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STUDIES ON THE STATUS OF CORAL REEFS AND SOME ASSOCIATED ORGANISMS IN GULF OF MANNAR BIOSPHERE RESERVE

K. Venkataraman and Ch Satyanarayan



ZOOLOGICAL SURVEY OF INDIA



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INTRODUCTION

The concept of Man and Biosphere Reserve (MAB) evolved during the 1st Intergovernmental "Biosphere Conference" in 1968. The Gulf of Mannar islands and neighbouring area was declared as marine biosphere Reserve by the Government of India on February 18, 1989. The Gulf of Mannar Biosphere Reserve (GoMBR) is expected to perform the following three functions, which are complementary and mutually reinforcing : a conservation function-to contribute to the conservation of landscapes, ecosystems, species and genetic variation; a development function-to foster economic and human development which is socio-culturally and ecologically sustainable; a logistic function-to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

The Biosphere reserves are organized into 3 interrelated zones: the core area, the buffer zone and the transition area.

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

The concept of Gulf of Mannar Biosphere Reserve provides a useful framework to guide and reinforce projects to enhance people's livelihoods and ensure environmental sustainability. The international recognition by UNESCO helps in raising the profile of the site and attracting resources for better management and in the improvement of socioeconomic status of the people living around GoMBR. GoMBR is governed through a soft statutory framework which allows flexibility in their management and establishment. GoMBR plays a very important role in the MAB goal of minimizing biodiversity loss through the use of ecological and biodiversity sciences in policy- and decision-making and promoting environmental sustainability. Biosphere reserves represent areas of representative terrestrial and

Keywords : Coral reefs, status, 2006, Gulf of Mannar Biosphere Reserve.

coastal ecosystems promoting solutions to reconcile the conservation of biodiversity through its equitable and sustainable use. They serve as 'living laboratories' for testing and demonstrating integrated management of land, water and biodiversity.

Rapid population growth and unsustainable exploitation of natural resources are putting tremendous pressures on planet's life support system. The concept of sustainable development to meet the needs of the present without compromising that of future generations is the key to the future of humans on the earth. This should be coupled with a holistic and interdisciplinary approach as well as a long term vision. The GoMBR is one of the living laboratories where new and optimal practices to manage nature and human activities can be tested and demonstrated. GoMBR offers unique venues and opportunities for raising awareness about the issues linked with cultural diversity and biodiversity. There is a need to fully explore and use the potential of these sites as learning laboratories for environmental education and education for sustainable development.

The Gulf of Mannar is one of the very few marine Biospheres Reserves in India. The Gulf of Mannar Biosphere Reserve covers an area of 1,050,000 hectares on the south-east coast of India across from Sri Lanka. It is one of the world's richest regions from a marine biodiversity perspective. The biosphere reserve comprises 21 islands with estuaries, beaches and forests of the near shore environment,

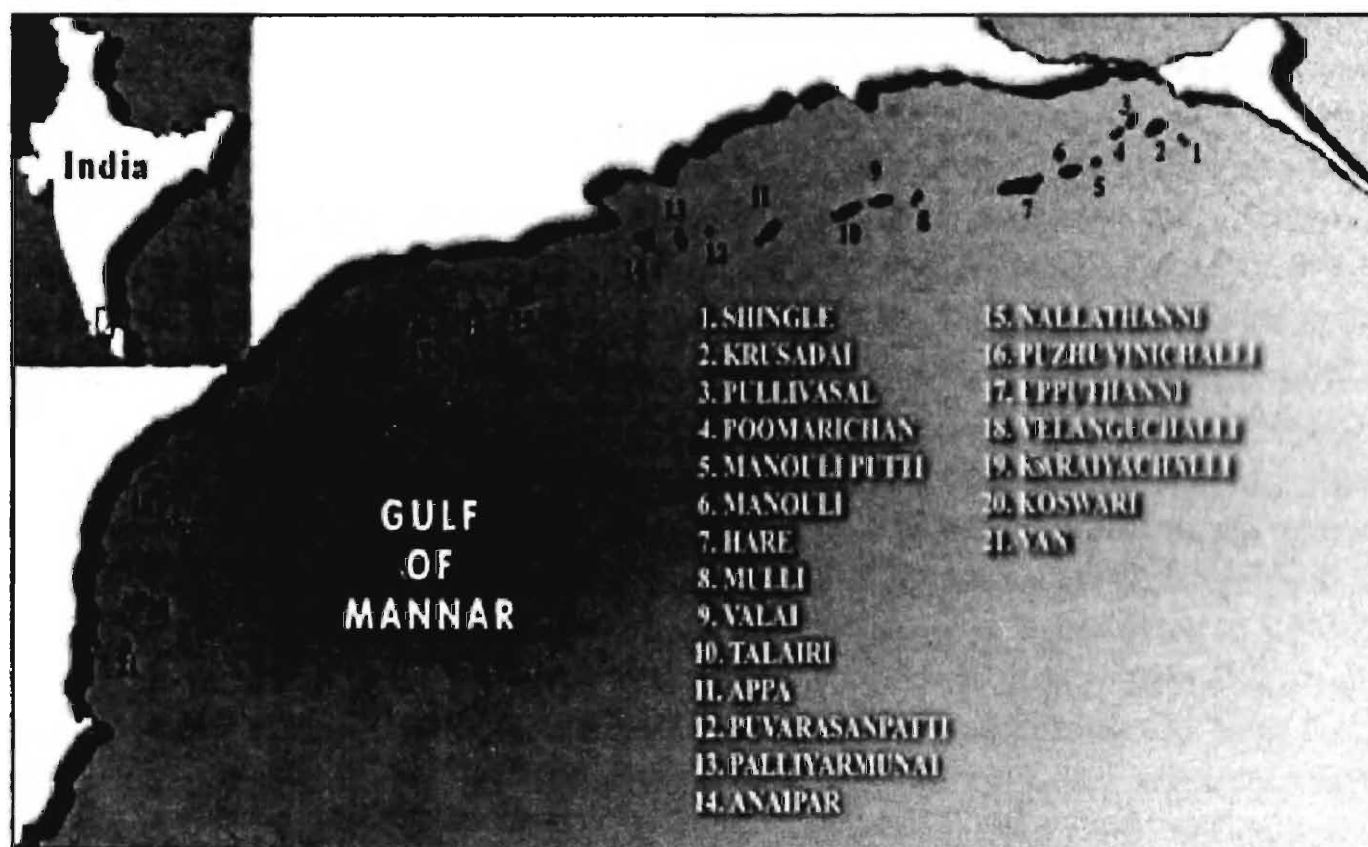


Fig. 1 : Map showing the location of 21 islands of Gulf of Mannar Biosphere Reserve.

including a marine component with algal communities, sea grasses, coral reefs, salt marshes and mangroves (Fig. 1). They are arranged in the form of a chain between 8°46' and 9°14' N Latitude and 78°9' and 79°14' Key words : Coral reefs, status, 2006, Gulf of Mannar Biosphere Reserve. E Longitude from Mandapam in the north to Tuticorin in the south. This area is remarkable for its faunal and floral wealth, especially one of the world's most diverse ecosystems, the coral reefs and its associates (Thurston, 1890, 1895, Graveley, 1927 and Pillai, 1996).

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

The Global Environmental Facility (GEF) provided support to the establishment of the Biosphere Reserve, including the setting up and functioning of the Gulf of Mannar Biosphere Reserve Trust, which is responsible for the coordination of the management plan for the Biosphere Reserve in association with Government agencies, private entrepreneurs, and local people's representatives.

Typically coral reefs contain number of specialized species representing almost all groups of marine animals. The holes and crevices in the reefs provide abundant shelter for fishes and invertebrates and are important for fish nurseries. The reefs of GoMBR have a variety of seaweeds, plenty of sacred chanks, (*Turbinella pyrum*), butterfly chanks, pipefishes, sea horses, pearl oyster, corals and gorgonid, the famous sea cow (*Dugong dugon*) and the balanoglossus (*Ptychodera flauva*).

Of the approximate 600,000 km² of coral reef worldwide, it is estimated that about 10 percent have already been degraded beyond recovery and another 30 percent are likely to decline significantly within the next 20 years (Wilkinson, 2000). Wilkinson (2000) noted that all Indo-Malayan reefs, except for those in Australia are in critical or threatened condition—categories applied to reefs that are likely to collapse within the next 40 years, if conservation and management measures are not properly implemented. Only fringing and patch reefs are present in the intertidal regions of GoMBR. The lagoon (the area between the coral reef and the shore) in these islands is shallow, and can be waded during low tides. The intertidal region of Gulf of Mannar islands is sandy and muddy.

The ever-increasing human pressure on the coastal zone to meet the needs of the growing coastal population has resulted in the rapid decline of biodiversity and biomass of the coastal ecosystems worldwide.

Although many have documented the richness of this area qualitatively, a long term monitoring data on the status of fauna and flora of this biosphere reserve, which is very much needed for effective conservation and management of this unique ecosystem is lacking. Therefore, the present study on the status of the coral reefs has been conducted in all the 21 islands of GoMBR.

MATERIAL AND METHODS

Depending upon the proximity to a major town, the 21 islands of GoMBR were divided into three groups, each group consisting of seven islands (Mandapam, Keelakarai and Tuticorin) (Fig. 1). The present study was carried out in different phases from 2002-2005. In the first phase seven islands of Mandapam group of GoMBR starting from Shingle Island in the north to Hare Island in the south were surveyed keeping Mandapam as base camp. In the second phase another seven islands belonging to Keelakarai group from Mulli Island in the north to Anaipar Island in the south were surveyed. The remaining seven islands belonging to Tuticorin group starting from Nallathanni Island in the north to Van Island in the south were surveyed. During the survey the status and inventory of some coral associated organisms were also conducted. The occurrence of coral reefs of Gulf of Mannar Islands are not continuous and are mostly patchy and table in nature as well as situated very close to the island shoreline (Fig. 2 and 3).



Fig. 2 : Patchy coral reefs around the littoral region of Shingle Island.

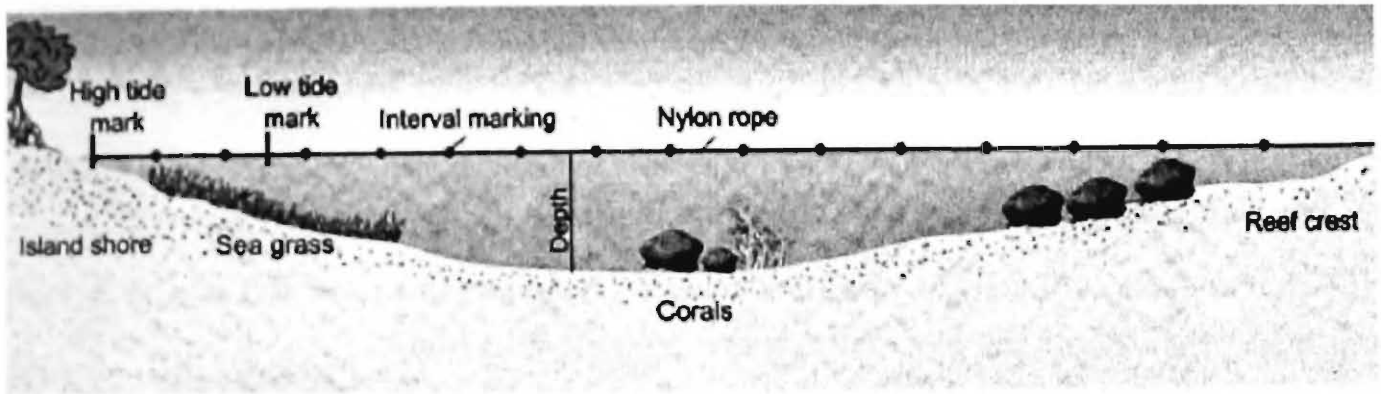


Fig. 3 : Schematic representation of a reef in Gulf of Mannar Islands.

Every status study begins with the “Manta tow” method before finally laying the 50 m Line Intercept Transect (LIT) mostly to find out the location of the coral reef, sea grass bed and general nature of the intertidal region. After confirming the location of the reef area with live corals a 50 m transect (LIT) was laid using a 50 m plastic tape using iron nails as hold. Underwater slates were used to collect data using snorkeling equipment, the intercepts of live and dead corals were noted down. The same procedure was repeated in all the islands of GoMBR.

Major Reef Zones of Gulf of Mannar coral reefs

A reef may include the following zones (not all zones are found on all reefs of Gulf of Mannar) (Fig. 4) :

Back Reef : The portion towards the landward side of the reef crest.

Reef Crest : The shallow portion that separates the fore and back reef areas.

Reef flat : A platform of coral fragments and sand that may be exposed to low tide.

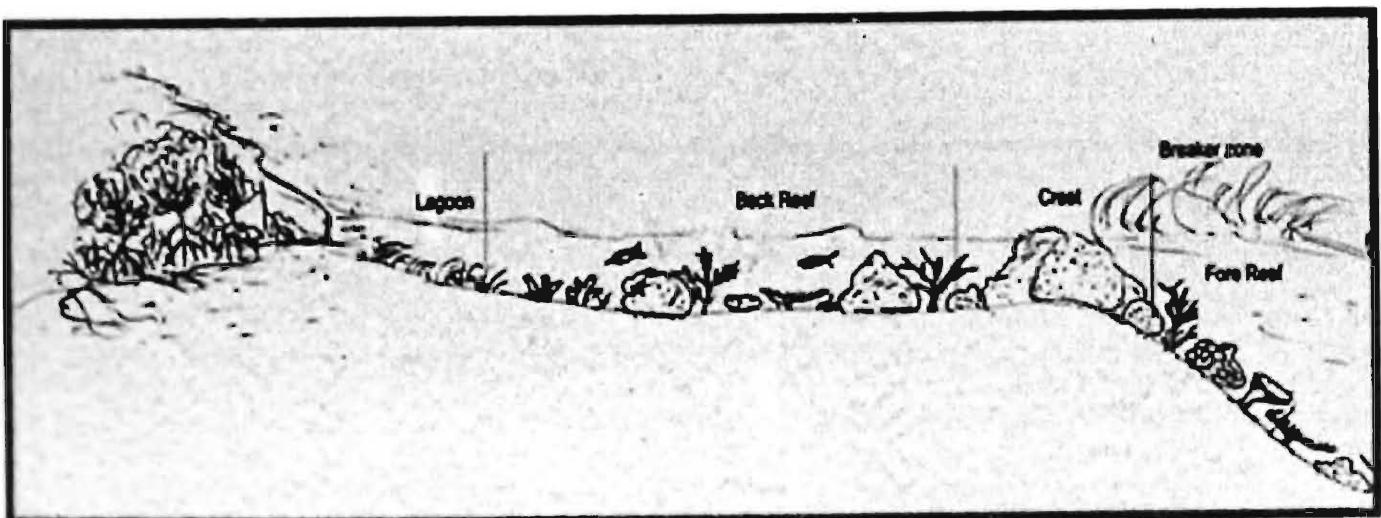


Fig. 4 : Different Reef Zones identified in Gulf of Mannar coral reefs Monitoring the Status of Coral Reefs of Gulf of Mannar.

Breaker zone : The area most exposed to breaking waves, often dominated by branching coral.

Fore reef : Area seaward of the reef crest may include a buttress region dominated by boulder coral (coral "spurs" alternating with sand channels, or "grooves").

Coral reefs are the most complex marine ecosystems on earth, and it is not practical to study all the associated reef's animals and plants.

The following techniques for coral reef status by English *et al.* (1997) were followed in this study. The methodology of the techniques is as follows :

Manta tow Survey

The Manta tow Survey was used to assess broad temporal and spatial changes in the benthic communities of coral reefs. It enabled visual assessment of large areas of reef of Gulf of Mannar within a short time (Fig. 5). Based on this technique the status study site was selected.

The following are the prerequisites used for Manta tow Survey :

- A country boat fitted with an outboard motor.
- A polyethylene rope attached to the towing board.
- The manta board (Fig. 6) with two indented handgrips positioned towards each corner of the front of the board and a hand hold at the central back position.
- Map of the reef to be surveyed.

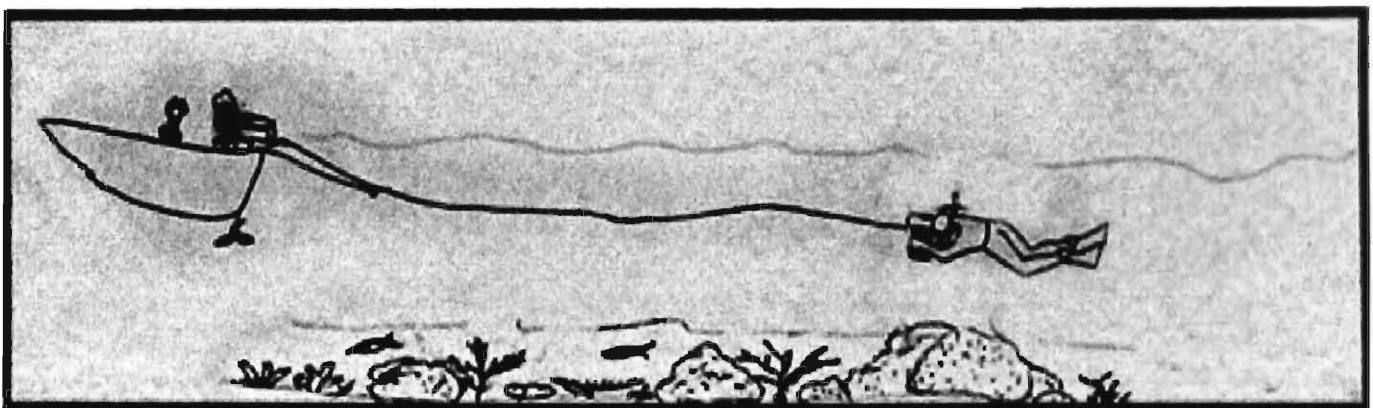


Fig. 5 : Broad scale Manta tow survey using Manta board in Gulf of Mannar Islands.

- GPS, a pencil attached with a twine to the board and a waterproof pen.
- Snorkeling equipment.

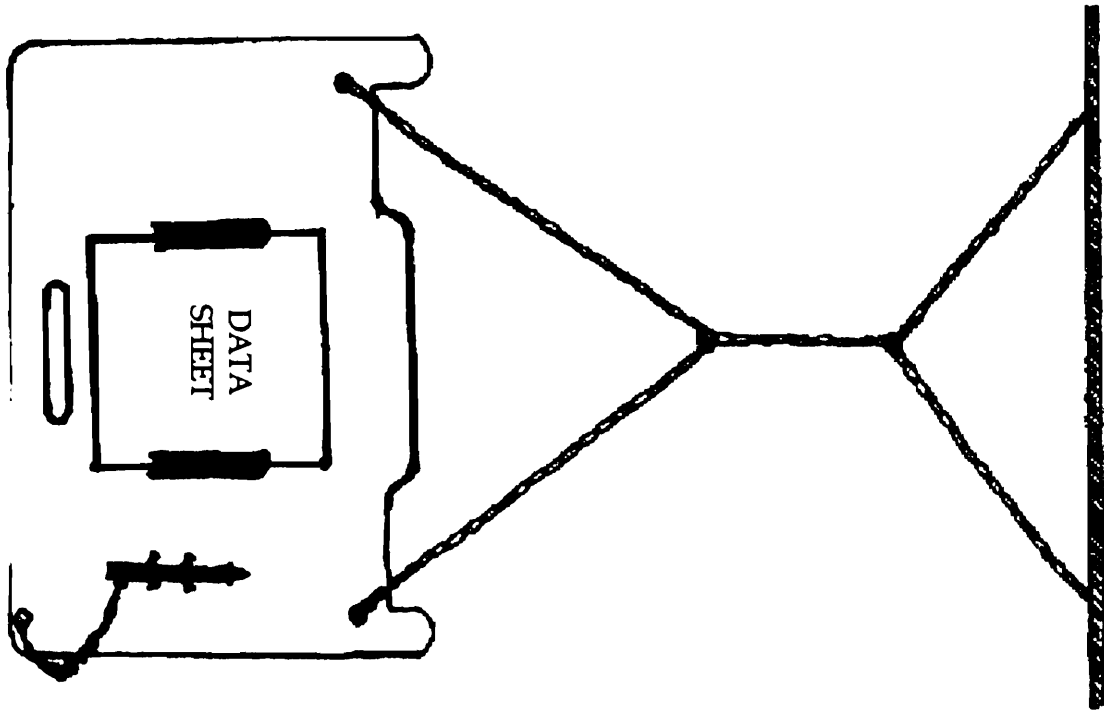


Fig. 6 : A sample Manta Board for the survey.

The Manta tow technique used in the present study involved towing an observer, with a manta board, behind a small country boat powered by an outboard motor to survey the margin of the reef. Tows were carried out and the coral reef site was identified. Additional information such as sand and rubble, sea grass and the presence of associated organisms was noted. Tow was continued around the islands for identification of many survey sites.

Line Intercept Transect Technique (LIT)

Line intercept transects technique (Fig. 7) was used to assess the status of benthic coral reef community. This technique categorized the reef community as life form categories and also based on morphological variability. The LIT technique helped us to assess the health and status of a coral reef community. LIT not only gave a picture of the coral reef community structure but also the percentage of dead corals, rubbles and silt present in the reef area. Mostly the LIT surveys were performed parallel to the shore to record data from uniform depth. The LIT surveys have been performed by snorkeling (in shallow reefs areas).

The following were the prerequisites followed in the LIT study :

- A 50 m-fibre glass measuring tape with hooks attached to its end.

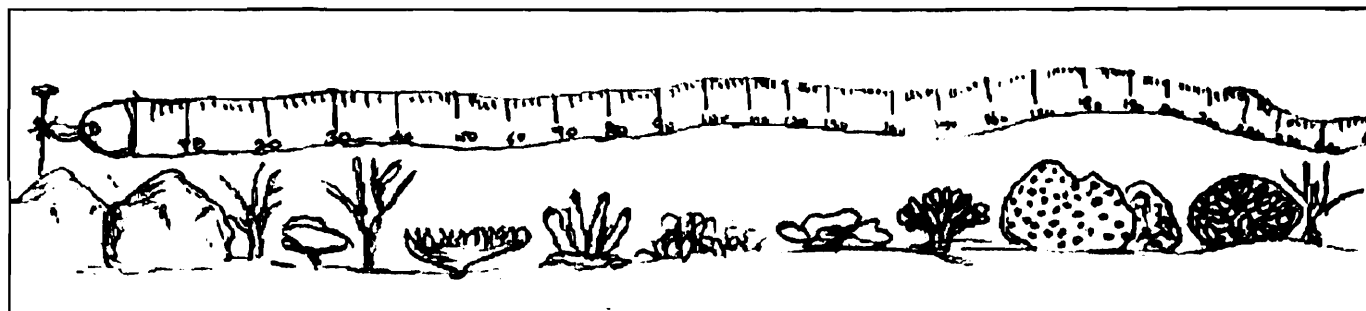


Fig. 7 : Status study with Line Intercept Transect (LIT) method in Gulf of Mannar coral reefs.

- Underwater slate, A4 underwater sheet (printed data sheet), GPS and a Pencil attached with a twine to the slate.
- Snorkeling gear.
- Plastic Clips.
- Water quality test kit.

For LIT studies initially coral reef sites were selected based on a general survey using Manta tow technique. Usually two sites were chosen, one on the fore reef and the other on the back reef. In each site at least three to five replicate transects of 20 m were laid in two depth profiles. Transects were laid in such a way that they follow the contour of the reef. The tape was pegged with plastic clips at regular intervals to hold it intact in position. About 31 life form categories under 11 groups were followed in the LIT method used (Table-1). All the life form for coral reef was categorized with code for easy remembrance and for data collection. After the lay of the tape, data was collected by snorkeling over the tape on a data sheet (Table-2). The ambient environmental parameters were recorded before beginning of each survey.

Table-1 : Codes used in the present study for life form categories (English *et al.*, 1997)

| | Categories | Code | Notes/Remarks |
|-----------------------|------------|------|---|
| Hard coral | | | |
| Dead coral | | DC | Recently dead, white to dirty white |
| Dead coral with algae | | DCA | This coral is stranding, skeletal structure can still be seen |
| Acropora | Branching | ACB | At least 2° branching, e.g. <i>Acropora palmata</i> , <i>A.formosa</i> |
| | Encrusting | ACE | Usually the base-plate of immature <i>Acropora</i> forms, e.g. <i>A. palifera</i> |
| | Submassive | ACS | Robust with knob or wedge-like for e.g., <i>A.palifera</i> |

Table-1 : Contd.

| | Categories | Code | Notes/Remarks |
|--------------------|------------------|------|--|
| | Digitate | ACD | No 2° branching, typically like <i>A.humilis</i> |
| | Tabular | ACT | Horizontal flattened plates e.g. <i>A.hyacinthus</i> |
| Non-Acropora | Branching | CB | At least 2° branching eg., <i>Seriatopora hystrix</i> |
| | Encrusting | CE | Major portion attached to substratum as a laminar plate e.g. <i>Porites spp.</i> |
| | Foliose | CF | Coral attached to one or more points, leaf-like, or plate like appearance e.g. <i>Montipora aequituberculata</i> |
| | Massive | CM | Solid boulder or mound e.g. <i>Platygyra daedalea</i> |
| | Submassive | CS | Tends to form small columns, knobs, or wedges e.g. <i>Porites lichen</i> , <i>Psammacora digitata</i> |
| | Mushroom | CMR | Solitary, free-living corals of the Fungia |
| | Heliopora | CHL | Blue coral |
| | Millepora | CME | Fire coral |
| | Tubipora | CTU | Organ-pipe coral, <i>Tubipora musica</i> |
| Other Fauna | | | |
| Soft coral | | SC | Soft bodied corals |
| Sponges | | SP | |
| Zoanthids | | ZO | Examples are <i>Platythoa</i> , <i>Protoplatythoa</i> |
| Others | | OT | Ascidians, anemones, gorgonians, giant clams, etc., |
| Algae | Algae assemblage | AA | Consists of more than one species |
| | Coralline algae | CA | |
| | <i>Halimeda</i> | HA | |
| | Macroalgae | MA | Weedy/fleshy browns, reds, etc., |
| | Turf algae | TA | Lush filamentous algae, often found inside damselfish territories |
| Abiotic | Sand | S | - |
| | Rubble | R | Unconsolidated coral fragments |
| | Slit | SI | - |
| | Water | WA | Fissures deeper than 50 cm |
| | Rock | RCK | - |
| Others | | DDD | Missing data |

Table 2 : Data Sheet used for conducting the LIT studies in Gulf of Mannar**LINE INTERCEPT TRANSECT DATA**

Location : Krusasdai Is.....Sample ID :.....IN_01.....Reef Name : Galaxea reef.....Reef Zone.....Back ReefLat.....Long.....Time : 5.30 AM.. Wind : normal.....Cloud...clear.....Turbidity.....pH : 8.3.....Temeprature : 26C.....Salinity : 35 ppt.. Depth : 5m.....Tide : high.....Surveyor's Name

| Sl. No. | Transition (cm) | Field Code | Notes |
|---------|-----------------|------------|----------------------------|
| 1. | 25 | DCA | |
| 2. | 36 | ACT | <i>Acropora hyacinthus</i> |
| 3. | 52 | DCA | |
| 4. | 68 | CM 1 | <i>Favia favius</i> |
| 5. | 80 | DCA | |
| 6. | 94 | CM 2 | <i>Porites lutea</i> |

$$\text{Percent cover Life form category 1} = \frac{\text{Total Length of Category 1}}{\text{Length of Transect}} \times 100$$

$$\text{Percent cover Life form Category 2} = \frac{\text{Total Length of Category 2}}{\text{Length of Transect}} \times 100$$

$$\text{Percent cover} = \frac{\text{Total Length of Category}}{\text{Length of Transect}} \times 100$$

Data collection and analysis

- The accuracy in the number of occurrences of the each life form was ensured and the life forms were recorded in a way by marking CM as CM1 and CM 2 and by linking the both on the data sheet.
- Coral species were identified and noted in the data sheet along with other associated organisms present.
- The percentage cover of the life was calculated using a simple formula :

Belt transect

Belt transects cover a larger area per census than stationary counts and are considered most useful for counting patchily-distributed species (Fig. 8). They can be conducted along the permanent transects marked with survey stakes or other markers, or along reef transects that are randomly selected at each time. Belt transect method is suitable for assessing fish and invertebrates populations.

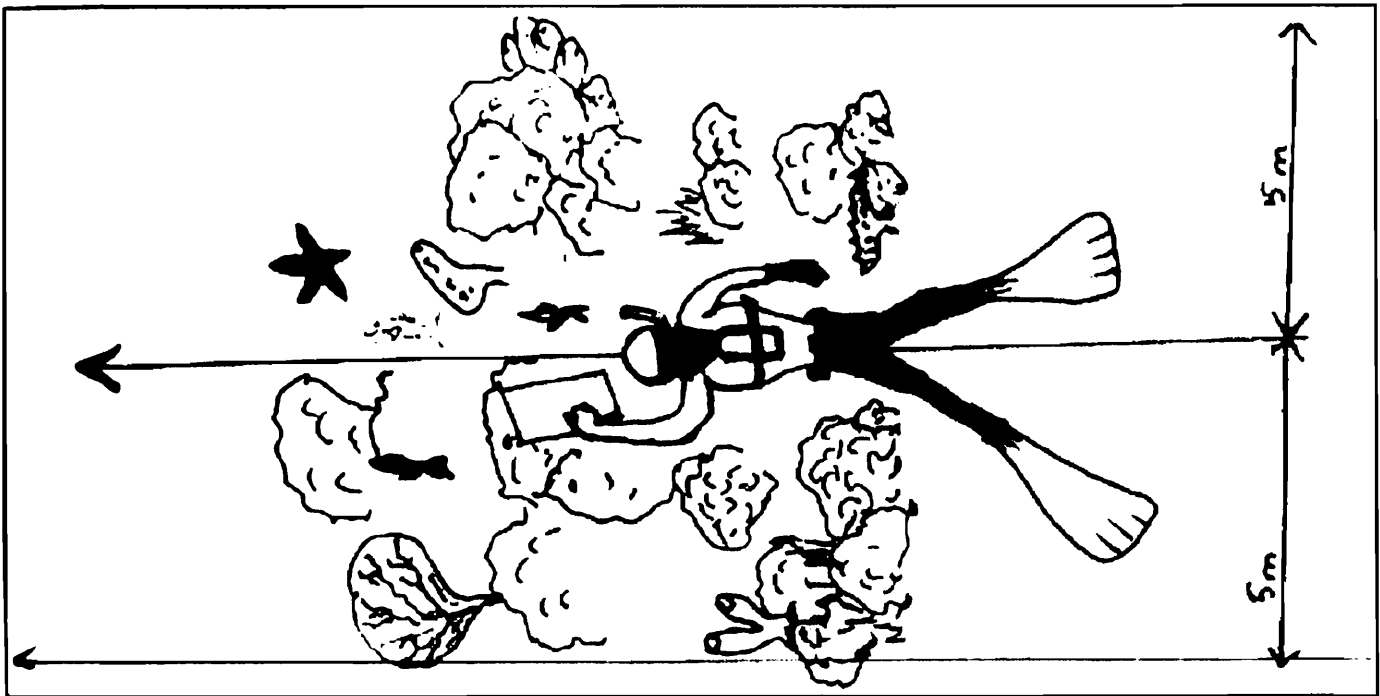


Fig. 8 : The methodology of Belt transect study in Gulf of Mannar.

Prerequisites for belt transect studies in Gulf of Mannar coral reefs :

- A 50 m tape with hook attached to its end.
- GPS, A4 size underwater data sheet, underwater slate, pencil attached with twine to the slate and a waterproof marker pen.
- Snorkeling gear.

At each site on a reef, at least 3 transects were laid for 50 m length at each of the two different depths. The transect lines included the benthic life form transects whenever both benthic life forms are surveyed at the same reef. Each transect were separated by 10 to 20 m. Thus, 3 replicates provide a total census area of 750 m² at each depth. Each transect is surveyed as a complete 50 × 5 m belt.

Quadrat

The term “quadrat” generally refers to square or rectangular sampling unit (Fig. 9) within which organisms are counted or measured, or to the frame, which marks this area. Quadrats were used to estimate percent cover of reef components and information about density, abundance, diversity and colony size.

One- meter square quadrats were used in the present study. Quadrats were randomly placed over the coral reef area to obtain general data on reef conditions. Quadrats were also used along transects by placing the frame on alternate sides along the transect line.

The following are the prerequisites for the study :

- PVC pipes with holes, bent and nylon rope.

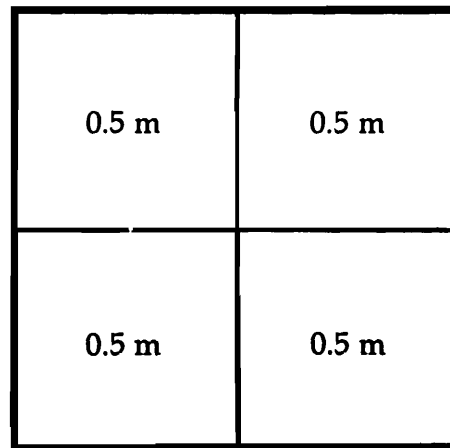


Fig. 9 : A model of Quadrat transect used in the study.

- A 4 size underwater sheets, underwater slate, GPS, pencil tied with twine and a waterproof marker pen.

A suitable site was selected and quadrats were laid at equal intervals. The area covered by the coral/associated species was recorded in percentage.

Data Collection and Analysis : The study area such as Gulf of Mannar coral reefs with relatively few species and little live coral and plant cover, quadrat studies were made in the field by counting the number of squares (or partial squares) covered by each species and recording these numbers as shown on the sample data sheet (Table-3).

Table-3 : Quadrat sample data sheet.

| Quadrant No. 3 | Percentage |
|---------------------|------------|
| <i>A. Formosa</i> | 4.0 |
| <i>A. rudis</i> | 2.0 |
| <i>P. decussata</i> | 1.0 |
| <i>F. pallida</i> | 6.3 |
| <i>F. abdita</i> | 0.7 |
| <i>T. peltata</i> | 10.0 |
| <i>S. sidereal</i> | 8.8 |
| <i>M. annularis</i> | 5.0 |
| Macroalgae | 20.0 |
| Rubble | 42.2 |

If the quadrats contain several species and more live cover, to reduce the likelihood of error, you can record the data square by square on a grid written on your underwater slate, and tally the squares after the dive.

From the data in the above example, you can calculate the number of coral species (5), and the total live coral cover (38%) by adding the numbers of squares occupied by each coral species ($1 + 0.7 + 4.0 + 2.0 + 6.3 + 5.0 + 10 + 8.8 = 38$); space occupied by algae and sand are not calculated for live coral cover).

Frequency and density : You can calculate the "frequency" of a species by counting the number of quadrats in which the species is observed and dividing by the total number of quadrats. The "density" is the number of different species or colonies found within a given area, usually per square meter. It is important to remember that the number of coral colonies can be independent of species diversity and coral cover. For example, a cyclone that causes significant mortality (loss of cover) may bring about an increase in the number of coral colonies because of fragmentation, but entirely different percent cover.

RESULTS

The following seven islands, which are located close to Mandapam town, were categorised as Mandapam group of islands *viz.* 1. Shingle, 2. Krusadai, 3. Pullivasal, 4. Poomarichan, 5. Manauliputti, 6. Manauli and 7. Muyal or Hare Island.

1. *Shingle Island* : The Shingle Island is situated near Pamban ($9^{\circ}15'$ Lat. and $79^{\circ}14'$ E Long.) and has an area of 13 ha. This island was composed of coral rubbles on the reef patch. Extensive coral reefs were found on the northeastern side as well as on the eastern side of the island. LIT were laid on the eastern side and on the northeastern side of the island.

2. *Krusadai Island* : Krusadai Island ($9^{\circ}14'$ N Lat. and $79^{\circ}13'$ E Long.) is situated near the Mandapam and Pamban of Rameswaram Island. The coral reefs in the island and the shallow lagoon between the reef and the shore formed excellent sites for collection of various kinds of flora and fauna. The southeast side of the Krusadai Island is called "Galaxea Reef" This reef was composed of dead corals with holes and crevices covered with seaweeds and algal growth. The coral reefs on the western part of the southern side contained luxuriant growth of corals and during the study period it was in critical condition.

3. *Pullivasal Island* : This Island ($9^{\circ}14'$ N Lat. and $79^{\circ}11'$ E Long.) spreads over an area of 30 ha. The coral reefs were found only in southern shore and it extended to about 300 m from the shore. During the low tide, the coral reefs were exposed and the most dominant coral species present was *Montipora* sp. Most of the exposed reefs were dead. The present observation revealed that all the *Montipora* sp. found are bleached, and the reef contains mostly dead corals.

4. *Poomarichan Island* : The Poomarichan Island is also called as Pulli Island ($9^{\circ}14'$ N Lat. and $79^{\circ}11'$ E Long.) and it covers an area of 17 ha. Coral reefs were found

only on the southern, western and northern side of the island. In the southern side dead coral beds were observed and in the northern part of western side different types of live corals were present. The coral reef in the western part of northern side appeared to be good in live coral cover when compared to the other parts of the island.

5. *Manauliputti Island* (New Islets) : This island ($9^{\circ}13'$ N Lat. And $79^{\circ}7'$ E Long.) covers an area of 0.34 ha. The coral reefs were observed on the eastern side of the island 650 m from the shore to the sea and cover an area of 6 sq km.

6. *Manauli Island* : Among all the islands Manauli Island exhibited more diversity among the corals. This island ($9^{\circ}14'$ N Lat. And $79^{\circ}7'$ E Long.) covers an area of 26 ha. Extensive reefs occurred on the northern side of the Manauli Island. It was exposed during low tide and a small stretch of sandy shore formed in between the Manauli Island and Manauliputti Island. LITs were laid on northern side of the island.

7. *Hare Island* : Hare Island is the largest island in the Gulf of Mannar and is also called as "Muyal Tivu" This island ($9^{\circ}12'$ N Lat. and $79^{\circ}5'$ E Long.) spreads over an area of 129 ha. Extensive coral reefs were found in the southern and northern side. LITs were laid on the western and eastern side of the island.

The following seven islands, which are situated close to Keelakarai, were categorised as Keelakarai group of islands viz. 1. Mulli, 2. Valai, 3. Thalyari 4. Appa, 5. Poovarasanpatti, 6. Palliyarmunai, and 7. Anaipar. A patch of coral reefs present close to the Keelakarai coast was also surveyed during the present study ($9^{\circ}14'$ Lat. and $78^{\circ}47'$ Long.). The coral reefs in the eastern part (near the custom house) were dead due to the dumping of municipal waste and sewage discharge. The corals in this coast were mostly dead and the dead corals were covered by the dense algal growth.

8. *Mulli Island* : It is situated 10 km away from Keelakarai (main land) at $9^{\circ}11'$ N Lat. $78^{\circ}56'$ E Long., covers an area of 10.2 ha. Extensive reefs were found on the North Eastern side of the island. Two LIT were laid on the north eastern and southern side of the island.

9. *Valai Island* : This island is located 10 km away from Keelakarai at $9^{\circ}11'$ N Lat. $78^{\circ}56'$ E Long. and covers an area of 10.10 hectares. Extensive reefs were found on the Eastern side of the island. Two LIT were laid to measure the coral reef cover in this area. The first transect laid on the South Eastern part of the Valai Island revealed a dead reef formed by rubble and the remaining dead coral with a cover of algae (*Caulerpa*, *Sargassum*, *Padina*, *Gelidella*, *Gracilaria* and *Turbinaria*) species.

Halimeda sp. was also seen growing as pockets. The eastern side was covered with one fourth sand and almost dead submassive coral. Live coral covers represented by *Pocillopora damicornis*, *Porites solida* and *Montipora digitata*.

10. *Thalaiyari Island* : Thalaiyari Island is the second largest island in the Keelakarai group of islands. It is situated 10 km away from Keelakarai at 9°11' N Lat. 78°54' E Long. and covers an area of 75.15 ha. Two LIT were laid on the southern side of the island. Although more than half of the reef is covered by Dead coral, nearly one fourth was occupied by the massive corals such as *Goniastrea retiformis*, *Goniopora* sp. and *Pavona decussata* and the other live corals covered in the LIT are *Favites abdita* and *Echinopora lamellosa*.

11. *Appa Island* : It is situated at 9°09' N Lat. 78°49' E Long., 8 km away from Keelakarai, and covers an area of 28.63 ha. Due to its high elevation and indiscriminate exploitation of weeds around, the Northern shore of this island was eroded. Reefs were found on the South Eastern part of the island. Three LIT were laid in the reef area. In the first transect, the dominant life form was DC contributing 18.4% followed by the sub massive coral (*Montipora digitata*). Other live corals present in this area were *Porites solida* and *Coscinaraea monile*. The live corals recorded in this island were *Montipora divaricata*, *Goniastrea retiformis*, *Porites lichen* and *Porites solida*.

12. *Poovarasampatti island* : This island is situated at 9°09' N Lat. and 78°49'E Long. and 9 km away from Keelakarai. The reefs rarely got exposed at low tide. An observation made on this island revealed the presence of growing weeds and grasses with associated Holothurian and Hermit crab fauna.

13. *Palliyarmunai island* : This Island with an area of 6.72 ha is situated at 9°09' N Lat. 78°44' E Long. lies 9 km away from Keelakarai. Extensive reefs were found on the Southern part of the island. Three transects were laid on the Southern part of this island. In the first transect the Dead Coral was dominated by branching and digitate forms. Massive Corals *Porites solida*, *Porites mannarensis* and *Favia pallida* were the only living forms available in this island. A few sponges were also seen among the reef associates with a few holothurians. The only species comprising the live coral cover was *Goniastrea retiformis*, *Porites solida*, *Pavona decussata* and *Pachyseris* sp. *Halimeda* sp. as well as *Caulerpa*, *Padina* and *Turbinaria* were also found on the dead corals. The presence of *Porites solida* confirmed its wide distribution in this area; along with the other massive coral such as *Goniastrea retiformis*. Another live coral found abundantly in this island was *Echinopora lamellosa*.

14. *Anaipar island* : This island is located 9 km away from Keelakarai at 9°09' N Lat. 78°42'E Long. covers an area of 11 ha. It exhibited more diversity and vast

expanse of live corals on its Northern side. Northern side of the island was dominated with all other live forms for the first time in the present study. Other than *Acropora* species *Porites solida*, *Goniastrea retiformis*, *Favites abdita* and *Favia pallida* were present in this island. Some areas are dominated with foliose coral *Montipora foliosa* in the front side followed by digitate corals *Acropora* spp. *Goniastrea pectinata*, *Acropora* sp. (tabular), *Montipora divaricata*, *Pavona decussata*, *Goniastrea pectinata* and *Porites solida* were often found on the coral reef on this island.

The following seven islands, which are situated close to Tuticorin town, were categorised as Tuticorin group of islands viz. 1. Nallathanni, 2. Puzhuvunnichalli, 3. Upputhanni, 4. Velanguchalli, 5. Karaichalli, 6. Kasuwar and 7. Van.

15. *Nallathanni Island* : This Island is the largest in the Tuticorin group of islands and second largest in the whole of Gulf of Mannar, covering an area of 101 ha. It is situated close to a fishing village called Munthal at 9°06' N Lat and 78°35' E Long. Big trees of *Tamarind*, *Ficus*, *Thespesia* were found in the island along with Palm and Coconut trees. Reefs were found all around this island especially on the Southern and Northern side. Among the live corals, massive corals such as *Goniastrea pectinata*, *Goniastrea retiformis*, *Porites solida*, *Favites* sp. and *Hydnophora* sp. were abundant in this island. Foliose coral *Turbinaria peltata*, *Acropora* sp, *Goniastrea pectinata*, *Goniastrea retiformis*, *Porites solida*, *Platygyra* sp., *Leptoria phrygia*. and Sea anemone are the other living form found in the present study. Macro algae *Turbinaria* sp. as well as calcareous algae was found in addition to the turf algae grown on corals.

16. *Puzhuvunnichalli Island* : It is located at 9°06' N Lat. and 78°35' E Long. The area is 6.12 ha and the circumference is 1372 m. It is 18 km from Vembar. This island has a good sandy beach, and thick vegetation. This island was surrounded by live coral reef all around except for a small gap on the eastern side. The following corals such as *Acropora* sp. (branching form), *Acropora* sp. (tabular form), *Porites* sp., *Montipora digitata*, *Montipora foliosa*, *Goniastrea* sp., *Favia fava* and *Favia* sp. were recorded from this island. *Gracilaria* sp., *Turbinaria* sp. and turf algae were the macro algae forms found on the dead corals.

17. *Upputhanni Island* : It is located at 9°05' N Lat and 78°30' E Long. The area is 22.94 ha and the circumference is 2292 m. It is 8 km from Vembar. It is a big sandy island with plenty of coral rubbles all over. Fringing reefs were found in the mid-eastern portion surrounding south up to the western middle portion at a distance of 150 to 300 m from the island. In the northern side major portion of the area was covered by dead corals dominated by *Acropora* sp. (tabular forms), followed by *Acropora* sp. (branching forms), other dead corals mostly covered by turf algae were massive *Porites* sp. and *Montipora foliosa*. Other algal forms found on dead corals were *Gracilaria* sp. and *Turbinaria* sp.

18. *Velanguchalli Island* : It is located at 8°56' N Lat. and 78°15' E Long. The area is 0.95 ha, and the circumference is 614 m. It is 15 km away from Tuticorin. This island is submerged 2-3 m below water. Isolated patches of thin reef of corals along southeastern side of the island were found.

19. *Karaichalli Island* : It is located at 8°52' N Lat. and 78°13' E Long. The area is 16.46 ha and the circumference is 1610 m. Recently some portion of the island has been eroded and the area has become 12.70 ha. It is 15 km from Tuticorin. It is a sandy island, thickly set with bushes in the center and western side. The whole island is covered with grasses and small shrubs. There was small reef along the island at a distance of 500 m to 1 km from the shore. Two transects, one on the eastern side and the other on the northern side was laid. Much of the intertidal region was occupied with sand with sea grass assemblages comprised of sea grasses such as *Halodule univerris*, and *Enhalus* sp. Dead *Acropora* branching forms, *Acropora tabular* forms and *Montipora foliosa*, *Goniastrea retiformis*, *Montipora foliosa* and *Montipora digitata* were also reported from this island. Poor representation of live coral forms and Rubble strewn around the island indicated the major human disturbances happening in this island. Few new young colonies of *Favia favius* and *Acropora* sp., were also seen in the island. On the northeastern side of the island not even a single live coral was found.

20. *Kasuwar Island* : It is located at 8°52' N Lat. and 78°13' E Long. The area is 19.50 and the circumference is 2160 m. Symptoms of recent erosion were observed and the area of this island has become 15 ha. It is 7 km away from Tuticorin. This island is found with small sand mounds and bushes here and there. The whole island is covered with xerophytic vegetation. Coral reefs were found at the southwest corner of the island at a distance of 500 m. The eastern side was covered by sand, sand with grasses such as *Halodule unnervis* and *Enhalus* sp. Close to this area diving up to 4-fathom depth revealed the presence of scattered live corals represented by *Favites abdita*, *Favia favius*, *Goniastrea* sp. and *Goniopora* sp.

21. *Van Island* : It is located at 8°50' N Lat. and 78°13' E Long. The area is 16.0 ha and the circumference is 2015 m. It is 6 km away from Tuticorin. This island is covered with some vegetation of low bushes mostly grasses and xerophytic plants. Fringing reefs were present on the eastern side of the island at a distance of 500 m. The southern side of the island was covered with a mixture of rubble and sand with macro algal forms such as *Caulerpa* sp., *Gracilaria* sp. and *Padina* sp. as well as a few individuals of *Holothuria atra* and a single *Stoichactis* sp.

The present study revealed the status of coral reefs of Mandapam, Keelakarai and Tuticorin Group of Islands (Fig. 10). Mandapam group of islands showed rich

coral cover (except massive coral species of *Porites* and *Favia* which is the maximum in Keelakarai groups of islands) when compared to Keelakarai and Tuticorin group of Islands. Species diversity was also more in Mandapam and Keelakarai group than the Tuticorin group. The reduction in coral species diversity in the Tuticorin group may be due to human activities such as over exploitation of reef resources, oil spill by fishing boats, lethal chemicals discharged from the coastal industries. Among the Tuticorin group of islands, the Nallathanni and Puzhuvinchalli had maximum live coral cover, and are far away from the Tuticorin town. The branching forms of hard corals recorded in three groups of Gulf of Mannar islands during the study period were *Acropora formosa*, *A. rudis*, *A. austera*, *A. florida*, *A. samoensis*, *Montipora digitata* and *Pocillopora damicornis*.

Status of Coral reef associates of Gulf of Mannar

Gulf of Mannar is an inlet of Indian Ocean located between south-eastern India and western Sri Lanka. The Gulf is 130-275 km wide and 160 km in length. The Palk Bay on the north of Gulf of Mannar is about 64-137 km wide and 137 km long which includes several islands of Sri Lanka. The Palk Bay and Gulf of Mannar sprawling over an area of 10,500 sq km (8°35'N latitude and 78°8'E longitude). This area is biologically rich and highly productive seas of the world and their biodiversity is considered globally significant. Gulf of Mannar includes 21 islands located between Rameswaram and Tuticorin covering an area of 623 ha which have been declared as Marine Park by Ministry of Environment and Forests, Government of India and Tamil Nadu State Forest Department. As many as 133 species of corals and its reef of fringing and patchy type are present at 5 m depth around the islands. About 3600 species of flora and fauna have been recorded in this area. This area also harbours rare and endangered species of sea turtles, dolphins, sea cows and whales. Gulf of Mannar produces about 20% of the marine fish catch in Tamil Nadu. More than 600 species of fishes recorded from Gulf of Mannar, out of them 72 species are commercially important and its fishery production gradually increased from 55,300 t in the year 1992 to 2,05,700 t in 2001 (NEERI, 2004). Apart from fishes, non-conventional fishing represented by pearls, chanks, seaweeds, ornamental shells and holothurians. The connective link between invertebrate and vertebrate such as Hemichordate, Cephalochordate and Urochordate has been recorded mostly around the islands of Gulf of Mannar. Approximately 300-400 species of green, brown, red and blue-green algae and seagrasses were recorded from this area. Whereas in Palk Bay a total of 42 species of green algae, 31 species of brown algae, 69 species of red algae, 5 species of blue-green algae and 13 species of seagrass were recorded. In addition, predominance of mangrove vegetation by *Avicennia* sp. and *Rhizophora* sp. are reported in few islands of Gulf of Mannar.

The faunal diversity of GoMBR coral reefs revealed the maximum number of species. The following are the different groups of fauna with their diversity such as soft corals 28 + species, gorgonids 15 +, sponges 275 +, fishes 551 +, molluscs 310, echinoderms 100, crustaceans 93 +, polychaetes 18 +, seagrass 13, algae 302 species (Venkataraman *et al.*, 2002). The Gulf of Mannar coastline is 170 km long and the reef area occupies 94 sq km. 47 fishing coastal villages have been identified depending on the coral reef resources and their population is 50,000 (2002 senses). A little over 5000 fishing trawlers and 300 trap fishers are engaged in fishing. Catch rate of reef fishes and the mode of marketing are not known.

An inventory of fauna of an ecosystem depicts the health of the ecosystem and status of individual organisms in that ecosystem. It helps in preparing effective managerial strategies to conserve that particular ecosystem and its threatened fauna.

The means and methods of disturbances to which some of the representatives of Cnidarians, Arthropods, Molluscs, Echinoderms, Hemichordates, Pisces, Reptiles and Mammals are subjected, the existing legislation and conservation efforts taken and suggested are given below and strategies are suggested for the effective conservation of the fauna of the Gulf of Mannar.

1. *Porifera* : At least 108 species of sponges belonging to Desmospongia are reported from this area (Thomas, 1986). A reduction in the abundance of the sponge species is noticed when compared to the first survey undertaken during 1988. Sponges in the GoMBR even though not exploited commercially are vulnerable due to bottom trawling, Habitat destruction is caused by coral mining, Trampling in the reef areas to collect fauna and flora, and to some extent scientific collections to extract bioactive substances does occur but bottom trawling is the major threat. As an example a sponge identified as *Cinachyra cavernosa* collected from the Tuticorin fish landing center found to shelter more than a dozen juvenile shrimps and crabs. This had been dislodged by a trawl net thus putting an end to the group of animals along with the host.

2. *Gorgonaceae* : The most severely affected invertebrate group in GoMBR reefs is Gorgonaceae. Their status is very very poor, This group is commercially threatened. Within a short span of time, this group has almost dwindled to extinction. Other causes for its decline are habitat destruction and scientific collections. In 1987, 15 species were recorded from this area (Thomas and George, 1987). They are the source of the prostaglandin drug used in numerous medical treatments (Thomas and George, 1987) and since 1975, six years after the drugs discovery four forms (black, red, flower and monkey tail) have been exploited for export, the GoMBR being at that time the only location where gorgonids could be found in fishable numbers.

Studies carried out during 1984 already showed a drastic decline in the catch. The maximum quantity exported amounted to 21.8t in 1976 but this declined to a minimum of only 134 kg in 1992, a clear indication of the reduction of this valuable resource (Thomas, 1996). A total of 106 tons were exported between 1975 and 1992 (MPEDA statistics of marine product export 1983-1992) (Thomas, 1996). The Gorgonids were exported to France, Germany, Belgium, USA and Netherlands. Four species *Gorgonella umbraculum*, *Echinomuricea indica*, *Heterogorgia flabellum*, *Echinogorgia complexa* have almost disappeared because of indiscriminate commercial exploitation. Now only two species *Solenocaulon tortuosum* and *Suberogorgia suberosa* are found in a few places. The export was stopped from 1992 onwards. Conservatively pruning only the rim of colonies, without disturbing the base has been suggested as a sustainable harvesting method which would allow replenishment (Thomas, 1996).

3. *Soft corals* : The present study reports the occurrence of seven species of soft corals in Gulf of Mannar Islands. Line intercept transect studies at Valai (Keelakarai Group) and Nallathani Island (Tuticorin Group) shows the occurrence of 12% soft corals in the intertidal region of the study area. The percentage occurrence of other life form categories in GoMBR islands are dead coral with algae (DCA) 56%, dead coral (DC) 5%, coral massive (CM) 13%, coral sub-massive (CS) 2%, sand (S) 9%, sand and rubble (S/R) 3%, others (OT) (sponges) 12% and soft corals 12% (Fig. 10). Dominant species of soft coral recorded are *Sarcophyton elegans* and *Sarcophyton trocheliphorum* in Nallathani Island. Other than the Nallathani Island the soft coral abundance was noticed only in Valai Island. The most abundant species of soft coral observed in Gulf of Mannar islands are *Sarcophyton crassocaule*, *Sarcophyton glaucum*, *Sarcophyton trocheliphorum*, *Lobophytum crassum* and *Lobophytum latilobatum*. The most common species recorded in the present study are *Sarcophyton elegans* and *Lobophytum sarcophytoides*.

The present survey shows that the percentage occurrence of soft corals in Tuticorin group of Island is comparatively lower than the other groups in Gulf of Mannar. Intensive studies are needed to explain the reasons for the high percentage of soft corals in this island. However, lesser human pressure and favorable conditions for growth of these soft corals may be attributed to the high occurrence. Possible reasons for the scarcity and low diversity of soft corals in Tuticorin group may be due to intensive coral mining, coastal erosion and pollution. Jayasree and Parulekar (1997) reported that the most abundant and dominant species in Gulf of Mannar is *Sinularia dissecta* and *Sinularia leptoclados*. In the present survey however, *Sarcophyton crassocaule*, *Sarcophyton glaucum* and *Sarcophyton trocheliphorum*, *Lobophytum crassum*, *Lobophytum*

latilobatum is abundant (Table-4). The present study shows some variation in abundance and diversity of soft corals in Gulf of Mannar with in a gap of five years from the earlier study by Jayasree and Parulekar (1997). Overall results of the present study indicate the dwindling of soft corals in this island, which is probably attributed to the high level of human pressure and coastal pollution in the study area.

Table 4 : Occurrence of species of soft corals in the Nallathanni Island.

| Species | Occurrence |
|-----------------------------------|------------|
| <i>Sarcophyton crassocaule</i> | + |
| <i>Sarcophyton elegans</i> | ** |
| <i>Sarcophyton glaucum</i> | + |
| <i>Sarcophyton trocheliphorum</i> | + |
| <i>Lobophytum crassum</i> | + |
| <i>Lobophytum sarcophytoides</i> | ** |
| <i>Lobophytum latilobatum</i> | + |

+ = Abundant; ** = common

4. Crustaceans : Twenty four species of prawns, 106 species of brachyuran crabs and six species of lobsters are reported from this area. A decline in their abundance is noticed in the landings due to over exploitation. This group is also commercially threatened and its present status is moderate. Among the 24 species of prawns *Penaeus semisulcatus* is the most sought after species. Out of 106 species of crabs only 10 species are commercially important. One, the mud crab *Scylla serrata* and all the species of lobsters are exported alive to Singapore and Hong Kong because of their protein value. All these groups are commercially overexploited and show a declining trend in their abundance. Even the non-commercial species of crabs in the reefs are declining. On Manauli Island where the mean density of brachyuran crabs was formerly between 31.0 and 42.5 per m³ five years ago (Jeyabaskaran and Ajmal Khan, 1998) the density is now below 10 per m³ because of habitat destruction. Mass mortality of these crabs due to bleaching is also reported (Jeyabaskaran and Venkataraman 2000).

Annually 2600 tons of prawns were fished from the GoMBR waters (Devraj, 1998) *Penaeus semisulcatus* the major contributor is facing over exploitation due to the operation of improved methods to catch this valuable bioresource. Habitat destruction due to destructive fishing methods is the other reason for the drastic decline in their abundance. Even two ends of a boat are used as trawling ends in

the shallow areas to catch this living resource. Juvenile *Penaeus semisulcatus* (45 to 70 mm) were also harvested at the rate of 2 to 10 kg per unit effort with an average annual effort of 2500 units, yielding an annual total of about 4800t. If allowed to reach marketable size the juvenile stock would have contributed 72,000 t (Devraj, 1996). The catches of the sand lobster *Thenus orientalis* and the rock lobster *Panulirus* sp. also exhibit continuing declining trends (Devraj, 1996). The following strategies are suggested for the sustainable utilisation of crustaceans (Devraj, 1996).

1. Restriction on fishing effort.
2. Imposition of closed seasons for fishing.
3. Cod-end mesh regulations for fishing nets, and
4. Restriction on capturing juveniles from nursery grounds.

5. *Gastropods* : Molluscs are commercially threatened in the Gulf of Mannar. They are widely used as source of food, for lime, pearl, decorative shells for the shell handicraft trade, raw material for the carbide industry and constituent for medical preparations. In the Gulf of Mannar the shells are mostly used for decorative and shell handicraft trade. The status of Gastropods is very poor. 178 species were recorded previously but the collections reported in the recent surveys are only 119 species. Among gastropods the sacred chank, *Turbinella pyrum* occupies a special cultural status. This sinisterly shell commonly called a *Valampuri chank* are highly priced for its rarity depending on its size. Bangles are also manufactured from these shells. Annually chank landing in this region varies from 1 million to 1.5 million even after a ban on the chank fishery imposed by the State Government (Appukuttan, 1996). Many species of gastropods are also being tried for the extraction of bioactive substances. The other reason for the reduction in the diversity of the gastropods is the destruction of their habitat.

Strategies suggested for the conservation of this group (Appukuttan, 1996) include :

- Restriction on professional and scientific collection of species.
- Ban on exploitation of breeding stock.
- Practice of farming.

Along with *Turbinaria pyrum*, Lambis, many *Murex* and *Cyprea* sps. are fished out indiscriminately for ornamental and decorative purposes. Some *Murex* sps. *Turbo* sps. and *Cerithids* are also being exploited for lime.

6. *Bivalves* : In the GoMBR 156 species of bivalves were previously recorded. The status is moderate with the commercial exploitation of only a few species.

Those that are commercially exploited are all threatened due to overexploitation. Once the Gulf of Mannar was very well known for its pearl fishery. 6 species of pearl oysters are recorded (Devaraj, 1998), one, *Pinctada fucata* which contributed to the natural pearl fishery has been fished to extinction not only because of its exploitation but also due to destruction of its natural environment by the trawlers, which disturb the bottom regularly causing continuous interruption to the settling spat now the fishery was reduced to a culture fishery in some areas of the GoMBR. Scientific collections are also being made for research on bioactive substances.

A ban on the pearl fishery is already imposed, with restrictions on professional and scientific collecting. Farming of commercially important species has been suggested. The green mussel *Perna viridis*, clams *Metrix* spp. and the common Indian edible oyster *Crassostrea madrasensis* are exploited for edible purposes.

7. *Echinoderms* : Echinoderm biodiversity was previously recorded as Crinoids, 9; Asteroids, 26; Ophiuroids, 19; Echinoids, 19; and Holothuroids, 22; (James, 1986). A detailed account about the status of holothurians are given here since they are included in Schedule III of Wildlife protection Act, 1972 and are overexploited than any other coral associate in this reef region.

Sea cucumber is also known as "kadal attai" in Tamil, "trepang" in Malay, "tripang or teripang" in Indonesian. The dried product is known as beche-de-mer in French and English. This product has been in demand in China since ancient times. It is considered delicacy and becomes tradition for festive occasions in most south Asian countries and in countries where ethnic Chinese communities exist. Beche-de-mer is consumed in a re-hydrated form exclusively by the Chinese. It is reputed to have favorable medical and strengthening properties. In Japan the intestine, gonad, and longitudinal muscle of sea cucumber are also processed into high-priced delicacy products. In 1985 Hong Kong imported dried sea cucumber around 6209 mt and re-exported 5008 mt leaving about 1200 mt for domestic consumption. It is interesting to note that those countries supplying products with a high average value experienced a severe drop in demand, particularly Japan dropped from fifth place in 1981 with 25.9 mt to 11th place in 1984 and down further to 13th place in 1985. The Philippines and Indonesia still be a lead in supplying some 80 per cent of the total imports over the years. The low average price and readily available volume are partly explaining their popularity. Products from these countries are re-exported after re-processing. The annual domestic consumption is in the region of 80-100 mt. In 1984, Singapore imported about 590 mt and re-exports 779 mt. It is obvious that the re-export volume of beche-de-mer exceeded the import. This cannot be explained solely by carry-over stocks. The export statistics are fairly accurate

considering identical figures found in the Hong Kong import and the Singaporean export statistics. The Singaporean import statistics of the beche-de-mer are rather sparse because of the way the Singaporean Customs Department classified the product. The beche-de-mer does not carry any import duty in the Republic and as such does not have to be specified in shipment papers. Consequently, it is often imported under the category of dried sea foods. From the media and from the Directorate Revenue Intelligence records that India (Chennai) is the major port from where the sea cucumbers are exported to Singapore. The Philippines has been the largest supplier to Singapore market. Other major suppliers are India, Sri Lanka and Malaysia. New Caledonia is a new exporter which moved to second place behind the Philippines. It is obvious that Indonesia which proximity to Singapore with frequent transport links, both surface and air transport, does not appear in the supplier list to Singapore market.

Food value : Holothurians are a delicacy in China, Japan and Korea. The Japanese and Koreans consume sea cucumber *Stichopus japonicus* in raw condition and they eat gonad, body wall and intestine of this animal. The Chinese consume only processed sea cucumber and they preferred only a body wall as delicacy. The product of sea cucumber is protein enriched and low fat content. Din (1987) worked on *Holothuria scabra* in Egyptian red sea showed that the *beche-de-mer* has nutritive values of protein 43%, fat 2%, moisture 27%, minerals 21%, and insoluble ash 7%.

Pharmaceutical value : The sea cucumber has aphrodisiac qualities which has undoubtedly enhanced its popularity. The product derived from sea cucumber is used as a medicine for high blood pressure, muscular disorder and also recommended for cholesterol problems. The soup made out of *beche-de-mer* is believed to possess certain curative properties for whooping cough, bronchial inflammation and respiratory disorders (James, 1998).

Sea cucumbers are echinoderms exploited in India for export market outside the country. Sea cucumbers are fished for the preparation of beche-de-mer that is exported mostly to other countries. Markets for beche-de-mer are concentrated within Asia. According to the FAO's annual statistics for 1984, the world echinoderm harvest in 1983 amounted to approximately 80,000 t. Hong Kong and Singapore are the main centers for the distribution of the beche-de-mer. From export statistics, it became apparent that both centers procure service from different zones. Singapore spread its spear of influence primarily in the west, while Hong Kong has its major links in countries in the south and its neighboring countries. The above two centers are not only limited to the physical movement of the product, but also performed certain functions to upgrade and add value to the product. These include grading, cleaning, drying and packing.

Exploitation of Sea Cucumbers in India

Sea cucumber harvesting is a traditional activity in India. Since ancient time people exploited and exported sea cucumbers to south East Asian countries regularly. This activity developed progressively from early nineties. After reaching significant tonnage in the late 80's, official beche-de-mer exports showed a significant decline.

In 1989 India exported 51.50 t of *Beche-de-mer* valued about Rs. 123 lakhs. Some of the companies in Singapore, Hong Kong, Thailand, Malaysia and Philippines are interested to import 10 t every month. Hong Kong is the foremost country in the world by importing 5000 to 6000 t of *Beche-de-mer* every year. India chiefly exports the processed sea cucumber to Singapore. The *Beche-de-mer* is further processed to add the value of the product at Singapore and sending them to Hong Kong and Chinese markets (James, 1993). Table 5 shows the data on the *Beche-de-mer* collected Gulf of Mannar and exported during the period between 1979 and 1986.

Table-5 : Size-wise export of *Beche-de-mer* from India (values expressed in tonnes)

| Year | Size range | | | | Total |
|-----------|------------|------------|------------|-----------|-------|
| | 4-6 inches | 3-4 inches | 2-3 inches | >2 inches | |
| 1979-1980 | 7.03 | 13.99 | 18.30 | 2.18 | 41.50 |
| 1980-1981 | 4.76 | 9.33 | 15.87 | 3.50 | 33.46 |
| 1981-1982 | 2.05 | 6.99 | 45.68 | 13.37 | 68.09 |
| 1982-1983 | 3.60 | 19.19 | 22.37 | 2.91 | 48.07 |
| 1983-1984 | 3.05 | 22.64 | 39.02 | 15.50 | 80.21 |
| 1984-1985 | 2.85 | 12.55 | — | — | 15.40 |
| 1985-1986 | 2.12 | 8.77 | — | — | 10.89 |

Source : MPEDA Regional Office, Chennai.

Beach-De-Mer Industry in India

The process of making raw sea cucumber to *Beche-de-mer* was introduced in India by Chinese in ancient times. Processing methods for *Beche-de-mer* believed to have been initiated by Chinese traders, include six stages: boiling, slitting the dorsal side, second boiling, gutting, smoke drying, and sun drying. These procedures vary according to the species processed. Processing considerably reduces the length and weight of the sea cucumber, and the final product weight is about 10% of the original weight (Durairaj *et al.*, 1984). The Indian *Beche-de-mer* industry is more than 1000 years old (Hornell, 1917). Palk Bay and Gulf of Mannar with their potential

sea cucumber resources, supported the *Beche-de-mer* industry in India. The industry has grown tremendously due to the attractive price and increasing demand for *Beche-de-mer* in the international market. In the year 1980s and 1990s, the industry has generated considerable foreign exchange of our country (Nithyanandan, 2003). However, the overexploitation result the depletion of holothurians population, leads to the conservation measures and ultimately halted this industry in India.

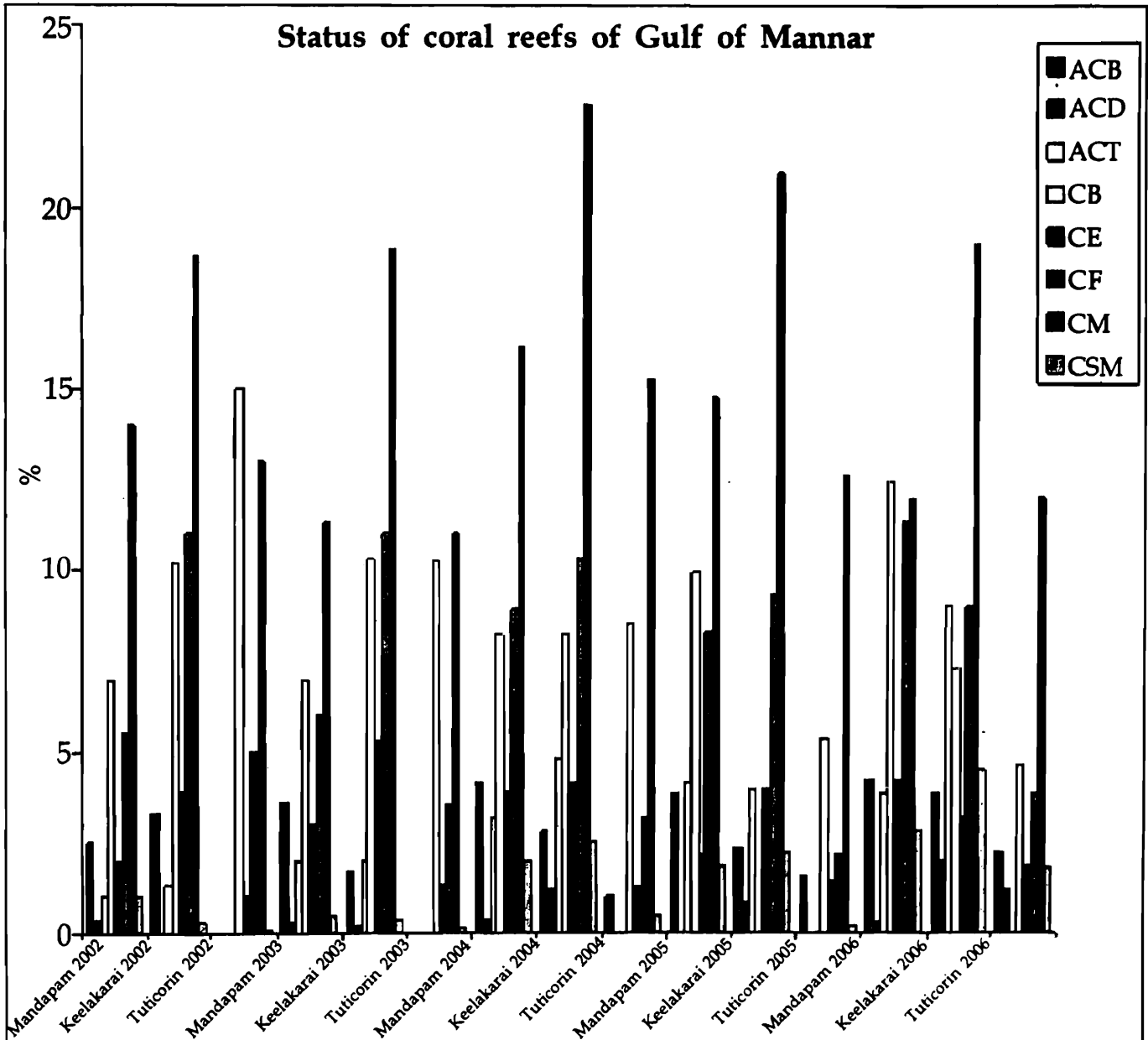


Fig. 10 : Percentage life forms of live corals of three groups of islands of Gulf of Mannar Biosphere Reserve (2002-2006).

For past several decades the Gulf of Mannar and Palk Bay has been the lifeline of the Indian *beche-de-mer* industry. The trend in *beche-de-mer* export from India was highly fluctuating; in 1979 it was very high to a tune of Rs. 155 lakhs (James and James, 1994) and in 1998-99 it reduced to Rs. 6.2 lakhs (MPEDA, 1999). The reason may be indiscriminate fishing and habitat destruction. In order to revive the natural

stock, Government of India has banned the fishing of all holothurians and brought them under Schedule I of wildlife protection Act, 1972 (Anon, 2001). After the ban clear-cut data on the recent status of *beche de mer* industry of India is not well known.

Sea Cucumber Resources in Gulf of Mannar

Little more than 1400 species of holothurians are reported from various parts of World Oceans. In India, nearly 200 species belonging to 6 orders and 16 families are reported, of which 75 are restricted to shallow waters with a depth of 20 m while 50 species collected from intertidal regions of the coasts of India. Among them around 12 species viz. *Actinopyga miliaris*, *Actinopyga mauritiana*, *Actinopyga echinites*, *Bohadschia argus*, *Bohadschia marmorata*, *Stichopus chloronotus*, *Stichopus variegatus*, *Thelenota ananas*, *Holothuria nobilis*, *Holothuria atra*, *Holothuria scabra* and *Holothuria spinifera* are commercially significant. Sea cucumber with larger size and thick body wall are suitable for processing. Holothurians can be divided into three groups based on their commercial value viz. high, medium and low values (James and James, 1994). *Holothuria scabra*, *Holothuria nobilis* and *Thelenota ananas* have high values; species such as *Holothuria spinifera*, *Actinopyga echinites*, *Actinopyga miliaris*, *Bohadschia marmorata*, *Bohadschia argus*, *Stichopus variegatus* and *Stichopus chloronotus* have medium value while *Holothuria atra* and *Actinopyga mauritiana* have low market value.

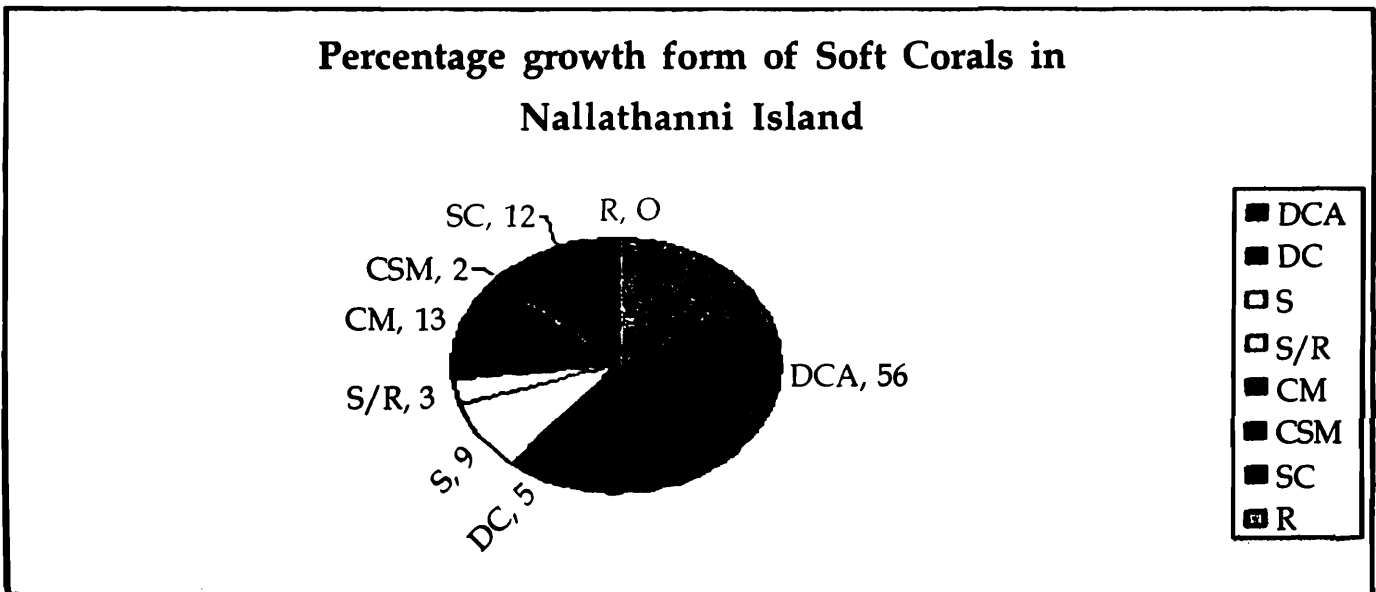


Fig. 11 : Percentage of growth form of Soft Corals in the coral reefs of Nallathanni Island.

Distribution of Holothurians : Holothurians are distributed in different ecological niche as they adapted themselves to live in different habitats. They found in many marine biotopes at all latitudes, from intertidal to deeper waters. They are benthic

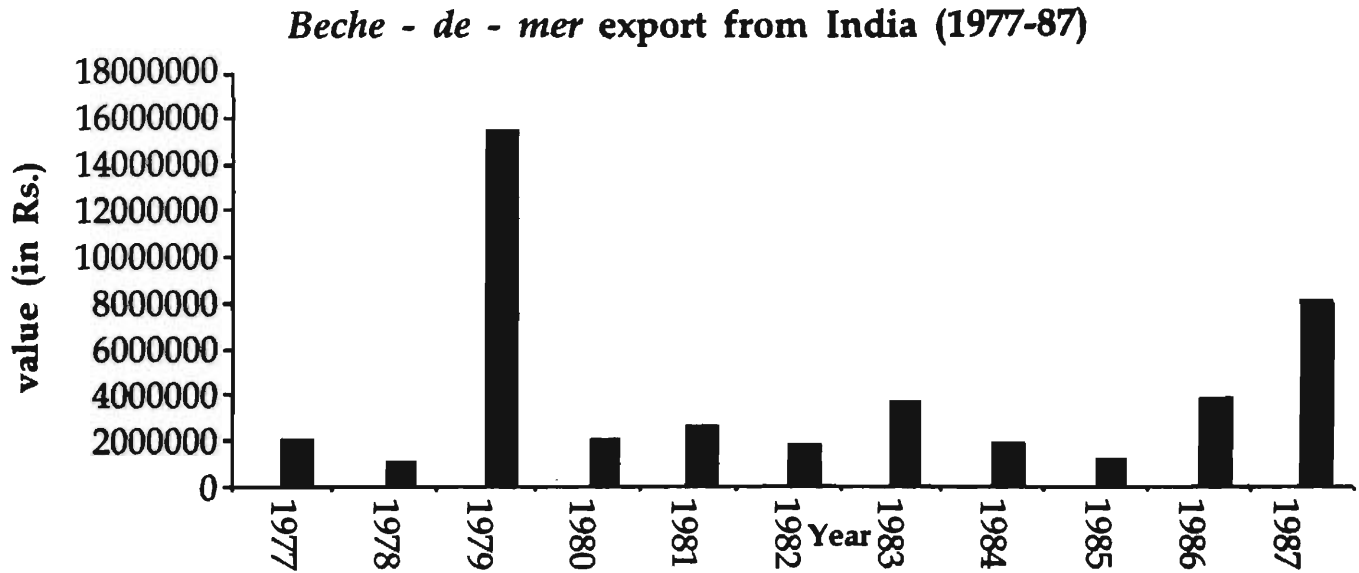


Fig. 12. Beche-de-mer export from India (1977-87) (James and James, 1994).

except Elaspodida which is pelagic form. Although some species live on hard substrates such as rocks, coral reefs or epibiosis on plants or invertebrates, they more regularly inhabit soft bottoms, either living on the seabed surface or temporarily or permanently in the sediment. The distribution of the various groups in coastal zones shows the predominance of Aspidochirotida between the tropics and of Dendrochirotida in temperate and higher latitudes. Holothurian diversity occurs in the tropical coastal area where the genus *Holothuria* comprises 114 species (Rowe, 1969). In Indian waters their ecosystem and habitat distribution is as follows.

Coral Reef Ecosystems : Coral reef is the most suitable place for species such as *Holothuria hilla*, *Holothuria pardalis*, *Holothuria arenicola* and *Holothuria impatiens*.

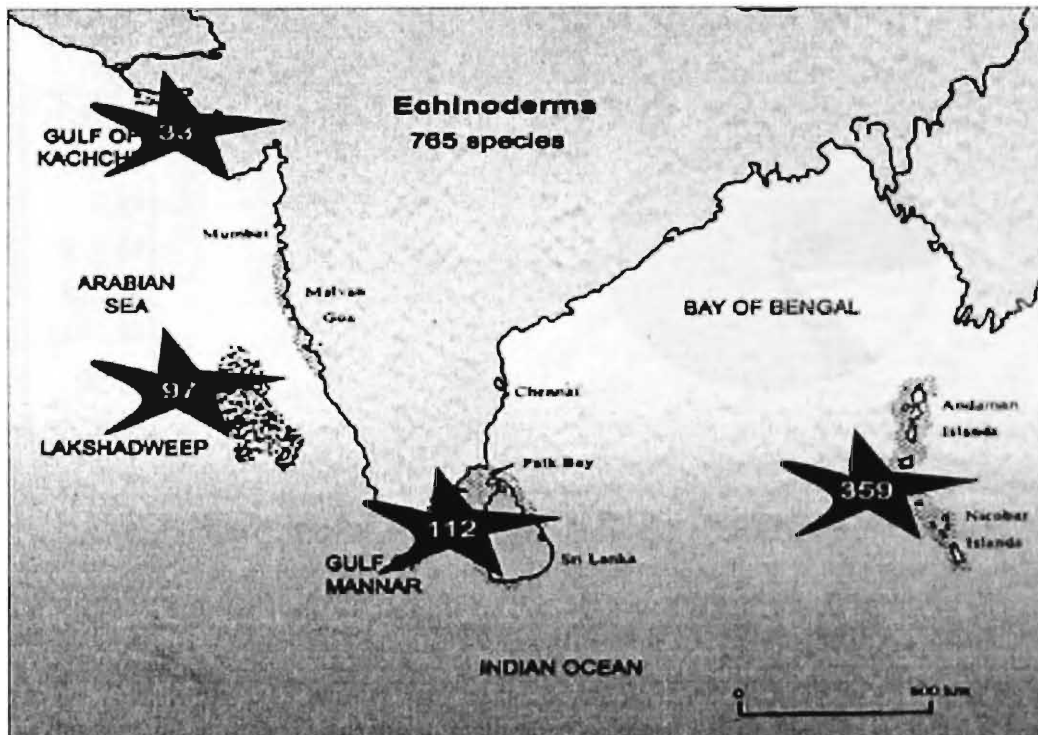


Fig. 13 : Diversity of species of echinoderms in Gulf of Mannar and other major coral reef areas.

Availability of some holothurians notably *Hemithyone semperi* and *Actinocucumis typicus* are marked in this ecosystem.

Seaweed and Sea Grass Ecosystem : Holothurians such as *Synpatula recta* found live on the seaweed in the intertidal region and they crawl on the algae with the help of tentacles and anchors present in the body wall. However *Stichopus variegatus* mostly associated with eel grass beds.

Rocky Shore Habitat : *Holothuria moebi* and *Holothuria cinerascens* live on the rocky shores by attaching to the underside of the stones. In such species the tube feet on the ventral side are well developed appearing like a sole (James, 1998).

Sandy Shore Habitat : Species live in sandy beaches have the ability to bury themselves in sand with the help of tube feet. *Holothuria atra* is one of the most common holothurians of India found in sandy bottoms and often coated sand on its body. *Holothuria leucospilota* and *Stichopus variegatus* also prefers sandy bottom.

Mud flat Habitat : *Holothuria scabra* normally prefers mud flats with half buried condition by keeping the posterior end of the body above the seafloor. Whereas, *Acuadina molpadioides* also abundant in muddy substratum and the whole animal lies buried in loose of fine mud (James, 1998).

Actinopyga miliaris (Quoy and Gaimard, 1833), *Bohadschia marmorata* (Jaeger, 1833), *Holothuria (Halodeima) atra* Jaeger, 1833, *Holothuria (Metriatyla) scabra* Jaeger, 1833

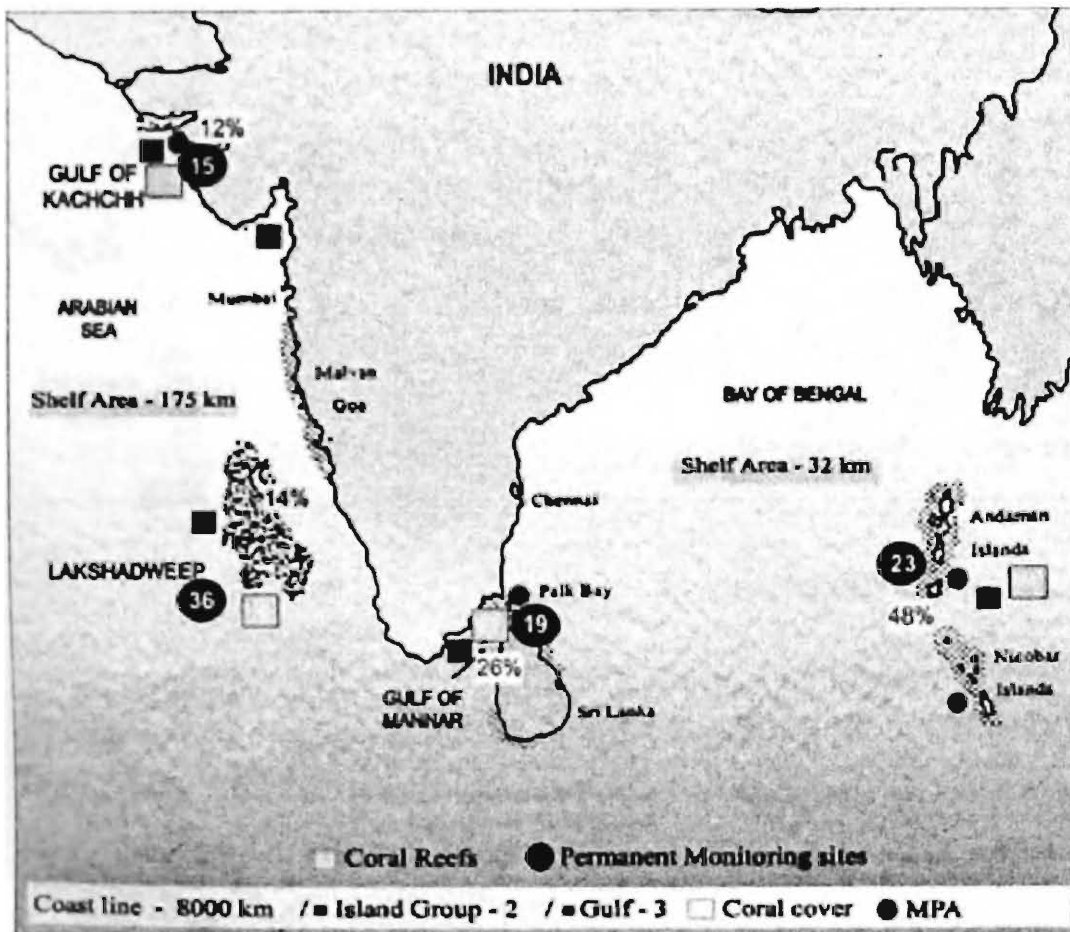


Fig. 14 : Reef distribution, coral species diversity, status of live coral cover and the location of Marine Protected areas in India.

and *Holothuria (Theelothuria) spinifera* (Theel, 1886) are some of the commercially exploited holothurians of Gulf of Mannar Islands.

Status of Holothurians in Gulf of Mannar

The commercial exploitation of marine invertebrates including holothurians increased attention during recent years and progress has been made in the knowledge of stock dynamics and fisheries management. Although marine invertebrates yield lower landing in quantity in comparison with fin-fishes, their economic value compensate for this difference by accounting nearly 40% of the value of the world fishery trade. Apart from the economic importance of the Echinoderms (holothurians), they are a vital component in the food chain at various trophic levels and play an important role through grazing, predation and structure and function of marine communities. The major objectives of the present report is to report the present status of holothurians along the west and east coast of India

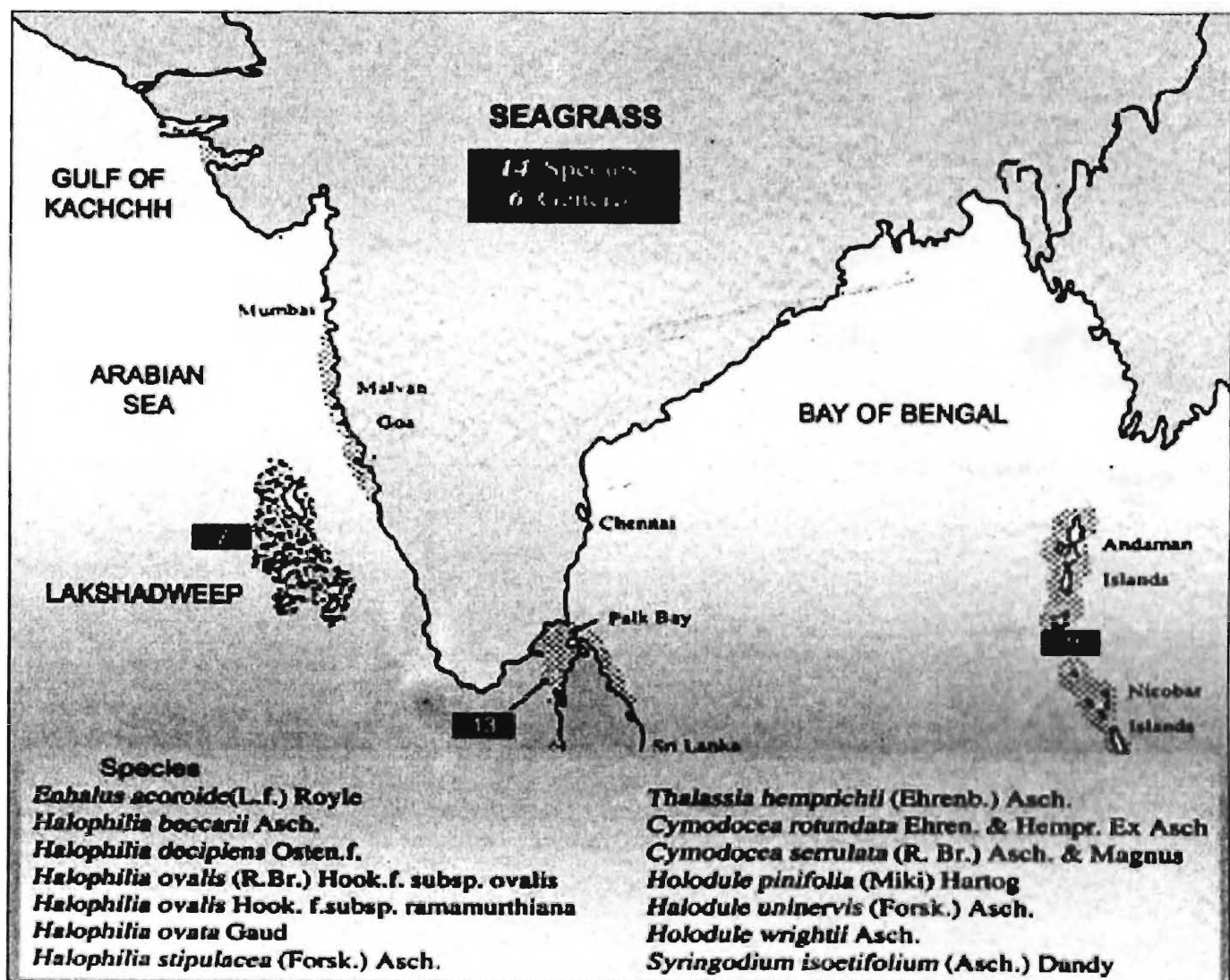


Fig. 15 : Diversity of sea grass in the four major coral reef areas in India.

and the extent of illegal harvesting hampering the conservation efforts by Government of India.

8. *Protochordates* : The diversity of the Ascidians and the famous endangered Hemichordate *Ptychodera flauva* is especially are well documented (Dhandapani, 1997). Their status is good. 18 species are recorded. However, suggestions are also made to exploit the Ascidians, which are edible through mariculture as practiced in some countries because of their availability. The majority of the species in this group are being tried for bioactive substances. Endangered *Ptychodera flauva* is available only on one island, Krusadai, which was once referred to as the "Biologist's Paradise"

9. *Pisces* : The ichthyofaunal diversity of the GoMBR is very high with many diverse shapes and sizes. 450 species belonging to 252 genera and 112 families have been documented including many vulnerable, rare and threatened species. 112 species are reported from the reef areas of the GoMBR and among them 60 have ornamental value (Devaraj, 1998). Their status is poor. The catch per effort is declining and the natural environment of the GoMBR is changing. This is evident from the change in the composition (Dorairaj, 1996).

The major reason for this shift is over exploitation, as illustrated by :

- the oil sardine (*Sardinella longiceps*) previously only by-catch now forms a substantial fishery (1419 t in 1996.)
- the Indian mackerel (*Rastrelliger kanagurta*) registered a substantial increase in catch from 213t in 1992 to 3711t in 1996.
- the sharks, goatfishes, threadfins, ribbon fishes and tunas which once formed a good fishery in the past are now showing a declining trend in their catches... They are mostly overexploited because of their food and pharmacological value.
- the beautiful Sea Horse *Hippocampus kuda* is exported to China because of its reputed aphrodisiac qualities, and for their ornamental value and also for pharmacological experiments.
- habitat destruction by coral mining and removal of seaweed and sea grass are the other major causes for decline in fish stocks.

Measures suggested for the sustainable utility of this resource (Sriramachandramurthy, 1996), include :

1. Restriction on fishing effort.
2. Imposition of closed seasons for fishing.
3. Cod-end mesh regulations for fishing nets.

4. Restriction on capturing juveniles from nursery grounds.
5. Popularisation of mariculture practices.
6. Popularisation of sea ranching especially for species like *Hippocampus kuda*

10. *Turtles* : Four species of turtle are recorded and all are in the endangered category (Rajagopalan, 1996). The three main species in the GoMBR are *Chelonia mydas*, *Lepidochelys olivacea* and *Caretta caretta*. Their status is very very poor. Their numbers dwindled drastically as the result of the turtle fishery during the 1960s. In the 1960's 3000 to 4000 turtles were exported annually (Rajagopalan, 1996). *Chelonia mydas* (green turtle) is the major species, and previously formed 75% of the landings. *Lepidochelys olivaceae* (Olive ridley) and *Caretta* (loggerhead turtle) formed 20% of the catch (Rajagopalan, 1996). Clandestine capture still continues depleting the stocks further. Dead juveniles and bones of adults can be seen on the islands indicating human interference in the nesting sites of turtles. Habitat destruction further reduces their number.

Strategies suggested for their preservation include :

- awareness programs and strict imposition of laws (Rajagopalan, 1996).
- habitat preservation.
- species preservation through recovery programs.
- translocation of nests and setting up of.

11. *Mammals* : The globally threatened herbivorous marine mammal *Dugong dugon*, two species of dolphins *Stenella longirostris* (spinner dolphin) and *Tursiops truncatus* (bottle nose dolphin) plus 10 species of stranded whales constitute the 13 species recorded from the GoMBR (Devaraj 1998). All the species are globally protected and are found in low numbers. Their status is very very poor. The reasons for their dwindling numbers are overexploitation, habitat destruction and poaching. In the Gulf of Mannar the dugong is exploited notoriously for its flesh. This clandestine fishing was at its peak during 1983-84 when 250 animals were killed in a year. Previously, between 1960 and 1980 only 25 animals/year were hunted. The fishery has reduced to 9 animals/year during 1986-1988 (Silas & Fernando 1988). Now their presence is rare.

Banning the capture of these animals both intentionally and unintentionally is needed by, for example :

- banning the operation of fishing gear in their habitats.
- strict imposition of laws.
- habitat preservation.

● awareness creation are of the strategies suggested for their conservation (P. Bensam & N.G. Menon, 1996).

Relevant Management Agencies in Gulf of Mannar Biosphere :

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

The Department of Environment and Forests (DOEF) is the nodal department for the conservation and management of corals and coral reefs in Gulf of Mannar. Corals of the Gulf of Mannar are governed by the Forest Department Rules. A separate Wildlife Warden for the Gulf of Mannar Marine National Park has been designated to implement various provisions of the rules. The DOEF has taken further steps to conserve corals by declaring the areas around all the 21 islands in the Gulf of Mannar as protected areas (National Parks) and Wildlife Sanctuaries), the management of which is the Department's responsibility. DOEF has made efforts to control human interference and provide protection by imposing various provisions of the Wildlife Protection Act, 1972 in these areas. Outside-protected areas, the degree to which the Department can extend protection to coral reefs is limited. However, with the imposition of provisions of the Coastal Regulation Zone notification 1991, the entire coastal area has been classified as a coastal Regulation Zone area. Coral reefs are brought under Category I according them full protection, and mining of coral is listed as a prohibited activity under CRZ rules as well as Schedule-I of Wildlife protection Act, 1972.

Zoological Survey of India (ZSI) : Zoological Survey of India, Marine Biological Station, Chennai has documented the occurrence of fauna in the marine and coastal regions of India, which is useful for conservation of all marine species including the endangered species. The Marine Biological Station of Zoological Survey of India

is established in 1975 at Chennai to conduct research on the Marine Fauna of Indian coast. The Station has participated in many National and International expeditions and has expertise on the coral reef studies in all the four major coral reef areas of India. ZSI is responsible for documenting the availability of all fauna in the terrestrial and aquatic environments, which is useful for conservation of all marine species including the endangered species. The first ever coral reef status survey of Gulf of Mannar was conducted by this station in 1998 to 2000 as well as reported the bleaching in different coral reef areas. This station has also documented the list of coral and associated reef fauna and is also responsible for the database on coral reefs of the east coast. This station has close interactions with the various other/relevant management agencies in the Gulf of Mannar such as the State and Central Fisheries Departments, the Forest Department etc.

Fisheries Department : The Fisheries Department is responsible for developing sustainable utilization of fisheries resources in the Gulf of Mannar and for enacting regulation of fisheries activities to prevent over-exploitation or destructive activities. Coral Reefs are important breeding grounds for many fishes and other marine organisms and the condition of reefs in the Gulf of Mannar is therefore a matter of major concern to the Fisheries Department. More over the spawning aggregation of fishes in the protected area is still not known.

Tourism Department : The tourism department is responsible for management of tourism development in the Gulf of Mannar region. During the ninth five-year plan the Tourism Department has planned to introduce pleasure boating in Krusadai and Hare islands of Gulf of Mannar. It needs to obtain information relating to impact of Tourism in the islands. The tourism development will launch an awareness programme specifying the need to preserve the ecology especially the coral reefs.

Madurai Kamaraj University : Centre for Marine and Coastal Studies, School of Energy, Environment and Natural Resources, Madurai Kamaraj University, Madurai 625 021, India being an academic research and teaching institution, concentrating on the status of ornamental fishes of coral reefs of Gulf of Mannar. The Centre in collaboration with the Department of Sociology has conducted studies on the socio-economic patterns of people in the Gulf of Mannar region, especially those depending on reef related/associated resources.

Central Marine Fisheries Research Institute (CMFRI) : CMFRI's is providing technical advice on the development of capture fisheries and mariculture in the Gulf of Mannar region.

Sugandi Devadasan Marine Research Institute, Tuticorin : This non-governmental organization is working mainly on the regeneration of corals and socioeconomic

aspects of GoMBR. This institute has received funds for research from Ministry of Environment and Forests, New Delhi for the regeneration of corals as well as from an international agency called Coral Reef Degradation in Indian Ocean (CORDIO) on coral reef degradation.

M.S. Swaminathan Research Foundation conducted studies related to community development in the Gulf of Mannar under a joint project proposal with Ministry of Environment and Forests, Directorate of Environment and Forests, Govt of Tamil Nadu entitled, "Conservation and sustainable use of the Gulf of Mannar Biosphere Reserves for coastal Biodiversity"

The Tamil Nadu State Forest Department implements the management action plan for GoMBR through its wildlife wing. Office of Wildlife warden is functioning at Ramanathapuram (district head quarters and major town close to GoMBR) to manage the biosphere reserve. Since the biosphere reserve does not have any legal status for protection currently, the state of management is not adequate. Actions are being taken to protect the reserve and to reduce the pressure from the coastal population depending on the resources of this reserve by implementing a GOI/UNDP/GEF project through the Gulf of Mannar Trust formed by the Tamilnadu State. In order to maximize the benefits to the local community, to generate a sense of stewardship in the fishing industry, to achieve effective enforcement and to minimize habitat damage, the state fisheries act is in the process of amendment. Other gaps in the management of GoMBR area are lack of awareness among the local public, limited scope for reducing the ever-increasing population pressure and lack of trained work force for marine protected area management which are expected to be culminated using GoMBR Trust out puts.

The 1998 bleaching event has played a major role in reducing the live coral cover not only in the coral reefs of GoMBR (Muley *et al.*, 2000). It has been reported that the 1998 bleaching reduced the live coral cover in the Gulf of Kachchh to 30%, 40% in the Gulf of Mannar, 20% in Lakshadweep and 65-70% in Andaman and Nicobar Islands (Venkataraman, 2000). The present study reveals the status of coral reefs and some associated organisms in the islands of Gulf of Mannar. Major problems in the management of coral reefs are inadequate awareness among the fishermen about coral reefs and their importance, increasing coastal industries and over exploitation. In order to conserve the coral reefs of Gulf of Mannar Marine Biosphere Reserve, the present study will help the managers to take proper initiative to conserve the coral reefs and their associated fauna.

CONCLUSIONS AND RECOMMENDATIONS

There was no status study prior to 1998 of the GoMBR. Status studies on coral reefs of India were initiated by GCRMN South Asia node only during 1997, which helped Zoological Survey of India, Marine Biological Station to carry out status studies in GoMBR and the first status studies on the coral reefs of GoMBR was conducted during 1998-2000 (Venkataraman 2000, Venkataraman *et al.*, 2003, Venkataraman *et al.*, 2004 a). Present studies on status survey (2002-2006) revealed that the GoMBR reefs showing recovery in live coral cover, especially in Keelakarai group of islands and on the other hand Tuticorin reefs are facing damages due to sedimentation, erosion and other major threats such as land based pollution from thermal power plant which may be the direct cause for the less live coral cover. Though there are government initiatives to conserve and manage the GoMBR coral reefs through UNDP-GEF funded Gulf of Mannar Trust and other research projects funded by Ministry of Environment and Forests, Government of India to study the coral reefs of Gulf of Mannar there seems to be very little awareness among the local community who are dependent on the reef resources for their day-to-day livelihood. There are many research institutions and NGO's are doing research in and around GOMBR. However, the problems of GoMBR coral reefs are more critical than ever before. The recommendations such as implementation of long-term monitoring programme on coral reefs, capacity building programmes for scientists and managers, education and awareness for local communities, database on coral reef for management, promotion of reef restoration and improvement of socioeconomic status of the coastal population may improve the situation in GoMBR in the future.

Before 1960, the reefs of GoMBR were in near pristine condition due to low level of exploitation of reef resources. The studies conducted during 1998 revealed that most of the coral reefs degraded due to over exploitation and 50-80% mortality due to 1998 bleaching event. During the present study (2002-2006) some reefs were recovering from 1998 bleaching and some to be still to recover from the bleaching. Tuticorin Islands (Karaichalli, Kasuwar and Van) are suffering due to siltation and erosion.

Coral reefs in the GoM Islands are under increasing pressure. Factors such as urbanization, population growth, industrial development, international trade, inadequate legislation, lack of trained persons and awareness, habitat degradation, and over exploitation of resources are the known threats to the survival of life support system of the GoMBR. There is no effective management plan to mitigate the threats to the ecosystem, root causes of these threat and cost effective

interventions to address these root causes. Networking among the scientific, government and non-governmental personnel in GoMBR is essential to avoid duplication to execute what is really needed. Long-term monitoring of the status of the coral reefs and socioeconomic status of the people depending on the reefs are the need of the hour. The data gathered in the present study may form the basis of the management action plan to save the GoMBR from the human threat.

REFERENCES

- Alfred, J.R.B., E.V. Muley and Ch. Satyanarayana, 2005. "A glimpse of the corals and coral associates of Gulf of Kutch, the first Marine National Park of India" *ENVIS Newsletter* Vol. : 11 (1&2) 12-16.
- Anonymous, 2001. List of Schedule I Species under Wildlife Protection Act, 1972, Ministry of Environment and Forests, Govt. of India.
- Appukuttan, K.K. 1996. Marine Molluscs and their conservation. In : *Marine biodiversity conservation and management* (Ed.) Menon, N.G and Pillai, C.S.G. published by CMFRI, Cochin, 66-79.
- Bensam, P. and Menon, M.G. 1996. "Conservation of Marine Mammals" In : *Marine Biodiversity Conservation and Management*. (Ed.) Menon, N.G and Pillai, C.S.G. published by CMFRI, Cochin, 133-142.
- Devaraj, M. 1996. "Coastal biodiversity-Conservation and sustainable management. In : *Marine biodiversity conservation and management* (Ed.) Menon, N.G and Pillai, C.S.G. published by CMFRI, Cochin, 177-192.
- Devaraj, M. 1998. "Conservation and sustainable management of the marine living resources of Gulf of Mannar Biosphere Reserve" *Proc. Technical Workshop on Biodiversity of Gulf of Mannar Marine Biosphere Reserve*, M:S. Swaminathan Research Foundation, Chennai., 22-31.
- Din, Azkaria Ez El, 1986 Beche-de-mer processing trials along the Egyptian red sea coast. RAB/81/001, 286-290.
- Durairaj, S., Nainar, M.M., Laine, M.K., Sudhakaran, R. and Inbaraj, S. 1984. Study on the quality of beche-de-mer trade and shrinkage of specimens during processing.
- English, S., Wilkinson, C, and Baker, V. 1997. "Survey manual for Tropical Marine Resources" Published by Australian Institute of Marine Science, 390. *Fish Tech.*, 21 : 1 > 24.
- Gravelly, F.H. 1927 Littoral fauna of Krusadai Island in Gulf of Mannar. Echinodermata. *Bull. Madras. Govt. Mus., (Nat. Hist.)* : 163-173.
- Hornell, J., 1917. The Indian beche-de-mer industry: its history and recent revival. *Madras Fish. Bull.*, 11(4) : 119-150.

- James, D.B., 1993. Sea cucumber culture In: Seaweed, Sea urchin and Sea cucumber Handbook on Aquafarming, Marine Products Export Development Authority, Cochin : 33-47.
- James, D.B. 1996. "Conservation of Sea Cucumbers" In : *Marine biodiversity conservation and management (Ed.)* Menon, N.G and Pillai, C.S.G. published by CMFRI, Cochin : 80-88.
- James, D.B., 1998. Ecological significance of echinoderms of the Gulf of Mannar. *Workshop on Coastal Biodiversity of Gulf of Mannar*. Organised by M.S. Swaminathan Research Foundation, Chennai, February 10-11, 1998: 118-128.
- James, D.B., Rajapandian, M.E., Baskar, B.K. and Gopinathan, C.P. 1988. Successful induced spawning and rearing of the holothurian, *Holothuria (Metriatyla) scabra* Jaeger at Tuticorin. *Mar. Fish. Infor. Serv. T. & E. Ser.*, 87 : 30-33.
- James, P.S.B.R. and James, D.B., 1994. Management of Beche-de-mer industry in India. In: K. Rengarajan and D.B. James (Eds.). *Proceedings of the National Workshop on Beche-de-mer. Bulletin of CMFRI*, 46 : 17-22.
- Jayasree V and Parulekar AK (1997) The ecology and distribution of Alcyonaceans at Mandapam (Palk Bay, Gulf of Mannar), south India. *J Bombay nat. Hist. Soc.*, 94(3) : 521-524.
- Jeyabaskaran, R and S. Ajmal Khan 1998. Biodiversity of brachyuran crabs of Gulf of Mannar. *Proc. Technical Workshop on Biodiversity of Gulf of Mannar Marine Biosphere Reserve*, M.S. Swaminathan Research Foundation, Chennai : 150-155.
- Jeyabaskaran, R and Venkataraman K. 2000. Mass mortality of Trapezian crabs in coral reefs of Gulf of Mannar (southeast coast of India). Paper presented at IX International coral reef symposium, Bali, Indonesia, 22-28, October 2000.
- MPEDA (Marine Products Export Development Authority), 1999. Share of cultured shrimp and freshwater fish in total exports.
- Muley, E. V., Subramanian, B. R., Venkataraman, K., and Wafar, M. V. M. 2000. Status of coral reefs of India, Poster presented in the 9th International Coral Reef symposium, Bali, Indonesia Posters D1: Status, p. 360.
- Nayak, S. 1997. Information needs of Integrated Coastal Zone Management. Role of remote sensing and geomorphic information system. *Proceedings of the workshop on Integrated Coastal Zone Management*. Space Application Centre (ISRO), Ahmedabad : 6-25.
- NEERI, 2004. Environmental Impact Assessment for proposed Sethusamudram Ship Canal Project. National Environmental Engineering Research Institute, Nagpur.

- Nithyanandan, M., 2003. Sea cucumber resources in peril. *Samudra*, Nov. issue, 24-26.
- Pillai, C. S. G. 1996. Coral reefs of India, their conservation and management. In: *Marine Biodiversity, Conservation and Management* (eds. Menon, N. G. and Pillai, C. S. G). Central Marine Fisheries Research Institute, Cochin, 16-31.
- Rajagopalan, M. 1996. "The Marine Turtle and its Conservation" In : *Marine biodiversity conservation and management (Ed.)* Menon, N.G and Pillai, C.S.G. published by CMFRI, Cochin : 126-132.
- Rowe, F. E., 1969. A review of the family Holothuriidae (Holothurioidea, Aspidochirotida). *Bull. Brit. Mus. (Nat. Hist.) (Zool.)*, 18(4): 119-170.
- Satyanarayana, Ch. & K. Venkataraman 2000. "Present Status of Reef fauna of Gulf of Mannar, a Biosphere Reserve on the Southeast coast of India and strategies for its conservation" Presented in the 9th International Coral Reef Symposium held at Bali, Indonesia in October, 2000.
- Satyanarayana, Ch. 2004. "A Review of Scleractinian Diversity in India and its Importance in the Reef Ecosystem Remediation and System Remediation - An Appraisal" Presented in the 10th International Coral Reef Symposium held at Okinawa, Japan from June, 28-2 July, 2004.
- Silas, E.G. and Fernando, A.B. 1988. "The dugong in India - Is it going the way of the Dodo? In : *Proceedings of the Symposium on Endangered Marine Animals and Marine Parks*, Marine Biological Association of India : 167-176.
- Singh, H.S. 2002. *Marine Protected Areas in India-Status of coastal wetlands and their conservation*. Publ. by Gujarat Ecological Education and Research (GEER) Foundation, Indroda Nature Park, Gandhinagar, India. 62pp.
- Thomas P.A. 1996. "The gorgonid resources and their conservation in India" In : *Marine biodiversity conservation and management (Ed.)* Menon, N.G and Pillai, C.S.G. published by CMFRI, Cochin, 32-40.
- Thomas P.A. and George R.M. 1987. "Gorgonid resources of India" *Mar. Fish. Infor. Serv. T & E. Ser.*, 74 : 1-13.
- Thurston, E. 1890. Preliminary report on the marine fauna of Rameswaram. *Madras Govt. Mus. Bull.*, No. 1.
- Thurston, E. 1895. Thurston, E. 1895. Rameshwaram Island and the fauna of Gulf of Mannar. *Bull. Madras Govt. Mus.*, (2nd Edition): 108-112.
- Venkataraman, K. 2000. Status of Coral Reefs of Gulf of Mannar, India 9th International Coral Reef Symposium, Bali, Indonesia, 35 p.

- Venkataraman, K, Ch. Satyanarayana, J.R.B. Alfred and J. Wolstenholme, 2003. "Handbook on Hard Corals of India" 1-266. (Published : Director, Zool. Surv. India, Kolkata).
- Venkataraman, K, Jeyabaskaran, R, Raghuram, K. P. and Alfred, J. R. B. (2004 a) Bibliography and checklist of coral and coral reef associated organisms of India, *Rec. zool. Surv. India, Occ. Paper*, **226** : 1-468.
- Venkataraman, K, Jeyabaskaran, R, Satyanarayana, Ch, Raghuram, K. P. (2004b) Status of coral reefs in Gulf of Mannar Biosphere Reserve. *Rec. zool. Surv. India*, **103** : 1-15.
- Venkataraman, K., Srinivasan, M., Satyanarayana, Ch. and Prabakar, D. (2002). *Faunal diversity of Gulf of Mannar Biosphere Reserve, Conservation Area Series*, **15** : 1-77.
- Watson R. & D. Pauly 2001. "Systematic distortions in world fisheries catch trends" *Nature*, **424** : 534-536.
- Wilkinson. C. 2000. Status of coral reefs of the world: 2000. Australian Institute of Marine Science, Queensland, 361 pp.