Remote sensing and GIS in coral reef environment : An overview

N. Chandrasekar[1], A. C. C. Victor[2], D. C. V. Easterson[2] and P. Muthiah[2]

[1]Chemistry and Marine Geochemistry Research Lab. SPIC Research Centre, V.O.C.College, Tuticorin - 628 0008

[2]Central Marine Fisheries Research Institute, Tuticorin - 628 001

Abstract

Indian Coast line particularly Tamilnadu, Andaman and Nicobar islands, Lakshadweep islands and Gulf of Kachchh are characterized by mangroves, coral reefs, sea grass and seaweeds. The need for better monitoring and mapping of these resources has increased dramatically in recent years. The main aim of this paper is to review the potential of high resolution satellites used for coral reef ecosystem. Recent studies have warranted the usefulness of GIS for better planning and management practices of Coral conservation.

Introduction

Studies have been in progress during last decades in various research centers aimed at monitoring and mapping the coral environment in India using satellite imagery and aerial photographs. Coral reefs have been destroyed by siltation, logging, mining and pollution. Sedimentation of reefs reduces live coral and species diversity and fish biomass. The knowledge about various zones and their conditions will help to plan preventive and conservative measures to protect the fragile ecosystem (Nayak et.al., 1996).

The major issues which require to prevent degradation of corals include (1) monitoring long term trends of dynamic changes, (2) planning and implementing coastal protection, (3) formulating proper criteria for the location of industries, aqua culture and recreational activities, (4) monitoring and conserving critical environmental features, (5) assessing the impact of reclamation of land from the sea, sand mining, dredging and recreational activities on coastal ecology, (6) controlling pollution of coastal and estuarine and (7) improving navigation systems etc.

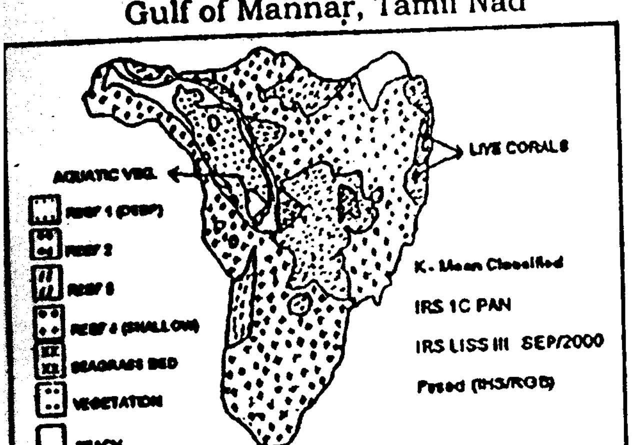
The major requisites for coastal zone monitoring and management are the availability of information on existing conditions and changes that may have occurred over the years. Several regional, national and global initiatives launched integrated management studies in coastal areas have revealed that the limitations posed by conventional means of information gathering with respect to space and time have been among the major constraints in achieving these goals. Several scientific studies carried out using satellite data for addressing various issues related to the coastal zone have proved to be extremely useful in mapping, detecting, quantifying and monitoring the features. This is mainly because satellite remote sensing has the advantage of providing multispectral, synoptic information over large areas including inaccessible regions. Remote sensing technology has given an additional option to assess the natural resources of the earth. This application is becoming more and more important due to attention now being given to the related issues, such as sustainable development.

In last two decades, the scenario related

› remote sensing has witnessed rapid ıanges. The data provided by each satellite nd their respective sensors have been etter, particularly considering the esolution and repeatability. Table 1 rovides the technical features of Indian atellites. Scientific studies carried out ısing satellite data, mainly obtained from RS have proved to be of immense use n identifying and monitoring the coastal eatures (Table- 2 & 3).

The advantages of using geographic nformation system for integration of 'arious thematic information derived rom satellite data with collateral data such as socio economic and cultural data are significant in arriving at an integrated coastal zone management practices. GIS coupled with remote sensing for selected regions of the coast in the country towards better planning and management practices of coral conservation (Desai et.al., 2000) are in primitive stage in India.

Fig 1a - Classified image of koswari reef, Gulf of Mannar, Tamil Nad



Coral Reef Mapping

Maps are critical tools in the characterization, management and conservation of coral reef ecosystems. Without maps, designating research areas, identifying where and debating the consequences of establishing marine protected areas or balancing the needs for resource conservation with resource extraction would be most difficult. So far, many of these decisions have been made without accurate, detailed maps.Maps are available for portions of the Great Barrier Reef in Australia and a few other locations. Worldwidc, detailed coral reef maps are essentially non-existent. NASA and USGS asked the marine science community

Fig 1b -Classified image of van reef Gulf of Mannar, Tamil Nadu

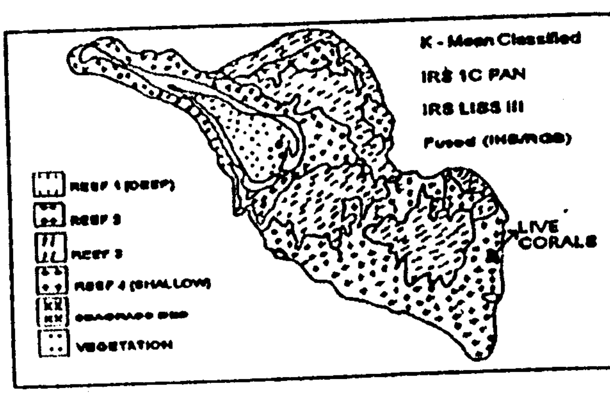


Fig 2 - A coral reef map of Lakshadweep Islands showing reef flat, live coral platform, uncharted coral heads lagoon, seagrass and coralline shelf.

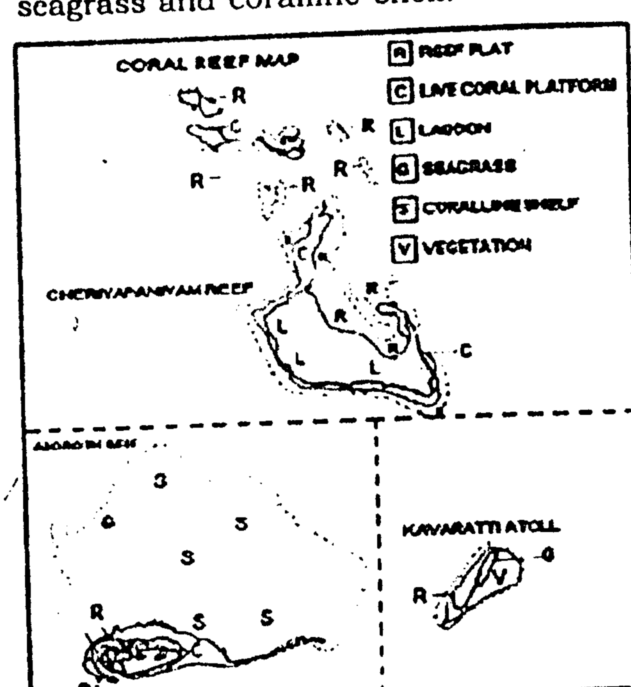


Table 1 - Technical Characteristics of Satellites

Features	Landsat 1-3	Landsat 4-5	Landsat 1-5	SPOT	IRS-1A	IRS-1B	IRS - 1C/1D LISS-III	IRS - 1C/1D PAN	IRS - 1C/1D WiFS	OCM IRS - P3 WiFS	OCM IRS - P3 MOS-A	OCM IRS - P3 MOS-B	OCM IRS - P3 MOS-C	IRS -P4
Year	1982	1984	1982	1987	1988	1991	1995 (1C), 1997 (1D)			1994				1999
Altitude	915	705		832	904	904	780	904	904					
Orbit	← Near Polar Sun synchronous →													
Inclination	99.09	98.2	98.0	98.7	99.0	99	99	99	99					
Repeat Cycle (days)	18 16	18	26	22	22	24	5	3	5	24	24	24	2	
Swath (km)	185	185	185	117	148	74 141 122 – 148	127 –	70 812	720 –	810	195	200	192	1420
No. of bands	4 7	5	4	4	4	4	1	2	1	4	13	1	8	
Bandwidth (Microns)	0.47-.57 0.58-.68 0.69-.83 0.505-.75	0.45-.52 .52-.6 .63-.69 .76-.9 1.55-1.75 10.4-12.5	.5-.6 .6-.7 .7-.8 .8-1.1 10.4-12.6	0.5-.59 .61-.68 .79-.89 .5-.73	0.45 - 0.52 0.52 - 0.6 0.63 - 0.69 0.73 - 0.9		0.52-59 .62-0.68 .77-.86 1.55-1.7	0.5-0.75	0.62-0.68 0.77-0.86	0.62-0.68	.755-.768	.408-1.01	1.5-1.7	.402-.422 .433-.453 .48-.5 .5-.52 .545-.565 .66-.68 .745-.785 .845-.885
Spatial Resolution(m)	79x79	30x30		20x20	73x73		23.5	5.8	169-188	188X188 1880x246	2.5x 2.5	727x580	1000x 727	6.6(V&H)km 10.65(V&H) 18.0(V&H) 21.0(V&H)

Table 2 - Comparison of IRS PAN, LISS II and merged (PAN+LISS-II) data for coral reef areas, Gulf of Mannar, Tamilnadu

Category	PAN data	LISS - II	Merged FCC
Reef extent	Distinct	Distinct	Distinct
Live Coral zones based on depth	4 zones	2 zones	4 zones
Seagrass beds	——	Demarcated	Demarcated
Vegetation	Cleary demarcated with sharp boundary	Demarcated	Clearly demarcated withsharp boundary

Table 3 - Remote Sensing Satellite Data and Analysis for Applications

Satellite Data	Type of Analysis	Applications and Results	Reference
Landsat-TM	Band Ratio	Discrimination and mapping of Pichavaram mangroves	Shailesh Nayak et.al (1994)
Landsat-TM	Band Ratio of 4/7	Discrimination of *Avicennia* and *Rhizophora* communities	Krishnamoothy et.al (1993)
Landsat-TM	Factorial Analysis	Differentiation of Band 2 fringing reef, path reef and reef area around Rameswaram islands	Krishnamoothy et.al (1993)
Landsat - MSS	Principal component Analysis Band	Coastal configuration	Chauhan P (1995)
IRS LISS-II	Re sampling Band 1	Salinity	Mandal and Sharma (2001)
IRS LISS-II	Contrast Stretching Band 4	Land and water boundary	Mandal and Sharma (2001)
IRS LISS-I	Density slicing Band 4/2	Variations in suspended sediment concentration	Shailesh Nayak et.al (1987)
IRS LISS-I FCCs	Visual Interpretation	Preparation of coastal landuse maps for brackish water aquaculture site selection	Krishnamoothy et.al (1993)
SPOT PLA	Classification	Coastal forestry mapping	Krishnamoothy et.al (1993)
SPOT MLA FCCs	Visual Interpretation	Coral reef and mangroves mapping in Andaman	Krishnamoothy et.al (1994)
SPOT PLA	Principal component analysis	Coastal pollution in and around Madras harbour (mostly oil spils)	Personal communication - Chandrasekar N
IKONOS	Visual Interpretation	Coral reef and mangroves mapping	Rohmann, O.S

for input during the planning of the Landsat-7 Enhanced Thematic Mapper (ETM) acquisition mission. At present Landsat-7 routinely acquires images of coral reef area. The technology now exists to acquire high resolution panchromatic and multispectral images of coral reef ecosystems. Previously, all satellite images are affected by sun glint (Rohmann 2000). However, IKONOS satellite can be pointed to minimize sun glint over water and maximize sunlight penetration and bottom feature visibility. That Capability, combined with its spatial and spectral resolution compared to Landsat-7 ETM - 1 meter panchromatic Vs 15 meter panchromatic and 4 meter MSS Vs 30 meter multispectral makes IKONOS a powerful tool in any effort to produce accurate, geo referenced maps of coral reef ecosystems. Monitoring the condition or health of coral reef ecosystems over time is an important application of high resolution satellite imagery. Coral reefs worldwide are being adversely affected by diseases, invasive species and bleaching due to abnormally warm water temperatures. Tracking the spread of black band disease, a tissue killing bacterial slime or invasive algal distributions and evaluating the extent if bleaching during an El Nino or La Nina weather year are potential uses of high resolution imagery. Many of the organizations responsible for managing and protecting these reefs are under funded and inadequately equipped to process satellite imagery as well as GIS software packages.

Preparation of thematic coral reef maps on 1:50,000 scale for Indian Coast was taken by Department of Ocean Development, Govt. of India. The knowledge about extent and condition of coral reef will help to plan preventive and conservative measures to protect this fragile ecosystem. IRS LISS-II data visually analyzed to map coral reef features such as type of coral reefs, mud and sand over reef, coralline shelf, reef vegetation, sand beach vegetation, algae, sea grass, sea weeds, type of lagoonal bottom, live corals as well as high and low water lines (Baldev Sahai, 1992). Comparison of spectral information content of remote sensing data has been carried out by visual interpretation. The summer season data are used for this study due to less vegetal cloud cover. IRS PAN and LISS-II merged product was also evaluated for coral reef zonation. The merged product for Van and Kosware reefs located 7-10 km NE of Tuticorin coast (Gulf of Mannar) was analyzed using unsupervised classification algorithm (Fig.1). It was possible to delineate four categories of reef based on depth between 1 to 20 m, beach and terrestrial region, sea grass bed and live coral zones were identified visually. A coral pinnacle N-NE of Okha in the Gulf of Kachchh was studied using LISS-III data. It was possible to delineate, for the first time, sea grass/ seaweeds bed separately, reef flat and sand cay on a coral pinnacle. These studies have improved understanding of coral reef ecology and geomorphology (Nayak et.al., 1996). IRS LISS-II and SPOT data were visually analyzed to map coral reef features on 1:50,000 scale (Fig.2) in Lakshadweep islands. The mapping has also been carried out in Lakshadweep islands and Andaman and Nicobar islands. The work revealed that Gulf of Kachchh and Andaman reefs are mostly degraded in nature while those of Gulf of Mannar (Krishnamoorthy et.al., 1993). Chandrasekar and Gopinath (in preparation) have measured the health of a coral reef ecosystem in Gulf of Mannar based on spatial auto correlation of SPOT MLA imagery data.

Sedimentation of reefs reduces live coral and species diversity and fish biomass is affected. Lakshadweep islands are mostly atolls with few coral heads, a platform reef and sand cays. Coral reefs of the Gulf of Kachchh and few reefs of Andaman and Nicobar islands are in degraded conditions as indicated by mud deposition (Bahuguna et.al.,1992; Bahuguna and Nayak, 1994; Nayak et.al., 1994). The feeling of mangroves and clearing of forests has affected the condition of reefs. Seaweeds, algae and sea grasses are in abundance on the reefs of Gulf of Kachchh and Mannar as well as on Lakshadweep islands. Chauhan and Nayak (1995) delineated the live corals in the coral reef lagoon of Bangaram island using IRS LISS-II green band data. Finally and possibly most important is the use of high-resolution satellite imagery to increase the public awareness on fragile coral reef ecosystems. Coral reef ecosystems must be protected and managed. Satellite imagery can go far to support such efforts. High spectral resolution remote sensing technology may provide a more synoptic and objective means of evaluating the health of coral reef ecosystems than broad band multispectral remote sensing or traditional ground-based surveying (Holden and Ledrew, 1998).

The insitu spectral reflectance database used in this study is the first of its kind. Mazel (1997) has begun to collect laser-induce fluorescence measurements of benthic organisms, but has published no quantitative analysis of the in situ spectra. Hardy et. al.(1992) measured laser-induced fluorescence in a laboratory setting, but have not published a follow-up study on work done in situ. Mumby et.al (1998) present two basic advantages of quantification of reef spectra such as in this study. The first is that prior knowledge of spectral of wavelength bands with which to operate. Secondly Mumby et.al.(1998) believe that the use of a spectral classification of hyper spectral imagery may become an automated procedure with access to spectral libraries. Furthermore, these researchers suggested that the use of a spectral library, such as collected for this research, could conceivably be used to the exclusion of field work.

Acknowledgement

Our sincere thanks to Director CMFRI, Cochin, Secretary and Principal, V.O.C.College, Tuticorin who permitted us to do collaborative work under NATP - ICAR sponsored research project. Thanks are due to Dr.R.K.Sarangi SAC, Ahmedabad for his helpful and critical suggestions for the improvement of the manuscript.

References

1. Bahuguna, A., A. Ghosh, S. Nayak, A. Patel, and J.P. Aggarwal, 1992. Proc. of National Symposium on Remote Sensing for Sustainable development, ISRS, Lucknow: 57-61.
2. Bahuguna,A., and S.Nayak, 1994. Scientific Note, Space Applications Centre, Ahmedabad. SAC/RSA/RSAG/DOD-COS/SN/07/94: pp.10.
3. Baldev Sahai, 1992. Utilization of coral reef maps. Proceedings of workshop, SAC, Ahmedabad.
4. Chandrasekar, N and R. Gopinath, (in preparation). Coral reef ecosystem measurement based on spatial auto correlation of SPOT imagery data.
5. Chauhan, P. and S. Nayak, 1995. Shore-line change mapping from space: A case study on the Indian coast, Presented at the Int. workshop on International Mapping from space, ISPRS, Anna University, Madras, India.
6. Desai, P.S, H.H. Gowda, K. Kasturirangan, 2000. Ocean research in India. Perspective from space. Current Science, vol.78 (3): 268-278.
7. Hardy, J., F. Hoge, J. Yungel, and R. Dodge, 1992. Remote detection of coral bleaching using pulsed laser fluorescence spectroscopy. Marine Ecology Progress Series, 88: 247-255.
8. Hochberg, E. and M. Atkinson, 2000. Spectral discrimination of coral reef benthic communities. Coral Reefs, vol.19: 164-171.

9. Holden, H. and E. Ledrew, 1998. Hyperspectral identification of coral reef features. International Journal of Remote Sensing, vol.20 (13): 2545-2563.
10. Krishnamoorthy, R., A. Bhattacharya, and T. Natrajan, 1993. Mangroves and Coral reef mapping of south Andaman Islands through remote sensing. In: M.S. Swaminathan and R.Ramesh (eds.). Sustainable management of coast ecosystems: 143-151.
11. Krishnamoorthy, R., S. Sundaramoorth and S. Ramachandran 1994). Coastal environment management for Tamilnadu and Andaman & Nicobar Islands, India. Presented in the Tenth Thematic conference on Geologic Remote Sensing, San Antonio, Texas.
12. Mandal, A.K., and R.C. Sharma, 2001. Mapping of water logged areas and salt affected soils in the IGNP command area. Journal of Indian Society of Remote Sensing, vol.29 (4): 229-235.
13. Mazel, C., 1997. Diver-operated instrument for in situ measurement of spectral fluorescence and reflectance of benthic marine organisms and substrates. Optical Engineering, 36: 2612-2617.
14. Mumby, P., E. Green, and C. D'elia, 1997. Digital analysis of multispectral airborne imagery of coral reefs. Coral Reefs, 17 : 59-69.
15. Mumby, P., C. Clark, E. Green and A. Edwards, 1998. Benefits of water column correction and contextual editing for mapping coral reefs. International Journal of Remote sensing, 19: 203-210.
16. Nayak, S., A. Bahuguna, and A. Ghosh, 1994. Scientific note, Space Applications Centre, Ahmedabad. SAC/RSA/RSAG/DOD-COS/SN/08/94: pp.13.
17. Nayak, S., M.C. Gupta, H.B. Chauhan, M.G. Shaikh, Anjali Pandeya and R.S. Roa, 1987. Scientific note, Space Applications Centre, Ahmedabad IRS-UP/SAC/MCE/SN/07/87.
18. Nayak, S., P. Chuhan, H.B. Chauhan, Anjali Bahuguna and A. Narendra Nath, 1996. IRS 1C applications for coastal zone management. Current Science, vol.70 (7): 614-618.
19. Rohmann, O.S., 2000. High resolution images offer in sight to the coral reef ecosystem. Space imaging: 24-25.