Status of Coral Reefs of the Gulf of Mannar, Southeastern India

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ABSTRACT

The coral reefs in the Gulf of Mannar, southeastern India, are important to the lives and livelihoods of coastal people in the area. However, human interference and management shortcomings have put this ecosystem under tremendous pressure. Over 32 km^2 of coral reef has already been degraded around the 21 islands of the Gulf of Mannar. This study provides baseline data on the coral reefs of the area that has been lacking so far. The present average live coral cover is 35%, with 117 coral species, including 13 new records. Dominant coral species are *Acropora cytherea*, *A. formosa*, *A. nobilis*, *Montipora digitata*, *Echinopora lamellosa*, *Pocillopora damicornis* and *Porites* sp. Fifty species of reef associated fishes in 27 families were observed during the study, with the Lethrinidae, Lutjanidae, Siganidae, Chaetodontidae, Ephippidae, Gerreidae, Pempherididae and Gobiidae most common. The surveys further indicate that habitat variables, in particular live coral cover, play a major role in the enhancement of fish diversity. Results on sediment loads and regimes are also presented. This can serve to support and underpin both ongoing and future conservation and management initiatives in the Gulf of Mannar.

INTRODUCTION

Background

India has four major coral reef areas, the Andaman and Nicobar Islands, the Gulf of Kachchh, the Lakshadweep islands, and the Palk Bay and Gulf of Mannar area. The Gulf of Mannar (GoM) is located in Tamil Nadu, on the mainland southeast coast of India (Fig. 1). Coral reefs in the area have developed around a chain of 21 uninhabited islands in four groups (Table 1) that lie along the 140 km coastal stretch between Rameswaram and Tuticorin, at an average distance of 8-10 km from the mainland. Narrow fringing reefs are mostly located at a distance of 100 to 350 m from the islands, and patch reefs up to 1-2 km long and 50m wide rise from depths of 2 m to 9 m.

Pillai (1986) provided a comprehensive account of the coral fauna of GoM, describing 94 species in 37

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Figure 1. Map of the Gulf of Mannar showoing the location of the 21 islands sampled.

genera, the most common being *Acropora* spp., *Montipora* spp. and *Porites* spp. Patterson et al., (2004) updated the checklist of corals of GoM adding 10 new records, to 104 species. A survey of the entire GoM conducted between 2003 and 2005 further updated the list of corals to 117 species (Patterson et al., 2007). The GoM is also rich in various other biological resources such as 147 species of seaweeds (Kaliyaperumal 1998), 13 species of seagrass (Rajeswari and Anand 1998), 17 species of sea cucumbers (James 2001), 510 species of finfishes (Durairaj 1998) 106 species of shellfishes such as crabs (Jeyabaskaran and Ajmal Khan, 1998), 4 species of shrimps (Ramaiyan et al., 1996) and 4 species of lobsters (Susheelan 1993). During recent surveys of mollusks, 5 species of polyplacophorans, 174 species of bivalves, 271 species of gastropods, 5 species of scaphopods (added for the first time) and 16 species of cephalopods were recorded (Deepak and Patterson, 2004).

In 1980 the Government of Tamil Nadu notified the public of the intention of setting up a Marine National Park in the gulf of Mannar. Subsequent to a re-notification in September 1986, the Gulf of Mannar Marine National Park was declared. The National Park covers all 21 islands, and regulates activities in the area for conservation and management of resources. In 1989 the Gulf of Mannar was declared a "Marine Biosphere Reserve" under UNESCO's Man and the Biosphere Programme, covering an area of 10,500 km2 from Rameswaram to Kanyakumari.

The coral reefs are still the main source of livelihoods for the thousands of small-scale fishers living along the GoM coast. Over 150,000 people live in the coastal zone of the GoM, many of whom (over 50,000) depend directly on reef fishery resources (Patterson et.al., 2007).

Issues

The Gulf of Mannar is under severe pressure from a number of human activities that have degraded the ecosystem. One important reason for this situation is that the coastal areas are densely populated and that both traditional and "modern" activities, e.g. small-scale and industrial fishing, are competing for limited resources. The majority of the coral reefs have been severely damaged by coral mining and destructive fishing practices, and no trend towards decreasing

Table 1. Islands in the Gulf of Mannar. Site number (corresponding to numbers in Figure 1), island name (and number of transects recorded), and brief description of island and reef.

Islands	Land/Beach features	Reef Type
MANDAPAM GROUP		
Shingle (23)	Narrow sandy beach, dead coral rubble on the northeast and southern side; coastal dunes in the middle of the island partly vegetated.	Fringing, extends down to 2 m depth
Krusadai (12)	Narrow sandy beach, coral rubble on the south and southeast windward side; vegetated sand dunes.	Fringing reef extends down to 3 m, with patch reefs to the east
Pullivasal (19)	Narrow sandy beach with coral rubble on the Southwest, South and Southeast sides; vegetated sand dunes.	Fringing reefs to 2.3 m depth with patch reefs to the North
Poomarichan (20)	Sandy beach, coral rubble on the Southwest and Southern shores; sand dunes are covered by extensive vegetation; island height 1.5 m over the mean sea level.	Fringing reef down to 2 m depth with patch reefs to the northeast.
Manoliputti (13)	Narrow sandy beach with coral rubble to the south; Small vegetated sand dunes	Fringing reefs down to 2.2 m depth.
Manoli (25)	Narrow sandy beach, coral rubble on the South and Southeastern side, sand dunes vegetated in the central part of the island	Fringing reefs to 2.2 m with patch reefs to the north
Hare (25)	Coral rubble along the South, Southeastern and Southwestern side; sand dunes with vegetation; depression on the western side of the island filled with water during high tide.	Fringing reef extends to 2.2 m depth; two patch reefs to the northwest 3 m deep
KEEZHAKKARAI GROUP		
Mulli (15)	Broad sandy beach with coral rubble on the southern windward side; vegetated coastal dunes	Fringing reef extends to 3.5m with patch reefs to the southeast and south at 2.9m and 3.2m.
Valai (11)	The Island is an extension of Thalayari Island. A submerged small sand patch separates the islands. Narrow sandy beaches with coral rubble along the southeast and south sides	Limited fringing reefs to 2.9 m
Thalaiyari (18)	Narrow, sandy beach to the North; beach erosions evident; coral rubble to the south; a depression on the western side is filled with water during high tide.	Fringing reefs extending to 2 m depth
Appa (18)	Narrow sandy beach, coral rubble on the northeast to southeast (windward) side; small sand dunes with vegetation on the island.	Fringing reef extends to 3.2 m with patch reefs to the southeast and northwest side at 3.5m.
Poovarasan-patti (14)	Continuous coral mining has made this island completely submerged, 1 m below the mean sea level.	Discontinuous patch reefs found up to 2.5 m depth
Valimunai (25)	Narrow sandy beach, coral rubble to the south and southeast	Fringing reef to 2.5 m depth; patch reef to the southeast at 3.4 m depth.
Anaipar (12)	Narrow sandy beach, coral rubble on the windward southeast and northeast sides, small sand dunes with extensive vegetation.	Fringing reef extends to 2.8 m.
VEMBAR GRUOP		
Nallathanni (20)	Low and narrow beaches, straight on the northwest and northeast side and more irregular elsewhere; coral rubble to the southwest, southeast and northeast, sand dunes with vegetation on the western side with a height of 8 m.	Fringing reef to a depth of 3 m and small patch reefs to the south side down to 3.9m depth
Pulivinichalli (12)	Low and narrow sandy coast, coral rubbles on the south and southeast sides, sand dunes with 0.5 m height on the central part of the island.	Fringing type, extends up to a depth of 2.5 m and patch reefs on the south side at 3.2 m depth.
Upputhanni (16)	Low and broad sandy shores to the northwest and northeast, with narrow rubble beaches to the southwest and southeast; large depression on the southern side of the island fills with water during high tide.	Fringing reef extends to 2.8 m depth with patch reefs to the south and west at 3 m and 3.5 m depths.

fishing intensity can be observed. It has been estimated that the degraded reef areas around the 21 islands is about 32 km^2 (Patterson et al., 2007).

Destructive fishing

Traditional fishers who make up the majority population along GoM have increased in numbers during the last decades. Crowded fishing grounds, increasing demand for fisheries products, and declining catches deprive artisanal as well as industrial fishermen and their families their livelihoods and food security (Deepak et al. 2002, Bavinck, 2003). The fisher communities of GoM are characterized by low literacy, lack of awareness of environmental issues, and low income. There is also reluctance among fisher folk to take up livelihood options other than fishing, which has led to a proliferation of destructive and unsustainable fishing practices, such as shore seining, purse seining and push net fishing, dynamite fishing and cyanide fishing, all of which are illegal in coral reefs areas.

Destructive trawling using indigenously fabricated gears, such as bottom trawl nets with mesh sizes below 10 mm fitted with rollers (roller madi), kara valai (shore seine), pair trawler madi (two boats operating a trawl), sippi valai (modified gill net with more weight on the bottom to catch crabs, lobsters, mollusks and certain demersal fishes) and push net operations are in practice in some parts of GoM. These activities completely sweep the seafloor, deplete the fish stocks, and cause damage to critical habitats, such as corals reefs and seagrass beds (Bavinck, 2003, Patterson et. al., 2007). Cyanide is used to catch reef fishes, in particular groupers, which fetch high market prices, and ornamental fishes like clownfish, dottybacks, damsels, and surgeons. A small section of fishermen are also involved in dynamite fishing, targeting shoaling fishes. Lastly, physical damage to reefs while collecting seaweeds, in particular *Gelidiella acerosa* growing in coral reef areas, as well as retrieving lobster and fish traps on reefs, add considerable impact to the coastal ecosystem, especially in the northern part of the GoM.

Coral mining

Coral has traditionally been collected from the seabed for use in construction or as raw material for the lime industry, as well as for ornamental purposes. For a long time the collection of corals did not pose an obvious threat to the resource as there were large reef areas in good condition in the Gulf of Mannar. However, gradually with increasing populations, the extraction of coral became too intensive and deterioration of reefs obvious. In the early 1970's it was estimated that the exploitation of corals was about 60,000 cubic meters (about 25,000 metric tonnes) per annum from Palk Bay and GoM together (Mahadevan and Nayar, 1972). As a consequence the Tamil Nadu government declared Gulf of Mannar Marine National Park in 1986. However, coral mining continued illegally. By the turn of the millennium, two islands (Poovarasanpatti and Vilanguchalli) had been submerged due to excessive mining and the resulting erosion. Erosion has also been observed on several other islands, including Vaan, Koswari and Kariyachalli. The inclusion of corals in the Wildlife Protection Act, in 2001 (the federal government included all Scleractinia, Antipatharia, *Millipora* sp., gorgonians and *Tubipora musicum* under schedule I of the Wildlife (Protection) Act, 1972, which prohibits collection, possession and trade) was instrumental in reducing the illegal mining by over 75% due to stringent enforcement. All the same a group of poor fishermen continued with the coral mining activity, with the highest number of boats involved in mining during the lean fishing season. The Indian Ocean tsunami, however, made a change in the minds of fishermen, who attributed protection of their villages from the tsunami to the presence of corals reefs and islands. Therefore, the majority of them voluntarily stopped the coral mining activity, particularly on the Tuticorin coast, and today only sporadic mining incidents are reported.

Land-based pollution

Increasing industrialization has also added stress to the coastal marine ecosystem, comparatively more so on the Tuticorin coast, e.g. with the discharge of untreated or partially treated effluents. At present, the major sources of pollution include a fertilizer plant, a thermal power generation plant, and the Dharangadhare Chemical Works Ltd (DCW). Acid wash from shell craft industries and, more importantly, solid wastes and wastewater from ice plants and seafood processing centers have also caused localized pollution (Easterson, 1998).

The 210 MW Tuticorin Thermal Power Station burns up to 2800 tons of coal/day, producing an estimated 560 – 700 tons of ash per day. 750 m^3 of seawater, used to cool the turbines, is discharged into the Tuticorin Bay every hour. The discharged “slurry” is noted from a distance of over half a kilometer away, with a thickness varying from 6 – 70 cm (Easterson, 1998). Though there is little variation in the salinity, pH and the dissolved oxygen content, increased levels in nitrite (0.4 – 0.84 µg N/ l) and silicate (17.6 – 19.8 µg Si/ l) were recorded by Easterson et al., (2000). The discharged seawater is usually 2 – 4^{o} C above the ambient level and can be experienced up to 2 kilometers away (Easterson et al, 2000).

The National Institute of Oceanography (1991) reported that, compared to other coastal regions in Tamil Nadu, Tuticorin is highly contaminated with metals (levels of Cadmium were between 0.4 – 2 µg/l, copper 4 – 5 µg/ l, lead 2 – 7.8 µg/l and mercury 0.1 – 0.12 µg/l). Copper and zinc are also found in high concentrations in seaweeds in the Tuticorin region (Ganesan, 1992). Elevated levels of metals like zinc, iron, copper and lead (> 100 ppb) were recorded among edible gastropod species in the Gulf of Mannar, including *Melo melo*, *Babylonia spirata*, *Hemifusus pugilinus*

METHODS

Coral Status

Surveys were conducted in all reef areas around the 21 islands between Rameswaram and Tuticorin, from January 2003 to October 2005, to assess the coral status, diversity, abundance and distribution. The duration of the baseline survey was long due to long distances and difficult access to some islands, rough weather conditions for 6 months of the year, and repeated surveys after the Indian Ocean tsunami.

Reefs were mapped using the Manta Tow technique (Done *et al.* 1982), based on which representative sites were selected. Line Intercept Transect (LIT) was used to assess the sessile benthic community of the coral reefs (English *et al.* 1997). 20m transects were laid randomly, at fixed depths at each site (1m-6m) and parallel to the depth contours, based on which the percentage cover of each life form category was calculated. In total 374 transects were recorded, with 11-25 transects per island depending on the size of the reefs..

The plant and animal community was characterized using life form categories, which provide a morphological description of the reef community. Reef condition was assessed based on coral cover, as described by Gomez and Yap (1988), whereby 75-100% live coral cover is "Excellent"; 50-74.9% "Good"; 25-49.9% "Fair"; and 0-24.9% "Poor".

Reef Associated Fishes

The reef fish composition was estimated using under water visual census in 30m long and 6m wide transects (Fowler, 1987, and English et al.,1994). Surveys were carried out in July and October 2004, and January and April 2005. A total of 109 transects were recorded at eleven randomly selected islands in the four island groups. Fish counts started 5-10 minutes after transects had been laid to reduce disturbance caused by the diver.

Fish abundance was recorded using 7 classes (1; 2-5; 6-10; 11-20; 21-50; 51-100 ;> 100 individuals per transect). The abundance of each species was described in this study by two indices: Relative Abundance (RA; the pooled number of individuals of a given species from all censuses/total number of individuals x 100) and Frequency of Appearance (FA; the number of censuses in which a given species/total number of censuses was noted x 100) for all sites (Alevizon and Brooks, 1975). Species diversity was assessed using the Shannon diversity index (H') in natural logarithms. Species richness (S') and evenness (J') were also calculated using the statistical software Biodiversity Pro (ver.2). Cluster analysis based on Bray-Curtis similarity measures was performed in order to examine similarity between study sites. Fish were divided into trophic groups using literature data (Allen, 1985; Myers, 1989; Russ, 1989).

Correlation between fish and habitat parameters were studied by means of Spearman rank correlation (Conover 1980, Sokal & Rohlf 1995) using the statistical software Biodiversity Pro (ver.2).

RESULTS

Status of Coral Reefs

The average live coral cover in GoM is 35%, with a cover of 37% in the Mandapam Group; 44% in the Keezhakkarai Group; 32% in the Vembar Group; and 29% in the Tuticorin Group. Table 2 provides details of reef status in GoM Island groups and Appendix 1 contains an updated check-list of corals.

Reef Associated Fishes

A total of 50 fish species in 27 families were recorded using UVC in the 4 island groups (see species list, Appendix 2). In the Tuticorin group the most abundant species recorded were *Lutjanus* sp (RA 8.01%), *L. russelli* (RA 7.43%), *Carangoides malabaricus* (RA 7.945), *Siganus javus* (RA 8.58%), and *Cryptocentrus* sp (RA 8.58%). *Arothron mappa* had the lowest relative abundance and the frequency appearance was below 25%. In the Vembar group commercially important species such as *Lutjanus russelli* and Siganus *javus* had the highest RA, of 8.11% and 8.72% respectively, and a 100% frequency

Table 2. Status of coral reefs in the Gulf of Mannar (CC - Live Coral Cover; DCA - Dead Coral with Algae; DC – Dead Coral).

Variables		Condition	Major Threats	Diseases
Mandapam Group				
Coral reef area (km²)		Fair – Shingle, Krusadai , Pullivasal, Poomarichan, Manoliputti, Manoli, Hare	Destructive fishing (Bottom trawling & bottom gill net); Seaweed collection; Lobster trap operation; Shell collection; Holothurian collection; Sewage disposal	Yellow blotch, Black band, White band, Red band, Aspergillosis and Pink blotch
CC&DCA	22.6			
DC	8.5			
DCA	11.4			
Total	42.5			
Coral cover (%)				
CC	36.5±8.3			
DCA	22.1±9.7			
Keezhakkarai group				
Coral reef area (km²)		Fair - Mulli, Valai, Thalaiyari, Poovarasanpatti, Anaipar, Valimunai Good - Appa	Destructive fishing (Bottom trawling, shore sine operation & bottom gill net operation); Seaweed collection; Holothurian collection; and Sewage disposal.	Black Band, Yellow Blotch, White Band, and Red Band
CC&DCA	20.4			
DC	6.7			
DCA	--			
Total	27.1			
Coral cover (%)				
CC	43.6±11.1			
DCA	15.7±5.5			
Vembar group				
Coral reef area (km²)		Poor - Nallathanno Good - Pulivinichalli Fair - Upputhanni	Destructive fishing (Bottom trawling & shore seine operation); Holothurian collection; and Seaweed collection	Black Band, White Pox, Red Band, Yellow Blotch Aspergillosis
CC&DCA	12			
DC	10.7			
DCA	--			
Total	12			
Coral cover (%)				
CC	32.0±24.1			
DCA	48.9±16.2			
Tuticorin group				
Coral reef area (km²)		Fair – Kariyachalli, Vaan Poor - Vilanguchalli Poor - Koswari	Coral mining; Sewage disposal; and Destructive fishing (Bottom trawling)	Black Band, White Band, Red Band and Yellow Blotch
CC&DCA	10.9			
DC	7.5			
DCA	--			
Total	18.4			
Coral cover (%)				
Live coral	29.8±13.4			
DCA	7.8±1.3			

of appearance. Other common species recorded included *Carangoides malabaricus*, *Pempheris* sp. and *Parapericanthus* sp. In the Keezhakkarai group the highest relative abundance was recorded in *Lutjanus* sp. (8.77%), *L. russelli* (8.41%), *Carangoides malabaricus* (8.32%), *Siganus javus* (RA-7.69%) and *Cryptocentrus* sp. (RA-7.5%). In the Mandapam group, the highest relative abundance was found in *Pempheris* sp. and *Cryptocentrus* sp. (8.26%), with commercially important species such as *Lutjanus russelli* and *Carangoides malabaricus* also common. Lethrinidae, Lutjanidae, Siganidae, Chaetodontidae,

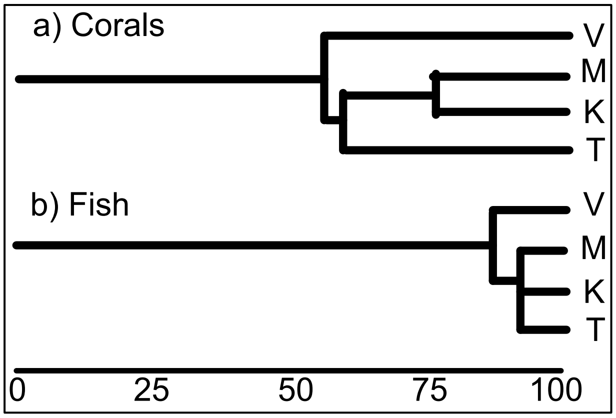

Figure 2. Dendogram of similarity between a) live coral cover and b) fish assemblages between the four island groups: Tuticorin (T), Vembar (V), Keezhakkarai (K) and Mandapam (M).

Ephippidae, Gerreidae, Pempherididae and Gobiidae had a frequency of appearance of 100%.

Community Indices

Only minor variation in community indices was observed, with the highest Shannon diversity index (H') of 1.60 and species richness (S) of 49.30 recorded in the Vembar group. The Tuticorin group showed the lowest H' (1.55) while the Keezhakkarai group showed the lowest S (48.0). No variation in evenness (J' = 0.97) was observed between island groups.

Cluster Analysis

Cluster analyses was applied to benthic cover and fish assemblage data (Fig. 2). The coral community was most similar (75%) between the Keezhakkarai and Mandapam groups, with the Vembar group most dissimilar from the other three (56% similarity). Fish assemblages were much more uniform with the highest similarity between Tuticorin, Keezhakkarai and Mandapam groups of islands (92%), and 88 % similarity between these and Vembar

Correlations

A summary of correlations between fish community variables (total abundance, species richness, Shannon diversity and trophic groups) and habitat variables (live coral cover, *Acropora*, non-*Acropora*, dead coral cover, coral rubble, and sand) from the reef areas is shown in Table 3. Among the habitat variables, only live coral cover was highly correlated with total fish abundance (though negatively), with coral rubble and species richness also showing significant correlation.

Table 3. Summary of correlations between fish community and coral habitat variables (significant levels are given as $p < 0.05$* and $p < 0.01$**).

	Live coral cover	*Acropora*	Non-*Acropora*	Dead coral cover	Coral rubble	Sand
Total abundance	-0.76 **	-0.29	-0.21	-0.30	-0.50 *	-0.06
Species richness	0.27	0.23	0.06	0.58 *	-0.90 **	0.05
Shannon diversity	0.11	0.81 **	-0.47	0.98 *	-0.54 *	0.65 *
Invertebrate feeders	-0.35	0.77 **	-0.78 **	0.46	0.53 *	0.83 **
Piscivores	-0.04	-0.51 *	0.27	-0.78 **	0.87 **	-0.37
Herbivores	0.63 **	-0.19	0.55 *	0.21	-0.70 **	-0.41
Planktovires	-0.97 **	0.07	-0.62 **	-0.23	0.12	0.37
Omnivores	0.51 *	0.38	0.08	0.71 *	-0.67 **	0.13
Corallivoris	0.42	0.68 **	-0.27	0.61 *	0.44	0.52 *

Shannon diversity of the fish population was significantly correlated with habitat variables such as coral cover, *Acropora*, dead coral cover, and sand. The habitat variables *Acropora*, non-*Acropora*, coral rubble, and sand were significantly correlated with invertebrate feeders. Piscivores showed significant correlation with non-*Acropora* and coral rubble, while herbivores showed significant correlation with live coral cover, non-*Acropora* and dead coral cover. Omnivores were found to be significantly correlated with habitat variables live coral cover, *Acropora*, non-*Acropora*, dead coral cover, and sand. Significant correlation was observed between corallivores and all habitat variables except non-*Acropora*.

DISCUSSION

There are numerous reports on the coral reefs and associated resources of the Gulf of Mannar, however predominantly from the Mandpam coast and on taxonomic aspects (Pillai, 1971, 1972, 1977, 1986, 1994 and 1996), and more comprehensive baseline information on the area has been lacking. This study adds to the pool of knowledge on the reefs of the Gulf of Mannar, in view of increasing stress on this ecosystem and in support of conservation and management efforts by state and federal governments and other organizations.

The study found fringing and patch reef common in all islands of the Gulf of Mannar. Keezhakkarai group has the highest percentage of healthy live coral cover, followed by Mandapam, Vembar and Tuticorin groups. The dominant coral species in Gulf of Mannar are *Acropora cytherea*, *A. formosa*, *A. nobilis*, *Montipora digitata*, and *Porites* sp., while *Echinopora lamellosa* and *Pocillopora damicornis* are commonly present in Keelakarai and Mandapam groups respectively. Recruit density, predominantly *Pocillopora* sp., *Montipora* sp., and *Acropora* sp, has increased by about 10-15% in each island since the Indian Ocean tsunami in 2004. Coral diversity has been highly affected by coral mining, which has also led to change in habitat and abundance of reef associated species.

However, in spite of being so vital for the local population, reef fish communities in the Gulf of Mannar are the least studied part of the ecosystem. Reef fishes are strongly influenced by the structure of their habitat, with more complex coral reefs generally supporting more fish (e.g. Sedberry and Certer, 1993; Nagelkerken et al., 2000, and Mateo & Tobias, 2001). Results presented herein indicate higher reef fish species richness in areas with high cover of live coral, as well as areas with dead standing coral with algal growth. This shows that habitat variables play a substantial role in the enhancement of fish diversity. Fish-habitat correlations from various regions (Caribbean, Southeast Asia and Great Barrier Reef) show significant relationship between structural complexity and reef fish diversity (Risk, 1972, Luckhurst & Luckhurst 1978, Carpenter et al., 1981, McCormick, 1994). Distribution patterns of reef fishes have been related to available shelter and food (Williams 1991, Sheppard et al., 1992, Ohman et al., 1993). Refuges may positively influence prey abundance (Hixon and Beets 1993) and the smaller reef fishes rely on branching corals for protection (Sale 1972). Herbivores feed primarily on filamentous algae that grow with a high turnover rate mainly in the shallows between coral colonies and among coral branches (Borowitzka, 1981, Scott and Russ 1987, Choat 1991).

The corals reefs in the GoM grow in an area of chronic sediment supply and resuspension, with the amount of suspended sediment largely controlled by local wind and tidal conditions, as well as water flushing. Sedimentation is high in coastal waters around almost all the islands, with mean rates from 20-70 $mg/cm^2/day$ at all sites measured. Sedimentation rates are high during August because of strong winds in June and July due to the southwest monsoon causing resuspension. In January the calm weather of the northeast monsoon tends to decrease turbidity and sedimentation. The reef biota is accustomed to these local conditions and to the natural variability in the system. In spite of the high rate of sedimentation at Krusadai Island, its reef community appears healthy and diverse, and overall the coral reefs of the Gulf of Mannar presently seem to be in relatively good condition with respect to sedimentation (Patterson et. al., 2007), although some corals with a wide table like shape, e.g. *Acropora cytherea*, tend to trap sediment particles and at times shows signs of stress and bleaching. However, in general, the turbidity and sedimentation regime of the area is believed to be one of the factors limiting reef development, and a possible increase in sediment loads from land is a cause for concern. Krusadai Island, located very close to the mainland, and Manoli Island in the vicinity of a fishing harbor, experience high sedimentation. Boat traffic and port operations may explain high sedimentation at the patch reef close to the mainland and Tuticorin Harbour. The high sedimentation rate around Vaan Island is probably caused by the sewage outlet in Threspuram village (Patterson et al., 2007).

The Gulf of Mannar coral reef ecosystem is stressed because of its proximity to the mainland and coastal populations, urban centres and activities. However, although people once injudiciously exploited and damaged the reefs and associated resources, the necessity for conservation and management for sustainable utilization has become more widely understood in the recent past, providing an opportunity for management and sustainable use of the area. The present average coral cover of 35% in the Gulf of Mannar is to an extent due to the enforcement of illegal coral mining activities before the tsunami. The tsunami itself, although not impacting the reefs directly, made coastal dwellers more aware of the broader benefits of coral reefs and marine and coastal ecosystems in general. There are also several research institutes and non-governmental organizations involved in awareness creation and introduction of alternative livelihood schemes to reduce the pressure of fishing, the impacts of which have been evident in the aftermath of the tsunami. Presently, the Gulf of Mannar Biosphere Trust, which was set up to implement a GEP-UNDP project on biodiversity conservation in the Gulf of Mannar, is also actively involved in awareness campaigns, capacity building for alternative livelihood options, participatory eco-development initiatives and collection of baseline information on various resources. The information on reef distribution, diversity, status, fish assemblages and rate of sedimentation provided herein has strengthened this development, and will support further management and conservation.

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APPENDIX 1 – SCLERACTINIAN CORALS.

Coral fauna of southeast coast of India including Gulf of Mannar and Palk Bay (References: Pillai, 1986, Patterson *et al.*, 2005 and Patterson *et al.*, 2007).

No. of Genera	40
No. of Families	14
No. of species	117
Hermatypic	
Genera	30
Species	106
Ahermatypic	
Genera	10
species	11

*Recorded by: * Pillai, 1986; ** Patterson et al., 2005; ***Patterson et al., 2007*

Family : POCILLOPORIDAE Gray, 1842
1. Genus: POCILLOPORA Lamarck, 1816
Pocillopora damicornis (Linnaeus, 1758) *
Pocillopora verrucosa (Ellis and Solander, 1786) *
Pocillopora eydouxi Milne Edwards and Haime, 1860 *
2. Genus: MADRACIS Milne Edwards and Haime, 1849
Madracis interjecta v. Marenzeller, 1906 *
(= *Madracis kirbyi*, Veron and Pichon, 1976)
Family : ACROPORIDAE Verrill, 1902
3. Genus: ACROPORA Oken, 1815
Acropora formosa (Dana, 1846) *
Acropora intermedia (Dana, 1846) **
Acropora valenciennesi (Milne Edwards and Haime, 1860) *
*A. microphthalma (Verrill, 1869)**
Acropora sp.novo **
Acropora corymbosa (Lamarck ,1816) *
Acropora nobilis (Dana, 1846) *
Acropora humilis (Dana, 1846) *

Acropora valida (Dana, 1846) *
Acropora hemprichi (Ehrenberg, 1834) **
Acropora hyacinthus (Dana, 1846) *
Acropora stoddarti Pillai and Scheer, 1976 **
Acropora indica (Brook, 1893) *
Acropora millepora (Ehrenberg, 1834) *
Acropora diversa (Brook, 1893) *
Acropora brevicollis (Brook, 1893) *
Acropora cytherea (Dana, 1846) *
Acropora hebes (Dana, 1846) ***
Acropora echinata (Dana, 1846) ***
Acropora nasuta(Dana, 1846) ***
Acropora abrolhosensis (Veron, 1985) ***
Acropora pillaii sp. nov **
4. Genus: MONTIPORA de Blainville, 1830
Montipora subtilis Bernard, 1897 *
Montipora digitata (Dana, 1846) *
Montipora divaricata Bruggemann, 1897 *
Montipora venosa (Ehrenberg, 1834) *
Montipora spumosa (Lamarck, 1816) *
Montipora tuberculosa (Lamarck, 1816) *
Montipora monasteriata (Forskal, 1775) *
Montipora jonesi Pillai, 1986 *
Montipora granulosa Bernard, 1897 *
Montipora exserta Quelch, 1886 *
Montipora turgescens Bernard, 1897 *
Montipora manauliensis Pillai, 1969 *
Montipora verrucosa (Lamarck, 1816) *
Montipora hispida (Dana, 1846) *
Montipora foliosa (Pallas, 1766) *
Montipora verrilli Vaughan, 1907 *
Montipora aequituberculata Bernard, 1897 ***
Montipora sp. Novo ***
5. Genus: ASTREOPORA de Blainville, 1830
Astreopora myriophthalma (Lamarck, 1816) *
II Suborder : FUNGIINA Verrill, 1865
Super family : AGARICIICAE Gray, 1847
Family : AGARICIIDAE Gray, 1847
6. Genus: PAVONA Lamarck, 1801
Pavona duerdeni Vaughan, 1907 *
Pavona varians (Verrill, 1864) *
Pavona decussata (Dana, 1846) *
Pavona divaricata Lamarck, 1816 (= *P.venosa*) *
7. Genus : PACHYSERIS Milne Edwards and Haime, 1849
Pachyseris rugosa (Lamarck, 1801) *
Family : SIDERASTREIDAE Vaughan and Wells, 1943
8. Genus : SIDERASTREA de Blainville, 1830
Siderastrea savignyana Milne Edwards and Haime, 1850 *
9. Genus : PSEDOSIDERASTREA Yabe and Sugiyama, 1935
Psedosiderastrea tayami Yabe and Sugiyama, 1935 *
10. Genus: COSCINARAEA Milne Edwards and Haime, 1849
Coscinaraea monile (Forskal, 1775) **
11. Genus : PSAMMOCORA Dana, 1846
Psammocora contigua (Esper, 1797) *
Super family : FUNGIICAE Dana, 1846
Family : FUNGIIDAE Dana, 1846
12. Genus: CYCLOSERIS Milne Edwards and Haime, 1848
Cycloseris cyclolites (Lamarck, 1801) *
Super family : PORITICAE Gray, 1842
Family : PORITIDAE Gray, 1842
13. Genus: GONIOPORA de Blainville, 1830
Goniopora stokesi Milne Edwards and Haime, 1851 *
Goniopora planulata (Ehrenberg, 1834) *
Goniopora minor Crossland, 1952 **
Goniopora stutchburyi Wells, 1955 (*Goniopora nigra*, Pillai,1969) *
Goniopora sp. novo ***
14. Genus: PORITES Link, 1807
Porites solida (Forskal, 1755)
Porites mannarensis Pillai, 1969 *
Porites lutea Milne Edwards and Haime, 1851 *
Porites lichen Dana, 1846 *
Porites exserta Pillai, 1969 *
Porites compressa Dana 1846 *
Porites complanata ***
Porites nodifera ***
III Suborder : FAVIINA Vaughan and Wells, 1943
Super family : FAVIICAE Gregory, 1900
Family : FAVIIDAE Gregory, 1900
15. Genus: FAVIA Oken, 1815
Favia stelligera (Dana, 1846) *
Favia pallida (Dana, 1846) *
Favia speciosa (Dana, 1846) *
Favia favus (Forskal, 1775) *
Favia valenciennesi (Milne Edwards and Haime, 1848) *
(= *Montastrea valenciennesi*)
Favia matthaii Vaughan, 1918 **
16. Genus: FAVITES Link, 1807
Favites abdita (Ellis and Solander, 1786) *
Favites halicora (Ehrenberg, 1834) *
Favites pentagona (Esper, 1794) *
Favites melicerum (Ehrenberg, 1834) *
Favites complanata (Ehrenberg, 1834) *
Favites flexuosa (Dana, 1846) **

17. Genus: GONIASTREA Milne Edwards and Haime, 1848
Goniastrea pectinata (Ehrenberg, 1834) *
Goniastrea retiformis (Lamarck, 1816) *
18. Genus: PLATYGYRA Ehrenberg, 1834
Platygyra daedalea (Ellis and Solander, 1786) *
Platygyra sinensis (Milne Edwards and Haime, 1849) *
Platygyra lamellina (Ehrenberg, 1834) *
Platygyra sp. Novo ***
19. Genus: LEPTORIA Milne Edwards and Haime, 1848
Leptoria phrygia (Ellis and Solander, 1786) *
20. Genus: HYDNOPHORA Fischer de Waldheim, 1807
Hydnophora microconos (Lamarck, 1816) *
Hydnophora exesa (Pallas, 1766) *
Subfamily : MONTASTREINAE Vaughan and Wells, 1943
21. Genus: LEPTASTREA Milne Edwards and Haime, 1848
Leptastrea transversa Klunzinger, 1879 *
Leptastrea purpurea (Dana, 1846) *
22. Genus: CYPHASTREA Milne Edwards and Haime, 1848
Cyphastrea serailia (Forskal, 1775) *
Cyphastrea microphthalma (Lamarck, 1816) *
*Cyphastrea japonica ****
23. Genus : ECHINOPORA Lamarck, 1816
Echinopora lamellosa (Esper, 1795) *
24. Genus : PLESIASTREA Milne Edwards and Haime, 1848
Plesiastrea versipora (Lamarck, 1816) *
Family : RHIZANGIIDAE d'Orbigny, 1851
25. Genus: CULICIA Dana, 1846
Culicia rubeola (Quoy and Gaimard, 1833) *
Family : OCULINIDAE Gray, 1847
26. Genus: GALAXEA Oken, 1815
Galaxea fascicularis (Linnaeus, 1767) *
Galaxea astreata (Lamarck, 1816) (= *G. clavus*) *
Family : MERULINIDAE Verrill, 1866
27. Genus: MERULINA Ehrenberg, 1834
Merulina ampliata (Ellis and Solander, 1786) *
Family : MUSSIDAE Ortmann, 1890
28. Genus: ACANTHASTREA Milne Edwards and Haime, 1848
*Acanthastrea echinata ****
29. Genus: Lobophyllia de Blainville, 1848
Lobophyllia corymbosa (Forskal, 1775) ***
30. Genus: SYMPHYLLIA Milne Edwards and Haime, 1848
Symphyllia radians Milne Edwards and Haime, 1849 *
Symphyllia recta (Dana, 1846) *
Family : PECTINIIDAE Vaughan and Wells, 1943
31.Genus : MYCEDIUM Oken, 1815
Mycedium elephantotus (Pallas, 1766) *
IV Suborder : CARYOPHYLLIINA Vaughan and Wells, 1943
Family : CARYOPHYLLIIDAE Gray, 1847
Subfamily : CARYOPHYLLIINAE Gray, 1847
32. Genus: POLYCYATHUS Duncan, 1876
Polycyathus verrilli Duncan, 1876 *
33. Genus: HETEROCYATHUS Milne Edwards and Haime, 1848
Heterocyathus aequicostatus Milne Edwards and Haime, 1848 *
34. Genus: PARACYATHUS Milne Edwards and Haime, 1848
Paracyathus profundus Duncan, 1889 *
V Suborder : DENDROPHYLLIINA Vaughan and Wells, 1943
Family : DENDROPHYLLIIDAE Gray, 1847
35. Genus: BALANOPHYLLIA Searles Wood, 1844
Balanophyllia affinis (Semper, 1872) *
36. Genus: ENDOPSAMMIA Milne Edwards and Haime, 1848
Endopsammia philippinensis Milne Edwards and Haime, 1848 *
37. Genus: HETEROPSAMMIA Milne Edwards and Haime, 1848
Heteropsammia michelini Milne Edwards Haime, 1848 *
38. Genus: TUBASTREA Lesson, 1834
Tubastrea aurea (Quoy and Gaimard, 1833) *
39. Genus: DENDROPHYLLIA de Blainville, 1830
Dendrophyllia coarctata Duncan 1889 *
Dendrophyllia indica Pillai, 1969 *
40. Genus : TURBINARIA Oken, 1815
Turbinaria crater (Pallas, 1766) *
Turbinaria peltata (Esper, 1794) *
Turbinaria mesenterina (Lamarck, 1816) (= *T. undata*) *

New records in Gulf of Mannar (Patterson *et al.*, 2007)
Acropora hebes
Acropora echinata
Acropora nasuta
Acropora abrolhosensis
Montipora aequituberculata
Montipora sp. novo
Goniopora sp. novo

Porites complanata
Porites nodifera
Platygyra sp. novo
Cyphastrea japonica
Acanthastrea echinata
Lobophyllia corymbosa

APPENDIX 2 – FISH

Lethrinidae
Lethrinus nebulosus
L. harak
Lutjanidae
Lutjanus sp
Lutjanus fulviflamma
Lutjanus russelli

Carangidae
Carangoides malabaricus
Carangoides ferdau
Caranx sp

Serranidae
Epinephelus coioides
Epinephelus malabaricus
E. areolatus
Cephalopholis miniata
Cephalopholis formosa
Cephalopholis sp

Siganidae
Siganus canaliculatus
Siganus javus

Scaridae
Scarus ghobban
Scarus sp

Holocentridae
Sarcocentron rubrum
Sarcocentron spiniferum

Mullidae
Upeneus sp
Parupeneus indicus

Haemulidae
Pomacanthus sp
Acanthorus sp
Plectorchinchous sp

Chaetodontidae
Chetodon sp
Heniochus diphecuts
Heniochus sp

Ephippidae
Platax sp
Amphiprion sebae

Terapontidae
Terapon jarbua

Tetraodontidae
Canthigaster solandri
Arothron mappa

Narcinidae
Narcine timlei

Centropomidae
Psammoperca waigensis

Labridae
Halichoeres sp
Thalassoma sp

Acanthuridae
Acanthurus dussumieri
A. xanthopterus

Ostraciidae
Ostracion cubicus

Gerreidae
Gerres filamentosus

Leiognathidae
Leiognathus sp

Platycephalidae
Platycephalus indicus

Sphyraenidae
Sphyraena genie

Plotosidae
Plotosus lineatus

Scorpaenidae
Pterois volitans

Pempherididae
Pempheris sp
Parapriacanthus sp

Gobiidae
Cryptocentrus sp

Nemipteridae