reflects the composition of assimilated food and by contrast value of ä ^{15}N can be used as a measure of an organism's trophic position (Michener and Schell 1994).

Food web based on stable isotope analysis in non mangrove waters

Stable isotopes of Carbon and Nitrogen (δ^{13}C and δ^{15}N) in the major producers (phytoplankton, zooplankton, seaweeds and seagrasses) and in consumer fishes from non- mangrove water of the Vellar estuary, in relation to different producers are shown in Fig.1. The data reveals that isotope values of fish samples are distributed very close to plankton, but not to other producers.

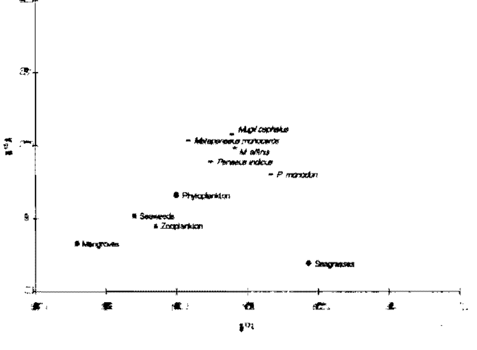

Fig. 1 **Changes of stable isotope values of δ^{13}C and δ^{15}N in producers and consumer fishes sampled from non mangrove waters**

Food web based on stable isotope analysis in mangrove waters

The stable isotope values of Carbon and Nitrogen ($\delta^{13}C$ and $\delta^{15}N$) in the producers and in consumer fishes of mangrove waters of the Vellar estuary reveals that the values of $\delta^{13}C$ and $\delta^{15}N$ fell ll in the range very close to microbes than any another producers.

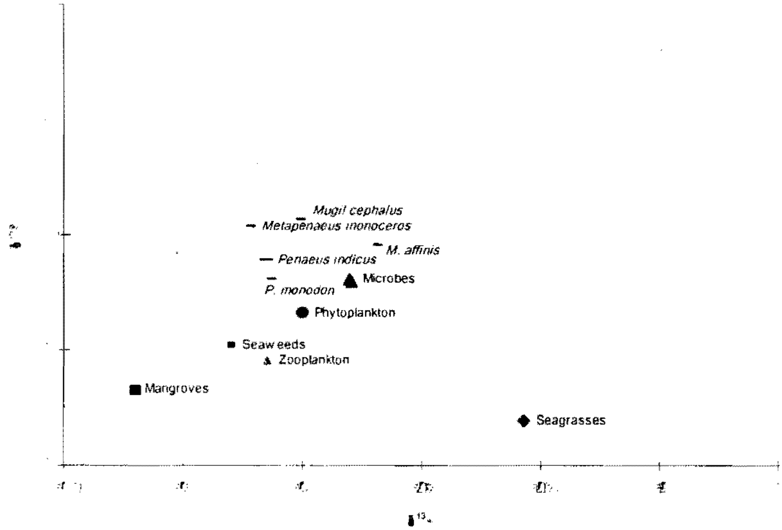

Fig. 2 **Changes in average value of stable isotope of $\delta^{13}C$ and $\delta^{15}N$ in producers and consumer fishes sampled from mangrove waters.**

In contrast to the mangrove waters, the fishes in the non mangrove water depend mainly on plankton rather than mangrove, seagrasses, and seaweeds as evident by stable isotope data (Fig. 1 and 2). The microbes that multiply in the mangrove habitat contribute to the food web of the environment and they are important source of carbon and nitrogen to the fishes in the mangrove area. This is evident by the findings of the present study that in mangrove waters, the st Fig. 2 Changes in average value of stable isotope of ä ^{13}C and ä ^{15}N in producers and consumer fishes sampled from mangrove waters.

Stable isotope values of carbon and nitrogen in fishes are nearer to microorganisms but not to any other producers such as mangrove, seaweeds, seagrasses, phytoplankton and zooplankton (Fig. 2).But in non-mangrove waters, the consumer fishes derive carbon and nitrogen from phytoplankton as evident by stable isotope (Fig. 1).The same species collected from mangrove and non mangrove water itself shows variation in isotope signatures. This can be attributed to varying local food availability. Chong et al., (2001) also found that the stable isotope signatures indicated difference between the sites of the collection but not with size groups of fishes. Newell et al., (1995) have found that mangrove detritus contributes to the nutrition of juvenile shrimp living in tidal creeks, but not to juveniles and adult shrimp found offshore. Juvenile fishes after deriving nutrients for their early development in the inshore waters migrate to offshore environment. During this developmental process, the juveniles depend highly on mangrove-based microbial detritus feed. However, after reaching the offshore their dependence on mangrove-based detritus food decreases gradually. This is because the fishes in non-mangrove waters derive little nutrition from mangroves detritus, presumably as the out-welled materials are dispersed over a wide area in the coastal waters (Chong et al., 2001). The result of the present study also comes to a similar conclusion.

Fatty acid biomarker analysis

Fatty acids are carbon-rich compounds, serving as an important source of energy, essential nutrients for survival and growth, and an integral component of cell membrane structure and function in all organisms. They are relatively easy to metabolize when consumed as part of the animals diets (Hazel et al., 1991; Parrish,. 1998; Parrish et al., 2000) but they are transferred to higher trophic levels without significant changes (Parrish et al., 2000). Previous studies have used fatty acids such as 15:0 ISO, 15:0 ANTEISO 17:0 ISO, 17:0 ANTEISO and 18:1þ7 as biomarkers for bacteria (Rajendran et al., 1993), 20:5(n − 3), 16:1/16:0 >1.6, ?16/?18 >2, and

20:5n -3/22:6n -3 >1 for diatoms, 22:6n -3 and 20:5n - 3/22:6n - 3 <1 for dinoflagellates (Parrish et al., 2000), 20:5n - 3/20:4n - 6 >10 for Red algae (Khotimchenko and Vaskovsky, 1990), 20:1 + 22: 1 for Zooplankton (Falk-Petersen et al., 2002), 18:2n – 6+ 18:3n - 3 for Seagrass (Kharlamenko et al., 2001), long chain fatty acids with more than 24 carbons for mangroves and other vascular plants (Wannigama et al., 1981).

In the present fatty acid biomarker content was analyzed in the dominant fish and prawn species that are collected from the mangrove waters. This revealed that the branched chain fatty acids 15:0 and 17:0 ISO and ANTEISO and the monounsaturated fatty acids 18:1þ7 are found in higher amounts. These are predominantly synthesized by bacterial communities (Jeffries, 1972; Volkman et al., 1980) and consequently, they are useful as bacterial biomarkers and indicators of bacterial biomass (Parkes, 1987). The enriched amount of bacterial fatty acid biomarkers such as 15:0 ISO, 15:0 ANTEISO 17:0 ISO, 17:0 ANTEISO and 18:1n-7 reveals the microbial link in the mangrove food web.

The result of fatty acid analysis provides further evidences to the outcome obtained from the stable isotope analysis. Both the results of stable isotope and fatty acid analysis reveals that none of the potential food sources are obligatory for the survival of the dominant organisms studied in mangrove and non-mangrove waters. Indeed, mangrove-derived material appears to have foremost effect on food web in mangrove waters. Contribution of mangrove carbon to prawn decreases in the offshore direction, as the contribution by phytoplankton becomes progressively more significant. This decrease may also because of tidal influence, which might have increased the production and import of phytoplankton but decreased the export of mangrove detritus to the offshore. Similar findings have been reported by Meziane and Tsuchiya (2002) in the Okukubi Estuary, Japan, and by Kieckbusch et al., (2004) in the Bahamas Islands. The reason for less dependence on phytoplankton derived carbon in the mangrove waters of the present study may also be due to less sunlight penetration through the dense mangrove canopy structure and through the detritus-based mangrove waters that might have resulted in relatively less phytoplankton bloom. In support of this, Lee (2004) suggests that the extent of intertidal areas and organic matter availability as represented by tidal amplitude rather than relative mangrove abundance have a stronger influence on prawn catch in tropical near shore environment.

Hence it is very clear that the food web inside the mangrove forest depends on carbon and nitrogen derived from mangrove associated microbes than any other sources. In non mangrove waters the exportation of organic matter from adjacent mangrove waters provides nutrients essential for phytoplankton bloom and they also enhance coastal food web (Odum and Heald, 1975). This view is largely accepted. However, trophic analysis of mangrove-dominated estuaries fails to provide convincing evidence that mangrove organic production forms the basis of near shore secondary production, except in some restricted circumstances (Lee 2005). The results obtained in the present study area cannot simply be generalized due to the larger environmental variability, found in mangrove ecosystems. However, the results of the present study provide a baseline data for future studies and models of relationships of this unique biotope with multiple habitat ecosystems. Hence this work is extended to different coastal ecosystems with multiple habitats in order to understand their inter-relationships between critical habitats in the Gulf of Mannar, the first Biosphere Reserve in the South and South East Asia.

Conclusion

The present study included (i) Stable carbon and nitrogen isotope analysis in producers and consumers in mangrove and non mangrove waters (ii) Fatty acid biomarker analysis in dominant species of fish, mangrove leaves and microbes (iii) identification of dominant species of the microbes associated with decomposing mangrove leaves. The present work fills the gap and confirms the role of microbes in nutrition of fishes associated with mangroves with the help of stable isotopic and fatty acid biomarker studies. Based on stable isotope results, it appears that the food web at the Vellar estuary depends on several food sources. The major producers (mangrove, phytoplankton, zooplankton, seagrasses, and seaweeds) contribute differently to the diets of primary consumer based on the local food availability. Fatty acid biomarker analyses proved bacterial biomarkers, branched fatty acids were significantly high fishes. The results reveal that the microorganisms play a vital role in food web of mangrove system. The prominent species of microbes in decomposing mangrove leaves are *Aeromonas hydrophila, A. punctata, Azotobacter beijerinckii, A. vinelandii, A. chroococcum, Bacillus cereus, Corynebacterium xerosis, Escherichia coli, Lactobacillus* sp., and *Pseudomonas aeruginosa.*

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HABITAT USE BY SHOREBIRDS IN GULF OF MANNAR MARINE BIOSPEHERE RESERVE, SOUTHERN INDIA.

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ABSTRACT

Habitat use of shorebirds along the coastal areas of the Gulf of Mannar Biosphere Reserve (GoMBR) was studied during 2005-2007. Twelve habitats (Five mainland and seven Islands) were surveyed for birds during the monsoon. Although a total of 75 species of birds were recorded for the entire coast of GoMBR, only 54 species of birds were observed for all the 12 habitats. Among habitats, *Kothandaramar* lagoon was observed with maximum species richness and diversity of birds. Species such as Blackheaded Gull, Plovers, Sandpipers and Eurasian Oystercatcher were observed largely in islands rather than mainland indicating their habitat specialization. As the islands were free from human disturbance, numbers of specialist's were found more in the island than the mainland where anthropogenic activities are severe. Besides periodical population monitoring of birds, awareness campaign and people participatory approach in the conservation of shorebirds are essential to enhance the population status and preserve the crucial coastal habitats for birds in GoMBR.

Key words: Shorebirds, Human disturbance, Gulls and Plovers, Gulf of Mannar.

INTRODUCTION

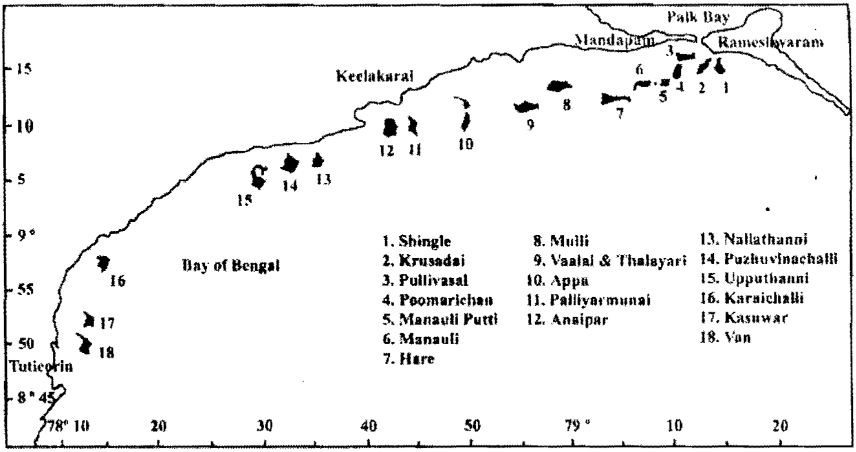
Shorebirds are an important biological component of coastal ecosystem as they play a major role in the aesthetic, sporting and economic values of wetlands. Moreover, they indicate the stability, quality and heterogeneity of the coastal ecosystem as birds are vulnerable to even slightest changes in structural and functional aspects of an ecosystem. Recently shorebirds are declining alarmingly throughout the world largely due to deterioration of the wintering habitats by manmade (urbanization, industrialization, fishing etc.) and natural changes (tectonic related activities such as tsunami, uplifting etc.). Recently, Ramesh and Ramachandran (2005) opined that the habitats available for flamingoes are affected by manmade and natural changes. Such deterioration reduces the resource availability and increases competition level among birds. In this ever declining scenario of birds and its habitats, identification of the distributional status of birds for all the available habitats are prerequisite for the biodiversity conservation.

The Gulf of Mannar Biosphere Reserve (GoMBR) being a Marine Biosphere Reserve and an aquatic habitat to support over 50, 000 individuals of shorebirds, has not been ornithologically well explored. However, there are some preliminary and sporadic avifaunal reports for various parts of GoMBR (eg. Biddulph, 1938 and Lal Mohan 1985 & 1986). A detailed attempt on migratory birds was made by Bombay Natural History Society under bird-ringing programme between"1985-88" in Mandapam and neighboring islands (Balachandran 1990a, b, 1991, 1995, 1998, and 2006). In the present study, distribution of shorebirds was studied in various habitats available in the mainland and islands of Gulf of Mannar Biosphere Reserve (GoMBR) during 2005 –2007.

STUDY AREA

The Gulf of Mannar (78° 08′ E to 79° 30′ E to and latitudes 08° 35′ N to 09° 25′ N) being the first Marine Biosphere Reserve for the entire south and Southeast Asia (Fig-1) covers 21 islands, uninhabited, ranging from 0.25 ha to 130 ha and spreading along the coast for 170 km with the closet being 500m the furthest over 4km from shore.

Fig-1. Islands of Gulf of Mannar Marine Biosphere Reserve



The islands and their shallow waters form the core of the Reserve. This core area is surrounded by a 10 km wide buffer zone. It experiences a tropical climate under the spell of both southwest (contributes only very little total rainfall during June to September) and northeast monsoons (moderate to heavy during heavy during October to mid-December). It experiences the dry climate from January to May. Rivers viz. Vaigai, Kappali, Kottanguli, Gundar, Vembar and Kallar drain into the GoMBR.

METHODS

As the accessibility was the major factor of concern, vantage count (Spindler *et al.* 1981) and boat survey (Bailey & Titman, 1984, Sjoberg, 1989) were adapted to survey the shorebirds. Vantage count was used in an area known for higher concentration of birds while boat survey was used in marshy areas and open waters. Double counting or missing birds was carefully avoided and there was a possibility of missing birds reported here were usually found on the edges of the vegetation i.e., on the open water vegetation interface. Birds were identified and counted with the help of binocular during early and late hours of the day. Counts were not made on days with rain, strong wind or extreme temperatures to minimize the bias caused by effects of weather (Verner, 1985). Two surveys were carried out in 12 different study areas (Table-1) during monsoons in 2005-07.

The bird species diversity was calculated using the Shannon-Weaver index (1949)

$$H' = -? \, p_i \log p_i$$

(Where H'= diversity and pi= the proportion of observation in subset i).

To find out the similarity in bird species composition and abundance between the habitat types, the Jaccard's (1904) similarity index was applied. This index refers to the ratio of number of species shared to total species among the various entities compared.

$$J = \frac{NC}{N1 + N2 - NC}$$

NC = Number of species in common

N1 = Number of species in the first habitat

N2 = Number of species in the second habitat.

RESULTS AND DISCUSSION

Habitats and bird species abundance:

A total of 75 species of birds were observed for the entire coastal region of GoMBR (Appendix). However, 54 species of birds were only recorded for the 12 habitats studied (5 in mainland and 7 in islands). Among the mainland habitats, highest number of bird species was observed in Thermal station, Tuticorin (23) followed by Valinokkam (21) and lowest number of bird species was observed in Munaikadu (11). Among the birds observed, Greater Flamingo, Whiskered Tern and Gull billed Tern were the dominat species of birds in terms of its numbers (Table-1).

Table: 1. Species richness and abundance of birds recorded in 12 habitats.

Mainlands			Islands		
Stations	**Species Richness**	**Abun-dance**	**Stations**	**Species Richness**	**Abun-dance**
Thermal station, Tuticorin	23	682	Kurusadi	12	71
Mandapam	13	651	Pullivasal & Poomarichan	17	313
Munaikadu	11	285	Manoli	20	3330
Kothandaramar lagoon	19	7856	Thalayari & Appa	6	75
Valinokkam	21	850	Nalla thanni	12	41
Total	46	10324	Hare	10	1090
			Shingle	4	72
			Total	54	4992

Among the Islands, highest number of bird species was observed in Manoli (20) followed by Pullivasal & Poomarichan (17) and the lowest was observed in Shingle Island. Gulls and Terns were the dominant species in the islands. In general, Kothandaramar Kovil lagoon supported the maximum number of individuals (largely Greater Flamingoes) in Mainlands and Manoli islands (3330 individuals) in islands studied. Balachandran (1995) also reported similar observation in these two areas. The Manali Island is about 2km long and 50m wide, covering an area of 24 hectares with small water pools and open mud flats. The small creeks inside the islands are fringed with mangrove vegetation and coarse grass. The shore is sandy and inshore areas are exposed during the low tide and attract a huge congregation of gulls and terns. Small areas are essential to guarantee that shorebirds can access all the tidal flats where they usually feed at low tide.

Species diversity: Diversity was recorded maximum in Thermal station, Tuticorin (2.1994) and lowest in Mandapam (0.9898) in mainland (Table-2). Among islands, Manoli showed the maximum diversity (2.4377) and Shingle showed the lowest (0.8476). In general, diversity was more in island (3.2424) than in mainland (2.1).

Table: 2. Diversity (H') of bird species recorded in 12 habitat types.

Mainlands		Islands	
Stations	**H'**	**Stations**	**H'**
Thermal station, Tuticorin	2.1994	Kurusadi	2.0863
Mandapam	0.9818	Pullivasal & Poomarichan	2.4185
Munaikadu	2.0286	Manoli	2.4377
Kothandaramar lagoon	1.1582	Thalayari & Appa	1.6171
Valinokkam	1.1589	Nalla thanni	2.1946
Overall	**2.1308**	Hare	1.7414
		Shingle	0.8476
		Overall	**3.2424**

Similarity in bird species composition between the habitat types: Similarity index of mainland varied from 0.14 to 0.41 and island varied from 0.11 to 0.57 (Table 3). The maximum similarity of birds was observed between Mandapam and Munaikadu and the lowest between Kothandaramar lagoon and Valinokkam among mainlands. Birds such as Median Egret, Little Egret, Grey Heron, Common Sandpiper, Little Ringed Plover and Little Cormorant were common among mainland habitats. Among the islands, maximum similarity was observed between Kurusadi and Hare and lowest was between Kurusadi & Thalayari and Appa habitats. Western Reef Egret and Gull billed Tern were common among island habitats. This indicated that these species were highly adaptable. Among birds, Grey Plover, Blackheaded Gull, Common

Sandpiper, Sand Plover, Marsh Sand Piper, Grab Plover, Eurasian Oystercatcher, and Terek Sandpiper were largely observed in Island habitats.

Table 3: Similarity of bird species between the habitat types

	Main land habitats					Island habitats						
	1	2	3	4	5	6	7	8	9	10	11	12
1	-											
2	0.38	-										
3	0.36	0.41	-									
4	0.20	0.14	0.30	-								
5	0.33	0.21	0.28	0.14	-							
6	0.13	0.04	0.01	0.11	0.22	-						
7	0.21	0.20	0.27	0.16	0.27	0.45	-					
8	0.19	0.22	0.24	0.26	0.21	0.33	0.37	-				
9	0.16	0.06	0.13	0.14	0.08	0.06	0.10	0.13	-			
10	0.13	0.14	0.05	0.11	0.18	0.14	0.16	0.19	0.20	-		
11	0.18	0.01	0.17	0.16	0.24	0.57	0.42	0.36	0.14	0.22	-	
12	0.04	0.00	0.07	0.15	0.04	0.00	0.00	0.09	0.11	0.00	0.00	-

1. Thermal station, Tuticorin 2. Mandapam, 3. Munaikadu, 4. Kothandaramar lagoon, 5. Valinokkam, 6. Kurusadi, 7. Pullivasal & Poomarichan, 8. Manoli, 9.Thalayari & Appa, 10.Nalla thanni, 11.Hare, 12. Shingle

It is evident from the present study that the majority of the shorebirds prefer island habitats than the mainland in GoMBR. Yasue (2006) and Zhenming, *et al.*, (2006) stated that shorebirds are responding quickly to human disturbance and tend to move to the neighboring habitats. Shorebirds were preferentially selecting areas further from forest cover that may have lower predation risk. In GoMBR, islands are comparatively less disturbed than the mainland by human and thus it could be the main reason islands are richer in avifaunal diversity than mainland. Nagarajan and Thiyagesan, (1996) stated that habitat selection of wintering birds is influenced also by prey availability and accessibility and the availability of feeding grounds (muddy flats, sandy). As the availability of feeding grounds and prey are richer in Islands than mainland habitats, it could also be one of the reasons for the richness of birds in island. Moreover, the abundance of benthic fauna (prey) is also higher in muddy flats than the other habitats (sandy and sediments).

Conservation measures

The Gulf of Mannar, which is supposed to become globally significant because of its unique biological diversity, came to lime light primarily due to constant exploitation of its flora and fauna. Next to Point Calimere on the southeast coast of India, the GoMB has been recognized for its ability to attract a large seasonal aquatic bird population of over 50,000. Pelagic birds were also occasionally recorded. People inhabiting in the villages along the coastal belts in GoMBR depend much on sea for their livelihood. Fishing and seaweed collection are the major income source for majority of the people. The usage of trawl nets, gill nets, long lines, traps and shore seines are used to plunder the biological wealth. Annually, on the average, 45,000 tonnes of demersals and 33,000 pelagic are fished out from the national park area, (Venkataraman., *et al*, 2002). Destructive methods used to overexploit the natural resources such as corals, seaweeds and sea grasses cause irreparable damage. The change in the climatic and topographic conditions due to human interferences, wipe-off the rich ecological diversity with in no time. Rapid industrialization around the reserve, usage of destructive fishing methods, poaching and commercial aquaculture are the other major threats in theses areas.

Conservation of an ecosystem or species would be successful only through the involvement of local people. Hence, effective implementation of existing rules in the fishing activities for the protection of Biosphere Reserve with the co-operation of the local people is prerequisite to preserve the ecosystem from further deterioration in the immediate future.

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Appendix - Check list of shorebirds

Sl. No	Common Name	Scientific name
	Order: Pelicaniformes	**Family: Pelecanidae**
1	Spot-billed Pelican	*Pelecanus philippensis*
		Family: Phalacrocoracidae
2	Little Cormorant	*Phalacrocorax niger*
	Order: Ciconiformes	**Family Ardeidae**
3	Little Egret	*Egretta garzetta*
4	Western Reef-Egret	*Egretta gularis*
5	Grey Heron	*Ardea cinerea*
6	Large Egret	*Casmerodius albus*
7	Median Egret	*Mesophoyx intermedia*
8	Cattle Egret	*Bubulcus ibis*
9	Indian Pond-Heron	*Ardeola grayii*
10	Little Green Heron	*Butroides striatus*

Sl. No	Common Name	Scientific name
11	Black-crowned Night-Heron	*Nycticorax nycticorax*
		Family: Ciconiidae
12	Painted Stork	*Mycteria leucocephala*
13	Asian Openbill-Stork	*Anastomus osciatans*
		Family: Threskiornithidae
14	Glossy Ibis	*Plegadis falcinellus*
15	Oriental White Ibis	*Threskiornis melanocephalus*
16	Black Ibis	*Pseudibis papillosa*
17	Eurasian Spoonbill	*Platalea leucorodia*
	Order: Phoenicopteriformes	**Family: Phoenicopteridae**
18	Greater Flamingo	*Phoenicopterus ruber*
	Order: Anserformes	**Family: Anatidae**
19	Northern Shoveller	*Anas clypeata*
20	Northern Pintail	*Anas acuta*
	Order: Falconiformes	**Family: Accipitridae**
21	Black Kite	*Milvus migrans*
22	Brahminy Kite	*Haliastur indus*
23	White-bellied Sea Eagle	*Haliaeetus leucogaster*
	Order: Charadriformes	**Family: Haematopodidae**
24	Eurasian Oystercatcher	*Haematopus ostralegus*
		Family: Charadridae
25	Grey Plover	*Pluvialis squatarola*
26	Common Ringed Plover	*Charadrius hiaticula*
27	Little Ringed Plover	*Charadrius dubius*
28	Kentish Plover	*Charadrius alexandrinus*
29	Lesser Sand Plover	*Charadrius mongolus*

Sl. No	Common Name	Scientific name
30	Greater Sand Plover	*Charadrius leschenaultiii*
31	Yellow-wattled Lapwaing	*Vanellus malabaricus*
32	Red-wattled Lapwing	*Vanellus indicus*
		Family : Scolopacidae
33	Pintail Snipe	*Gallinago stenura*
34	Common Snipe	*Gallinago gallinago*
35	Black-tailed Godwit	*Limosa limosa*
36	Bar-tailed Godwit	*Limosa lapponica*
37	Whimbrel	*Numenius phaeopus*
38	Eurasian Curlew	*Numenius arquata*
39	Spotted Redshank	*Tringa erythropus*
40	Common Redshank	*Tringa totanus*
41	Marsh Sandpiper	*Tringa stagnatilis*
42	Common Greenshank	*Tringa nebularia*
43	Green Sandpiper	*Tringa ochropus*
44	Wood Sandpiper	*Tringa glareola*
45	Terek Sandpiper	*Xenus cinereus*
46	Common Sandpiper	*Actitis hypoleucos*
47	Ruddy Turnstone	*Arenaria interpres*
48	Asian Dowitcher	*Limnodromus semipalmatus*
49	Great Knot	*Calidiris tenuirostris*
50	Red Knot	*Calidris canutus*
51	Sanderling	*Calidris alba*
52	Little Stint	*Calidris minuta*
53	Rufous-necked Stint	*Calidris ruficollis*
54	Temminck's Stint	*Calidris temminckii*
55	Long-toed Stint	*Calidris subminuta*
56	Dunlin	*Calidris alpina*
57	Curlew Sandpiper	*Calidris ferruginea*
58	Broad-billed Sandpiper	*Limicola falcinellus*

Sl. No	Common Name	Scientific name
		Family: Recurvirostridae
59	Black-winged Stilt	*Himantopus himantopus*
60	Pied Avocet	*Recurvirostra avosetta*
		Family: Dromadidae
61	Crab-Plover	*Dromas ardeola*
		Family: Burhinidae
62	Stone-Curlew	*Burhinus oedicnemus*
63	Beach Stone-Plover	*Esacus magnirostris*
		Family: Laridae
64	Heuglin's Gull	*Larus heuglini*
65	Palla's Gull	*Larus icthyaetus*
66	Brown-headed Gull	*Larus brunnicephalus*
67	Black-headed Gull	*Larus ridibundua*
68	Gull-billed Tern	*Gelochelidon nilotica*
69	Caspian Tern	*Styerna caspia*
70	River Tern	*Sterna aurantia*
71	Lesser Crested Tern	*Sterna bengalensis*
72	Large Crested Tern	*Sterna bergii*
73	Common Tern	*Sterna hirundo*
74	Little Tern	*Sterna albifrons*
75	Whiskered Tern	*Chlidonias hybridus*

DIVERSITY OF CORAL ASSOCIATED BRACHYURAN CRABS DURING POST MONSOON PERIOD IN GULF OF MANNAR MARINE BIOSPHERE RESERVE

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ABSTRACT

Gulf of Mannar is one of the important biosphere reserves of India. It includes 21 islands, which are classified into three groups, the Mandapam group, Keelakarai group and Tuticorin group. A detailed survey on the diversity of coral reef associated brachyuran crabs was done in all the islands during post monsoon (Jan-Apr), pre monsoon (May-Aug) and monsoon (Sep-Dec) seasons. The coral reefs were associated with the crustaceans in large numbers. Among these the brachyuran crabs plays a vital role in the reef areas as well as in the coral colonies. The selection of the habitat by the crabs depends solely on the basis of the requirements. Obligatory symbiotic crabs act as a bio indicator and generally indicate the health of the coral colonies and the reef status hence the crab diversity was estimated.

The results of the diversity enumerated the status of the coral reef in that particular area. The ecology and the behavior of the crabs were interesting. Crabs associated in both live and dead corals. But some depends only on the live corals and they are obligatory symbiotic in nature. The symbiotic species like *Trapezia* spp. and *Tetralia* spp. seems to occur only in *Acropora* spp. and *Pocillopora* spp. species of corals. Unfortunately very small amount of such crabs are recorded. Mostly the crab diversity was observed to be rich in dead *Pocillopora* colonies than the live. *Chlorodiella nigra* is a Xanthid crabs found abundant in the dead corals. Simultaneously the live corals are also observed for the presence of the crab. Very less number was recorded. The present survey result shows the recent status and diversity of the coral reef associated crabs. The crabs were assessed by Line Intercept Transect (LIT) method. The survey revealed 26 species of crabs from 8 families. The accepted Species of crabs in India is 640. The 1997 survey report on Gulf of Mannar codes 106 species from 15 families.

The wide variation from the earlier works reveals the decline of the coral reef crabs in Gulf of Mannar. This may be due to the exploitation of corals. Various natural and anthropogenic threats have an impact on the coral reef and its associated fauna. In spite of all the legal implications the poverty and the illiteracy of the coastal population tend to degrade the coral reefs and its associated fauna. The widespread perception of coral reef decline has led to increasing demands for documenting patterns of coral reef diversity and ecological processes essential for effective conservation and management.

Key words: *Trapezia. Chlorodiella nigra*, Dead coral, transect.

INTRODUCTION

The Gulf of Mannar is one of the Biosphere Reserves in India having wide biodiversity. It is the only area in the south Indian peninsula where continuous stretches of coral reefs occur near the shore (Mahadevan and Nayar, 1972). Whereas the biosphere reserve has the priority for base line inventories on faunal compilation, information of resources and preservation of genetic diversity through management practices (Jeyabaskaran and Ajmalkhan, 1998).

In India the coastline off shore waters is bounded with three types of reefs i-e Atoll, Fringing and Barrier. Coral reef ecosystem acts as a home for the associated faunal communities comparatively than any other ecosystem in coastal waters. According to Serene (1972) various faunal group including Coelenterates, Ecinoderms, Molluscs were abundant in both living and dead part of the corals. However, majority of the fishes are also associated with the coral reefs (Robert, 1970). A rough estimation of the brachyuran fauna along Indian coast was believed to be 705 species. Serene (1972) declares that 601 species identified for Indian region. Sankarankutty (1967) reported the occurrence of 88 species from both Gulf of Mannar and Palk Bay region. Recently Jeyabaskaran and Ajmalkhan (1998) reported 106 species of brachyuran crabs in the islands of Gulf of Mannar.

The diversity and distribution of brachyuran crabs were found abundant in between the coral branches (Patton, 1994). However the head forming corals provides more shelter than others (Robert, 1970). From the earlier days many works have been done on the taxonomy and ecology of the symbiotic cryptic crabs of coral reef ecosystem (Serene, 1969, 1972; Robert, 1970; Garth, 1973; Edwards and Emberton, 1980; Castro, 1996; Vytopil and Willis, 2001; Thomas *et al,* 2002; Nammalwar and Edwin, 2002). The present study emphasize the recent status of the coral reef associated brachyuran crabs during post monsoon period in Gulf of Mannar Marine Biosphere Reserve.

MATERIALS AND METHODS

Line intercept transact (LIT) method (English *et al.*1997) was adopted to measure the status of coral reef in Gulf of Mannar. LIT used to assess the sterile benthic communities includes coral reefs. Area where the *Pocillopora* coral colonies covered with algae were abundant was selected for LIT. At the selected site 5 numbers of 20m transacts were laid parallel to the island. The distance between each transect was 5m. From the transect area coral colonies with associated brachyuran crabs were randomly selected and covered with polythene bag and brought to the shore. The colonies were gently tapped the coral colony with hammer makes the crabs to come out of the coral branches and they were collected. The collected crabs were preserved in 10% formalin and identified using Alcock, 1895, 1896, 1898, 1899a, 1899b, 1900; Sankarankutty, 1967; Jeyabaskaran *et al* 2000. The diversity, richness and evenness were analysed using various indices with available software. Sex ratio was also studied.

RESULTS AND DISCUSSION

In GoMMBR *Pocillopora* colonies with the associated brachyuran crabs was observed more in twelve islands during post monsoon period and hence the present study was restricted with these selected islands with post monsoon period. Post monsoon and monsoon periods has not favored the brachyuran crab diversity, richness and evenness in the GoMMBR (Prasad and Thampi, 1953). Yoram and Uriel (1982) indicated the species with high-diversity that positively associate with the environmental factors.

Among the 21 islands, the Vaalai and Thalayari Island were considered as a single island, while Poovarasanpatti and Vilanguchalli Islands of Keelakarai and Tuticorin groups, respectively, were eroded completely (Arjan *et al.*, 2002; Thanikachalam and Ramachandran, 2003; Venkataraman, 2003). The transact results emphasized the status of the dead corals covered with algae in all the islands Gulf of Mannar was given in fig1. The present study during post monsoon period observed that the diversity and richness of *Pocillopora* corals associated brachyuran crabs were found maximum in Mandapam group of islands and minimum in Keelakarai and Tuticorin groups.

A total of 26 species of brachyuran crabs was observed during post monsoon period Among these 26 species, the xanthid crabs were found to have more number of species as well as individuals (Gokul and Venkataraman, 2005; Gokul, 2006; Kathirvel and Gokul, 2006). The Xanthid crab seems to have wide diversity in the fringing reefs in lagoonal area (Edwards and Emberton, 1980; Gokul and Venkataraman, 2005).

The present study observed that the Mandapam group recorded high number of *Pocillopora* colonies covered with algae (DCA) with associated brachyuran crabs, followed by Tuticorin and Keelakarai group (Fig.1). However individual estimation shows highest DCA in Shingle Island of Mandapam group and Anaipar Island of Keelakarai group. Similarly, the least DCA was recorded in Vaalai & Thalayari Island in Tuticorin group. It may be due to the location of the island which is far away from the mainland. However, in Mandapam group of Islands various ecological factors like shallowness, siltation etc. has an impact on the coral reefs and its associated fauna. Whereas, the Tuticorin group of Islands has a different underwater texture, which clearly indicates the devoid of coral growth in the lagoonal area. Tuticorin group recorded very least DCA and live coral percentage may be due to the exploitation of the coral reefs (Mahadevan and Nayar, 1972; Gokul, 2006). Xanthid crab *Chlorodiella nigra* found to be abundant in all the selected islands of GoMMBR. The highest number of *C. nigra* was recorded in Mandapam group (194 individuals) and the least (10) in Tuticorin group of Islands (Fig:2). Similarly the *Leptodius exaratus* and *Leptodius euglyptus* are the other xanthid crabs observed to have wide diversity in the biosphere reserve. Moderate distribution of crabs observed in the Keelakarai group of Islands. Among all the brachyuran crabs, these three species occur commonly and highly associated with *Pocillopora* corals covered with algae.

The Shannon and Weaver index for species diversity, Simpson index for richness and Pielou evenness index were hardly affected by sample size and usually have low variances (Trojan and Wytwer, 1997). Both the Shannon and Weaver and Simpson indices were widely used in faunistic research (Trojan, 2000).

However, during post monsoon period the maximum diversity was recorded at Krusadai Island and minimum at Anaipar Island. Similarly, maximum richness was observed at Shingle, Krusadai, Poomarichan, Pullivasal, Manauli Putti, Hare and Upputhanni Islands and minimum at Mulli, Appa, Anaipar and Nallathanni Islands. Comparatively, maximum evenness was recorded at Anaipar Island and minimum at Mulli and Vaalai and Thalayari Islands (Fig.2).

Habitat area, productivity, disturbance level and intensity of species interactions has an impact on the species richness of a particular area (Cornell and Karlson, 2000; Husein *et al.*, 2003). Based on the results obtained from the present study, it could be concluded that the diversity, richness and evenness during post monsoon period may be due to less disturbances in the coral reef areas. Husein *et al.*, (2003) also agreed that the crab diversity was constant with higher abundance was observed on the undisturbed ecosystems.

Diversity and richness of the species were observed to be low in both the Keelakarai and Tuticorin group of islands. Disturbed reefs could directly affect the community structure of the associated brachyuran crabs. However, depth also acts as a factor for species richness, evenness (Cornell and Karlson, 2000) and diversity (Tsai, 1999) of brachyuran crabs. Faunal richness is generally low on the shallow reef flats that are relatively close to the shore (Cornell and Karlson, 2000). Overall observations indicated that the healthy brachyuran diversity, abundance, richness and evenness were found among the Mandapam group of islands. According to Neves *et al.* (2003), high species diversity and richness indicated lesser degree of threats. However, according to Reed *et al.* (1982) the increased siltation accelerates the richness of associated species in the dead *Pocillopora* colonies. Studies on the species richness of brachyuran crabs were limited and a detailed study may declare a clear idea about the facts behind the correlation of species diversity, richness and evenness in the GoMMBR.

Sex grouping results shows the occurrence of equal male and female ratio (fig.3) during post monsoon period. Very minimal number (less than 5) of berried and young ones was recorded during the present study. The equal distribution of male and female ratio indicated that the brachyuran crab depend coral host mainly for breeding. The increase in female reflected the influence of female biased sex in coral crabs (Mayumi and Akira, 1994). However, Prasad and Thampi (1953); Sukumaran and Neelakantan (1997, 1998) observed the maximum breeding activity of the coral crabs during post monsoon period. Hence, the accumulation of females in the *Pocillopora* coral covered with algae during post-monsoon period indicated that it might be the breeding season for the coral crabs. The host selection by the brachyuran crabs is interesting. Generally, the reef habitats and the depth determine the availability of the associates (Tsai, 1999).

According to Thomas *et al.* (2002) the diversity density and relative abundance of coral crabs depend entirely on the fluctuating environmental factors. Regular and long term monitoring the coral reef would improve the status in the reserve area. However, the study declares the brachyuran faunal associates are comparatively more in the dense branched dead coral covered with algae. Hence preference should also give to the corals covered with algae as they are serving as a separate ecosystem. However the present study forms a baseline for the dead coral associated brachyuran crabs and further steps needed to study ecology and biology of these brachyurans.

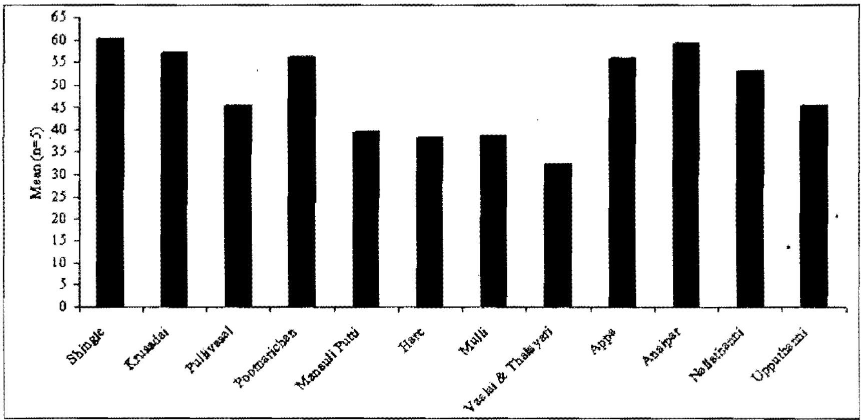

Fig:1 Percentage of Dead Coral with Algae in Gulf of Mannar group of Islands

	A	B	C	D	E	F	G	H	I	J	K	L
No. of Species	8	11	5	10	10	7	5	7	3	5	5	2
No. of individuals	123	140	61	96	174	142	175	92	39	43	32	34
Shannon- Wiener's Diversity (H) (max. 3.0)	2.3	2.4	2.1	2.3	2.0	2.2	1.2	1.4	1.1	0.9	1.1	1.8
Simpson's index for species richness (D) (max.1)	0.7	0.7	0.7	0.7	0.7	0.7	0.4	0.5	0.4	0.4	0.4	0.7
Pielou's Evenness (J) (max. 1.0)	0.8	0.7	0.8	0.7	0.8	0.8	0.6	0.6	0.7	0.9	0.7	0.8

A-Shingle; B-Krusadai; C-Pullivasal; D-Poomarichan; E-Manauli Putti; F- Hare; G-Mulli; H- Vaalai&Thalayari; I- Appa; J- Anaipar; K-Nallathanni; L-Upputhanni.

Fig: 2 Diversity, Richness and Evenness of coral crabs in GoMMBR

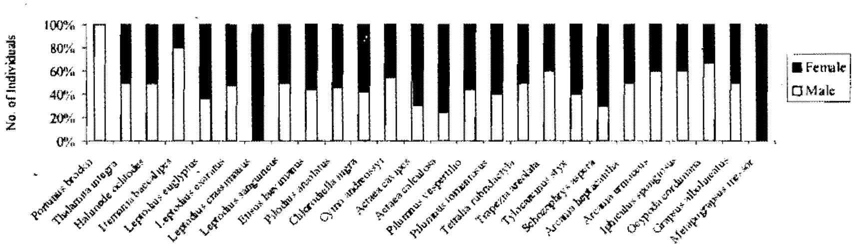

Fig: 3 Sex ratio of coral crabs in Gulf of Mannar during Post monsoon period

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MARINE SPONGES IN THE GULF OF MANNAR AND THEIR ENDEMICITY

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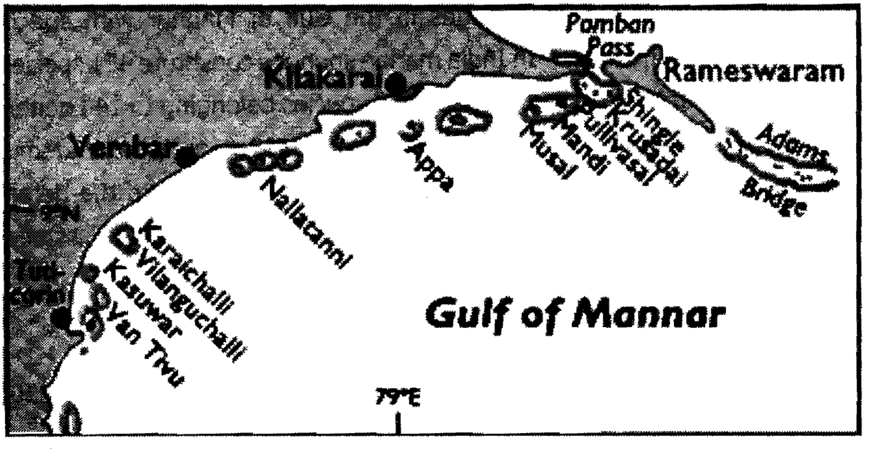
ABSTRACT

Marine sponges are one of the better known groups of invertebrates which are of great economical and biomedical importance. There are about 20,000 marine sponges world over. The present paper deals with the presence and distribution of marine sponges in the Gulf of Mannar with special reference to the endemics. In India marine sponges constitute 451 species. From the Gulf of Mannar and Palk Bay 350 species belonging to 144 genera are recoded of which 257 species belonging to 113 genera are endemic. The fauna is over-exploited and their habitats threatened and the details provided in this paper will form a base line data for biodiversity assessment and conservation measures.

INTRODUCTION

The Gulf of Mannar Biosphere Reserve covers an area of 10,500 km^2 of ocean, islands and the adjoining coastline on the south-east coast of India across Sri Lanka. The islets and coastal buffer zone includes beaches, estuaries, and tropical dry broadleaf forests, while the marine environments include seaweed communities, sea grass communities, coral reefs, sponges salt marshes and mangrove forests.

It is one of the world's richest regions from a marine biodiversity perspective. The biosphere reserve comprises 21 islands between 8^{o} 46' and 9^{o} 14' N latitude and 78^{o} 9' and 79 ^{o} 14' E longitudes. Each island has its unique characteristics, surrounded by coral reefs with rich faunal and floral diversity. Among the Gulf's 3,600 plant and animal species are the globally endangered sea cow (Dugong dugon) and six mangrove species endemic to peninsular India. (Patterson et.al. 2004). It is equally rich in sea-algae, sea grasses, coral reef pearl banks, fin & shell fish resources, mangroves, and endemic & endangered species. Sponges, although at casual glance look like plants, are animals, living singly or in colonies of many individuals. Their colours vary as much as their shape, being green, red, yellow, and even black or white. In the crevices, these sponges are found with many animals, ranging from tiny crabs and brittle star to bivalve mollusks. There are 486 species described in India. The coastal areas in the Gulf of Mannar and Palk -Bay provide asylum to 321 species under 129 genera and is described here.These include 131 species (26.95%) and 63 genera (41.85%) endemic to Gulf of Mannar region. The higher classification of sponges used here follows Hooper and Wiedenmayer (1994).



Classification: The sponge fauna of India is dominated by species of Demospongiae followed by those of Hyalospongiae and Calcispongiae as follows:

Phylum: Porifera

Class: Demospongiae,

Calcaria or Calcispongiae

Hyalospongiae or Hexactinella or Glass sponges

Sclerospongiae

Diversity of Sponges in World

Class	World species
Calcispongiae	47
Demospongiae	4000
Hyalospongiae	500
Sclerospongiae	15
Total	**4562**

Diversity of Sponges in India (Thomas, 1985)

Class	Area	Sponge species
Demospongiae	Gulf of Mannar	275 species
	Gulf of Kachch	32 species
	Andaman and Nicobar	144 species
	Lakshadweep	91 species
	Total	**428 species**

Diversity of Sponges reported from India (Pattanayak, 2001)

Class	Area	Sponge species
Demospongiae	Gulf of Mannar	319
	Arabian sea offshore	50
	Laccadives	82
	Karnataka& Kerala	10
	Andhrapradesh& Orissa	35
	Andamans	83
	Nicobars	12
	Bay of Bengal	12
	Total	451 species

Diversity of Boring sponges of Indian seas

Area	Sponge species
Gulf of Mannar	20
Andaman & Nicobar	5
Lakshadweep	18
Total	**32**

List of Sponges

Species which are abundant in the different areas in Gulf of Mannar

Rameswaram Area : *Callyspongia ssp., Dysidea fragilis* (Montagu), *Ircinia fusca* (Carter), *Fasciospongia cavernosa* (Schmidt), *Dendrilla nigra* (Dendy), *Haliclona tenuiramosa* (Burton), *Sigmadocia fibulata* (Schmidt), *Tedania anhelans* (Lieberkuhn), *Clathria frondifera* (Bowerbank), *Biemna fortis* (Topsent), *Spirastrella inconstans* (Dendy), *Aurora globostellata* (Carter).

Tuticorin Area: *Petrosia testudinaria* (Lamarck), *Clathria frondifera* (Bowerbank), *Axinella donnani* (Bowerbank), *Spirastrella inconstans* (Dendy).q

Endemic Marine sponges of Gulf of Mannar

Area	Genera	Species
Gulf of Mannar	144	350
Do-	113	257

(Please insert table here)

Drugs from sponges:

Marine sponges fascinate scientists from different disciplines that vary from chemical ecology, physiology and morphology to isolation of bioactive compounds and association with a wide variety of marine microorganisms in their tissues. Marine sponges have come to lime light in 1950's with the discovery of arabinose nucleosides (Bergmann and Feeney,

1951) from the sponge, *Tethya cripta* with biomedical properties. Anti HIV and cytotoxic from *Dysidea Sp.* More than 12,000 compounds have been isolated from marine sources with hundreds of new compounds still being discovered every year in the respect to the diversity of their secondary metabolites. Some of the sponge derived bioactive compounds and immunomodultors presently available in the market are Ara- A (antiviral) Ara-c (anticancer) IPL 512602 (anti-inflammatory) KRN 7000 (anticancer) are under clinical trial.

Sponges produce toxins and other compounds, for communication, to repel and deter predators (Uriz et al, 1996a), compete for space with other sessile species and protection against infection. Marine sponges distributed in eight different families are reported to have toxic properties. The species with toxic properties are primarily distributed in the warm waters of the Caribbean but others are known from the North Atlantic Ocean of North America and Europe, the Pacific Ocean of California, Mexico, and Australia. However, other potentially dangerous sponges may be located elsewhere. Reported responses associated with these sponges involve an almost immediate skin irritation and contact dermatitis similar to that observed following contact with poison ivy. Initial symptoms usually include redness at the contact area followed by stiffness in the finger joints (if handled) and localized swelling. Blisters often develop within a few hours. Using a small part of the suspect sponge on an unaffected body part can make diagnosis, although such testing usually is unnecessary. Treatment of the wounds with antiseptic lotions or dilute acetic acid (vinegar) will help ease the itching and burning.

Some sponges seem to produce potentially useful anti-fouling agents (Armstrong et al, 1999) Sponges often have associated symbiotic microbial populations (Lee et al, 2001) symbionts include bacteria, cyanobacteria, microalgae and fungi (Holler et al, 2000). In some cases, these microorganisms and not sponge cells are the source of the secondary metabolites. Thus sponges produce metabolites of potential commercial value

e.g *Dysidea herbacea.*

Culture and Sustainable use of Sponges

Producing many of these metabolites would require large quantities of sponge biomass that cannot be harvested from natural populations. Production of cultivated sponge biomass is feasible. Culture of sponge cells can become a future source of metabolites (Bakus et al. 1986) since they have a myriad of activities ranging from antibiotic activity including anti-coagulant, antithrombin, and anti-inflammatory as well as immunomodulatory activities. With the enormous potential for discovery, development and marketing of novel marine bioproducts comes the need to develop methods by which these products can be supplied in a way that will not disrupt the ecosystem or deplete the resource. With the enormous potential for discovery, development and marketing of novel marine bioproducts comes the need to develop methods by which these products can be supplied in a way that will not disrupt the ecosystem or deplete the resource. Supply of most marine derived compounds is a major limiting factor for pharmaceutical development. There is a long history of sponge aquaculture research but until recently; all efforts in this direction were concentrated with bath sponge production. Most recent reports showed that the sponge aquaculture could be an alternative approach for the production of bioactive metabolites. States like Kerala, Tamil Nadu, Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Orissa, and West Bengal are keen on promoting marine biotechnology in their respective states.

Exploitation of sponges from natural resources in bulk is an important issue. To overcome this problem for sustainable use of marine resource the following is suggested.

1. Chemical synthesis
2. Cultivation of sponges in the sea (Mariculture)
3. Growth of sponge specimens in bioreactors.
4. Cultivation of sponge cells in vitro.
5. Conservational aspects of source organisms.

6. Eco friendly collection of the source organisms and required supply of them in bulk for Scaling up process.

Threat of Marine sponges:

The major threats to sponges can be grouped under the following headings.

- Water pollution
- Sedimentation
- Human impact
- Natural disasters
- Disease

Water pollution: The two main sources of marine pollution are oil pollution from oil spills, oil drilling and water pollution have been identified as one of the primary causes of sponge degradation. Pollution comes from a variety of sources and is often hard to trace to one particular source. Oil, gas, and pesticides are poisons to the marine and sponge life. Water pollution comes from humans, animal waste and/or fertilizers that are dumped directly into the ocean or river systems. Hence, there are increased amounts of nitrogen and phosphorus that are added to the ecosystem. As a result an alga grows out of control and the sponge is smothered because the sunlight is cut off.

Sedimentation: It tends to have similar effects as water pollution. Sedimentation is a result of construction and deforestation along costs and inshore construction, mining, logging and farming. All these processes lead to erosion, which results in sediment overloading in ocean ecosystems. The sedimentation blankets sponge and actually smothers the coral because it deprives the corals of sunlight for photosynthesis. Some natural marine ecosystems include mangrove trees and sea grass beds. These are vital aspects of the marine ecosystem because the trees and grasses act as filters for sediment. Unfortunately these natural filters are being destroyed at alarming rates as well, which has lead to an increase in the amount of sediment that reaches the sponge resources.

Human impact: Sponges are particularly susceptible to human activities because most sponges occur in shallow waters that are near shores where human impacts are the greatest. Human impacts such as population stress, increased sediment load, shipping, development along shorelines, over-fishing, habitat destruction, pollution, careless tourism, and ocean warming and bleaching have dramatic negative impacts on the coral reefs. Human damage has a more significant effect on the sponge ecosystem and it can take a much longer time for the ecosystem to recover. Pollution especially siltation from land-based construction, and fertilizer runoff have lead to sponge destruction worldwide. The sedimentation clouds the water and blocks the sunlight required for photosynthesis by the symbiotic algae.

Human practices such as the use of dynamite or poison capture have lead to over-fishing as well as enormous damage to the sponge ecosystem.

Natural disasters

Natural disasters such as hurricanes and earthquakes have significant effects on the coral reef ecosystem however the damage is considered a natural cycle of the ecosystem. Global warming increases sea temperatures and therefore puts the delicate symbiotic relationship in jeopardy.

Diseases

In Andaman & Nicobar Islands parasites cause white band disease (WBD) in coral-boring sponges and bivalves (Dorairaj, 1998).

Conclusion

This review highlights the biodiversity and the biotechnological significance of marine sponges which comprise species diversity, their chemistry, microbiology, cell biology and molecular biology.

Efforts of marine natural product researchers to tap the fascinating chemical diversity in sponges have explored novel potential drugs. The success of this classical approach is highlighted by the leading position of sponge-originated compounds that are already in the market or in the stages of clinical trials. Cell biology provides us with new perspectives on the ecology

and biology of the cells, leading to the cultivation of sponges and ultimately to a sustainable use of marine resources. With the advanced molecular biological tools, target-oriented screens have become available that will accelerate the quest for new sponge-derived drugs. This review impressively illustrates the power of interdisciplinary approaches in the exploration of biotechnological implications of marine
Organisms.

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MORPHOMETRY OF CORAL REEFS IN SHINGLE ISLAND, GULF OF MANNAR MARINE NATIONAL PARK

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Abstract:

Shingle Island is the northern most island of the Gulf of Mannar. Land area covers 12.69 ha with a circumference of 1736 m. The island is covered with shrubs. Fringing reefs are distributed along the south and northeast of the island. Large amount of coral rubble is seen on the northeastern and southeastern parts of the shore. *Montipora digitata* forms a large part of the rubble. Species such as *Porites spp., Montipora digitata, Montipora aequituberculata, Pocillopora damicornis and Acropora spp.* are found on the island. Patchy distribution of boulder (massive) corals is observed on the northern side. Diversity of live coral is maximum at the northeastern corner. Parrotfish are commonly found along the southeastern and northeastern parts of the island. The fishing boat channel is present near the northeastern reef, less than 80 m from the shore. There is no fishing activity observed on this island. Seaweeds such as *Turbinaria spp.*, *Hydroclathrus sp.* and *Sargasum spp.* are found in north and south side of the island. Reef associated organisms such as *Holothuria atra,* seaurchin (*Diademma spp.*), sea anemone are commonly found in the northeastern reefs.

Shingle Island:

This island is the northern most island of the Gulf of Mannar. The land area covers 12.69 ha with a circumference of 1,736 m. This island is covered with shrubs (Venkataraman *et al.*, 2004). Fringing reefs are distributed along the south and northeast part of the island. Patchy distribution of boulder corals (massive) is also found along the Northern side.

Methodology: Morphometry of the reef was studied in the month of December 2002 by using the methodology of Pillai (1969). A 500 metre nylon rope was fixed with floats at five meter interval (Fig. 1). The transect was laid perpendicular to the island from the shore to the reef crest (outer reef edge). Transects were restricted up to 500 m depending on the proximity of the reef crest. The study was focused on shallow reefs. GPS readings were noted at the shore where the rope starts. A sq.m of the reef was sampled at 5 m interval. The data includes horizontal distance between the low and high tide level, depth, nature of the bottom (sand/muddy), flora (seagrass, seaweed etc.,), coral fauna and associated organisms (sponges, soft corals etc.,).

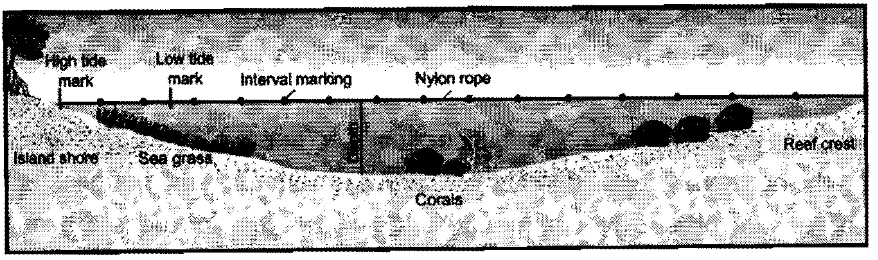

Fig.1. Schematic representation of the morphometry of a reef

Morphometry of the Shingle Island: Fringing reefs are distributed along the south and northeast of the island (Fig.2). The horizontal distance between low and high tide level was around 8 m. Large amount of coral rubble was seen on the northeastern and southeastern shores of the island. *Montipora digitata* forms a large part of the rubble. Species such as *Porites spp., Montipora digitata, Montipora aequituberculata, Pocillopora damicornis and Acropora spp.* were also found on the island. Patchy distribution of boulder (massive) corals was observed on the northern part. Diversity of live coral was maximum at the northeastern corner. Parrotfish were commonly found at the southeastern and northeastern parts of the island. A fishing boat channel is present near the northeastern reef, less than 80 m from the shore. There was no fishing activity observed on this island. Seaweeds such as *Turbinaria spp., Hydroclathrus sp.* and *Sargasum spp.* were found in northern and southern side of the island. Reef associated organisms such as *Holothuria atra*, seaurchin (*Diademma spp.*), sea anemone were commonly found in the northeastern reef.

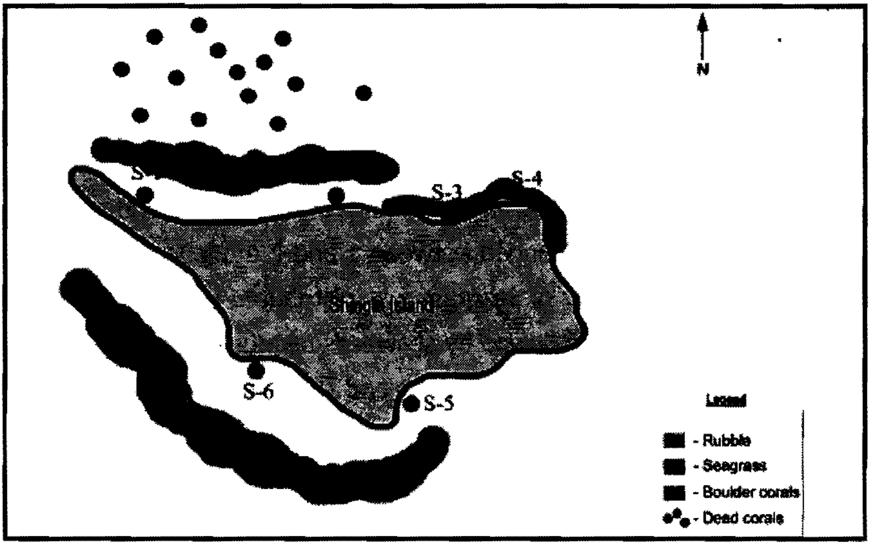

Fig. 2. Diagram of Shingle Island and its features

S-1: Transect was laid from the northwestern shore (9°14'623" N; 79°13'962" E) (Fig.3). The horizontal distance between the low and high tide level was 8 m. The depth ranged between 1 and 2 m along the transect. The transect showed rubble between 5-10 m, 50-60 m and 75-105 m. Seagrass, *Enhalus* sp. was distributed between 15-35 m. Seaweeds were distributed between 70-75 m. Massive forms such as *Porites* and *Goniastrea* were present between 60-70 m. Dead corals composing of *Montipora* sp. occurred between 45-50 m along the transect.

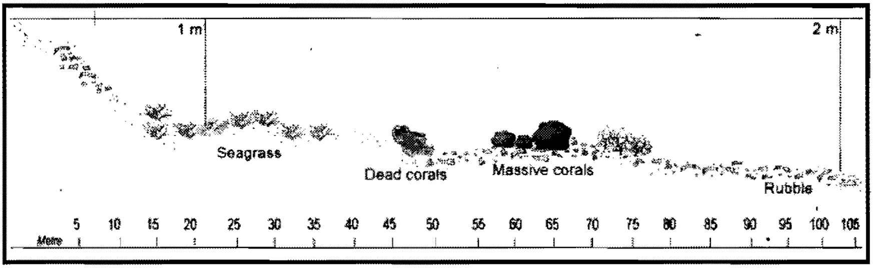

Fig.3. Diagram of bottom communities at northwestern reef

S-2: Transect was laid on the northern part of the island (9°14'596" N; 79°14' 860" E) (Fig. 4). Horizontal distance between the low and high tide level was 8 m. The depth ranged between 1 and 2 m along the transect. Bottom communities such as Seagrass was distributed between 5-20 and 55-60 m of the transect, followed by seaweeds distributed between 20-25 m. Rubble was present between 25–45 m and 75-90 m. Sand was observed in between 45-55 m and 60-75 m.

Few massive colonies of *Porites* spp. occurred between 90-95 m, followed by rubble to few metres. Massive colonies of *Porites* and *Goniastrea* were found between 100-105 m.

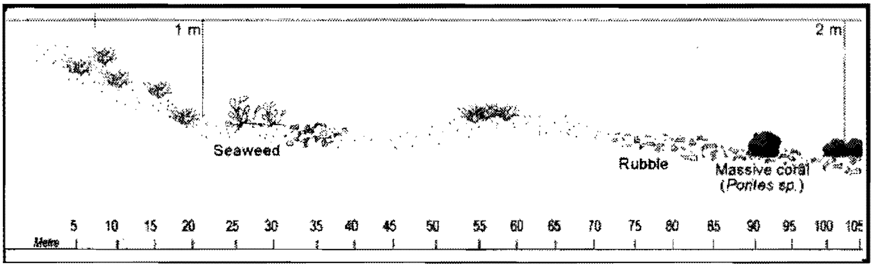

Fig.4. Diagram of bottom communities at northern reef

S-3: Transect was laid from the northeastern shore (9°14'510" N; 79°13'945" E) (Fig. 5). The distance between the low and high tide level was 9 m. The depth along the transect ranged between 1-3.8 feet. Rubble was present between 0-25 m and 30-35 m. Seaweeds were distributed between 35-45 m. Branching form such as *M.digitata* was distributed between 45-55 m, 85-90 m and 95-100 m. Dead corals occurred from 75 to 85m and 100 to 105 m. A single species of *A. cytherea* was found in the reef crest. Massive form, *Porites* was distributed between 90-95m, sandy bottom was seen between 25-30 m and 55-75 m of the transect.

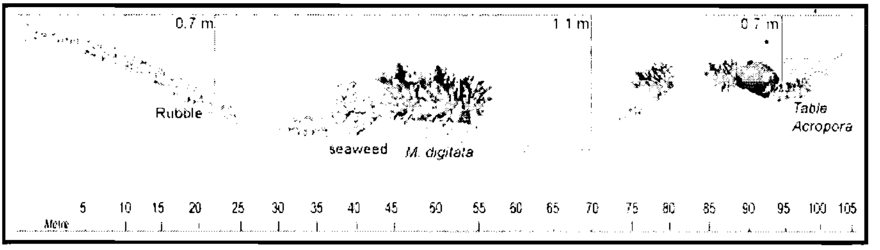

Fig.5. Diagram of bottom communities at northeastern reef

S-4: Transect was laid from the northeastern shore (9°14'599" N; 79°13'292" E) (Fig. 6). The horizontal distance between the low and high tide level was 10 m. Along the transect, the depth ranged between 1.5-3 feet. In the transect, 0-10 m was occupied by rubble. Sandy bottom was found between 10-12 m. Live coral such as, *P. damicornis, M. aequituberculata, M. digitata* and *A. formosa* along with few dead corals were distributed between 12-35 m. Dead corals comprising of *Porites* and *Montipora sps.* along with algae were distributed between 35-60 m.

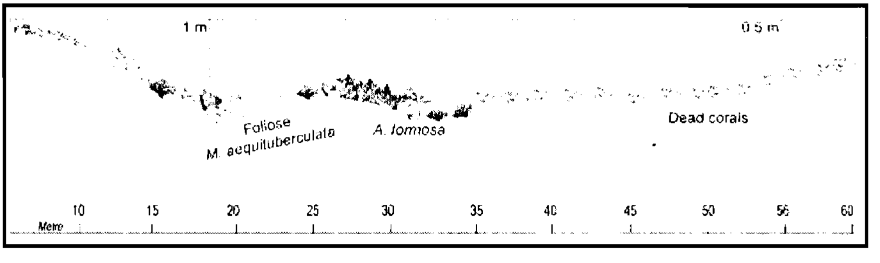

Fig.6. Diagram of bottom communities at northeastern reef

S-5: Transect was laid from the southern side shore (9°14' 540 N; 79°13' 310 E) (Fig. 7). The horizontal distance between the low and high tide level was 7 m. Along the transect, the depth ranged between 1-3.5 feet. The distance between 0-25 m and 45-55 m was occupied by sand and dead corals composed of *M.digitata* and *Porites* spp. Few dead *Acropora* and live *M. digitata* were distributed between 25-45 m and 55-80 m of the transect.

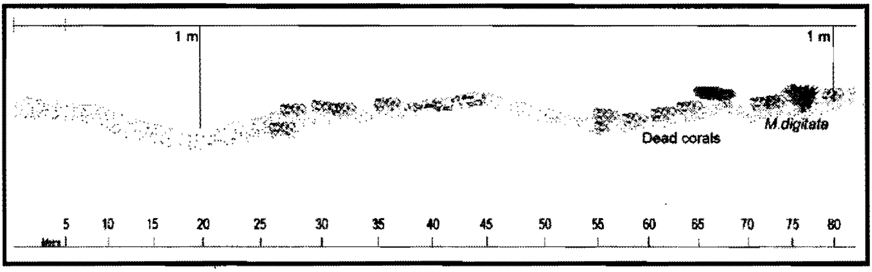

Fig.7. Diagram of bottom communities at southern reef

S-6: Transect was laid from the shore of southwestern side (9°14'599" N; 79°13'345" E) (Fig. 8). The horizontal distance between the low and high tide level was 5 m. Along the transect, the depth ranged between 1.0-3.5 feet. Sandy bottom occurred between 0-30 and 55-60 m of the transect line. Dead corals with algae was distributed between 30-55 m and 60-65 m. Major composition of the dead coral was *Montipora* spp. particularly of *M.digitata*. Also a few dead *Acropora* tabular forms were seen. Small colonies of live *M. digitata* had rejuvenated between the dead corals. Rubble was present between 65-75 m.

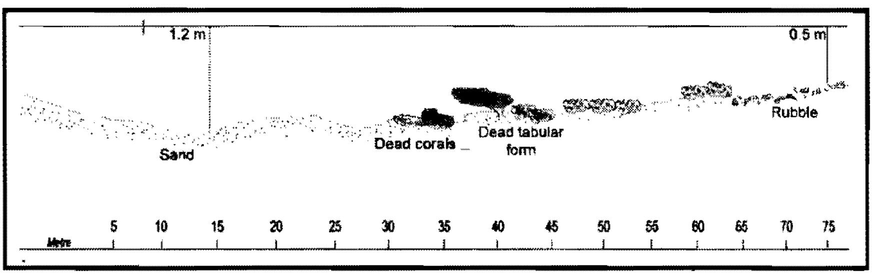

Fig.8. Diagram of bottom communities at southwestern reef

Hard corals recorded:

There were 17 sps of hard corals (Scleractinia) recorded in the present study. The recorded species are *Pocillopora damicornis, Montipora digitata, Montipora aequituberculata, Acropora formosa, Acropora millepora, Acropora cytherea, Acropora humilis, Acropora samoensis, Acropora hyacinthus, Porites solida, Porites lutea, Stylaraea punctata, Goniastrea retiformis, Leptastrea transversa, Cyphastrea micropthalma, Cyphastrea serailia,* and *Echinopora lamellosa.*

Discussion:

Morphometry of the reefs showed a general profile of the bottom communities. The morphometry studies on the Shingle Island showed 43% of live corals in the northeastern part and 24% in the southern part. The patchy distribution and poor growth of corals in the island indicated that the ecological factors are not very congenial for a luxuriant growth of corals. Sedimentation is one of the major factors, which determines coral growth. Geister (1977) and Barnes (1973) have stated that the shape of reef corals is affected by light levels and by wave stress leading to the well known zonation of coral form associations with exposure and depth. Similarly, coral calcification rate which is of importance both to coral form and to net reef growth, is light dependent and may be affected by other factors such as wave stress and sediment flux (Chappell, 1980). Gardiner (1931) has pointed out that the Indian Ocean reefs are shallow flats with not more than a few inches of water over them. In the present study, reef crests were mostly occupied by massive, branching and dead corals. However massive *Porites* and *Goniastrea* dominate the reef. Presence of the branching forms in the reef crests may be due to the availability of substratum for growth in between the massive corals. Similar pattern of the reef was reported from the Palk Bay (Pillai, 1969).

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FLOWERING PLANT SPECIES IN ISLANDS OF THE GULF OF MANNAR

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The Gulf of Mannar is well-known as "Biologists Paradise" for its biodiversity, endowed with a rich variety of about 3,600 marine organisms. However, there are only limited works available on flowering plants in the Islands of Gulf of Mannar, the first Marine Biosphere Reserve in the whole of South and Southeast Asia.

None of the early work focused specifically on the flowering plants. The earliest work is of Iyengar (1927) who, while studying algae, recorded the presence of angiosperms in two Islands of the Gulf of Mannar namely Krusadai and Shingle Islands. Similarly while studying fauna of Krusadai Island, Chacko et al., (1955) enumerated the angiosperms.

Almost all these works concentrated mainly on the flora of Krusadai Islands. Srinivasan (1960) described the vegetation of Van Island. Rao et al., (1963a, b) studied the ecology of coastal flora in Pamban, Rameswaram and Krusadai Islands. Sundararaj and Nagarajan (1964; 1966) enumerated the flora in three Islands namely Van and Hare and Krusadai Islands. Lakshmanan et al., (1984) studied the mangrove and seagrass ecosystems of Krusadai and Rameswaram Islands. Ramachandran and Balasubramaniyan (1991) explored coastal flora of Ramanathapuram district including Krusadai Island.

Thanks to the efforts of Daniel and Umamaheswari (1997) from Botanical Survey of India, who conducted a comprehensive survey of flora from Dhanushkodi to Kanyakumari and also in the 19 Islands of the Gulf of Mannar. They conducted a total of 13 field trips resulting in a collection of about 9,750 specimens. Kathiresan and Rajendran (1998) have recorded the occurrence of 7 mangrove species in the Gulf of Mannar Islands.

The floral specimens for the Islands are available at various herbaria such as the Central National Herbarium, Botanical survey of India, Howrah (CAL), Herbarium of the Botanical Survey of India, Southern Circle, Coimbatore (MH), that of the Presidency College, Madras (PCM), the Rapinat Herbarium, St.Joseph's College, Tiruchirapalli (RHT) as well as the herbaria of the Bharathiyar University, Coimbatore, Kongunadu Arts & Science college, Coimbatore and Centre of Advanced Study in Marine Biology (Annamalai University), Parangipettai.

The present study is a compilation based on the angiosperm species so far recorded in the Islands of Gulf of Mannar areas, by various workers, as well our field observations.

The occurrence and distribution of angiosperms and this in relation to extent area of Islands are shown in Tables 1 and 2 respectively. There are totally 219 species in the 19 Islands stretching from Mandapam to Tuticorin to a distance of 140 km along the coast. The number of species ranges from 18 to 89. Krusadai Island has the highest number of species and Monoliputti Island the least.

There are totally 219 species in 623 hectares - the total area of 19 Islands- at a rate of that each species is distributed at 0.35 ha area of the Islands. There is a significant correlation between the extent area of Islands and number of floral species present there (Fig.1). For example, Monoliputti is the smallest Island with an area of 2.34 ha, colonized with a minimum number of 18 species that is 8.2% of total. Krusadai Island with an area of 65.8 ha is the richest one with 40.6% of total species in the Gulf of Mannar (Table 2). Other Islands with high area also exhibit higher species diversity. For example, Muyal Island with 129 ha and Nallathanni Island with 101 ha have 74 species each (Table 2). However, Pumerichan Island has higher number of species (67), but less area of 16.58 ha. This may be attributed to its connection with species-rich Krusadai Island by shallow waters during low tides.

The extent of area of an Island alone is not the factor that determines the species diversity, but their ecological and environmental conditions prevailing there. For instance, Krusadai Island is rich in floral diversity due to the presence of different habitats such as foreshore sandy, inland sandy, salt marsh, mangrove, sand dune, and maritime habitats. Other Islands that are rich in species are Muyal and Nallathanni Islands, perhaps due to larger areas of those Islands. Pullivasal Island harbours good vegetation due to seagrass growth and this Island is well protected from wave action by dense growth of *Pemphis acidula* in most places. Monoli Islands are bestowed with luxuriant marshy places, whereas Valai, Shingle, Mullai and Monliputti Islands are poor in vegetation due to their sandy and calcareous soil.

Frequency of occurrence of individual floral species in Islands is also shown in Table 3. This exhibits 24 dominant species that occur in more than 50% of 19 Islands in the Gulf of Mannar.

Representative number of species in different botanical families is shown in Table 4. There are 70 families represented with a total of 219 species. Among them, only five families namely Poaceae, Cyperaceae, Fabaceae Euphorbiaceae and Asteraceae are dominant with respective representation of 22.5, 22.5, 16.9, 16.9 and 14 % of total species.

It is inferred from this study that the 19 Islands of the Gulf of Mannar are colonized with 219 angiosperms belonging to 70 families. The Krusadai is the richest in floral diversity with 89 species. The species diversity correlates with area extent of the Islands and ecological and environmental conditions that prevail in those Islands. There are 24 dominant species colonizing 53 to 90% of 19 Islands. Five families are dominant and they are Poaceae, Cyperaceae, Fabaceae Euphorbiaceae and Asteraceae, represented with with 14-23% of total species.

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Table 1 **Occurrence and distribution of floral species in the Islands of the Gulf of Mannar**

No.	Name of species	Island No.																			Frequency of occurence
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1	*Abrus precatorius*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
2	*Acacia norrida*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	1
3	*Acalypha indica*	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	2
4	*Acacia planifrons*	-	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-	+	9
5	*Achyranthes aspera*	-	-	-	-	-	+	+	-	+	-	+	-	-	+	-	+	-	-	-	6
6	*Aegiceras corniculatum*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
7	*Aeluropus logopoides*	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	2
8	*Aerva lanata*	-	+	-	+	-	-	+	-	+	+	+	-	+	+	-	-	-	-	+	9
9	*Aerva persica*	-	+	+	-	-	+	+	-	-	+	+	+	+	+	+	+	+	-	-	12
10	*Aloe vera*	-	+	+	-	-	-	-	-	-	-	+	+	+	-	-	+	+	-	+	8
11	*Alysicarpus rugosus*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	1
12	*Amaranthus polygamus*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
13	*Ammannia baccifera*	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-	3
14	*Anisomeles malabarica*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1
15	*Apluda mutica*	-	-	-	+	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	4
16	*Acrachne henrardiana*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
17	*Arthrocnemon glaucum*	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	+	-	+	+	5
18	*Asparagus racemosus*	+	+	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	6
19	*Asystasia gangetica*	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	-	3
20	*Atalantia racemosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	2
21	*Atriplex repens*	+	+	+	+	-	+	-	+	-	+	-	-	+	+	-	-	+	+	+	12
22	*Avicennia marina*	+	+	-	+	+	+	+	-	+	+	-	-	-	-	-	+	-	+	-	10
23	*Azadirachta indica*	-	-	-	+	-	-	+	-	-	-	-	-	-	+	+	+	-	-	-	5
24	*Azima tetracantha*	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3

No.	Name of species	Island No.																			Frequency of occurence
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
25	*Blumea obliqua*	+	-	-	-	-	+	+	-	-	+	-	-	-	-	-	-	+	-	-	5
26	*Boerhavia diffusa*	-	-	-	-	-	-	+	-	-	-	+	+	+	+	+	-	-	-	-	6
27	*Boerhavia erecta*	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	1
28	*Borassus flabellifer*	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	2
29	*Brachiaria ramosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
30	*Breynia vitis-idaea*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
31	*Bruguiera cylindrical*	-	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	3
32	*Bulbostylis barbata*	-	+	+	-	-	-	+	-	-	-	+	+	-	+	-	+	-	+	+	9
33	*Cadaba fruticosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	1
34	*Caesalpinia bonduc*	-	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	4
35	*Calotropis gigantea*	+	+	-	+	-	-	+	-	-	-	+	-	-	+	-	+	-	-	-	7
36	*Canavalia rosea*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
37	*Caralluma adscendens*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	1
38	*Cardiospermum canescens*	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	-	-	3
39	*Capparis sepiaria*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
40	*Capparis zeylanica*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1
41	*Cassia auriculata*	-	-	+	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	3
42	*Cassia italica*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	1
43	*Cassia senna*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1
44	*Cassytha filiformis*	+	+	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	5
45	*Cayratia trifolia*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	1
46	*Cenchrus ciliaris*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	2
47	*Ceriops tagal*	-	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	3
48	*Chloris barbata*	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	2
49	*Cissampelos pareira*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	1
50	*Cissus quadrangularis*	-	-	-	+	-	+	+	-	-	-	+	+	-	+	+	-	+	-	+	9
51	*Citrullus colocynthis*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
52	*Cleome viscosa*	-	-	+	-	-	-	-	-	-	+	-	-	+	+	-	-	+	-	-	5
53	*Clerodendrum inerme*	+	-	-	+	+	+	+	+	+	+	-	-	+	+	+	+	-	-	+	13
54	*Clitoria ternatea*	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
55	*Coccinia grandis*	-	+	-	+	-	+	+	-	-	+	+	+	+	+	+	+	-	-	-	11
56	*Cocculus hirsutus*	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	2

No.	Name of species	Island No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Frequency of occurence
57	*Colubrina asiatica*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
58	*Commelina benghalensis*	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	2
59	*Commelina paleata*	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
60	*Corchorus aestuans*	-	-	-	+	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-	4
61	*Corchorus fascicularis*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
62	*Cordia obliqua*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1
63	*Cordia subcordata*	+	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	5
64	*Crinum defixum*	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	2
65	*Crotalaria medicaginea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	1
66	*Crotalaria retusa*	-	+	+	-	+	-	-	+	+	+	-	+	-	+	-	-	+	+	+	11
67	*Croton bonplandianus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	1
68	*Cucumis melo*	-	+	-	+	-	+	+	-	-	-	-	-	-	+	-	-	+	-	-	6
69	*Cyanotis cristata*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
70	*Cymbopogon caesius*	-	+	+	+	-	+	-	-	+	-	+	+	+	-	-	+	-	+	+	11
71	*Cymodocea serrulata*	-	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	+	4
72	*Cyperus arenarius*	-	+	-	+	-	-	+	-	-	-	+	+	+	-	+	+	-	+	-	9
73	*Cyperus bulbosus*	+	-	-	+	-	-	+	+	-	-	+	+	+	+	-	-	-	-	-	8
74	*Cyperus compressus*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
75	*Cyperus conglomeratus*	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	-	+	+	+	16
76	*Cyperus pumilus*	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
77	*Cyperus rotundus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	1
78	*Cyperus squarrosus*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
79	*Cyperus stoloniferus*	-	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	-	+	-	4
80	*Dactyloctenium aegyptium*	-	+	+	-	-	-	+	-	-	-	+	+	+	-	+	+	-	-	-	8
81	*Datura metel*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
82	*Delonix elata*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
83	*Dichrostachys cinerea*	-	+	+	+	-	-	-	+	+	+	-	-	+	-	-	-	-	-	+	8
84	*Dodonaea viscosa*	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
85	*Echinochloa colona*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
86	*Eclipta prostrata*	-	-	-	-	-	+	+	-	-	+	-	-	-	+	-	-	-	-	-	4
87	*Ehretia canarensis*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
88	*Ehretia laevis*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
89	*Ehretia ovalifolia*	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	3
90	*Enicostema axillare*	-	+	+	-	+	+	+	+	+	+	-	-	-	-	-	+	+	+	+	12
91	*Enhalus acoroides*	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	3
92	*Epaltes divaricata*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1
93	*Eragrostis amabilis*	-	+	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	-	-	4
94	*Eragrostis coarctata*	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	-	-	3

No.	Name of species	Island No.																			Frequency of occurence
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
95	*Eragrostis riparia*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	1
96	*Eremopogon foveolatus*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	+	+	4
97	*Erythroxylum monogynum*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
98	*Euphorbia indica*	-	+	+	+	+	+	+	-	-	+	-	+	-	-	-	-	-	-	-	8
99	*Euphorbia rosea*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	2
100	*Excoecaria agallocha*	+	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	4
101	*Ficus benghalensis*	+	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	3
102	*Fimbristylis cymosa*	-	+	+	+	-	-	+	-	-	+	-	-	-	+	-	-	-	-	+	7
103	*Fimbristylis ferruginea*	-	+	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	4
104	*Fimbristylis polytrichoides*	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	2
105	*Fimbristylis triflora*	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	2
106	*Gloriosa superba*	-	+	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	4
107	*Gisekia pharnaceoides*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	1
108	*Halodule pinifolia*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	3
109	*Halodule univervis*	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
110	*Halophila ovalis*	+	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	5
111	*Halophila ovata*	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	3
112	*Halophila stipulacea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	1
113	*Halopyrum mucronatum*	+	+	+	+	-	+	+	+	+	+	-	+	-	+	+	-	+	-	+	14
114	*Hedyotis corymbosa*	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	2
115	*Hedyotis graminifolia*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
116	*Hedyotis puberula*	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	-	+	16
117	*Hedyotis pumila*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
118	*Heterostemma tanjorense*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
119	*Hydrophylax maritima*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	2
120	*Indigofera colutea*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	1
121	*Indigofera linnaei*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	1
122	*Indigofera oblongifolia*	-	+	+	-	-	-	+	+	+	+	-	+	-	-	-	-	+	+	+	10
123	*Iphigenia indica*	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	2
124	*Ipomoea dissecta*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
125	*Ipomoea nil*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
126	*Ipomoea - pes - caprae*	+	+	-	+	-	-	+	-	-	+	+	+	-	+	-	+	-	+	-	10
127	*Ipomoea pes - ti gridis*	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	1
128	*Ipomoea violacea*	-	+	+	+	+	+	+	-	-	-	-	-	+	-	-	-	-	-	-	7
129	*Jatropha glandulifera*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	2
130	*Lablab purpureus*	-	+	+	+	+	+	-	+	+	+	-	+	+	+	+	-	-	-	-	12
131	*Lannea coromandelica*	-		+	+	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	5

No.	Name of species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Frequency of occurence
		Island No.																			
132	*Launaea intybacea*	-	-	+	-	-	-	-	+	+	+	-	-	-	+	-	-	-	-	-	5
133	*Launaea sarmentosa*	+	-	+	+	-	+	-	-	-	-	+	-	-	-	+	-	+	+	+	9
134	*Leucas anandaraoana*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	1
135	*Leucas aspera*	-	+	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	3
136	*Leucas diffusa*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1
137	*Leucas mollisima*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	1
138	*Lindernia crustacean*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1
139	*Lindernia minima*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
140	*Lindernia parviflora*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
141	*Ludwigia perennis*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
142	*Lumnitzera racemosa*	+	-	-	+	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	5
143	*Manilkara hexandra*	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
144	*Mariscus squarrosus*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	1
145	*Micrococc mercurialis*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
146	*Momordica dioica*	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
147	*Moringa pterygosperma*	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	2
148	*Opuntia dillenii*	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	+	-	3
149	*Pandanus fascicularis*	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
150	*Pavetta indica*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
151	*Pedalium murex*	-	-	-	-	-	-	+	-	-	+	+	-	-	+	-	+	-	-	-	5
152	*Pemphis acidula*	+	+	+	+	+	+	+	+	+	+	-	+	+	-	-	-	-	+	-	13
153	*Pentatropis capensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	1
154	*Peplidium maritimum*	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	3
155	*Pergularia daemia*	-	+	-	+	-	-	-	-	-	+	-	-	+	-	-	+	-	-	-	5

No.	Name of species	Island No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Frequency of occurence
156	*Phoenix pusilla*	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
157	*Phyllanthus amarus*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
158	*Phyllanthus maderaspatensis*	+	+	-	+	-	+	+	-	-	+	-	+	-	+	+	+	+	-	-	11
159	*Phyllanthus rotundifolius*	-	+	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-	4
160	*Physalis minima*	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	2
161	*Pleurostylia opposita*	-	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	4
162	*Polycarpaea spicata*	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	-	3
163	*Polygala erioptera*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
164	*Pongamia pinnata*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
165	*Premna serratifolia*	-	+	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	5
166	*Prosopis chilensis*	-	+	-	+	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+	12
167	*Pupalia lappacea*	-	-	+	-	-	+	-	-	-	-	+	+	-	-	+	+	-	-	-	6
168	*Rikliella squarrosa*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	1
169	*Rhizophora mucronata*	-	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	3
170	*Salicornia brachiata*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
171	*Salvadora perisca*	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	-	+	15
172	*Sapindus emarginatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	1
173	*Sauropus bacciformis*	-	-	+	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	3
174	*Scaevola plumieri*	+	+	+	+	-	-	-	+	+	+	+	+	+	-	+	+	+	+	+	15
175	*Scaevola taccada*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
176	*Securinega leucopyrus*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1
177	*Sesuvium portulacastrum*	+	+	+	+	+	+	+	+	+	-	+	+	+	-	+	+	+	+	+	17
178	*Setaria verticillata*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
179	*Sida cordifolia*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1

No.	Name of species	Island No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Frequency of occurence
180	*Solanum pubescens*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
181	*Solanum trilobatum*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
182	*Solanum virginianum*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
183	*Sopubia delphiniifolia*	-	-	-	-	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	4
184	*Spermacoce hispida*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	2
185	*Spermacoce ocymoides*	-	+	+	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	4
186	*Spinifex littoreus*	+	+	-	+	-	+	+	-	+	+	+	+	-	+	+	-	-	+	-	12
187	*Sporobolus maderaspatanus*	-	-	-	+	-	+	+	+	+	+	-	+	+	+	-	-	-	+	+	11
188	*Sporobolus tremulus*	-	+	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	+	4
189	*Sporobolus virginicus*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	2
190	*Stemodia viscosa*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
191	*Striga asiatica*	-	-	-	-	+	+	+	-	-	+	+	-	-	-	-	-	-	-	-	5
192	*Suaeda maritima*	+	+	+	+	+	+	-	-	-	+	-	-	-	-	-	+	+	+	+	11
193	*Suaeda monoica*	-	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+	6
194	*Suaeda nudiflora*	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
195	*Suriana maritima*	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	6
196	*Syringodium isoetifolium*	+	+	+	-	-	-	+	-	-	-	+	-	-	-	-	-	+	+	+	8
197	*Tamarindus indica*	-	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	-	-	-	4
198	*Tarenna asiatica*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
199	*Tephrosia maxima*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	1
200	*Thespesia populnea*	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-	15
201	*Tinospora cardifolia*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
202	*Trachys muricata*	-	+	+	+	-	-	+	-	-	-	+	-	-	+	-	-	-	-	-	6
203	*Trianthema triquetra*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	1
204	*Tribulus lanuginosus*	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	2
205	*Tribulus terrestris*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	3
206	*Trichosanthes cucumerina*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
207	*Tridax procumbens*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1

No.	Name of species	Island No.	Frequency of occurence
208	*Tylophora indica*	- - - - - - + - - - - - - - - - - - -	1
209	*Tynha angustata*	- + - - - - - - - - - - - - - - - - -	1
210	*Vernonia albicans*	- - - - - - - - - - - - - - - - + - -	1
211	*Vernonia cinerea*	+ - + + + + + + + + + + + + + + - + +	17
212	*Vicoa indica*	- - + + - - - + + - - - - - - - - - -	4
213	*Vigna trilobata*	+ + - + - - - + + + - - + + - - + + +	11
214	*Vitex trifolia*	- - - - - - + - - - - - - - - - - - -	1
215	*Waltheria indica*	- - - - - - - - - - - - - + - - - - -	1
216	*Wattakaka volubilis*	- - - - - - + - - - - + - + - - - - -	3
217	*Wedelia biflora*	- - + - - - - - - - - - - - - - - - -	1
218	*Zizipus mauritiana*	- - - - - - - - - - - - - + - - + - -	2
219	*Ziziphus xylopyrus*	- - + - - - + - - - - - - - - - - - -	2

Table 2 **Number of floral species in relation to extent of area of the Islands of the Gulf of Mannar**

No	Name of Island	Area of Island (ha)	No. of floral species present in the Island	
			Number	% of total
1	Krusadai Island	65.80	89	40.6
2	Muyal Island	129.00	74	33.7
3	Nallathanni Island	101.00	74	33.7
4	Pumarichan Island	16.58	67	30.5
5	Thalayari Island	75.15	61	27.8
6	Pullivasal Island	29.95	57	26.0
7	Appa Island	28.63	49	22.3
8	Monoli Island	25.90	47	21.4
9	Upputhanni Island	22.94	41	18.7
10	Karaichalli Island	16.46	37	16.8
11	Van Island	16.00	36	16.4
12	Anaipar Island	11.00	35	15.9
13	Valimunai Island	6.72	34	15.5
14	Shingle Island	12.69	33	15.0
15	Kaswari Island	19.54	29	13.2
16	Valai Island	10.10	29	13.2
17	Puluvinichalli Island	6.00	25	11.4
18	Mullai Island	10.20	23	10.5
19	Monoliputti Island	2.34	18	8.2

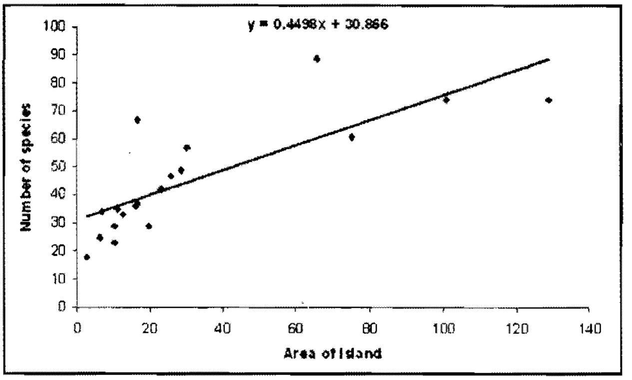

Fig. 1. **Number of species in relation to area in the Islands of the Gulf of Mannar**
($R2 = 0.6257, P>0.05$)

Table 3 **Dominant species in the Islands of the Gulf of Mannar**

Name of species	Botanical family	No. of Islands colonized (% of Islands colonized)
Sesuvium portulacastrum	Aizoaceae	17 (89.5)
Vernonia cinerea	Asteraceae	17 (89.5)
Cyperus compressus	Cyperaceae	16 (84.2)
Hedyotis puberula	Rubiaceae	16 (84.2)
Thespesia populnea	Malvaceae	15 (78.9)
Scaevola plumieri	Salvadoraceae	15 (78.9)
Halopyrum mucronatum	Cyperaceae	14 (73.7)
Pemphis acidula	Lythraceae	13 (68.4)
Clerodendrum inerme	Verbenaceae	13 (68.4)
Aerva persica	Amaranthaceae	12 (63.2)
Spinifex littoreus	Poaceae	12 (63.2)
Prosopis chilensis	Mimosaceae	12 (63.2)
Enicostema axillare	Gentianaceae	12 (63.2)
Lablab purpureus	Fabaceae	12 (63.2)
Salvodora persica	Salvadoraceae	11 (57.9)
Phyllanthus maderaspatensis	Euphorbiaceae	11 (57.9)
Suaeda maritima	Chenopodiaceae	11 (57.9)
Sporobolus maderaspatnas	Poaceae	11 (57.9)
Crotalaria retusa	Fabaceae	11 (57.9)
Coccinia grandis	Cucurbitaceae	11 (57.9)
Cyamopogon caesius	Poaceae	11 (57.9)
Indigofera oblongifolia	Fabaceae	10 (52.6)
Ipomoea pes- caprae	Convolvulaceae	10 (52.6)
Avicennia marina	Avicenniaceae	10 (52.6)

Table 4 **Representative species in different botanical families in the Islands of the Gulf of Mannar**

Botanical family	No. of species	% of total species
Poaceae	16	22.5
Cyperaceae	16	22.5
Fabaceae	12	16.9
Euphorbiaceae	12	16.9
Asteraceae	10	14
Rubiaceae	7	9.8
Chenopodiaceae	7	9.8
Asclepiadaceae	6	8.4
Caesalpiniaceae	6	8.4
Amaranthaceae	5	7.04
Cucurbitaceae	5	7.04
Convolvulaceae	5	7.04
Hydrocharitaceae	5	7.04
Scrophulariaceae	5	7.04
Boraginaceae	5	7.04
Lamiaceae	5	7.04
Mimosaceae	4	5.6
Potamogetonaceae	4	5.6
Solanaceae	4	5.6
Malvaceae	3	4.2
Verbenaceae	3	4.2
Liliaceae	3	4.2
Rhizophoraceae	3	4.2
Sapindaceae	3	4.2
Commelinaceae	3	4.2
Rhamnaceae	3	4.2
Capparaceae	3	4.2
Tiliaceae	3	4.2
Goodeniaceae	2	2.8
Salvadoraceae	2	2.8
Lythraceae	2	2.8
Vitaceae	2	2.8
Nyctaginaceae	2	2.8
Pedaliaceae	2	2.8

Botanical family	No of species	% of total species
Arecaceae	2	2.8
Zygophyllaceae	2	2.8
Sapotaceae	2	2.8
Menispermaceae	2	2.8
Elatinaceae	2	2.8
Moringaceae	1	1.4
Polygalaceae	1	1.4
Ebenaceae	1	1.4
Mulluginaceae	1	1.4
Combretaceae	1	1.4
Anacardiaceae	1	1.4
Apiaceae	1	1.4
Periplocaceae	1	1.4
Erythroxylaceae	1	1.4
Rutaceae	1	1.4
Typhaceae	1	1.4
Myrsinaceae	1	1.4
Brassicaceae	1	1.4
Tamaricaceae	1	1.4
Hernandaceae	1	1.4
Onagraceae	1	1.4
Clusiaceae	1	1.4
Amaryllidaceae	1	1.4
Pandanaceae	1	1.4
Moraceae	1	1.4
Cactaceae	1	1.4
Caryophyllaceae	1	1.4
Gesneriaceae	1	1.4
Celastraceae	1	1.4
Cleomaceae	1	1.4
Meliaceae	1	1.4
Surianaceae	1	1.4
Aizoaceae	1	1.4
Gentianaceae	1	1.4
Avicenniaceae	1	1.4
Lauraceae	1	1.4

RECOMMENDATIONS

Strategies for Bioresource Management

1. Capacity Building:

- Promoting training and capacity building: Capacity building to train local people especially facilitators and motivators, formulate and implement different training courses depending upon the target group like policy makers, reef managers, judges, advocates, school children, laymen etc.

2. Fisheries Management:

- Ecosystem based fishery management such as fishing holidays during breeding season, declaring sanctuaries, marine national park, marine protected area etc., shall be undertaken on participatory mode with active involvement of the community.

- Destructive fishing practices such as dynamite/cyanide poisoning, pair trawling, purse seine operation, illegal poaching of banned species, fishing in restricted area, pollution which affect the natural ecosystem shall be curbed through effective enforcement laws.

- Juvenile fishing and catching of undersized fishes are to be avoided.

- Overexploitation of resources despite high market demand shall not be allowed.

3. Coral Reef Management

- Developing integrated coastal management frameworks for coral reef management.

4. Knowledgebase Management Tools

- Reef Surveillance to deal with patrolling in collaboration with other protective agencies like Coastguard and Local Police.

- Establish a central knowledge portal for information management (GoMBR Information System).

- Prepare Predictive Models for sustainable use employing freely available and relevant commercial programmes.

- Develop Decision Support Systems (DSS) to formulate Active Adaptive Management Strategies.

Strategies for Research and Monitoring Programmes

Establish long-term monitoring programmes and Research and Monitoring wings are also to be developed.

Strategies on Conservation and sustainable use of resources

Conservation measures should take care of the community and their livelihoods also in consonance with the protection and enhancement of the biological resources and ecosystems.

Fisheries should deal with the idea and plans for sustainable utility of living resources, demarcation of 'No-take reserves' to protect the nursery, breeding and sensitive grounds, ecosystem based management etc.

Strategies on Fisheries Development and Coastal aquaculture

State/Central Government shall encourage offshore deep sea and high sea fishing to reduce fishing pressure in the inshore waters of Gulf of Mannar.

Sea ranching programmes may be intensified with special reference to endemic and over exploited commercially targeted fishes and shrimps.

Establishment of more number of Fish Aggregating Device and Artificial reefs along the coast in selected places may be given priority by the Development Agencies.

Sea farming, coastal aquaculture on seaweed culture shall be encouraged.

Strategies on Socio-economic Development

Ensuring appropriate livelihoods for those immediately dependent on reefs for their income; It must also be in contact with tourism wing for development of alternative employment to local people etc.

Involving local communities in decision-making and management. Community management to deal with community related matters like community based management, alternative generation methods, partnership ideas etc.

Tourism should think about formulating methodologies for eco-friendly regulated tourism like arranging fixed buoys to anchor the boats instead of throwing the anchors on live corals, organised tourism development etc.

Awareness campaigns may be conducted at all levels of individuals from the local community regularly to educate the fishers on responsible fishing.

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