

## Coral Reef Surveys in India

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**Abstract.** This paper briefly describes the history of coral reef surveys in India. All the surveys done so far have used simple techniques, but they have been quite effective in highlighting the damages to reefs in the short-term due to human interferences and in persuading the Government agencies to take protective and conservational measures. The current approach is towards establishing a monitoring design to detect changes in reef ecology in the long-term, and to standardize the survey techniques to be compatible with those practiced elsewhere. With these objectives, diversification of observations to include various reef responses both at community level and at organism level have just begun and may eventually be continued to integrate with global reef monitoring programs.

Pending a consensus on the modalities of global reef monitoring by IOC (along with UNEP, WMO and IUCN) and their implementation, we propose to review here the earlier surveys done on Indian reefs, and discuss how effective they were in the past, and would be in the future. In doing so, we trace the survey history in five stages.

The majority of the Indian reefs are fringing, located around chains of offshore islands in the Gulf of Mannar and Gulf of Kachchh along the mainland coast, and the islands of Andaman and Nicobar. Lakshadweep reefs are atolls. Patch reefs with low generic diversity exist at some places along the west coast, and vast submerged banks in the Arabian sea, north of Lakshadweep, harbour several coral genera. Fossil reefs, drowned as a result of Holocene transgression, and presently lying at depths of 92, 85, 75, and 55 m, are also known from the central west coast of India (Vora and Almeida 1990).

The first stage of surveys in late 1960s was primarily for an assessment of species diversity of corals, resulting in the record of 199 hermatypes (under 50 genera) and 44 ahermatypes (under 21 genera) from the Indian reefs (Pillai 1983 and other references contained therein; Wafar 1986). This is, however, not complete, since the collections were restricted to only a few reef areas (~10% of Indian reefs) and shallower depths (<3-4 m). The first quantitative survey of the distribution of corals on a fringing reef in India was also done at this time (Pillai 1969). The sampling technique was a line-transect laid from the shore to the reef slope, with 1m × 1m quadrat measurements taken at 5 m intervals. No records of percentage coral cover nor of other parameters were made, but a distinct difference in species abundance between shoreward

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We do not think that anyone would disagree on the urgent need to survey the present state of coral reefs and to monitor short- and long-term changes in them resulting either from natural causes, human interferences or from a global climate shift. Divergence of views begins only on the type of survey methods to be used (logistic-constrained), parameters to be measured (logistic- and finance-constrained), and application of hi-tech approaches such as remote-sensing or telemetry (resolution-constrained). Nevertheless, when used to detect changes in reef responses to altered environmental conditions, these approaches have generally been effective regionally (several papers in this Symposium), but less coherent on an international level.

**Table 1.** Overall percentage cover of abiotic and biotic components of surveyed areas South Andaman (Dec 1988)

Content	Stations						
	1	2	3	4	5	6	7
Length (m)	143	112	89.5	100	52.5	50	103
Rock	4	7.3	17	22.8	31.6	16.5	—
Sand	26.6	10.5	10.6	10.3	0.4	—	9.7
Mud	0.8	11	—	1.8	—	—	5.9
Rubble	11.3	33.2	17	—	—	1.3	3.3
Old dead corals	42.7	24.3	13.3	33.6	19.7	13.7	12.7
Live coral	5.5	5.2	32	33.2	34.1	59.9	47.7
Recently dead coral	0.5	—	2	1	6.5	2	8.9
Bleached coral	0.4	—	0.6	0.3	3.1	1.7	0.4
Soft coral	—	—	0.9	3.4	3.1	2.8	1
Sponges	—	—	0.3	0.6	0.4	—	0.3
Molluscs	—	0.3	0.2	0.6	0.6	1.2	0.8
Echinoderms	—	—	1.8	—	0.7	0.7	1.2
Seaweeds	7.3	4.9	4.1	2.2	—	—	7.5
Other materials	—	3.7	—	—	—	—	—

1—Chatham bridge; 2—Left of fisheries jetty; 3—Hospital area; 4—South Point girls school; 5—Mazar Pahad; 6—Corbyn's quarry area; 7—New wandoor

and seaward sides of the reef was demonstrated, with the former consisting of massive, large-polyped forms, and the latter, ramose, small-polyped forms.

In 1970s and 1980s reef surveys were mainly qualitative. This was because of two factors. The first was that planned coral reef surveys were yet to come into existence, and what was done was usually done as part of surveys for other coastal marine ecosystems as well. The second factor was that many reefs were apparently degrading because of intensive exploitation and rapid growth of on-shore developmental activities. These circumstances did not permit well-laid out quantitative surveys but called for a quick assessment so that a policy on the degree of control to be exercised could be formulated by the authorities. As a result, the surveys were usually visual, and the reef status was classified into two categories; where degradation was not perceptible and regulation of human activities was as yet unwarranted, or where damage was clearly perceptible and controls were recommended to be exercised. Examples of this approach are the Gulf of Mannar and Gulf of Kachchh reefs. In both of these geographical areas, coral mining was on a commercial scale, for the lime industry in the former (Pillai 1973; Venkataramanujam et al. 1981), and for the cement industry in the latter (Patel 1985). In both of these instances damages to reefs, often up to 50% and occasionally up to 100%, were strikingly evident even to a casual observer. Remedial measures were then proposed, and accepted, leading to a total ban on coral extraction and restriction of reef areas to other users. Both of

these areas have now been declared as Marine National Parks.

Planned quantitative surveys in the last few years constitute the third stage. The study area was the Andaman-Nicobar island group, with 110 stations located in 45 reef areas representing a range from pristine to heavily degraded reefs (INTACH 1989). The line transect method was employed at each site, with the transects laid out in triplicate, spaced at 50 m intervals, running from the shore to the reef slope. Several sites were surveyed in each location, the number having been chosen in such a way as to cover a reasonably wide area in the case of large islands, and the whole perimeter in the case of smaller islands. Proportionate lengths of live and dead hard corals, soft corals, sponges, other macro-organisms and sand or rock directly under the transect line were recorded meter by meter. In addition, one m<sup>2</sup> quadrats (divided into 16 sub-squares) were placed at different depths along the line and occurrence of all the major biotic and abiotic elements within each small square was recorded. Special attention was paid to looking for coral predators (especially the Crown-of-thorns starfish) and other possible agents of damage. Corals were further recorded as healthy, diseased or otherwise affected, and dead (old or recent). A snorkeller recorded visual counts of reef fishes within five meters on either side of the line. Along each transect at selected stations, hydrographic parameters (temperature, salinity, dissolved oxygen, pH and total suspended load) were also measured. Additionally, these hydrographic parameters were monitored at fortnightly intervals at 9 stations in the Andamans

(NIO 1990). A typical record of gross details from line transect survey is shown as Table 1. Finer details, not shown here, record percentage abundance of each identifiable species of faunal and floral groups.

The findings, especially a comparison of the state of reefs near human settlements with those unaffected by such influences, clearly demonstrate that the intensity of damage to reefs is in direct proportion to the onshore developmental activities (INTACH 1989), with the natural causes being responsible for only a smaller fraction. Chief factors among the developmental activities responsible for reef damages are discharge of industrial and sewage pollutants, and logging operations. The latter results in increasing quantities of silt being washed out into the coastal waters where suspended load levels usually are  $>10 \text{ mg l}^{-1}$  and occasionally up to  $200 \text{ mg l}^{-1}$  (NIO, 1990) and secchi depth was rarely  $>2 \text{ m}$ . This survey was also the first quantitative one on *Acanthaster planci*. Density of the Crown-of-thorns was  $1 \text{ km}^{-2}$ , with enhanced localised abundance. Another noteworthy observation was the frequency of the incidence of diseased corals. Seemingly fungal-infected massive corals were commonly observed (Raghukumar and Raghukumar 1991) with single or multiple necrotic patches. The fungus was identified as *Scolecobasidium* sp. but apparently this is only a secondary infector.

The fourth stage of reef monitoring was by remote sensing (Nayak et al. 1989). This was applied to the Gulf of Kachchh reefs, and the Landsat MSS and TM data for these reefs at selected time intervals (1975, 82, 85 and 88) were processed to delineate broad areas that include coral reefs, mangroves, mud flats, sandy beaches and salt pans. Calibration with ground truth and later comparison of the areal coverage of the different ecosystems clearly demonstrated a loss of reef cover in the Gulf of Kachchh Marine National Park area from  $117 \text{ km}^2$  in 1975 to  $53 \text{ km}^2$  in 1985, and a recovery subsequently by  $28 \text{ km}^2$  in 1988. The chief cause for the loss of reef cover was uncontrolled mangrove felling and the resultant increased transport of mud onto the reefs (NIO 1992). When the reef area was declared as a Marine National Park and enforcement of the controls on mangrove deforestation began, recovery of both the mangroves and coral reefs was remarkable (Nayak et al. 1989). Unfortunately, however, this approach is valid only to detect changes globally on large tracts, and finer records are difficult to obtain because of the low resolution of the remotely-sensed images. Nevertheless, this remains a good tool for long-term monitoring and we propose to rely more on this, and

plan to obtain pictures with better resolution and have more quality control of the ground truth data in the future.

The major component of the current stage of surveys is the establishment of a field laboratory at Kalpeni atoll in the Lakshadweep, dedicated for reef research. Over the last two years, regular monitoring for hydrography, nutrients, biological productivity and microbiological aspects have been commenced. The objectives are two-fold: the first is to provide baseline data for reef water quality and ecology, and the second is to be able to detect responses in them consequent to short- and long-term changes. In fact, this ideally fits with the proposed global monitoring program and would serve as an important geographical link in the network of monitoring stations planned to be established (IOC/WMO/UNEP/IUCN workshop deliberations in this Symposium).

In reviewing the reef survey history in India, it readily becomes apparent that the survey methods used here lack the refinement of sampling design. Nevertheless, as the results themselves indicate, they have been quite useful in solving short-term problems. However, for future surveys, selection of the sampling design and the methodology should be more rigorous, with adequate levels of replication at all spatial levels *i.e.* within sites and within locations; understandably, small well-conducted surveys can often provide more useful information than large surveys with poor design, as was the case until now. Continuing the transect surveys standardized to be compatible with observations elsewhere, extending them to other reef areas, and resorting more to remote sensing coupled with water quality control and coral physiological responses will, in our opinion, be adequate enough to monitor satisfactorily the state of Indian reefs in the long-term. Equally or more important is the need to create a better awareness both at the Government and public levels of the value of the reefs and their resources, and the need to rationalize the uses of these (Wafar 1986). If this happens, monitoring and funding will become so much easier and simpler.

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