Regional Workshop on the Conservation and Sustainable Management of Coral Reefs

Workshop Proceedings

M.S. Swaminathan Research Foundation, Chennai, India
Bay of Bengal Programme (FAO), Chennai, India

December 15-17, 1997

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FOREWORD

Coral reefs have been described as the marine equivalents of rain forests with reference to richness in biodiversity. Yet, recent estimates reveal that nearly 95% of the world's coral reefs have been damaged by overfishing, dynamiting, pollution, poisoning or ship's anchors. **Reef check** carried out at 300 sites in the Carribean, the Red Sea and the Indo-Pacific Region during the summer of 1997 has indicated that fish and shell fish that were once common on reefs are gradually getting decimated.

1997 has therefore been declared as the **Year of the Reef,** in order to focus public and political attention on issues relating to the conservation and sustainable management of coral reefs.

It is sad that just at a time when awareness of the crucial importance of biodiversity conservation to the future of global food, health and livelihood security is growing, these fortresses of biological diversity are giving way to a combination of natural and human assaults. 1997 is marked by ***El Nino*** events. ***El Nino,*** associated with the warming of the water currents in the equatorial eastern Pacific, led to the killing of huge quantities of coral along the coasts of Costa Rica, Panama, Colombia and Ecuador during 1982-83. In normal circumstances, the reefs recover from natural destruction within a few decades. But now, natural stresses are compounded by human activity, and the coral treasures are being increasingly degraded with less chance for regeneration.

The Regional Workshop convened by M S Swaminathan Research Foundation in collaboration with the Bay of Bengal Programme of FAO is designed to address these issues and to develop an action plan for saving the remaining coral reefs in the SAARC region. Since its establishment in 1989, M S S R F has given priority attention to the conservation and sustainable use of Coastal Mangrove ecosystems. In many areas, Mangroves, sea grass meadows and coral reefs constitute an integrated ecosystem. The Gulf of Mannar Biosphere Reserve represents one such integrated ecosystem. Currently, a detailed action plan is being prepared with assistance from the Global Environment Facility (GEF) and the UN Development Programme (UNDP) for preserving for posterity the biological wealth of the Gulf of Mannar region.

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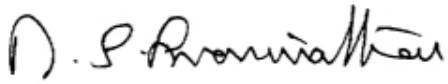
We are indebted to the following organisations for cosponsoring this Workshop and for providing financial support.

- The World Wide Fund for Nature - India
- United Nations Education Scientific & Cultural Organisation
- Department of Science Technology and Environment - Administration of the U T Of **Lakshadweep.**
- The Department of Ocean Development, Government of India
- The Ministry of Environment and Forests, Government of India
- Ministry of External Affairs, Government of India (SAARC Division)
- Ministry of Science and Technology, Government of India
- The Global Coral Reef Monitoring Network - South Asia
- The Bay of Bengal Programme of the FAO
- Australian Agency for International Development - Aus Aid

Our special thanks goes to the Bay of Bengal Programme, FAO for collaborating with us for the organisation of the dialogue and arranging for the country paper presentations. We are also grateful to the AUSAID for arranging to bring a monitoring expert from Australia and Dr Jason Rubens of the Global Coral Reef Monitoring Network for his valuable suggestions.

My sincere thanks go to my colleague Dr(Ms) Vineeta, Hoon for her tireless and dedicated efforts to make this Regional Workshop purposeful and memorable.



M S Swaminathan

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Part 1
Proceedings of Workshop

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1. Recommendations of the Workshop Participants

Group A: Sustainable Use and Equitable Sharing

The Group discussed the dynamics of all end-user and dependent groups of **reef** resources, classifying them into different categories of stakeholders. The table that follows summarizes information about stakeholders, their unsustainable practices, corrective measures required to manage the resources on sustainable basis remedial action necessary to bring about long-term sustainable use and equitable sharing of coral reef resources.

The stakeholder groups were divided into the following categories as shown in Table 1.

1. The most sociologically important group is traditional fishermen and coastal dwellers. Fishermen were divided into two groups:

a) Traditional Fishermen: These Include Indigenous People who have been living in the vicinity of coral reefs for millennia. Their services can be availed of under the program almost as wardens.

b) Commercial fishermen: They use modern fishing methods and regard the reef resources as a short-term commercial proposition. They are not particularly concerned with the long-term conservation of the reef as their financial mobility allows them to shift operations from region to region once the catch is depleted. They use fine-mesh nets, such as gillnet and purse seine, fish poisons, cyanide and dynamite. They also carry out bottom netting for lobsters.

Corrective measures: Fisheries management, limiting fish catch and improved methods of fish catch, education and people's participation and involvement in a long-term management plan.

Indicative values on a scale of 1-5 for the time, effort and money to be spent on these people because they are sociologically important for the coastal regions. A value of 4 is given to fishermen.

Divers: were further categorized as:

a) Sports divers: Diving as a sport can be sustainable if diving numbers (density) is regulated and maintained.

b) Commercial divers: Commercial divers who use scuba equipment without adequate training are destructive to the coral reef, This is because they do not fully appreciate either the ethics or function and use of scuba gear.

The diver code of ethics of PADI, NAUI, SSI, CMAS, and BSAC is Safety first and foremost; Insist on a buddy system (Two divers must always dive together); Protection of the environment and all its inhabitants. It specifically states that scuba gear should not be used for commercial purposes such as killing or catching fish, dynamiting, poisoning etc.

Corrective measures: There should be an organized program to train divers in safety regulations concerning scuba practices and bring them into the mainstream of International scuba activities with their rules and ethics involved.

Table *1:* Sustainable use and equitable sharing of coral reef resources

Stakeholder Users	Unsustainable Practices	Corrective Measures	indicative value 1(low) to 5 (high *
Fishermen	NON-DESTRUCTIVE		
1. Traditional Fishermen			
2. Exploitative Fishermen	Small Mesh Net Fishing Bilgewater, /Fish Offal Blast Fishing Cyanide Fishing (Poisons)	Education and Awareness Building Fisheries Management Measures	4
Ornamental Shell and Coral Collectors	Overexploitation	Culture shells & Corals. Revenue Generation Fisheries Management	2.5 4
Divers - Sports - Commercial - Scientific	Diver Overcrowding Lack of proper training in scuba Diving	Limit Number of Divers Scuba diving certification Education and training	
Tourist Operators	Glass-bottom Boats Sewage/ Solid Waste disposal Excessive Draw and Use of Ground- water Resources. Indiscriminate Construction	Stringent Control Sustainability Awareness Implement Existing Regulations	4
Ports and Harbors	Dredging/Blasting	Harbor Management	3
Coral Miners	Complete Destruction	Ban/Alternate Sources of Building Materials	
Naval Activities	Demolition Damage Anchor Damage Combat Diver Training	Environmental Education for Officers at School	1
Urban Developers	Waste Disposal Lack of Setbacks Reclamation	Implement Rules	2 5
Marine Archeology	Removal of Artifacts	Regulatory Agency	1
Aquaculture	Discharge of Effluents Antibiotics/Exotic Diseases Increased Sedimentation	Enforcement of Rules Better Management	3
Coastal Dwellers /settlers	Waste Disposal	Awareness building Bio Toilets	4
Shipping Industry	Oil Discharge Ballast Water Discharge	Enforcement Education	3
Ship Breaking Industry	Oil Seepage Scrap Matter	Designate Special Zones	
Coir Pith Producer	Increased Nutrients Pollution	Designate disposal areas Education	
Oil Industry	Oil-rigs	Improve Technology Laws Enforcement Awareness	3

4. **Tourist operators: Tourism brings** in revenue, creates employment and can be self regulating if **a code of** ethics is followed. Coral reef resorts live off the reefs and a lot of

capital has gone into providing an infrastructure. They depend on the pristine-ness of the reef and it is in their self-interest to preserve the reef environment.

5. Ports and harbors: They are necessary for developmental infrastructure. But their construction should be regulated stringently. Environmental impact studies must be conducted on every major project, to check sustainability or environmental damage.

Corrective measures: Spear-head teams or groups of highly motivated environmental and social scientists to motivate and educate end user groups into forming associations that can regulate and manage their own reefs.

The following action steps were suggested to operationalise marine protected areas and fish sanctuaries:

1. De-mystify protection and management. Protection does not mean no fishing.
    - Responsible fishing (code of conduct for responsible fishing.
    - Professional ethics/PADI scuba certificate.
2. Stakeholder consultation and analysis to promote community bonding
3. Set up community learning and earning center's in fishing villages to serve as a focal point for co-management.
4. Training and awareness building.
    - Provide worthwhile occupational skills.
    - Construct signboards and posts in strategic public areas through key messages.
5. Mangrove re-plantation schemes - rehabilitation of coastal contiguous wet lands.
6. Seagrass replanting and rehabilitation
7. Construct and install artificial reefs as management tools and not as gear.
8. Encourage rotational fishing
9. **Develop a core of community reef wardens (with/without incentives and a** supporting policy environment)

Group B: Local Governance of Reef Resources and Habitats

The group's discussion was based on the consensus that given the complexity of coral reefs and the multiplicity of impacts upon them, any measures to sustainably manage and conserve them would be futile without the active participation of stakeholders. In order to facilitate and enable participatory, stakehoTder governance the group through their discussions proposed recommended the following:

- Evolve supportive clauses into existing regulations to include coral reefs and to specifically delineate the area of jurisdiction;
- Evolve institutional frameworks to provide local decision - making platforms to manage and conserve coral reefs and to legitimize and empower such groups to undertake such efforts; and
- Propose miscellaneous tasks, which would enable and facilitate local governance options and build the capacity of agencies concerned to undertake similar efforts.

The recommendations of the group, broadly classified into three categories were:

1.0 Supportive Regulations and Legislation to include and delineate Coral Reefs:

1.1 All coral reefs should be declared 'protected areas" (ecologically sensitive areas with certain restrictions on destructive fishing practices, and activities) to enable conservation and sustainable management.

1.2 A special authority should be created in all coral reef areas to conserve and manage coral reefs or, an agency already existing should be empowered and authorized to undertake the mandate.

1.3 Legislation relating to Coastal Zone Regulation should be appropriately amended to enable integrated coastal zone management to cover the seaward side to depths of up to 200 meters.

1.4 Legislation to be appropriately amended to incorporate all coral species as marine fauna. In particular include the species 'corals' in the Schedules of the Wildlife (Protection) Act and include 'corals' in the definition of "wild animal".

1.5 As all South Asian countries are signatories of CITES, a complete ban on the export and trade of all coral species should be enforced.

2.0 Institutional Framework for Local Governance:

2.1 Under the aegis of the designated local coral reef authority, local governance of coral reefs should be encouraged and promoted. Appropriate local forums of stakeholders, including concerned government agencies, all user groups, interested parties and local government, where formed, should be empowered to assist and advise the CRA (Coral Reef Authority) in the development of conservation and management plans. These forums should participate actively in implementation of plans.

2.2 Coral reefs are vulnerable to human impact, some of which may be generated at points distant from the coast. In order to protect and conserve coral reefs, the Coral Reef Authority (or designated agency) should be empowered to co-ordinate with agencies whose area of jurisdiction impacts on coral reefs.

3.0 Miscellaneous proposals to enable and facilitate local governance:

3.1 Awareness building and education should be encouraged to promote the participation of stakeholders in conserving and managing coral reefs.

3.2 All users of coral reefs should be strictly licensed and regulated strictly, according to guidelines that specify extraction and use limits.

3.3 It is vital to document traditional management practices of coral reef communities to give direction to socially and politically feasible local governance modalities.

3.4 In evolving management plans for coral reef conservation and management, given the urgency of the task and the lack of hard scientific information, the CRA (Coral Reef Authority) should adopt the precautionary principle, depending on best available information.

3.5 To build the capacity of agencies concerned, to enable improved management and conservation of coral reefs, partnerships should be evolved in the region to make optimal use of available skills, talents, information, research facilities and tools.

Group C: Reef Research and Monitoring for Management

1. Issues

1.1 Networking and Information Sharing

Although there are a few significant gaps in the status of knowledge of South Asian coral reefs, the general condition of coral reefs, and related threats and resource-use issues are relatively well understood by regional specialists. However, it is widely recognised that information is restricted to specialist institutions and therefore tends to be fragmented and inaccessible.

1.2 Weaknesses in the Research Infrastructure

Certain weaknesses in the coral reef-related research community in South Asia were identified:

(i) although many institutions in India are conducting related marine work. India has no *dedicated* national centre for coral reef research; like Sri Lanka and Maldives.

(ii) South Asian regional institutions lack manpower for field activities, especially in-water data collection;

(iii) much of the present marine research activity is not related to management requirements and tends to be narrow-focused and qualitative. In particular there is a lack of quantitative survey work generating relevant management-related statistics;

(iv) there are problems in securing long-term commitment of funds for monitoring activities, which need to be continued year after year.

1.3 Community Participation in Research Activities

There is an acute awareness in the research community that extensive recommendations have been made over the years on coral reef management priorities, but very few have been put into practice by governments.

A fundamental reason, may be the lack of involvement of communities in the research process. This leads to recommendations that are neglect community interests. This in turn means that there is limited political will to implement such recommendations.

Greater active involvement by community groups would mean better integration of local or traditional knowledge of the coral reef environments and resource-use issues into the management recommendations.

1.4 Lack of Socio-economic Research on Coral Reefs

There are very few scientists from *socio-economic* disciplines who specifically address coral reef-related issues in the South Asia region.

This is one reason why community interests may have been insufficiently addressed in coral reef management recommendations in the past. Better participation by socio-economic scientists would also help to translate local understanding of coral reef environment into management planning processes.

2. Recommendations (not in order of priority)

2.1 Development of the South Asia regional component of the *Global Coral Reef Monitoring Network (GCRMN)* should be advanced as quickly as possible, especially to address the need to integrate available coral reef information and improve data accessibility.

2.2 Consideration needs to be given to establishing a nodal centre for coral reef research in India. Conferring the mandate for coral reef work on a single institution (either new or existing) may *not* be desirable, as there are strengths in the existing plurality and diversity of institutions. Nonetheless, some kind of national co-ordinating body is clearly required.

2.3 Research priorities at some marine research and related institutions and universities in India and Sri Lanka need to be fundamentally reviewed in the context of basic management needs; in particular, applied quantitative survey and monitoring work needs to be encouraged in favour of the current emphasis on qualitative studies such as taxonomic work, and detailed species-level studies.

2.4 National Government. funding sources in India should be requested to consider *routine* annual budgetary provision (i.e. *not* constrained to a fixed project duration) to fund ongoing coral reef monitoring activities.

2.5 There is a strong need for field scientists to encourage the active participation of community groups in field data collection, so that local knowledge can be accessed, and local awareness of the state of the environment increased.

2.6 Closer co-operation is needed between scientists, local communities and politicians and state and national government authorities in planning coral reef related research activities, so that such research is actively integrated into local management efforts and concerns.

2.7 Scientists from socio-economic disciplines would be encouraged specifically to address coral reef related issues and to develop resource-use and livelihood monitoring alongside biophysical monitoring.

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2. Report of the Workshop

Session 1: Inauguration

Dr. M.S. Swaminathan, Chairman of the MS. Swaminathan Research Foundation welcomed participants and guests. He mentioned that 1997 has been declared by UNESCO as the *Year of the Reef,* to focus attention on issues relating to the conservation and sustainable management of the remaining coral reefs on our planet. That this matter, needs urgent attention, will be clear from recent data, which indicate that nearly 95% of the world's coral reefs have been damaged by over-fishing, dynamiting, poisoning, pollution or ships anchoring. He urged participants to develop an integrated conservation and management strategy for coral reefs.

Dr. A. E. Muthunayagam, Secretary of the Department of Ocean Development, Government of India, inaugurated the Workshop. Stressing the importance of coral reef ecosystems, he said, that the Department of Ocean Development with support from the Ministry of Environment and Forests and the World Bank has embarked upon preparations for GIS based information systems for coral reef areas in the Gulf of Kutch, Malvan, (Kadmat) Lakshadweep, Gulf of Mannar and Wandoor (Andamans). This information system will be useful in the preparation of integrated management plans for the coral reef areas in India.

Dr. Graeme Kelleher, Vice Chairman (Marine) World Commission on Protected Areas delivered the keynote address[1] and stressed that it is essential to create public awareness on the delicateness and the fragility of the coral reef ecosystem. Education and extension programmes for the local people are useful tools in creating environmental awareness among local inhabitants. This is more likely to lead to lasting results than rigid conservation programmes.

Referring to his visit to the Gulf of Mannar area, he said that many areas of the Gulf of Mannar are already degraded and need strict enforcement of rules to protect them. A system of integrated coastal management (ICM) is needed to protect this fragile ecosystem. The goal of ICM is to improve the quality of life of human communities, who depend on coastal resources, while maintaining the biological diversity and productivity **of coastal ecosystems.**

The main problems caused by human activities to coral reefs and other marine ecosystems include pollution, overfishing, physical alteration of the seabed or coastline, introduction of exotic species and climate change

Dr. Vineeta Hoon proposed a vote of thanks.

[1] The keynote address is included in Section A of the Back ground papers.

Session 2: To review the current status of coral reefs in the SAARC coastal countries' experiences and to describe the problems

Chairpersons: Dr. A. E. Muthunayagam and Dr. Vineeta Hoon

Rapporteurs: Dr. Krishna Kumar and Ms. Devaki Pannani

Dr. Hussain Shihab, Director, South Asia Co-operative Environment Programme (SACEP) delivered a special address on the role of SACEP. SACEP has been in existence for 15 years. It was set up to evolve a common regional strategy for environmental management for South Asia. The nine member countries are:

1) Nepal, 2) Maldives, 3) Afghanistan, 4) Bangladesh, 5) Pakistan, 6) Bhutan, 7) Sri Lanka, 8) India and 9) Iran.

SACEP was ratified on the 15th of March 1995. All the SAARC countries are members of SACEP. There are 15 priority areas identified by the SACEP secretariat with a focus on faunal biodiversity and environmental law. A number of workshops have been held, the latest being a workshop on faunal biodiversity in Calcutta, the outcome of which will be a Faunal Biodiversity Action Plan. The SACEP secretariat is the focal point for Intemational Coral Reef Initiative (ICRI). It is collaborating with the Global Coral Reef Monitoring programme to develop a coral reef database for the South Asian countries. This database will be shared and developed by a network of Coral Reef Research agencies in South Asia.

The country papers[2] to review the current status of coral reefs in the SAARC Coastal countries were presented in the second session.

Mr. Maizan Hassan Maniku, Director General of Fisheries Research and Development, Ministry of Fisheries and Agriculture, Maldives (presently on leave of absence) presented the Maldives country paper, which had been prepared by Mr. Abdullah Naseer, of the Marine Research Section of the Ministry of Fisheries and Agriculture.

Mr. Arjan Rajasuriya, Senior Research Officer, National Aquatic Resources Agency (NARA), Ministry of Fisheries and Aquatic Resources Development of Sri Lanka **presented** the Sri Lanka country paper.

Dr. Vineeta Hoon, Social Scientist, MS. Swaminathan Research Foundation and Dr. Gopinatha Pillai coral reef Scientist (retired) from Central Marine Fisheries Research Institute (CMFRI) presented the India country paper.

Dr. A. R. Mollah from the Department of Zoology, Dhaka University, has prepared the country paper for Bangladesh.

Dr. Quddusi Kazmi and Dr. Afzal Kazmi from the Marine Reference Collection and the Department of Zoology have prepared the country paper for Pakistan.

[2] The country papers for all five countries, specially prepared for this workshop, are included in Section B of the Background papers.

Session 3: To discuss approaches and techniques of coral reef conservation and management experiences, particularly those involving stakeholders

Chairperson: Mr. Maizan Hassan Maniku **Rapporteur:** Dr. C. L. Rodrigues

1. BOBP's Approach in Fisheries Management:: By Dr. Kee-Chai Chong,[3] Programme Coordinator of the FAO/UN Bay of Bengal Programme

Dr. Chong provided a review of the Bay of Bengal Programme, highlighting the stakeholder approach to fisheries management in the region. He stressed the importance of involving all stakeholders in the marketing chain, from the primary producer to the final consumers. In between, there are the market intermediaries, fisheries manager and fisheries planners etc. Dr. Chong singled out fisheries planners as partly responsible for the pressure to expand production, which can then lead to overfishing. He poihted out that fisheries planners, in making their usual five year projections or even annual/biennial projections for planning purposes, invariably put down higher and higher projections without taking into consideration the existing per capita fish consumption and actual nutritional requirements. It is 65 kg/ capita/year in Japan, 45-50 kg/capita in Malaysia and Singapore. In short, fish consumption projections should not always be higher and higher but they should be realistic if we want to promote sustainable management.

Such projections place unnecessary pressures on existing fish stocks. There is a need to examine nutritional requirements and contribution of fish to the diet of the people in some countries; there is excess consumption of fish.

2. Management Experiences from Hikkaduwa National Park[4]: Dr. Ranjith De Silva

Dr. Ranjith de Silva spoke on his experiences from the Hikkaduwa Marine Park in Sri **Lanka.**

3. The Gulf of Mannar Protect : Mr. Jaganatha Rao, Project Co-ordinator, M.S Swaminathan Research Foundation.

Mr. Rao spoke about the Management Plan being developed for the Gulf of Mannar Biosphere Reserve. This Plan is being prepared with funding from the Global Environment Facility *(GEF)I* **UNDP.** The project was sanctioned in October1997. The project work has just begun and it is too early to provide a complete perspective of the plan. The plan will include a co-management strategy involving all the stakeholders in the Gulf of Mannar coast. Investigations are being undertaken to identify all the stakeholders. Discussions will be held with each stakeholder group to include their perspective in the Plan.

[3]Dr. Chong's complete paper is in section C of the Background papers.

[4]Ranith De Silva's complete paper is included in the Background papers

4. The Andaman and Nicobar Protect: Dr. A. K. Das, Sr. Scientist at the Zoological Survey of India (ZSI), Calcutta

Dr. A. K. Das of the Zoological Survey of India spoke about the Management Plan being developed for the Andaman and Nicobar Islands with the help of GEF funding. He said that since the project was sanctioned in October, 1997, the ZSI had not yet started implementing the project. The project would ensure stakeholder participation in **developing the co-management plan for the Andaman and Nicobar Islands.**

Session 4: To discuss tools to promote coral reef conservation and management efforts to include community participation in the sustainable management and conservation of coral reefs

Chairperson: Dr. Kee-Chai Chong, Rapporteurs: Ms. Barbara Bierhuizen and Dr. Hemal Kanvinde.

Altogether 14 papers were presented. The topics ranged from mechanisms for monitoring coral reefs and coral reef health (4 papers) to two papers on carrying **capacity and one paper on research and training on conservation and sustainable** management. Other subjects covered legal and trade issues in coral reef products, aspects of management of natural resources, definitIon and integration, role of media and communication in management and eco-tourism designed on the principles of **ecology, economics and enjoyment.**

1. Mechanisms to Monitor of Coral Reefs: By Mr. Will Oxley, AIMS, Townsville, Australia

Mr. Oxley set out by describing a joint venture between India and Australia in capacity-building and training in monitoring of coral reefs, with experiences gained from their programme in AIMS. In Australia the Great Barrier Reef monitoring programme started in 1992, based on 15 years of previous research work. The objectives of this work are **to assess the status** of the reef, detect changes through time and provide an ecological basis for these changes and thereby assist in informed management. He said that basically there are three types of reefs: inshore, midshore and outshore. They monitor, coral cover, water-quality, nutrient status, COT (Crown of Thorns) and certain reef fish. The visual sensing technique is used for counting large and small fish. The video technique is used for monitoring coral cover and benthos. The manta Tow technique is used for assessing COT prevalence. The survey results are depicted in graphs and tables showing the change in hard coral cover or changes in COT count in different sectors of the reefs over time. Such information helps in predicting an outbreak of COT. The Park Authority, in one instance had launched a media campaign to inform people about the impending outbreak of COT. Outputs from this monitoring that can be used by others are status reports, standard operation procedures and technical studies. The monitoring programme also conducts training for in-house staff, Australian environmental agencies and Asian countries. Mr. Oxley further described the training

programmes conducted in Papua New Guinea where local guards and resort owners monitor the status of the reef. These local researchers helped the government of Papua New Guinea to assess the extent of coral bleaching in their region. The monitoring programme has developed a user-friendly database management system (ARMDES) to assist researchers in handling their data. He summarized the system by saying that such monitoring systems, if carried out in all the coral reef regions of the world will provide a global scale for local data, The data should be gathered through simple yet standardized techniques, and practical training should be imparted to the people of the coral reefs.

Discussion:

Q: What are the reasons for outbreak of COT?

A: It is suspected that COT larvae experience lower mortality under certain water nutrient conditions and thus survive much better than normal. These larvae stages are microbial and cannot be detected in the monitoring programme. Such sustained build up of population over 3-4 years may cause an **outbreak of COT.**

Q: Do you consider it a natural phenomenon? Do you advise removal of this organism?

A: It is a natural phenomenon. In Australia we undertake localised measures, mainly in tourist centres.

Q: How do you take observer error into account during the survey?

A: Two types of error may occur: observer specific and site specific. We consider that these two errors may account for up to 4 % change in coral reef cover.

Q: Is COT an indicator of environmental quality?

A: COT is not an indicator of environmental quality.

Q: Are there any anthropogenic pressures on the reefs?

A: Anthropogenic pressures are caused by a) natural population growth, b) increase in tourist arrivals and c) increase in commercial fishing. d) increased silt runoff from land-based activities e) use of fertilizers by the sugar cane industry.

Q: Does the monitoring programme focus on conservation or on sustainable **use of the reefs?**

A: The monitoring programme's focus is on the sustainable use of reefs. It doesn't mean to isolate the reefs. It promote the concept of multiple use of the coral reefs.

Q: What is the impact of ballast water from ships on the reefs. Are there **instances of exotic species introduction due to this?**

A: **The impact of ballast water is not seen** in tropical waters. However, it happens in temperate regions. For example, an introduction of a star fish **caused reef degradation** in Tasmania.

2. Mechanisms In monitoring of coral reefs: by Jason Rubens, Regional Coordinator of the South Asia regional component of the Global Coral Reef Monitoring Network (GCRMN South Asia)

Mr. Rubens discussed the need for regular and repeated monitoring of the coral reef ecosystem. There are several reasons why reefs should be monitored. One is to find out who is responsible for causing the change, i.e. look at the reef as the scene of a crime, where criminal activities such as blast fishing, cyanide fishing and dumping of sewage take place. This leads to declining fish populations and corals. By monitoring reefs, we can find out the culprit responsible for the unsustainable use of reefs. Other reasons why reefs should be monitored are to improve understanding of the ecological changes taking place, to quantify known processes, to evaluate management effectiveness and to estimate carrying capacity and sustainable yields.

GCRMN is an inter-agency initiative of UNESCO, UNEP and IUCN. The GCRMN, South Aisia office is based in Colombo and funded by the UK Department for International Development (OFID). It seeks to develop a network to establish national databases on coral reefs, which is to be implemented at national levels within the present research framework. Each coral reef country has a national coordinator.

Discussion:

Q: How far do we understand the science of coral reefs? Do we not need to preserve all coral reefs as a world heritage?

A: Our present knowledge of coral reefs is fairly poor. We cannot preserve the reefs as a world heritage yet because the reefs are used by people. Some areas may be earmarked as preservation areas.

Q: What role does the international community play in conserving coral reefs?

A: The international community provides the funds that are essential for any conservation programme, including one for corals.

Q: Since the National Co-ordinator in each country is based far away from the reefs, how does the GCRMN provide for a trickle down mechanism of information dissemination for the benefit of the local community?

A: The monitoring and the database will be carried out by institutions already active in coral reefs research. The database will be housed in such institutions. The national coordinator will coordinate the activities of many such

institutions. It is true inaccessibility of information from the central government may be a problem.

3. Remote Sensing and GIS for Coral Reef Mapping: By Dr. R. Krishnamoorthy, Scientist, M.S. Swaminathan Research Foundation.

Dr. K. Krishnamoorthy spoke about the feasibility of employing Remote Sensing and **GIS techniques for monitoring the physical** condition of the reefs over time. He presented a case study of the mapping exercises carried out in the Andaman and Gulf of Mannar region, and explained that satellite imagery data was used to categorize reefs as fringing, patch or platform. He further explained that GIS can be used as a tool to highlight changes in the coastal configuration because of erosion and accretion and their impact on the coral reef ecosystem.

Discussion: The participants wanted to know the percentage of accuracy of information gathered by the use of remote sensing data compared to the information gathered by conventional method? And whether fieldwork was carried out for ground truthing the satellite images in the Andaman Islands?

Dr. Krishnamurthy explained that the percentage of accuracy is up to 90 % and that a team visited the area to carry out ground truthing.

4. Coral Mortality in Reefs: The Cause and Effect: A central concern for Reef Monitoring5

By Dr. Chandra Lata Raghu Kumar, National Institute of Oceanography, Goa.

Dr. Chandra Lata discussed her project on 'Coral and Sea grass Mortality in Reefs: Microbial Pathogens and Environmental Disturbances' funded by the Department of Ocean Development. She explained that the indicators of ill health in coral reefs are partial mortality, bleaching, black-band disease, white band disease and excessive growth of algae. Causes for these are several: sedimentation, stress factors, eutrophication/pollution and pathogenic organisms. Ms. Chandra Lata pointed out that she does not speak about 'diseases' of coral reefs, she uses the more objective word mortality; Reason: corals might not die solely from biotic factors solely, abiotic factors could also be involved. She says it is not any individual factor but a complex that causes disease.

Discussion: The participants wanted to know whether she had observed a brown sponge as a secondary invader since it was found in the reefs of Sri Lanka. Had she observed any diseases in the Gulf of Mannar? Does the Crown of Thorns leaves any bacteria or pathogens.

Dr Chandralata replied that she had not observed a brown sponge as a secondary invader in the areas where she had carried out her study. She had not observed any

This paper is included in Section C of the Background papers.

diseases in the Gulf of Mannar . We do not know yet whether COT leaves bacteria after infestation of a reef area.

5. Research and Training for Conservation and Sustainable Management of Coral Reef Ecosystems, Present Status and Future Directions: [6]By Dr. S. U. K. Ekaratne, Department of Zoology, University of Colombo.

Dr. S.U.K Ekaratne described the status of coral reef research and training in Sri Lanka. He explained that reef habitats in Sri Lanka are degraded and impacted by a multiplicity of causes. Survey work constitutes the bulk of recent research activities. Quantitative data on reefs in Sri Lanka is tacking, so is data on reef processes and the diversity of the reef biota.

There is very little reef expertise in the country. A handful of people are engaged in established reef research programmes. The lack of trained personnel is the main impediment to collection of research data that can enable effective conservation and sustainable management of Sri Lankan reefs.

His talk invited the following comments:

C: The term "conservation" should be defined. Infact every speaker should define the terms used in his or her presentation.

C: It is important to keep administrators, members of Parliament and Ministers about the status of coral reefs.

Participants wanted to know how Dr Ekaratne studied the growth mechanisms of corals and why he used 15 Mts. as the length of the transects?

Dr. Ekaratne replied that growth experiments were conducted through simple area extension measurements in the field to calculate a coral growth index. He further explained that a length of 15 meters was chosen for convenience.

Carrying Capacity of Coral Reefs: By Dr. M. V. Wafer, NIO, Goa[7]

Dr. Wafer defined the carrying capacity of a reef as "its ability to support a range of extractive and invasive uses without perceptible changes and/or degradation of its biological productivity and species diversity over a reasonable period of time.

He emphasized that this definition is not restricted to tourism-related activities but is intended to cover all those activities (e.g. waste assimilation capacity) which have a potential for expansion and exceed the reef's ability to cope with these. He discussed six indices that are useful in measuring carrying capacity. These are indices of 1) productivity, 2) pollution 3) biodiversity, 4) harvest practices 5) interactions with adjacent ecosystems and 6) tourism.

[6] This paper is included in Section C of the Background Papers
[7] Paper included in Section C of the Background papers

Discussion: Participants wanted to know whether DR. Wafer was referring to carrying capacity or standing crop in his paper and he clarified that he was referring to carrying **capacity.**

6. An Analysis of the Carrying Capacity of Lakshadweep coral reefs[8]: By Mr. C. L. Rodrigues, Department of Biotechnology, University of Goa.

Dr rodrigues analyses key parameters such as population size, number of houses, passenger traffic, cargo traffic and fish catch relating to major islands of the Lakshadweep archipelago to study the impact of human activities on the reefs. He explained that Lakshadweep has the third largest population density in the country. Rapidly escalating developmental activities are largely responsible for the degradation of the reefs. Fishery resources are under-exploited, and the fish catch can be augmented by adopting modem methods and diverting the impact of fishing boats to mainland ports. There is an urgent need to halt the degradation of reefs and reverse the trend.

Discussion: Participants wanted to know if Dr Rodrigues's results would have been different if he had based his analysis on island per kilometer^2 instead of per island. They also enquired why he used tuna catch as a measure of fish productivity. Since tuna is found outside the reef.

Dr. Rodrigues said that he felt a carrying capacity study per island was useful. The results would not be too different had he done it in any other way. As regards tuna catch as a measure of fish productivity . Dr Rodrigues said that tuna catch in Lakshadweep is dependent on live bait fisheries from coral reef areas. Therefore the amount of tuna caught reflects directly on pressure of the live bait species that are found on the reef.

7. Role of Communication: By Mr. Rathin Roy *Communications Adviser of the Bay of* Bengal Programme

Mr. Roy emphasized that communication should be a two-way process. In his experience, most valuable information at a meeting is acquired during thought exchanges in the tea and lunch breaks of a meeting. He said that it takes 10 years to become an expert, another 20 years to gain knowledge, but meanwhile nobody learns how to get it across. When talking about management of coral reefs, we mean management of the resource as well as of the people who use the resource. We must encourage and enable them to understand better the resources they are exploiting. Identifying stakeholders and making them participate in an activity is an important part of the stakeholder approach. It is not merely on 'getting together' to do something by highlighting areas of co-operation but rather to agree on removing areas of discord. Problem-solving involves mediation and communication skills and the capacity to listen.

[8] Paper included in Section C of the Background papers

8. Role of Electronic Media and Communication: By Mr. Prahalad Kakkar, Director LACADIVES

Mr. Kakkar explained that he got involved in coral reefs after his first scuba diving experience, which he called a religious experience. He wanted to share this experience with as many people as possible. By nature, Indians are afraid of the oceans, so many do not appreciate corals. He started by getting people together on the Kadmat Island in Lakshadweep. He stressed the value of introducing school children to coral reefs, because, once children are exposed to them, they are enthralled by the beauty of the reefs and want to learn everything about them. One consequence of his effort was that children stopped throwing garbage into the reefs and started collecting garbage. His training programme teaches people to take greater care of the reefs. His talk was followed by a short underwater video of the coral reefs around Kadmat Island.

9. Eco-tourism Designed on the Principles of Ecology, Economics, Education and Enloyment: By Mr. Jose Dominic, Director of the Casino Group of Hotels.

Mr. Dominic started his talk by pointing out that corals need to be protected not only because they are our heritage but because pristine reefs have a great potential for attracting tourism. He explained that tourism is a double-edged sword. Tourism brings in revenue and in some areas is the only development tool. However, unregulated and unplanned tourism can lead to a number of ecologically sensitive problems and eventually destroy the very resource that people come to visit.

The Casino group started a tourist resort at Bangaram in Lakshadweep in 1988. Cottages already existed on the island. Mr. Dominic's task was to make it a profit-making venture. Setting up the resort was hamstrung by, many regulations for example no building materials could be used from the island. Everything needed for running a resort including food, had to be brought in from Cochin. Running the resort is very expensive and logistics of getting to and from Bangaram is always uncertain. However, they managed to turn the limitations into opportunities through successful marketing and the resort became a success. Holiday makers at the resort enjoy it so much, they come back to it. The same clients have returned to Bangaram for a holiday up to four times in the last decade. The lesson learnt is that conservation pays.

According to Mr. Dominic the tourism industry is definitely interested in conserving the environment but it needs advice on how to go about the task.

Mr. Dominic's talk was followed by a presentation made by. Mr. P. K. Kasali, Director of The Society for Promotion of Recreation Tourism (SPORTS) in the Islands

Mr. Kasali pointed out that the Lakshadweep Administration has restricted the entry of people from the mainland to the Islands. Entry is through special permits only and foreigners can only visit Bangaram for limited periods. They are allowed to transit through Agatti Island, which has an Airport and take a boat to Bangaram. They now

also allow foreigners to visit Kadmat. Low profile, tourism is being promoted. All tourists are given a list of do's and don'ts upon arrival. The use of plastic is banned in the islands. Building materials used in the islands are brought from the Indian mainland and garbage is taken back to the mainland for proper disposal. Local people use bicycles and two-wheelers for transportation.

10. The coral reef ecosystem of the Andaman and Nicobar Islands; Problems and Prospects 9and the World Wide fund for Nature - India Initiatives for its Conservation: By Mr. Krishna Kumar, Project Officer for the Biodiversity Hotspots Programme of the WWF-India.

Mr. Krishna Kumar provided a summary of WWF-India's contribution to coral reef conservation and research in the Andaman and Nicobar Islands. He explained that WWF-India's interest in the Andaman and Nicobar Islands dates back to the mid-80's. Since then, WWF has continued to support several initiatives through local NGO's and various campaigns that have thwarted threats to the insular ecosystem.

11. Law and Policy for Conservation and Management of Coral Reef Areas in India[10]

By Ms. Devaki Panini, Environmental Law Department at VVWF-India

Ms Panani explained that the law and policy for coral reefs in India are virtually non-existent. The only law that explicitly outlaws coral mining is the CRZ notification of 1991. Her recommendation for law reform and policy making for coral reef conservation and management in the country, concern amending the Wildlife (Protection) Act 1972 to include species of coral, in the Schedules and specifically state that the extraction of coral is prohibited under the provisions of Chapter V-A of the WPA..

12. Trade Issues of Coral Reef Products: By Ms. Fahmeeda Hanfee is Sr. Project[11] officer - Traffic India at the WWF -India.

Ms. Fahmeeda has undertaken a pilot study on the status of trade of coral reef products in India. She points out that a large amount of coral is used within the country, and does not figure in trade statistics. This domestic exploitation is mainly for building, curio collection and chemical extraction. Ms Fahmeeda said it is difficult to estimate the magnitude of trade in coral reef products. For example the United States report, import of coral reef products from India amounting for US$ 28,000/- in 1986 but no export of reef products were reported from India in that year. Ms Fahmeeda also highlighted the constraints to coral trade regulation.

The main recommendations of her study are:

- Research on the coral trade is needed,
- The department of Fisheries has to be more involved in trade issues,

9This paper is included in section C of the Back ground papers.

10 This paper is included in section C of the Back ground papers

11 This paper is included in section C of the Background papers

- Management should be strengthened and an awareness campaign concerning coral reef products started.
- Customs officers need to be able to identify corals.

Discussion: Participants posed several questions to the three speakers from WWF-India. They asked whether trade was carried out in processed products from corals Fahmeeda replied that as far as she knew, only raw material was exported.

The talk invited the following comments:

"The Wildlife Act specifies that all wild animals are protected. Since corals are not domestic animals, they should be deemed "wild" and eligible for protection."

"India is a signatory to the CITES convention. This fact should be emphasized in all literature or discussion on the subject to protect corals."

"Most of the coral reef products are exported under an illegal name. Example: sea cucumbers are exported as dry fish."

"Similar to the Coastal Zone Management Act another Act is in the pipeline called a Ocean Zone Regulation Act.

While Ms Fahmeeda says sharks are overexploited. The CMFRI research concludes that sharks are not overexploited.

Session 5: Regional Co-operation and Initiatives to work towards sustainable management and conservation of the Coral reef heritage in the SAARC Region

Workshop Participants divided themselves into three groups to discuss the following topical issues with respect to coral reef management:

Group A: Sustainable use and equitable sharing: Inventory of reef resources and Stakeholder users dependent on reef products and services in order to assess existing exploitation practices that are unsustainable and suggestions to for remedies.

Group B: Local Governance of Reef Resources and Habitats: Steps that centre and State governments can initiate to share management and conservation authority and responsibility for coral reefs with reef users and other reef stakeholders

- Mechanisms to build partnerships and alliances between government and people to manage reef resources and habitats
- Mapping confHcts and evolving mechanisms for conflict resolution

Group C: Reef Research and Monitoring for Management: Steps that the scientific community can initiate to prioritise research focus, networking and sharing of information.

- Weaknesses and strengths with regard to reef research in adding knowledge to our reef heritage
- Mechanisms to build partnerships and alliances between research institutions towards developing a regional database such as the one initiated by GCRMN
- Scientific characterisation of reef resources and its ecology

Session 6: Recommendations of the three groups

Chairperson: Ms. Amarjit K. Ahuja, Jt Secy., Ministry of Environment and Forests.

The facilitators of the three groups presented the recommendations To Ms. Amarjit Ahuja. She concluded by saying that a lot of hard work had gone into this workshop. The recommendations would be very useful for developing a policy statement to be submitted to the Ministry of Environment and Forests.

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Part 2

Background Papers

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Section A
Special Addresses

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Conservation and Sustainable Use of Coral Reefs

Graeme Kelleher[1]

Introduction

The seas of South Asia include areas of extremely high biological productivity as well as biological diversity. Coral reefs are the most biologically diverse ecosystems on earth, but they and other marine ecosystems are subject to degradation from a variety of human activities, even though it is widely recognised that their living resources are vital to the survival of many of the region's human communities. The region has a long history of human interaction with the "natural' environment both on land and in the sea. It is necessary to preserve this cultural relationship and to build on it so as to achieve ecologically and culturally sustainable use of the marine environment.

It follows that procedures to evaluate and protect the region's coral reefs must focus on both cultural and ecological attributes. This conclusion is supported by almost universal experience from around the world. Nowhere has marine management been successful where the interests, traditions and involvement of local communities have been neglected.

As a general statement, one can summarise the problems caused by human activities which affect coral reefs (and other marine ecosystems) as;

- pollution,
- overfishing,
- physical alteration of the seabed or coastline,
- introduction of exotic species and
- climate change.

This paper will briefly address the first three.

There are two major deficiencies in our scientific and administrative systems, which place in jeopardy the attainment of ecologically sustainable management and use of coral reefs. The first is the absence of comprehensive, long term monitoring programs. This deficiency prevents us from defining the level of stresses that exist now and the trends in those levels. The second is the lack of integration of planning, management and research in the coastal zone. Without integrated programs, there is little chance that nations win be able to take the actions, on both land and sea that will be necessary to prevent insidious degradation of their marine environments, including coral reefs..

For these reasons, this paper concentrates on Integrated Coastal Management (ICM) and marine protected areas (MPAs). Both these approaches, which merge into each other in the

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case of large MPA's, incorporate processes for evaluation which have proved essential in the past to achieving community understanding of issues and to generating a sense of community agreement and 'ownership" of solutions to problems and conflicts. It is on the basis of such community agreement that coral reefs can in practice be protected so that their great contributions to the biosphere and to human welfare can be sustained.

Addressing the Major Problems

*Pollution and if***s** *Sources*

By far the greatest source, of pollution of the sea is land-based human activity. Not surprisingly, the degree of marine pollution at different parts of a coastline is often closely related to the size of the adjacent human population. There are exceptions to this where, for example, a major river system discharges remotely generated pollutants into the sea.

Forms of human-induced pollution include nutrients (mainly nitrogen and phosphorus), herbicides and pesticides and their derivatives and toxic chemicals and heavy metals.

Nutrients in sewage, combined with contribution of nutrients from other sources, particularly affect coral reef ecosystems adversely, resulting in reductions in strength of calcium carbonate skeletons and smothering of corals by algae. In coral reef environments, tertiary treatment (i.e., the removal of nitrogen and phosphorus) of sewage is essential if long term degradation is to be avoided.

Soil erosion results in suspended sediments being conveyed to the sea. The resulting marine turbidity reduces the ability of corals to gain energy from sunlight and thus their ability to compete with algae.

Fortunately, the interests of farmers coincide with those of people who depend on healthy marine ecosystems. Farmers do not wish to see their lands eroded and are not happy to pay for the application of expensive fertilisers which end up in the sea. An approach which has been started in Queensland, Australia is the establishment of joint research programs, involving farmer organisations, governments, research institutions and management agencies, aimed at defining the marine problems and their causes and formulating solutions which benefit an sectors of the community as well as the natural environment,

Fishing

Virtually every international marine fishery is considered by most experts to be, overfished. The evidence of impending collapse is decreasing catch/effort ratios. Input/output controls by themselves have usually not worked because pressure from the industry prevents imposition of sufficiently stringent controls until after the point of no return in the process of stock collapse has been passed.

Destructive fishing practices such as dynamite and poison fishing not only facilitate overfishing, but also lead to the destruction of the coral reef's ability to replace the fish or to provide the other critical services on which local communities depend.

These comments and the solution to the problems apply equally at local and regional levels. A possible answer to the problems of over-fishing and destruction of habitat is to combine multiple use MPA's with traditional fishery management practices. Such an integrated process would allow the various interest groups to agree on what areas and levels of protection should be provided to preserve habitats that are critical or that are representative of major habitat types which occur within each large marine ecosystem. Such protected areas fulfil the multiple roles of providing baselines against which to measure ecological changes caused by human activity, protecting critical life stages in commercially or recreationally fished species (such as nursery or refuge areas), providing sites in which to carry out ecological research and allowing tourists and the public to appreciate and enjoy relatively undisturbed marine environments.

lntegrated Coastal Management provides the framework for the community as a whole to make decisions which both provide maximum benefits to the people who depend on coral reef resources as well as ensuring that the reef systems am not progressively degraded i.e. ICW is the key to conservation and sustainable use of coral reefs.

Physical Alteration of the Seabed or Coastline

Destruction of coastal coral reefs and their associated ecosystems for coastal development continues to occur in most parts of the world largely because these developments occur in an unplanned, uncoordinated and disintegrated fashion. Decisions are made without taking into account adverse ecological and economic consequences of destruction of natural coastal environments. Activities such as dredging, harbour construction etc change water patterns and sediment regimes, often with ecologically undesirable results.

The ecological and economic costs of these piecemeal decisions are rarely taken into account in government approval processes. There is a great need for co-ordinated, integrated planning of the coastal environment in order to achieve both ecologically sustainable development and economically rationally use of coastal resources. This planning must be based on information provided by integrated, multi-disciplinary, ecological research, which defines the interdependencies of the various parts of the marine ecosystem and the coastal zone. This is unlikely to be carried out and the results applied in practice without the involvement of key stakeholders, particularly the local community, in all aspects of planning and research in accordance with the principles of Integrated Coastal Management, which are outlined below.

Integrated Coastal Management

Marine environments are particularly vulnerable to over-exploitation because they include large areas traditionally considered to be "commons". That is, they are not owned by anyone and everyone is entitled to use Them.. Before and since Garrett Hardin's essay *The Tragedy of the Commons* (1968), there has been ample evidence that the long term effect of uncontrolled human activity on the commons is usually to destroy them. Furthermore, coasts often include areas where a diversity of incompatible activities compete for limited space and resources. In

the case of some activities, the profits and benefits are confined to minorities, while costs am imposed on the community and the environment.

Although a clear understanding of the factors involved is otten Lacking, widespread concern over the condition of coastal environments has led to demands by the Public for the right to participate in decisions affecting the coast and for better protection of coastal resources. As a result, there has been parallel Development of ICM and MPA programs in various parts of the world that actively involve the public in improving the management of coastal areas, In economic terms, these methods aim to ensure that the costs generated by one sector of society are not imposed on another sector or on the community generally.

Integrated Coastal Management is a process that unites government and the community, science and management, sectoral and public interests in preparing and implementing an integrated plan for the protection and development of coastal ecosystems and resources. The overall goal of ICM is to improve the quality of life of human communities who depend on coastal resources while maintaining the biological diversity and productivity of coastal ecosystems (GESAMP, 1996).

Expressed in this way, the goal of ICM is clearly consistent with national and international commitments to sustainable development for all environments (terrestrial and marine), from the headwaters of catchments (watersheds) to the outer Limits of exclusive economic zones (EEZ), whether or not they are subject to multiple jurisdiction.

A subordinate goal of ICM is to provide an equitable, transparent and dynamic management process that is acceptable to the community.

Introduction to a region of a country of a comprehensive ICM project is very difficult. It is often advisable to focus on a few, relatively small-scale, areas where management policies and techniques can be implemented and to postpone attempts to manage an entire coastal ecosystem until community and governments have developed the capacity to manage as well as commitment. Trial and demonstration of the effectiveness of methodology in MPAs can be an effective starting point. This is often the most responsible approach to dealing with a crisis, such as coral reef blasting, where some early action may be needed pending development of overall commitment and capacity.

Many references exist in the world's literature to the methods necessary to achieve community support for management. The criteria for selection of Marine Protected Areas which appear in IUCN's *Guide fines for Establishing Marine Protected Areas* (Kelleher and Kenchington, 1992) place strong emphasis on social (cultural) criteria. These have been the subject of careful evaluation over the past seven years in various countries and fora. They are, in summary;

naturalness;

biogeographic importance;

ecological importance;

economic importance

social importance

scientific importance

international or national significance; and

practicality/feasibility.

The criteria in full can also be found in A *Global Representative System of marine Protected Areas* (Kelleher et al, 1995).

The ICM Process

The traditional ICM process can be conceived of as repetition of a cycle of five successive stages. (Fig 1). At the end of each cycle, the stages are repeated in sequence in the next cycle. In other words, ICM is a continuing process, not a single event. It is this continuity that allows ICM to adapt to changing natural conditions and to changing human requirements, knowledge and technology.(GESAMP, 1996). The five stages are:

STAGE 1. Issue Identification and Assessment.

This stage consists of compiling, integrating and prioritising information that defines the environmental, cultural and institutional context within which the ICM program will proceed. It is the first, formal stage in the evaluation process.

STAGE 2. Program Preparation.

In contrast to the relatively rapid assessments of Stage 1, this Stage involves a more protracted planning process that may take several years.. The main purpose is to develop a management plan that constitutes 'a vision for the future' and that expresses, in realistic and tangible arms, the qualities of the environment to be achieved and maintained, the way in which resources should be allocated and any necessary changes in patterns of resource use and human behaviour.

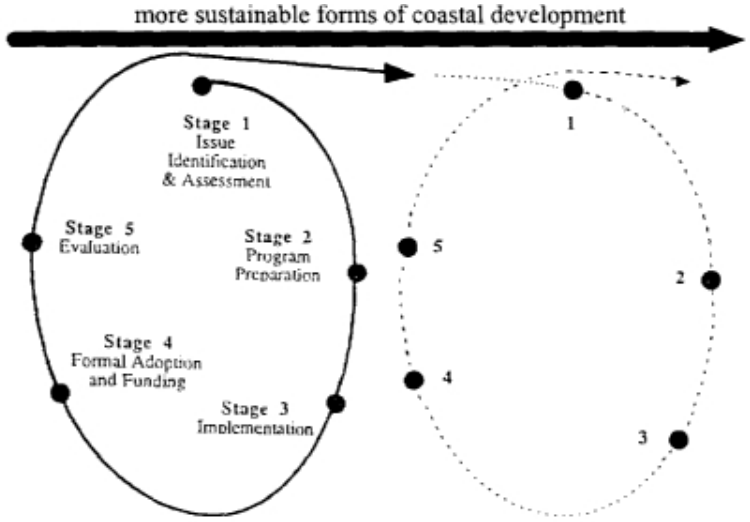

Figure 1. The stages of the ICM cycle to which sciences contribute.

The dynamic nature of ICM requires feedback's among the stages and may alter the sequence, or require repetition of some stages.

STAGE 3. Formal adoption and funding of the program.

Formal adoption of a program will generally require a 'high-level' administrative decision, for example by the head of a government agency, a minister or the cabinet, or perhaps by presidential endorsement. It will include consideration and agreement of a budget (i.e. levels and sources of funding) for each phase of the program.

STAGE 4: Program Implementation

At this stage in the ICM process the management plan becomes operational and the emphasis shifts to the introduction of new forms of resource development and use, new institutional arrangements and monitoring systems and the application of new controls, regulations and incentives.

Enforcement is an essential element of program implementation and one which clearly demands a constant supply of reliable and readily interpretable monitoring data.

Successful implementation of an ICM program invariably presents new, sometimes unforeseen, challenges and the ICM team must be able to respond to these while maintaining momentum within the core program. Some of the additional tasks to perform might include.

- conflict resolution;
- public education;
- inter-agency co-ordination;
- training of management or enforcement problems;
- infrastructural changes;
- planning and research on new areas or problems.

STAGE 5. Evaluation

This stage, where the greatest learning should occur, has been omitted or performed in a superficial manner in a great majority of coastal management initiatives. Yet, if ICM programs are to proceed through a series of cycles or generations to more sustainable forms of coastal development, this stage should be the critical juncture between one cycle and the next. The evaluation stage must address two broad questions:

- What has the preceding cycle of the program accomplished and learned and
- how should this experience affect the design and focus of the next cycle?

In other words, how has the context (e.g. environment, governance) changed since the program was initiated? This, in essence, sets the stage for repeating the assessments in Stage 1.

A meaningful evaluation can be conducted only if the program objectives have been stated in unambiguous terms and if indicators for assessing progress were identified in Stages 2 and 3,

and monitored during the preceding generation. Baseline data are essential. Many evaluations yield ambiguous results because these preconditions for assessing performance do not exist.

Integrating Science and Culture.

Public perceptions about the past, current and future status of the coastal environment and its resources, and how and why they should be managed are invaluable in developing strategies for a coastal management program. While not expressed in formal instruments such as laws and institutions, perceptions, aspirations and world views directly influence how a society manages its natural resources.

Experience has shown that, for ICM programs to work, managers and scientists must work together to achieve community support, minimising the creation of conflict and enmity and maximising opportunities to identify common interests. The generation of a commitment to a team approach is necessary for real co-operation.

Community groups must be involved in the design, conduct and interpretation of research that has the potential to lead to management decisions that seriously affect them. Otherwise they are likely to deny the validity of the research results and oppose strongly the decisions based on them.

Scientists and managers must work together continuously if science is to be relevant and applied to management decisions. lie two professions speak different languages, have different perspectives and imperatives and approach the solution of problems in different ways. They have to learn to work together effectively, for instance in posing management relevant questions in ways that allow them to be addressed by science.

Attachment 1 identifies the simple rules, in addition to those just mentioned, that have been demonstrated in practice to determine whether or not scientists and managers can effectively apply their disparate talents, methods and perceptions to the solution of marine and coastal problems in ways which protect the ecological and cultural heritage of a country, while contributing to the welfare of the human community.

Marine Protected Areas.

Marine protected areas can either form vital components of ICM or, if like the Great Barrier Reef Marine Park they encompass a complete marine ecosystem, they can be synonymous with ICM.

IUCN has had a major program to create MPAs for a number of years.- The first major phase of IUCN's program to establish a global representative system of marine protected areas was completed with the publication by IUCN in 1992 of *Guidelines for Establishing Marine*

Protected Areas (Kelleher and Kenchington, 1992) and, in 1995, in association with the World Bank and the Great Barrier Reef Marine Park Authority (GBRMPA), of the four volume report *A Global Representative System of Marine Protected Areas* (Kelleher, Bleakley and Wells (Eds), 1995).

This latter Report lists existing marine protected areas in each of the 18 major biogeographic regions into which the world's coastal seas have been divided and identifies priorities, on both regional and national bases, for establishing new MPAs or for improving management in those which exist but are poorly managed or not managed at all. As well, general recommendations are made relating to the protection and sustainable use of marine biological diversity and productivity, with particular emphasis on the need for management regimes which provide for integrated management of ecosystems, either by incorporating complete ecosystems in MPAs or by using MPAs as a component of a wider integrated system of planning and management.

Dr. Swaminathan is the IUCN MPA Working Group leader for the Central Indian Ocean (South Asia).

It is worth noting that there is a general recognition that MPAs which consist of one or more highly protected core areas, surrounded by areas (buffer zones) with lower levels of protection, offer significant advantages over the "classical" model of a small, highly protected MPA surrounded by areas that are subject to very little management. Those advantages include:

- the ability to protect the core area from effects generated outside that core area; and
- the opportunity to provide explicitly for commercial or productive activities in the buffer zones which are compatible with the protection of the core area, thus contributing to the sustainable welfare of the community and generating community support.

This model is consistent with and was developed in parallel with the Biosphere Reserve concept.

Because properly managed MPAs protect habitat, as opposed to individual species, they contribute strongly to the conservation of biodiversity, as well as sustainable use, whether or not there is significant knowledge regarding the species that occupy or use the habitat or habitats that are included in the MPA. In the face of continued acceleration in the over-exploitation of marine ecosystems in many parts of the world, MPAs represent an essential part of any strategy for maintaining marine biodiversity. However, they will not by themselves be able to constitute such a strategy, except in the rare cases where an MPA includes a complete ecosystem, because many species and habitats will not be adequately represented in any system of protected areas and because protected areas are vulnerable to the effects of human activities outside their borders. Protected areas must operate within a system of integrated ecosystem management if they are to be effective.

Local* community *involvement in MPAs and ICM.

In most countries, there is a long history of public or sectoral use of marine areas close to the coast, often for subsistence purposes. It is thus generally the case that consideration of continuing human use within and adjacent to MPAs must play a major role in their selection, design and management. Humanitarian, economic and pragmatic considerations often mean that where there is a choice of ecologically suitable areas, the dominant criteria for selection of MPA locations, boundaries and management systems will be socio-economic. Clearly, where there are few, if any alternative sites, ecological criteria should be critical and decisive.

Attempts to exclude traditional human uses from protected areas may jeopardise the physical or economic survival of the people. Community opposition will, in such cases, be very strong and will jeopardise successful management of these areas. It is often better to establish and successfully manage a MPA which may not be ideal in ecological terms but which nevertheless achieves the purposes for which it is established than it is to labour futilely to create the theoretically "ideal" MPA. The problems affecting choice of area and boundaries are reduced if political, legal and social conditions allow the creation of large MPAs covering complete marine ecosystems. Education is usually the means by which such community conditions are established. This allows integrated management regimes to be established which provide for continued human use while achieving conservation objectives.

Therefore, every effort should be made to ensure that local communities stand to gain **economically and socially from the operation** of a MPA. Developing locally owned, managed and staffed tourist enterprises is one approach that has been successful. Another has been the creation or conformation of exclusive fishing rights to local communities, thus providing an incentive to protect areas critical to fish production, such as nursery areas or coral reefs.

Capacity building and training.

In most parts of the world there is an urgent need for improvement in the capacities of local communities and of officials to manage human activities so that use of the marine environment is ecologically sustainable. In most places the greatest deficiency is in the application of the social sciences- how to inform, motivate and empower communities and officials so that they will work co-operatively and effectively to develop and apply practices that do not degrade the ecosystems on which they depend.

Under the aegis of UNEP's Regional Co-ordinating Unit of the East Asian Seas Action 91 Plan, a compendium of staff training materials for management of MPAs has been developed and applied in South East Asia (Kenchington and Ch'ng, 1994). These materials were designed specifically for application in the Region, but they form an excellent base for review for application in other parts of the world.

Conclusion

Sustainable development has been defined as "development that meets the needs of the present without compromising the ability of future generations to meet their needs". The historical approach by developed economies to the use of natural resources in the sea have failed to be sustainable largely because of the factors encapsulated in the phrase "the tragedy of the commons" (Hardin, 1968). The reliance on sectoral management, which fails to take account of effects of sectoral activities on other sectors, has shown that integrated coastal management is a necessity. Equally, the almost universal failure of traditional fishery management, based on control of fishing effort and/or catch, to prevent stock collapse and ecological damage, shows that new approaches are needed.

Marine protected areas are vital components of integrated ecosystem management regimes. They can provide almost complete protection of important elements of marine ecosystems and, if large enough, can protect entire ecosystems. The Great Barrier Reef Marine Park is the best example of the latter type of MPA, protecting an area more than twice as large as the island of Java while allowing economic activity worth more than ***$*** 1000 million per year and supporting a fishing industry worth about $300 million per year.

Marine protected areas, if they either by themselves or as part of integrated management programs encompass complete ecosystems, can provide for the needs of the present while ensuring that the ecological processes on which all life depends are protected for future generations. lie involvement of local communities in the establishment and operation of MPAs and the provision of definable economic and social benefits to those communities from the MPAs is vital in all societies.

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Rules for Scientists and Manager to Work Together Successfully in ICM,

The following summary identifies the simple rules that have been demonstrated in practice to determine whether or not scientists and managers can effectively apply their disparate talents, methods and perceptions to the solution of marine and coastal problems in ways which protect the ecological and cultural heritage of a country, while contributing to the welfare of the human community.(GESAMP,1996)

- Scientists and managers must work together continuously throughout the 1CM program. It is not enough for the relationship between the two groups of people to be sporadic or occasional;
- managers must make decisions, whether or not unequivocal scientific information is available. We have learned that managers should base their decisions on:
    - trends rather than states,
    - the precautionary principle so that where there is doubt about the outcome of the matter, the decision should err on the side of preventing environmental damage,
    - priorities i.e. management effort and scientific effort should be related to the importance of the issues. At present we are far from this,
- scientists are unlikely to address management issues unless there am incentives provided within the system for them to do so. Experience has shown that the transmission of a proportion of the funds for research through the management agencies will provide such incentive:
- managers and scientists, working together, must monitor the results of management decisions and adapt management to the results of that monitoring;
- managers will never be successful without community support. In a democratic society, governments follow community opinion. Therefore managers and scientists must work so as to achieve community support for decisions which protect the ecology of the area being managed,
- critical stakeholders must be involved in the design, conduct and interpretation of research that has the potential to lead to management decisions that seriously affect them. Otherwise they are likely to deny the validity of the research results and oppose strongly the decisions based on them.
- there are likely to be many opponents to ICM, both potential and real, in the community. Our mutual efforts will only be successful if we minimise the creation of enemies and maximise the opportunities to identify common interests. A particular example of this is the issue of run-off from the mainland of nutrients and suspended sediments. Farmers are just as interested as are those who care for the marine environment in preventing the removal of these materials from their farmlands. Our presentations and attitudes should reflect the fact that we recognise the commonality of our interests.

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Section B
Country Papers

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Coral Reefs of India: Review of Their Extent, Condition, Research and Management Status

Vineeta Hoon

Abstract

The major reef formations in India are restricted to the Gulf of Mannar, Pa/k bay, Gulf of Kutch, Andaman and Nicobar Islands and the Lakshadweep islands. While the Lakshadweep reefs are atolls, the others are all fringing reefs. Patchy coral is present in the inter-tidal areas of the central west coast of the countiy. Coral reefs in India are being damaged and destroyed at an increasing rate. They face serious problems of stress from anthropogenic pressures and interference. However we cannot be precise about how much and where, because of special difficulties of monitoring underwater. The Reef condition is generally poor and declining in near shore waters and areas of high population density. Relatively pristine reefs are located around uninhabited islands or ban-ier type reefs located away from population centers. Sedimentation, dredging and coral mining are damaging near shore reefs, while the use of explosives and bottom nets in fishing are damaging off shore reefs in specific sites. Although institutions and laws are sufficient in theoiy to manage and protect the reefs in India, authorities in the field have taken little effective action in implementing these laws.

Introduction

This paper provides a macro view of the status of coral reefs, coral reef research and Government policy towards conservation and management of reefs in India. It draws information from earlier reports prepared by Shepard & Wells (1988), Alan White & Arjan Rajasuriya (1995) and Gopinatha Pillai, (1996). More recent information is cited as available and analyzed to show the most recent trends in resource condition, use and conservation.

Field visits to the Andamans, Lakshadweep and the Gulf of Mannar were made to verify the physical condition of the most frequently visited reefs and to assess the local community attitudes towards reefs and their dependence on reefs. Discussions were held with officers from the Ministry of Environment and Forests, New Delhi, Department of fisheries; Department of environment and forests at the State level, Naval officers, Tourist resort managers and Diving Instructors, to provide a picture on the status of management of coral reefs in India and arrive at the recent trends on Government Policy towards conservation, management and monitoring of reefs. (A visit to the Gulf of Kutch was not possible due to time constraints).

To arrive at the current status and trends in coral reef research, discussions were held with scientists of premier institutions of India associated with coral reef research. Requests were also sent out to research Institutions to provide information on their contributions to coral reef research.

The paper reviews and analyses the existing information found in both published and unpublished reports on the coral reefs in India. It is divided into five sections. The first section deals with an inventory, distribution and extent of coral reefs in India. Section two deals with the status of coral reef research in India and who are the key players. Section three deals with the human impact on coral reefs. Section four discusses Government policy and approaches to coral reef management in India. Section five provides a concluding summary.

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Coral reefs are shallow water, tropical marine ecosystems which are characterized by a remarkably high biomass production and a rich faunal and floral diversity perhaps unequaled by any other habitat. Corals require certain conditions to occur and can flourish only in relatively shallow waters, exposed to direct sunlight, with optimum temperature of 23-25°c and free from suspended sediments.

The structure of a reef is formed by the calcareous skeleton that houses corals, a type of soft-bodied, radially symmetrical, marine invertebrates of the phylum coelenterata. Individuals of a colony are called polyps or hydroids. Millions of coral skeletons cemented together over a period ranging from a few thousand to millions of years give rise to such reefs (WWF1 992). Reefs can vary enormously in structure and complexity and are roughly divided into three major types.

1. *Fringing reefs:* reefs that grow close to the shore and extend out into the sea like a submerged platform.
2. *Barrier reef:* reefs separated from the land by wide expanses of water and follow the coastline.
3. *Atolls:a* roughly circular ring of reefs surrounding a lagoon, a low lying island, common in the Indian and South pacific oceans.

Inventor,', distribution and extent coral reefs in India

India with its coastline extending over 7,500 kilometers and subtropical climatic conditions has very few coral reef areas. The absence of reef in the Bay of Bengal is attributed to the immense quantity of freshwater and silt brought by the rivers (Seawell,1932). Other disincentives to reef growth are the heavy monsoonal rains and the high human presence on the coastline (Arthur:1996)

The mainland coast of India has two widely separated area's containing reefs: The Gulf of Kutch in the north west, which has some of the most northerly reefs in the world (Kelleheretal, 1995) and Palk Bay and the Gulf of Mannar (with numerous fringing reefs around small islands) in the south east.

There are patches of reef in the inter-tidal areas of the central west coast of the country. Coral patches have been recorded in the intertidal regions of Ratnagiri, Malvan and Redi, south of Bombay (Qasim and Wafer, 1979) and at the Gaveshani Bank, 100 Km west of Mangalore (Nair and Qasim, 1978). Hermatypic corals along the shore are reported from Quilon in the Kerala coast to Enayem in Tamilnadu (Pillai, 1996). Corals also occur on the east coast between Parangipettai (Porto Novo), south of Cuddalore (10°50'N, 79°80'E) and Pondicherry but these communities have not been surveyed (Ramaiyan and Adhiyapatham, 1985)

Important off shore island groups of India with extensive reef growth include the Andaman and Nicobar Islands in the Bay of Bengal and the Lakshadweep group of Islands in the Arabian sea. The Andaman and Nicobar islands have fringing reefs and a 320 km long barrier reef on the west coast. The Lakshadweep Islands are made up of atolls.

Figure 1 shows the distribution of coral reefs in India. Table 1 provides an overview of the area estimates of coral reefs in India. These area estimates were calculated from maps developed from IRS LISS II, Landsat TM (bands 2,3 & 4) and SPOT bands 1,2 and 3) FCC (DOD & SAC:1997). Table 2 provides an overview of the diversity of hermatypic corals in the Indian seas.

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Table 1: Area Estimates of Coral Reefs in the Country (Km^2)

Category	Gujrat	Tamilnadu	Lakshadweep islands	A&N Islands
Reef flat	148.4	64.9	136.5	795.7
Sandoverreef	11.8	12.0	7.3	73.3
Mud over reef	117.1	-	-	8.4
Coraline shelf	-	-	230.9	45.0
Coral heads	-	-	6.8	17.5
Live coral platform	-	-	43.3	-
Algae	53.8	0.4	0.4	
Seaweeds	-	-	0.7	-
Seagrass	-	-	10.9	-
Reef vegetation	112.1	13.3	-	8.9
Vegetation over sand	17.0	3.6	0.4	10.5
Lagoon	-	0.1	322.8	-
Sandy substrate	-	-	(67.4)	-
Reef patch	-	-	(13.4)	-
Deep	-	-	(98.5)	-
Uncertain	-		(143.5)	
Total	460.2	94.3	816.1	959.3

Ref: DOD & SAC,1997 "Coral reef maps of India," DOD and SAC, India

Table 2: Diversity of hermatypic corals in the Indian Ocean

Locality	Genera	species
Gulf of Kutch*	24	37
West Coast Patches*	17	29
Lakshadweep Islands	37	103
Palk bay and Gulf of Mannar	36	96
Tuticorin	19	21
Andaman Islands	31	82
Nicobar Islands	43	103
Total for India*	37	199

Source: Bakus,G.J (1994) and * Pillal, G(1996).

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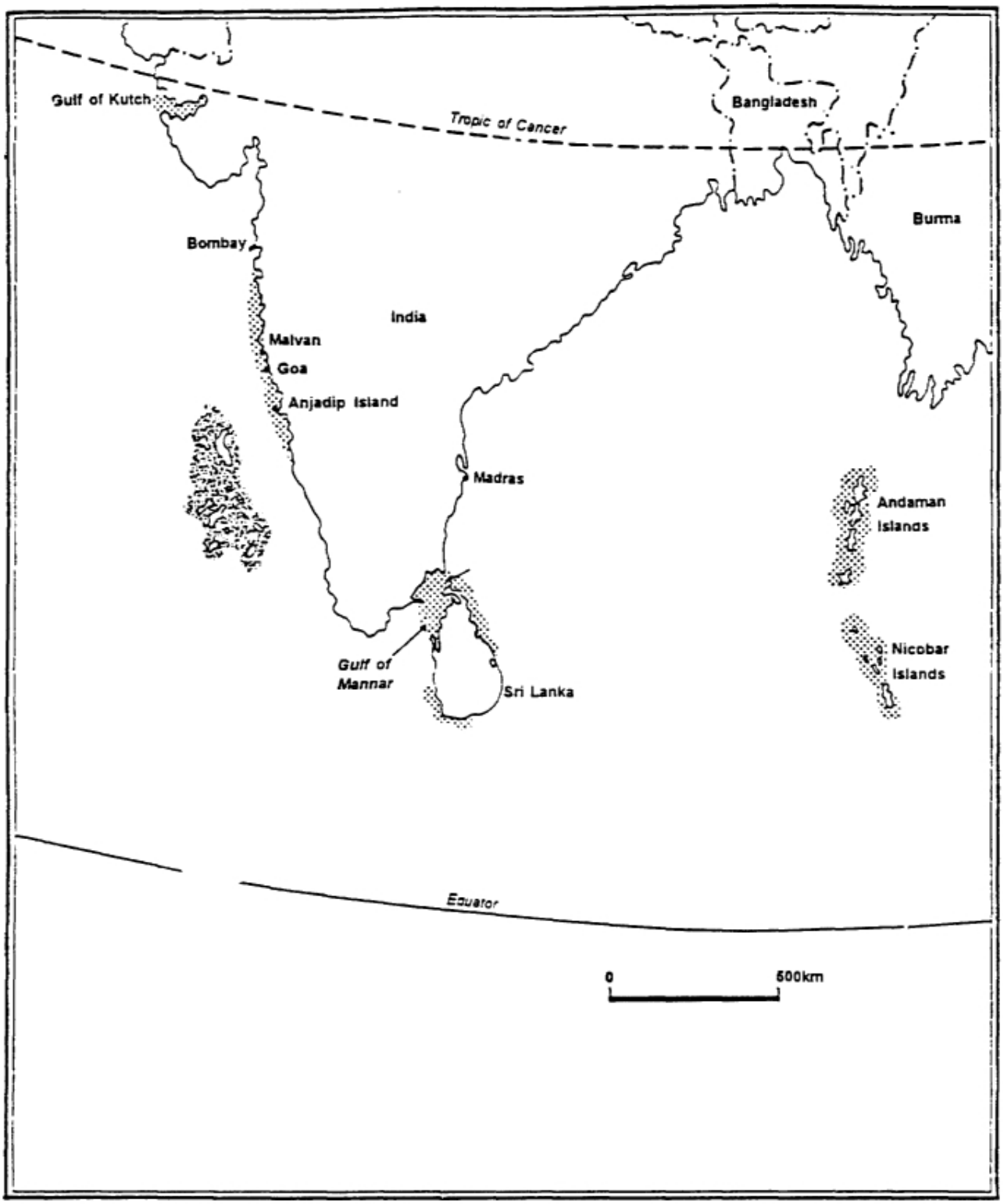
Figure 1. Distribution of coral Reefs in India



South East Coast of India

Palk Bay

Coral reefs on the Tamil Nadu coast are located in Palk Bay near Rameswaram and in the Gulf of Mannar. Palk Bay is separated from the gulf of Manner by Mandapam peninsula and Rameswaram island. The reef is centered on 9°17'Nand 79°15'. There is only one fringing reef in the Palk bay, which lies in an east-west direction along the mainland from the Pamban channel at the Pamban end of the bridge to Rameshwaram Island. This reef is 25-30km long, and generally less than 200m wide; maximum depth is around 3 m. Visibility is poor around 1 meter and it is badly affected by the north east monsoon. The reef flat is relatively broad from Pamban channel to the southern end near Ramnad and narrow from Pamban to south of Rameshwaram.

Diversity in the Palk bay reef consists of common sea grasses, sixty five species of coral have been recorded with a large number in the family *Acroporidae.* Turtles and Dugongs are found in the area. Squid breeding grounds occur near Rameshwaram.

Present status

The present day reef growth is poor and it is not in a pristine condition since it was quarried in the sixties (Pillai,1996). Satellite data shows that the reef flat is barren and is followed by sandy beach on the landward side. A small patch of reef fringes at the Dhanushkodi tip (Bahuguna A. & Nayak, S, 1994).

The Gulf of Mannar

The Gulf of Mannar reefs on the other hand are developed around a chain of 21 islands that lie along the 140 km stretch between Tuticorin and Rameswaram (Krishnamurthy, 1987; Kumaraguru, 1997). These islands are located between latitude 8°47'N and 9°15'N and longitude 78° 12' E and 79° 14'E. A detailed account of each Island is provided by Krishnamurthy (1987) and Deshmukh and Venkatramani (1995). The islands lie at an average of about 8 km from the main land. They are a part of the Mannar Barrier reef which is about 140 km long and 25 km wide between Pamban and Tuticorin (Venketesan, n.d). Different types of reef forms such as shore platform, patch, coral pinnacles and atoll type are also observed in the the Gulf of Mannar. The islands have fringing coral reefs and patch reefs around them. Narrow fringing reefs are located mostly at a distance of 50 to 100 m from the islands. On the other hand patch reefs arise from depths of 2 to 9 mt and extend to 1 to 2 km in length with width as much as 50 meters. 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 reef and its associated features is 94.3 sq km. Reef flat and reef vegetation including algae occupies 64.9 and 13.7 sq km, respectively. (DOD & SAC, 1997). Visibility is affected by monsoons, coral mining and high sedimentation load. The reefs are more luxuriant and richer than the reefs of Palk bay.

Reef diversity and resources

A detailed report on the Gulf of Mannar, their coral fauna, reef associated resources and suggestions for conservation and management was prepared by Krishnamurthy (1987). A

comprehensive account of the coral fauna of this region are provided by Pillai (1986). There are about 96 species of corals belonging to 36 genera in the Gulf of Mannar. In a recent survey only 94 species of corals have been identified (Ramaiyan V et al, 1995). The most commonly occurring genera of corals are *Acropora, Montipora* and *Porites.* The hermatypic coral harbour filamentous algae in their "skeletal framework" as well as symbiotic zooxanthellae in their soft parts. The imprisoned algae release enough oxygen to meet the entire respiratory needs of corals. Apart from algae the reefs also harbour boring sponges, molluscs, worms, echinoderms, common shrimps, and fish (Krishnamurthy, 1987). Coral associated ornamental fishes belonging to the family *Chaetodontidae,* (butterfly fish); *Amphiprion spp* (clown fish), *Holocentrus spp* (squirrel fish), *Scarus* spp (parrot fish), *Lutjanus* spp (snapper fish) and *Abudefdufsaxatilis* (sergeant Major) are abundant. (Kumaraguru, 1997). Extensive sea grass beds are present; green turtles, olive ridley turtles and dugongs. are dependent on the sea grasses.

Current Status

Pillai (1975,1978,1986,1996) presents an overview of the status of coral reefs in Mannar and the species diversity. His publication (1975) cites the example of Manali island in the Gulf of Mannar, and lucidly presents the situation in the gulf before the 1960's coral mining activities and the situation after the mining had taken place. He feels that coral growth in the Gulf of Mannar will be irretrievably stunted since the bottom is sandy and the planulae will not be able to settle (Pillai: 1996). Recent underwater survey's conducted by Kumaraguru (Personal Communication: 1997) are more encouraging. They reveal that there is luxuriant coral growth around the Mannali island and that the overall condition of the reef patches in the Gulf of Mannar is not too alarming.

Andaman and Nicobar Group of Islands.

The Andaman and Nicobar group of Islands are located in the SE of the Bay of Bengal, between 6°-14°N lat and 91°-94° E longitude. They are the emerged part of a mountain chain and lie on a ridge which extends southward from the Irrawaddy delta area of Burma, continuing the trend of the Arakan Yoma range.

They consist of 350 islands, of which only 38 are inhabited along with a number of exposed islets and rocks. The principal of these are the North Andaman, Middle Andaman with Ritchies archipelago to the east, South Andaman, little Andaman, Baratang and Rutland island. Barren island lies to the east with Narcondum and other extinct volcanoes to the north (Reddiah, 1977). The larger islands are mountainous and several are fully forested. Mangroves form extensive coverage along the shores. Annual rainfall is about 3000 mm and salinity of the waters is around 33 ppt. The coral reefs are of fringing type and except for a few investigation reports the reefs of the area still largely remain unknown. A deep oceanic ridge along 10°N seperates the Andaman Group and the Nicobar group of Islands. The general orientation is north-south.

Reef structure and corals

Almost all the islands of the Andaman and Nicobar groups exhibit narrow, linear and extensively well developed fringing reefs. Nayak et al, 1994 have published lists of the coral reefs for every island and classified them as either fringing reef or coral pinnacles. A detailed report on the corals of Andaman and Nicobar is provided by Dorairaj and Soundararajan, 1987. A total of

135 species divided among 59 genera is know to both Andaman and Nicobar (Pillai 1983). The biodiversity of fauna is yet to be ascertained. These areas have biotic elements from Polynesian, Indo Malayan as well as Burmese provinces.

The reef flats are dominated by massive *porites* and *favids* that form the chief frame builders. The shore-ward side is generally with luxuriant growth of arborescent genera such as *Acropora, Pocillopora, Seriatopora, Stylopora* etc. The reefs are rich in soft corals (Pilai, 1996). The wind ward side slopes down to a depth of 350-540 m and is subjected to the monsoonal winds. Channel reefs are found on the leeward side of the shore line.

The reef-flat occupies an area of 795.7 sq km. Coral heads and coraline shelf occupies 17.5 and 45 sq km respectively. 8.4 sq km is occupied by mud over reef. Mud deposition on the reef flat near navy bay, flat bay, reef island etc. indicates degraded condition of the reef. The deposition of mud on the reef flat is as a result of felling of mangrove trees and dearing of other forests. Conservation measures should be taken up to prevent further degradation of the reefs.(Nayak et al: 1994).

Reef *diversity and resources*

The islands have important nesting beaches for leatherback, hawksbill, olive ridley and green turtles and marine mammals such as Dugong. Several hundred estuarine crocodiles occur in densities inversely propotional to human populations (Whitaker and Whitaker 1978). Clams *Donex* spp and *Actactodea,* several gastropods and species of crabs are found in the sand and shingle of the upper littoral zone. Seagrass beds *(Cymodocea* and *Thalassia)* are found in the nearshore waters. They harbour three species of sea cucumbers, star fish and two species of brittle stars. Bivalves and pearl oysters are found amongst the subtidal dead shingles. 442 fish species are were reported for the Andaman and Nicobar (Dorairaj, Soundararajan and Singh, 1987).

Current status

Reef watch studies indicate that the reefs have been badly damaged in the recent past (Wood, 1991). This survey was limited to a few locations around the South Andaman islands. My own experience as a lay observer, snorkelling around Jolly Boy and Scuba diving at Pig head reef in Rutland Island in October 1997 was that the reef was fairly rich in life forms. In a qualitative comparison with the reefs in Lakshadweep and the Gulf of Manner I feel that the reefs were in a better condition than the Gulf of Mannar and a clOse second to Lakshadweep (Bangaram and Kadmat dive locations). One observed some sedimentation in the near shore reef and the visibility in October was around one to two meters. There is not enough recent information about the reefs around North Andaman and the Nicobar islands to provide a true picture of the current status of the reefs.

The Gulf of Kutch

The Gulf of Kutch located at 22°15'-23°40 N Latitude and 68°20'-70°40'East Longitude, is one of the indentations found on the northern side of the Saurashtra Peninsula. It has and area of approximately 7350 sq km. The Gulf which is aligned approximately E-W is about 170 km long and 75 km wide at the mouth, after narrowing down abruptly at a longitude of 72°20' it gets divided into three major creek systems at the island of Satsaida bet. The southern shore is fringed by numerous live and some dead coral reefs, islands and extensive mud flats, that dry at low tide. In contrast the northern coast is fringed by tidal flats only.

The coral formations of the Gulf of Kutch represents one of the extreme northern limits of corals in the Indian ocean. The approach to the corals is difficult due to the existence of vast intertidal mud flats which are difficult to negotiate by foot at low tide. The sudden influx of tidal waters also renders it risky to work on the exposed bank (Pillai, Rajagopalan, Varghese, 1975).

These reefs are mostly of fringing type along with offshore platform reefs, patch reefs and coral pinnacles. There are some 40 islands with patchy coral formation of which the largest is Pirotan Island. The coral reefs are in a highly degraded condition. The major source of degradation has been mud deposits on various coral reefs e.g. Bural Chank, Kalubhar, Munde ka bet and Jindra reef. Mud over reef occupies a major portion (117.1 sq km. of the reef). The reef area of the gulf of Kutch is 148 sq km and the total area occupied by the reef is 315 sq km (DOD & SAC, 1997).

Reef diversity and resources

The available data reveals that the area supports 120 spp of algae, 70 spp of sponges, 200 types of fish, 8 types of sharks, 27 spp of prawns, 30 spp of crab along with lobster and barnacles. There are two hundred species of phyllum molluscs with oysters, three species of turtles and three species of marine mammals (dugongs, dolphins and whales) (GEC:1997).

The coral fauna is comparitively less diverse when compared to other parts of India. According to a taxonomic study conducted at 15 reef locations in Kutch viz, Okha, Dholiogugar, Dona, Boria, Magunda, Savaj, Paga, Manmarudi lanmarud, Ajad, Burel reef, Dhani, Kazimbar reef, Narara reef, Goose reef and Piroten islands has reported 40 species of corals (Pillai and Patel 1988 in GEC 1997). Ramose corals such as *Acropora, Pocillopora, Stylopora* and *Seriatopora* are not found at present though semi-fossilised specimens of ***Acropora*** are found on some beaches in moderate density (Pillai, 1996).

Current status

Living coral area rarely exceed 20-30 % (GEC, 1997). The preventive measures taken in the marine national park has resulted in the restoration of the area under reef significantly.

West Coast of India

The west coast of India between Bombay and Goa is reported to have submerged banks with isolated coral formations (Nair and Qasim, 1978). Coral patches have been recorded in the intertidal regions of Ratnagiri, Malvan and Redi, south of Bombay (Qasim and Wafer, 1979) and at the Gaveshani Bank, 100 Km west of Mangalore (Nair and Qasim, 1978). *Porites, Coscinarares, Turbinaria,* some favids and *Pseudosicterastrea* are reported. All the genera recorded are massive or encrusting without any of representation of ramose forms (Pillai, 1996). Siltation is of high rate and salinity may drQp to 20 ppt during monsoon in these habitats which may restrict the growth of ecologically sensitive forms of ramose corals (Bakus et al, 1994).

Hermatypic corals along the shore are reported from Quilon in the Kerala coast to Enayem in Tamilnadu. *Pocilipora* spp is the most common genus in this area. *Accropora* is found with representation of three species. *Pseudosiderastrea* and Pofites spp are also found. A recent investigation has shown that 29 species in 17 genera of scleractinians occur in this area (Pillai, 1996).

Current status: Unknown for several of the areas.

The Lakshadweep Islands

The Lakshadweep islands lie scattered in the Arabian sea about 225 to 450 km from the Kerala coast. Geographically, the islands lie between 8°N- 12°3' N lat. And 71°E-74°E longitude. The islands consist of coral formations built up on the Laccadive-Chagos submarine ridge rising steeply from a depth of about 1500 m to 4000 m off the west coast of India. The U.T of Lakshadweep along with the Maldives and the Chagos Archipelagoes form an interrupted chain of coral atolls and reefs on a contiguous submarine bank covering a distance of over 2000 km. This ridge is supposed to be a continuation of the Arravali mountains, and the islands are believed to be remnants of the submerged mountain cliffs (P.S.B.R. James et al: 1986).

There are 36 tiny islands, 12 atolls, 3 reefs and 5 submerged banks, covering an area of 32 km^2 with lagoons occupying about 4200 km^2. Only 11 of the 36 islands are inhabited. They are Androtт, Amini, Agatti, Bangaram, Bitra, Chetlat, Kadmat, Kalpeni, Kiltan, Minicoy and the headquarters at Kavaratti. The Minicoy island is separated from the rest of the islands by a 180 km wide stretch of sea known as the nine degree channel. Kavaratti is the administrative headquarters. Agatti houses the only airport and airstrip. A resort catering to international tourists has been functioning in Bangaram since 1988 and a resort catering to national tourists with a dive school has been set up at Kadmat in 1995. In addition tourist huts have been erected at Kavaratti, Minicoy and Agatti.

The islands are flat and scarcely rise more than two meters. They are vulnerable to storms and sea erosion. They are made up of coral sand and boulders which have been compacted into sandstone. These islands have a warm humid climate (air temperature 17°-38°C, humidity 70%). The surface water temperature varies between 28-31 °C.While the salinity ranges from 34-37% Ground water is found a couple of meters below the land surface and is replenished by an annual rainfall of about 150 cm during the south west monsoon from June to September.

Structure of the Reef

Coral reefs of the islands are mainly atoll except one platform reef at Andreth. Almost all the atolls have an orientation of NE-SW with the low lying island on the east, a broad well developed reef on the west, with a lagoon in between, connected to the open ocean by one or more channels.

The reef flat occupies 136.5 sq km area. Sea grass occupies 10.9 sq km and lagoon occupies 309.4 sq km (Bahuguna, A and Nayak, S, 1994). The depth of the sea increases outside the coral reef and can reach upto 1500-3000. Andrott is the largest isTand with an area of 4.84 sq km and the only island that does not have a lagoon. Bitra with an area of 0.10 sq km is the smallest in land area but perhaps has the most magnificent lagoon. All the islands lie north to south, excepting Androth which lies east to west. The distance betweeen them varies from 11 km to 378 km.

On the seaward side the reef slopes into the sea. The first plateau is found around a depth of 5-6 mts. The second plateau with sandy patches is found around 25 mts - 30mts (Andreas:1997). During high tide water exchange takes place between the lagoon and the open sea over the reef. The lagoons have sandy bottoms with scattered coral boulders and pinnacles followed by extensive sea grass beds at the landward side.

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Reef diversity and resources

A detailed report on the islands, their coral fauna, reef associated resources and suggestions of conservation and management are set in a detailed report based on an intensive survey of scientists by CMFRI (bull No 43, 1989) and Rodrigues (1996). The coral fauna of Lakshadweep is known to harbour a total of 105 species divided among 37 genera (Pillai 1996), Rodrigues (1996) has recorded 29 new records for species in Lakshadweep. The lagoon and reef flat faunal elements are dominated by *Accropora* spp., *Pocillopora* spp., *Porites* spp. and massive and encrusting favids. *Psammocora* spp is common in the northern islands. There is a profusion of blue coral *Helipora coerulea. Miiepora* spp. forms the dominant element in the lagoon. One finds a latitudinal difference in coral fauna assemblage in the lakshadweep. Minicoy has some elements such as *Lobophyllia* and *Diploastrea* that are common to the Maldives but rarely found in the northern lslands. Similarly the genera *Montipora* and *Echinopora* recorded from the northern group of atolls are not recorded in Minicoy (Pillai, 1996).

86 species of macrophytes, 10 species of Anomuran crabs, 81 spp of Brachyran crabs, 155 spp of Gastropods, 24 spp of bivalves, 13 spp of sea stars, 6 spp of brittle stars, 23 spp of sea cumbers, 15 spp of sea urchins and 120 spp of fish are found in the lakshadweep (Rodrigues, 1996). The green turtle and the hawksbill turtle are also found in all the islands. They graze on the sea grass beds and are hunted for their fat.

Current Status

The most recent scientific ecological survey of the islands has been conducted by Rodrigues (1996). This is based on transect studies conducted in the Lagoons in 1993,1994 and 1995. He reports that corals on the reef flats and lagoons of uninhabited islands was diverse and dense however in most inhabited islands their status can be classified as endangered.

Qualitative observations of Andreas who runs a dive school in Bangaram and has been diving off Bangaram, Agatti and Peru mal Par for the last nine years, is that the corals are growing and that he had observed some damage due to *Acathansterplancii* attack in a portion of the reef five years ago and that today it is one of his favorite dive locations. The fact that the same diving tourist have made even upto four return visits to Bangaram in the past decade also speaks for itself.

Qualitative observations of two dive instructors at Kadmat is that diving is quite fantastic. They however have also observed Acathanster plancii in the dive area and in April 1997 removed two hundred in a matter of twenty minutes of diving time.

There is a unanimous feeling that one had to take proper controls for sewage disposal. The contamination from fecal matter and kitchen waste in the lagoons alone can take its toll of the coral reef.

2. **Status of Coral Reef research in India**

The major institutions involved in some level of research of Coral reefs and problems related to management and monitoring are: Department of Ocean Development, GOI, The Space Applications Centre, Ahmedabad, The Zoological survey of India, Central Marine Fisheries Research Institute, Madurai-Kamaraj University, CAS, at Parangipettai, Annamalai University, Centre for Earth Studies, Trivandrum, Institute for ocean Management, Madras, National Institute of Oceanography, Goa and the World Wide fund for Nature-India.

The Space Applications Centre at Ahmedabad has used remote sensing data to assess the area under coral reefs and prepare a coral reef atlas of India.

In the fisheries institutes the research focus has been on studying marine fish habitats, fish catch and the economics of fish catch. In areas of coral reefs they have focused on studying the ecology of the coral reefs with a focus on fisheries of commercial value; such as ornamental fish, holothurians, live bait availability for tuna fisheries etc. Reliable base-line data does not exist on the extent of live coral cover, species diversity and abundance or status of the reef. This could be mainly due to the paucity of facilities and trained manpower to monitor and collect underwater data. There is also very little hard data on the impact of human activities on coral reefs and the relationship between the human economy and coral reef ecology has not received much emphasis.

The Department of Ocean Development has recently received a grant from the world bank, to prepare a GIS based information system for critical habitats for coastal ecosystems. This will include all the coral ecosystems in India including the patches and submerged banks found along the West coast of India. The institutions involved in carrying out this huge task include: Mangalore university, Gujrat Ecology Commission, Cochin University, NIO, Goa, NlO, Bombay, Anna University, Annamalai University, Andhra University, Zoological Survey of India, Madras, Madurai-Kamaraj University, CARI, Andaman and Nicobar Islands, CMFRI and Botanical Survey of India (Ramachandran:per.comm. 1997).

Gulf of Mannar and Pa/k Bay

The Reefs in the Gulf of Mannar are fairly accessible to researchers from Tamilnadu and so have been well studied. The CMFRI has regional offices at Mandapam and Tuticorin and have carried out pioneering work related to surveys of the islands and the reefs. An effect of environment and human interference on the coral reefs of Palk bay and Gulf of Mannar has been carried out by Pillai in 1975. A study of the different species and genera of corals found in the Gulf of Mannar has been carried out by Pillai in 1986.

The Centre for Advanced study in Marine Biology, Annamalai University has also carried out several studies on the ecology and status of the reefs in the Gulf of Mannar.

The Madurai-Kamraj University is involved in an underwater survey using scuba equipment, of the islands of Gulf of Mannar in relation to studying the ecology of ornamental fishes of export value in the Gulf of Mannar. They have established Scuba diving facilities with all the necessary equipment to carry out underwater ecological studies in the Gulf of Mannar. These facilities will be utilized for man-power development in this field of practical significance. (Kumaraguru, 1997).

With the emphasis on people centered development and sustainable management of biodiversity, maragement research has become a priority. The MS. Swaminathan Research Foundation has recently received GEF funding to develop a management plan for the Gulf of Mannar. The project report is being prepared jointly with the Tamilnadu Forest Department. The focus of the plan has to be on co-management initiatives involving participation by local people.

Andaman Islands

Several studies in this region have been undertaken by Zoological Survey of India (ZSI), National Institute of Oceanography (NIO), Central Agricultural Research Institute (CARI) and Central Marine Fisheries Research Institute over the last five decades.

The Zoological Survey of India (ZSI) and the Central Agricultural Research Institute (CARI) are the principle Scientific institutions who are located at Port Blair and are currently involved with coral reef research. At CARI while the research focus is on agriculture and culture fisheries, pioneering work on coral and related species taxonomy has also been carried out.

National Institute of Oceanography (NIO) and Central Marine Fisheries Research Institute (CMFRI) regularly sends teams of scientists to the islands to conduct surveys and research. The CMFRI has published a special issue on the Andaman and Nicobar islands (CMFRI Bulletin 34, 1983) based on the detailed studies carried out by their scientists. This includes a detailed report on the islands, their coral fauna, reef associated resources and suggestions for conservation and management.

The Department of Ocean Development also has an office in Port Blair and has funded both Space Application Centre at Ahmedabad and the Anna University of Madras to prepare GIS Maps for the coral reef areas of the Andaman Islands. The Anna University has prepared but not published 1:25,000 scale of maps for the Andaman islands. The Department is also conducting a programme for the rejuvenation of coral reefs in A& N Islands through Andaman and nicobar Centre for Ocean development Ocean news, 1997)

Two environmental Non Governmental Organisations, Society for Andaman and Nicobar environment (SANE) and A &N Environmental Team (ANET) have also independently carried out a few studies on the status of reef for select areas of the Andaman islands. The research focus has now shifted from carrying out taxonomic studies of corals and related species to extensive surveys and ecological studies of the coral reef and monitoring reef health. A status report of the corals of Andaman and Nicobar has been carried out by CARI, (Dorairaj and Soundarajan, 1987). The most surveyed area are five reef patches of the Mahatma Gandhi Marine national Park at Wandoor (Arthur, R, 1996, Dorairaj, K, 1994, Wood E, 1988). No research on human-reef interactions exists. However impacts of human activity such as logging on reefs has been studied (Sounderajan & Whitkar, 1989). The INTACH - Andaman chapter have collaborated with SANE to produce public awareness pamphlets for corals and other endangered marine animals. Independent studies of the reefs have also been carried out on a reef watch program (Wood C, 1991)

With the emphasis on people centered development and sustainable management of biodiversity, management research has become a priority. ZSI has recently received GEF funding to develop a management plan for the entire Andamans and Nicobar groups of islands. The focus of the plan has to be on co-management initiatives involving participation by local people.

The Lakshadweep Islands

The fauna and flora of Lakshadweep islands have attracted the attention of many naturalists, one of the earliest being Dr. J.S. Gardiner (1903-1906) who explored the Maldives and Minicoy the southern most island of the Lakshadweep group. During the last nine decades, several studies in this region have been undertaken by the National Institute of Oceanography, Zoological Survey of India and the Central Marine Fisheries Research Institute. The ZSI carried out extensive surveys in 1982-87 and published in 1991, a volume on the fauna of Lakshadweep (State fauna series 2). Likewise, the CMFRI carried out a survey from January to March 1987 to study the fishery potential which culminated in the publication of a special

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issue on Lakshadweep (MFIS No 68, 1986) and (CMFRI bulletin 43, 1989). Studies conducted in the Lakshadweep so far have recently been compiled by Bakus (1994.) a study of the literature however reveals that most available information is qualitative in nature and there is no published quantitative data, on densities and community characteristics of the fauna and flora of the Lakshadweep. Quantitative data on the distribution and abundance of corals and other associated organisms on a reef flat at Agatti reef flat are now available (Rodrigues, 1996).

In the UT of Lakshadweep CMFRI has located a field station at Minicoy Island, while the focus of their work is related to the commercial fish resources of the Lakshadeep seas, pioneering work in coral and related species taxonomy has also been carried out.

Centre for Earth Studies, Trivandrum has prepared several reports relating to erosion and coastline changes. The Space Application Centre at Ahmedabad has mapped the coral reefs and atolls for the entire Union territory. The A.M.M. Murugappa Chettiar Research Centre, Chennai carried out a study on Energy use in the Islands with an emphasis on time and Energy availability for women's needs. (Hoon V and Seshadri, CVS, 1990). The MS. Swaminathan Research Foundation, Madras conducted a case study on Gender and Biodiversity in the Lakshadweep islands. (Hoon, V, 1997).

The M.S. Swaminathan Research Foundation is carrying out a project on developing an Agri-biodiversity Conservation Corps of local volunteers. In May 1997, ten volunteers were trained in simple techniques of underwater transect surveys to carry out regular monitoring of the underwater reef biodiversity.

Gulf of Kutch

The Gulf of Kutch has been studied extensively by scientists from the National Institute of Oceanography, Goa. Taxonomic surveys have been carried out with the help of Gopinadha Pillai from the CMFRI. The Space Application Centre, Ahmedabad has prepared maps including coral reef areas with the help of satellite data. The Gujrat Ecology Commission, a Non Governmental Organisation has been active in carrying out field research based on socio-economics in this area and has also been active in developing and carrying out awareness programmes among students, policy makers and the forest department.

3. Human and economic impact on the reef systems

Reefs resources have traditionally been are a major source of food for local inhabitants and of major economic value in terms of commercial exploitation. Reefs in India provide economic security to the communities who live alongside them. In the villages around the Gulf of Mannar the traditional fishermen have been catching reef fish, diving for pearls, sacred chanks, holothuria and sea weed for centuries. In Lakshadweep the reefs are a safety net for food in the monsoon season and also provide the live bait that forms the basis for the commercial Tuna Fishing.

Perceptions of Coral reefs differ according to the priorities of the people in contact with the reef. Traditional fishers and people whose livelihood is dependent on the reef perceive reefs as a safety net in their food production system. For them they are happy hunting grounds where clams, octopus, mollusks and other rich food organisms live and provide them with food and cash income. They also perceive the reef as a defense against the erosive forces of the ocean

waves. These people would never willingly destroy the reefs since they realize that they have a long term dependency on them and any destruction of the reef would be destroying the goose that lays golden eggs.

Navigators dread reefs and associate them with ship wrecks. Naval officers only see them as hindrances that come in their way of carrying out their navigational duties. They consider them as hazard zones on their navigation routes. Scientists, scuba divers and snorkeling tourists perceive reefs as places of mystery and wonder. How the corals grow and reefs develop have been questions that have excited their imagination and stimulated their enquiries for several centuries. Mainland communities see reefs as a storehouse of limestone to be extracted for the cement and lime industry. These different perceptions and the fact that reefs are common property resources can often lead to conflicts in resource use on reefs. It also raises special questions on how to effectively manage and monitor coral reef resources.

To have an understanding of the human ecology of the coral reef islands it is important to understand the relationship between local populations and the reef resources. These are the people whose livelihoods become endangered when the reefs are provided protection under protected areas such as biosphere reserves, sanctuaries or marine parks.

One also has to take into account the corporate sector such as cement and lime industries and their exploitative extraction of the reef and the new sector that is coming up in live ornamental fish and reef fish trade. Coastal populations even if they do not live off the reefs will have a effect on the reef habitat merely by their presence. Sewage disposal is becoming one of the biggest management problems both at the Gulf of Mannar and the inhabited islands of Lakshadweep. All this gives us an idea about interactions between the communities and their ecosystem. It also gives an idea about the political situation and answer questions such as: Who are the main stakeholders of the coral reefs?, are their conflicts arising due to different priorities of users? What are the perceptions of the local population *vis-a-vis* coral reefs etc.

Pa/k Bay and the Gulf of Mannar

There are about 47 fishing villages along the coast of which 38 are in the Ramanathapuram district and nine in V.0 Chidambaranar district bordering the Gulf of Mannar park area. Exploitation of fishery resources in the inshore waters have been the sole occupation of hundreds of fisher families along the coast for centuries. The reefs are used to carry out, reef fishery, chanks and pearl fishery, ornamental shell trade and illegal mining of corals. The villagers around Palk Bay harvest holothurians. Other harvesting activities include chanks and milk fish fry. Turtles are being harvested up to a 1000 individuals annually; Dugongs are also taken.

There are about 50,000 fisher-folk in these villages of whom more than 12,000 are active fishermen. They employ traditional craft such as catamarans, valians, masula boats, dug out canoes and mechanized boats for their operations. The fishing gear used for fish capture are trawl nets, gill nets, shore seines, drift nets, long lines, traps and others. The average annual fish landings from the Gulf of Mannar in the period 1989-94 are around 46,000 tonnes of demersab fishes and 33,000 tonnes of pelagic fish. These are banded in 33 landing centres along the coast bordering the park area. (Deshmukh S & Venkatramani, 1995). Trawl net fishing and gill nets used for catching lobster causes damage to the reefs around the Tuticorin group of islands.

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My own observations at Mandapam in November 1997 are that here are three hundred families from seven villages who are totaTly dependent on reef fisheries. They place a fish trap *(Kood)* in the patch reef areas in the Gulf of Mannar and every morning go to collect the fish trapped in the trap. Two men go together in a small dug out canoe one dives in to bring the trap and the other in the boat empties the trap and returns it to the diver to place in the reef flat. Shrimp heads are used for bait and trap fishing seems to be restricted to the people who have access to these shrimp heads. These fishermen fish in the Gulf of Mannar during the NE monsoon and for six months in Palk Bay. Personal observations show that this method of fishing causes no harm to the corals.

Studies carried out by various authors indicate severe coral exploitation in the Gulf of Mannar and the Palk bay region. Corals were used in large scale as raw material by the calcium carbonate industry. Extensive areas were leased by the government for coral mining and large scale quarrying was taking place until 1979 when the leases were stopped. However illegal removal still takes place. Coral mining is centered on the reefs of the Tuticorin group of Islands. Pillai (1973) estimated the annual exploitation of the Gulf reefs to be 90,000 m^3. Venkata-ramanujam et al (1981), show that annually about 15,000 tonnes of coral stones are removed from four islands near Tuticorin alone. Acropora formosa fragments are collected for lime preparation; In tuticorin about 30 boats are involved in this activity and collect over 80,000 m^3 annually. The genera Porites and Favia the principal reef builders and the most abundant massive species on the reef are quarried for use as building blocks, the construction of roads and for the lime industry. It is estimated that the amount of coral removed over 7 years from Mulli, Talaivi and vali in the Kilakarai group is equivalent to a strip of reef 1 m deep x 18.5 m wide x 10 km long (Shepard and wells, 1988). The net result is that the growth rate of their removal and as present day exploitation is largely confined to water less than 1 m deep, the destruction of live corals is extensive, up to even 100 % in localized sites (Wafer, 1986, Ramaiyan et al, 1995)

Other activities in this area include sea weed collection by local people (mainly women) for supply to institutions and agar-agar manufacturing units. Corals especially the branching type, chanks and shells are collected for selling as curios for the tourist market along the coast. Tourism is not well developed and tourism associated disturbance is minimal.

This being an excellent area for various rare marine specimens, students and scientists tend to be over enthusiastic about collecting zoological specimens. Krusadai and nearby islands are the worst hit.

Population pressure around the Gulf of Mannar and the untreated sewage disposal is causing bacterial infection. Disposal of sewage including the fecat matter and urine due to defecation on the beach is causing problems since it ends up in the Gulf of Mannar. Coliform count even around the islands is high. With the high growth rate of the population in the coastal areas, both due to migration and natural increase these problems are going to be more severe.

All these activities are no longer sustainable and have a serious impact on the breeding habitats of several species and the reduction of density of the commercially exploited species.

Andaman and Nicobar Islands

According to the 1991 census the population of the islands is 2,79,111 and the estimated population by the year 2000 would be 4,05, 100 of this the total tribal population is only 23, 704

of which the Nicobarese alone are 23, 000 and the other four tribal groups Great Andamanese (38), Jarawas (200), Onges (118), Shompens (250) and Sentenilese (98). Very little documented information exists on the relationship between the original tribal population and the coral reefs. From the artifacts available at the Museum in Port Blair one can gather that their subsistence activities do include reef fisheries. Fishing was carried out by using bows and arrows by the Andamanese and spears by the Nicobarese. (Silas, 1983).

The population mainly consists of settlers from the mainland who came after the establishment of penal settlements in 1857 (Khan I.P & Kala, N 199?). Clearly the greatest impact of human activities on reef resources will be due to the demands of the settler populations, government servants, business opportunists and tourists who visit the islands for pleasure.

It is difficult to provide a good status of the human and economic impact on the reef systems in the Andaman and Nicobar Islands since the entire reef stretch is not regularly monitored or managed. One can only hazard a guess that the maximum impact is in the South Andaman region which is densely populated. Pollution from the Chatham saw mill is asiphixating the reefs around Chatham. Logging derived siltation is smothering the reefs (Soundararajan, R, Whitaker, R, and Acharya, S. 1989). The increasing population densities and rapid industrialization have also resulted in increasing discharge of sewage and effluents into the ecosystem.

Tourism is yet to realize its potential and tourist pressure is limited to two areas regularly visited, Jolly Boys and Red skin. Some tourist induced damage of reefs can be seen on these reefs. Tourism derived damage is caused by trampling of corals by snorkelbers and swimmers, and anchoring of boats. Glass bottom viewing is also available within Wandoor national park. There are four dive shops in Port Blair, a rapid assessment shows that in the peak season which last four months around four to six hundred scuba divers dive every month in Wandoor around . Pig head reef off Rutland island and Havelock island.

Unplanned collection of shells and corals for ornamental trade and commercial exploitation of fishes also contribute to reef damage. It is now very rare to find the Turbo shell which was once abundant.

It is also difficult to give an account of the dependence of local communities on coral reefs and reef resources since there is no published literature from this angle. The anthropological studies on the tribes have mainly been with regard to their material culture. It would therefore be of interest to carry out a socio-economic study based on stakeholder analysis vis a vis the coral reefs. As majority of the population of the Andaman and Nicobar Islands have been settlers their knowledge of the coral reef ecology is very minimal. The majority of the settlers came from Bengal and prefer eating fresh water fish to marine fish. The indigenous knowledge component if any lies with the tribal population whose voices are not heard.

Gulf of Kutch

Commercial exploitation of coral sands by the cement industry is considered to be the main cause of the destruction of corals. Felling of mangroves has also attributed to the increase in sediment load arising out of enhanced erosion of exposed mud flats. Pirotan island represents the northern limits of the coral growth with living corals confined to a small area along the northern side of the island. The eastern side exhibits vast areas of dead corals giving a clear indication of mass mortality (GEC, 1977).

Fishing in the park-sanctuary area causes stress on the coral reefs owing to the unsustainable practices that are now popular such as killing fish through chemicals and concentration of fishing activities in the near shore areas owing to the rise in population of fishing communities. Fishermen increasingly use near shore areas, fixing their nets on coral reefs, collecting shells, corals and other marine life for sale. Breeding grounds are over exploited by the use of fine meshed nets that also cause unnecessary killing of commercially non-valuable species that are indiscriminately netted (Nambiar, Oza and Kacher, 1995).

The Lakshadweep Islands

The major economic activity of the Lakshadweep islands is oceanic tuna fishery. Reef fishery have traditionally been exploited to a very low subsistence level. The lagoon and reef patches are however are extremely important to the survival of the islanders since they provide them with a safety blanket for food security during the monsoon season. During this season the fishermen are not able to venture into the open sea and the only food the islanders can bank upon is coconuts and the fish catch available in the lagoons (Hoon V, 1990, 1997).

Table 3: Agencies and Users of the Reef

1. The Department of Fisheries	Fishing research, collection of species for Museum, Aquarium for scientific purposes and awareness creation.
2. *CMFRI*	Collection of specimens for scientific research purposes
3. Harbour works department:	Mainly for surface transport: dredging and deepening of navigational channels.
4.Port Department	Provide anchoring buoys for mooring ships and boats and conduct servicing of the vessels.
5. Public Works Department:	Provide tetrapods to stall sea erosion on the island
6. Society for Promotion of Recreation and Tourisms (SPORTS)	Tourism promotion, takes tourists into the lagoon to snorkel, scuba dive and use glass bottom boats to view the corals and associated fish life.
7. Department of Science Technology and Environment,	is the nodal and moderating department. They conduct an environment Impact assessment on the 9th five year plan of the Administration of Lakshadweep. Approve the coastal zone Management Action Plan of Lakshadweep.
8. The islanders	building materials, reef fishing and deep sea fishing
9. Tourist	By there very presence add quantities to the waste disposal and sewage problems

The islanders have developed several traditional tools to capture fish and extract resources from the lagoon. They capture fish by using nets, fish traps, wounding gear and ingenuity. Pole and line fishing for tuna has gained popularity in all the islands. The fishermen use mechanized craft to carry out tuna fishing operations outside the lagoons. However the tuna fisheries are also dependent on live bait. These are one variety of coral associated fish, found only in the lagoon. Hence indirectly the islanders are completely dependent on reef resources for their survival.

The lagoon and reef flats are looked upon as common property resources and therefore equity in resource sharing is an important issue. For example discipline has to be maintained in case more than one person wants to do net fishing. Only one net is placed in the lagoon and the catch is shared by all the parties concerned.

Coral and shingle extraction: The islanders make bricks out of coral shingle and use them for house and building constructions. The islanders know that it is the reef that protects the islands and rarely collect boulder coral for individual use-. They rely on shingle collection on the lagoon side. They mix cement with the shingle to make bricks and build their homes.

Developmental and recreational activities: blasting and dredging in lagoon for navigational channels leads to coral mortality. Tourism poses problems of garbage and sewage disposal, anchor damage by tourist boats, collection of souvenirs

Population Pressure: for the isolated island economy of Lakshadweep, pressure of population is the prime concern. At the present rate of growth, the average density which at 1616 per sq kilometers is the third highest in India, will reach socially unacceptable levels in the near future. Even subsistence use will not be sustainable in the long run. Garbage and sewage disposal will cause the main threats to the reef. Right now the Toilets are connected to a septic tank and the waste water ultimately finds its way into the lagoon or open sea and creates both unhygienic conditions for the people and upsets the balance of nutrients in the lagoon, causing algal growth to compete with reef growth.

4. Institutional Jurisdiction and Management Responsibility

The coral reefs of India come under the jurisdiction of the department of forests and wildlife and it is their responsibility to monitor, manage and conserve these fragile eco-system. The Ministry of Environment and Forests is responsible to develop an action plan to manage the reef resources and issue guidelines for the sustainable utilization of coral reefs. These plans have been under preparation since 1986, they are however yet to be published. The management of coral reef ecosystems has also been affirmed in India's National Conservation Strategy and Environment Action Plan. (UNDP, 1997).

The National Committee constituted for conservation and management of wetlands and mangroves also advises the Government on policy issues rebated to conservation and management of coral reefs. State level steering committees have been set yp for the formulation and implementation of the Management Action Plans for the identified coral reef areas. Management plans for the Gulf of Kutch Marine National Park and Sanctuary has been prepared by the Conservator of Forests in 1994. Recently the Ministry of Environment and Forests has sanctioned preparation of management action plans for the Andaman and Nicobar and Gulf of Mannar coral reefs (MoEF, 1997).

The wildlife protection act 1972 as amended up to 1991 covers various important aspects with regard to protection of wild animals and certain plants. Corals are not as yet covered by this act. It is important to stress here that coral reef areas come under the jurisdiction of the state Wild life department only when the area is deemed a protected area.

The coastal regulation zone notification, 1991 offers the only legal protection to all coral reefs and In this coral reef areas come under **the CRZ1 category. A special category CRZ 4 has** been prepared for the Islands of Andaman, Nicobar and Lakshadweep. Norms for regulation of activities within the CRZ state that corals and sand from beaches and coastal water shall not be used for construction and other purposes. Dredging and underwater blasting in and around coral formations shall not be permitted. Section 7 (2) also states that construction of beach resorts/hotels shall not be permitted in ecologically sensitive areas such as marine parks and coral reefs (Notification S.O114 (E) of 19 February, 1991).

Table 4: Protection Status of Coral reef areas

Locality	Protection	
	established	proposed
Gulf of Kutch	Marine National Park (110 Sq Km -1982)	Nil
Lakshadweep Islands	collection of corals is banned.	Nil
West Coast Patches	Nil	Sanctuary proposed at Malwan - South of Bombay.
Palk bay	Nil	Nil
Gulf of Mannar	Gulf of Mannar Biosphere reserve.	Nil
Andaman Islands	Mahatma Gandhi Marine national Park at Wandoor - **234** sq km.of islands and reefs.	Ritchies Archipelago
Nicobar Islands		Nil

While the formation of protected areas and the CRZ notifications and Acts are laudable one finds that there seem to be problems in trying to implement them. These problems are magnified due to the difficulties arising out of monitoring coral reefs and lack of trained departmental staff to carry out these activities. A good example is that coral reefs in protected areas have now come under the control of foresters and Wildlife specialists, who have very little understanding of coral reef ecology and many of them have also never seen a reef first hand. They therefore are only following a protectionist policy where possible and banning the entry of people into the protected areas.

Palk Bay and the Gulf of Mannar

The Government of Tamilnadu has banned the quarrying of massive corals; dead corals on landward sides can be extracted under a lease. Collection of marine organisms are allowed only

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for scientific purposes around Krusudai island. Management responsibility of the protected areas and marine biosphere lies with the state department of forests and wildlife. No management or legal protection exists for Pabk Bay.

Gulf of Mannar has been declared a Marine Biosphere Reserve. All 21 islands have been notified as reserve lands under sec.26 of the Tamil nadu Forest Act. Notification of these islands and the sea around the island up to 3.5-5 fathom deep, as a national park under the provisions of the wildlife Protection Act 1972 has also been published. Dugong hunting has been banned and awareness created among fishermen.

Zoning for tourism development; education and scientific purposes have been recommended for total protection of marine life including dolphins, turtles and sea weeds (Krishnamurthy, 1988).

The M.S. Swaminathan Research Foundation and the Tamilnadu Department of forests are currently in the process of developing a management plan for operationalising the management activities of the Gulf of Mannar Biosphere Reserve.

Andaman and Nicobar islands

All the coral reefs included under the National Marine park status come under the jurisdiction of the Department of Forests and Wildlife. The unprotected area falls under the purview of the department of fisheries. The department of wildlife and forests lack expertise in managing marine national parks and have yet to develop a strategy for the management and monitoring of coral reef ecosystems. They follow a protectionist policy and restrict entry of people into the parks. Tourists are allowed to visit only the Redskin and Jolly boy islands within the national park.

There is a ban on gathering corals and endangered molluscs however the corals are not included in the wildlife protection act. It is therefore difficult to take action against offenders outside the national park. They cannot be convicted and only the material gathered is confiscated by the department of police. Tourists are not allowed to collect shells, corals etc. for souvenir purposes.

Gulf of Kutch

The Gulf of Kutch including 42 islands along the coast of Jamnagar was declared India's first marine protected area' through a series of notifications between 1980 and 1982. The first notification dated 12-8-80 made a sanctuary of approximately 221 sq. Km and it was later extended by a second notification dated 20-7-82 to include 237 sq. Km more (Nambiar et al, 1995). The national park comes under the jurisdiction of the Department of Forests.

Though there is a ban on gathering corals and endangered marine species, the laws relating to the ban are vague and difficult to implement.

Lakshadwoep islands

The Lakshadweep islands do not boast of a protected area, however this is India's only atoll Union Territory. The administrator therefore declared at the National Development Council meeting in January 1997 that The corner stone of all polkies in the 9th plan is going to be ecology and environment" This declaration is based on the realization that the long term survival of the Union Territory depends upon the protection, preservation and conservation of its unique and extremely fragile eco-system. All development plans in the islands have to be ecologically compatible and must avoid ecological stress.

The Department of science, technology and environment has recently completed an Environment Impact Assessment report of the 9th plan document in which Environment Impact statement in respect of each of the schemes proposed by the plan implementing departments has been prepared and stated from Chapter 1-15. The statement which will have a direct beneficial impact on coral reef management are the following:

1. Cattle rearing is incompatible with the island ecology and so should be halted.
2. All toilets should be biological toilets to eliminate sewage.
3. Stress on Non conventional energy use.
4. Environment audit of all existing factories in all Government and private sectors to be conducted.
5. The shipping vessels should be so designed that the wastes generated should not be dumped into the lagoon but should be stored and disposed in the seas far from the islands.
6. When new vessels meant to enter the lagoons are to be procured it should be ensured that the draft of the vessels should be limited to the existing depth of the channel and further deepening, dredging will not be permitted as prescribed by the CRZMP.
7. Scheme No 8 providing harbour facilities in all the islands by widening channels and extending and widening jetties should be dropped and no dredging work be done in the lagoon as this increases sedimentation which will ultimately effect the health of the corals.

The Department of Science, Technology and Environment also conducts periodic awareness programs and has proposed establishment of a Marine National Park and National and World environmental Heritage status for some of the chosen islands of the UT of Lakshadweep.

Development of an appropriate Sewage systems in association with competent institutions.

They propose to monitor the degradation of corals both inside and outside the reef by regular diving and to employ protective measures to prepare a master plan for the conservation of corals.

With regard to tourism the following statement has been made "the negative impact of tourism, generation of sewage, waste, increased consumption of water and change in landscape etc. An extremely low volume, high value added very specialized tourism therefore would be appropriate to make tourism environmentally sustainable." A regular system to educate tourists of prohibitions under CZMP and environmental laws regarding corals may be introduced. (Srivastava et al, 1997).

Environmental wardens and Wildlife wardens have been appointed in each of the inhabited islands. They have been given scuba diving training. Their duty it is to see that no coral shingle collection takes place and the islanders do not fish endangered marine animals. Recently one chief conservator of forests has been given a post in the Administration of Lakshadweep to develop a management plan for the coral reefs of Lakshadweep.

5. Conclusion

Coral reef research fn India is still at a preliminary stage and has not yet gone mainstream. Enormous data exists on corals and related species taxonomy. However very little information exists on population density of corals and reef associated species in relation to abundance.

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Little information is available on the coral reef ecosystem as a whole or on the relationship between human economy and the ecological resources of coral reefs. This makes development of realistic management plans for coral reef areas involving local community participation especially difficult. The main problem is that each institute has its own research agenda and special focus. Coral reef research has been more incidental than a main stream programme in nearly all these institutes. This has to change if we are serious about developing people centered management plans for conserving and managing our reef heritage.

Status of Coral reefs in India

	Bio-physical	Research	Perceived threats
Palk Bay	Slow recovery from 60's coral mining	Mainly on Bio-physical aspects	Population Pressure and associated effects
Gulf of Mannar	Slow recovery from 60's coral mining	Bio-physical aspects; associated fauna and Human activities damaging the reefs.	Population Pressure and associated effects
Andaman & Nicobar	Fair Excellent, Problems around south island	Bio-physical aspects; associated fauna and Human activities damaging the reefs	Siltation due to logging, Sand mining.
Lakshadweep	Excellent off uninhabited islands and endangered along habited islands.	Bio-physical aspects; associated fauna and Human activities damaging the reefs	Population Pressure and associated effects
Gulf of Kutch	30% of the reefs are living	Bio-physical aspects; associated fauna and Human activities damaging the reefs	Sedimentation and siltation due to cutting of mangrove forests, sand mining for industrial use. Population pressure
West Coast	Unknown	Limited	Unknown

Changing the mandate of research institutions is difficult, hence it is recommended that a special institution to serve the purposes of Coral Reef Research, Conservation and Sustainable Management may be set up under the control of the Department of Ocean Development. This could be an agency bike MPEDA or an authority like the Great Barrier Reef Marine Park Authority in Australia. Such a National Centre can help to bring together all agencies / institutions working on coral reefs into a National Network on Coral reefs.

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Status of Research on Corals in Pakistan

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Abstract

it seems appropriate In this paper to briefly describe the marine environments of Pakistan and effects of neotectonic on them. The paper gives the status of research on coral through previous and present studies. The results are summarized. The strategies mentioned for conservation of corals encompass a broad range of problems i.e. the influence of abiotic factors on the community structure, human-induced damage, enforcement of legislation and preparation of management projects. The future plans of the government for the conservation of the marine ecosystem are also mentioned.

Introduction

Geomorphology of Pakistan Coast & Coastal Environment:

The Islamic Republic of Pakistan is situated roughly between 20° and 25° north, 59° and 70° east longitude on the northern part of the Arabian Sea. Pakistan has a coastline of 990km stretching from the border of Katchh to the border of bran and has administrative jurisdiction upto 19 km seaward as maritime provinces of Sindh and Babuchistan and from 19 km to 320 km the Federal government has jurisdiction on this water area. From the standpoint of fishing operation it may be considered in two areas: (a) the western sector - from the Hub River, the Makran coast extends for 522km to the border of Iran near Dasht River and is formed of bays, starting at Sonmiani Bay and ending in Gwatar Bay. Along this coast the continental shelf is narrow, (16-24 km) descending abruptly; the bottom is mainly rocky. This coast is sparsely populated and lacks inland communication and shore facilities. (b) A the South East sector (270 km), stretching between Karachi and Sir Creek on the Indian border, is flat and has innumerable creeks, the islands inbetween are studded by mangroves forest of covering area of 7,680 sq.km. The bottom is sandy/muddy according to All & Memon (1995) neotectonic movement have uplifted certain areas of the Indus delta and Hub River causing destruction of the mangroves, the presence of coral beds far inland on Mango Pir Range mentioned by Pithawala (1936) may be indicative of such activities. From Oligocene time the area onshore was also subjected to shallow but fluctuating marine conditions. These environments are well evidenced by the texture and lithology of Nan and Gaj Formations of Oligocene (35 MY.) and Miocene (25 M.Y.) ages respectively. The presence of lithified coral colonies and silicified tree trunks are also indications of

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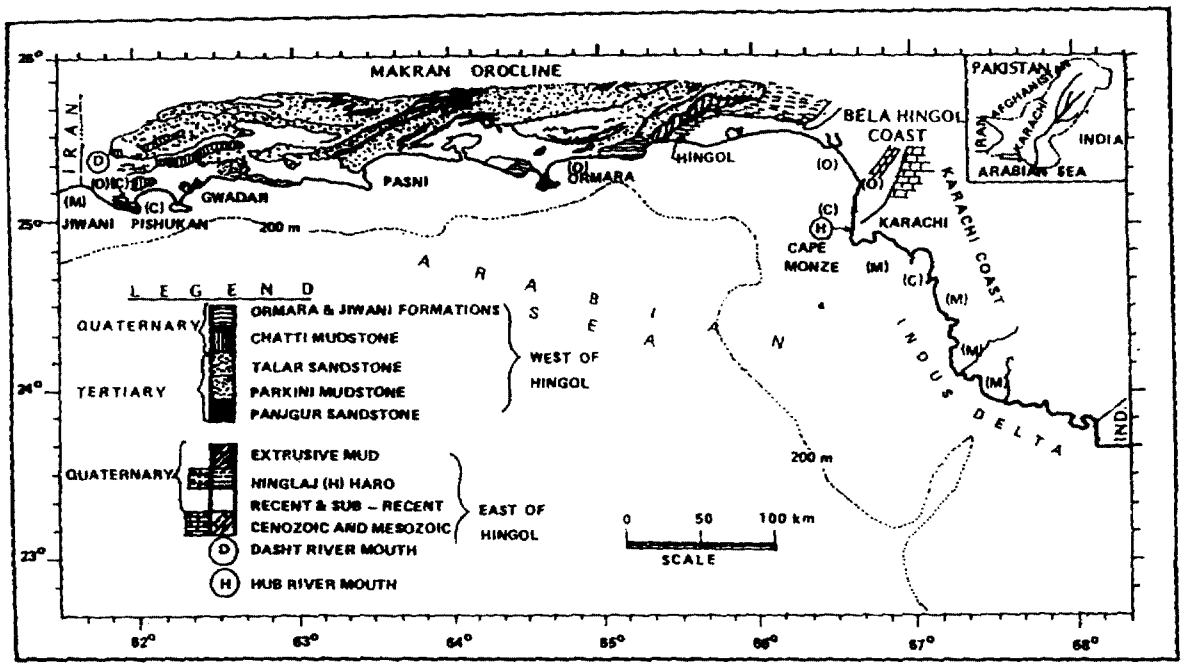
the marine transitional environmental conditions. Development of thick coralline limestone beds are evidence of favourable conditions during geological past (Naseem et ab., 1996) which deteriorated with the passage of time and due to regression of the sea towards south. The entry of the River bndus is about midway along Sindh stretch. Here the continental shelf is shallow and much broader (70-120km). The Indus delta is the main cause of change of marine environment over 200 years. A drastic decrease in the sediment load of Indus also leads to the erosion of the coastline giving rise to much turbidity in the coastal environment. No conventional upwelling occurs along the coast, on small scale upsloping brings up nutrient rich oxygen poor water all along the coast. The dearth of the dissolved oxygen in Pakistan waters correlates with not a very rich fisheries in our EEZ. The beaches of Pakistan are relatively free from man-made pollution, only few instances may be cited but non has modified the environment radically.

The only significant offshore island is the Astola Island, approximately 25 km off the main land coast of Baluchistan, the island is about 6 km in length.

From the geological point of view the Pakistan coast has been divided into 4 major sections (Map 1): a) The Indus Delta prograded into the Katchh Rift Basin, with high water turbidity and loose sediment substrate, tectonicably active and susceptible to level changes;



Map. I Map showing geomorphological divisions of the Pakistan coast. **C.** corals; **0.** oysters; **M.** mangroves. (after Ali & Memon, 1995)

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b) The Karachi arc forming peninsular-protruding rocky hills with shoals and an island the Chuma Island; it has low water turbidity and hard rocky substrate. This arc is tectonically active less than the Indus Delta; c) Bela Hingol coastal plane, with piedmont deposits, mainly with sandy shore and turbidity slightly higher than the Karachi coast with loose sandy weak substrate and tectonically less active than Karachi; and d) Makran orocline formed by accretionary mudstone, siltstone, and sandstone prism of a trench arc, with very high water turbidity, almost muddy, the substrate is formed by weak and friable rocks, tectonically, most active zone of the Pakistan coast, highly susceptible to sudden level changes. (modified from Ali & Memon, 1995)

Recent coral reefs are absent, otherwise geomorphology of the coastline is relatively complex comprising of beaches, sand dunes, sea cliffs, rocky headlands, intertidal mud flats, mud volcanoes, deltas, estuaries, tidal lagoons, bays, island and shelf area. The lagoon system of the Makran coast is undoubtedly the largest and most complex coastal lagoons system of the Arabian Sea (Alizai et al., 1988).

Present situation

The coastal environment of Pakistan at present is not conducive to the healthy growth and formation of corals reefs and as such coral reefs are not at present found in Pakistan (UNEP, 1986). A world map (Map 1) given in an encyclopaedia also indicates presence of corals here as a small block. The seabed on Makran coast with patches of corals in some areas, which is more suitable for coral growth than that of Sindh coast (Qureshi, 1961). In a 'Country Profile of Marine Environment' Ahmed (1986) has also pointed out this fact that corals do not flourish in our environment. Temperature, salinity, light, currents, siltation, sedimentation, earth quakes, sea level rise, hostile animals, over-growth of corals and pollution may be the effecting factors controlling the horizontal coral distribution as discussed by scientists working on maritime zone. The Red Data Book of IUCN (1996) does not include any coral species under provision of UNCLOS relating to biodiversity. Pakistan's principal obligations relate to the conservation of marine species, the establishment of marine protected areas and the prevention of marine pollution (BAP Pakistan, first draft, 1997).

Whatever work has been done previously or is being done presently is summarized here.

Organisations expected to work on coral

a) Governmental:

Environmental and Urban Affairs Division.
National Institute of Oceanography, Karachi.
Zoological Survey Department, Karachi.
Pakistan Navy
Port Trusts and Shipping Divisions
Pakistan Coast Guards.

b) Non Governmental:
WWF, Pakistan; IUCN, Pakistan; EPA, Sindh.

c) Universities:
University of Karachi.
Department of Botany
Department of Zoology
Department of Geology
Department of Geography
Marine Reference Collection and Resource Centre
Centre of Excellence in Marine Biology.
Institute of Environmental Studies

Survey

The studies on the coral of the area include Ali & Memon (1995) who also discussed the neotectonic effect on the mangrove forest and other coastal taxa specially the sessile ones. As taken from Ali & Memon (1995) both living and fossilized corals have been discovered on Pakistan coast, living corals were seen by divers between the Cape Monze and Churna Island (or Churma Island) (Map.2). Here the substrate is limestone. The water temperature does not drop below 20 C and water turbidity is much bower than anywhere along the Pakistan coast except in monsoons for a few weeks and is caused by the Hub River. The corals are found in patch reefs on the rocky shoals of Churna waters. There are three kinds of corals: Hump corals at 5-15m, Leaf corals at 10-20m, and Star corals (Acropora) at 15m. The fossilized corals of late Pleistocene are more flourishing. They are also found at the Cape Monze on the lowest terrace of Cape Monze and Churna Island. The reason for deterioration of present day corals of Churna waters may be the turbidity from floods of Hub River in monsoon. Now the Hub Dam has reduced the suspended sediment load, a better growth of corals can be foreseen.

Living corals are reported in Sindh at the eastern part of Karachi in the Gulf of Katchch (Port Okha, Pirotan Island) by Srivastara et al (1991).

The Department of Geology of the Karachi University was also visited for their fossilised corals repository. According to the staff of this department the fossilized corals of the Churna Island are more diversified than the recent ones.

Makran as a subductive zone is of particular interest for elucidation of the means by which superficial sediments are deformed. Fossilized corals are extensively found on the Makran coast at Gwadar and Jiwani headband area of the same late Pleistocene. They contain the following corals - Bush coral, Brain coral, and Finger coral as common, Branch corals as dominant, Pipe organ coral and Flower coral as less common, Pillar coral as fairly common and Star coral as predominant and Sea Fans as the rare ones.

This distraction between Sindh and Makran coasts results from difference in natural environment that the corals in these two areas encounter.

No living reefs were located in this area, however, about 100km west of Pakistan border at Chah Bahar living reefs are described by Sheppard & Wells (1988). A recent survey was conducted by the NIO near Astola Island on Baluchistan coast (25'07'N, 63'50'E) through naval hydrographic survey ship. It is where divers have brought up live corals. The transparencies prepared for 3 different species were kindly loaned to us. Earlier Tomascik (1977) has reported "extensive veneering coral communities" on "offshore rocky outcrops" on this island.

Geochemistry

Naseem et al. (1996) have made an attempt to verify the reefal conditions for limestones in Cape Monze and adjoining areas on the basis of geochemical studies.

Taxonomy

The investigation of corals in the Indian Ocean started with Forskal in 1775. The knowledge was enlarged during many expeditions particularly the John Murray (1933-34) and IIOE (1963-64). In 1971 Rosen compiled a table showing the distribution of hermatypic coral genera for the Indian Ocean. There is belt of high diversity in the Indian Ocean with total 53 genera and 11 endemic genera (Scheer, 1985).

With the establishment of Marine Reference Collection and Resource Centre, University of Karachi in 1969, a great deal of work has been carried out on other marine taxa, however, no systematic information exists on corals. Numerous specimens of dead corals and other groups involved in reef formation are deposited in the Marine Reference Collection & Resource Centre and Department of Zoology, University of Karachi. They are entered there as Scleractinines or Madreporarians, Gorgonaceans (Octocarablians), Pennatulaceans and Alcyonaceans. They have been either collected from the Fish Harbour landings or obtained from trawlers or were purchased from the fishermen. They were photographed (Plates) for the sake of inclusion in this paper and most of them are given a preliminary identification or are incorporated here as coral sp.1, coral sp.2 and so on just to give an idea of their diversity. They are altogether 23 types. They include all the three categories i.e. vertical, vertical/horizontal and horizontal as discussed by Pichon (1978). Interesting findings are expected at the time of exact determination of species due to faunal movement through Suez.

Biological Diversity

Gosliner et al. (1996) have prepared a report on Indo-Pacific coral associated animals exclusive of the vertebrates. In Pakistan biodiversity of coral ecosystem is in its infancy due lack of knowledge. We do not have central biodiversity information centre. We have cited references of those publications which also deal with coral dwelling species or groups.

GROUPS	SOURCE	LOCALITY
Mollusca		
Nudibranchia	Kazmi etal., 1996	Karachi coast
Bivalve (Cockles, Scallops, Clams, Pearl Oyster)	Moazzam & Ahmed, 1994	Areas near coral colonies shown in given maps
Cephalopoda		
Crustacea		
Brachyuran crabs	Tirmizi & Kazmi, 1982;	Baluchistan coast
	Tirmizi & Kazmi, 1988;	Sindh & Babuchistan coast
	Tirmizi & Ghani, 1996	Sindh & Baluchistan coast
Spiny lobsters -3 species	Tirmizi & Ahsanullah, 1966;	Karachi Fish Harbour
Stomatopods-Gonodactylids	Tirmizi & Manning, 1969;	Western end of Astola Island in scanty scattered coral.
	Tirmizi & Kazmi, 1980	Cape Monze
Echinodermata		
12 species	Tahira, 1996	Karachi coast
Fishes		
Heniochus sp. and Cephalophalis sp.	Ahmed & Wazarat, 1993	Churna Island
Gastrophysus lunaris, Sufflamen capistratus, Artothron hispidus	Ahmed et al. 1973	Coastal reefs
Snappers; breams, scads, croakers and others	Brandhorst & Crockett, 1994	From Churna Island
Turtles		
Chelonia mydas Lepidochelys olivacea	Firdous, 1988	Karachi coast
Snakes		
Hydrophis ornatus ornatus	Mertens, 1969	Astola Island
Algae		
Coralline algae (Jania capillacea and J. adhereus)	Shameel & Tanaka, 1992	Pakistan coast
Reef building algae (Lithothamnion fruticulosum)		

As Medicine

Corals are collected for their medicinal values and purchased through the fishermen and used in Unani / Islamic medicine. They are locally known as marjan.

Strategies and Approaches

A concerted effort is required to improve the present state of affairs regarding the corals colonies in the country. The approach has to be technically feasible. The strategies and approaches can take several forms: technical, administrative and research. There is great need globally to preserve the health of marine environment and to conserve the living corals. Legislation on environment is to be adequate and fully enforced. More involvement of people and interest groups is required in improving legislation. Destructive fishing methods near popular spot like Churna Island should be checked; collection of coral for commercial purposes needs cautioning - this include collection of corals and other reef animals as souvenirs for sale in aquarium shops and for their use in Islamic medicine. Pollution resulting from sedimentation and turbidity from freshwater runoff and erosion, heated water from industrial plant cooling, domestic waste, sewage affluent and dredging may be the main cause of damaging corals which in the past may be forming the reefs, but now show little sign of recovery. The management of coral communities be entrusted to a special agency/body.

Encouragement is required to draw upon inventory of our coastal ecosystems,with priority given to the protection of vulnerable ones. A community of scientists is required to carry out the surveillance, policy-making and management for coral communities. There is an urgent need for training programmes in the coastal zone problems and management and best hope of protecting or conserving the corals would be to declare these areas as protected. This has already been pointed out by Pernetta (1993), regarding the Astola Island.

Community participation will remain a vital component of any strategy for environmental education and awareness and finding of ways to reach this majority is a challenge.

Plans for future

IUCN has planned a proposal “Marine and coastal protected area project”, through which a detailed and systematic survey of the corals is expected (Courtesy T. Qureshi of IUCN, Pakistan).

The Biodiversity Action Plan (BAP, 1997) is currently being developed and hopefully will take nto consideration the corals of the region. A regional workshop of IUCN/WWF and the government on BAP, 1997 was convened on the 11th Nov. 1997 in Karachi, several actions regarding marine fauna to identify gaps and to initiate new research programmes were recommended.

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Status of Coral and Associated Resources in Bangladesh

A. R. Mollah[1]

Abstract

While no formed coral reef exists, the subtidal zone of Narikel Jinjira island supports a total of 66 sceleratianian coral species, belonging to 22 genera, a number of which represent reef building species. The coral beds in Narikel Jinjira extends from the seaward margin of the intertidal to about 200-600m offshore. Corals are found around most of the Island, but their abundance and cover is generally low. Coral covers various from 4-10% of the surface area. The density estimate of coral is 1.3 colonies/m2. Porites spp. are the most abundant group of coral, followed by Favites spp., Goniopora, spp., Cyphastrea spp., and Gontastrea spp. The coral resources are heavily exploited in Narikel Jinjira. It has been estimated that about 30,000 colonies are removed annually which is 24% of the existing coral population in the extractable areas. The coral community in Narikel Jinjira supports associated fish and invertebrate fauna characteristics of coral reef environment There are at least 86 species of reef associated fish, 4 species of Zoanthids. 4 spp. of Echinoids. one species of Asteroids, one species of Holothuroid and 4 spp. of Crinoids have been identified from the coral beds of the island. Molluscs are the most abundant group of invertebrate found in the coral bed, 61 species of them have been identified. Siltation, fluctuations in salinity, cyclonic storms and tidal surges, over exploitation of resources have been identified as the potential threats to the resource degradation, Narikel Jinjlra satisfies the requirements for category 11 (Marine Park) designation. A zoning plan has been proposed as a key tool for the management of Narikel Jinflra as a Marine Protected area. Local community based eco-tourism has been strongly suggested. It is strongly recommended that new scientific studies are planned for the island, since the unique and dynamic nature of the intertidal and subtidal rocky habitats offer excellent research opportunities.

1. Introduction

1.1. Location

In Bangladesh, corals are found only on the Narikel Jinjira(St. Martin's Island). Narikel Jinjira is a small island in the north-eastern part of the Bay of Bengal, about 9 km south of Cox's Bazar-Teknaf peninsular tip and forms the southern most tip of Bangladesh. It lies roughly between 20°34'N - 20° 38.8'N and 92°18' - 920 20.8'E

1.2. Geology

In some recent literature's (UNEP/IUCN, 1988; Khan, 1985; Chowdhury *et. al.* 1992; Ahmed, 1995). The island has been classified as a coral island of biogenic nature. The assumption was probably made on the presence of coral communities on the island. However, according to Akhtar(1 992), the base rock of Narikel Jinjira is of sedimentary in origin and consists of sand

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stones of tertiary age, mixed with shell deposits. The boulders found on the intertidal and subtidal zones are mostly sedimentary in orgin and probably the continuation of base rock (Tomascik, 1997). Some spherical boulders, intermixed with dead corals colonies, (origin and probably the continuation of base rocks (Tomascik, 1997). Some spherical boulders, intermixed with dead corals colonies (boulders), are probably formed through accretion process (Alam and Hasan, 1997). According to Warrick et al. (1993) the island is located on the eastern flank of an anticline and probably the part of Arakan-Naga folded system and therefore the island may be regarded as a sedimentary continental island whose coastal environment supports diverse coral communities.

1.3. Physiography

The island is (dumbell-shaped. about 7.8 km in length and few hundred to little about 1 km in width, the surface area is about 8 km^2 at low tide and about 5 km at high tide. The island is located on a shallow continental shelf with a maximum depth of 25m. The maximum depth of coast of Narikel Jinjira is only 10m.

The main shoreline habitats are sandy beaches and dunes and scattered rocks and coral boulders. Some boulders are also found on the interior into the island. The shallow water marine habitats include, rocky and sandy intertidal, intertidal rockpools, off shore lagoons, rocky and sandy subtidal and offshore soft bottom habitats.

Due to differences in exposure, benthic habitats along with the east and west, coasts of the island support different benthic communities. However, the upper and middle intertidal habitats along both coasts generally support similar communities. A generalised zonation of the east coast benthic communities along an inshore to offshore gradient starting from the lower intertidal is as follows: 1) intertidal gastropod-algal community 2) Coral-algal community 3) mixed seagrass-algal community, 4) soft coral community and 5) soft bottom. The zonation on the west-coast is as follows: 1) gastropod algal community: 2) Coral-algal 3) algal community, and 4) soft bottom community.

2. Environmental Conditions

2.1. Surface Water Temperature

The surface water temperature around Narikel Jinjira ranges between 18-31 C (DoZ, 1997, Tomasick, 1997) and thus lies within the optimal range (20-30 C) for both coral and coral reef development.

2.2. Salinity

The coastal water salinity of Narikel Jinjira, as measured on few occasions during drier seasons (DoZ, 1997 ; Tomasick, 1997), fluctuates between 26 to 35 ppt. It is expected that the level will drop further below this marginal value due to the increased freshwater discharge from Naaf River during rainy season (July-October). This level is therefore below the optimal range (32-36 ppt). However, some species may tolerate low salinity in some areas of the world (Tomascik, 1993).

2.3. Light/ Turbidity

The turbidity of inshore water as measured by the sechi disk depth, ranges from I.5m to 8.0m depending on the sea condition and tide cycle. This low light penetration is the consequence of many factors. In addition to silts coming with Naaf discharge, the combined action of wind generated waves, ocean swell and high velocity tidal current cause resuspension of bottom sediments (fine sand; silts and mud). A sechi depth of >7m is required for optimal growth of reef-building corals. Since corals are light-sensitive organisms, high turbidity coastal waters of Narikel Jinjira is the key environmental factor for impeding the development of coral reefs. However, some coral species may tolerate turbid waters of this magnitude(e.g. *Porities).*

2.4. Substrate

The shelf of Narikel Jinjira is covered by a layer of sedimentary boulders that vary greatly in size. While they provide a very suitable substrate for the settlement of coral larvae, as it evident by relatively high recruitment rates of juvenile corals, the boulders are very susceptible to disturbances (i.e. over tuming, translocation, etc.) by heavy seas that are frequently generated by cyclonic storms and tidal surge. The growing corals on the boulders are thus damaged or destroyed during translocation and shifting of substrate boulders.

2.5. Tide

The tides affecting Narikel Jinjira are semi-diurnal (i.e. two high tide and two low tides per day). The mean tidal level at Shahpuri Island (about 9km north-east from Narikeb Jinjira) in the Naaf estuary Is 1.874m. The mean low spring tide is 0.19m and mean high water spring tide is 3.56m. The highest astronomical tide is 4.lm (BIWTA, 1996). It is expected that somewhat similar tidal condition exists around Narikel Jinjira.

Based on the environmental data (i.e. surface seawater temperature, salinity and turbidity) . it is concluded that natural environmental conditions around Narikel Jinjira are marginal for the development and survival of coral communities, and sub-optimal for the development of coral reefs. However, a year round environment monitoring programme is required to obtain a clear, picture of the environmental conditions. The rainy season is the critical bench-mark for environmental conditions.

3. Corals and Associated Resources

3.1. Fossil Corals

The fossil corals are mainly scattered among the boulders on the beach and on the land interior into the island. Some isolated massive coral blocks (measuring 1.5m x 0.65m x 1.1m are found on the beaches and on the inter-tidal rock pools. However, percentage of corals boulders as eye estimated to be less than 2-31 1/o of the boulders (DoZ, 1997).

3.2. Live Corals

Corals are found around most of the island except the northern part (Fig. 1) The rocky subtidal seaward margin of intertidal to about 200-600m offshore support coral communities. Corals are also found in the rock pools of lower intertidal. A total of 66 seleleratinian coral species, belonging to 22 genera and 10 families, has been recorded from Narikel Jinjira (Mahamud and Haider,1992; Khan 1985 Tomasick 1997, DoZ,1997). All families represent reef forming corals. Table.1 provides the scientific names and relative abundance of the recorded species. The genera Porites, Favites, Goniopora, Cyphastrea and Goniastrea are most abundant. In terms of coral coverage, Porites is by far most important genus: In relative terms, almost all other coral genera, perhaps with the exception of *Acropora,* can be viewed as rare. The abundance of corals and their cover is low. The coral cover varies from 2-10% of the rocky substrate (DoZ,1997). Based on the quadrant transect survey, the density at some selected areas is about 1.3 colony/m^2 (Tomascik, 1997).

3.2. Coral Associated Fauna

3.3.1. Soft Coral (Order Octocoralina)

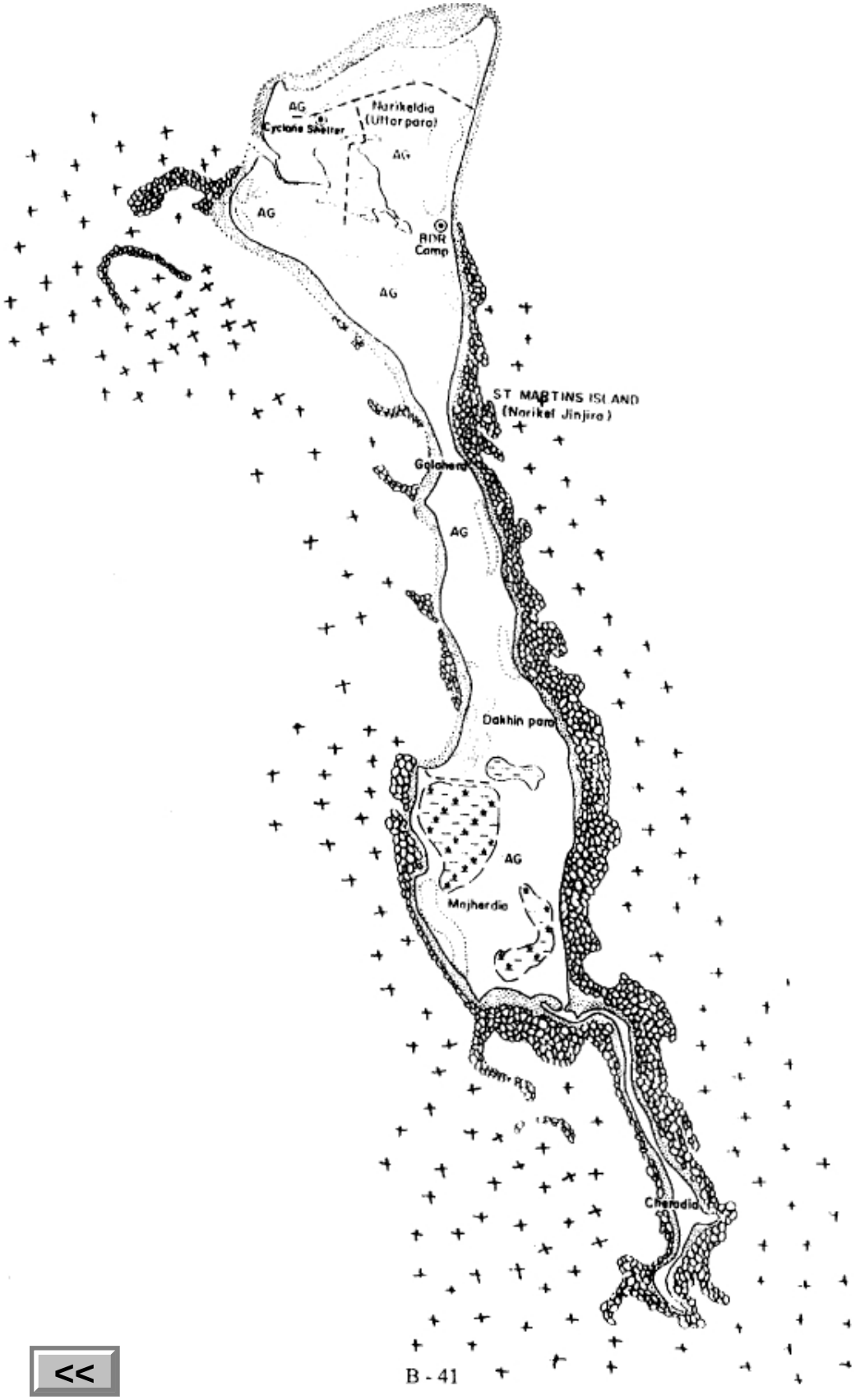
The soft coral community on Narikel Jinjira is a unique feature of subtidal zone. The deep water soft coral belongs to 6 families, namely, Plexarudae, Aanthogoridae, Subergorgoniidae (gorgonians sea fans) and Malithacidae, Anthothelidae (small sea fans), Ellisellidae (sea whips). The species level identification is being done at the Department of Zoology, Dhaka University. The species number may go above 12. The soft corals collected from shallow subtidal included Sinularia, Lobophyton and Authelia (Tomasick, 1997; DoZ, 1997).

3.3.2. Other macro-invertebrates

The other macro-invertebrates were represented by 61 species of molluscs, 9 species echinoderms, 4 species zonathids and 4 species of Bryzoans (Tomascik, 1997, DoZ, 1997). By far the most abundant macro-invertebrates are the gastropod molluscs, notable of them are periwinkles, nerites, top shells, cowries, murex, and cone shells. There is high abundance of *Conus striatus, C. textiles, C. geographus, Trochus niloticus* and *Tarbo marmoratus,* two economically important gastropod throughout Indo-Pacific, are also present, but their population are depleted world-wide. A number of colourful nudibranchs (Mollusca, Opistobrachia) were recorded from the shallow subtidal rocky reefs. The four species found were Joruna funebris (Kentodordidae), Glossodoris atromarginata (Chromodorididae, and one unidentified species.

The diversity of macro-invertebrates is surprisingly low considering the abundance of algae and benthic detrital material. Only four species of sea urchins (Echinodermata, Ecinodea) namely *Echinotrix diadem, E.calamaris, Echinometra mathaei,* and *Echinostrephus aciculatus* are present in the rocky subtidal habitats on Narikel Jinjira (Tomascik,1997). One species of sea star (Echinodermata, Asteroidea) belonging to genus Protoreaster was collected. There are a number of brittle stars (Ophiruoidea) present, but these were not assessed since they are cryptic (i.e. live under the boulders) by nature. Only one sea cucumber (Hobothuroidea) was found in the lower intertidal in the intertidal pools. The sea cucumber (Holothuria atra) occurs in very low numbers due to over exploitation. Bryozoans (Cheilostomata) are an abundant group of encrusting calcareous invertebrates. The main genera are *Retepore//ina, Tryphyllozoon, Scrupocellaria* and *Stylopoma.*

Figure 1: General distribution of coral beds on Narikel Jinjira



another important group of antozoans in the lower intertidal and shallow subtidal are the zoanthids (Zoanthidae). The genus *Palythoa* dominates, and covers many large boulders. Other anthozoans observed in the subtidab were Nemanthus, (Nemanthidae), Telemactis sp. (Isophellidae) and Discosoma spp. (Dicosomtidae).

Table 1: Seleractinian reef-building corals (order Seleratetinia) of Narikel Jinjira (St. Martin's Island) (tentative list). Relative abundance categories based on visual observations during snorkelling : A- abundance, C- common. and R- rare, indicates need for taxonomic verification.

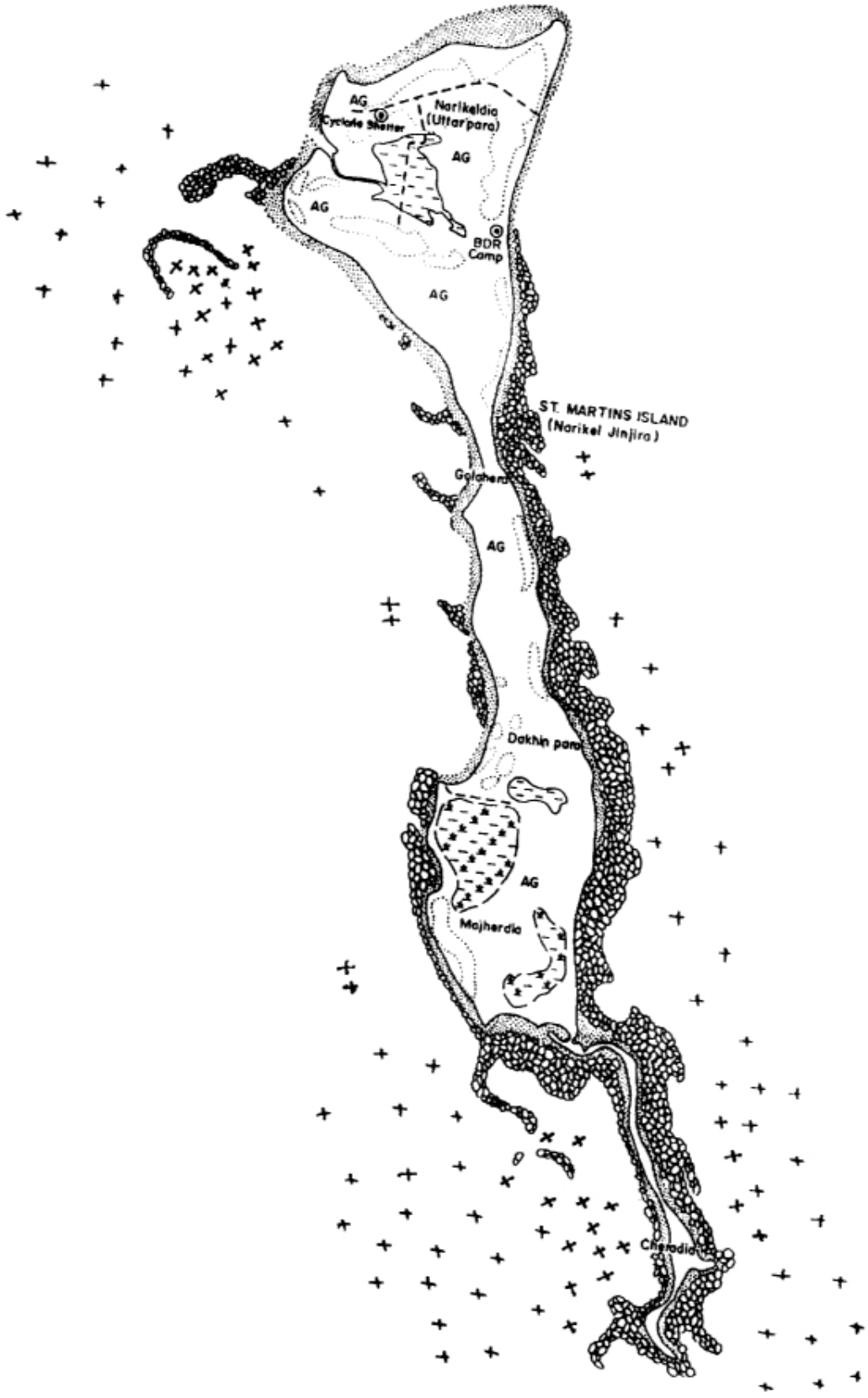
FAMILY	GENUS AND SPECIES	ABUNDANCE
ASTROCOENIIDAE	*Stylocoeniella armata*	C
ACRPORIDAE	*Montipora angulata* -	R
	Montipora hispida -	R
	Montipora informis	C
	Montipora spongodes	A
	Montipora turtlensis -	A
	Montipora verucosa	R
	Acropora glauca	A
	Acropora multiacuta -	R
	*Acropora vaughani**	R
	Acrpora austera	R
	Acrqora aculeus	A
	Acropora rudis	C
	Acropora latistella	R
PORITIDAE	*Porites lobata*	A
	Porites solida	A
	Podtes lutea	A
	Porites murrayensis -	C
	Goniopora columna	A
	Goniopora djiboutiensis	A
	Goniopora stokesi	
	Goniopora stutchburyi	A
	Goniopora tenuidens	R
SIDERASTREIDAE	*Psammocora hatmeana**	R
	Psammocora profundacella	A
	Coscinaraea columna	A
	Psedosiderastrea tayami	A
AGARICIIDAE	*Pavona decussata*	R
OCULINIDAE	*Galaxea astreata*	C
	Galaxea fascicularis	C
MUSSIDAE	*Acanthastrea echinata**	R
	*Acanthastrea hillae**	R
FAVIIDAE	*Favites abdita*	A
	Favites halicora	A

	Pauttes flexuosa	C
	Favites sp. 1	R
	Pavites sp. 2	R
	Gonioastrea aspera	A
	Gonioastrea edwardsi	A
	*Goniostrea palauensis**	R
	*Goniostrea pendulus**	*R*
	Goniostrea retiformes	*C*
	Platygyra daedalea	A
	Platygyra pini	C
	Ptatygyra stnensis	R
	Leptastrea purpurea	C
	*Leptastrea pruinosa**	R
	Leptastrea transversa	A
	Cyphastrea serallia	A
	Cyphastrea chalcidicum	*A*
	Cyphastrea sp.	R
	Monastrea curta	R
	Monastrea magnistellata	R
	Favia favus	R
	Favia pallida	R
	Favia speciosa	R
MERULINIDAE	*Hydnophora exesa*	A
	Hydnophora micoconos	A
	Hydnophora pilosa	C
DENDROPHYLLIDAE	*Turbinira frondens*	R
	Turbinira peltata	R
	Turbinira reniformis	R
	Turbinira steliulata	R
	Dendrophyllia sp.	C

3.3.3. Fish

Although as many as 240 fish species were recorded from the catch landed on Narikel Jinjira, (DOZ, 1997), only 86 of them are coral reef associated (Tomascik, 1997; DOZ, 1997). It may be mentioned that some reef associated fish were not represented in the catches but were observed during scuba diving. The most abundant reef associated herbivore are the damsel fish (Pomacentrids), parrot fish(Scaridae), surgeon fish (Acanthuridae). The important predators are groupers (Serranidae), snappers (Lutjanidae) and emperors(Lethrinidae). Only 5 species of butterfly fish were recorded from the island. There is only one species of angel fish. It is expected that if proper survey is carried out the number of coral associated fish may exceed 100.

Figure 2: Main Coral collecting areas on Narikel Jinjira



4. Resources Exploitation

4.1. Coral Extraction

The main threat to future viability of coral communities comes from direct extraction of corals colonies. Coral collection activities started in 50's but until recently extraction was at low level.

Coral collection is done by using about 18 small manual boats. It was estimated that the weight of harvest ranges from 40-100 kg/ day/boat or about 20-40kg/day/person (DoZ, 1997). It has also been estimated that about 30,000 coral colonies are collected annually and current extraction activities remove about 24% of the existing population from the extractable areas.

Fig.2 shows the areas where coral collections are currently being made. Earlier, only *Acrpora spp.* were sought after. These are being becoming relatively rare. Now-a-days, 4 kinds of corals are mainly collected. These are locally called, pataphu *(Acropora spp.),* gachphul *(Acropora spp.),* shaibal *(Favites* spp.) and mog *(Goniastrea* sp.). At present there are 8 middle men engaged in coral trading. It was gathered that coral worth about Tk.4 lakhs are traded annually (DoZ.1997).

4.2. *Shell Extraction:*

Of all the marine habitats on the island, the lower intertidal is most heavily exploited. Shell extraction is the main activity. Few families in the island are fully dependant on shell collection. Earlier only the larger shells were collected, but now, with tile introduction of diversified use of shell smaller species are also collected. Unavailability of shell has lead to the collection of live molluscs.

4.3. Fish

Fishing in inshore waters over the boulder reefs is done only by 24 boats using weighted gill nets. Gill nets are also set by other fishermen and non-fishermen, It seems that fisheries resources over the coral beds are over-exploited.

Sea cucumber (Holothuria) and seagrass on the lower intertidal are also heavily exploited.

5. Potential Threats to Coral and Associated Resources

The following are the key environmental (natural and anthropogenic) concerns in Narikel Jinjira which pose threats to environment and resource degradation. A summary of the potential threats is also provided in Table 2 with their relative contribution to environment and resource degradation.

5.1. Anthropogenic Threats

- Overexploitation of renewable marine and coastal resources (e.g. rocky reef fisheries, coral and shell extraction, removal of coastal vegetation)
- Large scale removal of key-stone species from intertidal subtidal habitats (I.e. corals, cucumbers and molluscs).
- Destructive fishing practices, mainly the use of rock weighted gill nets over the inshore boulder reefs.
- Increased water turbidity and sedimentation from agricultural practices, deforestation and urbanisation,

- Waste disposal, particularly fish offals from large number of fish dry farms.
- Tourists activities (e.g. collection of sample specimens other destructive activities)

5.2. Natural Threats

- Cyclonic storms and tidal surge probably cause serious damage to coral communities by shifting and overturning substrate boulders.
- Silts coming with Naaf discharge causing turbidity problems on the east coast of the island. Resuspension of sediments also help to increase water turbidity and directly impeding the coral develpoment and survival.
- Increased discharge of freshwater flood water fro Naaf River during rainy season causes salinity to fall to a suboptimal level.

Table 2 Major threats to enviromnent and coral & associated resources.

Anthropogenic Threats	**Relative Threat Level**
Coastal erosion	4
Turbidity and sedimentation	5
Coral extraction	5
Shell extraction	5
Intertidal boulder removal	5
Coral use for construction and lime	1
Destructive fishing techniques	3
Tourism activities	5
Domestic pollution	3
Agricultural polluttion	5
Oil pollution from boats	3
Boat anchoring	2
Fish processing	3
Boat building	2
Overfishing	5
Natural Threats	
Cyclones and storms	5
Sedimentation and resuspension	5
Freshwater flooding	5
Earthquakes	1
Source: Tomascik, 1997. Threat level 0 (low) to 5 (high)	

6. Management Efforts for Narikel Jinjira Coral Resources

Past planning activities on Narikel Jinjira have proceeded without much government involvement concerns regarding the Narikel Jinjira coral resources first came as one of the NCS (National Conservation Strategy) recommendation. NCS recommendation for Narikel Jinjira is as follows: Declaration of St. Martin's Island (Narikel Jinjira) and the Jinjira coral reef a Protected Area and development of a management plan".

The Ministry of Environment and Forest is executing the conservation programme through establishment of NCS implementation Project 1. IUCN Bangladesh is providing the technical assistance. At the initial stage, collection of baseline information and preparation of resource inventories were made through the implementation of Survey of Fauna, Survey of Flora and Base Map Preparation Projects. At this stage various universities and research institutes of the country became involved with the survey programme. A coral reef management specialist was also hired with view to develop a Management Action Plan for the sustainable management of coral resources.

Unfortunately, the government planning included single sector approach and has contributed to particularly troublesome developments. It is imperative that the management plan should be formulated to allow for inter-government co-ordination and co-operation.

For the sustainable development and management of coral resources on Narikel Jinjira, the Marine Protected Area concept has been proposed with a suggestion for the establishment of a Marine Park.

Table 3: Conservation value of selected coastal and marine areas on Narikel Jinjira

Criteria	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7
Naturalness	0	1	1	2	2	0	1
Habitat diversity	3	5	7	9	4	5	6
Unique habitats	0	0	1	1	1	0	2
Coral diversity	0	0	1	2	2	0	2
Coral cover	0	0	1	2.	2	0	2
Fish diversity	0	0	1	2	2	1	1
Coral damage	0	0	0	1	1	0	0
Scientific value	0	0	1	1	1	0	1
Total score	3	6	13	20	15	6	14

Naturalness indicates the extent to which the area has been protected from, or not been subjected to human-induced damage (0= low; 1= medium; 2= high). Habitat diversity is the sum of the following habitats present; beach; dune; rocky intertidal; coral associations; seagrass; lagoons; mangrove; soft coral habitat; offshore rock reefs (o= absent; 1= present). Unique habitats: presence of habitats not found elsewhere on the island: Area 3 has a large intertidal sandy lagoon; Area 4 has subtidal rocky reefs where *Acropora* is present in relatively high numbers; Area 5 has a turtle nesting habitat; Area7 on the high energy coast of the island has a bettered Coral diversity (qualitative assessment): 0=low; 1 = medium; 2=high. Coral cover(qualitative assessment): 0= low; 1= medium; 2high. Fish diversity (qualitative assessment) 0= low; 1 medium; 2=high. Coral damage(qualitative assessment) :0= high l= low. Scientific value (qualitative assessment) reflects potential research possibilities biological, ecological, taxonomical, environmental and geological): 0= low; l high. "Conservation value calculated as the percentage of the total score(=20)"

Source: Tomascik, 1997

Narikel Jinjira has got unique geographical features and diverse habitats and many of which is still undisturbed. The island support diverse coral communities which are not seen elsewhere in the country. The island also contains a number of rare (e.g. cone shells) and endangered (e.g. Lepidochetys otivacen) species in Bangladesh. The Island is also used as nesting ground by three

marine endangered turtle species. Quantitative analysis of criteria, used by IUCN (1994) to determine whether an area is suitable candidate for a protected area status, suggest that Narikel Jinjira satisfies the requirements for category 11 (Marine Park) designation. Table 3 shows conservation values of selected coastal and marine areas on the island. A zoning plan is proposed as a key tool for the management of Narikel Jinjira as marine protected area. The proposed plan identifies a range of purposes for the protected area description and provides a clear rational for the zoning plan (Table 4). The zoning system consists of 1) General use zone; 2)Buffer zones; 3)Coral appreciation area, 4)Coral reserve 5)Coral Sanctuary (Fig. 4). Various community based programmes are suggested in the Proposed Action Plan to include the local community in the conservation process.

Table 4 Management objectives of protected area categories following IUCN recommendation (IUCN,1994)

	Protected Area Categories						
Management Objectives	**Ia**	**Ib**	**II**	**III**	**IV**	**V**	**VI**
Preservation of Biodiversity	1	2	1	1	1	2	1
Maintenance of Environmental Services	2	1	1	0	1	2	1
Wildness Protection	2	1	2	3	3	0	2
Sustainable Use of Resources	0	3	3	1	2	2	1
Scientific Research	1	3	2	2	2	2	3
Education	0	0	2	2	2	2	3
Tourism and Recreation	0	2	1	1	3	1	3
Maintenance of cultural/traditional attributes	0	0	0	0	0	1	2
Protection of specific natural/cultural features	0	0	2	1	3	1	3

Protected Area Categories : Ia- Strict Nature Reserve/Wilderness Area, protected area managed mainly for science or wilderness protection. Ib- Wilderness Area protected area managed mainly for wilderness protection. II- National Monument, protected area managed mainly for conservation of specific natural features. **III** - Habitat/Species Management Area, protected area managed mainly for conservation through management intervention V- Protected Landscape, protected area managed mainly for landscape/ seascape conservation and recreation. **VI-** Managed Resources Protected Area, protected managed mainly for the sustainable use of natural ecosystems. Key: 1 - Primary objective; 2 - Secondary objective; Potentially applicable objective:- not applicable.

Source : Tomascik, 1997

Ecotourism

Narikel Jinjira lacks the main criteria to be considered as a potential international destination for SCUBA diving. However, coral viewing using glass-bottom boat has been suggested. Development of small scale community based ecotourism, to satisfy national demand for new travel destinations, is a viable option on Narikel Jinjira that needs to be promoted. Development of community based ecotourism will not only benefit local conservation efforts

through community participation but will also expose tourists to new experiences. Table 5 provides a preliminary assessment of seven areas on Narikel Jinjira in terms of their potential ecotourism value. Based on the ecotourism potential analysis, it has been suggested by Tomasick (1997) that areas 3,5, and 7 are to be considered as the target areas for ecotourism development (Fig 4). The choice of areas for ecotourism development is supported by the analysis of conservation value these areas (Table 3). Due to high score of Area 4 in the conservation potential analysis, it has been suggested to designate this area as a "coral refuge."

The proposed Action Plan for the management of the island provides a set of environmental guidelines for future tourism and agricultural development. The guidelines identify the links between various environmental impacts and functional and structural integrity of the coral communities on the island.

Table 5: Ecotourism value of seven selected coastal and marine areas of Narikel Jinjira

Criteria	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7
Aesthetics	0	0	2	2	1	0	2
Naturalness	0	1	1	2	2	0	1
Safety	0	1	1	0	0	1	2
Local sensitivity	0	0	1	1	1	0	1
Accessibility	2	2	1	1	1	2	2
Fishing activity	0	0	1	1	1	1	1
Total score	2	4	7	7	6	4	9
Tourism Value	**20**	**40**	**70**	**70**	**60**	**40**	**90**

Notes : Aesthetic criteria used: high coral cover, abundance, large coral size, presence of fish, water quality, good swimming area (0= low, 1= medium, 2 high). Naturalness criteria: the extent to which the area has been protected from, or not been subjected to human-induced damage (0=low; 1 = medium; 2 high). Safety criteria little or no wave action, protection from swells, slow currents, no chance of entanglement in fishing tiers, no boat traffic, safe entry for swimmers (0=low; 1= medium; 2= high safety factor). Local sensitivity relates to attitudes of local inhabitants to western style water recreation (i.e. use of bathing suits): 0= high; 1= low, Accessibility criteria! distance from port of entry, distance from guest houses, easy of entry for divers or skin divers (i.e use of snorkel only) from boats, case of access from beaches, cast of entry for glass bottom boat operators (0= low; 1= medium; 2= high). Fishing and other extractive activities: based on distance to villages, relative fishing activity observed in the areas (0= high; 1=low). Ecotourism value calculated as a percentage of the maximum potential score (= 10). Source Tomascik, 1997

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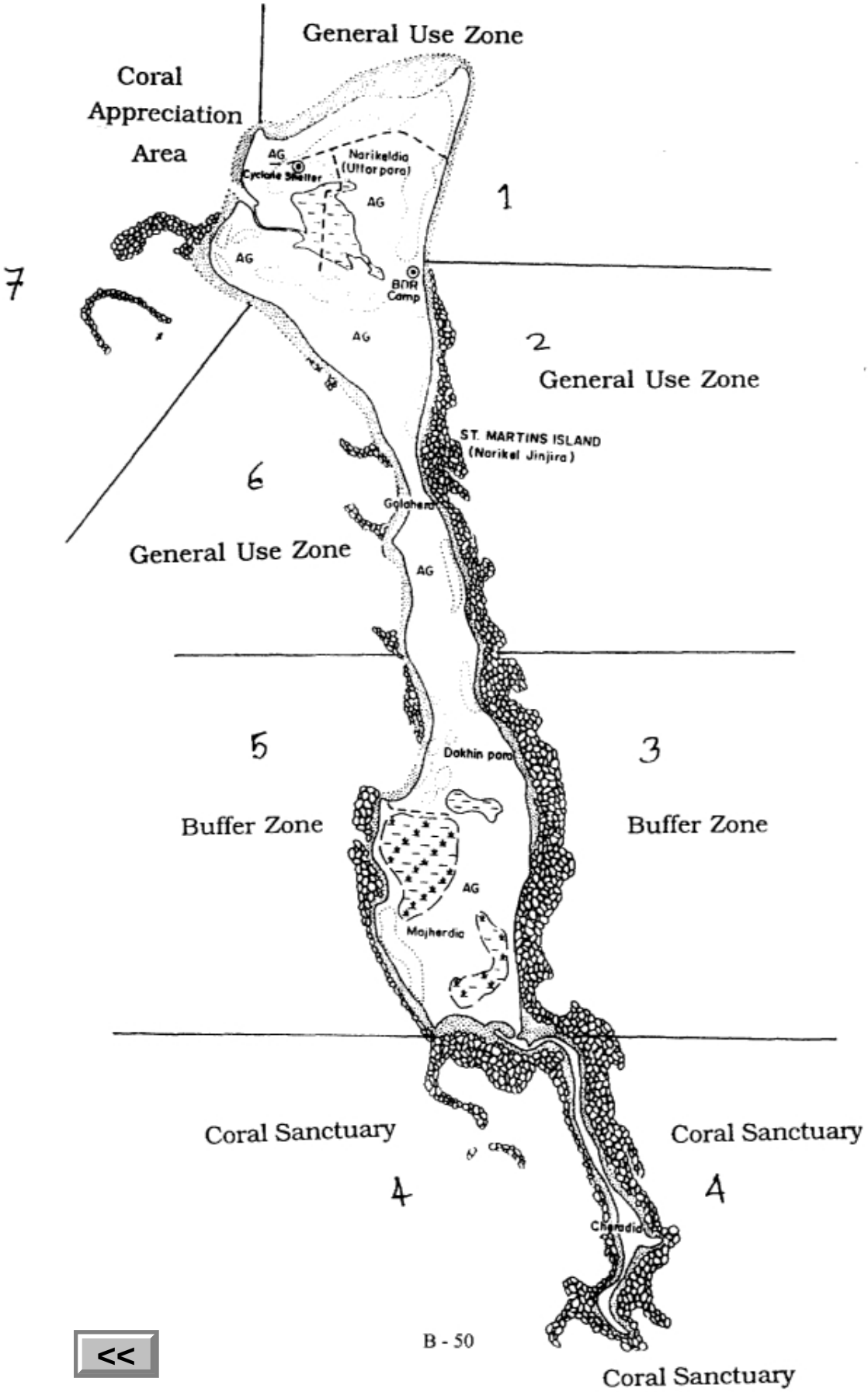
Figure 3: Proposed zoning plan for national park on Narikel Jinjira



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7. Research Needs

The unique and dynamic nature of the intertidal and subtidal rocky habitats offers excellent research opportunities. The following research areas may be considered

- Physico-chemical characteristics of water and other environmental aspects.
- Taxonomic studies of fish.
- Biology of some important molluscs species and other macro-invertebrates.
- Interaction studies of macro-invertebrates algae and other organisms.

It is strongly felt that a small field laboratory should be established to facilitate research.

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Coral Reefs of Sri Lanka: Current Status And Resource Management

Arjan Rajasuriya1

Introduction

Sri Lanka is situated south of the Indian sub-continent between 5°and 10° north of the equator. The island has a total land area of 65,000 km^2 and a coastline of about 1, 585 km of which 300 km are beaches and sand dunes (GSL, 1985, Lowry and Wickremaratne, 1989, Olsen et al., 1992). The country's land area is about 65,610 sq km and is inhabited by approximately 18 million people. The maritime area of 230,000 sq km belonging to Sri Lanka is about three times larger than the land area. The continental shelf of the country as an area of about 31,000 sq km and the width ranges from 9 to 45 km with an average depth of 66 m (Cooray, 1967).

There are fringing and offshore reefs of varying conditions around the country. These have been categorized into three main habitat types. They are the true coral habitats consisting of live coral as well as calcareous substances, sandstone and rocky habitats (Rajasuniya & De Silva, 1988; De Silva & Rajasuriya, 1989; Rajasuriya, De Silva & Ohman, 1995). According to Swan (1983) about 2% of the coastline contains nearshore fringing reefs. The growth of coral reefs around Sri Lanka is influenced mainly by the monsoons which has a major impact on the level of turbidity and fresh water input into the coastal waters. As a result extensive coral reef habitats are limited to areas with lower levels of sedimentation with semi-dry climates found in the north-western and eastern coastal areas. Coral reef development in the southwestern sector of the coastline is poor due to heavy rainfall during the monsoon and the resulting impact from sedimentation and turbidity. Fringing coral reefs also occur around some of the islands around the Jaffna Peninsula.

Sandstone and rocky habitats are extensive and widespread. They are found from near-shore areas to offshore areas to depths more than 50 m. Although living corals colonize them to varying levels, live coral cover on these habitats is generally below 10%.

The coastal region supports 32% of the country's total population on 24% of its land area. This region also contains 66% of the urban land, 67% of the country's industry, and 80% of its tourism infrastructure. The marine fisheries contribute about 65% of the animal protein consumed by the population. The coastal fisheries classified as within 40 km from the shore provide the majority of the marine fish production (Baldwin, 1991). Nearly all of Sri Lanka's reefs are located within 40 km from the coast and they contribute significantly to the marine fish production (Rajasuriya and White, 1995).

[1] National Aquatic Resources, Research and Development Agency, Sri Lanka.

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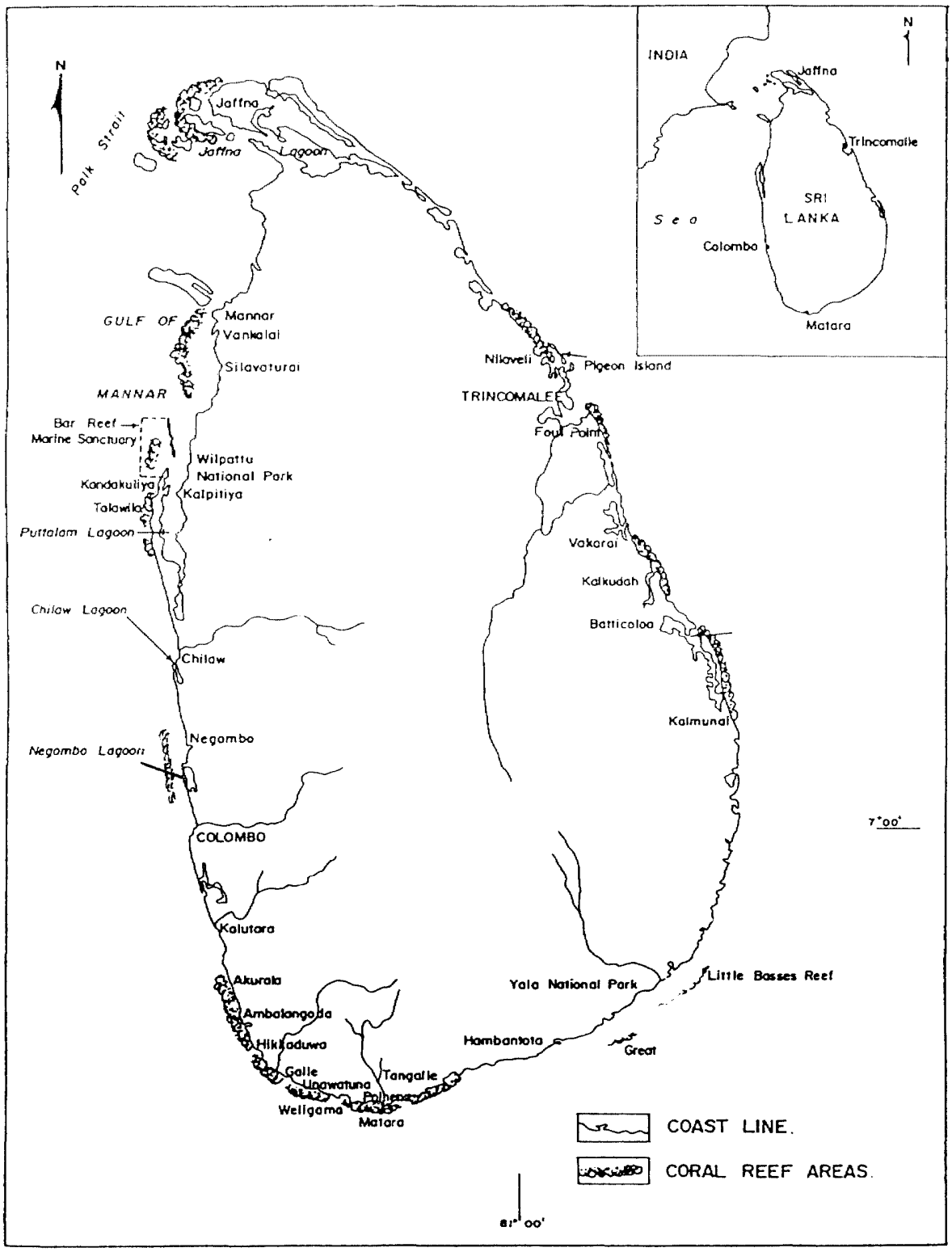

Figure 1. Important recorded coral reef areas in Sri Lanka. Source: NARA Rajasuriya and White **1995.**

For centuries, reef resources have been utilized for food and building materials. Increased human activities in recent times have begun to degrade the quality of the reefs, particularly the nearshore habitats. The major uses of the reefs are extraction of living and dead coral for the lime industry, capture fisheries and the harvesting of exotic reef resources such as ornamental fish for export and for tourism related activities.

Major causes of reef degradation are sedimentation, destructive fishing methods such as the use of explosives and bottom-set nets, mining of coral from the sea for lime production and uncontrolled harvesting of reef resources. Pollution and sewage have also contributed to the overall degradation of the marine environment (Table 3).

Reef Condition

The condition of reefs based on a combination of substrate cover, diversity and abundance of reef organisms indicate that the best reefs are associated with the Barrier-type reefs located offshore (Fig.1). These are found mainly in the northwestern, southeastern and the eastern waters. Similar reefs have also been investigated off Colombo and Negombo in the western area. Most nearshore reefs are affected by human activities including destructive fishing and coral mining in specific areas. Other than the direct impact from coral mining and destructive fishing the greatest threat to Sri Lankan reefs overall is from sedimentation. Many nearshore reefs, particularly along the southwestern and western coastal areas are being silted up rapidly. Increased turbidity in the coastal waters during the southwest monsoon also hinders the growth of reef building corals.

Live reef building coral cover in excess of 50 % is found mainly in some of the offshore reefs (Fig.2). The live coral cover on most inshore coral reefs is less than 50% while the rocky and sandstone habitats support a percentage of live coral less than the true coral reefs (Rajasuriya and De Silva, 1988; Rajasuriya et al 1995). A total of 183 species of stony corals divided among 68 genera have been recorded from Sri Lanka. The dominant reef building species belong to the families of Acroporidae, Faviidae, Poritidae and Pocilloporidae. Almost 400 species of reef and reef associated species have been identified during the reef surveys conducted by NARA from a total of nearly 1000 known reef and reef associated species. A very high diversity of butterfly fish species (35 species) have also been recorded for Sri Lanka.

Sri Lankan reefs also support many species of invertebrates including commercially important species of spiny lobsters, shrimps and crabs and marine flora such as sea grasses and algae. Dolphins, whale sharks and sea turtles have also been sighted among inshore and offshore reefs.

Most nearshore reefs in Sri Lanka have been severely damaged due to human activities. The major causes of reef damage from human activities are coral mining in the sea, destructive fishing and uncontrolled harvesting (De Silva, 1985; Rajasuriya, 1991; Rajasuriya et al. 1995; Rajasuriya and Wood, 1997). Anchor damage to coral reefs is also common during fishing

operations and when boats are anchored within reef lagoons. Studies conducted at the Hikkaduwa Marine Sanctuary indicate that the live coral cover has declined from 21.7 percent in 1985 to 13.2 percent in 1994 where the boats are anchored within the sanctuary (Nakatani et al 1994).

Resource Use And Human Impacts

Coral Mining

Coral mining in the sea to produce lime for the construction industry has destroyed most of the fringing reefs along Sri Lanka's southwestern coast. The construction industry accounts for nearly 92% of the lime used in Sri Lanka. Sometimes lime is also used in agriculture to reduce the acidity in soils (Hale and Kumin, 1992). There are two types of coral mining primarily targeting lime production; traditional mining of ancient fossilized coral reefs found inland and below ground, and a more recent and harmful activity of mining both live and dead coral from the sea.

Some of the ancient reefs which date back to more than five thousand years (Katupotha, 1988) are located in the south-western and southern parts of the country. The most exploited and extensive ancient reefs are concentrated along the coastal belt from Akurata to Hikkaduwa in the south-

western coast and in the Matara District in the southern coast. In some areas inland coral deposits extend more than 5 km inland and down to depths of almost 10 m from ground level.

A survey conducted in 1984 by the Coast Conservation Department (CCD) in the south-western and southern coastal areas has revealed that 18,000 t of coral is being supplied annually to the lime industry. A major portion of this (42%) originates from mining inland ancient coral deposits beyond the coastal zone while 16% is mined on land within the coastal zone. Another 30% comprises coral debris illegally collected from the shore. The balance 12% contain coral illegally mined from the sea (Hale and Kumin, 1992). A survey carried out by the Coast Conservation Department in 1990 from Ambalangoda to Hambantota had revealed that nearly 2,000 persons were dependent on inland and offshore coral mining activities (Ranaweera Banda, 1990). Coral mining in the sea is also reported from the east coast around Kalkudah and Passikudah Bays. Coral mining from the sea has resulted in severe coastal erosion in all these areas where the government has spent millions of rupees to build coast protection structures.

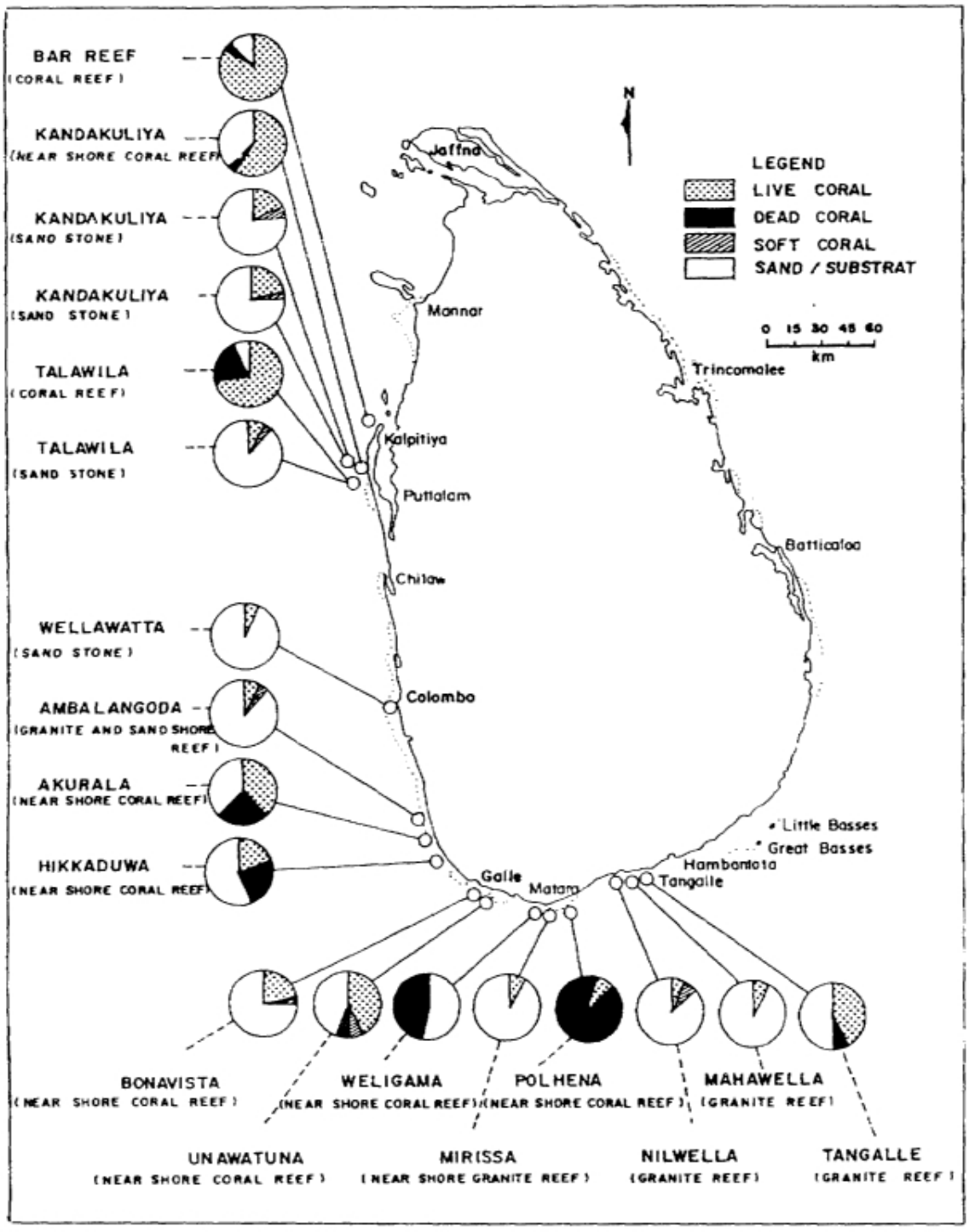

Figure 2. Percent substrate cover of coral reef sites investigated by NARA along the Sri Lankan coast. Sources: De Silva and Rajasuriya (1989); Rajasuriya (1991a and b).

Table 1 . Coral Collected for Lime Production from Sri Lanka's South-western Coastal Area in 1984

Location of Coral Collected	Amount (Tons)	Total Harvest (% of total)
Relic reefs on land		
Inland of the coastal zone	7,532	42
Within the coastal zone	2,868	16
Coral rubble on the beach		
Within the coastal zone	5,377	30
Live coral at sea from the reef		
Within the coastal *zone*	**2,282**	12
Total	18,059	100

Source: CCD, 1984, Hale and Kumin, 1992,

Fishing

Today Sri Lanka has a population of about 18 million people and nearly half of the population live in the coastal districts. The majority of economic centers are also located within these areas. Fishing is the most important economic activity carried out in the sea and supports a large number of coastal dwellers. Fish amounts to approximately 65 % of the animal protein consumption and 13 % of the total protein intake of the people. Over 90 % of the total fishing population in the country belongs to the marine sector and the marine fisheries had supplied over 97 % of the total fish production during 1987 - 1988 (Baldwin, 1991). However it is not clear how much of the total catch is supplied by reefs.. Most of the fishing is concentrated in coastal waters classified as within the first 40 km from the shore (Baldwin, 1991). Prior to the last two decades, fishing in Sri Lanka was primarily carried out from non-motorized crafts such as dugout canoes, catamarans and log crafts employing non-destructive fishing techniques such as angling, gill-netting in deep waters and beach seining.

Recently introduced highly efficient techniques such as the bottom-set nets to catch spiny lobsters and reef fish cause severe damage to coral reefs. Blast fishing using explosives is also commonly practiced in many parts of the country, being most prevalent in the southern coastal waters in the Galle District.

Ornamental fish collection and other exports

In addition to fishing activities, collection of reef fish, invertebrates and live coral for the ornamental fish export industry is of considerable importance. In fisheries export products, ornamental fish exports is rated as the third highest in volume and value after prawns and lobsters (Baldwin, 1991). Uncontrolled collection and destructive collecting techniques such as the 'moxy net' technique tends

to causes damage to the habitats (Rajasuriya, et al. 1995). Other fisheries and aquatic products harvested around coral reefs are sea cucumber, spiny lobsters and vanous species of molluscs (e. g. cowries). Collection and export of ornamental fish has increased several fold in recent times (Table 2). However the available data does not indicate the numbers of flsh exported or any records by species.

Table 2. Variation in annual export value (Rs. Million) of ornamental species from Sri Lanka over the period 1962 - 1994. Source: Wood 1996.

Period	Minimum annual export value in Rupees (million)	Maximum annual export value Rupees (million)
1962-1970	0.17	2.16
1971 - 1980	0.09	17.68
1981 - 1990	24.77	96.12
1991 - 1994	93.38	248.30

Tourism and recreational activities

Coastal areas, particularly beaches and areas with fringing reefs have become important locations for tourism development. Swimming, snorkeling, scuba diving and viewing corals through glass- bottom boats are popular activities. The majority of hotels along the coast line have been constructed without proper planning and as result numerous problems such as liquid and solid waste disposal have become major issues. In some locations such as in Hikkaduwa these issues have become acute and it has now begun to have an adverse impact on the marine environment (Nakatani et al. 1994; Rajasuriya et al 1995).

Environmental pollution

Dumping of garbage into city waterways and onto beaches has a negative impact on the marine environment in general and on the reefs in particular. The volume of non-biodegradable garbage such as polythene products in inshore waters increase daily particularly near cities and coastal towns. In addition untreated industrial effluent is discharged directly into rivers or canals that eventually pollute the sea. Oil pollution in harbours is a chronic problem particularly when fishing boats are anchored in the protected bays formed by fringing reefs or estuaries. Waste oil and bilge water is washed into these waters.

Table 3. Coral Reef Locations, Status & Causes of Damage or Threats (Major causes of damage are underlined), Sources: DeSilva, 1985; Rajasunya & White 1995; Rajasuriya *eta!.* 1995;)

Location	Status	Causes of Damage or Threats
Bar Reef Marine Sanctuary	Shallow coral area are partially damaged, deep coral area are in good condition	Crown of Thorns Starfish. destructive Fishing, uncontrolled harvesting, boat anchors
Kandakuliya	Shallow coral areas are heavily damaged	destructive fishing, boat anchors, uncontrolled harvesting
Talawila	Shallow coral areas are damaged	destructive fishing, boat anchors, uncontrolled harvesting
Chilaw	Partially damaged	destructive fishing. uncontrolled harvesting
Negombo	Mostly in good condition, damage is evident, inshore reefs are damaged	destructive fishing. sedimentation on inshore reefs. uncontrolled harvesting
Colombo	Inshore reefs degraded, offshore reefs are in good condition	sedimentation, uncontrolled harvesting, pollution
Ambalangoda to Hikkaduwa	Inshore reefs degraded offshore reef relatively good	coral mining, sedimentation. destructive fishing. uncontrolled harvesting
Hikkaduwa Marine Sanctuary	Partially degraded	sedimentation, boat anchoring. reef trampling, pollution, use of glass bottom boats, increase of Halimeda
Galle including Rumasssala reef	Degraded	sedimentation, uncontrolled harvesting, destructive fishing. pollution
Unawatuna	Partially degraded	sedimentation. pollufion, reef trampling, anchors, uncontrolled harvesting
Weligama	Partially degraded	sedimentation, pollution, reef trampling, anchors. destructive collecting, uncontrolled harvesting
Poihena, Matara	Heavily degraded	coconut husk seasoning. sedimentation. uncontrolled harvesting
Tangalle	Partially degraded	sedimentation, reef trampling. souvenir collection
Great and Little Basses	Undegraded	uncontrolled harvesting
Batticoloa & Trincomalee	Some locations degraded	destructive fishing. uncontrolled harvesting

Reef Research In Sri Lanka

Early research on corals and coral reefs were carried out at the turn of the century by Ridley (1883), Ortmann (1889) and Bourne (1905) who described primarily the solitary corals collected from the Gulf of Mannar. Pillai (1972), recorded the species diversity of stony corals for Sri Lanka which contained a total of 90 species divided among 39 genera. In 1974 Mergner and Scheer carried out an ecological study at Hikkaduwa and reported on the Physiographic Zonation and ecological conditions of fringing reefs. Scheer (1984), updated the list of stony coral genera for Sri Lanka to a total of 40 genera based on their investigations and the work of previous authors.

More recent research was reported by De Silva and Rajasuriya who carried out research from 1985 through the National Aquatic Resources Agency. In 1985 they discovered 25 species of stony corals previously unrecorded for Sri Lanka, many of these were from Hikkaduwa. An additional 34 species and 8 genera were recorded for Sri Lanka by Rajasuriya and De Silva in 1986, A total of 171 species of stony corals divided among 65 genera were recorded by Rajasuriya and De Silva (1988) of which 65 species and 15 genera were new records for Sri Lanka. Their coral list was based on previous records and on extensive coral collections made by the Coral Reef Research Team at NARA from Tangalle in the South coast to Kandakuliya in the north-western coast. In 1994 Rajasuriya updated this list by adding another 12 species and 3 genera previously not recorded for Sri Lanka, increasing the total to 183 species of stony corals divided among 68 genera.

A detailed survey of coastal reefs was carried out by NARA from 1990 onwards with the support of the Swedish Agency for Research Cooperation with Developing Countries (SAREC) (Ohman et al. 1993; Rajasuriya, et al., 1995). Initial surveys conducted by Rajasuriya (1990), at the Bar Reef led to the declaration of the Bar Reef as a Marine Sanctuary (BRMS) in 1992. De Bruin (1972), reported on the destruction of coral reefs off the east coast by the coral predator *Acanthaster plancl* in the early 1970's. In 1994, Rajasuriya and Rathnapriya reported on the destruction of coral reefs in the northwestern of Sri Lanka by the Crown of thorns' Starfish and its implication for management of the Bar Reef Marine Sanctuary.

The first investigations geared towards the management of coral reefs was carried out at Hikkaduwa by De Silva and Rajasuriya in 1985. They proposed a zonation and management plan for the Hikkaduwa Marine Sanctuary in 1985 and recommended that the sanctuary be declared a marine park in view of the multitude of activities within the existing sanctuary. This management plan has now been adopted in the Special Area Management Plan (SAMP) for Hikkaduwa prepared by the Coastal Resources Management Project which carried out a Special Area Management Project for Hikkaduwa from 1992 to 1995. The National Aquatic Resources Agency played a central role in the SAM studies which was reported by Nakatani et al. (1994), in the Coastal Environmental Profile of Hikkaduwa.

Research on coastal erosion and socio economic aspects of coral mining has been mainly conducted by the Coast Conservation Department (Madduma Bandara, 1989; Dayananda, 1992; CCD, 1990; Ranaweera Banda, 1990; Baldwin, 1991; Ranaweera Banda etal. 1994)

At present the National Aquatic Resources Agency is conducting studies on the potential of the marine ornamental fisheries in Sri Lanka and is conducting underwater video monitoring of the status of the reefs. These programmes are supported by the Darwin Initiative of UK and by SAREC/Sida of Sweden.

Marine Protected Areas And Management

In Sri Lanka there had been Legislation to protect marine organisms more than a century ago. An example can be traced back to the late 19th century when the Chanks Ordinance of 1880 was introduced to control the collection and export of chanks from the Gulf of Mannar region and around the Jaffna Peninsula.. Subsequently this legislation was expanded to introduce a ban on the collection of chanks, heche-de- mer, coral and shells from Mannar to a point 2 miles south of Talawila. The protection to marine organisms had been provided under the 'Crown Lands Ordinance of 1929', where removal of coral and certain organisms were prohibited from specific locations. Sanctuaries were declared in Ambalangoda and Hikkaduwa Rocky Islets by Gazette No. 8675 of 25th October 1940. Similarly the Naval Headworks in Trincomalee and the Great and Little Sober Islands within the Trincomalee harbour were declared in 1963. In 1973 the Paraitivu Island west of the Jaffna Peninsula and in 1974 the Pigeon Islands north of Trincomalee were declared as sanctuaries (Gazette No. 136 of 1st November 1974). Although these areas were mostly offshore islands it is not clear whether the sanctuary status extended to include the adjacent waters. In 1973 regulations were drafted to declare the sea area between Mt. Lavinia and Galle Face on the west coast as a Lobster Reserve, but there is no evidence to indicate that it was ever Gazetted. In 1980 Cabinet approval had been granted to the Ministry of Fisheries to declare the Hikkaduwa Harbour area, Polhena Reef area, Great and Little Basses Reefs, Passekuda and Kalkuda Bay and the Pigeon Island as Marine Sanctuaries under the Fisheries Ordinance. However, there is no indication that these areas were ever declared as marine sanctuaries under the fisheries ordinance.

In 1982, an Inter-Ministerial Committee on Marine Parks and Sanctuaries formed by the National Aquatic Resources Agency (NARA) had identified more than 20 coral reef areas around the island to be declared as sanctuaries. However, at present there are only two sea areas that have been declared as marine sanctuaries especially to protect the coral reefs. They are the Hikkaduwa Marine Sanctuary (declared in 1979), and the Bar Reef Marine Sanctuary (declared in 1992) declared under section 2(2) of the Fauna and Flora Protec-tion Ordinance (Chapter 469) as amended by Act No. 44 of 1964 and Act No. 1 of 1970.

Table 4. Ministries and government departments directly or indirectly responsible for the coastal waters.(*) Those with direct authority over coral-reef management or research.

Ministry of Fisheries and Aquatic Resources*

Development and management of all fisheries activities, conservation of aquatic habitats and protection of vulnerable, rare and endangered species. Licensing of fishermen, crafts and gear, also construction and maintenance of fisheries harbours.

Ministry of Forestry and Environment

Responsible for terrestrial and aquatic environments.

Ministry of Ports and Shipping

Activities connected with shipping and commercial harbours.

Ministry of Tourism

Responsible for planning and developing the tourist industry.

Department of Wild Life Conservation*

Management of protected areas and conservation of selected species.

National Aquatic Resources Agency -

Research and development of all aquatic living and non-living resources.

Central Environmental Authority -

Establishing national environmental standards and the principal coordinating body for all environmental related activities, which includes overseeing Sri Lanka's environmental impact assessment (EIA) process.

Coast Conservation Department -

Regulating development activities within the coastal zone and safeguarding coastal resources. Responsible for implementing the Coastal Zone Management Plan.

Urban Development Authority

Responsible for planning and development of towns, cities and their networks of garbage disposal systems etc.

Ceylon Tourist Board

Planning and development of tourist facilities and licensing authority for tourist related activities.

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Ceylon Fisheries Harbours Corporation

Development and maintenance of fishery harbours.

Sri Lanka Ports Authority

Supervises port development and management.

National Drainage and Water Supply Board

Supply of drinking water and sewerage facilities.

Coral reefs are an extremely important resource for the people of Sri Lanka, offering a number of economical and environmental benefits. From the presently available information it is clear that they are being depleted at an increasing rate. Almost all the reefs around the island are influenced by people. Although laws have been introduced to protect reefs and regulate human activities, few have been implemented. There are also a number of government organizations that are responsible for the well being of coral reefs and the associated coastal habitats (Table 4).

Sri Lanka's Coastal Zone Management Plan, the National Environmental Act, the Fisheries Ordinance and the Fauna and Flora Protection Ordinance provides the necessary guidelines and regulations for the use and protection of the marine environment in general and sensitive marine ecosystems in particular. Nevertheless due to inadequate coordination at different levels of government as well as various political considerations make it difficult to implement the laws and regulations.

The Coastal Resources Management Project (CRMP) supported by the USAID carried out two Special Area Management Projects (SAMP) at Hikkaduwa Marine Sanctuary and at Rekawa where coral mining from the sea was a major problem. Whilst these projects have had their benefits the lack of continuation of the SAM process poses problems for the sustainability of management efforts at both sites.

Protection has also been given to selected marine species listed under the Fisheries ordinance as well as the Fauna and Flora protection Ordinance of the Department of Wild Life Conservation (Wood and Rajasuriya, 1996). In 1993 and 1994 the CCD implemented the ban on operation of lime kilns within the coastal zone. However it has proved difficult to enforce the ban due to lack of alternative employment and the inability to enforce the law.

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Profile And Status Of Coral Reefs In Maldives And Approaches To Its Management

Abdulla Naseer[1]

1. BACKGROUND AND INTRODUCTION

1.1 Location and Geography

The Maldive islands are located just south of Lakshadweep Islands (7° 06'N to 00° 45' S latitude and 72°13'E to 73° 45' Longitude) about 480 km South west of Cape Comorin, India and 650 km South west of Sri Lanka (Fig. 1). It comprises of 26 Natural atolls and some 1190 islands. The total length of the chain is 648 km north to south and 130 km east to west forming a double chain in the center.

1.2 Atoll Geomorphology

The physical setting of the Maldivian atolls vary from open structures with numerous *islands, faros* (ring-shaped reefs) *patches* and *knolls* in the atoll lagoon and around the rim to almost closed structures with few lagoons, knolls and patches. *Faros* are ring shaped reefs emerging during tidal low water each with their own sandy lagoon and are separated by deep channels. They generally have a rim of living coral consisting of branched and massive types. *Patches* rise to 40 meters above the lagoon floor and are topped by robust wave-breaking corals. *knolls* do not reach the surface and often support profuse coral growth, as do the reefs associated with many of the islands

In geological time the filling up of the lagoons of *faros* by reef sediments has resulted in the formation of *coral islands.* The geomorphology of these islands varies tremendously in different atolls and it is influenced by a variety of factors such as location, climate, currents, tides, sea level change and also human factors. The islands are thought to be situated on top of layer of beach rock (about 1 m thick), underlying the islands at about 30 cm to 60m above present mean sea level. At the edges of the isiands the beach rock dips slightly seawards and forms a platform on which the beach sediments are seasonally transported around the islands. Within the atolls, the water depth is about 60 meters.

The islands are made up of coralline sand and have a very low elevation (on the average they are no more than 2 meters above sea level). The soil is highly alkaline, the water table is high and the vegetation is sparse. Main vegetation types are coconut palms and salt resistant plants and mangroves.

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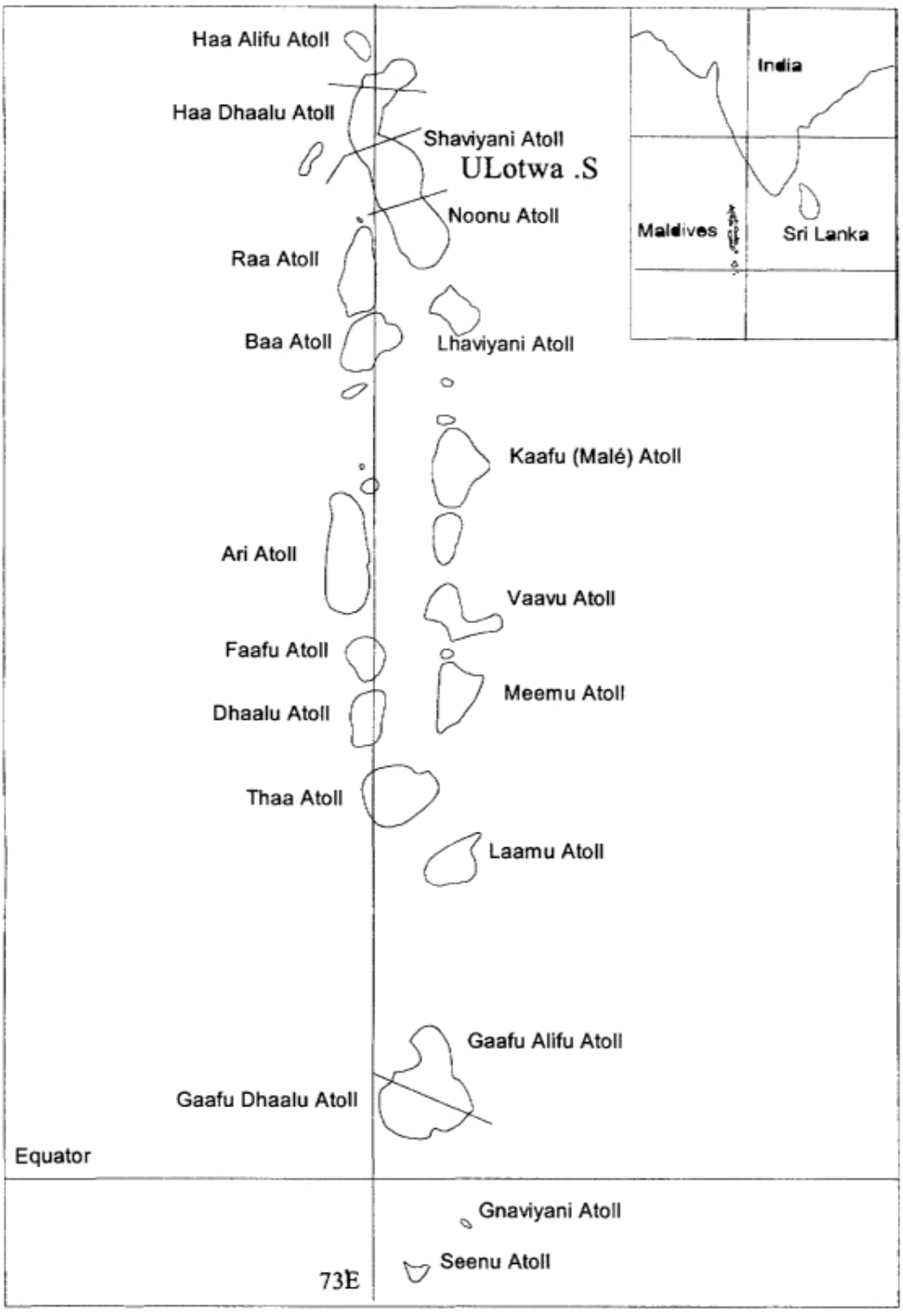
Figure 1. Location Map of Maldives



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1.3 Climate and Oceanography

The south-west and the north east monsoons play a major role in climate and oceanography in the Maldives. The climate is totally governed by the monsoons. The south-west monsoon (May - Oct.) brings rain and the seas are moderate to rough during the SW monsoon winds. The north east monsoon (Nov.- April) are marked by calmer and dry conditions. Surface currents and winds, humidity and rainfall and temperature and salinity are strongly effected by the monsoons.

The absence of rivers and runoffs mean that sediments from inland sources are almost nil and hence the waters around Maldives are very clear and exhibit ideal conditions for coral growth. The Maldives is located outside the normal cyclonic zones and thus violent storms are rarely been experienced. Precipitation is on average 160-230 cm /year. Air temperatures range between 24°-31°C. Spring tides range from 0.3-1.2m. Tides are semi diurnal sometimes mixed.

1.4 Population and Economy

The islands have population of about 280,000 scattered thinly over 200 islands. The capital Male, with an area of about 4 sq. km and a population of over 60,000, is located almost in the center of the archipelago. The population is young, 50% of the population is under 18 years of age and the population growth rate is 3.4%.

Being a country with more territorial sea than dry land, Maldivians depend on resources almost entirely from the sea. The coral reefs, which built the country, play a vital role in the economic and social well being of the country.

Fishing and tourism are the two main industries of Maldives. Both these industries are very healthy with good potential growth rates. They rely on healthy reefs for their existence. The majority of fish caught are tuna and tuna-related species. Other reef dependent species of fish and invertebrates are also exploited.

Fishery production has increased from 82,000 MT in 1992 to over 104,000 MT in 1996. The export earnings from marine products has increased from RF 332 million in 1992 to RF 433 million in 1995 (1US$ = RF11.82). The reef fishery especially for the live food fish has increased tremendously from 127,000 nos. in 1994 to 400,000 nos. in 1995. Total fish production in 1996 was 105,000 MT of which reef fish landing for 1996 was 14,600 MT.

About 70 of the uninhabited islands are developed as tourist resorts and in 1996 there were more than 300,000 visitors. Visitors are thought to be constrained by the number of beds available.

Industrial activities especially those relating to fishing and tourism are being developed in many atolls. Usually one island is developed for a particular economic activity. Tourist resorts and fish processing facilities are examples of such development. Over 80 tourist resorts are developed in Baa, Lhaviyani, Male, An, Vaavu, Meemu, Dhaalu and Seenu Atolls. Fish processing and cold storage facilities are situated in Laviyani, Gaafu Alif and Laamu Atolls. Laamu Atoll has also been declared as an industrial zone.

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1.5 Marine Ecosystems and Ecology

The predominant ecosystem being coral reefs in the Maldives, much effort has been put into the study of diversity and dynamics of reefs. However the remoteness of many reefs and their wide distribution makes it all very difficult for research work. The reefs that have been best studied are in Male atoll, Ari atoll, and Addu atolls. Pristine reef areas are still found in many parts of the country. Hence the majority of reef areas are unexplored. Important ecological areas include:

Open seas and deep seas

The Maldives has more sea than land. Open seas and deep waters are important resource bases in the country. Very little work has been carried out to identify fauna of the open seas. Commercially important species of pelagic fish especially Tuna are abundant in the waters of the Maldives and they are perhaps the best known of all marine animals in Maldives. Work is ongoing to study deep-sea fishery resources.

Coral reefs

The Maldives is entirely made up of atolls and associated coral structures. Extensive and largely intact reefs are found in pristine conditions and comprises of perhaps the most complex reef systems in the world. Several of the atolls have unusual ring shapes reefs locally known as faros in the atoll lagoons each with its own sandy lagoons and rims of lining corals. The atoll lagoons also have numerous knolls and patch reefs.

Seagrass beds

Seagrass patches are very often found in the shallow lagoons just behind coral reefs and various fish, molluscs and crustaceans inhabit the seagrass beds. It is widely believed that coral reef fishes migrate to seagrass areas for breeding. Seagrass beds are not very extensive in the Maldives and few studies have been carried out on these areas at ecosystem levels.

Mangroves

Fringing mangroves are not found in the Maldives. Mainly depression mangroves are found in enclosed areas along the coast. Inland fresh water systems though very rare are found in some atolls.

Though a representative number of islands were surveyed during 1992, it was felt that there is a need to obtain more information on a countrywide basis. A clear pattern of distribution of mangrove species was observed during this initial study. For example *Brugiera cylindrica* (kandoo) was the dominant species in the northern atolls whereas *Rhizophora sp.* was the dominant species in the south.

1.6 Coral Reef Biodiversity

The Maldives consists entirely of coral reefs the most diverse of all marine ecosystems. Coral reefs are known to host many levels of biodiversity ranging from planktonic organisms to

sharks. The dominant species on reefs are corals and fishes. Both these account for a large share of the diversity of coral reefs.

Although the corals are the major organisms that form the basic reef structure, there is bewildering array of other organisms associated with reefs, such that these areas are perhaps the most diverse and species rich areas that exist in the marine environment today. Members of practically all phyla and classes may be found on coral reefs.

A total of over 1000 species of fish have so far been catalogued from the Maldives. Over 300 of these. were recorded from the Maldives for the first time. Seven species have been described as new to science, several more await description. Over 400 have been identified and catalogued and many are now held in the reference collection.

Scleratinian corals of the Maldives have been relatively well studied. Descriptions of 147 species, and literature records of a further 94 species, making a total of 241 species have been recorded. The total number of coral species recorded from the Maldives to date is about 200, representing over 60 genera.

5 species of turtles have been recorded for the Maldives of which only *Chelonia mydas* and *Eretolochelys imricata* are the most common two species that breed in the Maldives.

51 species of echinoderms, 5 species of sea grasses and 285 species of alga have also been identified. Studies on crustaceans, sponges, tunicates as well as deep sea fishes are being carried out at present. Sponges have gained a special interest as five species have already being identified as having anti-tumor and anti-cancer properties.

A reference collection of all marine species collected so far is kept at the Marine Research Section of the Ministry of Fisheries and Agriculture. There are also a number of specimens that have not been identified.

2. PATTERNS OF CORAL REEF EXPLOITATION

The marine environment is critical to th& natural and cultural heritage of the Maldives. Marine ecosystems and resources are fundamental to the sustainable development of the country providing food, construction materials and a vast range of other products. It is widely believed that coral reefs in the Maldives are in a relatively pristine state, and of high aesthetic quality. However with increasing environmental pressures, rising environmental sensitivity, adverse effects may be felt sooner rather than later.

Apart from supporting a growing tourism and recreation industry, coral reefs also play a vital role in fisheries, and in the culture and life style of people in Maldives. Development undoubtedly effects the environment and bio diversity in a negative manner. Maldives is no exception. The traditional life style of the people had almost negligible impact on the marine environment, but recent socio-economic developments have led to deterioration of the environment. With the increase in population growth and increased wealth from tourism and fishing, the pace of development have increased at a significant rate in the country, during the last two decades.

The need for land led to land reclamation programmes. Harbours are dredged to facilitate economic growth in islands. The demand for building materials in the form of coral nodules has increased steadily and coral mining has become a major environmental concern in the country. In addition to this the country is faced with localised environmental impacts as a result of tourism and waste discharges. Tourism, reef fishing, coral mining, dredging, reclamation and the construction of maritime structures and pollution do have impacts on coral reefs. Both tourism and fishing, which represent the main industries in the Maldives, rely heavily on coral reefs.

2.1 Tourism

Tourism began in the Maldives in 1972 and is now the largest industry in the Maldives. Tourist arrivals increased 300 folds from 1097 in 1972 to 338,733 in 1996. During the last 25 years of tourism development in the Maldives, positive growth rates have been recorded every year except for the years 1983 and 1986, which showed a slight decline. The number of resorts also increased over the last 25 years and theje are 73 resort islands concentrated mainly in two atolls (Male and Ari Atoll). Tourism is a major source of revenue to the country. In 1996 revenue from tourism accounted for over 30% of the government's total revenue that amounted over 408 million Rufiyaa (Statistical Year Book of Maldives, 1997).

With the introduction of tourism in the Maldives, the coral reefs gained a major economic significance. Tourism in the Maldives is centered around coral reefs and relies on these rich and healthy reefs for the welt being of the industry. Diving, snorkelling, water-sports, sun, and white sandy beaches are the major products sold for tourists in the Maldives. A significant proportion of the visitors who come to Maldives do so to enjoy and admire the beauty of underwater gardens of corals and the colorful fishes and invertebrates which inhabit coral reefs. If the health of reefs decline through ill-conceived management or other causes, then the tourism industry will be affected adversely. The tourism industry in the Maldives can only be sustained and prospered by proper management of its coral reef resources. Hence coral reefs are vital to the sustainable development of the tourism in the country.

It is evident that there are few serious environmental concerns in the tourism sector in the Maldives. Most resorts are conservation centers in real time due to high priority extended to the protection of the environment and to the management of the natural systems. Reefs happen to be one of the most important products the resorts are trying to sell apart from sun, sand and the seas. It is absolutely essential that reefs around resorts are maintained in healthy conditions. Hence many tourist resorts in the Maldives have stringent controls in the collection of fauna from the reefs. Collection of corals, shells and reef fishing are not allowed at tourist resorts. The government declared a tourism zone in the early stages of Tourism development in the country and this has certainly benefited the reef ecosystems. Sustainable use of coral reefs and successes in the development of tourism in the Maldives can be attributed to the following:

- One island - one resort
- Little intervention by locals and hence very few conflicts

- The government regulates and controls resort building and development efficiently
- It is the government who selects and decides which islands can be developed for tourism.
- Tourism zones has been established early in development
- Commitment by most resort owners to conserve reefs
- Awareness high among resorts on the marine environment
- Most dive centers at resorts are very committed to conservation and report illegal activities promptly
- Reef fishing and curios collection banned at resorts
- Pressure on reefs low due to wide distribution, scatteredness of resorts and hence the tourist population.

The second 10-year tourism masterplan has been drawn up for tourism development in 1996 and 14 islands have been selected for development under the plan.

There are localised impacts of tourism. Diver and snorkeller damage to reefs have been described. Anchor damage to reefs has been highlighted as a major problem in some areas. More recently concerns have been raised over the discharge of sewage and wastewater its consequences on the reef environment at some resorts. Sewage pollution needs to be looked into urgently.

2.2 Reef Fisheries

Maldives is a large tuna-fishing nation and hence its people are very dependent on tuna fish for food. Reef fish are not widely used for consumption by the local people. Reef resources have been little used in the past and was limited to live baitfish for the pole and line tuna fishery. Major baitfish types caught are: sprats, juvenile fusiliers, cardinal fishes and anchovies. Live bait catches has increased dramatically over the last two decades. Over 10,000 tonnes of bait were collected from reefs around the country in 1994.

With the introduction of tourism in the 70's and rapid socio economic developments in recent years, a growing reef fishery has developed in the Maldives over the last two decades, The reef fishery is now is expanding rapidly. In the late eighties and early nineties new reef fisheries activities have developed. These are mainly export oriented and include giant clam, sea cucumber, groupers and aquarium fish.

The giant clam fishery, which started in 1990, was short lived. Two species were exploited *(Tridacna squamosa* and *Tridacna maxima).* Within six months of the fishery, stocks were exhausted and the fishery is now banned as a result.

The sea cucumber fishery began in 1985 in the Maldives and increased rapidly. Main species collected are: Prickly Red Fish *(Thelonota ananas),* White Teatfish *(Microthele nobilis) Holothuria atra.* The fishery reached a peak in 1990 and has fallen since then. The

government has brought in restrictions on the fishery as a result of over exploitation. SCUBA gear cannot be used to collect sea cucumbers by government regulations now in the Maldives.

The grouper fishery, which started in 1993, has increased dramatically. Due to high prices paid for groupers the fishery has expanded in a short period of time and its wide spread. There are already signs of over exploitation. Groupers are exported live and frozen.

The export oriented aquarium fishery began in 1980. The fishery increased steadily since then.' Concerns have been raised over the exploitation of rare species and several species are now banned from export. A quota system has also been introduced.

Reef fishing in general can be carried out virtually anywhere by the local fishermen. There are few restrictions as to where fishermen can fish except only around resorts and Marine Protected Areas. Concerns have been raised on the sustainable exploitation of reef fish resources and plans are underway to demarcate zones for reef fishing. Reef resources that are under pressure from over exploitation include giant clams, sea cucumbers, groupers, certain reef sharks, turtles, and corals. Management measures are being implemented to alleviate the pressure on these populations and reef resources in general.

2.3 Coral Mining

Coral reefs in Maldives represent strategic natural offshore sea-defence. They are also important as habitat for baitfish and primary source of building material, Coral blocks have been historically mined and used for buildings and road construction. The coral blocks are extracted from shallow reef flats at 1-2 meters depth, with help of iron bars to break up the living coral. The lumps are break in smaller sizes, available to transport.

The biological and physical impacts of coral mining on reefs in Male' Atoll, Maldives were investigated by Brown and Dunne, (1986;1988). They reported that live coral cover on reefs subject to coral mining was very low compared to unmined reefs. Response of reef associated fish to coral mining was reported by Shepherd *et al.* (1992) and Brown *et al* (1990). Fish community structure was compared on mined and non mined reef flats and their adjacent slopes. Abundance of reef fish was found to be low on mined reefs compared to non-mined reefs.

The use of concrete blocks as an alternative to corals is now wide spread in the country as a result of the awareness programmes and due to regulations which came into effect recently. It must also be said that people are finding it increasing difficult to obtain corals for building purposes as a result of higher costs and regulations.

Corals are not used to any extent at Male, the capital island, and at resorts now for building purposes. Concrete blocks are manufactured in large quantities by the public and private sectors in Male to cater for the building industry. Of special interest is that the Ministry of Construction and Public Works now produce concrete blocks at low prices in large quantities and sell them to the public at any quantity required.

3. CORAL REEF MANAGEMENT AND RESEARCH IN THE MALDIVES

3.1 Legislation relating to coral reefs

The Ministry of Fisheries and Agriculture is legally responsible for the management of all issues and activities relating to marine living resources in the Maldives.

The Fisheries Law of Maldives (Law No. 5/87, 24-08-87) governs the management of all fisheries activities in the Maldives. Fisheries Regulations (1997) drawn under the Fisheries Law of Maldives and gives details and updates relating to fisheries regulations in the form of notifications and written regulations.

Specific destructive fishing practices are banned in the Maldives. The following are banned **methods of fishing:**

- **Use of dynamite or explosives**
- **Use of guns and such devises to catch fish**
- **Use of any chemical to collect or catch fish**
- **Use of scuba gear to collect sea cucumber and lobsters**

Under the Fisheries Law of Maldives special areas or species can be protected from exploitation or export if the need arises. The Fisheries Regulation gives details of protected marine species in the Maldives from exploitation and/or export. This is part of the steps taken by the government to conserve and manage coral reefs and the marine environment in a sustainable manner.

Marine species banned from export (as of December 1996) in the Ma/dives include:

1. Black corals
2. Trochus shells
3. Triton shells
4. Pearl Oysters
5. Lobsters and lobster meat-
6. All types of corals except organ pipe coral
7. Turtles
8. Puffer fish
9. Eels
10. Bigeye scad under 6”
11. Skates and rays
12. Dolphins
13. Whales
14. Parrot fish
15. All types of bait fish

Marine species totally prohibited from collection or exploitation (As of December 1996) in the Ma/dives include:

1. Dolphins
2. Whales
3. Whale shark
4. Turtles
5. Triton shells
6. Napoleon Wrasse
7. Berried female lobsters and those less than 25cm in total length
8. Black coral
9. Giant clams

Much effort have been put recently into the development of mariculture activities in the Maldives. Pilot projects have been carried out on the culture of seaweeds. Other projects in the pipeline include sea cucumber, lobsters, aquarium fish, giant clam and pearl oysters. Currently there is no aquaculture specific legislation designed to manage aquaculture ventures in the Maldives. Aquaculture activities are known to have adverse effects on coral reefs. Although there are no aquaculture establishments yet in the Maldives, temporary cages or holding facilities are maintained for reef fish before they are exported live. Under the fisheries regulation government issued permits are required to set up floating or other cages to hold and rear reef fish species.

3.2 Regulations relating to Coral Mining

The government is concerned about the environmental implications of coral mining. Prior to 1992 there were very few regulations as to where people could or could not mine corals. It was then simply a matter of protecting properties such as islands belonging to individual owners.

In 1992 new regulations were introduced to combat uncontrolled mining activities. The following regulations are now in effect in the country. These Regulations are now under revision.

- *Mining is not to be carried out on island house reefs.*
- *Mining cannot be carried* out *on atoll rim reefs and common bait fishing reefs.*
- *Applications are required to be submitted to the atoll offices through island offices by any one needing corals to build any structures and permissions need to be granted by the atoll office before any mining can be carried out.*
- *The island office is required to estimate the quantity of corals required for the applied construction work and hence should ensure that only the required amount is granted.*
- *Every island is required to keep a log book of the amount of corals mined.*

3.3 Environmental Legislation and Marine protected areas

Government realises the urgency in its commitment to stewardship of he environments contained in the Agenda 21. In 1993, the Parliament enacted the Environment Protection and Preservation Act of the Maldives (law No. 4/93). Key elements in the Environment Law include

the submission of an Environmental Impact Assessment report to Ministry of Planing Human Resources and Environment prior to implementation of any developmental project that may potentially impact the environment. Hence EIA's are mandatory for all projects relating to coral reefs. The law prohibits disposal of wastes, oil, poisonous chemicals or environmentally harmful substances within the territory of Maldives. Fines of up to Maldivian Rufiyaa 100 million may incur depending on the offence for environmental damage.

The Environment Act also paved the way for the establishment of marine protected areas and nature reserves. As a first step, 15 coral reef dive sites have already been declared as Marine Protected Areas on June 5 1995 (Table. 1).

These sites are protected under the Environment Act of Maldives and come under the jurisdiction of the Ministry of Environment. In addition a number of islands of ecological significance, for example as seabird roosting and nesting sites, are under active consideration for protection.

Recognising the difficulty of effectively managing multispecies reef fishery, the Ministry of Fisheries and Agriculture of Fisheries and Agriculture has recently proposed to declare two large areas as strict reserves, mainly to assist recruitment of the fisheries.

3.4. Organisations Involved in Coral Reef Management and Research

Many sectors of the government are involved in the management of coral reefs and their resources. The Ministry of Fisheries and Agriculture (MOFA) represents a focal point for many marine activities. The Ministry of Fisheries & Agriculture is responsible for the management of living resources in the Maldives. The ministry manages coral reefs and associated species. Law and regulations concerning the management of coral reefs are formulated by MOFA.

Marine Research Section

The Marine Research Section (MRS) is the research arm of the Ministry of Fisheries and Agriculture. Its main fields of activity include biological sciences, coral reef ecology, marine fisheries, resource management and information services.

MRS was established with a mandate to undertake research in marine biology and fisheries, particularly the study of population dynamics of commercial fish, with an emphasis on **management of the fishery. Fisheries research in coastal marine waters and reef conservation are the** two main functions carried **out at present. It had played a central role** in coral reef **research and management during the last 10 years. Many research projects both local and foreign funded have been carried out on reefs. It represents the major institution in the country responsible for managing and carrying out coral reef research work.**

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Table 1. Established marine protected areas in the Maldives

—	Atoll	MPA	Location	Special features	Area
1	Lh.	Fushivaru thila	Channel south of Lh. Fushivanu	Superb hand corals Abundant reeffish; pelagic fishes. Manta Rays	100 m
2	N. Male'	Makunudho o kandu	Channel to west of Makunudhoo	Conals; reef fishes; shanks.	100 x 2000 m
3	N. Male	Rasfani	Outen neef of Rasfani Island	Grey reef Shanks, Manta nays	5000 x 1700m
4	N. Male'	H.P. Reef	Thila in channel between Girifushi & Himmafushi	Soft corals and gongonians; reef and pelagic fishes; sharks.	100 m radius
5	N. Male	Banana Reef	Between Kunumba Club Med & Full Moon Resorts	Fish and corals	100m nadius
6	N. Male	Giraavanu Kuda Haa	Inside south end of North Male Atoll	Corals abundant fish and stone fish	100m radius
7	N. Male'	Lions Head	Centre of Thila Falhu facing Vadhoo Channel	Shanks.	500m nadius
8	N. Male'	Hans Hass Place (Kikki Reef)	West end of Galhu Falhu facing Vadhoo Channel	Corals; caves; neef fishes.	500m nadius
9	S. Male'	Embudu Channel	Entine Embudu kanduolhi	Sharks; pelagic fishes.	Entine Channel
10	S. Male'	Gunaidhoo Channel	Entire Gunaidhoo kanduolhi	Conals; reef and pelagic fishes; sharks.	Entire Channel
11	Ani	Maaya thila	Thila to west of Maayafushi	Abundant fish life; sharks. Manta nays	500m nadius
12	Ani	Fish Head /	Mushimasmingili thila	Sharks.	500m nadius
13	Ari	Onimas thila	Thila in channel south of Onimas faru	Corals; soft corals; neef fishes.	100m nadius
14	Ari	Kuda Rah thila	Thila east of Kuda Rah	Corals; reef fishes; sharks.	100m radius
15	Vaavu	Devana Kandu	West side of Vaavu Atoll	Soft corals, fish and gney neef shanks	Entire Channel

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Major research activities relating to coral reefs carried out by the MRS are out line below. A number of reports and publications are available on these research topics at MRS.

- Baitfish research
- Collection and identification of economically important reef fish species
- Reef fish stock assessment
- Reef fish resources surveys
- Coral and reef fish taxonomy
- Effects of reef degradation on local reef fisheries
- Impact of crown-of-thorns starfish on coral reefs
- Impacts of coral mining
- Reef monitoring
- Rehabilitation of reefs subject to coral mining activities
- Biology and ecology of corals and reef fish

Environment Research Unit

The Environment Section of the Ministry of Planning Human Resources and Environment is responsible for co-ordination of all environmental activities in the country. It plays a central role in all marine environmental management as well as setting environmental standards and guidelines.

The Environmental Research Unit (ERU) is entrusted with carrying out all research work relating to the environment, and making available all relevant data for programming, planning, enforcing and regulating environmental matters.

The aims and objectives of the ERU are:

- to establish environment research capability within the country.
- Carry out research in all environment related fields in the country.
- make available all relevant data and information to provide for sound environmental management in the country.
- Develop and strengthen the technical know-how and manpower in the field of environmental research and management.
- Create sound environmental awareness and knowledge within the public and government administration.

Ministry of Construction and Public Works

The Ministry of Construction and Public Works (MCPW) undertakes major locally managed government projects; most significantly, dredging and harbour construction projects. There are many ongoing dredging projects throughout the country for which it is responsible. MCPW is also responsible for the management of all solid wastes in Male'. It also therefore has a role to play in the management of reefs in terms of solid waste disposal and sedimentation. Therefore this ministry is an integral part in the management process.

Ministry of Tourism

All aspects of tourism in the country are the responsibility of the Ministry of Tourism including the management of the marine environment of tourist islands. For most purposes it has its own regulations. Permission for activities such as dredging and the construction of artificial maritime structures at resorts will need to be cleared by the Ministry of Tourism. It is also responsible for **tourism regulations in the country.**

The Government of Maldives commissioned the second Tourism Master Plan in 1994 and was completed in 1996. The plan clearly spells out the policies, strategies, targets and details of tourism expansion in the country for the period 1996-2005.

The Tourism Master Plan 1996-2005 spells out the future strategy for balanced regional tourism development. Under the plan the tourism zone was expanded recently to include atolls North **and South of Male and An Atolls. The estimated targets for visitor arrivals for the year 2005** is 650,000 and the resort beds to be increased to 20,500. The plan proposes the following actions for environmental management in tourism development:

- **Integrating Tourism with coastal resources management;**
- **Tourism and marine research;**
- Developing marine protected areas;
- Environmental public awareness programmes;
- **Resort environmental improvement measures;**
- **Resort infrastructure standards.**

The tourism regulations are drawn under the Law on Tourism in the Maldives (Law No: 15/79). There is a written regulation available at the Ministry of Tourism for the general public. However there are also many regulations in the form of circulars or notification that aren't necessarily compiled. Given below are some of the circulars that have been issued in relation to environment protection at resorts.

Disposal of garbage	MoT Circular 06/84
Disposal of garbage	MoT Circular 03/85

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Waver of customs duty on incinerators	MoT Circular 19/85
Incinerators and compactors	MoT Circular 19/86
Incinerators on credit	MoT circular 01/90
Blockage of jetties	MoT Circular 21/90
Catching and sale juvenile and berried lobsters	MoT Circular 22/90
Keep the environment clean	MoT Circular 13/91
Mining of Coral	MoT Circular 25/91
Dredging an reclaiming of land	MoT Circular 07/92
Rubbish collection	MoT Circular 24/92
Crown of Thorns Starfish programme	MoT Circular 62/92
Incinerators and compactors	MoT Circular 27/92
Waste minimising project by LTU	MoT Circular 27/93
Supply of incinerators through Norwegian grant loan facilities	MoT Circular 5/94

4. POLICY AND STRATEGIES ON CORAL REEF MANAGEMENT

A number of activities have been initiated by MOFA and various sectoral agencies of the government to manage and conserve coral reefs. A National Environment Action Plan was drawn up by the government in 1989 with the objective of integrated environmental management in the country. Under the Environment Action Plan, the following issues relating to coral reefs were designated for immediate consideration:

- Coral mining;
- Sewage contamination of coastal waters;
- Sea level rise;
- Solid waste management;
- Dredging.

4.1 Awareness and Education Programmes

Regular awareness programmes are carried out by MOFA and MRS to increase awareness on coral reefs amongst school children and the public. Poster, magazines and leaflets are produced and distributed. In addition to this, lectures, video and slide presentations are organised for schools on coral reefs. Such programmes are incorporated into the work schedules of the Marine Research Section.

With financial and technical assistance from the Bay of Bengal Programme (BOBP) a major awareness programme on reef resources was conducted in Vaavu and Meemu Atolls during the period 1992-1993. This was essentially a pilot activity to investigate and monitor the levels of community participation and involvement in marine resources management. Many workshops, seminars and surveys were carried out in both atolls under the programme. Committees at various levels of organisation in the atolls participated in these workshops.

An informative colouring book on reefs (Life on our Reefs - A colouring book, BOBP/MAG/20) was produced under this programme. It contained basic information on coral biology, ecology and associated fauna. Ways in which coral reefs could be destroyed and how to conduct preventive actions were also given. The books were meant for grades 5 to 8 in the schools it was well received and used in the atolls by students and teachers.

4.2 Data for the Management of Reef Resources

It is widely believed that the Maldives has a relatively efficient system of resource data collection. The Fisheries Law states that resource data should be submitted to MOFA on a regular basis. Regulations and mechanisms are in place to gather data from all the inhabited islands in the country. The government offices in all the inhabited collect data and submit to MOFA on a regular basis. A relatively accurate picture of the status of reef resources can be derived from these data.

Resource data collected for management purposes are maintained in databases at the Economic Planning and Co-ordination Section of MOFA. Data on catch, landings, exports and socio economic data relating to reefs are available on databases.

4.3 Integrated Reef Resources Management Programme

The Ministry of Fisheries and Agriculture (MOFA) is the key sectoral agency for coral reef protection and management. However it cannot undertake this function with out the assistance of line ministries and stakeholders. An integrated approach to resource management was felt necessary and MOFA embarked on an Integrated Reef Resources Management Programme in 1995 with the assistance of the Bay of Bengal Programme (BOBP).

The IRRM programme seeks to identify the key issues for reef resource management in selected atolls and tackle these in an integrated manner. The following key issues were identified:

- Coral mining
- Bait fishing
- Grouper fishing
- Aquarium fishing
- Mariculture activities
- User conflicts – Tourism vs. Fishing

The IRRM concepts are consultative and participatory. The management approaches are community based and efforts have been made to practice this in the target atolls. A workshop was convened in 1995, which brought together stakeholders from the atolls, private sector and the public sector parties. The concepts of integrated reef resource management and its approaches were discussed in the workshop and recommendations were made on key issues.

The community based approach in the implementation of the IRRM programme will be pursued in the coming years and if successful will be introduced to other atolls in the country.

4.4 Participation in International and Regional Efforts to Manage Coral Reefs

The Maldives has participated and played a central role in regional and international coral reef initiatives. It is an active partner of the International Coral Reef Initiative (ICRI) established in 1994. The Maldives hosted the ICRI South Asia regional meeting in 1995. A major output of this meeting was to identify options for regional policy and action framework. The Maldives is committed to fulfill the outcomes of this meeting and continues to be an active partner of ICRI.

The Maldives is also an active member of the Global Coral Reef Monitoring Network for which a regional network work was established recently in the South Asia Region. It will participate in the training and pilot monitoring programmes under the network and hopes to contribute fully to understand the status and health of coral reefs in the Soufh Asia Region.

Maldives has also participated in regional coral reef activities organised by the South Asia Co-operative Environment Programme (SACEP). SACEP plays a central role in the coordination of environmental issues including coral reef issues in the region.

The International Year of the Reef 1997 (IYOR) has been marked in the Maldives with many activities. Many awareness-raising activities were organised to mark the year of the reef. The IYOR was launched in the Maldives on 5th June, the World Environment Day. Leaflets were produced on how to care for the reefs and information about the IYOR. A Reef Day was held in November as a major awareness raising campaign. Posters, leaflets, magazines, were displayed on Reef Day. Slide shows and videos were shown on coral reefs. A special reef poster displaying common reef animals was launched in December with assistance from the BOBP. This poster will be distributed widely to all schools in the country so that a poster is displayed in every classroom of all the schools in the Maldives.

5. SUMMARY AND CONCLUSIONS

The Maldives consists entirely of coral reefs the most diverse of all marine ecosystems. The reefs of Maldives consist of atolls and associated reef structures. A total of over 1000 species of fish have so far been catalogued from the reefs of Maldives. The total number of coral species recorded from the Maldives to date is about 200, representing over 60 genera. 51 species of echinoderms, 5 species of sea grasses and 285 species of alga have also been identified.

It is widely believed that coral reefs in the Maldives are in a relatively pristine state, and of high aesthetic quality. Apart from supporting a growing tourism and recreation industry, coral reefs

also play a vital role in fisheries, and in the culture and life style of people in Maldives. Tourism, reef fishing, coral mining, dredging, reclamation and the construction of maritime structures and pollution represent some of the impacts on coral reefs.

With the introduction of tourism in the Maldives, coral reefs gained a major economic significance. Tourism in the Maldives is centered around coral reefs and relies on these rich and healthy reefs for the well being of the industry. It is evident that there are few serious environmental concerns in the tourism sector in the Maldives.

The reef fishery in the Maldives is expanding rapidly. These are mainly export oriented and include giant clam, sea cucumber, groupers and aquarium fish. Concerns have been raised on the sustainable exploitation of reef fish resources and plans are underway to demarcate zones for reef fishing. Reef resources that are under pressure from over exploitation include giant clams, sea cucumbers, groupers, certain reef sharks, turtles, and corals.

Corals are mined and used for construction purposes in the Maldives. Coral blocks are extracted from shallow reef flats at 1-2 meters depth, with help of iron bars to break up the living coral.

The Fisheries Law of Maldives (Law No. 5/87, 24-08-87) governs the management of all fisheries activities in the Maidives. Fisheries Regulations (1997) drawn under the Fisheries Law of Maldives and gives details and updates relating to fisheries regulations in the form of notifications and written regulations. Several coral reef species are protected under the FisherIes Regulation.

In 1993, the Parliament enacted the Environment Protection and Preservation Act of the Maldives (law No. 4/93). Key elements in the Environment Law include the submission of an Environmental Impact Assessment report to Ministry of Planing Human Resources and Environment prior to implementation of any developmental project that may potentially impact the environment. 15 Marine Protected Areas have been established under the Environment Act.

The Ministry of Fisheries and Agriculture (MOFA) represents a focal point for many marine activities. The Marine Research Section (MRS) is the research arm of the Ministry of Fisheries and Agriculture. Its main fields of activity include biological sciences, coral reef ecology, marine fisheries, resource management and information services.

The Environment Section of the Ministry of Planning Human Resources and Environment is responsible for co-ordination of all environmental activities in the country. It plays a central role in all marine environmental management as well as setting environmental standards and guidelines.

All aspects of tourism in the country are the responsibility of the Ministry of Tourism including the management of the marine environment of tourist islands. It is also responsible for tourism regulations in the country.

Programme are carried out by MOFA and MRS to increase awareness on coral reefs amongst school children and the public. An informative colouring book on reefs (Life on our Reefs - A colouring book, BOBP/MAG/20) was produced under this programme.

Regulations and mechanisms are in place to gather resource data from all the inhabited islands in the country. Data on catch, landings, exports and socio economic data relating to reefs are available on databases at the Ministry of Fisheries and Agriculture.

MOFA embarked on an Integrated Reef Resources Management Programme in 1995 with the assistance of the Bay of Bengal Programme (BOBP). The IRRM programme seeks to identify the key issues for reef resource management in selected atolls and tackle these in an integrated manner.

The Maldives is a partner in many international and regional initiatives on coral reef conservation and management.

Section C
Invited Papers

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Research and Training for Conservation and Sustainable Management of Coral Reef Ecosystems in Sri Lanka: Present Status and Future Directions

S UK Ekaratne,[1]

Abstract

Reef habitats in Sri Lanka are degraded and impacted by a *multiplicity of causes. Survey work carried out on reefs constitute the bulk of recently carried out research activities. Quantitative data on reefs, reefprocesses and data on the diversity of the reef biota are lacking for Sri Lankan reefs.*

There is little reef expertise in the country, with not more than a handful of people engaged in established reef research programmes, and this lack of trained personnel is identified as the main impediment to the collection of research data enabling effective conservation and sustainable management of Sri Lankan reefs.

Since conservation and sustainable management are inextricably linked, though not synonymous, both these objectives can be realised through the maintenance of species as well as habitat diversity and integrity for which a range of data inputs is required which can be collected through an integrated programme of training and data collection in the areas identified in this paper, which include survey work, inventorising reef organism biodiversity, collection of quantitative data on reef processes, evaluating effects of physico-chemical factors and impacting organisms, developing reef rehabilitation methods, identifying high biodiversity niches and undertaking relevant physiological studies. These constitute the directions along which future management-based ecological research should be conducted. The paper summarises the state of knowledge with respect to ecological data on Sri Lankan reefs as well on the availability of trained Sri Lankan personnel.

The multitude of current reef exploitative and degradatory practices, together with the paucity of knowledge on reef ecology, dictates that the precautionary approach incorporating an integrated course of action be speedily adopted for the sustainable management of Sri Lankan coral reefs. The training of more researchers in reef ecology would be pivotal for understanding the ecological processes that need to be incorporated into appropriate reef management strategies in Sri Lanka.

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Coral Reefs of Sri Lanka

Sri Lanka is an island nation of 65,610 km 2 having a 17 million population and located off the southern coast of India. Nearshore reefs, mainly of the fringing type, are found along 2% of its 1,585 km coastline (Olsen et al, 1992). Patch reefs on rocky bottoms, reefs growing on beach-rock and sandstone as well as 3 barrier reefs and 2 ridge-colonised reef formations also contribute to enrich the reef ecosystems of Sri Lanka (Ekaratne, 1989b, 1990b; Rajasuriya. and White, 1995). All reefs have not yet been surveyed, particularly those on the north and east coasts. The locations and physical status of the surveyed reefs are dealt with in Rajasunya and White (1995). The reader is referred to the above papers for further details on reef structure and condition.

Reef Resource Use, Legal Protection Status and need for Sustainable Management

Most of the known reefs, particularly readily accessible near-shore reefs, are degraded due to human-induced damage (Ekaratne, 1990b). Reefs in better condition, with over 50% of live hermatypic cover, are present at the Bar Reef off the north west coast, at the Great and Little Basses which are located off the south east coast and a few reefs in the southern coast, including Hikkaduwa in the south-west. Reef sites at Hikkaduwa and Bar Reef constitute the only 2 legally-protected Marine Sanctuaries in Sri Lanka, the former having been accorded Sanctuary status in 1979 and the latter in 1992 (Pernetta, 1993). Although legal enactments for reef and reef-related protection are well in place, implementation and monitoring are grossly inadequate, thus effectively permitting the continuation of reef degradation practices (Ekaratne, 1990b; Nakatani et al, 1994; White and Ekaratne, 1995).

Among the foremost destructive practices adversely impacting directly on physical structure of the reef are the removal of coral for conversion into wall plastering material, reef organism removal for the export aquarium industry, fishing practices that employ explosives and the indiscriminate use of fishing nets. Particulate matter, such as sediment, arising from unsound land-use practices, agro-chemicals derived from agricultural overuse, other polluting wastes draining into reefs, including those from sewage and industry, are the major impacting agents destabilising reef ecosystem processes leading to reef degradation and loss of reef biodiversity (Herath, 1990; Ekaratne, 1990a, 1990b; White and Ekaratne, 1995; Ohman et al, 1993). The Crown-of-thorns starfish, Acanthaster planci, has been reported to periodically increase to form large populations in reefs on the north-west and the east coasts (De Bruin, 1972; Rajasuriya and Rathnapriya, 1994). Following in the wake of anthropogenic disturbances, location-specific invasions of Sri Lankan coral reefs have taken place by

other organisms such as didemnids, corallivorous gastropods, sponges and algal species like Halimeda and Ulva (Ekaratne, 1997),

Thus, various reef resources are extracted and utilised by coastal communities, mostly without any practical limitations or management measures being imposed on their exploitation. Impacts resulting from land-based polluting practices further erode the resource base of the reef ecosystems, contributing to the causative factors leading to reef degradation (Ekaratne, 1990b). There seem little prospect of this trend being stemmed; on the contrary, it is thought that the projected expansion of coastal communities in Sri Lanka over the next few decades (Olsen et al, 1992) as well as the increasing focus placed on locating industries along the coastal zone would bring about greater degradative impacts on our coral reef resources. There is, therefore, an overwhelming and urgent need for sustainable management of the Sri Lankan coral reef ecosystems and their resources.

Sustainable Management and Conservation

The concept of sustainability has been around for a long time, although it **has** entered popular culture only relatively recently. Its recent interpretation views sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WECD, 1987). This concept interlinks the conservation and sustainable use aspects and leads us to the concept of sustainable management of our natural resources, including our rich heritage of biological diversity.

Conservation, by itself and for its own sake, would mean keeping the natural resource without subjecting it to anthropogenic change through its utilisation and would be **possible only within legally protected areas, such as marine reserves.**

Such conservation would require that we identify areas which would characterise representative reef ecosystems that, in our opinion, merit their being preserved **outside the influence of human intervention. For this purpose of** identifying areas for conservation, **it is necessary for us to have a sufficiently robust data base that would yield information as to the variety, richness and spatial functions of the habitats within reef ecosystems. Research into gathering the data for such an information base** is **therefore of importance if we are to delimit conservation areas or zones and to accord them legally protected status.**

Conservation could also mean the conservation of a given species or a number of species which, **however, would become meaningful for coral reef conservation only** if **such conservation of a species was** carried out **as part of a functioning ecosystem (as in situ conservation), rather than in isolation or away from its normal habitat** (= **ex situ conservation).** The **advantage of in situ conservation is that it would conserve not only the**

species in question, but other interacting species and, of course, the ecosystem as a functional entity.

As against conservation, sustainable management requires a far greater input of time, effort, personnel and other resources as well as a more detailed information data base that need to be updated continuously and related to the management strategy that is being applied. Sustainable management also requires that the user community be educated regarding the advantages of using a resource sustainably as against using it as a "common property" natural resource where every user would exploit the resource maximally without being accountable for its long-term upkeep or sustainability.

Sustainable management is dependent on adopting a cohesive holistic approach where ecological data comprise only one of the necessary components. Aspects and data including those relating to socio-economics, education, community empowerment and reforms of policy and institutional methods as well as major land-use methods should be used simultaneously and in combination so that an integrated practical strategy becomes established through a period of time. It is not practical or opportune to go into all these aspects during the time available and this paper therefore identifies more closely with the biological and ecological aspects in relation to sustainable management.

Basic Ecological Data Base for Sustainable Management

One of the basic requirements for sustainable management of a natural resource is to know our species base (species diversity and species richness) and to know the interacting ecological processes that sustains this species base, in turn requiring that the biological diversity at the three levels (i.e. genetic, species and ecosystem levels) be understood.

The sustainable utilisation of a natural resource, such as coral reef dwelling species, requires that we have data with regard to the quantities that we can harvest without impairing its potential to maintain a population size with which the species can perpetuate itself in the long term. For estimating such quantities, we need to know the following;

population sizes

- population influencing processes, such as growth, reproduction, interactions, environmental impacts, etc.
- the influence that harvestable quantities would have on the population
- measures that could be adopted for stock regeneration whenever it becomes necessary to do so.

It is now considered that effective conservation and sustainable use is possible through participatory approaches (e.g. Community based resource management = CBRM).

Knowledge Base Status and Future Directions for Research

Knowledge Base Status and Future Directions for Research

In order to look at the future directions in research and training that we may follow for conservation and sustainable management of our coral reef ecosystems and their resources in Sri Lanka, it would be instructive to review briefly the availability of research data and personnel that would be required to meet our stated objectives. It must be stated that this paper only reviews the recently-available data which would be ecologically meaningful in the present context of management. The data of earlier periods, such as of the last century and early parts of this century (e.g. Ridley, 1883; Bourne, 1905) are not included while the reader is directed to any available references summarising information, when such a work is available, rather than to individual multiple references.

With regard to the species base of our reef ecosystems, species diversity and richness are known, with some degree of comprehensiveness, only for the scleractinian coral and fish fauna from some of our reefs. Data from reef surveys, cataloguing the status and condition of reefs, are available for some of the Sri Lankan reefs. For this purpose, reef surveys have been very effectively carried out by the National Aquatic Resources Agency (NARA) of Sri Lanka and this is a necessary area where NARA can expand their surveys to include other reef areas and to assess the changes in reef condition. NARA is well equipped to do these surveys and some of the reefs have been surveyed qualitatively for fish and scleractinian coral cover, but not for other organisms, while the extensive reef formations in the north and east have not been surveyed due to security reasons. The survey programme of NARA has revealed the existence of 183 species of stony corals, in 68 genera, and over 300 species of fish, in 62 families, including 35 species of Butterflyfish, as also the occurrence of spiny lobsters, dolphins, whale sharks and 5 species of sea turtles. The common reef-building corals belong to the families of Acroporidae, Agariciidae, Faviidae, Caryophyliidae, Merulinidae, Mussidae, Oculinidae, Pocilloporidae and Poritidae. Common octocorals include Sarcophyton, Sinularia and dendronephthids. (Mergner, and Scheer, 1974; Rajasuriya, 1994; Rajasuriya, and de Silva 1988; Ekaratne, 1997)

In relation to the smaller animals (most invertebrates), that contribute and maintain the complex inter-relationships of reef ecosystems, we know almost nothing or very little. With regard to filling of these gaps a start has only now been made, as for example with the Biodiversity Skills Enhancement Project implemented by March for Conservation (MfC) in Sri Lanka where taxonomic training is being given, particularly with regard to reef invertebrates and a data base is being compiled for these organisms (Ekaratne et al, 1997b). Such training conducted by a NGO (viz., MfC) is hardly adequate on a national scale and taxonomic training for young interested persons should be conducted on an expanded scale in the future. Another area which requires attention, specially where trained manpower is lacking such as in Sri Lanka, is the development of rapid methods for assessment of reef diversity, such as by using the concept of Recognisable Taxonomic Units (RTU's).

It is therefore necessary, in the future, to establish and maintain an inventory of reef organism biodiversity to start on the path towards conservation and sustainable use of coral reefs.

Mergner and Scheer (1974) forms the only work that documents the zonation of a reef habitat in Sri Lanka, indicating the paucity of knowledge on such issues of importance. Quantitative data on reefs are lacking and studies on reef ecological processes have commenced only recently at Colombo University. It has been found that, at Hikkaduwa Sanctuary, coral recruitment extended almost throughout the year, and was maximal from May to August. In south-west reefs, linear growth of Acropora formosa ranged from 5.0 to 18.7mm month-1. with maximum growth in February/March and a lesser peak in September/October. A. formosa weight increments were high from March to July and peaked in June/July, in phase with pre-recruitment periods. Plankton studies of reef lagoons are likewise lacking and are limited to a study by Colombo University where annual cycles of plankton availability are being documented (Ekaratne, 1997a).

Data on physico-chemical factors associated with reefs are also lacking and are limited to a few studies, including that of Colombo University. Although sediment and particulate matter have been widely identified as one of the major impacting agents on reef ecosystems (e.g., Rajasuriya and White, 1995; Ekaratne, 1990b, 1997a), surprisingly, no related documentary data existed up to last year, when Colombo University undertook a study where it was shown that south-west reefs experienced high loads of particulate matter, including sandy material, from May to November, with maximum loads of up to 3.2 kg day-1 m-2. Such studies are urgently needed for other reef locations over acceptable time scales.

The effects of other destructive practices that adversely impact on reef ecosystems need to be studied and evaluated. The removal of coral ("coral mining") for conversion into wall plastering material is well documented by the Coast Conservation Department (CCD) while reef organism removal for the export aquarium industry was the focus of a study by Wood (1986). The status of marine aquarium fish is being studied by Dr Elizabeth Wood (with NARA, on a Darwin Initiative funding programme) which would form a very good data base on completion. Colombo University is cataloguing the exports in the aquarium export trade and together with the above-mentioned Darwin Initiative study, the results would form a robust data base on this trade practice. The Crown-of-thorns starfish, Acanthaster planci, merits further study as does the effects by other organisms on reef ecosystems such as by didemnids, corallivorous gastropods, sponges and algal species like Halimeda and Ulva; some of which studies are being presently carried out by Colombo University.

Developing in situ methods suited for sustainable management is an accepted priority area in resource management and some preliminary work carried out by the University

of Colombo at Hikkaduwa Marine Sanctuary, using Acropora species, indicates the **feasibility of reestablishment,** restoration and rehabilitation **of degraded reef areas. These methods** require field testing on **a broader** scale and constitute another important **area** meriting future research focus.

A common method for in **situ** resource management for the conservation of genetic varieties, species and habitats in the wild is their protection through Protected Areas, such as at Hikkaduwa and Bar Reef Sanctuaries. In order to develop Protected Areas further, it is necessary to identify ecological niches of reef areas in association with the biodiversity that such niche types harbour, so that characteristics can be developed for the design of effective Protected Areas taking into consideration the physical extents that are required of each niche type in order to maintain the quantum of reef biodiversity that we desire to conserve. Identification of niche types that are associated with reef ecosystems have been carried out to a limited extent by Colombo University where 6 niche types have been identified at the Hikkaduwa Marine Sanctuary. The food and feeding studies of reef-dwelling fish species carried out by Colombo University would also assist in designing Protected Areas by identifying types and threshold levels of interacting species that are required for maintenance of the desired fish species biodiversity and richness within a defined reef area.

Reef-associated habitats having high biodiversity **and nursery value** also require identification for effective reef management and for planning the design of a Protected Area Network. Such habitats have been identified by Colombo University to include Halimeda mats that harbour a rich diversity of organisms that included polychaetes, amphipods, shrimps, crabs, molluscs, bryozoans, ascidians, foraminiferans, nemerteans, pycnogonids and platyhelminths. During periods of strong wave force, Halimeda clumps also served as a protective nursery habitat for a number of reef-associated organisms, including pipe fish, gobies, ophiuroids, holothuroids, echinoids, crabs, olives and other molluscs (Ekaratne, 1997a).

Physiological **responses** to reef impacting processes in reef organisms need to be understood in order to identify threshold values that can be allowed with regard to reef impacting processes. On a general basis, these can be extrapolated to the Sri Lankan reef organisms using data from other countries, but need to be checked for applicability to Sri Lankan species and conditions. Such studies are ongoing at Colombo university, but need expansion and adoption by other institutes.

Ecosystem level research and thinking are needed if we are to address impacting events on a long-term basis. It is only then that causative factors can eventually be controlled for effective long-term management of our reef habitats. In the absence of ecosystem level approaches, management can only be short-term, and can even be damaging in the long-term, where we will perforce have to adopt short-term remedial

measures rather than long-term ecologically sustainable approaches. An example of short-term management is the total eradication at Hikkaduwa Sanctuary of the coralline alga, Halimeda, which is documented as facilitating coral recruitment, without examination of a controlled eradication approach incorporating an ecosystems level integrated strategy where the underlying causative factors would be examined and managed as a long-term sustainable management measure.

Manpower considerations

A few NGOs (Nature Conservation Group, Sub-Aqua Club, March for Conservation), University of Colombo and a government research institute (NARA) carry out hands-on reef research/surveys. Research on reef-related issues, such as on social and economic aspects, is being carried out by many organisations in Sri Lanka, including universities, government organisations and NGOs. The Department of Wildlife Conservation is mandated with managing reef protected areas and require its personnel to be trained in reef research methodology.

An analysis of the availability of manpower in Sri Lanka to conduct full-time reef research is very revealing and illustrates why reef data in Sri Lanka is very meagre. Although personnel conducting reef-related work on a part-time basis are present in some organisations such as the CCD, full-time trained researchers are present only at NARA and the University of Colombo. Of these, NARA has 2 experienced persons, while of the three persons active in reef research at Colombo University, 1 is qualified at Ph D level and the other 2 have B Sc Honours degrees and are carrying out post-graduate research studies. in an atmosphere where reef research has to be encouraged and fostered, there are only 2 Sri Lankans doing post-graduate level reef research in Sri Lanka and only 5 Sri Lankans are trained to conduct ecological-related/survey-type reef research. This situation throws into question what our institutional priorities are with regard to reef research within Sri Lanka and the situation has to be changed urgently if we are to seriously consider effective reef management. There are quite a few instances where consultants from overseas have come into Sri Lanka with good intentions of trying to carry out management of our reef resources, and ended up in mismanaging reef issues, which basically is because we continue not to train Sn Lankans in the much-needed reef research methodologies. Training a wider group of young people and recruitment of such trained research staff with requisite qualifications are therefore essential if we have reef management goals as a sincere priority.

Conclusions

The paucity of data and trained personnel in reef research require planning our research and training activities in an integrated manner if we are to manage our reef resources sustainably. One of the key areas is the expansion of training to include young post-graduate training for developing the human, financial, infrastructural and

institutional capacity to address these management objectives. Since conservation and sustainable management are inextricably linked, though not synonymous, reef management objectives can be realised through the maintenance of species, as well as habitat, diversity and integrity for which a range of data inputs is required which can be collected through an integrated programme of training and data collection in the areas identified in this paper, which include survey work, inventorising reef organism biodiversity, collection of quantitative data on reef processes, evaluating effects of physico-chemical factors and impacting organisms, developing reef rehabilitation methods, identifying high biodiversity niches and undertaking relevant physiological studies.

For optimum impact, this research and training approach has to be integrated with efforts aimed at increasing public and stake-holder awareness with regard to sustainable reef resource management, policy-level strategies and efforts to establish ethical guidelines in carrying out research activities for the benefit of the community and long-term sustainability of the resource. Until such time that effective integrated management strategies, based on a robust incrementable data base, have become accepted and are firmly in place, it behoves on us to adopt the widely accepted precautionary approach in devising reef management strategies.

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A Brief Resume of Research and Understanding of the Reef corals and coral Reefs around India

C. S. Gopinadha Pillai[1]

Introduction

The researches on the various aspects of corals, and coral reefs of the seas around India, **including the oceanic atolls** and continental islands have a span of more than a century. **However** it **is not the intention here** to present an exaustive review of all those work and the **available results obtained by Indian** and foreign investigators; but only a half hearted attempt to **elucidate some** of the aspects as gleaned from literature and personal observation of the **author.**

More than a hundred scientific reports are available in **various indian and** foreign publications on the reef corals and coral reefs of India not to speak of the large number of articles available in literature on the living reef associated resources of our waters. Majority of them are from the last 30 years. The section on references in this communication is only selective and many references cited in the text are not carried over to the reference section to save space.

Reef morphology and ecology

Early reports on the reefs of south India (Walther,1892 with comments by Pillai,1994; Foote,1883 and Thurston,1888) Lakshadweep (Gardiner, 1903-06**)** and from Andaman and Nicobar (Sewell, 1922) are of purely qualitative description. There was a long gap on reef research from this area since then either due to lack of interest or due to various difficulties confronted on working in reefs, for reefs as Foote said are mostly "un-get-at-able". The situation changed in the latter half of this century and some work was initiated at the C.M.F.R. Institute, Mandapam Camp. The 1st International Symposium on corals and reefs organised by the Marine biological association of India at Mandapam Camp in January 1969 in fact gave a phillip to reef studies and many Indian and foreign works paid considerable interest on our reefs **and reef resources.**

The Extent of The reefs

All the four major types of reefs occur in our waters. Fringing reefs are found in (or were found) in Gulf of Mannar and Palk Bay. Patchy coral growths of wave cut platforms on subsided land are seen along the Saurastra coast in Gulf of Kutch. Some patchy outcrops are also present near Vizhinjam and Enayam along the west coast of Kerala and Tamil Nadu. Deep water coral formations are reported from the Maharashtra and Karnataka coast. Typical atoll formations are in Laksadweep. Fringing and Barrier formations are in Andamans and Nicobar Islands. Stoddart and Fosberg (1972) opined that the reef formations from Rameswaram to Tuticorin should be called the Mannar barrier.

But for the early surveys and charting of the reefs by the British Admirality and later by the survey of India the only existing attempt to estimate the extent of our reefs by remote sensing

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method seems to be that of Beldev Sahi (1994) contained in a report submitted to the Ministry of Environment and Forests Govt. of India. Shai determined the reef areas of Lakshadweep. A & Nicobar Islands, Gulf of Kutch and Gulf of Mannar totalling to 1166.6 sq km, the maximum area being in A & Nicobar Islands (813.2 sq. km).

Physiography and zonation studies

Recent physiographic and zoning pattern studies on our reefs are those of Pillai (1971, 1972 and 1977) from Gulf of Mannar and Palk Bay; Mergner and Scheer (1974) from S. India; Pillai et al (1979) and Patel (1979) from Gulf of Kutch; Pillai (1971) from Minicoy; Reddiah (1977), Pillai (1983) and Mukerjee (1984, 1985) from Andamans all pertain to shallow-water environs. Except for some transect and quadrat method of estimation from CMFRI no quantitative assessment on the reef resources are made.

Taxonomy and Faunal Diversity of Reef Corals

Early works on the taxonomy of *Scieractinia* from the Indian waters are those of Alcock (1892), Gardiner (1903-06), Brook (1893) Bernard (1905) . Matthai (1914, 1928) and Gravely (1927), wherein corals from the deep waters of India, Rameswaram. Lakshadweep and Andamans were described. However, intensive effort to study the reef corals of India was started only in the early sixties from C.M,F.R Institute. In the last thirty years we have gained reasonable information on the species diversity and composition of the coral fauna of India. Some of the major studies in the recent past are those of Pillai (1972), Scheer and Pillai (1974) Pillai (1983), Pillai (1986) Pillai and Patel (1988), Pillai and Jasmine (1989) and Pillai and Jasmine (1966). The following is a tentative list of genera and species of scleractinia hitherto recorded from this area.

	Genera	Species	Reference
Lakshadweep	27	105	Pillal and Jasmine 1989
Gulf of Kutch	24	37	Pillai and Patel 1988
Gulf of Mannar and Palk Bay	37	94	Pillai 1986
A & Nicobar	59	135	Pillai 1983
W,Coast of Kerala & T.Nadu	17	29	Pillai and Jasmine 1996
Total for India	37	199	

However very recent studies from Lakshadweep by the research scholars of CMFRI as well as the one by Rodrigues have indicated the existence of a few more species. Therefore the number of species mentioned above from Lakshadweep is subject to revision. Local and regional variation in species composition, was elucidated by Pillai in a series papers in the last twenty five years.

Assessment of Reef Associated Living Resources other than Corals

Fairly good account of the reef associated living resources such as other coelenterates, polychaetes. molluscs crustaceans echinoderms and marine algae are available in literature particularly in the various publications from CMFR Institute and NIO Goa. Quantitative estimation is still wanting in many cases. The icthyofauna is well documented particularly from Lakshadweep accounting to nearly 600 species (Jones and Kumaran, 1980). The ecology and biology of many species of reef fishes were studied by Pillai and Colleagues from Lakshadweep. A & Nicobar islands also is reported to harbor nearly 600 species of fishes including both resident and migrant. A comprehensive list of marine fauna from our reef, as is known to date is given by Bakus (1994).

Despite these realistic statistical and quantitative estimation of the standing and exploitable stock is yet to be made

Estimation of Primary Production

Some of the primary production determination by flow-respirometry are those of Nair and Pillai (1972) from G. Mannar, Lakshadweep and Andamans. Qasim et al (1972), from Lakshadweep and Gulf of Mannar and Mukerjee (1984, 1985) from South Andamans. The result indicated that the continental island reefs as well as those along the mainland coast are heteroprophic while the atoll reefs are autotrophic. However, the data on primary production as summarised in Bakus (1994) seems to have little relevance in the present situation. The reason being the vast deterioration of reefs at the original sites of experiments. Reinvestigation will yield data on loss of efficiency due to mass mortality to corals and associated organisms on our reefs.

Geology and geomorphology

The Indian **reefs,** particularly the surface features of our atolls are believed to have reached the present form in the Holocene period. Gardiner made notes on the formation and geologic history of Lakshadweep in 1903. Corals are ideal tools in the determination of geological changes. Local tectonic changes and sea level variations along the mainland coast of India and Lakshadweep were interpreted in the past by the age determination of coral samples from S. India, Gulf of Kutch and Lakshadweep (Stoddart and Pillai 1972; Gupta. 1972) and also from Kochi by Pillai et al MS). Mallik (1979, 1985) studied the geology and sedimentology of Lakashadeep.

Natural and anthropogenic interference on reefs

The coral reefs, and their living resources are facing deterioration all over the world, probably **due to the fact, that they have a very long survival history and on their way to extinction slowly.** However, present day ecological and natural interference's and human involvement on reef ecosystem hasten their dwindling. Indian reefs are no exception and several factors have affected them.

Impact of natural factors on Indian reefs are comparatively insignificant compared to human interference. Pests and predators as well as pathological conditions are seldom reported. A notable incidence of *Acanthaster planci* infestation was reported from the Wandoor area in

1990 (James et al, 1990). White Band Disease (WBD), is reported from Andamans and Lakshadweep especially on branching ***Acropora*** spp.

Excessive rain, cyclones and fresh water influx rarely kill coral from our area, though elsewhere in the Indo-Pacific these types of calamities are a major factor, A major case of crude oil spill, occurred at Kiltan Atoll in northern Lakshadweep in 1974, though the mortality to corals on reef was negligible . Washing off tarballs into the lagoon beaches is a common occurrence in many atolls. A major deleterious natural factor that affect coral growth in our waters is siltation due to sea erosion as is seen in Lakshadweep Andamans and Gulf of Kutch.

The human interference is very significant. Indiscriminate overexploitation of corals and reef associated organisms from our reefs in the last few decades have effected immense damage to this tropical marine ecosystem. These have been reported in a series of recent scientific publications (Pillai. 1975, 1985, 1996, Pillai and Madan Mohan, 1986, Pillai and Jasmine. 1996, Salm, 1981. Rashid, 1988, Patel. 1988 and Dorairaj et al. review of the results are presented by Wells (1988). Quarrying of corals for industrial purposes from G. Mannar and P. Bay resulted in the total destruction of fringing reefs. Pillai 1973) estimated that about 250 M3 of reef was daily removed from G. Mannar during sixties and seventies. Ramanujam estimated that on an average 80,000 t. of corals were removed from the vicinity of Tuticorin in eighties. A well developed fringing reef that existed in Piroton Island iii Gulf of Kutch was found quarried during 1985. It is sad to note that even Krusudai Island *the one time paradise of marine biologists* was destroyed of her fauna and flora beyond recovery especially after the declaration of the Marine Park in G. Mannar. Over and indiscriminate exploitation of not only corals but other living resources associated with reefs is also rampant, including molluscs, echinoderms goreonids, marine algae and live bait fishes.

Yet another damaging factor was dredging of the lagoon in almost all islands in Lakshadeep for post independent developmental activities. Consequent to the direct and indirect effect in many sites luxuriant growth of corals and other fauna in the lagoon are no more in existence. Dredging has also enhanced sea erosion and subsequent sediment deposition on the lagoon shoals and reef flats. Destruction to natural atoll vegetation in Lakshadweep due to intensive agricultural operation and introduction of cattle and sheep beyond the carrying capacity is all **the more notable.**

Who is to be blamed?

Relegating the responsibility for the destruction of our valuable coral reefs to any single individual or institution is incorrect. It **is apparent that the coastal people, islanders,** industrialists, bureaucrats, and perhaps the scientific community are collectively responsible. Passionate appeals from scientists, conservationists and the press were heard in scientific meetings and conferences then and there to halt the criminal destruction But unfortunately all these remained a cry in the wilderness to the date.

Why we speak of reef conservation

The value of coral reefs, both for the biosphere and human species is well established. Reefs are centres of high biological productivity, sites of Co_2 sink, ecosystem of very high biodiver-

sity, shore line protectors, source of huge deposif of CaCo3, centres of scientific research; additionally they provide us with many natural raw material for pharmacological products or life-saving drugs. The value of coral reefs as tourist spots are also all the more important. However, it seems, that we in this country, except for overexploiting the lime stones and resources they harbour, made very little efforts to utilise them in the correct perspective. We are yet to recognise the value of coral reefs for our very existence, especially the coastal people. From a fisheries point of view - the value of reefs - one cannot underestimate.

Action on Reef Conservation in India - Achievement and Audit

There is a global awareness, on the need of protection and conservation of reefs and many national and international organisations are on the job. As already stated, in our country also the need is felt at certain quarters for quite sometime. Infact we gave the world countries a fillip in reef studies and reef conservation by way of organising the First international Symposium on corals in 1969. In the last 25 years we have had several meetings and workshop on coral reef conservation and management. The following are some them.

1. 1st Inter. nat. Symp. on corals and coral reefs. Mandapam Camp (Mar. biol. Ass. India).
2. Seminar on world nature conservation. BNH Society Bombay, 1983.
3. SYMP.on Endangered Marine animals and Marine Parks. Mar.biol. Ass, India, Cochin, 1983.
4. Work shop on Lakshadweep. RRI Trivandrum. 1987
5. Workshop on coastal zone of Tamil Nadu. Anna Univ. Chennai 1989
6. Workshop on taxonomy of corals and crustaceans . **NIO Goa 1994**
7. National conference on coastal zone management. Committee on S & T Kerala and Earth Science . Cochin,1889
8. Workshop on a scientific data base in Lakshadweep. Geological survey of India. . Cochin 1995.
9. Workshop on coral reef management. Kamaraj College Tuticorin Tamil Nadu,1996.
10. Workshop on Indian Ocean Marine conservation . IOMAC. Mombassa, Kenya, 1995.

These workshops, symposia and seminars have discussed the problems of reef in India and have made several recommendation for their conservation and management. True most of them remain in literature only.

In addition, we in India have formulated several national and state level committees with a view **to protecting our reefs**

1. National committee on wetlands, mangroves and coral reefs Ministry of Environment and Forests. New Delhi.
2. National committee on coral reefs (Defunct?)

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3. Marine Park evaluation committee. Ministry of E & F New Delhi No sitting seems to have taken place.
4. Lakshadweep S.T Committee.
5. Technical Advisory committee for critical habitats. D.O.D, New Delhi. 1997.

Others if any, is not known to the author.

What we have achieved

As a developing nation, it is heartening that our scientists and administrators, so also the peoples representatives, are aware of the need for nature conservation . We are certainly familiar with global concepts on conservation, catchwords and many ACRONYMS, such as, Sustainable Development of Bruntland, Judicious exploitation, over exploitation, habitat preservation and species protection, endangered and threatened habitat and species, biosphere reserves and Marine parks . CITES, GATT, eco-development, sea ranching, eco-friendly approach for development. eco-tourism, critical habitats, core area and zonation. traditional rights, alternate employment and Holistic approach for nature conservation. There we seems to stand, as far as coral reef ecosystems are concerned.

Scientific output and infrastructure

The reef research so far done has helped to have some understanding, of the, present status, especially the taxonomy of corals and interference's on reefs. The data thus gained is available in several papers and reviews as listed in the reference. These, might help us to identify specific problems and draw action plan for the management and conservation of the coral reefs.

Constraints

Ideological conflicts between conservation and developmental strategies looms large. we have to protect the traditional rights of reef users and if necessary alternate employment or resource have to be provided to them. Though we speak of peoples participation in conservation we are yet to make awareness among the public. We are yet to evolve a data based, practical action plan in this regard. Very little physical effort is applied for eco-development. Prevention of injudicious exploitation has not been effected. Remaking a coral reef may be beyond the capacity of man despite all his scientific breakthrough and technical achievements. But once we take our hands off from the reef, they may still take care of themselves and survive for some time.

Infrastructure for reef research is still limited. A nodal institution or a Research laboratory is yet to take shape. Trained personal are wanting. Capacity building may be our prime objective. We are yet to declare the coral reefs as national heritage and yet to set an authority to protect them.

Action effected:

Collection of corals from Lakshadweep and Gulf of Mannar and Andamans are banned by law except for genuine scientific purpose. But clandestine exploitation is still going on. We have declared at least three marine Parks in coral growing areas viz. Wandoor in S. Andamans, Gulf

of Kutch and Gulf of Mannar. The management is entrusted with the forest authorities Trained marine biologist are not yet incorporated.

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A Brief on the Contribution of The Central Marine Fisheries Research Institute To Research and Knowledge of Coral Reefs of India

M. Devaraj[1]

The coral reefs found in different parts of the coasts of the Indian mainland and Lakshadweep and Andaman Islands have always been a subject of scientific interest and fascination. They include the sensitive fringing reef ecosystems in the Gulf of Mannar, Palk Bay, Gulf of Kutch and the atolls of the Lakshadweep Islands and the continental island reefs of Andaman and Nicobar, all covering an estimated area of about 1217 sq. km.

These coral reefs support myriads of beautiful organisms and. present a pristine seascape, which thrilled nature loving tourists, biologists and students. Their rich and varied biological diversity, parallel to the. tropical rain forests, is being degraded by man for various extractive and nonextractive uses. The coral reefs which constitutes an important coastal life supporting system, contribute significantly to the sustained production of commercially exploited seaweeds, lobsters, crabs, bivalves, gastropods, cephalopods, holothourians, table fishes and ornamental finfishes belonging to many taxa. The Indian coral reef ecosystems are estimated to be capable of a fish production potential of 1.8 to 2.7 lakh tonnes per year. The social, economic and biological value of these ecosystems has therefore been recognised by the CMFRI in the early 1960 s itself as one of the priority areas for fundamental as well as applied research.

The taxonomic and ecological studies on the coral reef fauna, initiated in the sixties, have revealed the occurrence of 199 species of scleractinian corals under 37 genera from the reefs of India. Their diversity is high in Andaman and Nicobar (135 species and Lakshadweep (105 species). The reef biocomposition also includes 180 species of benthic algae, 14 species of seaweeds, 12 species of seagrass, 4 species of lobsters, many species of sponges (108 'species), crabs, bivalves, gastropods, cephalopods, echinod.erms (103 species) and 600 species of finfishes each in Lakshadweep and Andaman & Nicobar Islands. The productivity of the reefs is estimated at 9.1 g C/M2/ day in the Minicoy island, 7.3 g c /m2 / day in the Gulf of Mannar and 3.9 g c /m2 /day in the Andamans.

The institutes studies have facilitated a better understanding of the natural and anthropogenic factors responsible for the regression of coral growth and the degradation of species diversity. Besides natural deleterious processes like cyclones, erosion, siltation, diseases, pests (boring sponges & bivalves), algal blooms (Noctiluca, Trichodesmimum, Alexandrium etc.) the indiscriminate exploitation of corals and the associated flora and fauna, dredging, reclamation, and pollution have further threatened the reef ecosystem (Marine Biodiversity Conservation and Management, 1996). The Institute has conducted special indicative surveys in the coral reefs of the Lakshadweep, and the Andaman & Nicobar Islands during 1978 and 1987 respectively to assess their mariculture potential and to estimate the impact of fishing and other allied activities in the reefs on their biodiversity, habitat alterations . degradations etc. The survey findings helped to identify and assess the threats and to formulate appropriate strategies for the conservation and sustair1able management of the reefs around the mainland and the Islands.

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Gulf of Kutch

The nearshore areas of the Gulf, with a catalogued list of 37 species (24 genera) of coral fauna, is heavily silted with terregenous deposits brought in by the tides and the winds. Dredging of sand f or the cement industry and the mining of massive corals also caused severe damages to the reefs. The effect is further compounded by oil pollution and overcollection of reef fauna. A total area of 400 sq.km in Okha to Jodia along the Gujarat coast has been brought under the Gulf of Kutch National Marine Park, administered by the state Forest Department with the objective of protecting and conserving the reef ecosystem and the fauna living therein, based on the proposal of the CMFRI, NIO and other scientific instituteions.

Gulf of Mannar and Palk Bay

The indiscriminate use of reefs began in the sixties for various industrial purposes at an estimated rate of 250 m 3 / day . Indiscriminate quarrying has led to the destruction or even disappearance of some of the islands in the Gulf of Mannar off Tuticorin. The once pristine coral reefs and the small islands in the Gulf of Mannar are all severely trampled, while exploiting the seaweeds, crabs, ornamental shells and ornamental fishes from the reef flats.

The reefs along the southeast coast of India support 94 species (under 37 genera) of scieractinian corals. In view of the importance of this ecosystem to humanity and the ever growing dangers to the reef biodiversity, the region embracing 21 islands in the Gulf of Mannar from Rameswaram to Tuticorin has been declared as the National Marine Park and administered by the Park Authority of the Wildlife wing of the Tamilnadu Forest Department. As the park region is biologically rich (primary productivity of 7.3 g c /m2/ day) and veritable, clandestine exploitation of seaweeds, corals, shells, fishes . turtles and dugongs, is still going on inspite of legal controls.

Andaman & Nicobar Is lands

The indicative survey conducted by the Institute during 1978 was chiefly intended to identify the areas! groups suitable for mariculture and to assess the environmental qualities and infrastructure facilities available (CMFRI Bull. 34, 1983). SCUBA diving conducted in the nearshore reefs has revealed many details of the community structure and the ecology of the reefs. A total of 135 species under 59 genera of scleractinian corals have been are recorded from the Island. The reef suffered many threats from natural causes like siltation, sea erosion, predation by starfish **(*Acanthasterplanci),*** parasite causing White Band Disease (WBD) and from coral boring sponges and bivalves. Large scale removal of corals and other curious molluscs, dredging, quarrying, effluents from the timber factories and dynamiting for fishing are the major human imposed threats to the reefs. Today only some sites in the Andaman & Nicobar re-main in pristine condition and the live corals show patchy growth in the reef area. As per an action plan for the conservation of the reefs, drawn up by the Andaman and Nicobar Administration . the Wandoor National Marine Park covering an area of 281.5 sq. km within the Labrythine Islands of S. Andaman has been declared as a protected area and wing of the Andaman Forest is managed by the Wildlife Department.

Lakashadweep Islands: The 1987 indicative survey conducted in the reef ecosystem of 12 Islands of Lakashadweep points to the need for urgent conservation and management of the

atolls. A total of 105 species of scleractinian under 27 genera have been identified and catalogued from the reefs. The major threats to the reefs and their biodiversity are natural processes like sea erosion, siltation, predation (by ***Acanthaster* planci**) and diseases (WBD); whereas the human activities like construction, cattle grazing, removal of natural vegetation, mechanised fishing, dredging for cargo transport and exploitation of livebaits aggravate further reef destruction and faunastic devastation. The results of the study and the possible management measures are discussed in t he Institute's publication (CMFRI BUll No. 43, 1989)

All the research findings of the CMFRI stress the need for new research inputs, regular monitoring and specific guidelines for the effective management of the three National Marine Parks such as the Gulf of Kutch Marine Park, the Wandoor National Marine Park and the Gulf of Mannar Marine Park. Although many threatened and vulnerable reef organisms are brought under the CITES, which might control exploitation, it is essential to conduct further research on the biological, chemical and pharmacological values of all such species and other reef biota and their products or derivatives for evolving development and management options. The tropical coral reef ecosystem is a trophic network, that carries many food chains, some of them end up in economically important sedentary edible groups, with qualities of bioaccumulation. Therefore knowledge on the toxicological qualities of the reef biota, their taxonomy, distribution and abundance in space and time and their areawise catalogueing is very vital for any disaster management in the ecosystem relating to human poisonings. either direct or through food chain. The Institute's researchers feel that an integrated reef ecosystem conservation and management concept is imperative for evolving a National Reef Conservation Policy.

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A Brief on The Contribution of Z S I To The Research and Knowledge of Coral reefs in India

R.B. Sewell, the last British Director of the Zoological Survey of India has made considerable contributions (1922, 1932, 1935, 1936) on general pattern of Coral reefs in the Indian seas. Hydrographic surveys conducted by Sewell (1935-38) in the Bay of Bengal provide useful information regarding contours, depth and general oceanographic and meteorological conditions. However, it gives little information on reef characteristics and their growth.

Reddiah conducted a survey from September to November, 1972 in Andaman and Nicobar Islands, more particularly in South Andamans and Cincque Is., Ric,iiels Archepelago, Car Nicobar, Camorta and Nancowry islands and published his findings in 1977 with particular reference to reef structure.

In Andaman islands platform formation by coral reefs of about 500 metres in width are built by the corals belonging to the genera *Porites, Favia, Pocillopora* and *Acropora* on the reef edge. The alcyonarians (soft corals) like *Sarcophytum, Lobophytum, Sclerophytum* and the gorgonids, and *Chalcogorgia* sp. occur in shallow shores and reef edges. In the Nancowry Is. platforms upto 1,000 metres in width from the shore have been reported by -Reddiah (1977). These platforrrisconsist of Porites, Favia, *Acropora, Pocillopora, Heliopora, Tubipora* and *Montipora* which are the most common among the reef builders of Nicobar islands.

Reddiah (1977) has also given an account of geomorphological aspects of Coral reefs and distinguished the following categories of Coral reefs in Andaman and Nicobar Islands.

i) Emergent reefs of recent and subrecent origin.

ii) Modern reefs consisting of wind ward reefs, channel reefs, bay reefs, knoll reefs and patch reefs.

Reddiah et al (1974) described the presence of two coral knolls in the Bay of Bengal. In this particular study he has indicated the coral patches emerging from the shore reefs at Keelakarai in the Gulf of Mannar Biosphere Reserve area which according to him is the only shore reef present in the Indian coast. He has described about a knoll such as Klingan paar in Gulf of Mannar and predicts that it would ultimately develop into sand cays by deposition during the cyclone.

Recent investigations by the Marine Biological Station (MBS) of the Zooloclical Survey of India, Chennai in the Great Nicobar islands, during 1992 revealed the presence of 12 species of corals on the eastern side of the island along the intertidal region. Presently, M B S, ZSI, is carrying out extensive survey in the Gulf of t\Aannar Biosphere Reserve Area and studying corals and their formation around all the 21 islands.

The Zoological Survey of India has now given emphasis on studying coral associated fauna. ZSI Scientists have surveyed and studied the faunal diversity of tne Marine National Park of Gulf of '<atchch (Gujarat) and an article dealing with 402 spp. (42 spp. of sponges, 48 sDp. of corals, 205 spp. of molluscs, 29 spp. of echinoderms and 78 spp. of fishes) is almost finalised.

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Since the inception of the Andaman & Nicobar Regional Station at Port Blair in 1977 several intensive and extensive surveys have been conducted to explore and assess the faunal diversity of the islands. 45 islands of Andamans and 8 islands of Nicobars have been surveyed and fauna of some of the reef areas like North Reef and South Reef sanctuaries, Nortn Aiddle and South Buttom National Parks, ivlahatma Gandhi Marine National Parks (all in the Andamans) are being documented. This Regional Station has also taken up a project on "Study of fauna associated with Coral reefs of Andaman and Nicobar islands". In this connection several islands have been surveyed and a large number marine species belonging to sponges, anthozoans including corals, polychaetes, crustacea, molluscs, echinoderms and fishes have been identif ied. Studies on ornamental fishes and fishes associated with coral reefs have also been carried out. The Station has also undertaken projects on marine sponges, soft corals (Alcyonarians) and echinoderms and collected 35 spp. of marine sponges, 40 spp. of soft corals and 60 spp. of echinoderms.

The Zoological Survey of India is also engaged in carrying out Environment assessment stugdies in some reef areas. A recent study conducted by Marine Biological Station, ZSI, Chennai, in the Gulf of Kachch area indicates that coral reefs located closer to shores have been extensively damaged/destroyed due to industrial installation like chemical factories, fertiliser factories, salt pans and for laying the pipeline to pump crude oil from the Gulf of Kachch area by placing a Single Point Mooring near Coral reefs.

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List of field stations of ZSI dealing with the subject

1. Andaman & Nicobar Regional Station, Port Blair. 2. Marine biological Statation, Chennai.

The Coral Reef Ecosystem Of The Andaman And Nicobar Islands: Problems And Prospects And The World Wide Fund For Nature - India Initiatives For Its Conservation

Krishna Kumar[1]

WWF-India's (WWF hereinafter) interest in the Andaman and Nicobar Islands (ANI) dates back to the mid eighties when it brought out a publication *Endangered Andamans* on the status of islands' development and conservation scenario. Since then, WWF has continued to support several initiatives through local NGOs and lend support to various campaigns that thwarted various threats to the insular ecosystem which keep emerging from time to time. The islands came on to the centrestage in 1994 with their inclusion in the ambit of WWF's *Biodiversity Hotspots Conservation Programme* (BHCP) underway since 1992 in the Eastern Himalaya region and the Western Ghats -the two hotspots in India of the 18 sites (all terrestrial) identified across the globe (Myers; 1988, 1990). ANI figured as subsidiary! hotspots therein. BHCP brought under its purview the ANI, in view of it being critical insular ecosystem in India. BHCP in the phase I primarily focused its attention on the terrestrial ecosystem in the Eastern Himalaya and the Western Ghats region. The phase II took cognizance of this gap and identified coastal and marine biodiversity as the focus for the Western Ghats. For the ANI, BHCP chalked out priorities to address fragile ecosystem like coral reefs and to start with identified, development of an action plan for coral reef conservation.

Subsequently, in a bid to continue the efforts to identify global representative system of Marine Protected Areas (Kelleher, *et al.,* 1995), WWF contributed substantially for the Central Indian Ocean Marine Region (Wells et *al.,* 1995). The classification for this region draws primarily from Dwivedi *et al.* (unpublished) which developed a biogeographic classification (this should rather aptly be called bio-oceanographic classification) of the Central Indian Ocean Marine Region (Western Indian Ocean, Eastern Indian Ocean, Northern Bay of Bengal, East Bay of Bengal and the Central Indian Ocean Region, the latter includes the ANI). Among other things existing Marine Protected Areas in the region were assessed. Marine sites and coastal sites in this region were also identified. This study highlighted the fact that only India (including ANI) and Sri Lanka have semblance of MPAs in the Central Indian Ocean Marine Region with other countries in the region [Bangladesh, British Indian Ocean Territory (Chagos Archipelago, Maldives and Myanmar] drawing blank. However, regional priorities for establishment of MPAs in each country of this region was chalked out. For the ANI, Wandoor Marine National Park, rechristened Mahatma Gandhi Marine National Park (MGNP) which is strictly a marine site under protection, was accorded regional priority and recommended for the management support as also for its expansion and effective management. MGNP also happens to be the sole MPA in the Central Indian ocean region. A recent Wildlife Institute of India's proposal to draw up a management plan for the National Park addresses the abovesaid recommendations for the MGNP.

Wells et al. Lc. proposed following new MPAs for the ANI:

[1]Biodiversity Hotspots Conservation Programme (Andaman and Nicobar Islands segment) WWF-India, New Delhi

Upgradations

- Upgrading of some sanctuaries to Park status: Narcondam Island; North Reef Island; South Sentinel Island; Barren Island; and all islets in the west coast Shearme group, the northern Landfall group, and the east coast Table-Brush group
- Little Andamans: 300 sq km National Park proposed for southwestern half of islands to include turtle nesting beaches and Giant Robber crabs
- Little Nicobar with surrounding islets: proposed as a National Park
- Great Nicobar: northern area (north of Casuarina Bay - Dagmar River and Mt. Tuiellier) to be a wildlife sanctuary
- Extension of Mount Harriet National Park to include an adjoining marine area,

Amalgamations:

There are also proposals for amalgamating some of the tiny individual island sanctuaries into ten larger units for more efficient administration; for bringing a larger area of mangroves into the protected area network; and for creating a number of other protected areas. Highest priorities relating to MPAs are as follows:

- Creation of North Andaman Peninsula Wildlife Sanctuary
- Creation of a sanctuary in West Rutland to act as a buffer for the Marine National Park.
- Establishment of Little Andaman National Park
- Upgrading of South Sentinel Wildlife Sanctuary to National Park
- Extension of Button I. National Park to include Outram I. and surrounding waters
- Upgrading of Narcondam Wildlife Sanctuary to National Park
- Upgrading of North Reef Wildlife Sanctuary to National Park
- Establishment of Great Nicobar Wildlife Sanctuary
- Establishment of Little Nicobar National Park

While it is to be appreciated that such proposals have been made, the recommendations for these sites have been made largely on the basis of considerations other than coral reefs, *but* this is the best possible given the lack of spatial data and information on the status of the coral reefs in the islands. The islands' coral reefs are not yet explored completely and reports on the record! new species continue till today. Occurrence of new and distributional records for as many as 26 species of soft corals were reported recently. Further, new coral growth has been mapped offshore in a few places in the MGNP, etc.

Following account would give some idea on the coral reefs distribution and species diversity.

Coral reefs are stretched over an area of 11,000 sq km in the Andamans while the Nicobars have 2,700 sq km under coral reefs. The ANI have fringing reefs around east coast and a long barrier reef (320 km) on the west.

The reefs are poorly known scientifically but may prove to be the most diverse in India and those in best condition. So far 39 genera with 179 species are recorded *(ca.* 76 genera and 342 species in India). The reefs in the islands stand out when considered *vis a vis* other areas in the region:

117 Species in the Gulf of Mannar and Palk Bay, India

134 Species (65 genera) in Sri Lanka

60 Species (30 genera) from Mergui's Archipelago in Myanmar.

While enumeration on the coral reef species is an ongoing activity, the associated coral reef biota like fishes and others are not given due attention. Realising this lacuna, BHCP is supporting a project on the coral reef fishes which is implemented by the a local NGO Society for Andaman Nicobar Ecology (SANE) in collaboration with the UT's Forest Department, Fisheries Department and the Central Agricultural Research Institute. Among other things, enumeration of species and their abundance in selected coral reefs sites is being made. Identification of the coral reef fishes to assess the status of coral reefs is also envisioned.

As a spin-off, SANE and BHCP have developed a ReefWatch programme and enlisted the support of local administration's like Forest and Fisheries Departments, divers of Navy and the Central Fisheries Survey of India. The Coast Guards are also being roped in for monitoring. Also, links with the South Asian region part of Global Coral Reef Monitoring Network are being forged.

It is visualised that an Action Plan would be possible once the project gathers data on the current status of coral reef and the fishes therein in the selected sites.

The WWF project is also to suggest strategies for the conservation and management of coral reefs which would further meet the needs of the projected action plan. Till such time, BHCP is developing a monitoring program for the selected protected areas which includes among others, the MGNP.

In the meantime, to focus the attention on the sites of global importance, Conservation Science Program of WWF-US has identified 200 odd sites called Ecoregions across the world (terrestrial and marine). The ANI terrestrial and marine ecosystem figured in the Global 200 ecoregions. The Andaman Islands forests (Ecoregion # 41) and Nicobar lowland forests clubbed with Sumatran Island of Indonesia (Ecoregion # 31) are the terrestrial ecoregions. The conservation status of the Andaman Islands forest is vulnerable while Nicobars are assigned critical or endangered status. The Global 200, under the coral reef and associated marine ecosystems listed the Andaman and Nicobar Islands marine ecosystems as a marine priority ecoregion **(#** 198).

This representative approach sets it apart from the earlier priority setting for conservation like hotspots, megabiodiversity country approaches which largely overlooked marine and freshwater biodiversity and distinctive ecological or evolutionary phenomenon.

The marine ecoregions designated as Global 200 are nestled within a large marine ecosystem framework developed by WWF-US which itself is based largely on several global analyses including that of Myers and Kelleher *l.c.* The delineation of marine ecoregions is intended to highlight general regions within which characteristic animals, plants, ecological interactions and biophysical processes occur. Relative to most terrestrial ecoregions, these are

more spatially and temporally dynamic ecological and biogeographic units. The marine ecoregions encompass coral reef and associated marine ecosystems. In general, marine ecoregion associated with isolated islands and enclosed seas tend to display higher levels of endemism.

The ecoregions concept which is by far the most representative kind of priority setting enabled WWF to launch Living Planet Campaign: countdown to the year 2000. Through this campaign WWF will work with individuals, corporations, industries and governments to achieve concrete actions for conservation of these Global 200 ecoregions and the animals and plants that live there.

Gap analyses:

Though, there are over 100 National Parks and Sanctuaries in the islands, there is no sizable MPA barring MGNP (281.5 sq km) which protects coral reefs habitat. Rodgers and Panwar, 1988) while recommending various sites as national parks and sanctuaries in the ANI overlooked areas which could conserve marine biota including coral reefs. They however, identified two islands (coral reefs groups) in Lakshadweep Islands as sanctuaries. However, there 15 small PAs (Annexure I) which cover coastal habitats, but their seaward boundary is not clearly defined. There are, but few gaps particularly in the design of the protected area planning and management which are analysed herein.

Most of the island sanctuaries, were recommended to be Strict Nature Reserve (IUCN category # 1) to the MOEF committee for amending Wildlife Protection Act (1972) (Bhatt and Kothari, 1996). SNR has no legal status as such. Rodgers and Panwar, *l.c.* also stated that PAs should either be national parks or sanctuaries. This recommendation, if thus amended would dilute the existing protected area network in the islands. The proposal made herein to have the Large Marine Conservation Units (LMCUs) would further strengthen the PA network since LMCU would contain islands which are not PAs but would facilitate monitoring and research activities in the PAs in the LMCU, for *e.g.* Smith Island in the Andamans which has presence of UT's Forest Department.

The LMCU proposed herein follows by and large MGNP model which has several islands for *e.g.* Red Skin, Boat, Malay, Jolly Boys, Rifleman, *etc.* included in the national park and are thus protected. The exception being that PAs are part of the LMCU besides other islands, to facilitate monitoring and management of the LMCUs.

The West coast of the Andaman Islands have a long 320 km of the barrier reef which is recognised among the other barrier reefs like those of New Caledonia, Belize, Fiji and Western Australia. There are about 40 small PAs on the West Coast of the Andaman Islands excluding Little Andamans which has none. The long stretch of barrier reef remains largely outside the PAs network barring the MGNP. The Eastern coast of the Andamans with fringing coral reefs has majority of PAs (about 60%). It is not known whether these PAs cover fringing reefs. Though, it is easy to suggest a Barrier Reef Marine Park, for the entire 320 km stretch the along the lines of the Great Barrier Reef Marine Park Authority in Australia, management of this could be a daunting task given the lack of fiscal and human resources.

It is worthwhile to mention that most of the human settlements and various anthropogenic activities are mostly concentrated on or towards the eastern coast than on western. Conservation remedial measures should take this fact in to consideration.

Andaman group of Islands:

Recommendations for new MPAs (Wells et al. I.c.) involving upgradations and amalgamations are rather silent on the presence or absence of coral reefs. For example, extension of Mount Harriet National Park to include marine area should take into consideration whether the marine area has coral reefs and the status thereof. Delineation of the park boundary should cover the entire coral reef stretch around the existing boundary. There is a proposal to add portions of the North Andaman Reserve Forest to the west and south of the Park which would cover terrestrial habitats including the Mt Harriet.

Proposals for extension of Button Islands (N, M, and S) National Parks to include Outram Island and surrounding waters and the creation of a sanctuary in West Rutland to act as a buffer for the MGNP should see if the coral reefs around these PAs can be included, if any.

Recommendation to upgrade existing sanctuaries to Park status like Narcondam Island, North Reef Island, South Sentinel lsland and Barren Island would not conserve marine areas unless we define their seaward boundaries and see whether coral reefs around them can be brought under protection.

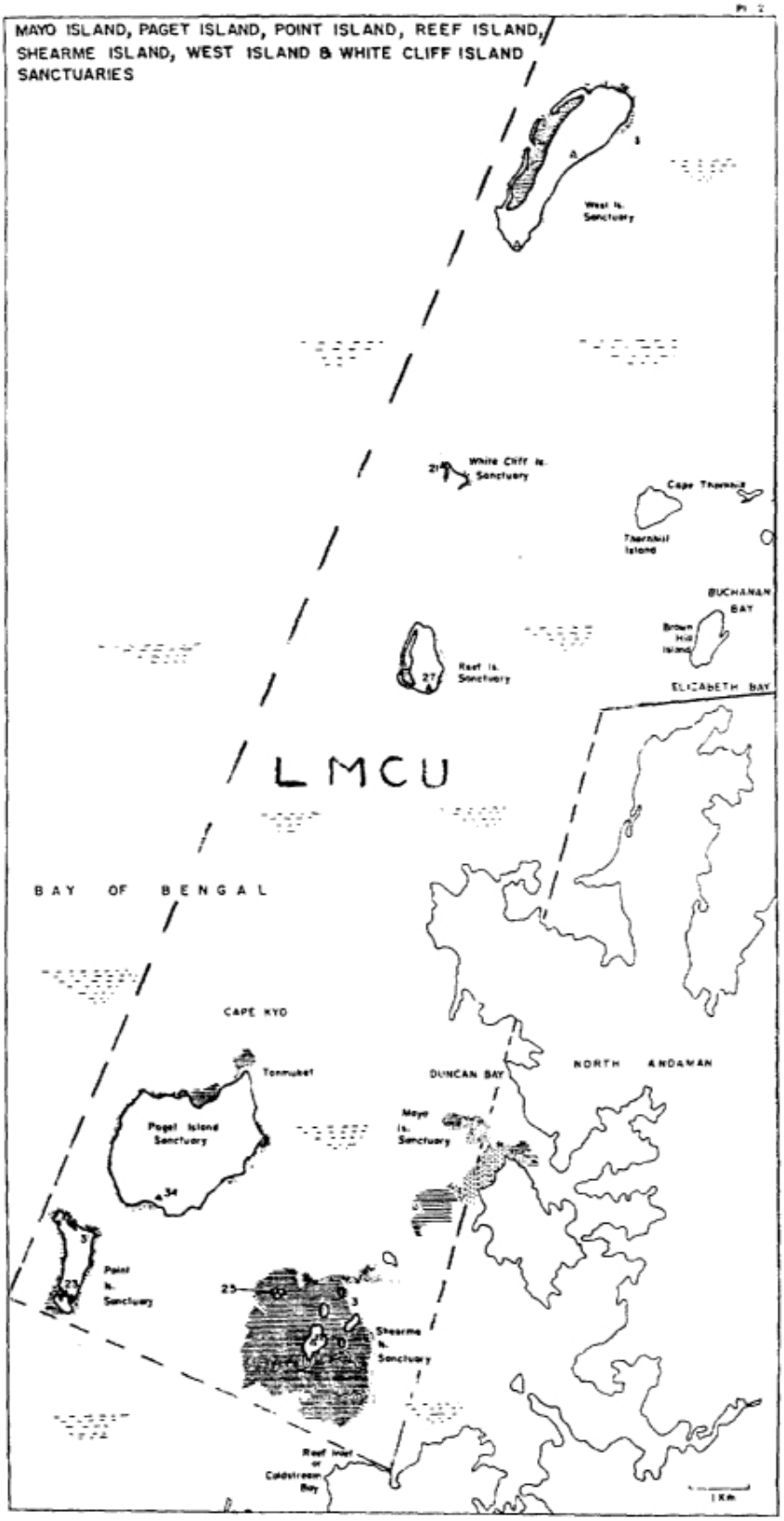
The proposal to have all islets in the west coast Shearme group is, however a noteworthy one since small islets around the Shearme Island Sanctuary can be conglomerated as one unit. Infact, the neighbouring island sanctuaries like Point Island, Paget Island and Mayo Island Sanctuaries and island sanctuaries northwards like Reef Island, White Cliff Island, West Island hold the potential of an effective LMCU which is proposed here. Besides, the outlying isles like Thornhill and Brown Hill can also be included in the proposed LMCU. (Map l)

Likewise the northern Landfall group which includes Landfall, East and Peacock Island sanctuaries can be an effective LMCU and monitored and managed from the inhabited Landfall Island Sanctuary. (Map II)

The east coast Table-Brush group comprising of Tables (Excelsior and Delgarno) Island Sanctuaries and far off Brush Island Sanctuary down south could be expanded to have Island sanctuaries like Trilby Island Sanctuary, Tree Island Sanctuary, Table Island, Temple Island Sanctuary, Turtle Island Sanctuary, Ross Island Sanctuary, Wharf Island Sanctuary North Island Sanctuary and Jungle Island Sanctuary included in the LMCU unit with monitoring and management facilitated through the presence of Union Territory' Forest Department presence at the Smith Island which can be included in the LMCU. (Map III)

The Little Andaman Island which has no protected area, could be a paradigm to have the concept of IMCAM implemented (discussed later) in the ANI. The proposal to have a national park in the south western half of island and to include turtle nesting sites and Giant Robber Crab's coastal habitats is laudable. Due attention to the coral reefs around the S W Little Andaman Island should be given and included, if any. Wells et *al. I.c.* proposed MPA in the island accorded it national priority.

Map - 1



Based upon Survey of India map with the permission of the Surveyor General of India.
The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate basic line.

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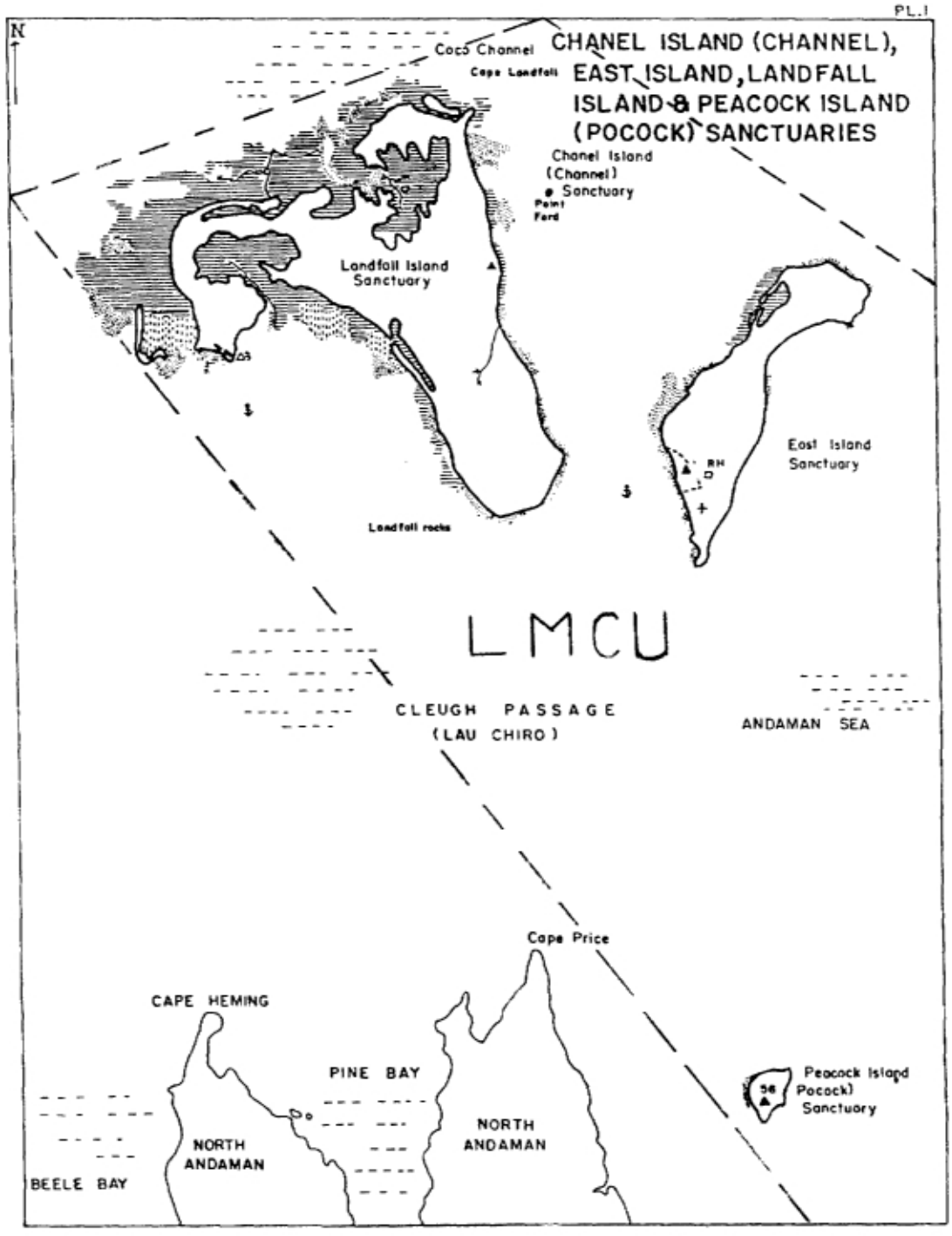
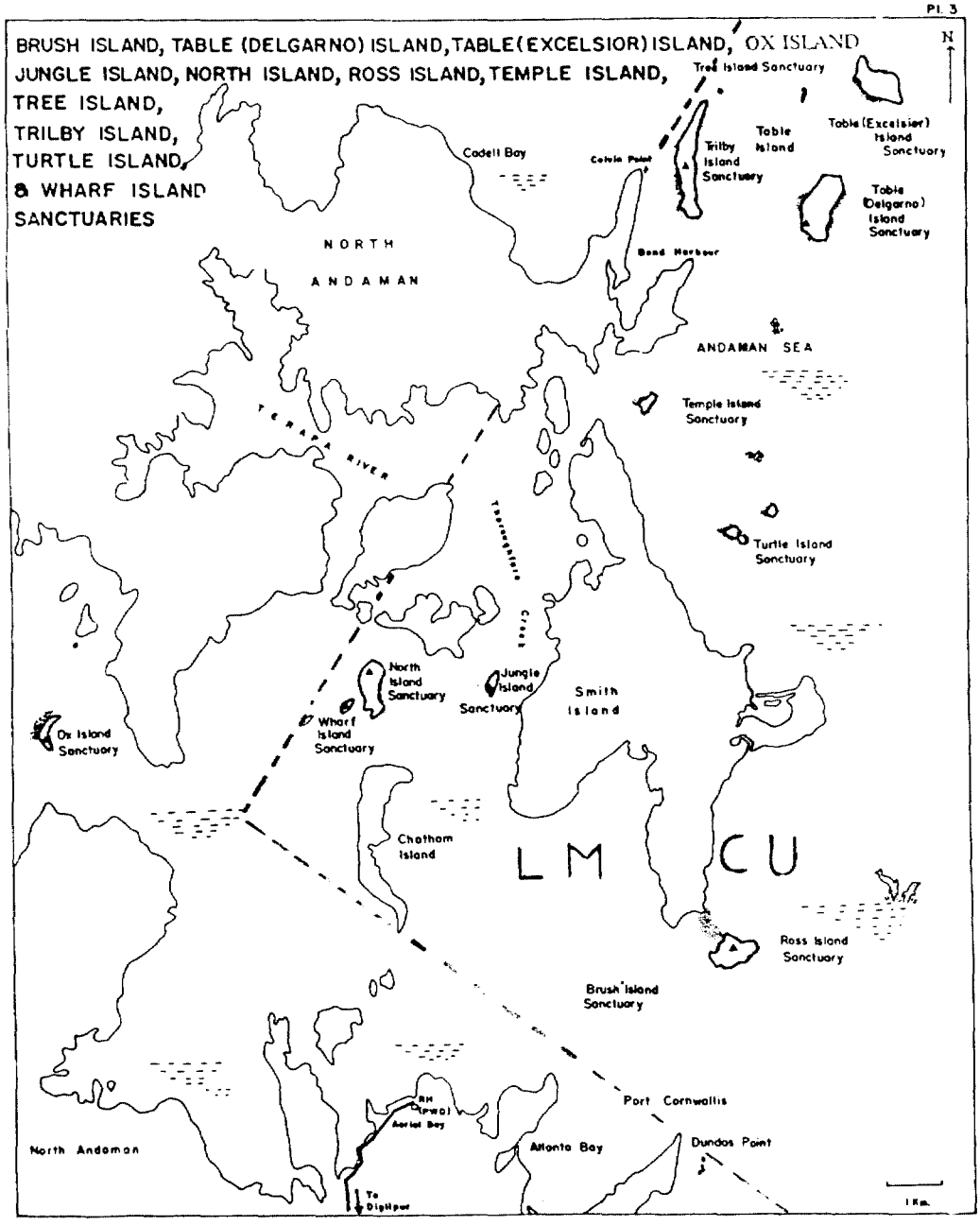
Map - 2



Based upon Survcy or India map with permission of the Surveyor General of India.
rhc territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line,

Map - 3

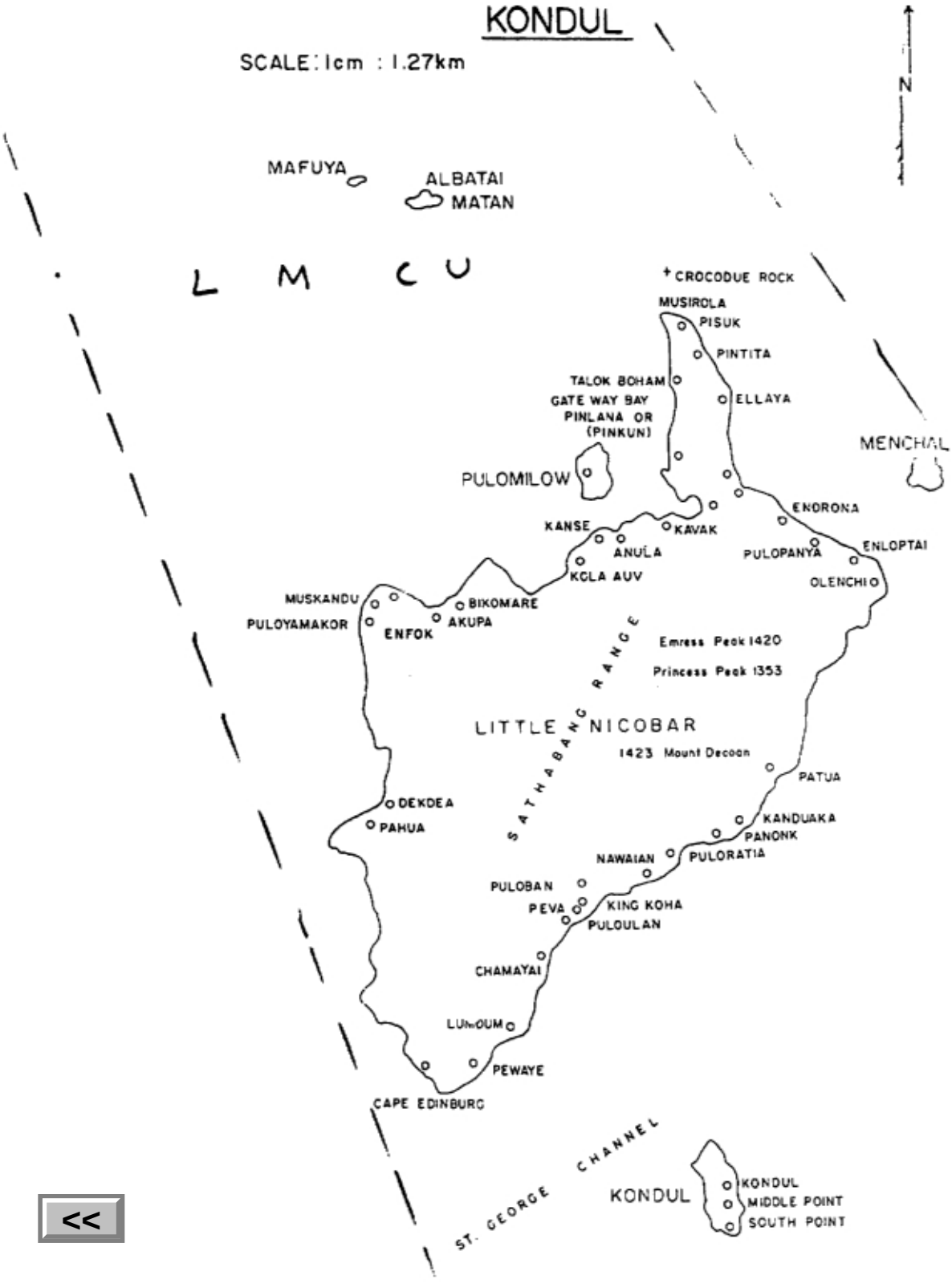


Based upon **Survey of India map with** permission **of the Surveyor Genenal of India.**

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the **appropriate base line.**

Map - 4

MEROE , MAFUYA , ALBATAI MATAN, MENCHAL, LITTLE NICOBAR, PULOMILOW & KONDUL



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Nicobar group of Islands:

Nicobar group of Islands with 2700 sq km area under coral reefs is grossly neglected as far as marine protected areas are concerned. Nicobar reefs have been found to be more productive than Andamans.

None of the existing small island PAs in Nicobars (Battimalv Island Sanctuary, Tillangchong Island Sanctuary and Megapode Island Sanctuary) have marine areas under protection. Though Rodgers and Panwar *I.c* recommended for the upgradation of Tillanchong, among others, as National Park, they didn't delve into the issue of marine biodiversity conservation. These islands are uninhabited and inaccessible and is likely that coral reefs around them are in pristine state. Though the Great Nicobar Biosphere Reserve covers most of the island's terrestrial and to an extent coastal habitats, marine areas including those having coral reefs are not covered. Though MPAs have been proposed for Nicobars, it is not yet known whether the coral reefs are covered in the MPAs boundary.

Little Nicobar Island with surrounding islets which are proposed as a national park could be in contiguity with the proposed wildlife sanctuary in the Great Nicobar's northern area (north of Casuarina Bay - Dagmar River and Mt. Tuiellier) if Kondul Island is also included along with the outlying small islands around Little Nicobar Island like Menchal, Pulowmilow, Atbatan Matan, Mafuya, Meroe, and those falling within the limits of Sombrero channel which would conserve marine stretches acting as an effective LMCU (Map IV). Nicobar coral reefs stretches would thus be conserved. The BHCP-SANE project on coral reefs fish is likely to flag some coral reefs sites which could be considered to be included in the areas already proposed or proposals put up separately particularly for the Nicobars.

A status survey of the islands' reefs should be carried out so that they can be included in the proposed LMCUs which is open for modification as and when the information on the coral reef distribution is made available.

Threats:

Sedimentation appears to be the major cause for the decline of most coral reefs which is also associated with large-scale mortality in reefs, reduced coral growth, reduced fertility, increased mortality of coral planulae and abnormal changes in polyp behaviour (Rogers, 1990). It is also important to establish the extent to which marine protected areas like MGNP are being damaged by murky or polluted water coming from upstream in South Andamans.

A pointer towards the shape of things to come is the observation that mud deposits have been found on the reef area at few places near Port Blair, Navy Bay, Flat Bay, Reef Island, *etc.* Sedimentation in the recent past in the ANI and elsewhere triggered off infestation of the crown-of-thorns starfish *Acanthaster planci* which has the potential to destroy whole reefs in a short period (Wood, 1989). Adding to further reefs problem is disease and bleaching imputed to rising turbidity. Protracted bleaching brings down growth rates and could be fatal. Corals particularly the branching types, are prone to breakage, especially in the areas open to tourist or fisherfolks and others. Over-collection for construction or for sale as curios and ornamental and edible shellfish is proving to be a bane for the corals.

Regulation of tourism adds another dimension to the coral reef conservation which is going to ensure tong term survival of the islands. That coral reefs are the centre of attraction for the visiting domestic and overseas tourists is borne out by the fact that MGNP is increasingly coming under pressure from tourism related activities, especially on the reefs. Tourism in the islands is likely to come on the centrestage following Department of Tourism, Government of India, the ANt Administration and UNDP study to earmark certain island/islands group for promoting tourism which is treated as an industry. The said report is being considered by the Government of India.

In the years gone by, immigration of hordes of settlers to the islands have brought the coral reef habitats under various threats like the one resulting from siltation (attributed to soil erosion, deforestation), over-collection of shellfish and corals (for sale to tourists and local handicrafts industry), coral mining for construction, and trampling of the corals by tourists and fisherfolks, Added to this is the changing land use in the islands, including intensive modern agricultural practices using pesticides and organic and inorganic fertilizers, which may have unforeseen impacts on the reefs due to surface run-off from the fields.

Monitoring and management of various activities in the islands is another awesome task which has to be carefully planned and effected. Various levels of protection afforded to coral reefs on *site* may turn meaningless if the *off site* activities like deforestation leading to soil erosion, *etc.* in the islands continue unabated.

Where do we go from here?

Nowhere else the imperatives for the conservation of the two closely linked fragile ecosystems become apparent as in the islands. The ANI presents an excellent opportunity for the implementation of integrated marine and coastal area management (IMCAM) as per Jakarta Mandate on marine and coastal biodiversity. It is also a tool for the signatory parties of the Convention on Biodiversity to fulfill their obligations. WWF is in the process of addressing the IMCAM in conjunction with the Marine Program of WWF-International. The various issues related to the existing PAs and the new proposals on the MPAs linking them with IMCAM will be addressed by the WWF initiative.

Tentatively the following need *immediate* attention:

- all stakeholders relevant to the IMCAM process must be identified in the initial stages and included in the planning process-these should include local communities (mostly in the large islands) and fishing communities, the tourism industry and Union Territory Administration's agencies responsible for economic development, water management, coastal defenses, environment and physical planning, among others. Eventhough there are about 50 fisherfolk cooperatives in the islands except few, all are defunct. These needs to be vitalised so that they are involved meaningfully in the process. Tourism has already been declared an industry.
- stakeholders must be provided with the necessary information and education and training provided where required, so that they can contribute effectively to the IMCAM process
- an appropriate institutional mechanism must be developed, with a clearly defined decision-making body in place such a body may vary in form according to the characteristics of the

situation (e.g. designated institution, committee with due representatives of NGOs and other individuals)

For marine and coastal areas following should be established:

- a consultative mechanism *(e.g.* Advisory Committee) should be established from the beginning to ensure participation by and representation of all stakeholders.
- a mechanism to ensure sustainable financing should be developed for each MPA.
- the agencies and communities responsible for the management of an MPA should receive appropriate training, education, and support *(i.e.* capacity building). The Marine Specimen Centre run by the Fisheries Department of ANI Administration has on display living and non living marine species such as ornamental fishes, various kinds of corals, sea shells, sea cucumber, sea urchin, crustaceans, eel, sharks, *etc.* This centre popular with visiting tourists, students, scholars, researchers, scientists, *etc.* could be structured to meet the requirements. Establishment of Marine Aquarium and Ocean Science Technology Centre at Port Blair has been a given a thought to. Possession of land has been taken over by the Department of Ocean Development, Govt. of India. Perhaps this needs to be expedited. Provision of infrastructural facilities-like sea worthy vessels, communication equipments, and other such gadgets which would equip and enable management authorities to cope up with the mounting poaching pressure - need to be given a thought. Many remote PAs in ANI do not have even one sea worthy vessel for *e.g.* Narcondam Sanctuary in Andamans and Great Nicobar Island in Nicobars which is designated as a biosphere reserve.
- a monitoring and evaluation programme should be established from the beginning, and should cover socio-economic parameters as well as environmental and ecosystem one.

  Islands have diverse marine wealth including commercially important species. Illegal collection of such species have increased considerably, particularly by the people from neighbouring countries like Myanmar and Thailand. Poaching of this kind should be curbed. Coral reef fishes are collected from the reefs for their use in aquariums. Sea shells and others marine products are increasingly being used in local sea shell based handicraft which is a thriving industry today on which people depend for their livelihoods. These attributes must be looked into, while defining socio-economic parametres as well as environmental and ecosystem for monitoring and evaluation programme.
- no-take zones (fish refugia or sanctuaries) should be established within all MPAs in appropriate areas, to ensure that each MPA contributes to sustainable fisheries management.

Sustainable use of coastal and marine living resources: The island economy has hitherto been dependent on the forest resources. It is time that a policy for sustainable uses of marine and coastal resources is developed.

Mariculture: This approach would meet the abovesaid objective. The island has in place Marine Product Export Development Authority. The latter has developed a methodology for shrimp farming. Besides, Andaman and Nicobar Centre for Ocean Development, ANCOD under the Department of Ocean Development (DoD) has a presence in the islands. DoD had commissioned the National

Institute of Oceanography a project on intensive polyculture in the island ecosystem of India. Suitable sites for floating wooden cages have been identified in Andaman waters to demonstrate culture technique of commercially important marine organisms.

Non authocthonous species: The abovesaid approach needs to be exercised with caution. In the recent past there have been attempts at bringing exotic fish species like European Seabass and Gilthead Seabream to cage culture them in islands water.

legal and Policy Framework for the Conservation of Coastal and Marine Resources and Protected Areas:

The following account gives an overall picture (including annotations) of the legal and policy support for the conservation of coastal and marine resources and protected areas:

1. ***Constitution of India***

   Art 48-A: The state shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country.

   Art-51A(g): Imposes a similar responsibility on every citizen to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures.

2. ***Wildlife Protection Act 1972***

   Section 35(1) Declaration of national parks (this includes the coastal and marine protected areas)

   Section 35(6) Prevention against destruction, exploitation, removal of any wildlife from a national park or destruction or damage of the habitat of any wild animal or deprive any wild animal of its habitat within such national park is necessary for the improvement and better management of wildlife therein, authorizes the issue of such permit.

   Notes: Coral reef species and reef dwelling fishes are not included in the schedules of the Wildlife Protection Act. This is more because of lack of data on the species than willful negligence.This perhaps also explains for their exclusion from the Red list of threatened animals. Further, there seems to be no restriction on the coral collections from the reefs outside the protected areas.

3. ***Convention on International Trade in Endangered Species of wild flora and fauna (CITES):***

   Notes: CITES has some coral reef fishes listed on its appendices, information for these from ANI is far from complete because of lack of data on coral reef fishes which is being currently addressed by WWF. Some coral genera have been listed like Milleporidae, order: Athecate (Fire corals) and Tubiporidae, order Stlolonifera (Organ Pipe Corals). This would of course, in principle covers all the species of these genera.

4. Environment (Protection) Act, 1986

Section 3(1) subject to the provisions of this Act, the Central Government shall have the power to take all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of the environment and preventing controlling and abating environmental pollution.

Notes: Though the pollution load on the islands' reefs is not known, coral reefs are threatened because of dumping of saw dusts generated by local plywood industries. The latter may not be dumping the waste *on the coral reefs directly* but it has the potential of smothering the reefs. Siltation resulting from deforestation is the primary reason for the decline of coral reefs. Oil slicks and spillage by plying and berthing cargo/passenger vessels have the potential to affect the reefs adversely. Issues relating to dumping of hazardous materials, waste management, oil spills affecting both the coasts and oceans falling in the ambit of Disaster Management also need attention. A mention may be made of an oil spill in January 1993 in the Great Channel of 40,000 tons of light crude oil. During the span of a fortnight, the oil slick covered an area of 80,000 sq km coming as close as 10 nautical miles off the Great Nicobar Island. Though the Coastal Ocean Monitoring and Prediction Systems (COMAPS), a component of the Department of Ocean Development's Coastal Zone and Islands programme, is monitoring pollution levels around Port Blair, much needs to be done. The EPA should be made sensitive to the pollution of kinds as discussed above which threaten coral reefs long term survival.

4 a. The Coastal Regulation Zone Notification 1991 (Notification No.S.O.114(E) of 19 February 1991)

Notification under section 3(1) and section 3(2)(v) of the Environment (Protection) Act 1986 and rule 5(3) (d) of the Environment (Protection) Rules, 1986, declaring coastal stretches as Coastal Regulation Zone (CRZ) and regulating activities in the CRZ.

For regulating development activities, the coastal stretches within 500 metres of the high tide line of the landward side are classified into 4 categories.

Category 1 of CRZ:

(i) classifies areas that are ecologically sensitive and important, such as national parks/marine parks, sanctuaries, reserve forests, wildlife habitats, mangroves, corals, coral reefs, areas close to breeding and spawning grounds of fish and marine life, areas of outstanding natural beauty/historical/heritage areas/ areas rich in genetic diversity, areas likely to be inundated due to rising sea level consequent upon global warming and such other areas as may be declared by the Central Government or the concerned authorities at the state/union territory level from time to time.

(ii) Area between low tide line and high tide line.

The CRZ has specifically classified the Andaman and Nicobar Islands besides Lakshadeep under category IV except those designated as CRZ-I, CRZ-II or CRZ-III. It has categorically mentioned that corals and sand from the beaches and coastal waters

shall not be used for construction and other purposes; and dredging and underwater blasting in and around coral formations shall not be permitted.

For the small islands, the above said conditions also apply.

Notes: In 1996, five years behind the schedule and under Supreme Court's pressure, the Coastal Zone Management Plan (CZMP) of the UT's Administration-which prescribes coastal development without ecological destruction and identified and categorized the coastal areas for different activities-submitted to the Ministry of Environment and Forests has come in for a flak in view of it being considered 'anti people' and 'anti development'. CZMP also aims to ban all kinds of construction works including drawal of ground water from the coastal areas. Because CRZ does not allow for the collection of sand and corals which are used for construction purposes in the islands, discontentment among public is growing. Also, coral rubble is used for the beautification purposes such as lining the driveways to the offices, hotels and guest houses in the islands.

It is to be appreciated that removal of sand and coral would in turn endanger human settlements in the islands. For e.g. in Great Nicobar Island, the ex servicemen settlement has been endangered because of coastal erosion owing to the lifting of sand, gravel, coral rubble, *etc.* Notwithstanding, collection of such materials continues contravening CRZ prescriptions. It is difficult to estimate the quantum of dead coral rubble collected/mined in the islands.

5. *The Fisheries Act of A&N Islands*

License is given for fishing by the fisheries department. For shell fishing, license is given by the D C of Andaman Islands and it comes under A&N shell fishing rule 1978.

India has an Exclusive Economic Zone (EEZ) estimated to about 2.02 million sq km. Of this about six lakhs sq km *(ca* 30%) is constituted by the ANI. Also, India has over 7,000 sq km coast line of which over one fourth (1962 km) is contributed by the ANI. In 1976, India amended its constitution enacting the Maritime Zones Act. India is also signatory to the Third United Nations Convention on the Law of the Sea (UNCLOS III) which came into force in November 1994 and was ratified in 1995 by India. A large majority of coastal state/UTs conform to the provisions made in UNCLOS III on the various sea uses and resources utilization upto a distance of 200 miles of EEZ from the coast line. Since ratification of the UNCLOS, effective control of EEZ has assumed significance.

Coastal states/UTs are also extending their jurisdiction in the EEZ in so far as environmental pollution, control of shipping including supervision of dangerous cargo and general problems of safety are concerned.

The South Asian Seas Regional Program with the participation of India, Bangladesh, Maldives, Pakistan and Sri Lanka is one of the 13 Regional Seas Program of United Nations Environment Program (UNEP). An Action Plan for protection and management of the marine environment in South Asian Seas was adopted on 24th March 1995. India is the repository of the final Act conveying the adoption of the Action Plan by the countries concerned. Action Plan has specified the priorities

including development of Integrated Coastal Zone Management Plans, development and implementation of national/regional oil and chemical spill contingency plans, human resource development through strengthening of regional centres of excellence and protection of the marine environment from land based activities.

The South Asia Co operative Environment Program (SACEP) formed under the *aegis* of the Marine Environment Program of the UNEP has been designated as the Secretariat for the program.

This forum should address the coral reefs conservation within the framework of SACEP which has by and large similar priorities as WWF's and for which some semblance of legal and policy, institutional support exists. Perhaps this workshop should look into the modalities of filling the gaps and strengthening of the existing structures.

Acknowledgements:

I am grateful to Mr Samar Singh, Secretary General, WWF India and Mr A R K Sastry, Director, BHCP for giving me an opportunity to present the scenario of coral reef conservation in Andaman and Nicobar Islands. I am thankful to Mr Sastry for giving valuable advice during the genesis of this paper.

Annexure 1

Other coastal areas include:

- Saddle Peak National Park: includes a long rocky beach
- North, Middle and South Button Island National Park: nesting turtles, mangroves
- Barren I. Sanctuary: active volcano, with coral communities

  C3ral reefs around the Barren Island were reportedly damaged during the volcanic eruptions in 1991.
- Battimalv I. Sanctuary (Nicobars): mangroves
- Interview I. Sanctuary: mangroves, hawKsbills
- South Reef I. Sanctuary: lies off the tip of Interview I.
- Megapode I. Sanctuary (Nicobars): reefs, mangroves
- Narcondam I. Sanctuary: beaches, corals, mangroves
- La Touche I. Sanctuary: green turtle
- Saltwater Crocodile Sanctuary: an extension of Wandoor Marine National Park to the north; numerous creeks and inlets, mangroves, turtles, crocodiles
- South Sentinel I. Sanctuary: small coral island, beaches, large green turtle nesting beach, mangroves; established mainly for coconut crab
- Tillongchang I. Sanctuary: cliffs, mangroves, beaches

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A Review of the Contribution of Centre for Earth Science Studies (CESS) Towards Understanding The Totality of Environment of Lakshadweep, India

Ramachandran, K.K. and Ajaykumar Varma, R[1]

Introduction

Because of the proximity of the islands of Lakshadweep to Kerala, and partly on account of cultural lineage, they have always remained upper most in the research activities of the Centre for Earth Science Studies (CESS) right from its inception in 1978. The research programs pursued spans over a wide spectrum of topics, from geologic and geomorphological evolution of the islands to resource evaluation and environmental impact assessment of developmental projects. Of particular contextual interest are the programs on groundwater resource assessment and management, environmental impact assessment, shoreline dynamics, wave climate and power potential and pollution monitoring of the seas surrounding these islands. Following is a resume of the work that has been either completed or ongoing in CESS in these areas.

1. Studies on the groundwater resource potential and its management

The fresh groundwater resource of the tiny coral atolls of Lashadweep, by and large, occurs as lenses floating in hydraulic continuity with sea water. Cases of increased extraction from these fragile lenses and resultant salinisation were reported from many islands where pumping activity has been on the increase, especially, during the last two decades. This necessitated a detailed study in all the inhabited islands of Lakshadweep, to delineate the geometry of the fresh groundwater lenses, to evaluate their storage potential, and to assess the sustainable rate of production in order to suggest appropriate, futuristic groundwater development and management options for the island territory.

The hydrogeological environment of these islands is complex. The terrain is mostly flat and the surface and near-surface coral medium is porous and permeable. Rainfall, averaging about 1600mm annually, is the sole source of groundwater recharge in these islands.

Hydrogeological and geophysical methods using innovative procedures were adopted for direct mapping of the fresh groundwater lens, for hydraulically characterizing the aquifer and for assessing the sustainable long-term production capability of the fresh groundwater lens system (Varma, et al., 1989; Varma and Ramachandran, 1992; Varma and Ramachandran, 1995 a&b; Varma, et al., 1995 a&b; Varma and Ramachandran, 1996; Varma, 1997). The geophysical method employed electrical resistivity profiling and sounding, the result of which was used to describe the lateral extent and the thicknesses of fresh water and transition zone of the groundwater lens. The transmission and yield capabilities of the aquifer represented by its porosity, transmissivity, specific yield etc. were determined from pump tests, formation resistivity factor analysis, tidal wave propagation method and permeability test on core samples. The sustainable production capability of the lenses was finally assessed based on

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the quantum of annual recharge determined from climatic water balance, chloride balance, water table fluctuation and groundwater storage change.

Based on the studies, maps depicting the lateral extent and isoplethes of the fresh groundwater lens of all the inhabited islands were prepared. A specimen map of Kavaratti on these aspects is shown in Figure 1.

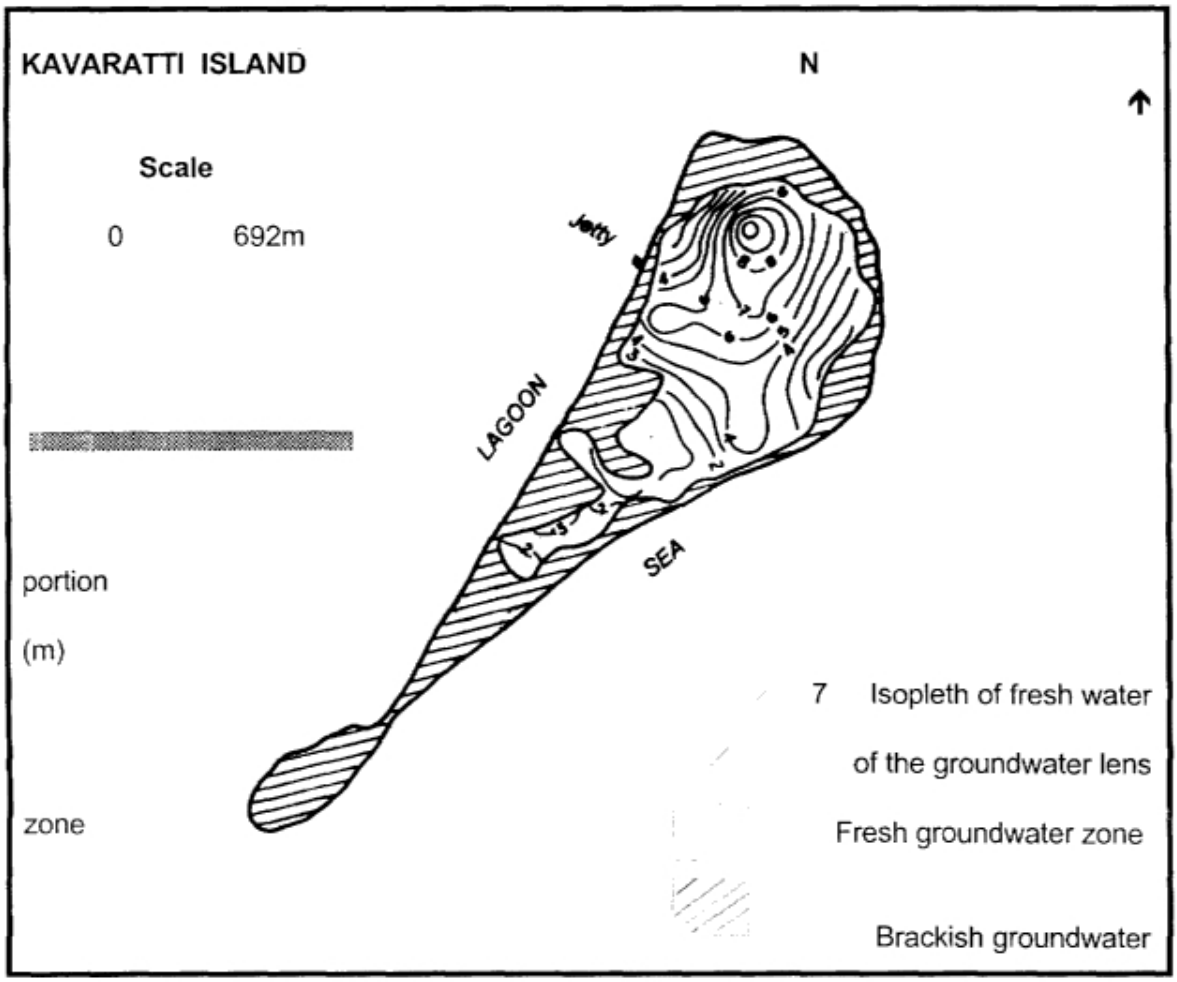
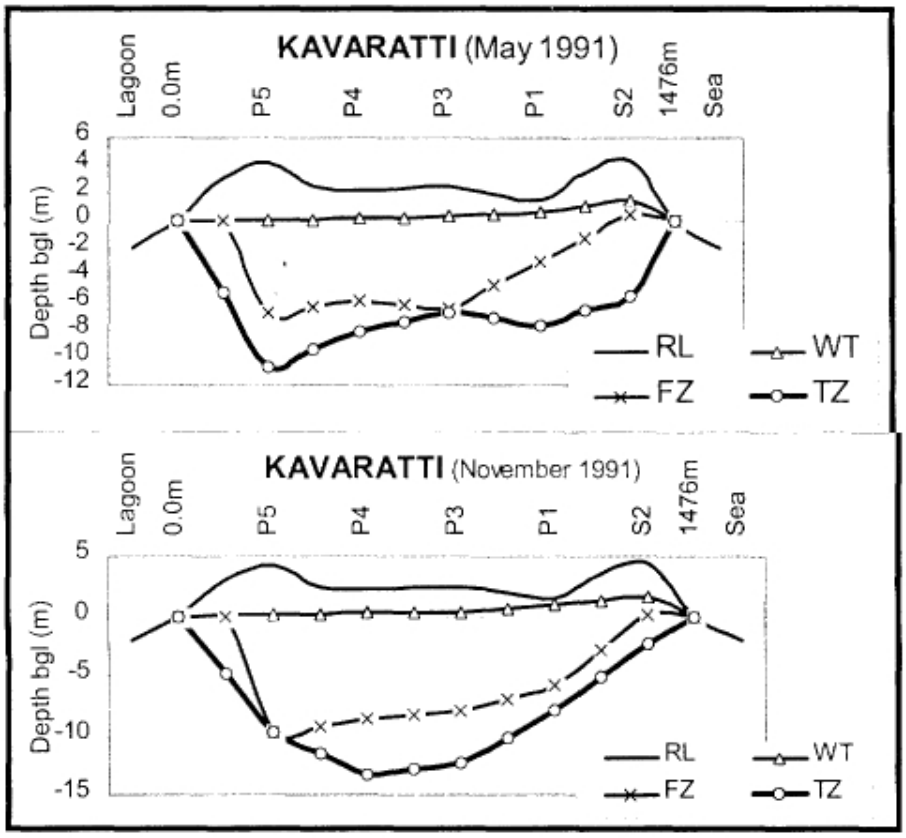


Figure *1.* Lateral extent and isopleths of fresh water portion of the groundwater lens

The study assessed that about 500 mm of rainfall reaches the groundwater body, annually, as recharge. Irrespective of this, t was found that the water table rise, upon incidence of rainfall, diminishes in a couple of days. It was suggested that the annual rainfall that infiltrates to the groundwater lens escapes to sea as rejected recharge. However, this was negated by the geophysically derived fresh groundwater lens model of premonsoon and postmonsoon period at Kavaratti (Figure 2).



(RL- Ground level, WT- Water Table, FZ- Base of the fresh groundwater lens, TZ- Base of the transition zone)

Figure 2. Geophysically derived vertical section model of the fresh groundwater lens at Kavaratti during premonsoon and postmonsoon period.

The static and dynamic storage potential of the inhabited islands of Lakshadweep, determined based on the geometry and specific yield of the fresh groundwater portion of the aquifer is given in Table 1. In general, it indicates that the dynamic storage of inhabited islands Es adequate to serve the needs provided the development of the resource does not tell upon the sustainable yield, worked out to be about 10% of the average annual recharge (AAR). Contrary to this, the estimated draft of fresh groundwater at Kavaratti was about 0.17 MCM as against the AAR. It suggested that either an overdraft takes place or a part of the groundwater draft (about 25%) reenters the ground, which is logical in the island situation.

The salinity index of the island groundwater system indicates that no fresh groundwater without saline contamination is available in any island of Lakshadweep. However, the contamination fortunately is very marginal except at a few spots at Kavaratti and Minicoy. It is also observed that the quality of water d3teriorated with longer duration of pumping. There is no doubt, therefore, that over extraction would deteriorate the quality of fresh groundwater in these islands.

The study also reveals that the thickness and shape of the lens derived using the classical Ghyben-Herzberg relationship, does not match with the one delineated by the electrical

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resistivity method. It is, however, found that the groundwater lenses of the islands comprise of a fresh water portion on the top and a tran Uon zone at the bottom (Figure 2).

Table 1. Static storage, annual recharge and projected dynamic storage of fresh groundwater in various inhabited islands of Lakshadweep.

Name of Islands	Area of fresh GW zone Km^2	Sp. yield %	Volume of fresh GW portion of the aquifer MCM	Static storage potential of fresh GW MCM	Annual water surplus mm	Recha rge area Km^2	Dynamic storage potential MCM
Agatti	1.070	21	2.344	0.4922	193	1.284	0.2478
Andrott	4.077	11	63.633	6.9996	414	4.077	1.6879
Amini	1.563	17	6.463	1.0987	193	1.876	0.3621
Chetlat	0.514	22	2.381	0.5238	414	0.514	0.2128
Kadmat	2.200	17	15.424	2.6221	414	2.200	0.9108
Kalpenl	1.180	25	14.990	3.7475	414	1.180	0.4885
Kavaratti	1.930	18	6.450	1.1614	474	1.930	0.9140
Kiltan	1.172	26	10.667	2.7734	414	1.172	0.4852
Minicoy	1.226	25	7.325	1.8313	459	1.226	0.5627

One of the prime considerations that evolved from the study for the development and management of the groundwater resources in the islands of Lakshadweep is the maintenance of a minimum thickness of lens as a critical factor for the upkeep of island groundwater system. It implies that the fresh groundwater extraction from island lenses has to be limited to the sustainable yield. Considering these factors, the study recommended stoppage of indiscriminate pumping and advocates the use of infiltration galleries and low capacity pumps (about 60 1pm), if pumping is needed. It is also suggested to limit pumping locations to zones where the thickness of lens is greater. These measures alongwith popularization of water harvesting has done a world of good in protecting the fragile fresh groundwater lens from irreversible damage that would have happened, otherwise, if callous pumping had been continued.

2. Environmental Impact Assessment

Being one of the most thickly populated areas of the Indian Union (2000 per Km^2 in 1991), they are overwhelmingly interfered by man, often to the detriment of himself. The increasing pace of developmental activities add further to the environmental deterioration of this highly sensitive coral ecosystem. One such activity has been the blasting and dredging of coral reefs for the development of a harbour in the island of Kavaratti (Ramachandran, 1981). While the primary impact was the destruction of living corals, the secondary impact that it generated was marine erosion. The study suggested minimization of establishment of institutions in a single island so that the magnitude and importance of impacts become minimum. It further emphasized the need for having mandatory environmental impact assessment (EIA) of all the developmental projects, irrespective of their size in these islands.

Two of the sectors identified by the Island Development Authority (IDA) for the economic development of the islands of Lakshadweep are fisheries and tourism. It is estimated that,

annually more than 8000 tourists can be accommodated on these islands on a sustainable basis, which amounts to more than 5 times the number of tourists of both Indian and foreign origin, who visit these islands today. However, the experiences of many islands of the world, where the tourism industry has taken root, shows that unless proper care is taken right at the preinvestment stage of various development projects, things might turn suicidal in terms of environment, economy and culture, as pointed by Ramachandran (1982) in his study on the natural environment of Lakshadweep, landuse capability, problems and prospects.

The recently enacted Coastal Regulation Zone Act, 1991 and the overwhelming necessity to safe guard the sensitive coral environment coupled with public awareness have recently imposed various restrictions on any type of activity in these islands. This has obviously made it obligatory on the part of the Union Territory Administration to make any activity transparent by resorting to EIA and making it public. One such EIA was done by CESS (1997) with regard to construction of five air strips of 500 m x 50 m in the islands of Kavaratti, Andrott, Minicoy, Kadmat and Kiltan, primarily to examine its feasibility in terms of development of tourism. The feasibility study for air strips was based on Geographical Information System (GIS) based on thematic maps of 1:4,000 scale on Coastal Regulation Zone, Agricultural Landuse, Natural Vegetation Cover, Groundwater lens, Settlement and Built-up Area, Physical Factors etc. Linear features such as roads, communication lines etc. were also considered. This resulted in suitability assessment and overlay factor maps leading to demarcation of air strip corridors with very low environmental impacts. Supplementing this spatial approach, an interactive matrix analysis was also attempted to facilitate understanding the various dimensions of the likely environmental issues involved in the total tourism development and also the Environmental Management Plans (EMP) that might be needed to ameliorate the negative impacts, in future, and the probable costs involved in the process.

3. Shoreline Dynamics

Wave diffraction plays a significant role in the distribution of wave energy along the Coasts of the islands and thus affects the stability of the coast. To understand the relationship between the erosion-cycle and wave diffraction in selected islands, a beach monitoring survey involving beach profile measurements was carried out during 1991 - 1992 (Prakash et al., 1995). The beach profile data have been processed for the beach volume changes and critical areas of erosion and accretion demarcated. It is observed that the SW and SE portions experience critical erosion whereas the NE portion of the island shows a seasonal erosional/accretional behaviour. Wave data from a Directional Waverider Buoy deployed off Kavaratti show that wave heights vary from 0,56 to 8.95 m. The S-SW waves are dominant with periods ranging from 5 to 8 s during monsoon and 8 to 12 s during fair weather period. The diffraction coefficients were computed for the dominant wave directions and wave periods. The diffraction coefficient along the boundary of the islands vary from 0.71 to 1.45. Higher diffraction is observed at the SW and SE coasts where critical erosion is observed. At the NE portion of the islands where there is no net erosion the diffraction coefficient is less.

4. Wave Climate and Power Potential

The wave climate and power potential of the seas surrounding Lakshadweep islands were also studied by the CESS using wave data collected with a Directional Waverider Buoy deployed off Kavaratti (Baba et al., 1995). The study reveals that the wave climate of the Lakshadweep sea is influenced by the southwest monsoonal winds. The period from June to

August is the roughest season for the Lakshadweep sea. The maximum wave height observed during the one year period is 8.95 m in August. Waves generally do not exceed the height of 5 m during November-March. During southwest monsoon the dominant values of maximum wave height is around 5 m and during the non-monsoon season it is around 1.4m.

The significant wave heights range from 0.4 to 4.7 m, the lowest being observed in February and the highest in August. Generally, Hs are higher during June, July and August when the range is 1.75-4.70 m and are lower during November-March. The zero-crossing period (Tz) ranges from 3.5 to 13.3 s. The maximum ranges are observed in February and April and the lowest ranges during June-August. The dominant Tz during southwest monsoon is in the range 7-8 s and during non-monsoon it is 5-7 s. The peak period ranges from 8.4 to 26 s during the year, the lowest being observed in November and the highest in February. Generally, Tp is lower during June-August with smaller variations, the wave direction ranged from 106° to 316° N. The waves are least persistent in direction during January and February. The easterly components are observed during the period November-January. The S-SW directions persist throughout the year and these directions dominate most of the period except when the southwest monsoon is intense with westerly waves,

The maximum wave power observed during the year is 110 kw/m in July. During November to March the dominant wave power is in the range 0-5 kw/m and during April, May, September and October it is the range 5-10 kW/m. The peaks of the distributions of the wave power are in the range 20-25 kw/m during June, 30-35 kw/m during July and 15-20 kw/m during August. The monthly mean wave power ranges from 28 to 40 kw/m during June-August. The average wave power for the complete year is about 14 kw/m and that for June, July and August is around 35 kw/m.

5. Monitoring of Marine Pollution Parameters

As part of the nation wide project on the Coastal Ocean Monitoring and Prediction System (COMAPS), the CESS has been continuing monitoring of various marine pollution parameters in the seas around Lakshadweep, particularly, off Kavaratti, Ardrott and Minicoy (Ouseph, 1997). As part of the program, the marine water samples are being analyzed for total suspended solids, pH, salinity, Dissolved Oxygen, Biological Oxygen Demand, silicate, total Phosphorous, ammonia-Nitrogen, nitrite-Nitrogen, nitrate-Nitrogen, total-Nitrogen, petroleum hydrocarbon and trace metals. Chlorophyll- a pigment and primary productivity values were determined to assess the productivity level. Identification and assemblage of plankton communities and microbial parameters are also attempted.

Data so far collected provide the status of water quality and productivity in the region. Water temperature were almost uniform and the suspended solid concentration was recorded high at Kavaratti. High pH was noted at Minicoy. Low Dissolved Oxygen concentration was recorded at Kavaratti and Androtт. Nutrients concentration was almost constant in all the regions. High Biological Oxygen Demand (BOD) was noted at Kavaratti and Androtт. The low Dissolved Oxygen and high BOD recorded in this regions indicate the environmental stress. The petroleum hydrocarbon concentration was also noted to be high at Minicoy in comparison to Kavaratti and Androtт.

Minimum pigment concentration was noted at Minicoy. The highest biomass was recorded in the Kavaratti waters and the lowest in Androtт. *Coscinodiscus* and *Chaetoceros* were the

dominant phytoplankton groups observed in the Lakshadweep waters. *Copepods* and *Decapods* were the dominant groups among he zooplankton.

Inter island comparison of Kavaratti, Minicoy and And rott indicates that Kavaratti island is the most viable in terms of microbial activity. The highest Total Viable Count is noted in the shore sample of Kavaratti Airport point. Anthropogenic pollution of shore water, recorded as coliforms and faecal coliforms, was also maximum at Kavaratti. In Minicoy and Andrott faecal contamination is found spreading beyond 2.5 km distance. Faecal Streptococcus, another indicator of faecal contamination, is found maximum in Andrott harbour point. Faecal contamination of sea shore is obvious in all the three islands by the presence of *Streptococcus* sp. Other type of pollution indicators such as *Salmonella* sp, *Shigella* sp.and *Vibrios* sp. were also observed, the maximum being in Kavaratti island. The present study reveals that the coral environment is subjected to stress mainly by anthropogenic sources. The high microbial activity is likely to affect the coral ecosystem.

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Status of Coral Reefs of Mahatma Gandhi Marine National Park, Wandoor, Andamans

K Dorairaj[1] and R. Soundararajan[2]

Introduction

The marine ecosystems of the Andaman and Nicobar Islands are unique in having very high degree of biodiversity and endemism in fauna and flora. The coral reefs of these Islands are one of the richest in the Indian Sub-continent. They not only protect the coastline against sea erosions but also harbour host of animal communities like fishes, molluscs, sponges, echinoderms and other organisms. Commercial fisheries often indirectly depend on coral reefs which serves as nursery grounds for juveniles. Of late, the coral reefs have also come under heavy pressure due to uncoordinated and inconsistent developmental activities on coastal land leading to deforestation, mangrove habitat destruction, and degradation of marine ecosystems.

In the Andaman and Nicobar islands, a total of 733.12 sq. km. of area have been brought under protected areas under Wild Life (Protection) Act, 1972. They include 6 National Parks, and 94 Sanctuaries. The total area of the 6 National Park is 361.79 sq. km. and of which about two third is marine water area. All the National Parks and 91 Sanctuaries are located in the Andaman district, while 3 Sanctuaries in Nicobar district, besides the Great Nicobar Biosphere Reserve.

Mahatma Gandhi Marine National Park

Under the Wildlife (Protection) Act of 1972 the Mahatma Gandhi Marine National Park, Wandoor was notified on 24th May 1983 for the protection of marine life including corals and nesting sea turtles. The Park is located on the South Western coast of South Andaman, in the Bay of Bengal, encompassing 15 islands and several islets of the labyrinth group of islands, like Alexandra, Red Skin, Boat, Hobday, Tarmugli, Grub, Chester, Snob, Bell, Pluto, Malay, Jolly Boys, Riflemen, Twins and parts of Rutland island (Fig. 1). The parks boundary runs along the coasts as well as some time along island within the range of latitude between 11°22, o6" and 11°36 -34" N and longitude between 92°30.00"W and 92°40.33' E covering a total area of 281 50 ha (281.5 sq km). The area includes vast stretch of enchanting marine waters, bushy vegetated islands, magnificent coral reefs and sparkling sandy beaches and mangroves.

The park is under the overall administrative control of the Chief Wildlife Warden of the forest department of A&N islands administration. Though the park is uninhabited, there are 8 villages adjacent to the park area with a population of about 3000 (1981 census).

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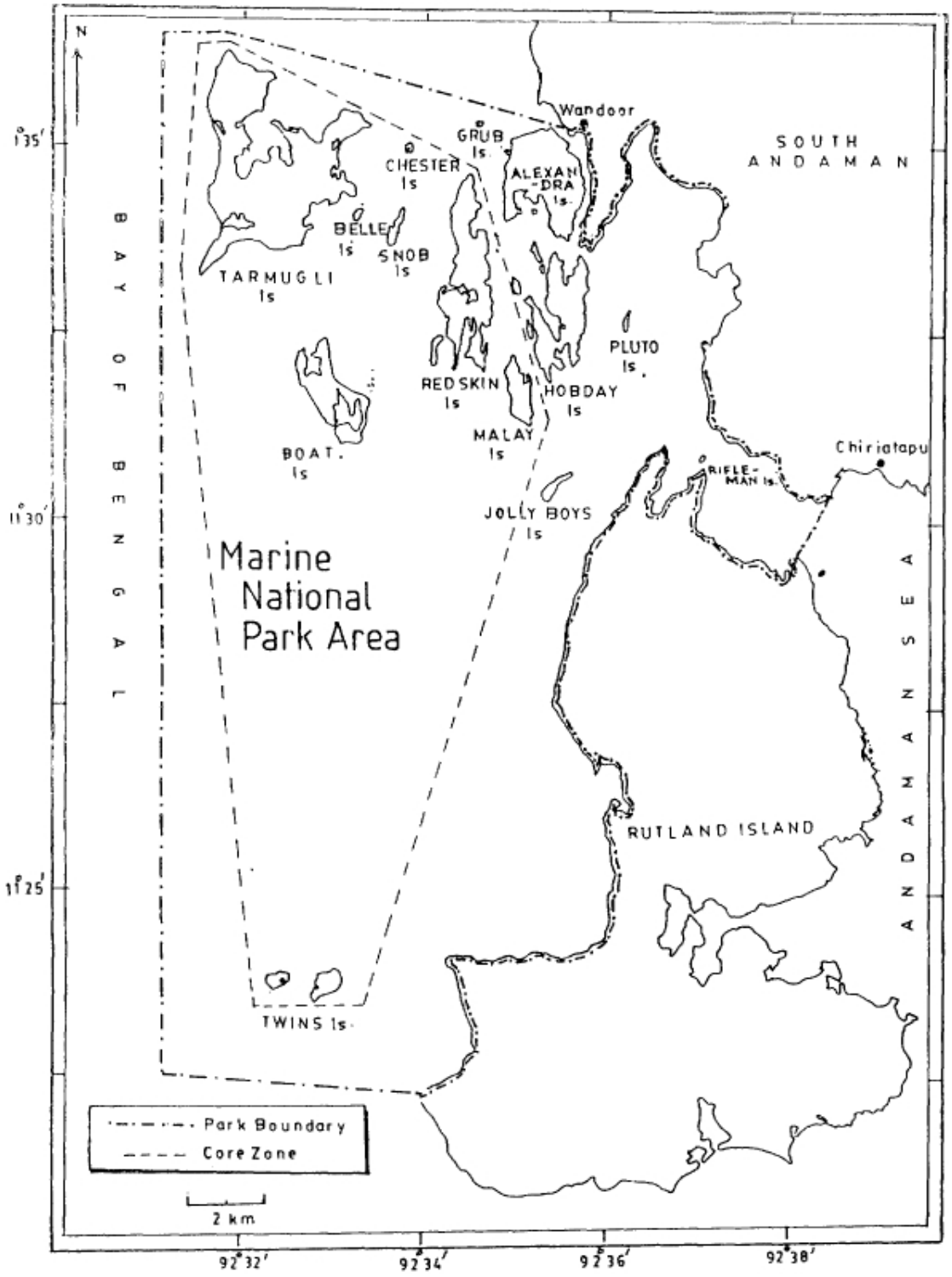
The fishermen of the villages continue to carry out fishing within the park area and are given license by the Fisheries Department. To encourage tourism, two islands in the park viz., Jolly Boys and Red Skin are opened for the tourist to visit during fair seasons.

Figure 1: The National Marine Park are of Wandoor showing the boundaries, core zone and different islands in the park.



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Coral reef survey

Out of the 15 islands and islets in the Park, Wandoor, five islands were selected for detailed survey. They are Jolly Boys, Red Skin, Tamiugli, Boat and Twins Islands. The islands were selected in such a way so as to have a homogenous representations of all ecosystems in the park area. The Jolly Boys and Red Skin islands are open to tourist and thus subjected to greater disturbances. Tarmugli and Boat Islands are less disturbed while Twins islands is least disturbed due to their far off location and less human interference. Survey stations ranging from 4 to 9 in various islands were fixed so as to cover the maximum perimeter of the islands. Detailed quantitative and qualitative observations were made following live transect and quadrate survey methods.

A total of 99 transects in 33 stations at five islands were surveyed. The total distance covered was about 15,000m in which 1,569 quadrates were sampled to record the occurrence and density distribution of marine flora and various fauna such as hard corals (=live coral), soft coral, dead coral, sponges, fishes, gastropods, bivalves, sea cucumbers, sea stars, sea urchins, crabs, lobsters and sea anemones.

Status of coral reefs

The coral reefs of the Park were mostly of Fringing type. The live coral coverage on the reef and their composition and the list of coral species recorded in five islands are given in Tables 1 and 2.

Jolly Boys Island

This island is located in the buffer zone of the Park and has a total land area of about 17 ha. The coast line vegetation leads to sand and in some places to rocks. The island is not having any mangroves. However uprooted tree trunks are seen along the coastal area in a few places. The surveys were carried out at 6 station. The coral reef is of fringing type and it starts at 30m from the shore in station 1 and at 160 m in station VI.

The live corals in different stations were between 37 and 50%, with 42.3% for the whole island. Corals species diversity was moderately good. A total of 26 species under 17 genera were recorded, of which *Acropora and Porites* were dominant, forming 33 and 28% respectively. Soft corals were also available in all stations and were represented by 3 species; maximum coverage (1 2.4%) was in Station 1. Nearly 38% of the reef was strewed with dead corals; a small percentage of them were in 'Bleached' condition caused due to predation of coral polyps by the dreaded crown of thorns *(Acanathasterplanci).*

Red Skin Island

This island is located in the core zone of the Park and has total land area of about 347 ha. The east coast of the island is profusely bordered with mangrove vegetation while the west coast by sand and sheet rocks at few places. Uprooted tree trunks are strewn on the beach. Fairly extensive mangrove swamps are also found on the west, south and eastern parts of the island. Survey,s were carried out in 8 stations. The coral reef are of fringing type; generally the reef starts from 80m and extends upto 210 m. In station VII the reef is very close to the shore and

its slope suddenly increases from 2m to 7m. Damages to coral reef were seen in Station VI caused mainly due to boat anchorage.

Nearly half (51 %) of the reef area was occupied by luxuriant live corals and at Station VIII it was as high as 62%. A maximum of 18 genera and 26 species of corals were record in the island. Dominant forms were *Porites* (47%) and *Acrqpora (21* %). Soft corals were poorly represented and were found only in 3 out of 8 stations; in Station 1 it formed 4.2%. The dead coral proportion (37%) was more or less similar to that observed in Jolly Boys island.

Table 1: Live Coral Covarage and their composition (%) in the five islands of Mahatama Gandhi Marine National Park

Species	Jolly Boys	Red Skin	Tarmugil	Boat	Twins
live coral coverage	42.5	51.4	45.0	40.3	52.9
Composition					
Seriatopora	0.4	0.6	0.1	1.8	0.3
Stylopora	0.1	-	0.2	-	2.3
Pociliopora	0.6	0.9	1.0	0.5	0.9
Acropora	33.0	20.5	44.9	30.6	55.3
Montipora	15.6	6.4	3.4	7.4	1.5
Pavona	0.3	1.2	0.3	-	0.3
Pachyseris	-	0.2	-		0.3
Fungia	0.6	0.7	0.3	0.5	-
Herpolitha	0.1	0.1	-	-	
Goniopora	1.3	4.5	0.5	0.5	1.2
Porites	28.5	47.0	34.7	46.5	3.9
Favia	0.5	2.0	0.6	0.7	0.5
Favltes	3.6	5.2	4.8	3.2	0.8
Platygra	0.6	0.3	0.5	-	
Leptoria	0.6	0.4	2.1	0.6	-
Hydnopora	0.6	0.1	-	-	-
Diploastrea	0.2	-	0.1	0.2	-
EchInophora	-	-	-	0.6	-
Galaxea	-	0.3	0.1	-	0.1
Merulina	8.0	2.4	0.6	-	1.5
Lobophyllia	-	1.6		-	0.2
Millepora	5.3	5.7	5.8	6.9	30.9
SOFT CORALS	6.2	0.8	2.3	2.2	2.9
DEAD CORALS	**37.9**	**37.4**	**30.9**	**38.5**	**38.0**

Table 2:List of corals, sponge and flora species recorded in different islands of Mahatma Gandhi MNP, Wandoor, Andamans

Species	Jolly Boys	Red Skin	Tarmugil	Boat	Twins
Hard live **corals** **Pocillioporidae**					
Seriatopora hystrix	+	+	÷	+	+
Stylopora pisilata	+	+	+	+	+
Pocil/opora verrucosa			+	+	+
Acroporidae					
Acropora gravida	+		+	-	+
A. hyacinthus	-	+	+	+	+
A.nobilis	+	+	+	+	+
A.humilis	+	÷	+	+	+
A. efflorescens	+	+	+	-	+
A. palifera	+	+	+	+	+
Acropora sp	+	+	÷	÷	÷
Asteropora sp.	-	+	+	-	+
Montipora sp	+	+	+	+	+
Agaricidae					
Pavonasp.	+	+	+	+	+
Pachyseris sp.	-	+	-		+
Fungidae					
Fungiasp.	+	+	+	+	+
Herpolitha sp.	+	+			
Poritidae					
Goniopora sp.	÷	+	÷	+	+
Porites sp.	+	+	+	+	+
Faviidae					
Faviasp.	+	+	+	+	+
Favites sp.	+	+	+	+	+
P!atygra sp.	+	+	+	+	+
Leptoria sp.	+	+	+	+	+
Hydnopora sp.	+	+	+	+	+
Diploastrea sp.	+	+	+	+	+
Echinophora sp.	÷	-	-	+	+
Oculinidae					
Galaxea sp.	-	+	+	+	+
Merulindae					
Merulina sp.	+	+	+	+	+
Mussidae					
Lobophyllia sp.	+	+	+	+	+
Symphyllia sp	+	-	+	-	
Pectinade					
Mycedium sp		-	-	-	+
Milliporidae					
Millepora sp			-	-	+

Table 2 Contd.

Species	Jolly Boys	Red Skin	Tarmugil	Boat	Twins
SOFT CORALS					
Dendrophyllidae					
Turbinaria sp.	+	+	-	-	-
Sargophytum sp.	+	+	÷	–	+
Sinularia sp.	+	+	-	-	+
Gorgonia sp.	-	-	-	+	
Sponges					
Phyllospongia sp.					
Flora					
Sargassum sp.	+	+	+	+	+
Turbinaria sp.	+	+	+	+	+
Padinasp.	+	+	+	+	+
Halemeda sp.	+	+	+		
Gracillaria sp.	÷	-	-	-	-
Filamentoussp.	+	+	+	+	+
Sea grass	+	-	+	+	+

+ **+:PRESENT** - **-:ABSENT**

Tarmugli island

This is the biggest island in the park area, having a total land area of 945 ha, located west of Chester and Belle islands. The characteristic feature of the coastline of the island is the presence of very thick mangrove vegetation, sandy beaches, uprooted trees and sheet rocks. Very extensive mangrove swamps are found on the northern side of the island with a few patches of swamps on the east, south eastern and south western parts of the island. Surveys were carried out in 9 stations. Coral reef is patchy/fringing type and starts from 50 m to '150 m from the shore. However, in station VIII ft starts very close to the shore. Damaged dead shells are found at several places inside the sea at Station lll. Maximum dead corals upto 70 m from the shore were seen in station IV as well as in station VII at 240 250m from the shores. Damages to the live corals (stag horn) was also seen in this station.

The live coral density at Tarmugli island was not uniform; its coverage varied between 20% in Station 1 and 58% in Station IX. The overall coverage for the island was 45%. A total of 26 coral species under 17 genera were recorded during the survey; *Acropora* (45%) and *Porites* (35%) were the dominant forms. Only one species of soft *coral (Satgophytum)* was recorded in 7 out of 9 stations; its percentage coverage in Station lll to V were between 4.2 and 4.9. Of the five islands surveyed, the percentage proportion of dead coral was lowest (31 %) in this island; it was as low as 14% in Station IV.

Boat island

This island is situated in the core zone of the park, on the south of Tarmugli, Belle and on the west of Malay island. The total land area of the island is about 180 ha. Fairly extensive

mangrove swamps are found both on the northem and south-western part of the island. Sheet rocks are present on the south eastern and north western parts of the island. Coastal vegetation leads to sandy as well as rocky beaches and in some areas uprooted tree trunk are lying on the sandy beaches. The survey was carried out in 6 stations. Coral reefs are patchy/fringing type and ft starts very close to the shore in Station 11 and extends up to 250 m in station VI.

As compared to other islands in the park, live coral (40%) coverage was lowest in **Boat island.** Species diversity was also low; only 24 species under 14 genera were recorded. Porites(46.5%) *and Acropora* (31%) were dominant. However, the maximum dead coral coverage (39%) was also observed in this station. In Station V, nearly half of the reef region was with dead corals. Soft corals were found in four stations, with coverage ranging from 1 to 8%.

Twins island

As the name implies it represents two small islands situated side by side in east west directions in the southern most core area of the park, far away from rest of the Labyrinth group of islands. The total land area of Twins islands is about 49 ha. In the eastern Twins island, the coastal vegetation leads to sheet rocks, edged rocks and sandy beaches while in the western Twins island mostly to vast stretches of sandy beaches and edged rocks. In some places uprooted tree trunks were seen. This island is an important breeding ground for Turtles. Large number of turtles were seen swimming in the sea and their foot prints were observed on the sandy beaches.

Among the five islands, live coral coverage was highest (53%) in Twins island. In 3 out of 4 station, its proportion was over 50%. In Station 11 and III, they formed nearly 57% substaratum coverage. Coral species diversity was moderately good, with 25 species under 15 genera. The dominant coral was *Acropora* (55%) followed by *Millepore* (31 %). Though *Millepore* was recorded in all the 5 islands, its density distribution was very high in Twins island, Soft corals *(Sargophytum* sp and *Sinularia* sp) were recorded only from Station 1. Among the dead corals which formed 38%. a small proportion were in Bleached' condition.

An overall analysis revealed that nearly 47% of the reef in the Park were with live and luxuriant corals in varying density; soft corals from about 3%. A total of 31 coral species under 25 genera were recorded. *Acropora, Porites and Millepora* were the dominant coral forms in the park region. Soft corals were relatively more in number in Jolly boys and Twins islands than in other islands and they were represented by four genera.

Based on species diversity and substratum coverage with live corals, the status of coral reef of the park area may be broadly categorised as 'Fair' in Jolly Boys, Tarmugli and Boat islands and as 'Good' in Red Skin and Twins islands.

Associated fauna of coral reefs

Among the reef inhabiting invertebrate fauna, the major groups found in order of abundance were Gastropods (35%), Bivalves (25%) and Echinoderms (25%). *Conus, Cyprea, Lambis,*

Trochus, Blood clam, Pearl oyster, Rock oyster, Giant clam, Sea urchin and Holothurian were the commercially important forms found in varying densities. Fairly high density of invertebrate fauna were found at Red Skin, Twins and Boat islands. Gastropods and Echinoderms were more common in Twins island, while Bivalves in Red Skin island. A total of 31 species of Gastropods, 26 species of bivalves, 3 species of Cephalopods and 16 species of Echinoderms were recorded from the park area. Crabs, lobsters and sea anemones were observed in small numbers only.

The fish assemblage on the reef region was moderately high at Twin island, followed by Red Skin, Tarmugli, Boat and Jolly Boys islands. Pomacentrids represented by 5 species were the dominant group in all the island. Lutjanids, Acanthurids and Chaetodontids, each represented by 6 species were more common than other groups. An overall 'analysis showed that Angle fishes formed 32%, Snappers and Fusiliers 19%, Surgeon fish 18%, Coral fish 12%, Spine foots 4% and Wrasses 3%. The other fish groups such as Breams, Reef cods, Parrot fishes and Gobis were represented by 2% each. Out of the 55 fish species recorded in the park area, many of them were of highly priced ornamental fishes and important tuna live bait fishes.

The algal coverage in the park was generally poor. ft was represented by *Turbinaria, Sargassum, Padina, Halemeda and Gracillaria.* Filamentous algae was found attached on the dead corals in all the islands. Sea grass was found in good patches at Station VI of Tarmugli island, suggesting that ft could be the feeding ground *for* Sea cow, *Dugon dugon.*

Among *sponges, Phyllospongia* sp was the only species recorded in all islands, but in small numbers. Its occurrence was relatively more in Red Skin and Jolly Boys islands.

General remarks

The sea water quality of the park area in respect of temperature, salinity, dissolved oxygen and pH were in optimal range, free from oil and other pollutants, with very high clarity and transparency, inspite of several fishing and tourist boats ply within the park area. The shores of these islands were also unpolluted; litters were not observed even in Jolly Boys and Red Skin Island which are opened to tourist.

Several factors like predation by crown of thorns, siltation of coastal waters, effluent discharge, unfavourable environmental conditions, human interference, etc are stated to be the responsible factors for the damage and destruction of corals. As far as the Park is concerned, human interference and crown of thorns infestation, have definitely caused damages to coral and coral reefs. In some areas like Station VI of Red Skin island, corals in the reef slope were badly damaged, mostly due to boat anchorage. Shell collection activity also caused considerable damage to corals at Station 11 of Twins island and Station Ill of Tarmugli island. Tourist activity like trampling, overturning the coral blocks, Snorkelling and Scuba diving have damaged the corals at Station Il) in Jolly Boys island.

Wood (1989) had observed significant and localised damages to corals by crown of thorns in the park area. However, James et *a!* (1 990) had stated that 'predation by *Acanthaster* might have played some role in the death of corals but this is not of an alarming state at present'. As

is well known that some of the reef inhabiting animals like fishes, sea urchins, shrimp, polychaete and molluscs also feeds to a limited extent, on the coral tissues and cause damage to coral colonies. However, the prey-predator inter-relationship and mechanism of coexistence of corals and coral inhabiting the organisms of the Park have not been studied.

Though there are several reports about the damage and death to corals due to siltation and effluent discharges in the inshore areas of South and Middle Andaman, (Dorairaj *et a!* 1987, Wood 1989, James *et al* 1990), these problems have not been encountered in the Park area, except at a few coastal areas near the New Wandoor and on the west coast of Rutland island. The strong monsoonal winds and cyclones also appear to exert strong influence on reef flats, turning them into rubble banks. The exposed reef are normally affected by tidal emersion due to prolonged exposure. The tidal amplitude in the Andaman is 2.5 m. At times of prolonged exposure, the corals tend to extrude the zooxanthellae and the loss *of* tissue give way for algal growth and thus widespread damages are likely to be caused due to unfavourable environmental factors.

Environmental awareness campaign need to be organised, particularly in the bordering villages of the Marine National Park Wandoor, to educate and to create an awareness among the general public, the need for protecting the coral reef and preserving the valuable 'germplasnm' of the National Park.

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Carrying Capacity of Coral Reefs

M. Wafar

Introduction

When we begin to talk of coral reefs, several things spring to the mind forthwith. One is the high biological productivity, highest among all tropical marine ecosystems, they sustain, the second is the largest biological diversity associated with them, the third is the richness of their inorganic (coral blocks, debris, sands, ornamental corals, molluscan shells) and organic (food fishes, aquarium fishes, marine algae) resources, the fourth is the biomedical prospects the reef dwellers hold, the fifth is the aesthetic value of the reefs and the tourism potential, and so on. At the same time we also become conscious of the need to manage the reefs in a sensible way if we are to draw benefits from their resources over a long term. The distinction is obvious: no reef resource can be brought under total protection, especially when the local population depends on them for sustenance. The next best alternative is 'have your cake and eat it too' - adopt a sustainable use policy, be it for extractive (e.g. fishing) or invasive but non-extractive (tourism) uses.

This brings us to the concept of carrying capacity of the reef. In a sense it is analogous to what constitutes the biological and environmental (including fishing effort) factors that go into an assessment of the sustainable yield of a commercially exploited fishery. Such parameters with a reef, however, are vastly diverse - size, location, species diversity, productivity, type of extractive activities (fishing, mining, dredging), onshore developmental activities (that lead to industrial and sewage pollution), susceptibility to natural disasters, interactions with adjacent ecosystems (e.g. coral reefs and mangroves), current level of tourism and future prospects of it, and a host of others including as test sites for nuclear explosions. This presents us with a wide choice of parameters to assess the carrying capacity of a reef and monitor it.

I may define the carrying capacity of a reef as its ability to support a range of extractive and invasive uses without perceptible changes and/or degradation of its biological productivity and species diversity over a reasonable period of time. I wish to emphasize here that this definition is not restrictive to tourism-related activities but is intended to cover all those activities (e.g. waste assimilation capacity) which have a potential for expansion and exceed the reefs' ability to cope up with these. The time parameter, naturally, is subjective but not the 'perceptible changes'. Enough literature exists as such to enable us to recognize them and the indices with which we can do that.

My aim is here to summarize these indices and provoke, in doing so, an useful discussion. Easily said than done as the diversity of such indices become obvious as we progress.

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Indices of productivity:

Environmental and biotic changes can both decrease and increase the productivity. Changes in both directions can be easily assessed from a diel oxygen balance (which measures the reef community metabolism as a whole and hence is ideal for situations with a range of auto- and heterotrophs as in a reef). Decrease in P/R (production/ respiration) ratio or a shift to negativity in it would suggest a degradation of the community. P/R ratios may also vary seasonally, if the reefs experience unfavourable conditions during a part of the year. These effects, however, could easily be removed from interannual variations in P/R ratios by time-averaged ratios or by restricting the measurements to specific periods of an year.

As an ecosystem tends to be in a steady stare increase in the productivity also is a cause fore concern and it is very often as a result of eutrophication. As the reefs are ecologically tuned to survive in low-nutrient waters by efficiently recycling the nutrients within the ecosystem, the effects of eutrophication manifest in a dramatic increase of benthic macroalgal production. This does not augur well for the reef since the proliferation of the algae is often at the expense of corals (competition for space and light). While appearing to benefit the reef initially this will, in the long run, transform a coral reef to an algal ridge with attendant reduction in biodiversity and change in trophic structure. Indices of eutrophication - inorganic nutrients, among which nitrogenous nutrients are the most important, and the organic matter load - are easy to recognize and measure in the field.

Indices of pollution

While at eutrophication we may also dwell with pollution of other sorts, since it is conceivable that developmental activities lead to both. The latter come in the form of oil, heavy metals, thermal effluents and high suspended inorganic load, among others. While all of these may affect a reef gradually and chronically, the very fact that these occur in reefs close to sites of onshore and coastal developmental activities and hence subjected to EIA monitoring regulations (in most of the countries), would render it easy to keep track of them. The indices that we may have to watch out for are heavy metals that may be accumulate in reef biota, petroleum hydrocarbons, and suspended solids that may reduce light penetration and smother the corals.

Indices of biodiversity

The diversity of the reefs is greatest of all the marine ecosystems and it would be practically impossible to monitor the whole or even part of it all the time. Instead changes in abundance and zonation of corals can be better indices of the changes in the carrying capacity of the reef. This also brings us to the usefulness of indicators species. They fall into two categories: environment-type indicators and environment-change indicators. The latter,

of more pertinence to us, can be grouped into indicators of component (communities), structural (functional relationships) and process (rate, direction) changes.

Though none is known with any certainty, several **of the reef dwellers, because of their** stenotypic nature and specificity to reefs hold a potential as indicator species of carrying capacity.

Indices of harvest practices

Besides the effects of overharvesting, as with any marine resource, harmful harvest practices also tend to affect markedly the carrying capacity of a reef. Such practices are collection of ornamental corals and shell, dynamite fishing, poison fishing, mining and dredging. Destructive fishing methods cause irreversible damages to the carrying capacity of the reef and need to be totally discouraged. As far as overharvesting is concerned, it can be regulated by application of fishery yield models (as is available for the red coral fishery), quotas, closure seasons, and rotation of the zones. Again, the response of the carrying capacity may not be the same with respect to overharvest of organic and inorganic resources: restoration of it may be rapid in the case with organic than inorganic resources. For example, the Gulf of Kachchh (India) reefs which lost more than 50% of the reef cover and biota following commercial dredging of coral sands, are yet to return to 'normalcy' even 20 years after the extraction of coral sands has been discontinued.

This also brings us to the question of whether the carrying capacity will be affected even at level of unorganized harvest of resources. It is quite possible, For example, in the Lakshadweep islands, until recently, the coral blocks served as building materials. With the increase in construction of individual houses, the damage to the reefs and the shoreline as a result of mining became substantial. This could not be stopped for the simple reason that the management practices did not foresee provision of alternate building materials at affordable costs. The lesson is that enhancement of carrying capacity, at least in third world countries, will succeed only when the dependence of the local population on reef resources is alleviated in a manner economically satisfactory to them.

Indices of interactions with adjacent ecosystems

Coral reefs occur quite often in association with other ecosystems, especially the mangroves, and the changes in the latter often entrain damaging effects on coral reefs. For example, in the Gulf of Kachchh, the extensive deforestation of mangroves has led to an increased flux of coastal sediments onto the fringing reefs, so much so that almost every reef in this area lies partly covered with mud. In fact, this is probably a major cause for the reduction in the abundance of corals on the reefs. In this instance, the impairment to the carrying capacity of the reef cannot be remedied without remedying the situation in the mangroves.

Indices of tourism

Tourism is increasingly being advocated as a means of increasing the economic returns from the use of the reefs with minimal damages. However, in several reef areas the carrying capacity has been exceeded by the tourist activities, especially at sites which are very popular with easy access. Though the major impact is predicted to be generally on the reef biota, the fallout of tourism will cover all factors that might otherwise strain the carrying capacity of the reefs: these will include constructional activities on or near the reefs, boat traffic and oil spills, pollution with sewage and non-degrading material (plastic bags, soft drink cans), abandoned or lost diving and reef-walking accessories and so on.

For many third world countries tourism to reefs is a novel and lucrative way of earning money and is likely, in the process, to be oversold. It would prove to be a sensible idea if the management action plans for reef areas are mandated to include projected growth of tourism to reefs and contain it within the estimated carrying capacity of the reef.

Conclusion

Adjusting the diverse reef-related activities to confine within the limits of the carrying capacity of a given reef or a reef region will necessitate a knowledge of the activities the reef is (and expected to be) subjected to and the intensity of the likely impacts. A use and impact chart, as the one prepared for the Gulf of Kachchh reefs (annex), may prove to be useful in summarizing and quantifying them. This is only a part of the game. It would not be a healthy practice to recognize that the carrying capacity has been exceeded only when it indeed occurs. Instead it would be more sensible and practical if the entire concept of the carrying capacity, as I have defined, is brought under a model form: then it would be possible to recognize the trends and contain the activities on the reefs long before they reach the limits of the carrying capacity. Ecosystem modelling is not a new concept - basic models and EIA models exist: adopting them to the specific needs of defining and setting the limits of carrying capacity of the reefs and managing them would be rewarding in the long run.

Use and impact chart for the Gulf of Kachchh coral reefs

Use category	Existent or not	Level of use	Nature of damages
A. Living resources			
1. Commercial fishing within reef areas	NE		
2. Commercial fishing in offshore waters	yes	high	Sustainable catch
3. Subsistence fishing in reef areas	yes	moderate	Habitat destruction
4. Recreational fishing	N.E.		
5. Commercial coral collection	Yes	Was high. Presently controlled	Live coral cover loss. Habitat destruction. Increase in sediment load leading to further coral mortality.
6. Commercial shell collection	Yes	Was high for pearl oysters. Presently at low level for other pecies.	Overexploitation and failure of pearl oyster fishery. For others, no perceptible damage
7. Aquarium fish collection	N.E.		
8. Aquaculture	N.E.		
9. Turtle hunting	Yes	Modest	Damage to recruitment
10. Bird hunting	Yes		
11. Plant harvesting-terrestrial	Yes	High	Severe erosion of shore-line and transfer of silt and clay into the coastal waters.
12. Plant harvesting-marine	Yes	Modest	
13. Other resources	N.E.		
14. Destructive fishing methods	N.E.		
B. Non-living resources	N.E.		
1. Oil and gas mining			
2. Limestone mining	Yes	High	Habitat destruction
3. Extraction of construction material	Yes	Moderate to high	Habitat destruction
4. Other minerals	N.E.		

Use category	Existent or not	Level of use	Nature of damages
C._Developmental_activities			
1 Discharge of effluents	Yes	**Low** to moderate	Pollution
2. Onshore mining	N.E.		
3. Dams/river flow modifications	Yes	Tidal power plant proposed	Might affect circulation pattern and the coral reefs
4. Harbor/navigational works (dredging, blasting, filling etc.)	Yes	High	Erosion, topography changes, pollution, habitat destruction
5. Domestic sewage	Yes	Less	Localized algal growth
6. Industrial sewage	N.E.		
7. Reclamation	Yes	Less	No visible damage
8. Solid waste dumping	Yes	Less	Dumping of dredged material can kill corals
9. Research and development	Yes		Encouraging Formul-ations of measures for conservation
10. Offshore navigation and oil spills	Yes		Occasional mortalities of corals
D. Non-extractive uses			
1. Resident tourism	Yes	Modest	Visible damage (Ex. Pirotan is.)
2. Sea-borne tourism	N.E.		
3. Air-borne tourism	N.E.		
4. Water sports (SCUBA, snorkeling etc.)	N.E.		
5. Reef walking	N.E.		
6. Constructional activities related to tourism	Yes	Modest	No visible damage

An analysis of the carrying capacity of Lakshadweep coral reefs

C.L. Rodrigues[1]

Abstract

Key parameters such as population size, number of houses, passenger traffic, cargo traffic and fish catch often major islands of the Lakshadweep archipelago are analysed to study the impact ol' Human activities on the reefs. *Lakshadweep has the third largest population density in the country. Rapidly escalating developmental activities are largely responsible for the degradation of the reefs. Fishery resources are under-exploited and the fish catch can be augi-nented by adopting modem methods and diverting the impact of fishing boats to mainland ports. There is an urgent need to halt the degradation of reefs and reverse the trend.*

Introduction

The Lakshadweep archipelago (8°N-12°30' N, 71°E-74° E), the smallest union territory of India, is located (Fig. 1) about 220-440 kni from the mainland city of Kochii (Cochin) in Kerala. There are 36 islands (including 12 atolls, 3 reefs and 5 submerged banks) covering all area of 32 kM2 with lagoons occupying about 4200 kM2. They comprise the only atolls in Indian territorial waters. Of these, only eleven islands viz. Agatti, Amini, Andrott, Bangaram, Bitra, Chetlat, Kadmat, Kalpeni, Kavaratti, Kiltan and Minicoy are inhabited. Kavaratti is the administrative headquarters. A resort. catering to international and local tourists, has been set up at Bangaram to promote tourism. In addition, tourist huts have been erected at Kavaratti, Kadmat. Minicoy and recently at Agatti. The main occupation of the islanders is agriculture (coconut, *Cocos nucifera)* and fisheries (skipiack tuna, *Katsuwomas pe/amis).*

During the past few decades there has been rapid development on these islands which has resulted in the degradation of coral colonies on the reef flats as well as in lagoons. Can the islands afford further developmental activities? Can the coral colonies withstand the pressure? In other words have the Lakshadweep coral reefs attained or crossed their carrying capacity? In order to analyze this problem, quantitative time series data on human activities and live coral cover are required. Unfortunately no quantitative data on coral cover are available. Qualitative changes that have occurred over the years in the environment and the biota of Lakshadweep have been described (James cl al., 1989). In the seventies, the distribution of live corals in lagoons of several islands was reported to be extensive (Pillai, 1996). It appears that the carrying capacity of the reefs was attained in the eighties. In this paper, an attempt is made to quantify and analyze human impact on the islands, relate it to the degradation of reefs and estimate the carrying capacity of the reefs.

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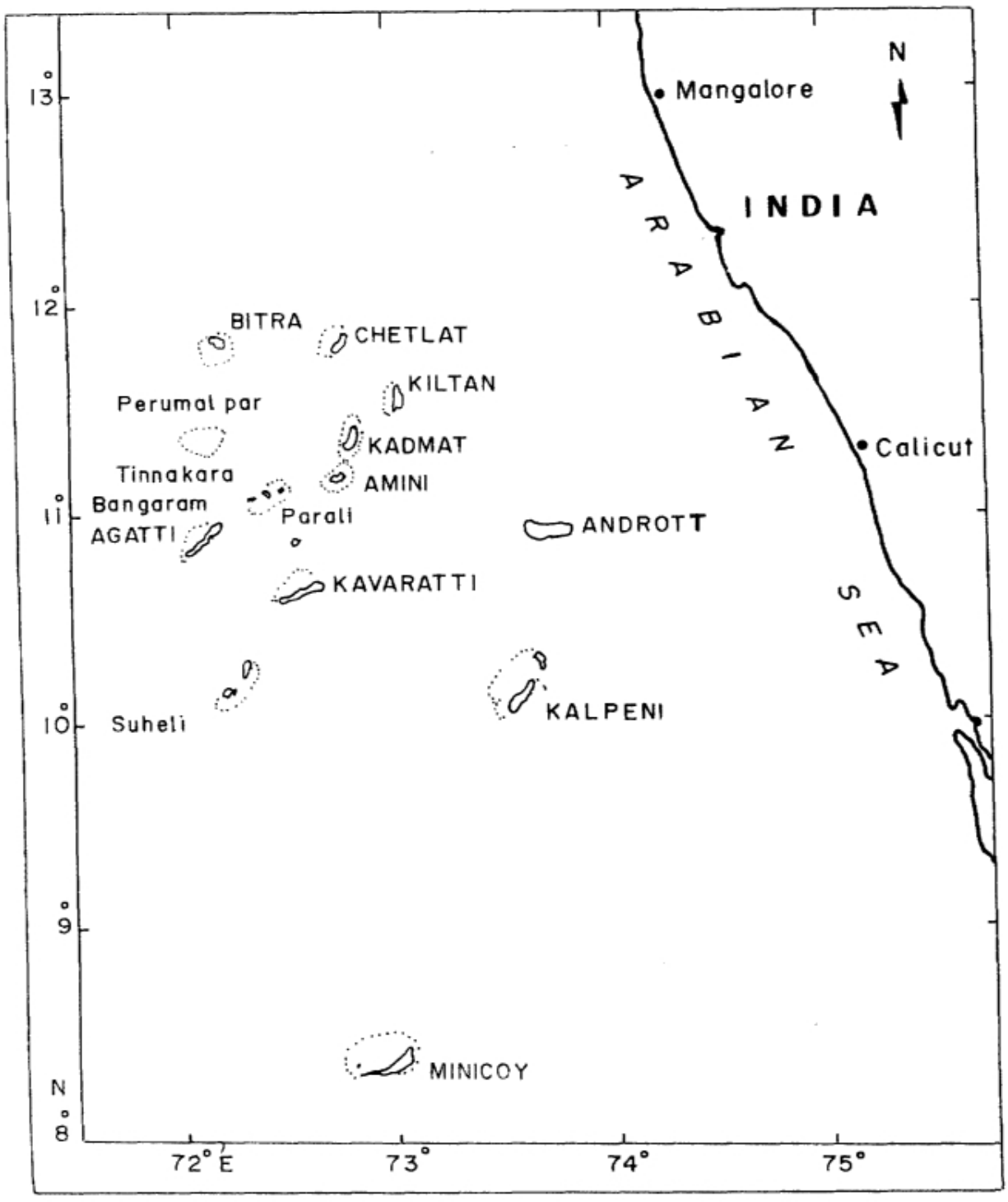
Fig. 1. The Lakshadweep archipelago.



Key parameters

The raw data used in this study have been obtained from publications of the Department of Planning and Statistics, Kavaratti, Lakshadweep. Five key parameters are considered:

1. population size
2. number of houses
3. passenger traffic
4. cargo traffic and
5. fish catch.

Tourism has not been included as a key para-meter as its impact is limited and regulated by permits required to visit the islands.

Population size indicates the pressure exerted by exploiters (humans) on the reefs by way of exploitation of resources and sewage generated which includes defaecation on the reef flats and corailine sands due to the unavailability of toilets.

The number of houses highlights the pressure exerted on reefs for construction purposes. Islanders exploit corals for construction purposes as the cost of-transporting materials from the mainland is prohibitive. it is only in the early nineties that a ban has been imposed on collection of corals for construction purposes. The magnitude of passenger and cargo traffic indicates the activities of small mechanized boats used to transport passengers/cargo from the island jetty to the vessels stationed outside the lagoon.

Lagoons have to be dredged and widened regularly to maintain the navigation passage and accomodate increasing number of boats, Incidentally, dredging in and around coral formations is not permitted under the guidelines of the Coastal Regulation Zone of the Environment lrotection Act (1 986). The increased sedimentation causes harm to corals. Boats also cause unintentional damage to reefs through anchor operations, elc. Fish catch data illustrate the number of fishing boats operating in the islands.. The major method of fishing is the traditional pole and line method which requires live bait.

Live baits are small fishes (particularly *Spratelloidos delicatu/us)* associated with corals and are used to lure tuna. They are collected from lagoons and reefs, resulting in unintentional damage to coral colonies. Other potential living resources are not considered in this study.

It has been necessary to standardize the data to enable comparisons between islands which are of different sizes. Population size and number of houses have been converted to density values per unit km2. The decennial percentage increase in the population density and the density of houses was computed for each of the major ten inhabited islands taking 1951 as the base year. In the case of passenger and cargo traffic, the percentage increase was computed yearly taking 1980-81 as the base year. Similarly, the yearly percentage increase in total fish landings on each island was computed taking 1980 as the base year.

Fig. 2. Percentage increase in population density in Lakshadweep islands.

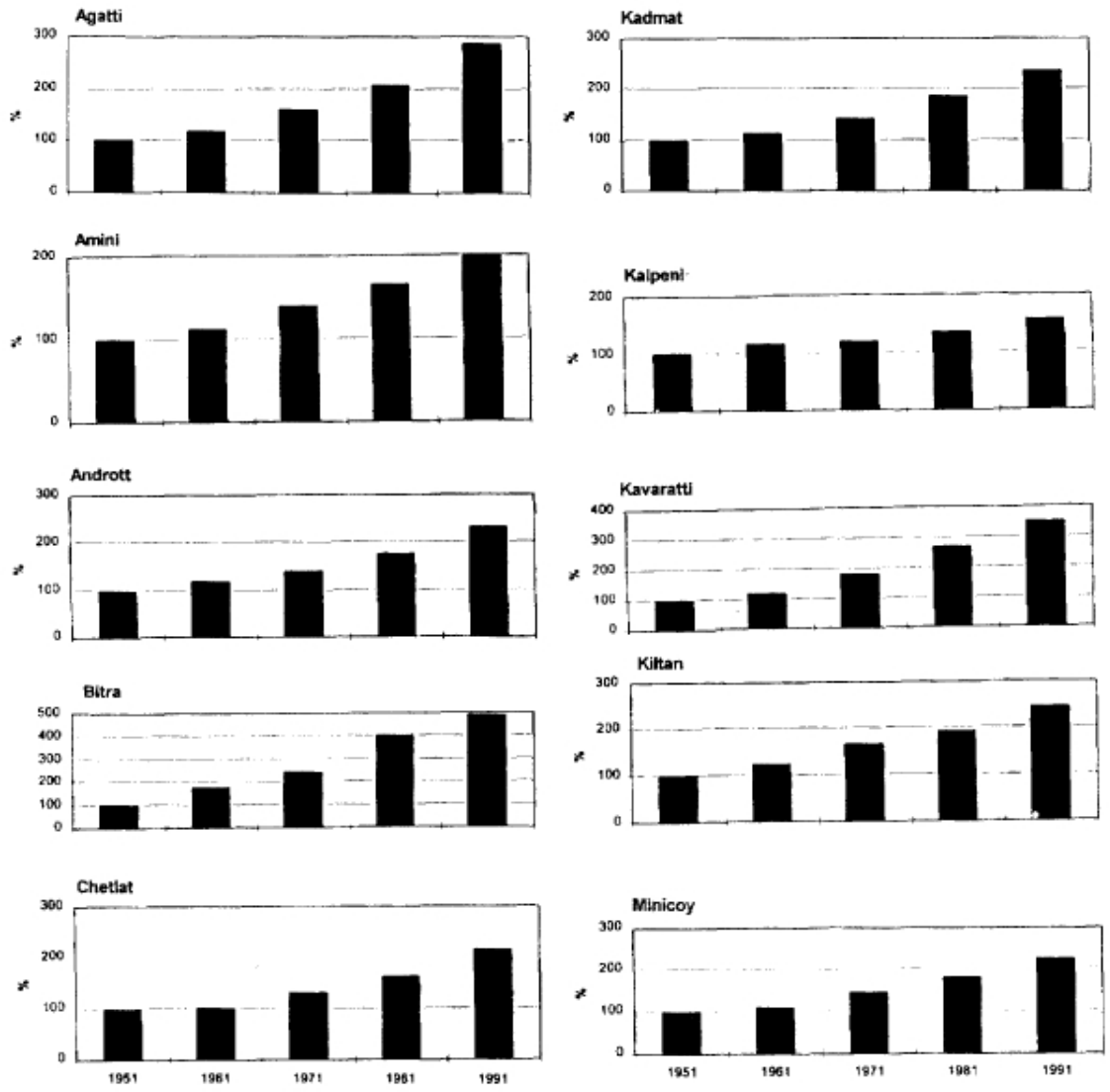
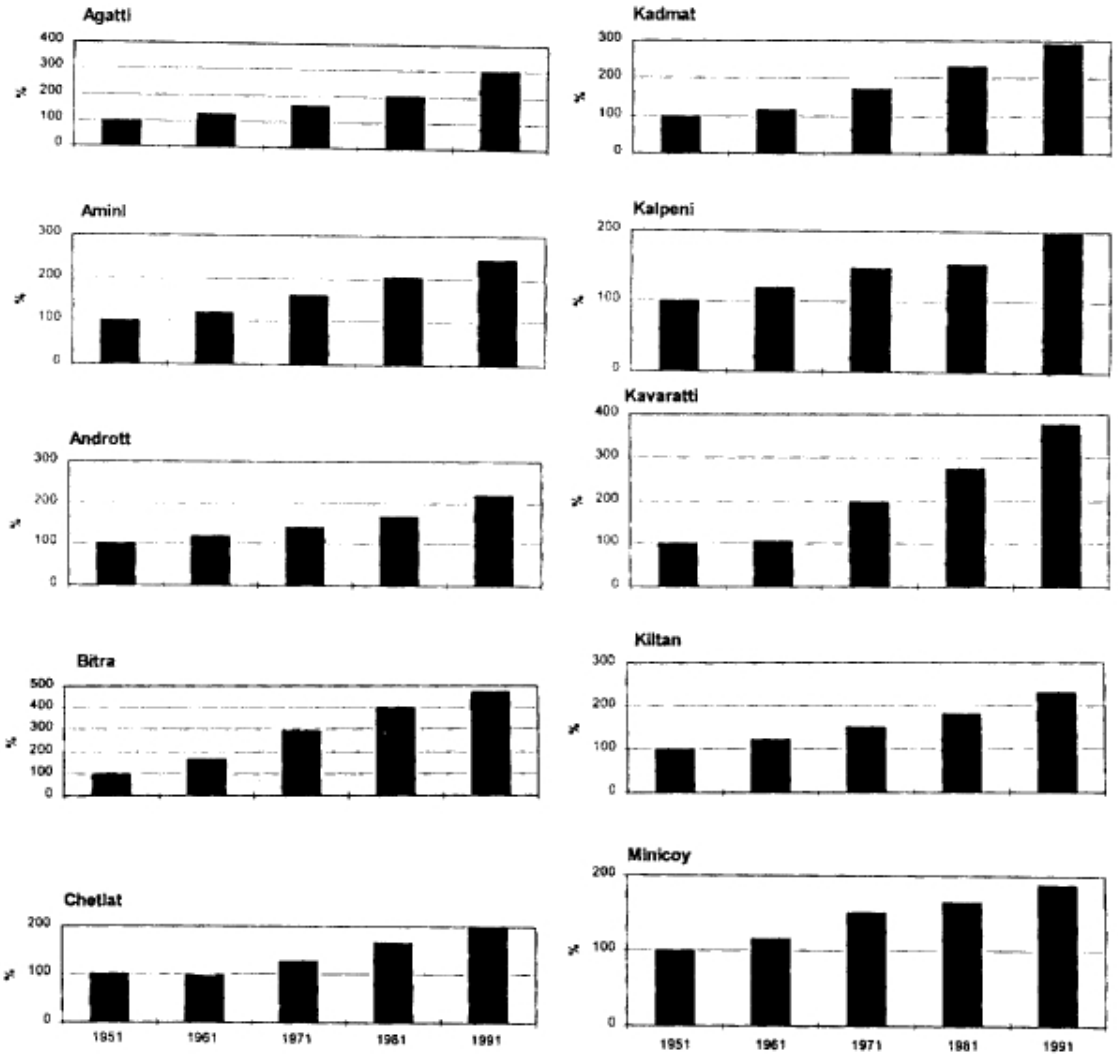


Fig. 3. Percentage increase in density of houses in Lakshadweep islands.



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Human impact

There has been more than a 200% rise in population density as well as density of houses (Figs 2, 3). The population density of Lakshadweep (1615/ km^2) ranks third in the country, next to Delhi (6352/ km') and Chandigarh (5632/ km'). Increase in population size will result in escalating human activities and increasing defaecation on the shores leading to the accumulation of pathogens and resulting in health hazards. Unidentified worms were observed wriggling in some wells (Rodrigues, 1996). Increased population will exert pressure on the limited land available for housing. Subsidies for transportation of construction materials could be provided. Power requirements from diesel generators will also steeply increase. Frequent power cuts are already common. The maximum increase in population density and density of houses has been recorded in Bitra, followed by Kavaratti and Agatti. Bitra is the smallest inhabited island (0.1 km^2) with the largest lagoon (42 km'). In 1951 there were less than 50 inhabitants and the number has grown to 225 as per the latest census report. On this island, there is acute scarcity of freshwater which is rationed to its inhabitants. However, the region is rich in fish resources. Scarcity of freshwater is a chronic problem in most islands where groundwater instead of seawater is being desalinated. The minimum increase in population density is observed at Kalpeni, the island which boasts of intellectuals and where literacy is considered high.

There has also been a dramatic increase in passenger and cargo traffic (Figs 4, 5). The 1985-'86 and 1986-'87 data on passenger traffic appear to he incomplete. Data presented exclude passengers and cargo transported by sailing vessels *(odums).* The data illustrate the increased mobility of islanders and increasing cargo demands. Up to 1987-88, passenger traffic was handled by *mv. Amindivi, mv. Bharal, Seema and m.v Dwoep Sethu,* besides sailing vessels. From 1988-89 onwards, a 658 capacity passenger vessel, m.v Tipu Sultan was introduced. These vessels cannot enter the shallow lagoons and hence passengers have to be transported to the jetty and *vice-ierva* by small mechanized boats. From January 1992 onwards, two high speed catamarans, *ni.v. Khadeeja Bivi and m.v Hameedath Bivi* were commissioned for inter-island service. Unlike other passenger vessels, these catamarans can enter into the lagoon and berth at Kavaratti jetty, eliminating the boat jouney that had to be undertaken to board vessels. This was made possible by deepening the navigational channel in the Kavaratti lagoon. These vessels do not appear to be suited for the islands as they operate only during the fair season and their itineraries are unpredictable due to frequent breakdowns. It is not known whether any study on corals was carried out before and after deepening the channel. It will not be surprising if the area is found to be devoid of live corals.

It epitomizes the degradation of corals due to technological advances in mode of transportation.

Except for Minicoy, Androtl and Kadmat, the total fish landings at other islands have more than doubted during the last few years (Fig. 6). It indicates the increasing number of fishing boats operating from these islands and the proportional amount of live bait resources collected from reefs/lagoons These data do not reflect the fishery resources of the respective islands as

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fishermen fish in the vicinity of other islands, such as Bitra, Pitti, Suheli, Cheriyakara and Suheli Valiyakara, which harbour rich fishery resources.

Fig. 4. Percentage increase in passenger traffic in lakshadweep islands.

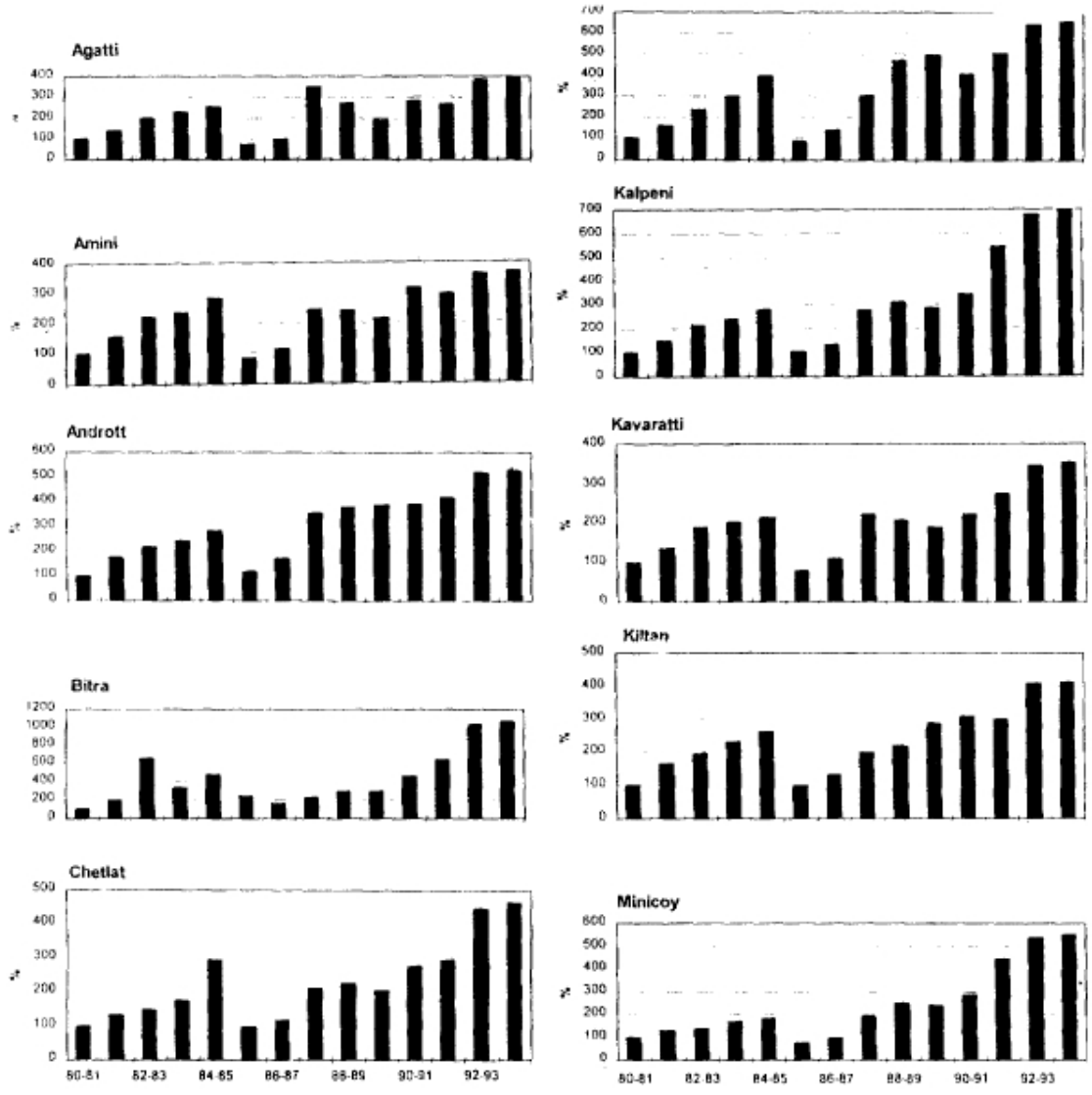

Fig. 5. Percentage increase in cargo traffic in Lakshadweep islands.

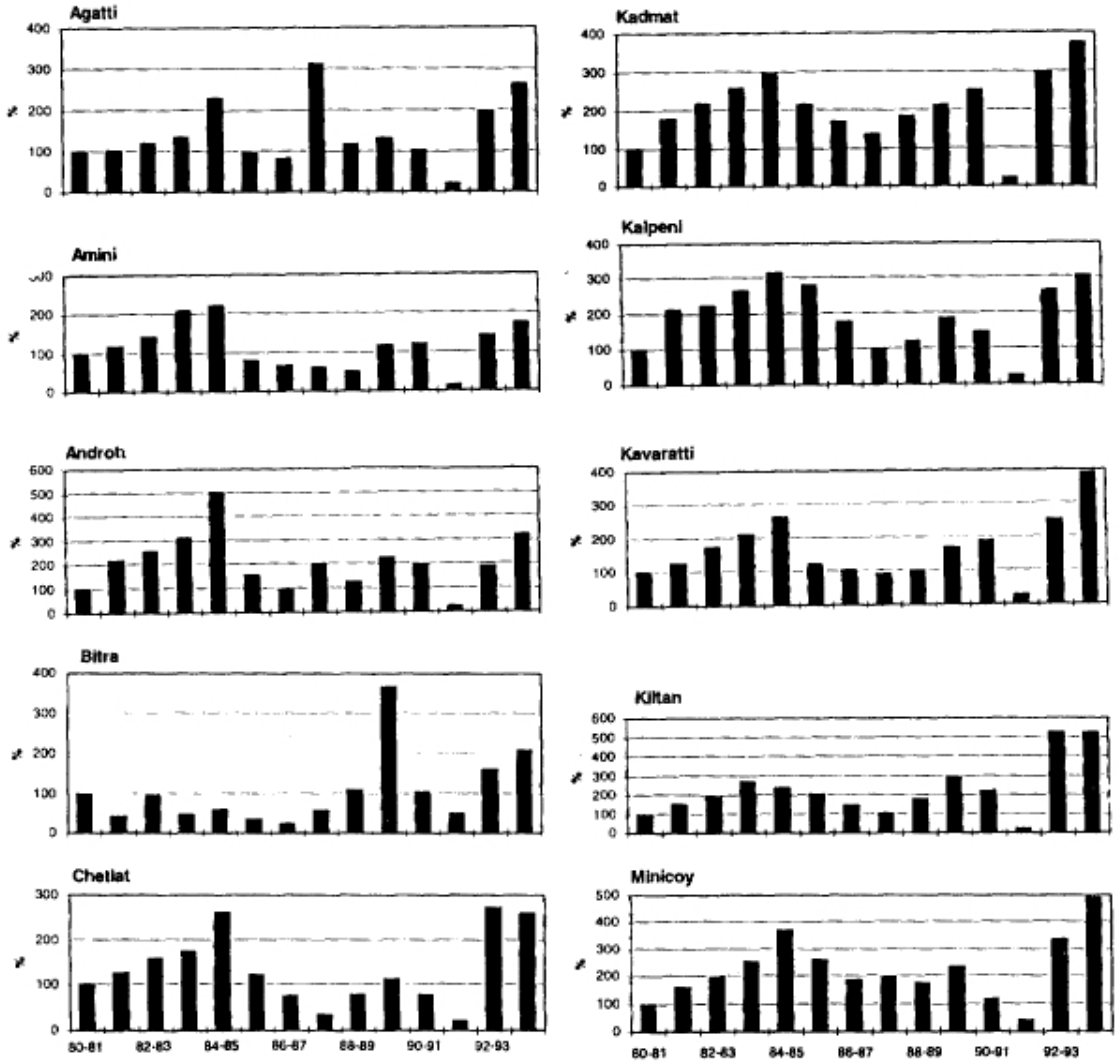

Fig. 6. Percentage increase in fish landings in Lakshadweep islands.

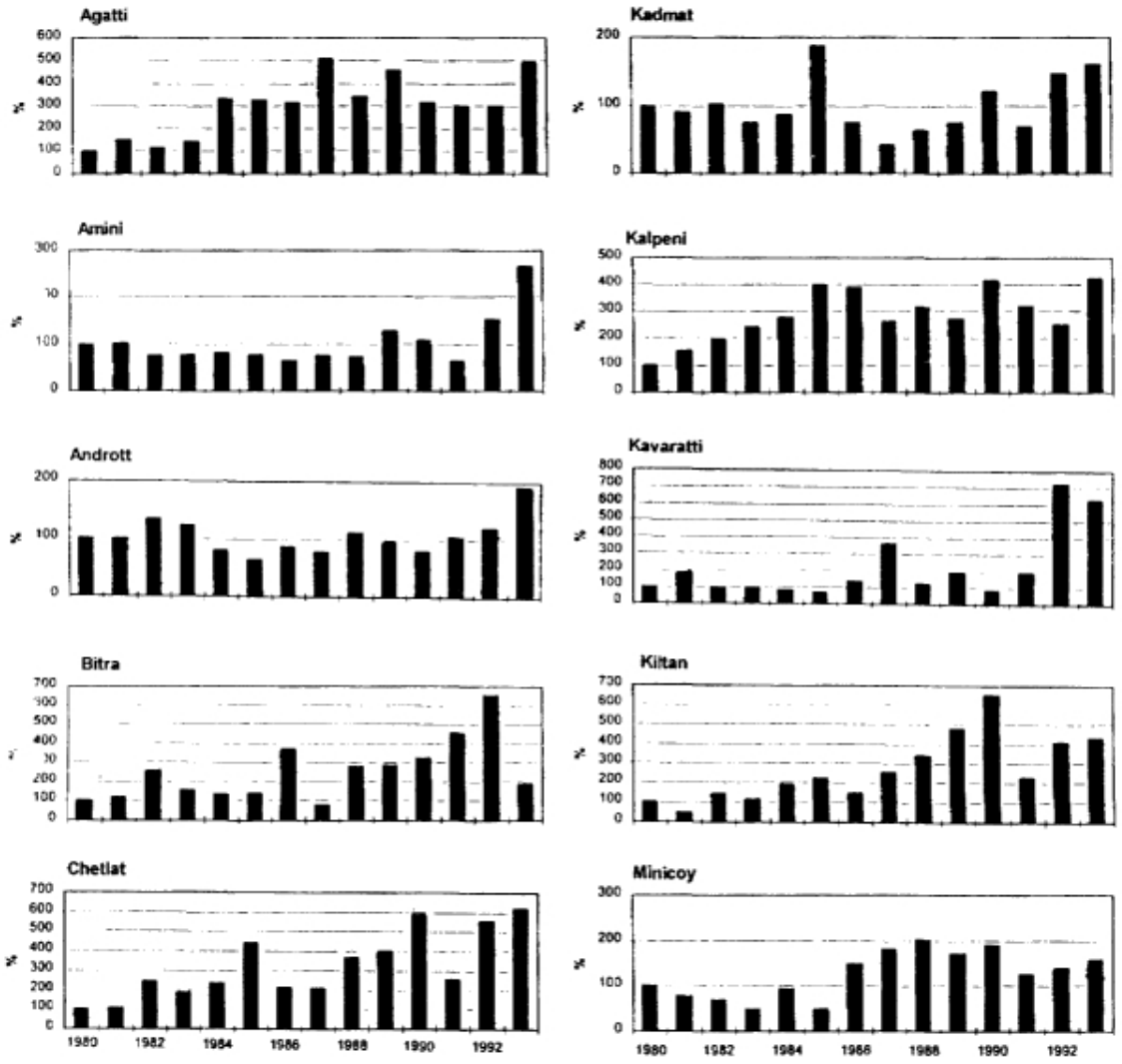

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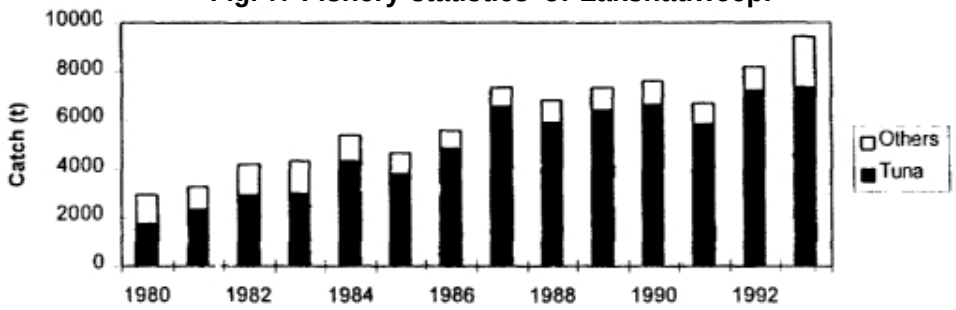
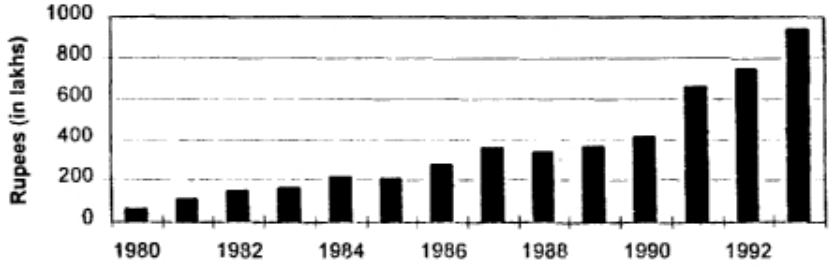
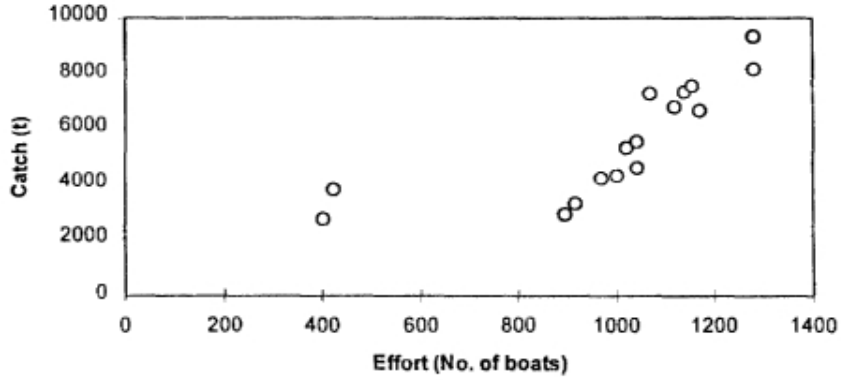
Fig. 7. Fishery statistics of Lakshadweep.



Value of total fish catch



Relationship between fishing catch and effort



Catch/effort vs effort

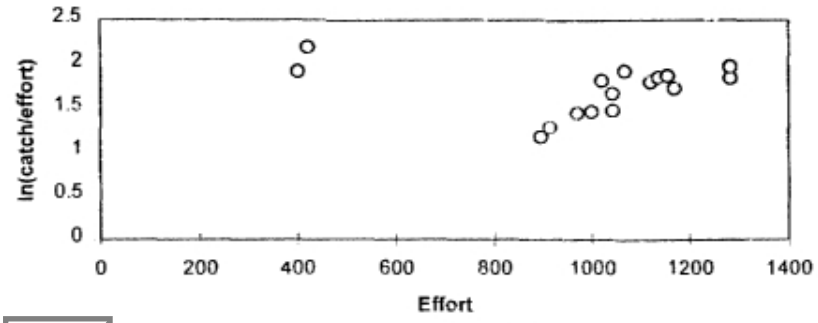


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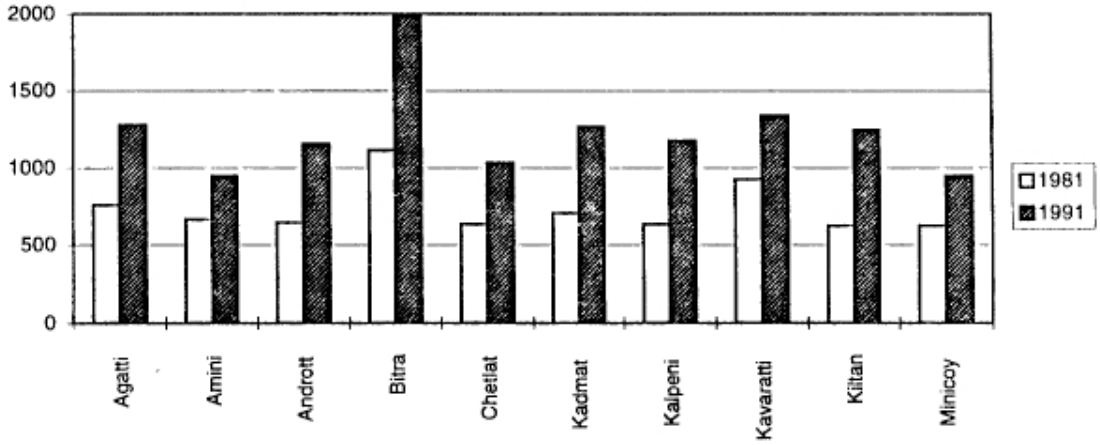
Fig. 8. Total human impact on Lakshadweep coral reefs



It is necessary to analyze further the fishery statistics of these islands. Coral reefs are considered the most productive among marine ecosystems, annually yielding about 9% ot'the world fisheries (Smith, 1978). As per the latest figures, the annual fisheries yield of Lakshadweep is around 9000 t, of which tunas constitute 7000 t. Though the total fish catch has only tripled since 1980, its value has increased sixteen fold (Fig. 7). In the absence ol' refrigeration facilities, most of the tuna catch is parboiled, smoked and dried to produce *mas.* The relationship between fishing catch and effort as well as between catch per unit effort and effort (Fig. 7) suggest that there is no overfishing. Data of fish catch and fishing efforts by boats operating from the mainland have not been taken into consideration. Data on fishing effort have not been standardized but are realistic, as fishing boats in Lakshadweep are more or less of the same size. The potential fish yield is estimated to be 90,000 t (Jones & Banerji, 1973) while the potehtial tuna yield is 50,000 t (George *elal.,* 1977). The pole and line fishing method for catching tuna requires live bait collected from coral colonies, resulting in reef damage. The total live bait catch is around 125 t (Pillal el al., 1995). Thus, an increase in fishing activities will increase requirements of live bait, which will in turn adversely affect the reefs. Modern methods, such as purse seining, gill netting and longlining, need to be adopted to increase the tuna yield. There is also scope for increasing the catch of sharks, bill and sail fishes and diversifying fish products. Floating ship factories with bases at mainland ports need to be introduced by a Lakshadweep Fisheries Co-operative to divert the impact of fishing boats away from Lakshadweep islands (Rodrigues, 1996).

The total impact on reefs can be visualized by sumniing up the percentage increases. In this simple model, population density and density of houses have been assigned a relatively higher weightage. The analysis suggests that Bitra, Kavaratti, Agatti, Kadmat and Kiltan are among the worst affected (Fig. 8). The 500 point level could be considered as the carrying capacity of the reefs that was attained in the eighties. The data could be re-analysed when live coral cover data becomes available.

Future scenario

What can be done to save the reefs? fluman developmental activities have been responsible for the degradation of Lakshadweep coral reefs and there is an urgent need to stop the degradation and reverse the trend. Several suggestions and recommendations have been made (James & Pillai, 1989; Pillai, 1996; Rodrigues, 1996). Due to increased revenue from fish catch. improved medical care and other facilities, the life styles of islanders have improved over the years. Technology has been used to raise the standards of living and it must now be utilized to save the reefs. A study on the attitudes and perceptions of islanders towards reefs needs to he undertaken. If the coral reefs were to be destroyed. the fishery, which is the main source of income for islanders, will collapse. We thus need the reefs and tile reefs need our protection. Let us learn from the symbiotic relationship of coral polyps with zooxathellae which holds the secret of the high productivity of coral reef ecosystems.

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Coral Mortality in Reefs: The Cause and Effect; A Central Concern for Reef Monitoring

Chandralata Raghukumar1

During the International Year of the Reefs (IYOR), a major event called Reef Check 1997 was launched. The purpose of this was to survey the health of corals in the Caribbean. During the survey, living corals were counted along transects besides the dead and dying corals, bleached and diseased corals In the past two decades, a variety of symptoms which plague corals are being reported from the world over. Destruction of corals can be caused by abiotic and/or biotic agents or a combination of both. Bioerosion, sedimentation and pollution are some of the major abiotic causes. The biotic causes are unbalanced predation, competitors for substratum and diseases. The major visible effects of these causative agents are partial mortality in massive corals, bleaching, black-band and white-band disease.

Partial mortality

Whenever a coral surface is damaged, the tissue surrounding this lesion regenerates and grows inwards to recover the wounds. However, when this does not occur, the result is partial mortality which appears as a bare patch of skeleton on the surface of the coral. This regeneration capacity varies in different species of corals and is used as an indicator of physiological condition of coral. It has therefore, been recommended as a tool for assessing health of corals in a reef. Our field observations have shown the presence of multiple open lesions littering the living tissue of coral colonies. These patches were observed to be colonised later by algae and other boring animals which ultimately weaken the coral skeleton. Many coral reefs lose more living tissue cover through such chronic partial mortality than total death due to calamities like hurricanes or storms (Meesters *et al.* 1996; 1997). Permanent lesions on corals indicate low regeneration capacity of corals in a population and this might be indicative of stress on this population.

Bleaching

The phenomenon of bleaching is of widespread global occurrence. Bleaching of corals is either due to loss of zooxanthellae or reduction in chlorophyll per zooxanthellae. As a result, the coral tissue loses its colour exposing white skeletal calcium carbonate. Three different mechanisms which could account for the reduction in zooxanthellae have been proposed (Brown *et al.* 1995). These are i) the zooxanthellae may be degraded in *situ.* Distorted zooxanthellae have been detected in partially and full bleached material, ii) release of zooxanthellae from endoderin into coelenteron of the polyps and iii) release of intact endodermal cells with their intracellular zooxanthellae out of polyp's tissue. Elevated temperature plays a critical role in bleaching. Bleaching in turn affects coral growth, reproduction and regeneration. The response of different coral species towards bleaching differs. It

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affects colony density and coverage. How the elevated temperature affect the zooxanthellae is the basic question which still remains unanswered.

Black-band disease

Excessive nutrients such as nitrates and phosphates supplied by sewage waters from land act as fertilisers for seagrasses and mangroves, but they are fatal to corals which are adapted to nutrient poor or oligotrophic waters. Algae, cyanobacteria, fungi and bacteria thrive in such waters. Algae grow as tufts on coral scars. The algal patch develops into a black ring around a bare white skeletal patch and hence the name black-band disease (BBD). As the algal band advances it kills more coral tissue. The growth of algal band varies in different species of corals. The older, dead part gets overgrown with various epilithic algae which trap very fine sediment. Small corals can get killed this way in a very short time of few weeks. On larger colonies, the infection may disappear completely or remain restricted.

One such cyanobacterial infection called BBD caused by *Phonnidium corallyticum* has been reported to occur throughout the Caribbean. How the infection begins and where the pathogen comes from are not known. Healthy corals directly in contact with infected colonies show infection. When the two are kept apart at a distance of < 2mm in aquarium tanks, the healthy ones do not show symptoms of infection even after many days (Rutzler *et al.* 1983). Cyanobacterial trichomes were not found in the Plankton tows. The results from all over the world show that this pathogen play an important role in regulation of population. The killed colonies also create primary space for further recruitment. BBD is shown to be directly dependent on higher temperatures (Antonius, 1981). Injured corals become infected with *P. corailyticum* more easily. Less than 2 % of Caribbean corals are reported to be infected with BBD (see Edmunds, 1991). Scleractinian and Octocorals are quite susceptible to the disease.

We have observed a dark brown fungus, *Scolecobasidium* sp associated with massive corals showing necrotic patches in the Andamans (Raghukumar and Raghukumar, 198 1) and latter also in the Lakshadweep islands.

White-band disease

No pathogen associated with this disease is reported yet. The disease is so termed because of denuded exposed white skeleton of calcium carbonate. It appears as a simple interface in a coral colony. It is mostly reported in *Acropora palmata, Diploria* sp and *Montastrea* sp. It is believed that white-band disease (WBD) can serve as a starting point for BBD which can kill a substantial part of coral. It appears that WBD might be manifested in response to some stress causing factors.

Causes

The primary causal agents of the above discussed maladies are described below. They are sedimentation, eutrophication and pollution. All these factors individually and! or in combination cause stress to corals.

Sedimentation

Deforestation, construction and coastal development, dredging and other developmental activities can increase the sediment load in coastal waters and cause damage to coral reef ecosystem. A detailed study carded out in the Great Barrier reef has shown that the effect of sedimentation varies with morphologically different species of corals, sedimentation rates, turbidity, quantity, size and composition of sediment, its nutrient and bacterial loads (Stafford-Smith, 1992). Chronic sedimentation can cause total or partial mortality or bleaching depending on the response of corals.

We have observed excessive deposit of sediment on coral colonies in the Gulf of Kutch and these corals exhibit partial or total mortality. Similar sediment deposition and the resulting mortality of massive corals is noticed on massive corals in the lagoon of Kavaratti (Lakshadweep) and in the Vandoor Marine National park, Port Blair (Andamans).

Eutrophication

Corals are always found in oligotrophic waters. The coral reef ecosystem is an excellent example of well managed nutrient budget. The organic carbon fixed by the photosynthetic symbionts, the zooxanthellae is supplied to coral polyps and the essential amino acids released by polyps are utilised by the zooxanthellae. The land run-off adds extra nutrients to this ecosystem. Excessive nutrients encourages growth of sea grasses and algae which in turn release a lot of dissolved nutrients in the form of leachates and these are killers of corals.

Recommendations

Under the coral reef monitoring programme, the primary health of corals should be a main concern. During the coral reef monitoring programme, a few selected sites need to be monitored over a period of time for their response towards regeneration of lesions. Regeneration is important for survival of corals. It affects growth, reproduction, disease resistance and competitive ability (see Oren *etal.* 1997.).

The above mentioned effects of various causal organisms or events are destructive and long-lasting. Excessive nutrients and sedimentation and various diseases can destroy entire coral reef Coral reef monitoring program should identify reefs in various localities and monitor them routinely for various diseases. This will help us in understanding the causes of diseases and thus evolve strategies to eliminate them.

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Remote Sensing and GIS for Coral Reefs Mapping

R. Krishnamoorthy[1], S. Ramachandran[2] & S. Sundaramoorthy[2]

Abstract

The launch of Earth Resources Technology Satellite -1 (ERTS-1) in 1972 proved to be of great importance as it gave a new tool of remote sensing to the scientific community. The subsequent launch of the Landsat series of satellites, the French satellite Systeme Probatorie d'Observation de la Terre (SPOT) and the Indian Remote Sensing (IRS) satellites with high spatial resolution increased the potentiality of this new *toot for coral reef mapping.* **Case** *studies in Gulf of Mannar and Andaman & Nicobar Islands have proved the mapping of reef categories such as fringing reef, patch reef, platform reef with or without central lagoon which are clearly discernible in SPOT and IRS satellite imagery. Also the tidal action and water circulation patterns in reef areas between 2 and 10 km coastal belt of Andaman & Nicobar Islands were mapped using remote sensing data. Case studies in Gulf of Mannar using GIS* too! *have brought out the changes in coastal configuration due to erosion and accretion and its impact on the adjacent coral reef ecosystem.*

Optical Remote Sensing Data

Studies were carried out for mapping the coral reefs in Andaman & Nicobar and Gulf of Mannar islands using optical remote sensing data especially SPOT, Landsat TM and IRS LISS-II. Due to high spatial resolution, all the above sensor data are found to be useful for coral reefs mapping and monitoring. More details on reef categories like fringing reef, platform reef, patch reef and coral pinnacles could be mapped more accurately using SPOT and IRS data by visual analysis. The fringing reefs are adjacent to the coast and are the predominant type bordering the western coast of Andaman & Nicobar islands. Reefs occur in shallow depth (within one to two meters depth) will appear in blue tone and the deep reefs in turquoise blue tone. Tonal variation is the important key element to classify and map shallow and deep reefs using satellite imagery. Validation of coral reef maps by ground truthing has proved that reefs occur up to 13 meters depth in less turbid coastal waters could be demarcated from satellite imagery by visual interpretation. Based on visual interpretation of SPOT and IRS

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imagery and incorporation of SOI toposheet details, fifty two coral reefs maps on 1:50,000 scale for Andaman & Nicobar and seven maps for Gulf of Mannar were jointly prepared and validated by the Institute for Ocean Management, Anna University and the Space Applications Centre (ISRO).

Digital analysis using VIPS32 functions in VAX 11/780 image analysis system has brought out the utility of visible bands of Landsat TM for mapping coral reefs and other near shore parameters like suspended particulate matters and ocean colour variations due to chlorophyll concentration, etc. Selected image analysis functions like factorial analysis, band ratioing, local optimisation, convolution filtering and correspondence analysis were attempted using TM digital data of Gulf of Mannar coral reef areas. Comparison and validation of digital analysis output has confirmed that factorial analysis of TM band 2 digital data could be used for demarcating reef areas more accurately and the filtering and band ratioing techniques are useful in mapping suspended particulate matters in coastal waters and ocean colour variations rather than mapping reef areas.

GIS based CZIS Analysis for Gulf of Mannar Biosphere

Since GIS is a powerful tool to assemble, analyse, store, utilise, retrieve, manipulate and disseminate scientific/technical data and thus aid in decision making, a GIS based Coastal Zone Information System (CZIS) for Rameswaram has been developed using PAMAP-GIS approach at the Institute for Ocean Management funded by Dept. of Ocean Development. An interim report of this study was distributed to various user departments to receive their feedback. Two user utilisation workshops have been conducted by the Institute for Ocean Management to illustrate the results obtained from this study (Ramachandran et. al., 1994). The CZIS developed using GIS for Rameswaram contains thirteen theme maps derived from remote sensing data, SOt toposheets and conventional surveys. The overlay analysis of 1968 SOI toposheet and 1990 satellite data (taking care of tidal boundaries) clearly shows the erosion and accretion sites along Rameswaram island and also the changes in areal extent of other small islands in Gulf of Mannar. Subsequent ground truth work in Gulf of Mannar has confirmed that the shoreline erosion in Rameswaram leads to deposition of sediments over reef areas around Shingle, Kurusadi, Kovi and Pumurichan islands. This is an important biophysical factor to be considered for the conservation of reefs in Gulf of Mannar. Prevention of shoreline erosion in near by Pamban bridge and boat jetty areas in Rameswaram island will reduce further degradation reefs due to sediment deposition in the adjacent islands.

Conclusion

Optical Remote Sensing data and GIS are useful tools for mapping coral reefs and analyse the impact of certain biophysical factors like shoreline erosion/accretion responsible for degradation of reefs. GIS based CZIS method could be suggested for the preparation of management plans for coral reefs.

Acknowledgements

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Law and Policy for Conservation and management of Coral Reef areas in India

Devaki Panini,1

The law and policy for coral reefs in India is virtually non existent. There are a few laws in the Country that can be activated for the protection of coral reef areas such as the Environment (Protection) Act, 1986 and the Coastal Regulation Zone Notification of 1991 issued under the broad EPA as well as the Wildlife (Protection) Act, (WPA) 1972 since all coral reef areas in India are protected areas declared under the Wildlife (Protection) Act 1972. The other laws that would have a bearing on coral reef areas are the Indian Forest Act, 1927, the Forest Conservation Act, 1980 and the Indian Fisheries Act which is of vintage origin. Various state fisheries acts would be relevant for conservation and management of coral reef areas. It must, however be noted that even under the WPA, coral reef areas have, no separate legal status and short comings of the WPA in affording protection to coral reef *areas* is discussed subsequently. The Marine national parks which have coral reefs come under the charge of the Ministry of Environment and Forests, However, the national laws that are applicable to coral reef areas involve various departments of the government agencies (state forest departments, fisheries departments and most recently the state coastal management authority at the state level). The laws are inadequate as they are not area specific and do not distinguish *coral* reef areas from other islands, coastal and marine areas.

The only law that explicitly outlaw, coral mining is the CRZ. notification of 1991. The CRZ-notification of 1991 issued under the Environment (Protection) Act 1986 places restrictions on industries, operations and processes in the CPZ areas (which extend upto 500 m from the High Tide line and the land lying between the Low Tide Line and the High Tide Line). Some of the, prohibited activities in the CRZ are listed below

- setting up of new industries and expansion of industries in the CRZ areas.
- manufacture and handling or storage or disposal of hazardous substances.
- setting up or expansion of fish processing units including warehousing (excluding hatchery and natural fish drying)
- land reclamation, bunding or disturbing the natural course with similar obstructions except those required for control of coastal erosion
- mining of lands, rocks and other sub-strata materials.
- Harvesting or drawal of ground water and construction of mechanisms, within 200 Mts. of HTL in the 200 mts;-500 mts it shall only be permitted when done manually through ordinary wells for drinking, horticulture, agriculture and fisheries,

[1] Wetlands division, WWF-India

- construction activities in ecologically sensitive areas as specified in Annexure 1 of the notification,
- any construction activity between the LTL and HTL except facilities for carrying treated effluents and waste water discharges into the sea, facilities for carrying sea water for cooling purposes, *oil* gas and similar pipelines under this Notification,

CRZ- I

Areas that are ecologically sensitive and important such as national parks, Sanctuaries, reserve forests, wildlife habitats. mangroves. corals coral reef areas; areas close to breeding and spawning grounds of fish and other marine life, areas of outstanding beauty! areas rich in genetic diversity, areas likely to be inundated due to rising Sea level consequent upon global warming and such other areas, as may be declared by the Central and State Government at the State or Union territory level from time to time.

ii) Area between low Tide Line and the High Tide Line,

Category II (CRZ -II)

Areas that are already developed upto or close to the shoreline.

category III (CRZ-III)

Areas that are relatively undisturbed and are those that do not belong to either category I or It, These include coastal zones in the rural areas (developed and under developed) and also areas within municipal limits or in other legally designated urban areas which are not substantially built up.

Category **IV (CRZ.IV)**

Coastal stretches in the Andaman and Nicobar, Lakshadweep and small islands except those designated as CRZ I, CRZ II, CRZ III

The relevant norms for regulation of activities are as follows:

For CRZ-I: No new Construction shall be permitted within 500 meters of the High tide Line. No construction activity except as listed under 2 (ix) will be permitted between the Low, Tide Line and the High Tide Line.

For CRZ-III: The area upto 200 meters from the High Tide Line is to be earmarked as - No development zone". No construction shall be permitted - within this zone except for repairs, agriculture, horticulture, gardens, pastures, parks, play fields, forestry and salt manufacture from sea water.

For CRZ-IV (Andaman and Nicobar Islands)

I) No new construction of buildings shall be permitted within 200 Mts of the HTL.

IV) Corals and sand from the beaches and coastal waters - shall not be used for construction and other purposes.

'V) Dredging and under water blasting in and around coral formations shall not be permitted.

VI) Further, in some islands, coastal stretches may also be classified into categories CRZ I or II or III with the prior approval of the Ministry of Environment and Forests and in designated stretches, the appropriate regulations given for respective categories will apply,

Lakshwadweep and small islands:

i) For permitting construction of buildings, the distance from High Tide Line shall be decided depending on the size of the islands. This shall be laid down for each of the islands, in consultation with experts from the MoEF keeping in view the land use requirements for specific purposes vis-à-vis local conditions including hydrological aspects, erosion and ecological sensitivity.

iv) corals and sand from beaches and coastal waters shall not be used for construction and other purposes;

v) dredging and under water blasting in and around coral formations shall not be permitted and

vi) in some islands coastal stretches may be classified into categories CRZ 1 or II or II or with the prior approval of the MoEF and in such designated stretches the appropriate regulations given for respective categories will apply.

Thus the CRZ notification has recognised the significance of corals and coral reef areas and includes *these as* CRZ I i.e. areas that are ecologically sensitive and important. However, apart from banning new construction within 500 meters of the High tide Line and specifying that no construction activity except as listed under 2 (xii) the 'notification does not specify that even pearl culture or coral digging for limestone shall be prohibited in these coral areas. Thus the notification is not area specific and function! use specific. It depends on the Coastal Zone Management Authority to ensure the enforcement of Notification and not allow coral digging in the CRZ 1 areas as identified in the Coastal Zone Management Plans (CZMPs). However even the requirement of CZMPs by the state governments and union territories was not achieved until the Supreme Court of India acting on a petition filed by the Indian Council for Enviro-Legal Action verses Union of India (JT 1996(4) S.C 263-285) issued notices to the respondent coastal states, of Andhra Pradesh, Gujarat, Kamataka and Kerala had not (even after the issuing of the notice by the Court) submitted their plans and were asked by the Court to show cause as to why appropriate action against non-compliance should not be taken against them.

However since in our country, the four major coral reef areas are declared as protected areas, the provisions of the Wildlife (Protection) Act, 1972 (last amended in 1991) (hereafter referred to as the WPA) would apply. Ironically while the definition of "wildlife" in the WPA includes any animal, bees, butterflies, crustacea, fish and moths and aquatic or land vegetation which forms part of any habitat, corals do not figure in any of the schedules to the Act. The definition of "wild animal" given in section 2, clause (36) says "wild animal" means any animal found wild in nature and includes any animal specified in Schedule I, II,III,IV, wherever found'. Thus corals would be included in the definition of "wild animal" since this definition is inclusive and not exclusive. Further section 39 of the Act states that Wild Animals, etc. are Government property

Section 39

1) Every

a) wild animal, other than vermin which is hunted under Section 11 or sub sec 35 or kept or bred in captivity or hunted in contravention of any provision of this Act or any rule or order made there under, or found dead, or killed by mistake

b) *animal article, trophy or uncured or meat derived from any wild animal referred to in Cl (a) in respect of which any offence against this Act or any rule or made thereunder has been committed,,*

c) *ivory imported into India and an article made from such ivory in respect of which any offence against this,Act or any rule or order made thereunder has been committed*

d) *vehicle, vessel,* weapon, trap *or tool used for committing an offence under the provision of the Act.*

shall be the property of the State Government and, where such animal is hunted in a Sanctuary or National park declared by the Central Government such animal, trophy, uncured trophy, or meat derived *from such animal or any vehicle, vessel, weapon,* trap *or too! that has been used in such hunting, shall be the property of Central Government.*

Further section 39 clause (3) reads

"No person shall, without the previous permission in writing of the Chief Wildlife Warden or the authorised officer

a) acquire or keep in his possession, custody, or control or

b) transfer to any person, whether by way of gift, sale or other wise or

c) destroy or damage such Government property".

Section 29 of the Wildlife (Protection) Act essentially concerns Destruction, etc. in a sanctuary prohibited without a permit.

It states that - *No person shall destroy, exploit or remove any wildlife from a sanctuary or destroy or damage the habitat of any wild animal or deprive any wild animal of its habitat within*

such sanctuary except under and in accordance with permit granted by the Chief Wildlife Warden and no such permit shall be granted unless the State Government is satisfied that such destruction, exploitation or removal of wildlife from the sanctuary is necessary for the improvement and better management of wildlife therein, authorises the issue of such Permit".

Similarly section 35 clause (6) states that No person shall destroy, exploit or remove any wildlife from a National Park except under and in accordance with a permit granted by the Chief Wildlife Warden and no such permit shall be granted unless the State Government, being satisfied that such destruction exploitation or removal of wildlife from the National Park is necessary for the improvement and better management of wildlife therein, authorises the issue of such permit.

Thus in a protected area i.e. a National park or a Sanctuary the illicit removal of coral would be illegal vide section 29 and section 36 clause (6) since corals in the Park! Sanctuary would be the property of the Government.

However as corals are not included in the Schedules to the said act, Chapter V-A which essentially addresses Prohibition of trade or commerce in trophies, animal articles, etc. derived from certain animals cannot be made applicable to corals. Therefore section 49-B that deals with prohibition of dealing in trophies, animal articles, etc. derived from Scheduled animals cannot be made applicable to corals. It must be mentioned here that the Wildlife (Protection) Act does not speak of trade in 'wild animals" i.e. an animal found wild in nature and thus extraction of corals for lime stone kilns or curios cannot be prevented outside the sanctuary or National park limits. This would inevitably cause problems for the management of coral reef area, (even within Sanctuaries or National Parks), It is significant that the Ranjit Singh committee instituted by the Ministry of Environment and forests has in the draft amendment to the Wildlife Protection Act included several species of coral in Schedule IV of the Act, There is an urgent need to revise the Wildlife (Protection) Act and include coral in the schedules and make the provisions of the WPA, 1972 more region specific (since the same provisions apply to marine national parks where there is substantial presence of coral).

As discussed earlier the WPA, 1972 only applies to protected areas and in most of the marine national parks in the Andaman and the Gulf of Mannar, the final notification of the sanctuary or the national park has not been achieved. In a recent case filed by WWF India (CEL, WWF-India versus 'Union of India and Ors W.P (c) No 337/95) the Supreme Court took cognisance of the fact that further steps (after declaration of a sanctuary, or National Park under S18 and 35 respectively) envisaged by the Act i.e. Under section 21 and other procedure contemplated by the Act, have not been taken. The Court ordered that the further steps under section 21 be taken with respect to sanctuaries and National Parks by the concerned state governments Union Territories within two months and complete the process of determination of rights as contemplated by the Act, within a period of one year. Thus in Marine National parks as well, the final notification and the determination acquisition of rights as laid down in the WPA, has to he done within the time limit set by the Apex Court.

Interestingly while the CRZ notification is applicable to coastal areas (500 m, from the high Tide Line and the land lying between the Low Tide Line and the High Tide Line and corals, coral reef areas would be included in CRZ 1, it is telling that the restrictions imposed in CRZ I (ecologically sensitive and important areas) and CRZ IV (Andaman and Nicobar and other islands) apply only to the land ward side. However the sea ward side of those areas (CRZ 1 or IV) do not enjoy any protection under this notification or any other national law. The boundaries of the Marine National Parks may not be accurately or appropriately defined, therefore there is a need to give these coral reef areas a special legal status, in order to regulate activity and prevent harmful activity, and marine pollution in the surrounding areas. One option would be to declare these areas as ecologically sensitive under the environment (Protection) Act, 1986, This would enable the agencies responsible for management of these coral reef areas to extend protection beyond the protected area limits and towards the seaward side and also be able to restrict ecologically harmful activity like mechanised trawling in areas close to corals and coral reefs. Certain types of activity could then be outrightly banned in these ecologically sensitive areas. This, would be the only way to restrict environmentally harmful activity in the these areas. India is also a party to several international Conventions, like the UNCLOS, the Ramser Convention, the CITES and the CBD. Under Section 56 of the United Nations Convention on the, Law of the Sea (UNCLOS) which formally came, into force in July 1995, coastal states may exercise sovereign rights to living resources within 200 nautical miles of their ,shores. Thus there is an overall responsibility on Coastal states to ensure that living *marine resources* within their EEG's, are not over exploited and foreign fleets operating in the EEG (with the due permission of the coastal state) must abide by conservation measures as well as respect the national laws and *policies of* the concerned country. In fact Article 61(3) of the INCLOS requires coastal states to consider the effects of fishing upon associated and dependent species but does not specify the scope of this obligation (Pusch, *1996).* Our country must keep in *mind the international* obligations under UNCLOS and CITES and the CBD and therefore must bring about much needed changes in the domestic legislation like the Wildlife (Protection) Act to adequately protect corals. Further the broad Environment (Protection) Act, 1986 (EPA, 1986) could be activated to suitably designate these coral reef areas (and surrounding areas) as ecologically sensitive and regulate and restrict industries, operations and processes in these, ecologically important areas. Although the central Ministry of Environment and Forests, has a National Committee on Wetlands, Mangroves and Coral Reefs . the committee has yet to formulate a sound and coherent National policy for Coral reef areas or even wetlands. It would be extremely useful if such a policy could be formulated in order to enable sound and sustainable management of these areas.

Recommendations

The recommendations for law reform and policy making for coral reef conservation and management in the country essentially concern amending the Wildlife (Protection) Act 1972 to include species of coral, in the Schedules and specifically state that the extraction of coral is prohibited under the provisions of Chapter V-A of the WPA, Since the CRZ notification

essentially covers coastal areas extending 500 Ms from the High Tide Line and the land lying between the Low Tide Line and the High Tide line in the landward side, the areas extending beyond corals and coral reefs on the sea ward side, remain unprotected. Thus the major coral reef areas (and adjoining areas) could be declared as ecologically sensitive under the Environment (Protection)Act, 1986 and restrictions could be imposed on environmentally dangerous industries. Operations and processes in these areas. The legal status of ecologically sensitive areas would help in ensuring that activities like the plying of mechanised fishing trawlers could be banned and restricted in these areas close to the protected areas. A national level policy especially focusing on wetlands and *corals is* imperative in order to take up and guide conservation efforts by Government agencies as well as; local communities who are residing in close proximity of these ecologically sensitive areas and who are dependent on these ecosystems for their livelihood.

Trials and Tribulations of Sri Lanka's First Marine Sanctuary - The Hikkaduwa Marine Sanctuary -

M.W.Ranjith N.De Silva[1]

1. Introduction

Coral reefs are under tremendous pressure from over exploitation of resources, unplanned tourism development, pollution and other direct or indirect human related activities. They also face pressure from natural hazards such as storms, typhoons and cyclones, and at times overgrdwths or population explosions of reef related organisms.

The concept of the need to conserve South Asia's coral reefs for sustainable use goes back much further than half a century. However, The first international Corals and Coral Reef Symposium held at Mandapam Camp, India in 1972, no doubt was responsible for the initiation of a concerted effort to focus attention on valuable coral reefs and the need for their conservation not only in the region, but worldwide.

During the past two decades, there has certainly been an increase in the awareness on the need to conserve and the need for the sustainable use of coral reefs of South Asia. In addition to the First Corals and Coral Reef Symposium mentioned earlier the "Symposium on Endangered Marine Animals and Marine Parks" held in Cochin, India in 1985, was also a mile stone in this direction. At this Symposium, De Silva (1985a) stated that "Although at many of these international gatherings, the need for rational management of coral reefs have been stressed, the coral reef management and conservation programmes of many developing countries of the Indo-pacific region have yet to receive the enthusiastic support of their governments". After a lapse of over 10 years this statement still appears to be valid. This is despite the large sums of money that has been spent in the name of coral reefs - more for meetings, workshops and conferences than for actual management oriented research and ground level action.

Major obstacles to coral reef conservation and management in developing countries, like for many other programmes, could be attributed to lack of sustained political will, lack of sufficient and dedicated skilled manpower - particularly at management and implementation levels -. and limited financial resources for ground level implementation where it is most required. Now more than ever, there is a need to change focus from talking, to doing something. Waiting for ideal conditions and for everything to fall into place might not be the answer.

The Hikkaduwa Marine Sanctuary (HMS), in Sri Lanka could be taken as an example to illustrate some of the conflicts spanning conservation, management, traditional and contemporary interests which have created problems to implementing ground level action to stem the degradation of the coral reefs.

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2. The Hikkaduwa Marine Sanctuary

Hikkaduwa is a picturesque seaside fishing village located in the Galle District and lies approximately 100 kilometres south of Colombo, the capital of Sri Lanka. Its main natural assets are the golden sand beaches, high diversity coral reefs with brightly coloured fish, clear waters and the shallow reef lagoon. For the sustainable management of these natural assets ,and in particular to provide some protection to the coral reefs, the 44.5 ha (110 acre) Hikkaduwa Marine Sanctuary was created on 18 May 1979 (De Silva, 1985b). Today, Hikkaduwa is one of the more popular coastal resort areas in Sri Lanka, The area has undergone rapid development of tourist facilities from one hotel in the 1960"s to nine big hotels and 125 guest houses, 40 restaurants, 157 shops, 5 dive stations in 1994 (Nakatani et al., 1994).

The Hikkaduwa Marine Sanctuary (HMS) could be taken as an after thought as critical irreversible changes had already taken place to the area and the coral reefs before it was declared a sanctuary. The status of the once unstressed coral reefs had already changed dramatically with the introduction of mechanised fishing boats to the reef lagoon, the tourist boom, and the collection of ornamental marine fish for a lucrative export market. The beach front is now almost completely occupied by hotels, guest houses or restaurants. The reef lagoon serves as an anchorage to over 30 mechanised fishing crafts that use massive concrete structures and heavy chains to anchor. Glass bottom boats numbering over 80 compete not only for passengers, but also for anchoring space on the beach. The level of pollution had also begun to steadily increase prior to the area being declared a Marine Sanctuary.

2.1 Historical background

On 25 October 1940 the Ambalangoda/Hikkaduwa Rocky Islets were declared as Sanctuaries under the Fauna and Flora Protection Ordinance (Gazette No. 8675). The intention of these sanctuaries were to afford protection to seabirds nesting on the islands and limited to the land boundaries of the rocky islets. De Silva (1987) has stated that;

"Many people mistakenly believe that these sanctuary regulations were applicable to the marine environment and the coral reefs of Hikkaduwa as well".

The first real attempt to afford protection to the coral reefs was by the declaration in 1961 of 110 acres of territorial waters of Hikkaduwa under the Fisheries Ordinance (Gazette No. 12304 of 3rd March 1961) as an area from which no fish could be removed without a permit. This area included the fringing coral reefs and the reef lagoon where the shallow water good coral reefs were located. The main threats to the coral reefs at that time was from net fishing, spearfishing and ornamental fish collections. The fishing permits restricted fishing gears to hooks and lines, and cast nets. It also provided a list of colourful coral reef fishes that could not be taken from the area. Unfortunately, the two buoys placed in the sea to demarcate the seaward boundaries of the area were lost during the monsoon

season. In the absence of these buoys the published regulations were not legally enforceable (De Silva I 985b and 1996) although respected by the fishing community.

In 1979, the fishery protected area declared in 1961, was gazetted as the Hikkaduwa Marine Sanctuary under the Fauna and Flora Protection Ordinance (Gazette No. 37 of 18 May 1979). It is interesting that no attempt was made to replace the buoys lost earlier which defined the seaward boundary.

In 1982, the National Aquatic Resources Research and Development Authority (NARA) took the lead role in initiating government interest in coral reef based Marine Parks and Sanctuaries by appointing a Marine Parks, Sanctuaries and Refuge Committee which submitted a comprehensive report in 1982. The report provides details of areas considered suitable to be made into Marine Parks, Sanctuaries or Refuges (Fig. 1).

In 1985, the coral reef research team of NARA was formed under UNDP Project SRI/84/008. One of the first tasks undertaken by the team was to survey and report on the status of the coral reefs of Hikkaduwa and to propose a management strategy. The outcome was the proposal by De Silva and Rajasuriya (1985a) to administer the Hikkaduwa Marine Sanctuary as a multiple use Marine Park zoned for different activities (Fig. 2). It was proposed that the Marine Park be divided into the following 3 zones (Joseph, 1986):

a) General Use Zone 'A': Where activities other than the following could be allowed:

- Use of anchors and anchor chains.
- Stepping and walking on corals.
- Removal of fish, corath and other marine organisms without a permit.

It was also recommended that;

- the number of glass bottom boats operating in this zone be restricted to no more than 5 at any one time.
- Rafts and mooring buoys be placed at strategic locations to prevent damage to corals by stepping and walking, and by the anchoring of boats.

b) General Use Zone 'B': Where activities other than the following could be allowed:

- Removal of fish and other reef organisms without a permit.
- Stepping, walking and anchoring of boats on corals and coral reefs.
- Entry into the Rocky Islets Sanctuary without a permit.

It was also recommended that;

- Mooring buoys need to be provided for boats near the Rocky Islets.
- Fish feeding could be encouraged as an additional tourist attraction.

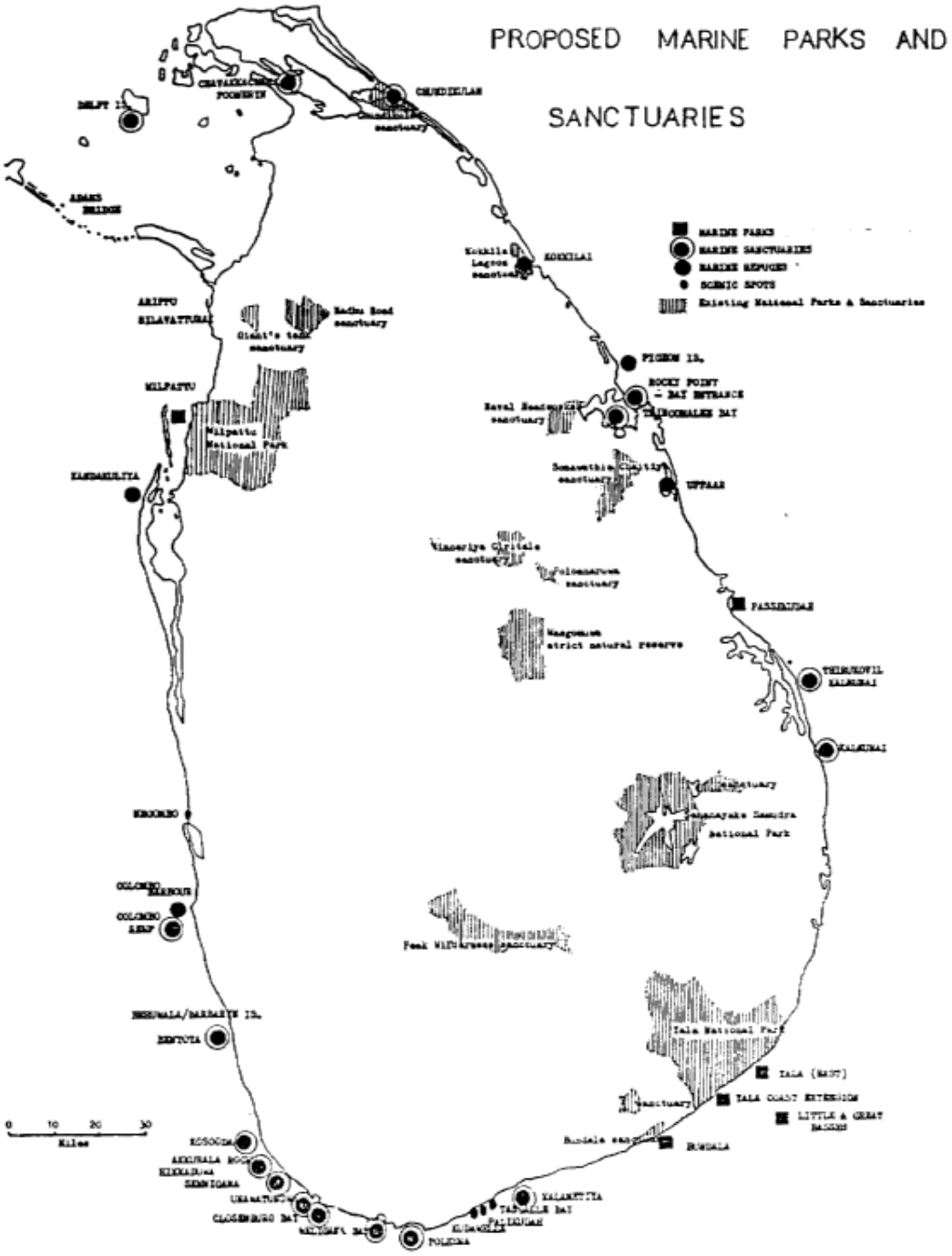

Figure:1 Location of Marine Parks, Sanctuaries and refuges proposed by the Committee on Marine Parks, Sanctuaries and Refuges Committee of the National Aquatic Resources Agency (NARA) in 1982.

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C) Research Zone: This area has some relatively undisturbed coral and has been subjected to low visitor pressure as a result of strong currents especially during tidal changes. Although many of the usual activities such as bathing . swimming and surfing could be allowed as these activities were in areas devoid of coral, the following activities were not recommended:

- The entry of any boats into the lagoon reef area of this zone.
- The use of diving and snorkelling gear by unauthorised persons.
- The removal or disturbance of organisms unless for research by authorised persons.

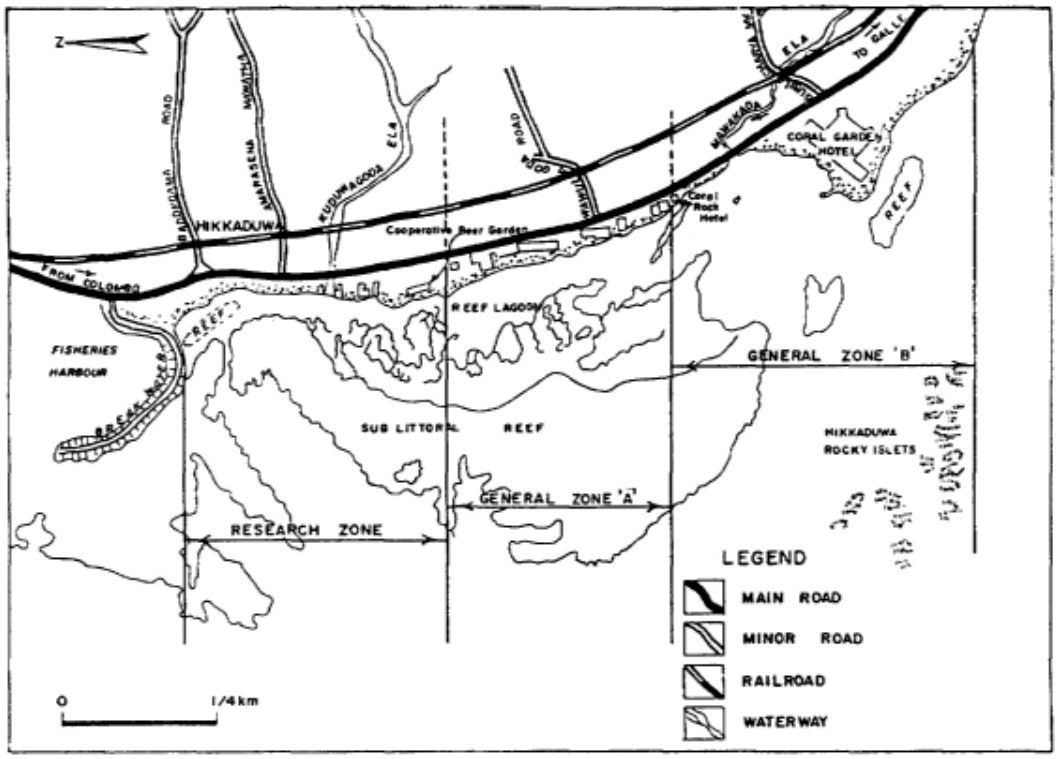

Figure 2. Zonation of Hikkaduwa Marine Sanctuary (Park) proposed by De Silva and Rajasuriya (1985 b)

The demarcation of the 3 proposed zones was decided after an intensive one year study of activities by NARA with funding from the International Development Research Agency, Canada (IDRC). The study included surveys of the quality of the coral reefs using a line transect method (De Silva, 1984), local and foreign visitor activities, beach and water based activities, fishing and glass bottom boat operations etc. (De Silva, 1987).

In 1986, NARA with the assistance of the Urban Development Authority office in Hikkaduwa put up 2 concrete boards along Galle Road - one in front of the Hikkaduwa market and the other near the Coral Garden's office indicating that no corals, fish and other organisms could be removed from the Sanctuary without a permit. Posters were also put up in strategic locations with the same message.

Some of the steps recommended by De Silva and Rajasuriya (1985a) to prevent the degradation of the Hikkaduwa Marine Sanctuary included:

Publicising the Hikkaduwa Sanctuary as an area from which no marine organisms whether dead or alive could be removed. This was primarily aimed at preventing the removal of corals, shells and ornamental fish.

To allow traditional fishermen fishing with permits to continue to fish according to the terms and condition of the permit.

Removing sand from the so called 'Fisheries Harbour' lying outside the Sanctuary and providing other amenities to enable the shifting of the fishing boats which anchor within the reef lagoon.

- Controlling the number of glass-bottomed boats through registration and issue of permits.
- Publicising Sections 14, 28 and 42 of the Coast Conservation Act, 57 of1981 which makes it an offence to deposit wastes or other materials from out-falls, vessels or by other means and the removal of coral, shells, natural vegetation, etc. from the coastal zone as defined by the Act. The contravention of these regulations make a person liable in the first instance to:

I. A fine of up to Rs. 25,000.00 and/or

II. Imprisonment of either description not exceeding one year.

III. Confiscation of vessel, craft, boat, vehicle used in the commission of the offence.

De Silva (1987) also made the following recommendations:

a) Establishment of Marine Park Headquarters with:

i) Facilities for formal and non-formal education of the public including an aquarium, museum and auditorium facilities for showing films etc.

ii) Underwater guided tours and glass bottom boat tours of the Marine Park

iii) Changing rooms lockers and dean toilet and other facilities at a reasonable charge,

iv) Marine biological research facilities and Sufficient manpower and equipment to en force regulations of the Marine Park.

b) That it was feasible to transplant coral (based on coral growth studies using Alizarine dye) and selected fish varieties such as the Clown fish and sea anemones that have disappeared from the area.

The recommendations of De Silva and Rajasuriya (1985a) were ratified for action by the Urban Development Authority's (UDA's) meeting to discuss Development Projects of Hikkaduwa held on 22 August 1985. The Marine Park was the subject of discussion at several subsequent meetings of UDA's Development Projects of Hikkaduwa, where many of the interested departments numbering over 15 were present.

The long awaited breakthrough for the Hikkaduwa Marine Sanctuary came on 17 December 1991 through a decision of a Committee appointed by the Parliamentary Consultative Committee on Ministry of Tourism and Rural Industries for the purpose of discussing the implementation of the proposal for a Hikkaduwa Marine Park by De Silva and Rajasuriya (1985a). At this meeting chaired by the Honourable Minister of Lands, Irrigation and Mahaweli Development, the Department of Wildlife Conservation was identified as the agency which should be responsible for the development of the Hikkaduwa Marine Sanctuary. This was to be carried out under the "Hikkaduwa Special Area Management Project" in collaboration with the USAID/Coastal Resources Management Project (CRMP) of Sn Lanka, Natural Resources and Environment Policy Project (NAREPP) and the National Aquatic Resources Agency (NARA).

Following the decision of the Parliamentary Consultative Committee, several initial meetings chaired by the Department of Wildlife Conservation (DWLC) were held with the relevant departments, institutions and agencies to work out a management strategy for the Hikkaduwa Marine Sanctuary. In early 1993, the first Hikkaduwa Special Area Management (SAM) Committee Meeting was held (Nakatani et al. 1994). The SAM Committee interests were much wider than the interests of the Hikkaduwa Marine Sanctuary although it formed a major component. NARA provided the technical expertise and the CRMP Sri Lanka played an important catalytic role by assisting in the coordination of the activities of the committee. The SAM Committee now functions under the under the chairmanship of the Divisional Secretary, Hikkaduwa Division.

The formation of the SAM committee backed by DWLC, NARA, CCD and the CRMP Sri Lanka and the appointment of a Marine Sanctuary Coordinating Committee under the SAM Committee were significant developments in thehistory of the Hikkaduwa Marine Sanctuary.

The initiatives by the DWLC, NARA, CCD and the CRMP Sri Lanka with the concurrence of the SAM Committee during the period 1992 to 1996 led to several important developments which included:

a) The establishment of a CRMP Sn Lanka office at Hikkaduwa.

b) The establishment of a DWLC office in the Sanctuary area. Initially, the office was manned by 5 members of the DWLC Staff. At present, there are three, headed by an Assistant Ranger.

c) The putting up of colourful boards on the beach by the DWLC providing information on the need to protect coral reefs and marine life.

d) Catalysis of the process to initiate the building of a Fisheries Harbour to shift the mechanised fishing boats anchored in the reef lagoon to a location out side the Sanctuary.

e) Acquisition of a fibreglass boat and engine by the CRMP Sri Lanka which was later handed over to the DWLC.

f) Building local community awareness on the need to conserve the coral reefs for their own benefit. The presence of the CRMP Sri Lanka office (synonymous with NARA to most local people), the establishment of the DWLC office and the field surveys carried out by NARA had a very positive impact on creating awareness about the need to conserve coral reefs.

The initial focus of the DWLC was to prevent visitors to the Sanctuary from walking and stepping on coral, catching fish, breaking coral as well as removing coral and other organisms.There were several instances where the local youth were involved in preventing the removal of coral and even preventing people stepping or walking on coral.

g) The organisation of a beach cleanup with the hoteliers of Hikkaduwa providing lunch for the participants.

h) Publication of the following:

i) The Coastal Environmental Profile of Hikkaduwa in 1994 (Nakatani et al. 1994).

ii) Special Area Management Plan for Hikkaduwa Marine sanctuary and environs, Sri Lanka (Hikkaduwa Special Area Management and Marine Sanctuary Coordinating Committee,1996).

iii) A flier handout on the Hikkaduwa Marine Sanctuary.

On the negative side a misinterpretation or misunderstanding of the legal provisions of the Flora and Fauna Protection Ordinance which is very clear on traditional rights [Section3(3)] led to a ban on the few elderly traditional fishermen holding valid fishing permits under the Fisheries Ordinance to fish in the area. Appeals by the fishermen went unheeded for one year. This is despite of it being brought to the notice of the SAM Committee, DWLC and CRMP Sri Lanka. 8 fishermen were finally issued with permits in

April 1997. Of the 9 applicants one had died of old age, by the time the decision to issue permits was taken by the DWLC.

The Special Area Management Plan for Hikkaduwa Marine Sanctuary and environs, Sri Lanka (Hikkaduwa Special Area Management and Marine Sanctuary Coordinating Committee,1996) adopted the zonation and several other recommendations as given by De Silva and Rajasuriya (1985a) for a Multiple Use Marine Park. Some of the significant differences were;

a) A new recommendation to increase the area of the Sanctuary from the original 45 ha (110 acres) to 100 ha.

b) The retention of the management of the Sanctuary under the DWLC instead of a separate authority for the management of the Marine Park.

2.2 Threats to the coral reefs and blodiversity

The major threats to the coral reefs of the HMS are given in Table 1.

Table 1.

Main threats to the coral reefs of the Hlkkaduwa Marine Sanctuary (De Silva, 1985b, 1987 and 1996; De Sllva and Rajasunya, 1985; Nakatani et al., 1994; Rajasurlya et al., 1995; and Hikkaduwa Special Area Management and Marine Sanctuary Coordinating Committee, 1996; De Silva, 1997)

a) Uncontrolled glass bottom and mechanised fishing boat activities:
   - Spillage and discharge of diesel, kerosene and petrol
   - Discharge of bilge and waste oil
   - Disposal of wastes
   - Damage caused by anchors and chains
   - Glass bottom boats coming in direct contact with the coral Glass bottom boat operators stepping on coral to hold the boats steady for the passengers to get a better view of corals or to release boats caught on the reef.

b) Sedimentation

c) Collection of corals and shells as souvenirs

d) Tourists/visitors stepping and walking on live coral areas

e) Collection of ornamental fish/lobsters/organisms

f) Discharge of untreated/semi-treated effluents \sewage from hotels & restaurants.

g) Polluted freshwater runoff from canals.

h) Collection of ornamental fish/lobsters/organisms.

I) Changes to current patterns due to illegal constructions on the beach.

j) Discharge of waste by visitors

k) Use of explosives to catch fish just outside the Sanctuary.

l) An overgrowth of the calcareous green alga *Halimeda* invading into live coral areas.

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2.3 Management issues

Although a substantial effort had been made between 1991 to 1996 to focus attention on the HMS and to stem the degradation of the coral reefs very little ground level action had been taken resolve some of the conflicts.

De Silva (1996) provides an analysis of what has led to many of the present problems of the Hikkaduwa Marine Sanctuary, the real problems at the ground level and proposed some ground level actions that could be taken to resolve some of the user conflicts and initiate the protection of at least small areas of good coral. He pointed out that the real problems at the ground level were:

a) The presence of over 30 mechanised fishing boats anchoring in the lagoon causing damage through anchors (usually large blocks of concrete) and chains as well as by spilling oil etc.

b) The increasing number of glass bottom boats -22 in 1985, 50 in 1991,66 in late 1995 and over 80 today.

c) It is interesting to note that De Silva and Rajasuriya (1985a) recommended a maximum of 5 GBB's in General Use Zone 'A' and 10 near the Rocky Islets (General Use Zone 'B'). The decision of the Hikkaduwa SAM Committee was to register and provide permits for 50 GBB's.

d) The meaningless enforcement of a ban on fishing by traditional fishermen who have been issued with permits by the Fisheries Department. This has angered and confused the small, and fast declining number of traditional fishermen.

e) The increasing number of glass bottom boats anchoring in the "Research Zone" from none in 1995, to three or more at present.

f) The self interests of politically and otherwise influential individuals having priority over all other concerns of the Marine Sanctuary.

De Silva (1996) also expressed the opinion that the key to protecting the coral reefs of the Hikkaduwa Marine Sanctuary would depend on the ability to;

a) Sustain the political will to rehabilitate the Hikkaduwa Marine Sanctuary.

b) Obtain the support and goodwill of all the stakeholders and the community.

c) Enforce legal regulations without interference or favour.

d) Remove all the mechanised boats (fishing as well as the glass bottom) from the lagoon area into the proposed Fisheries Harbour.

e) Prevent the glass bottom boats from getting too close to the live coral and damaging them.

f) Rehabilitate the "Research Zone" to stand up as an example of what a good coral reef could be.

Everyone would agree that as the custodians of the sanctuary the task before the Department of Wildlife Conservation is enormous. In addition to working with an entirely new area – the marine environment, it had to face a large number of inherited complex problems.

In the face of all odds the Department has got a foot-hold in the sanctuary by establishing a small office and stationing staff on site. With a genuine effort on the part of the DWLC and the support of all parties concerned in the SAM process induding the police, it might still be possible to rehabilitate the coral reefs and bring them back to their former glory.

De SIlva (1996) also stated that without of waiting for all the elements of the SAM plan to fall into place, especially the construction of a Fisheries Harbour, some immediate actions would be required at ground level to protect the coral reefs and to minimise user conflicts.

24 Ground level action to resolve some user conflicts

During the period 10 March to 28 April 1997, several ground level management activities were carried out by the Coastal Management Center (CMC), Philippines with the assistance of NARA with funding from the University of Rhode lsland/CRMP Sri Lanka (De Silva, 1997). These activities related to the implementation of the Marine Sanctuary component of Hikkaduwa SAM Plan were approved by the DWLC, NARA,CCD and the Hikkaduwa SAM and Marine Sanctury Coordinating Committee. The implementation of these management actions, particularly within a very short period of one and a half month as requested by CRMP Sn Lanka required not only community support and assistance but also an intimate knowledge of the HMS. For this reason the proponents of the first Management Plan for the HMS (De Silva and Rajasuriya, 1985a), closely associated with later research and management efforts of the HMS were involved in the process.

Some of the actions implemented and the processes involved were;

a) Demarcation of protected, snorkelling and bathing zones with buoys and float lines. Which necessitated the following;

   i) Briefing the Special Area Management and Marine Sanctuary Coordinating Committee on 14 March 1997 on what was going to be done.

   ii) Surveys of the reef lagoon with the coral reef researchers of NARA and the staff of the DWLC stationed at Hikkaduwa who were familiar with the HMS to identify areas for the protection of coral, snorkelling and bathing.

   iii) Discussions with fishermen, traditional fishermen, glass bottom boat operators, reef front hoteliers, staff of the DWLC and dive group operators etc. on the proposed demarcation of zones

   iv) Demarcation of the Protected, Snorkelling and Bathing Zones after discussions with stakeholders and shifting boats and anchors out of the identified areas. Shifting of buoy and float lines to accommodate additional requests that did not compromise the demarcation objectives.

   v) Providing an additional opportunity for glass bottom boat operators to comment on the demarcated zones on 2 April 1997.

vi) Report on zone demarcation that has been carried out, problem of the overgrowth of the calcareous alga *Ha!imeda* posing a threat to the live corals of the Hikkaduwa Marine Sanctuary etc. to a meeting on 6 April 1997 chaired by the Director of the DWLC. All members of the Hikkaduwa Special Area Management and Marine Sanctuary Coordinating Committee, interested parties and the community at Hikkaduwa were invited to the meeting. It was attended by 68 interested persons. The only protest recorded at this meeting was about effluent being put out from hotels into the reef lagoon and that no action is taken against such offenders.

vii) preparation of the float lines, concrete anchors, fibreglass work, setting the concrete anchors for zone buoy etc. utilised traditional fishermen, glass bottom boat operators and other members of the local community.

viii) Painting 3 large notices on walls at strategic locations indicating activities that are not allowed within the Sanctuary. Local talent was contracted to do the job.

ix) Infra structure improvements to the DWLC office to make it habitable with provision of water and electricity as well as repairs to the roof and walls with funding from a sponsor from the local community.

In addition, the following were also accomplished which enhanced community awareness and participation;

a) Facilitated the issuing of fishing permits together with the DWLC to 8 traditional fishermen who had been banned from fishing in the HMS. This greatly assisted in obtaining ground level support and participation of the Hikkaduwa community to implement the programme of work.

b) A three day snorkel diving course from 25 to 27 March 1997 leading to PADI qualification for the Department of Wildlife Conservation staff, 7 local participants and one from the CRMP office, Hikkaduwa.

c) 2 day skin diving and basic marine biology from 8-9 April 1997 for 28 local youths.

d) 2 day course in first aid for local youth conducted by the Sri Lanka Red Cross Society - 28 participants attended. There is now a core group of youth on the beach at Hikkaduwa who could be called upon to assist in cases of near drowning or in need of first aid assistance.

e) 2 day *Halimeda* (a calcareous green alga posing a threat to live coral in the Hikkaduwa Marine Sanctuary) clean up which funded an average of 26 participants from Hikkaduwa to assist in the clean up. Funding was through IUCN Sri Lanka.

The DWLC the authority for the management of the HMS has been provided with a maintenance schedule in early June 1997. This provided details of immediate, short term and long term actions required to maintain the float lines and buoys demarcating the protected, snorkelling and bathing zones as well as the large notices drawn on the walls facing the HMS. No action seem to have been taken up to carry out the required maintenance.

The float lines and some of the buoys of the Protected and Bathing Zones as well as the buoys of the Snorkelliing Zone (the float line was removed during the monsoon season) were still intact in October 1997. It is sad to note that although the Protected Zone was respected by the GBB's initially, slack or no enforcement has led to the entry of large numbers of GBB's into this area.

Ekaratne (1997) who carried out a research project for CRMP Sri Lanka 'On coral reef ecology at Hikkaduwa Marine Sanctuary' stated that "Reef studies in Sri Lanka are limited to inventorisation of selected reef resources (de Silva and Rajasuriya, 1985, Rajasuriya et al, 1995. The present study which incorporates the first study of an ecological nature on reef ecosystems in Sri Lanka is financed by a non-governmental body the NAREPP programme of the USAID".

It is indeed suprising that Ekaratne (1997) does not consider the work carried out by several others on the same coral reef of the HMS where he carried out his studies as ecological in nature. Let alone the reef ecosystems of Sri Lanka the following studies carried out on the coral reefs of Hikkaduwa are of a ecological nature or have strong ecological components: Tambiah and De Silva (1965), Mergner and Scheer (1974), De Silva and Rajasuriya, (1985a,1985b and 1989), Do Silva (1987), NARA (1987), Rajasuriya and De Silva (1988), Rajasuriya, (1992 and 1994), De Alwis, Dissanayake and Azmy, (1994).

Ekaratne (1997) was very critical of the management actions that had been taken to implement the Marine Sanctuary Management Proposals under the Special Area Management Plan for the Hikkaduwa Marine Sanctuary. It is ironical that he makes no reference to the Special Area Management Plan for Hikkaduwa Marine Sanctuary and Environs, Sri Lanka - a basic document on the management of the HMS. The Terms of Reference for plan implementation by the CMC had been sanctioned by the DWLC, NARA, CCD and the Hikkaduwa SAM and HMS Coordinating Committee. Further, it was carried out in consultation with the stakeholders of the HMS and the community at Hikkaduwa; first in small groups and then presented at the meeting for general comments on 6 April 1997, chaired by the Director of Wildlife Conservation. Despite these efforts and the fact that plan implementation was carried out under the leadership of the original proponents of the Hikkaduwa Marine Park management Plan with many years of research experience in the area. Despite all the effort that has been made to obtain the cooperation of the stakeholders and the community of Hikkaduwa Ekaratne (1997) made the following observations;

"It is strongly recommended that such plans be carefully considered and opened for public scrutiny before they are considered for implementation, particularly where visiting personnel from overseas are involved on short-term assignment basis as was the case with the above ill-conceived plans ..

As the criticisms were made by a responsible member of the Advisory Committee of the DWLC, this too might have added to the complex problem of managing the HMS. This also becomes a classic case of two projects funded by the same organisation leading to further confusion in management efforts.

3. Lessons to be learned from the Hlkkaduwa Marine Sanctuary

One can see in the HMS some of the common problems and conflicts of interest eg. fisheries vs conservation, tourism vs conservation and fisheries, and also the dangers of not preplanning prior to development of tourist and other facilities. Some of lessons that could be learned from the experiences of the HMS could be summarised as follows.

a) Although concepts could be developed and even legal declarations made, it takes a long time for the process to mature before some tangible results could be expected.

b) Regular and constructive pressure would be needed to keep the process in motion.

c) A practical management plan developed on a sound footing with a scientific basis could stand the test of time.

d) Implementation of even what appears to be simple ground level action requires the support and co-operation of the stakeholders and the community.

e) There should be some flow through benefits to the stakeholders and the community to get their whole hearted support and co-operation.

f) Constructive criticisms and viable options should be given due consideration. Baseless criticisms however, should not be a source of distraction or frustration as they will not stand the test of time.

g) There is a need to update and harmonise legislation to avoid overlapping responsibilities.

h) There is a need for regular monitoring and evaluation to determine progress of management actions and to keep on top of threats like pollution, sedimentation, population explosions of reef organisms. Monitoring would also enable the identification of new or increased human activities within and outside the area that could compromise the equilibrium of the coral reef ecosystem.

i) Highly stressed coral area such as the HMS cannot be considered as pure and natural ecosystems. Human interventions might be necessary keep the integrity and prevent it heading towards a new and completely different climax.

3. CONCLUSIONS

De Silva (1996) had stated that the Special Area Management approach in principle was good. But, the outcome would depend on whether all parties concerned were prepared to make the declared goal a reality by not making self interests override the common interests.

Some of the major constraints to the conservation and sustainable management of coal reefs in many developing countries could be summarised as follows:

a) The inability to convince the top policy and decision makers of the long term value and the possibilities of sustainable management of coral reefs.

b) The need for proactive, precautionary and anticipatory approaches to management efforts.

c) Preference for management by crisis rather than pre-planned strategic management.

d) The short term greed of a few over-riding the long term interests and needs of the majority.

e) Insufficient expertise to develop and implement practical management plans.

o Lack of enthusiasm to enforce regulations.

g) Looking for excuses rather than looking for innovative ways of getting a job done.

h) Insufficient management oriented coral reef research such;

- The determination of carrying capacities and sustainable extraction levels of reef resources,
- Breeding of popular marine ornamental fish.
- Enhancement and rehabilitation of degraded reefs.

I) Lack of proper coordination and cooperation at national, regional and international levels to optimise the use of skilled manpower and available finances. This has led to competition among donor, aid and non-governmental agencies and to duplication of effort and waste of limited expertise.

j) international and other organisations spending more money and energy under the name of coral reefs, on meetings, workshops, conferences, publishing reports and proceedings etc., than for ground level action, truly management oriented research and community participation in management efforts.

Many of the present constraints to coral reef conservation and sustainable management efforts will continue to be issues of the future unless immediate corrective measures are taken. Recommendations of many meetings such as this may increase awareness

among those present, but would rarely be taken up at top decision making levels unless packaged in a proposal format with viable options ready for a decision by those in authority.

At a regional level it is best to identify at least one pilot coral reef area for each country and make a concerted effort, with external funding and expertise where necessary, to manage the area as a model in conservation and sustainable use. Immediate steps should be taken in the region to plan for coral reef based tourism which is bound to be a major issue in the future. Enhancement of buffer zones of protected areas and compatible income generating activities for local communities should also be given due consideration (De Silva, 1994).

A mechanism need to be established to coordinate the efforts of various funding agencies interested in the conservation and sustainable management of coral reefs to prevent wasteful duplication of effort, and to focus attention on solving ground level management problems with true community participation.

In conclusion let me echo what has already been said earlier by De Silva (1996)

"Research and science alone wilt not help sustain our coral reefs. It is a dedicated and honest effort on the part of everyone involved including the politicians, scientists, managers, technocrats, stakeholders, the tourists, the police, the media as well as departments and institutions concerned that will determine what their future would be. We have to stop and think, and be honest with ourselves when we ask the question "are we really interested in sustaining the coral reefs and the communities or are we just using the coral reefs as an excuse to sustain our institutions, self interests and positions".

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Destruction of Coral Reef By Boring Sponges

P.A. Thomas[1]

Introduction

The part played by sponges in the destruction of coral reefs and gregarious molluscs has been well documented in the past by several workers, and as understood at present the sponge constitutes a major group among 12 different taxa of marine plants and animals that cause considerable damage and ecological disturbance in the marine ecosystems. Various borers resort to various methods in gaining entry into calcareous substrata; in some it may be by chemical means, in others by mechanical means or by a combination of both.

Since Calcium carbonate forms the hard skeleton in different marine organisms such as coral, molluscs, barnacles, calcareous algae etc. the deterioration caused to them by other marine organisms has been a topic of interest to both marine biologists and geologists alike. The biological, chemical and geological changes that the boring organisms would bring about in the marine environment are, by no way, insignificant as they cause bio-erosion, influence calcium balance in the sea and control the structure of calcium carbonate secreting communities in the sea.

How Sponges bore into hard Calcareous skeleton in Corals?

Sponge bore into the hard calcareous substrata through tunnels and cavities formed by the etching of hard calcium carbonate in the form of microchips of almost the same dimensions (0.056 x 0.047 x 0.032 mm average), and hence the interior of these cavities, when viewed under high magnification, may have a pitted appearance. These chips are of uniform size, shape and ornamentation and are etched out by the filopodial structures borne by peculiar cells of archeocytic origin. These filopodial structures cut hard calcareous particles by the help of a chemical agent (probably carbonic anhydrous) and then the chip is pulled out from the site by the contraction of filopodial basket (mechanical means). Chips, thus formed are drained into the canal system of sponge and thence to the exterior through the excurrent stream of water (again mechanical means). Since boring sponges etch out microscopic calcareous particles of uniform size and shape this phenomenon may be termed micro-erosion or blo-erosion.

A bio-erosion at microlevel

The quantity of calcareous chips dislodged from any coral substrate by the activity of sponge varies considerably both in time and space, Rutzler (1975) has shown experimentally that 1 mg (dry weight) of *Cliona lampa* can dislodge16 mg of calcium chips over a period of one year, and based on this it is calculated that, in Bermuda reefs, as much as 250 mg/sq.m/yr are removed from coral and this corresponds to a layer of 0.1 mm

[1] (Vizhinjam Research Centre of C.M.F.R.I., Vizhinjam - 695 521)

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thick every year from an area of 1 sq.rn. But this may go up to 3 kg/sq.m/year (or 1 mm thick) in areas where sponge concentration is high. The above figure is in addition to 2 to 3 per cent calcium carbonate which goes in solution in chipping process, and hence the problem of altering the calcium balance of the sea water in the adjoining realms is not severe.

Goreau and Hartman (1963) have shown that such chips contribute much to the mud fraction of the sediment generated in the reef environment in Jamaica, and constitute 2 to 3 per cent of the total sediment load in the Adriatic Sea and the Persian Gulf, while it is to the tune of about 30 per cent in Fanning Island.

Factors influencing bio-erosion

Rutzler (1975) has shown that when a coral piece infected with boring sponge is cut into two the resultant bits show accelerated boring activity. Hence intervention by man or by boring organisms by way of cutting channel across the reef or by burrowing into it may accelerate boring activity of all existing species of boring sponges along the cut ends of the reef. Calcite blocks infested by boring sponges, when illuminated by low voltage microscope lamp may produce chips at an accelerated rate (0.5 mg/sq.cm/day). Clarity of sea water is another factor. Euphotic zone, in Lakshadweep area, is upto 90 m. and this may also give some clue to the accelerated activity of boring sponges in this area.

Sponge infection in Lakshadweep atolls-a case study

The Central Marine Fisheries Research Institute, Cochin, initiated a project to investigate the living resources of Lakshadweep in 1887, and 12 atolls were surveyed in detail and the results were published in the form of Bulletin in 1987 (Bulletin No.43). An interesting feature noticed with regard to the sponge fauna, both morphozone-wise and transect-wise, is the dominance of boring sponges in relation to non-boring ones. The total percentage of boring species in each atoll may be given as follows: Kavaratti - 46.4 per cent, Kalpeni - 36.1 per cent, Suheli - 48.3 per cent, Androth - 66.6 per cent, Minicoy - 50.0 per cent, Amini - 38.4 per cent, Kiltan - 20.0 per cent and Kadamath - 58.3 per cent. The abundance of coral skeleton may be the main cause of the richness of boring sponges in the various atolls investigated.

Atoll-wise data on sponges were collected on a transect-morphozone basis, and the abundance of boring sponges was calculated. Mortality of coral due to sponge attack was calculated for an area of $25m^2$. it was seen that in some places the mortality was as high as 80 per cent.

It is found that sponges can bore into both dead and living corals. Since boring sponges obtain their food from sources other than the host, the death of a coral will never affect the sponge adversely. And as such the chipping of calcium carbonate matter can go incessantly even after the death of the coral. The galleries formed inside the coral by the removal of calcareous particles weaken the entire reef frame-work making it more susceptible to the wear and tear caused by waves. Further, such a weakened substratum may also accelerate the activity of secondary borers such as polychaete, molluscs, sipunculids etc.

When the inroads of boring sponge reaches the climax stage, the interior of coral becomes practically hollow except for a few 'pillars' of calcium carbonate stretching across these hollow cavities inside. The outer surface of the coral remains untouched except for a few microscopic pores through which the incurrent and excurrent papillae protrude for taking in and expelling water respectively. Hence it is difficult to assess the damage caused to a coral mearly by external examination, Though the outer layer of coral appears normal slightest pre3sure would make the entire outer layer cave in as the interior is practically hollow. Massive corals examined from various atolls of Lakshadweep showed this character extensively.

Damage caused to corals

In order to evaluate the damage caused to corals by boring sponges data were collected separately for branching the massive corals. For branching forms the damage caused to branches as well as for stalk portion was collected, and it could be noticed that in branching corals the tip of branches just above the point of penetration of the sponge larvae usually die out as the sponge grows up through the interior of branch. Some filamentous algae of black colour usually colonise these dead branches giving *a* black furry appearance to such branches underwater. The sponge makes chamber and tunnels inside the branches initially, but later these cavities fuse together and form a single continuous tunnel running through the centre of each branch. It is noticed that the sponge *Cliona ce/a(a* prefer to grow upwards (negatively geotropic), i.e. towards the distal end of each branch, and hence the portion below the penetration point of the larvae (of boring sponge) remains unaffected. Such dead distal portion of coral branches may later break off due to the action of secondary borers or waves.

Stalk of branching coral is also analysed for various boring sponges/boring groups, and it could be seen that nearly 40 per cent of the area of stalk, in cross section, is being damaged by an array of boring organisms drawn up from different phyla of the animal kingdom. In any branching colony, that too when it occupies the reef front zone, a partially disintegrated stalk can result in the sliding away of the entire colony into deeper areas where it will be buried by sediments.

Massive corals are also equally infested by boring sponges, and here also the boring sponges show a tendency to grow upwards (negatively geotropic) from the point of penetration of sponge larvae. When many larvae penetrate a massive coral at different points and all of them grow upward they will ultimately reach the summit or the distal part of the coral causing damage to living polyps. Side by side boring algae or other borers may settle at this damaged part and establish themselves. It could also be seen that in some cases the coral colony compensates the situation by accelerating the growth along the periphery producing a circular rim around the zone of dead polyps. This outer rim, in due course, may curl in and completely cover the central area of dead polyps. If the damage is

extensive and when this type of a growth is not possible, other sedentary forms may attach and grow luxuriently on the damaged summit of any massive coral.

Biodiversity of boring sponges

Extensive survey on sponges in Lakshadweep revealed the presence of a total of 91 species referable to 30 families and 66 genera (Thomas, 1989). Abundanance of boring sponge specimens over non-boring ones was seen not only with regard to various atolls investigated, but with each collection site also. In some sites only boring sponges were represented. The abundance of boring sponges in these atolls may be attributed to the easy availability of calcareous matter in the form of coral skeleton.

The total number of boring species represented in the various atolls of Lakshadweep is 18, and these are referable to 4 orders, 5 families and 9 genera of the Class Demonspongiae of *Phylum porifera.*

The various genera of boring sponges and the number of species under each genus are as follows: 1. Genus *Rhabderemia* (1); 2. Genus *Spirastrela* (4); 3. Genus *Amorphinopsis* (1); 4. Genus *Aka* (2); 5. Genus *ClJona* (6); 6. Genus *Thoosa* (1); 7. Genus *Jaspis* (1); 8. Genus *Halina* (1) and 9. Genus *Samus* (1). Of these, species falling under the genus *Cliona* are widely distributed in the various atolls of Lakshadweep followed by those of the genus *Spira Strella.*

In order to get a clearer picture of the abundance of various species of boring sponges, the total incidence and the species wise incidence in the various atolls were calculated for 5 atolls. It could be seen that *Cliona celata* Grant was the dominant species in two atolls (Kavaratti and Suheli); *C. ensifera* Sollas in Kalpeni and *C. mucronata* Sollas in Androth. In Minicoy atoll both C. *celata* and C. *vastifica* Hancock dominated equally. The other species of *Cliona* viz. C. *viridis* (Schmidt) and *C. carpenteri* Hancock, had stray occurrence.

Out of 4 species of the Genus *Spirastrella,* two species viz., *S. inconstans* (Dendy) and *S. aurivilli* Lindgren are somewhat well distributed. Of these the former show a tendency to overgrow the substratum in an advanced stage of growth. Asexual buds formed from the tip of tubular branches later get nipped off, and these later get anchored to the substratum and form new colonies; this character is widespread for *S. inconstans.*

The other boring species are of no significance at present from the point of coral destruction; but it is possible that any species can cause an outburst and dominate over others.

While analysing the boring sponges of the Indian seas it could be seen that 32 species infest the various calcium carbonate secreting organisms such as coral, mollusc etc. (Thomas, 1979). This number (32) is very large when compared to any part of the world seas, but all species were equally dominant during the time of the above study. During the survey of Lakshadweep atolls also a few species were dominating. But here also a

number as high as 18, with a few dominating, indicates that the coral reefs of Lakshadweep group of islands are under severe threat of sponge infection.

Out of the total of 91 species recorded from Lakshadweep atolls (Thomas, 1989) only 18 were boring species while the others (73 species) may be considered harmless associates. Subsequent studies made on some of these 73 species indicate that at least some may elaborate peculiar chemical compounds with biodynamic properties, and many of these compounds could be used in synthesising 'wonder drugs' which will fight many a dreadful disease in man. Hence it is time to think in this line, and the vast sponge resource available in these atolls may be judiciously exploited for initiating R & D programmes on marine organism based drug industry.

Recommendations

During the present survey of Lakshadweep atolls (Thomas, 1989) only 5 atolls were studies in detail, and based on the information collected it is possible to say that the boring sponge infection was quite widespread and the mortality due to the same was very high in some transects. Studies on boring sponges of the Seychelles Bank (mainly Mahe Island) also indicated the presence of 15 species of boring sponges infecting the corals of that area (Thomas, 1973). It is not known whether the other reefs in the Indian Ocean are infected in the same pattern, and how much mortality is effected through sponge infection. A detailed study in this line is worth undertaking in all coral formations in the Indian Ocean.

An exhaustive study made on the boring sponges infecting the economically important shells of the Indian seas (Thomas, 1979) revealed that the frequency of occurrence of various boring species can vary from time to time and any one or more species can at any time cause an outburst creating severe havoc and then disappear into a quiescent stage, while some others may continue to exhibit moderate incidence without causing any such deleterious effects, This shows that the composition of the boring sponge fauna of Lakshadweep islands is likely to get altered in future, and such changes, if any, may be well affirmed by comparing with the observations presently reported. Hence regular surveys, at least after every five years, may be attempted in these atolls to study the changing patterns in the boring sponge populations.

Since boring sponges etch out microscopic particles of calcareous matter making the hard substrata susceptible to the vagaries of nature, the problem of bio-erosion is of considerable importance to both marine biologists and geologists alike, and any study, in this line, should be undertaken as an inter-disciplinary one. In India this aspect is now covered by biologists only, and geologists have not yet taken it seriously.

It may often be difficult to control the attack of borers on coral or molluscs in the marine environment effectively, but the changing patterns in the their abundance, both in time and space, when monitored on a long term basis, will be of considerable vaiue in the management of calcium secreting animals.

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Recent Changes in The Coral Reef Ecosystem of Palk Bay: A Corn parititve Status of Previous Reports and Researches.

O. Asir Ramesh and T. Kannupandi[1]

Abstract

Comparing old data with present data is the only way to analyse the ecosystem and assess changes caused by nature and anthrophogeic influences. Coral reef constitute a sensitive and fragile ecosystem little researched in India. The coral reef of Pa/k bay has been thomughty studied by Gopindhapillai (1969), Thomas (1969), Appukuttan (1969(, Mallik (1983), Silas and Fernando (1985), Umamaheswara Rao (1989), Manchamy (1983). This paper aims to analyse the present status of the coral reef of Pa/k Bay by comparing it with previous studies. The conclusion is that the Pa/k Bay coral reef ecosystem is in good health but certain areas need attention.

Distribution of Palk Bay Reef

The reef in Palk Bay runs parallel to land (east to west direction) between longitudes 79^0 17'E and $79^0$8'E at the latitude $9^0$17'N. The Bay is a very shallow flat basin and the depth never exceeds 15 metres. The average depth is 9 meters. The coral reef in Palk Bay starts from Munakad as a wall-like formation 1-2 m broad and run east upto Tonithurai a distance of nearly 5.5 km. Here the reef width is more than 300 metres. East of Pamban pass, the reef again starts near Thangachimadam and ends near Agnitheertham (Rameswaram) (Mahadevan and Nagapan Nair 1969). The Palk strait between India and Ceylon is about 75 km wide, with a water depth of 9-13 mt, except where local coral reef rises above sea level.

Physical Parameters of The Reef

The south-west and north-east monsoons are both active in this area but the south west monsoon contributes very little to the total annual rainfall. Rain is moderate to heavy during the period October to January. The mean annual rainfall varies from 820 mm to 1650 mm. The monthly average temperature of the waters of Palk Bay ranges between 24.6°C and 29.1°C (minimum during December and the maximum during May). The tidal elevation is around 1 m. Palk Bay is generally calm, except during the onset of the north-east monsoon when turbulent condition prevail (CS. Pillai, 1969). The salinity of the water decreases gradually along an axis in the south-west direction, running from the strait. There is a point of high saline water in the south-west corner of the bay. This may be because of the incursion of Gulf of Mannar water through the Pamban pass.

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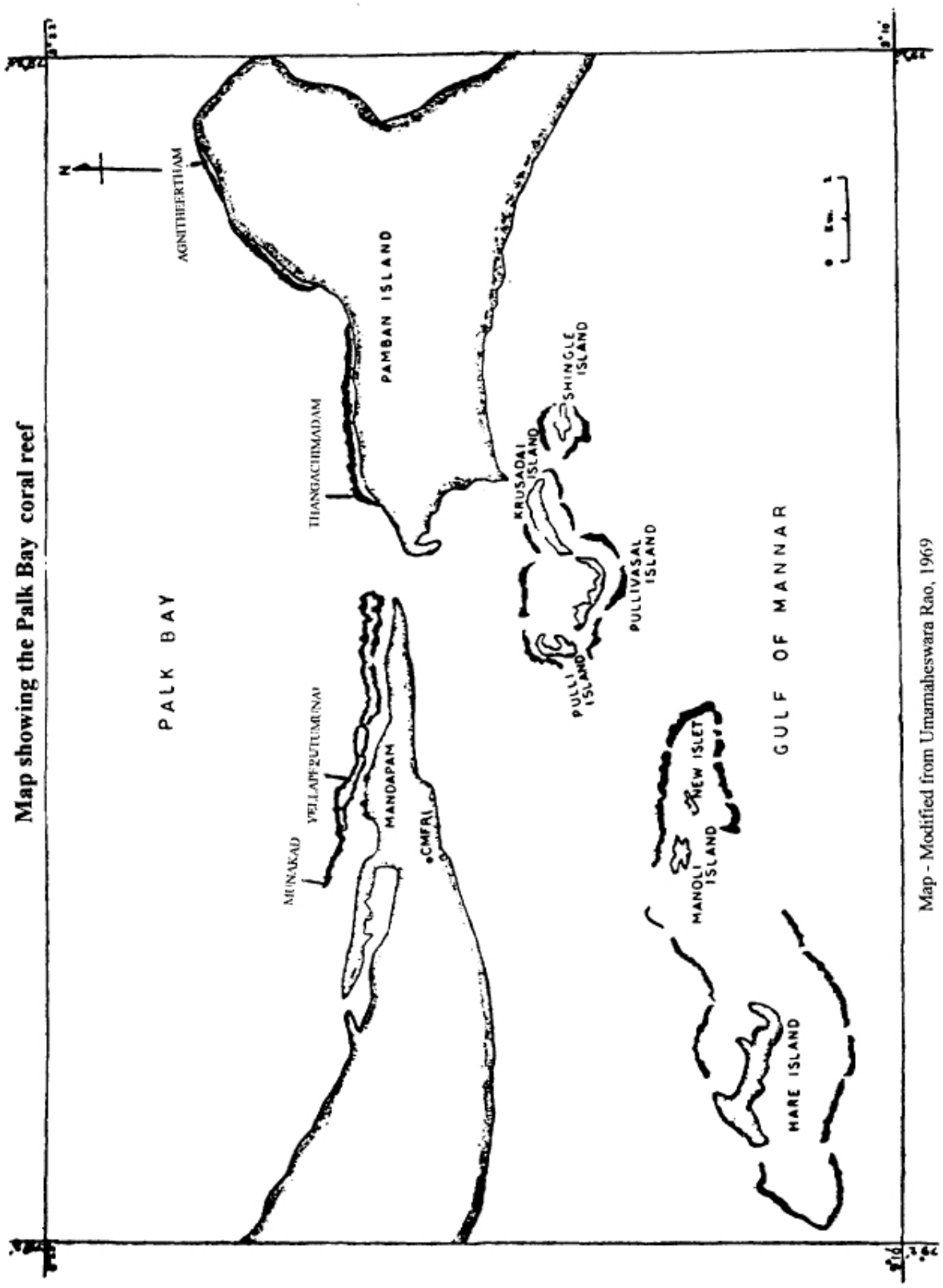
Mapi


Map showing the Palk Bay coral reef
PALK BAY
PAMBAN ISLAND
AGNITHEERTHAM
THANGACHIMADAM
SHINGLE ISLAND
KRUSADAI ISLAND
PULLIVASAL ISLAND
PULLI ISLAND
GULF OF MANNAR
MANDAPAM
CMFRI
MANOLI ISLAND
NEW ISLET
MARE ISLAND
Map - Modified from Umamaheswara Rao, 1969

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The density of the water also decreases along an axis in the south-western direction from the strait. The strength of the north-east wind at Nagapattinam is about 8 to 10 knots (North of Palk Bay) and at Pamban the wind strength is only 2 to 4 knots. The temperature, salinity, density and dissolved oxygen of the surface waters of the Palk Bay indicate that the Bay of Bengal waters entering the Palk strait have a major influence on the hydrographic condition of Palk Bay. The Gulf waters influence the hydrological parameters only to a minor extent (Murty and Udayavarma, 1964). Silt settlement has a remarkable effect on the distribution and diversity of coral reef associated plants and animals. This appears to have a greater influence in the inshore regions of Palk Bay especially during the north-east monsoon.

The inshore waters of Palk Bay become muddy during the monsoon because of the presence of suspended sand and silt stirred up from the sandy shore by wave action. Cyclonic winds with high velocity capable of generating mechanical damage to corals of this area are common during the monsoon season. A severe cyclone in 1964 with a wind speed of 100k. devastated most of the corals (Pillai, 1971).

The bottom sediments of Mandapam consist of silt and clay, clayey silt and sand, fine to medium sand, coarse sand, and coarse sand with gravel. Distribution of various size classes indicates that the offshore sediment in this area is usually unimodal with the primary mode around 1.5 to 2 (medium sand). A secondary mode is sometimes present around 3.5. Beach samples have a prominent mode around 2.25, 1.75, 2.75 and 3.25, suggesting the polymodal nature of the sediment (Mallik, 1983).

Review of the Coral Reef Ecosystem of Palk Bay

Gopinadha Pillai (1969) classified the reefs of Palk Bay into five zones - shore, lagoon, shoreward slope, reef crest and seaward slope. The shore of the reef is mostly sandy with dead pieces of corals, except at the extreme eastern and near the Pamban bridge where one can see traces of sandstone's. The vegetation on the shore comprises *Cocos nucifera, Borassus fiabellifera, Casurina equisetifolia, Azadirdicata indica* and few other thorny shrubs.

The width of the lagoon varies from 200 to 600 meters at different places with a depth of 1 to 2 metres. The bottom is sandy with molluscan shells and pieces of disintegrating corals. Living corals are practically absent in the lagoon, probably due to the absence of any hard substratum on which coral planulae can settle. Sponges such as *Hercina fusca, Dysidea fragilis, Spirastrella inconstans* and *Calispongia diffusa* are fairly common at the bottom. The vegetation is composed of Cymodocea sp, Ulva *reticulata, Turbinaria sp, Padlina sp, Halimeda sp* and *,Amphiora sp* are common *Holothuria scabra, Holothuria aria* and *Pentaceraster australis* are common inhabitants of the sandy lagoon floor (Pillai 1969).

Corals distributed along the shoreward slope are encrusting and massive types with comparatively large polyps, such as *Favia pallida, Favus, Favites virens, Goniastrea* pectinata, G retiformis, Piatygyna lamellina, Hydrophora sp., Cyphastrea sp., *Leptastrea sp., symphillia sp. and Goniopora sp.* Living colonies of *Porites sp* are rare or small in size. *Galaxea fascicularis, Turbinaria peltala, Pavona varians* are the rarest species. This zone of the reef supports a good many reef dwellers like encrusting sponges, bryozoans and calcareous algae. Among the fleshy corals *Lobophylum sp* and *Sarcophylum sp* are represented.

The reef crest is often completely exposed at low tides. Corals are very rare at the reef crest, probably because of the influence of exposure to sun light. However *Heptastrea transversa* and *Goniopora duofaciata* are occasionally seen under the rocks.

The coral growth of the reef along the seaward side slope is comparatively richer than on the shoreward side. Majority of corals are ramose genera viz., *Pocillopora sp, Acropora sp* and Montipora sp. The vegetation comprises of *Turbinaria sp, Sargassum* sp, Padina sp, Caulerpa sp and rarely Cymodocea sp. Halimeda sp and a few other encrusting calcareous algae are commonly seen.

A total of 61 species of algae has been collected. They are distributed among the three major groups - green algae (14 genera and 28 species), brown algae (8 genera and 13 species), red algae *(17* genera and 20 species). The frequency occurrence of different species in the quardrat samples show that *Halimoda opuntia* is the dominant algal member of the reef. Species of Cauleipa and Sargassum are the other most common plants found in the reef. The physical conditions such as the nature of the substratum and water level above the substratum, influence the distribution of flora in the coral reef area (Umamaheswara Rao, 1989). Boring sponges are the major group among the marine organisms causing considerable destruction to the reef system. The bores made by the sponges weaken the entire reef, making it more susceptible to the wear and tear caused by the waves. There are altogether 20 known species of boring sponges from the Gulf of Mannnar and Palk Bay, falling into nine genera. The most conspicuous genus is *Cliona,* both in number of species and in distribution (Thomas, 1969). Among the coral boring organisms, bivalve molluscs cause considerable destruction to coral reefs. They act as biological agents in the erosion of hard coral stones. In Palk bay and Gulf of Mannar, only 17 boring bivalve species have been recorded from this area (under 10 genera of six families) (Appukuttan, 1969). Asir Ramesh (1996) recorded a total of 73 species of molluscs associated with corals in Palk Bay viz., 46 species of gastropods belonging to 17 families, and 27 species of bivalves belonging to 13 families.

The dried sea horse *(Hippocampus kunda)* is in great demand in south-east Asian countries, especially in Singapore and China - not only for extraction of soup which is a delicacy but also for its medicinal values. Along the Ramnad coast, the dried sea horse

is used as a medicine to arrest whooping cough in children. The dried sea horse is finely powdered and the roasted. This powder is mixed with honey and administered as a engulfing medicine. In some places the powder is mixed with coconut oil and pasted on the cut wounds. It is also used for curing asthma (Marichamy et al., 1993).

Dugongs are long living animals with a low reproductive rate. They have a long gestation period and a large gap between each off spring. Around 25 dugongs were caught accidentally in this region during 1960. In Palk Bay Karangadu, Nambuthaalai, Morepanai and Mullimunai are minor fishing villages. Valivalai (drift net) shore seins and Thirukkaivalai are used to capture dugong in the shallow regions. Explosives (Country bombs and dynamites) are used for capturing the dugong in Thiruppalaikudi and Devipatnam (Ramnad District). During the 1960's the fisherman of Palk Bay region bitterly complained about the disappearance of large beds of algae owing to the cyclone in 1964, and turtles and dugongs almost disappeared in this area. Fishermen, now report that the algal beds beds have sprung up once again (Silas and Fernando, 1985).

Present Status of Palk Bay

Nearshore areas of Palk bay are polluted because of increased coastal urban development. Sewage outlets are increasing the suspended load, turbidity, nutrient etc. The coral reefs are under stress wherever processing industries let out their sewage. The indiscriminate cutting of near shore forest, leads to coastal soil erosion with huge quantities of nutrients that aggravate the physical stress on the coral reef.

The Palk Bay lagoon has a width of around 230 m. from the shore. The lagoon contains a large number of boulders, occupied by various species of scieractinian corals. Table reef are also found in the lagoons. These newly found boulders and table reef are formed by a process of wind drift. The green algae population is greater in areas close to the sewage outlets of processing industries than in healthy reef systems. *Pema virdis,* a rare component of the coral reef ecosystem, is densely distributed in Palk Bay. Six scieractinian coral species are recorded from the lagoon of Vellaperukkumanthai reef whereas Gopinadha Pillai has identified two *species (porities somaliensis* and *favia pallida)* from the lagoon (Table 1). Fishermen suggest that the sponge population and soft coral population have decreased over the past two decades. Our investigations also confirm an increase in the boring sponge species and a decrease in the macrosponge species.

The shoreward slope of the reef has a width of 70 m in the area between 230 m and 300 m from the shore. The coral population has been increasing remarkably in distribution and diversity along the shoreward slope. The 1969 record of Gopinadha Pillai shows 11 species in this area, however, present investigation shows 20 coral species with a density of 50 colonies/10m2. *Padina sp* and *Halimeda sp* are most common algae present in this zone. The sponge population is comparatively higher

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than in the lagoon. The coral species *Platygyra lamellina, Hydnophora sp, Galaxea fascicularis* and *Turbinaria pelata* recorded by Pillai (1969) are no longer present in Palk Bay (Table 1).

Table 1: Transect at vellaperukkumunai reef scleractinian distribution and diversity (east and present)

sl.	*Scieractinian* coral	la*	shs*	rc*	ss*	la	shs	rc	ss
1	*Porites somaliensis*	X	X				X		
2	*Favia pallida*	X	X	X		X	X	X	X
3	*Leptastrea transversa*		X	X			X		
4	*Cyphastrea microphthalma*		X						
5	*Favitos virens*		X				X		
6	*Leptastrea purpurea*		X						
7	*Porites lichen*		X				X		
8	*Acropora corymbosa*		X				X		
9	*Cyphastrea sp.*						X		
10	*Favia valenciennesii*		X			X	X		X
11	*Goniastrea pecinata*		X		X		X	X	
12	*Pocillopora damicomis*				X	X	X		X
13	*Montipora digitata*				X		X		X
14	*Montipora divaricafa*				X		X		X
15	*Acropora haimei*				X		X		X
16	*Monitipora foliosa*				X		X		X
17	*Acropora formosa*						X		
18	*Acropora valenciennes*						X		X
19	*Acropora indica*					X	X		X
20	*Acropora humilis*						X		
21	*Pocillopore brevicornis*						X		X
22	*Pavona varians*					X			
23	*Porites cornpressa*					X			
24	*Porites mannarensis*					X			
25	*Favia favus*						X	X	

* CS. Gopindha Pillal, 1969: la=lagoon-230 mts.depth:shs+shorewardslope-230 to 300 mts.: rc=reefcrest 300 to 350 mis.:ss=seawardslope-350 to 450 mts. depth

The reef crest area are exposed to sunlight during low tide for a very long period (maximum 7 hrs). Over exposure to sunlight leads to animal mortality and radiation

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infection. Thereby the animal population in this area is lower than in the other zones of the reef. Slopes of the reef crest area are densely populated by algal groups.

Gopinadha Pillai recorded all the ramose corals in the seaward slope of the reef. However, our present investigation shows that ramose corals are also distributed along the shoreward slope and lagoon. The present study indicates that 10 scleractinian species are present in the seaward slope, whereas the previous record (Gopinadha Pillai 1969) shows only 6 species (Table-I).

Fishermen, report the presence of the dugong and turtles are in Palk Bay. Awareness of the ecological and genetic significance of the coral reef and legislation's brought about by the Marine Park Authority have contributed to reduce the interest of fishermen in dugong and turtle fishing. Mollusc fishers report a reduction in mollusc capture over the decade.

Asir Ramesh (1966) expressed the opinion that Gulf of Mannar corals are healthier than the reef's of Palk Bay. The sick status of Palk Bay is because of the discharge of the processing industries and fish landings. Present data reveals that coral reef's of the Palk Bay are undergoing rejuvenation.

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BOBP's Approach to Integrated Coastal and Marine Resources Management

Kee-Chai CHONG

The Programme Coordinator of the BOBP discusses the approach and activities of the Programme during its third phase. (Condensed from a presentation at a recent Regional Workshop on Conservation and Sustainable Management of Coral Reefs in Chennai, India).

As we enter the next millennium, there is a need to look beyond conventional methods and approaches to management of dwindling natural resources and a degrading ecosystem that supports their regeneration and renewal. One of these approaches is to re-examine the professional perceptions and attitudes of fisheries planners. Why is it that each time fisheries planners make projections on fish consumption or demand for fish, their projections are invariably higher and higher. It is true that greater output is needed to feed a growing population, but per capita consumption levels must somehow be capped at a certain limit and not exceed it, In Japan, the per capita fish consumption is already well beyond 65 kg/capita/year, yet Japanese planners project higher and higher per capita increment in consumption. Similarly in Malaysia and Singapore, the per capita consumption is projected to increase when the present level is already 40-50 kg/capita per year.

Should not a cap on per capita consumption be considered? The reason is simple. Any consumption, whether of fish or any other food item, should have an upper threshold because any dietary intake in excess of body requirements is not only wasteful but probably injurious to health. It does not contribute nutritionally to human health and well being.

However the present approach to fisheries planning, generates unnecessary pressures on those concerned with fisheries production. They will devise all kinds of fishing technologies to achieve the projected growth in consumption through expanded production. Is there any wonder that our fish stocks are always under tremendous fishing pressure?

Fisheries planners should review the "projection approach to planning". They can work together with nutrition specialists to determine the dietary need for fish (e.g. minimum requirement) to maintain good health. To sustain resources, consumers should curb excessive indulgence--even on fish, which is nutritionally superior to other sources of protein.

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What is BOBP? The Bay of Bengal Programme (BOBP) is now 18 years old. It has gone through two earlier phases. We are presently in its third phase, which began in 1995 and goes on till the end of this century. The first phase was concerned with increasing productivity and production of the fisheries sector. The second phase dealt with the human factor, paying particular attention to the welfare of the fishing community -- improved standards of living and quality of life. The third phase shifted focus from expanded production and extension activities to management of the resources for sustainable production. The people, in particular the fisher-folk community, must be made aware that they cannot continue to take from Nature without at the same time giving back to Nature the means to sustain the renewable resources. Management intervention is therefore the driving force of the present phase.

When BOBP started in 1979, there were only a few million fisherfolk in the region. Today, there are more than seven million, with a total fishing community population of at least 35 million. These fisherfolk, especially the small-scale, limited-resource fisher-folk, suffer from a low standard of living. Many of their villages lack basic amenities. Their low literacy further inhibits them from obtaining the necessary information and assistance to better their lives.

Increasing population pressures in this region, especially among those living in abject poverty, have exacerbated these problems. The goal of the BOBP third phase, to serve as a catalyst for developing innovative participatory approaches and solutions to small-scale fisheries management, is a timely response to this need.

BOBP's Stakeholder Approach to Management

BOBP faces a situation in fisheries that, at first glance, holds two mutually conflicting demands. On the one hand, there is **a** definite need to increase the availability of fish as a source of protein to meet the needs of an increasing population and surging export demand. On the other hand, there is a crucial need to conserve the fast-dwindling fish resources of our member countries. BOBP's vision is to resolve these seemingly conflicting demands. It assists countries identify policies, actions and solutions that take a long-term perspective and promote resource sustainability, and also ensure livelihood security for fisher-folk. Thus, the programme meets both demands. This vision is reflected in BOBP's programme goals:

- Sustainable exploitation of fisheries resources through increased management awareness and
- development of management solutions in collaboration with fisherfolk, and government officials,
- not only in management and production but also in planning.

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- Equitable access (social and gender) to and use of aquatic resources for livelihood security.
- Promotion of integrated coastal area management to ensure sustainable use of coastal resources for future generations.

The third phase builds on the achievements and lessons of the earlier phases. The earlier phases prepared fisherfolk communities for the responsibility of participatory management expected and required by the third phase. Early activities during the third phase have found a fisherfolk population that is more aware of fisheries problems and has ideas to help solve them.

BOBP assists member countries introduce innovative approaches to institutionalize the participation of fisherfolk and other stakeholders to develop and implement workable measures to improve fisheries management. In sum, the third phase will help turn local concerns into action. The components of this third phase are:

- Building awareness and public opinion among fisheries stakeholders on fisheries management needs, benefits, options.
- Building the capacities of local fishing communities and national fisheries agencies to plan and carry out integrated fisheries management.
- Human resources planning and development.
- Providing technical assistance and other identified needs of member countries for implementation.

BOBP achieves this by:

- Working together with countries to identify coastal resources problems (situation analysis and stakeholder consultation and analysis).
- Getting all stakeholders identified to the discussion table.
- Making the fisherfolk's voice matter in fisheries management under the principle of "resource users as resource managers".
- Integrating the roles of women and youth in fisheries management.
- Acting as a catalytic and facilitating agent to help stakeholders come up with informed and comprehensive solution options to problems.
- Providing innovative ways to generate the financial means to implement solutions on a self-financing basis,

Programme Strategy

The third phase of BOBP centres on the following general strategic principles and activities:

- Reduction of excess or surplus fishing capacity to a level that can sustain fisheries resources, including development of alternative income-generating activities for fisherfolk to reduce their dependence on the sea and attract them out of fisheries.
- Creating awareness to instill in resource users a pride of ownership in the ideas and concepts of management.
- Re-examination of fishing technologies to determine whether those in use deplete living resources and impair resource habitat.
- Promotion of action-oriented projects that produce measurable positive effects and impact.
- Implementation of programme activities that reflect the opinions of the public involved in fisheries and coastal communities.
- Assumption of greater responsibility and leadership by BOBP's national counter-parts in project implementation.
- Encouraging governments to allocate human and financial resources for fisheries management.
- Coordination of national and regional information systems and exchanges.
- Integration of the environmental impacts of fishing practices and *vice-versa* into fisheries management decisions.
- Coordination and consultation in fisheries management decisions among national agencies with jurisdiction in the coastal zone.
- Establishment of a regional forum or mechanism to reduce fishing conflicts between member countries and minimize arrests of fisherfolk caught fishing illegally in the national waters of BOBP member and non-member countries.

National Activities in **Management and Early Impact**

Bangladesh

The Bangladesh Government had identified *two* highly stressed fisheries for BOBP's assistance in the context of conserving coastal fish resources and ensuring the sustainability of coastal fisheries. BOBP is assisting the Government to facilitate and enable improved management of the estuarine set bagnet (ESBN) and push net (PN) fisheries in selected coastal areas of Bangladesh, through awareness building, strengthening the institutional capacity of the agencies concerned and provision of technical

assistance. As poverty is widespread and endemic in coastal areas, efforts to attract fisherfolk out of overcrowded fisheries must be accompanied by other gainful means of employment or income-generating opportunities. Both GOs and NGOs are working with BOBP to address this basic requirement. As an example, the Programme has arranged for selected women fisherfolk to be trained in the production of boneless hilsa (Hilsa illisha) for export as each year about 25% of the hilsa run is lost because of the lack of market absorption capacity within the country. Management options such as gear substitution or outright ban, closed season or area are being looked into. This work is being contracted out to an active grassroots NGO which has previously worked in the communities.

India

The Union Government collaborates with BOBP to address integrated coastal fisheries management in two states (Tamil Nadu and Orissa) and integrated coastal aquaculture in two other states (Andhra Pradesh and West Bengal).

Stakeholder identification and consultation and stakeholder perception analysis were carried out systematically, and on an extensive scale. Preferred communication channels to reach them were also studied. A manual on stakeholder consultation and analysis has been prepared for widespread application. Preliminary results of the stakeholder analysis showed that fishermen would like to go further offshore to fish using different gear such as troll, gill net and longline which hitherto have not been tried out in offshore waters. As a result, limited training on commercial exploratory fishing, emphasizing design and methods, were carried out in the two states.

Guidelines for sustainable coastal aquaculture, in particular for shrimp, are being prepared with both scientific and stakeholder inputs. These guidelines emphasize water quality management, feed and feeding, group or cluster farming. The use of common effluent treatment ponds and common water reservoirs is being explored to minimize pollution and disease outbreak from haphazard discharge of pond effluent.

Indonesia

The Government of Indonesia is interested to evolve model fishing villages to undertake community-based fisheries management. The specific aims at present are to facilitate and enable improved management of mariculture, anchovy lift-net fishery and small-scale fisheries in the Tapian Nauli Bay area of North Sumatra Province, with BOBP support. The Government is intensifying public outreach programmes to spread awareness on the benefits of management, strengthen the local institutional capacity of concerned agencies and provide technical assistance. Long used to open access fishing, the fisherfolk are resisting efforts at managing their fisheries. They are not as receptive to new innovations in management as their counterparts in other countries. They are not confident about the proposed management measures in their area, given that enforcement is still weak.

Indonesian fisheries managers are trying to change fisherfolk's ingrained perceptions and attitudes by demonstrating to them that fisheries management works, and leads to rewards – improved catch rates, better prices, higher incomes.

Malaysia

As a pilot exercise in developing and testing methodologies and approaches, the Malaysian Government intends to focus on a marine protected area cum marine park that has been established in a chain of four uninhabited islands – Pulau Payar, Pulau Segantang, Pulau Lembu and Pulau Kaca near Langkawi island off the coast of Kedah and Perlis. The DOFM/BOBP project enables and facilitates sustainable coastal zone management. The management intervention is paying off, as fisheries in the area are recovering. For example, before the establishment of the marine protected area and park, anchovy fishing was limited to 3-4 months each year. Today, anchovy fishing is possible round the year. The park is also drawing growing numbers of visitors and generating valuable employment opportunities for local area fisherfolk as tour guides, boat operators and divers. In 1996 alone, there was a total of 90,307 visitors. This number is projected to grow. The fishing population is declining because fishermen are moving out of fisheries and into factories, resorts, hotels and the construction industry.

Maldives

In the Maldives, the Government is trying to enable the development of a model for participatory community-based, integrated reef resources management (IRRM). A pilot exercise focuses on Vaavu, Meemu, Faafu and Dhaalu atolls, through awareness building and consultation, strengthening the institutional capacity of concerned agencies and technical assistance. The Maldivian fishing community is very receptive to innovative management ideas as they fully understand the need for management and benefits to sustain the resources. An atoll community learning center is being set up to be the nucleus of such management intervention. A unique feature of the Maldives IRRM model is the active involvement of school children in its work. As awareness and community bonding are high, due in part to the nature of the island population, fisherfolk compliance with management measure is not problematic, in the Maldives. A Fisheries Advisory Committee, set up as a result of the MRS/BOBP Workshop on Integrated Reef Resources Management, provides policy guidelines and directs IRRM work in the country.

Sri Lanka

The government is very anxious to conserve critical aquatic habitats such as coral reefs, lagoons, mangroves, sea grass beds, coastal, estuarine and riverine systems, and ensure that resources utilization from such habitats is sustainable. In this context, the Government with the help of BOBP has embarked on improved management of the ornamental fish sector of Sri Lanka. The tools are awareness building, strengthening the institutional

capacity of concerned agencies and technical assistance. Ornamental fish identification guides, manuals and posters have been produced to assist customs officials to control and regulate the export of such fish, and educate divers about the ornamental fish that are endangered, or whose export is banned. Trade exhibitions and workshops on ornamental fish are regularly organised to educate the public about the value of this sub-sector to the national economy and the need for sustainable development.

Thailand

Phang Nga Bay is a microcosm of Thai fisheries. The Thai Government is keen on developing community-based management approaches by setting up marine protected areas, deploying village-based artificial reefs, and better enforcement through higher public awareness and participation. All this is being tried out in Phang Nga Bay. Regular bi-monthly public hearings are steadily bonding the different communities and bringing them together to solve their problems in their own way. For example, community spawning cages have been installed in strategic locations. Fisherfolk will place gravid female crabs in these cages and let them spawn, then sell the spent crabs. Community bonds are so strong that trawlers and push netters are now kept out of the Bay. In fact, trawl owners are financing the construction and installation of artificial reefs at the entrance of the Bay to ensure that their master fishermen or fishing boat captains do not encroach into Bay waters. A combination of extension activities and close monitoring, control and surveillance(MCS) from DOF patrol boats, has had its effect on push net operators – many of them have now given up this gear and substituted it with other gear such as gill net. The Department of Fisheries is demonstrating and handing out gill nets to these fisherfolk.

Why BOBP is unique

How is BOBP unique? While other organizations are pursuing new interests in the light of new trends in environmental management and resource sustainability, BOBP remains committed to its founding role in food production and poverty alleviation. Not only is it the only regional co-operative effort in the Bay of Bengal that facilitates coordination among countries on common small-scale fisheries issues and problems; but foremost for BOBP is its larger role in continuing to highlight the strategic importance of food production for the region's poor, whose livelihood relies heavily on the region's coastal and marine resources. While BOBP has continuously learned from and applied the latest trends and findings in fisheries, environmental and marine resources sciences, as well as policy analysis, to its programme and activities, it has steadfastly maintained its role and obligations to coastal fishing communities.

Effective cost-cutting strategies and measures are built into BOBP's objectives and management strategy. For instance, the programme emphasizes the application of solutions founded on a broad base of knowledge from a cross-section of stakeholders.

Tapping the experiences and expertise of all stakeholders and disciplines makes possible solutions that are holistic and efficient in design. Further, the acceptance of plans and solutions for implementation is achieved through consultation and consensus. When consensus-building proves difficult, a negotiation tack is taken to work out a settlement which all stakeholders are comfortable with. The latter may not be entirely satisfactory to each and every stakeholder group but is something they can live with. Such solutions are not only more meaningful but are also enduring.

Besides by encouraging participatory co-management, the government can transfer costs incurred in fisheries enforcement to the fishing communities themselves. The money saved can help protect and rehabilitate the resource habitat.

Small but imaginative funding is required for implementing the third phase, largely as seed money to initiate projects that will become self-financing over the long-term. The governments of member countries and donor agencies are co-funding individual projects that directly reach their ultimate beneficiaries, the small-scale fisherfolk. In fact, BOBP third phase projects have strong support for implementation from the fishing communities that were involved from the beginning in the problem-solving process. This ensures that the likelihood of success is high.

The Governments of each member country are prioritizing projects in coastal fisheries management for implementation with:

- Advisory inputs from BOBP.
- BOBP assistance in developing greater local capacity.
- Effective utilization of local capacity.

BOBP has advanced incrementally through successive programme generations, incorporating achievements and lessons learned into solid building blocks for its current phase. To kick-start implementation work during its third phase, the importance of co-funding by the governments of member countries and donor agencies, to make national execution possible, cannot be over-emphasized. This partnership has steadily borne fruit in the member countries.

Lastly, BOBP attaches great importance to information packaging and dissemination. It publishes a popular quarterly newsletter, *Bay of Bengal News;* it brings out working papers, technical reports, manuals and guides. It has organized video films and audio-visual materials on fisheries and its management. It communicates with fisherfolk communities through comic books, instruction books in local languages, radio programmes, art competitions and street plays. It maintains a well-equipped library to support research and provides a reference service for those who seek fisheries information about the Bay of Bengal region and beyond.

Trade in Corals

Fahmeeda Hanfee[1]

Corals are as important to the marine world as tropical rainforests arefor mammals. They provide excellent spawning and feeding grounds for fish and other marine species.

In India we have coralline areas either contiguous to the land or near to the shore in Gulf of Kutch and small portion of reef at Mandapam and this makes it easily approachable and more threatened.

Threats are many like :-

- Rapid lndustrialisation
- Biology (growth rate of hard coral is slow)
- Lack of knowledge/ proper legislation
- Oil pollution / siltation
- Fisheries, salt-pans, cement manufacture, chemical industries, navigational activities, oil-terminus etc.

It is well understood that coral reefs are vulnerable to several human activities and natural enemies such as *A. planci.* But the most important and neglected aspect at the same time is trade in corals

Generally, corals are collected for their skeleton alone, the living tissues are only rarely of direct value to humans. Some portion of the live corals is the result of increasing demand for aquarium trade.

Corals of commercial value are divided into 3 types:

- Hard corals
- Semi-precious corals and
- Precious corals

Domestic exploitation: Domestic exploitation is mainly for construction purposes.

(A) Hard corals are used as building materials, for

- road construction and building material Countries known to use corals in this way are SriLanka, Phillipines, Malaysia, Indonesia, Brazil, Maldives and India.
- production of lime, calcium-carbide and cement : In the islands where terrestrial sources of lime are limited corals are particularly heavily exploited.

[1] Fahrneeda Hanfee, Traffic-India C/o WWF for Nature New Delhi

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- other industrial purposes

TYPES OF CORALS IN TRADE

	CORALS INVOLVED	OUTLETS / PRODUCTS
HARD CORALS	Wide range of reef-building or reef-associated species from the order Scleractinia, (class Zooantharia), with a few species from the classes Hydrozoa (order Athecata) and Alcyonaria (orders Coenothecalia and Stolonifera).	s Collected by hand, snorkelling and divers. s Used whole cr cut into blocks for building. Crushed or broken for use as aggregate . e.g in road construction. • Broken and tired for production of lime • Cleaned and dried, and sold intact as curios and display items.
	Cirrhipathes spp. and *Antipathes* spp. from the order Antipatharia (class Ceriantipatharia).	• Live for aquaria. • Collected by hand by scuba diving. s Skeleton made into jewellery and curios.
SEMI-PRECIOUS (BLACK) CORALS	Mostly *Corallium spp.* from the class Alcyonaria (order-Gorgonacea	• Collected mainly with dredges (remotely controlled vehicles have been used); also by divers.
PRECIOUS CORALS		• Skeleton made into fine jewellery and carvings; also traditional medicinal uses.

Source : Sue Wells, 1992

(B) Curio collection

- Valued due to their un-usual shapes and attractive colors for souvenirs. Much of it is ultimately exported by tourists when they return home from countries like SriLanka, Seychelles, Hawaii, Philippines, Thailand etc.
- decorate houses and ornaments are made e.g. in Asia and middle-east, Black corals have traditionally been made into amulets which are worn to ward off evil spirits and diseases.
- aquarium trade: In India specially in West Bengal and other states having metro cities coral forms a major part of this trade.

(C) Chemical extraction

Sea-fans[2]* constitute the only known source of Prostoglandins and pharmaceutical industry. India has been exporting sea-fans under the head 'curio' for a long period and by the beginning of 1970's several countries started exporting them in bulk from India. The reason for large scale trade export was discovery of 'prostoglandins'. This triggered of a worldwide hunt for the species.

This 'wonder-drug' serves for many a systematic diseases. To meet the demand and increasing popularity India stepped up commercial expatiation and export during 1975 and now also the material is being exported in tons to countries like France, West-Germany, Belgium, USA. Netherlands to mention a few. (Thomas, 1997)

International trade in hard corals

In 1992, an international symposium on coral reefs, estimated that to date people have directly or indirectly caused the death of 5-10% of the world's living reefs. At this rate another 60% could be lost in the next 20-40 years.

A major destination for corals is the U.S.A which accounts for more than a 3rd of the world demand for coral reefs - says a worldwatch Institute report. Philippines is the main supplier to the International market and has exported unworked corals since the mid-1950's.

Table 1: US Imports of corals from India

U.S IMPORTS FROM INDIA	1983	1984	1985	1986	1987
Weight (tonnes)	0.5	0.1	40.6	62.9	-
Declared import value US$000	7	61	-	28	64

Table 2: India's Custom export for 'unworked coral' for 1978 - 82

1978	1t	1983	101
1979	5t	1984	51
1980	12t	1985	1t
1981	3t	1986	nil
1982	10t		

Black corals wore listed in App. II in 1981. To protect the most exploited stony corals, CITES parties listed another 17 genera on App.II in 1985.

[2] *Gorgonids (sea-fans) are a closely associated species which has similar biology as corals. It's exploitation directly effects the corals.

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Despite the ban exports have continued, and U.S is the largest consumer of raw coral. In 1986 it imported nearly 1,400 tons.

As can be seen from table 1 and 2, India is one of the main suppliers to U.S.A. The Indian custom's report records no export of corals in 1986, however, the USA has recorded imports from India of over 40 tons in 1985 and over 60 tons in 1986. That shows the illegal trade of corals from India in 1985-86 was about 100 tons. It is assumed that since then coral has been exported illegally. This shows the difficulty in controlling the trade. That are enforcement is unaware of this illegal trade and that this aspect is overlooked and neglected.

CORAL TRADE-constraints in control

The volume of coral trade is difficult to estimate and monitor because

1. Coral exploitation and trade are very hard to control, in part because it is often collected in offshore areas seldom patrolled by national authorities.
2. When raw coral enters the market, it is difficult and sometimes impossible to identify particular species.
3. Once coral is dried and processed, identification becomes even more difficult.
4. They are often combined with other goods or marine products (especially shells) in official customs statistics.
5. Mixed consignments of shells and corals are labeled as "shell" on trade permits and documents.
6. Where corals are included under a separate category, there are seldom any indications of the type involved.
7. Data cannot be compared and amount of trade cannot be assessed because in the annual reports of CITES, records are as 'pieces' and customs record the quantity by weight.
8. International trade statistics do not include domestic trade (souvenirs, other uses in the country of origin) Thus export / import figures cannot necessarily be equated with total exploitation.

Facts

- Approximately 700 species of reef building or reef-associated corals have been described but the numbers involved in trade is un-known.
- Of 200 known species of Black corals (semi-precious) about 10 are used for commercial production of jewelry, carvings and tourist souvenirs. The most commonly used is the unbranched whip-coral *(Cirrhipathes anguina)* from Indo-pacific region.

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- Of precious corals approximately there are 20 species and 6 are of commercial importance.
- Japan is the hub of precious coral market. It is world's largest black coral processing center and leading exporter of black and pink worked coral items.
- Japan imports unworked specimens, primarily from Taiwan, for domestic processing and exports worked corals to Italy and other European countries as well as Taiwan and India.
- Far-East is the leading center of precious coral processing. The supply in large part is from Taiwan . Japan and Philippines imports.
- Bulk of raw Black coral used in commercial processing comes from the Philippines. Whip coral *(Cirrhipathes anguina* an Indo-pacific species also makes up much of the international Black coral trade.
- At the height of the coral trade, in mid 1970's the Philippines exported over 1,980 tons in a single year. Out of which three quarters had gone to US.
- United States is the largest consumer of raw coral and in 1986 it imported nearly 1,400 tons.
- In 1986, Indonesia, Malaysia, Taiwan, Fiji and India, each exported over 50 tons of crude coral to the United States.
- In Yemen, crushed Tubipora is sold in spice shops.

Recommendations

- Basic research on trade is required. (no. of species involved, volume trade routes etc.
- International cooperation in research programs
- Strengthening Management and enforcement (closed seasons, closed and open areas for collection, minimum size limits, quotas)
- Fisheries departments should collect records of catch and effort for coral fisheries.
- Importing countries should introduce appropriate controls in order to respect the legislation of countries which have restricted/prohibited coral export.
- Countries should try where possible to provide a more detailed breakdown of imports and exports of corals, separate from marine curios.
- Awareness campaign at tourist spots, shops, airlines, tour-operators. hotels, resorts, marine park interpretive centers etc.

- Customs officials should be notified and efforts made to ensure that they have ready access to experts who can identify corals.
- Countries involved in trade should work with CITES to enhance coral identification tools and procedures to enable wildlife and customs inspectors to more readily and accurately check and record coral taxa in trade.

Conclusion

When after considerable international pressure coral exports from Philippines dropped, they had almost lost 70% of the coral reefs. Suddenly Indonesia began to increase its supplies to the world market. India may be the next victim if not legal export, illegal trade

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