Proceedings of the Seminar on

REMOTE SENSING IN MARINE RESOURCES

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Foreword

The Space Research Programme in India is applications oriented and the decision to launch an Indian Remote Sensing Satellite IRS-1, in 1986, is a major step forward. India is a vast country, full of resources and it has been recognised that for the management of these resources timely information is an important factor. Space based remote sensing technique promises such timeliness and for a National Natural Resources Management System (NNRMS) it is envisaged to have a hybrid information system consisting of an optimum mix of remote sensing based system as well as conventional systems.

Marine resources development, specifically, Fisheries development is one of the major areas demanding immediate attention. In this field work carried out in other countries have shown that remote sensing can be successfully used in mapping and monitoring of ocean features like thermal fronts, eddies, upwelling, concentration of sediments and biomass. For locating probable areas in the ocean having fish schools such information is very useful. With this in view and for learning the use of remote sensing in marine fish resources a project was carried out in the early seventies, the UNDP/FAO/GOI Pelagic Fisheries Project.

When a decision was taken to plan for an Indian Remote Sensing Satellite, in 1979, a decision was also taken to conduct Joint Experiments with the actual users so as to provide data for optimising the sensor parameters for the IRS as well as jointly develop the operational methodology for different remote sensing applications in the country. One such Joint Experimental Project for Marine Resources and Fisheries Survey has been conducted, in a comprehensive manner, jointly by Central Marine Fisheries Research Institute (CMFRI) of the ICAR, Fishery Survey of India (FSI) of the Ministry of Agriculture and the Space Applications Centre (SAC) of ISRO. The present seminar is planned to discuss and review the results of this joint experiment to help in planning the future work for the utilisation of the IRS-1 data.

The results presented in this proceedings bring out the techniques and methodologies developed for the primary sea truth data collection and extraction and mapping of biological parameters from airborne and spaceborne sensors. Efforts have been made in the difficult area of developing models for atmospheric correction of Nimbus-7 Coastal Zone Color Scanner (CZCS) data to retrieve the phytoplankton pigment. Apart from the CZCS sensor, which is optimised for ocean colour sensing, efforts were also made in the use of Landsat satellite data, which is basically designed for earth resources survey, for fish resources survey.

It is hoped that a long term plan, mutually worked out by all agencies concerned with Marine Resources Survey, will evolve out of these efforts.

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Preface

The seminar proceedings on the role of Remote Sensing in Marine Resources is the outcome of the collaborative efforts between Indian Space Research Organisation, Indian Council of Agricultural Research and Ministry of Agriculture, as one of the projects under Joint Experiment Programme (JEP) (1979-1984). The objectives of this programme were to address the spaceborne sensor requirements under Indian Remote Sensing Programme for the application of detection and mapping locations of marine living resources and also to develop methodologies for the extraction of information related to marine living resources survey from remotely sensed data.

Seminar proceedings in all contain nine papers. These papers essentially cover the following topics in terms of our understanding about the role of remote sensing in marine resources survey:-

1. Biological productivity of the Indian Ocean, developments in fisheries technology and scope of remote sensing techniques in marine fish resources survey.

2. Methods in estimating the optical parameters and their relationship with oceanic/biological parameters.

3. Ocean colour mapping from airborne and spaceborne sensors

There are three overview papers which cover a detailed discussion on biological productivity of the Indian Ocean, role of remote sensing in fish resources survey and the scope of Indian Remote Sensing Programme in marine living resources. A detailed understanding of optical processes in remote sensing of ocean colour, relationship between optical and oceanic/biological parameters has been brought out using sea truth data collected during the period preceding South West monsoon i.e. October, November and December 1981 and November 1982 in oceanic waters off Cochin. This area is well known for the occurrence and abundance of pelagic shoals of **oil sardine** and **mackerel.** Role of airborne sensors and spaceborne sensors on **Landsat** and **Nimbus-7** satellites, have been discussed in detail towards extraction of information related to fish resources survey.

We are extremely grateful to Director, Space Applications Centre (SAC/ISRO) and Director General, Indian Council of Agricultural Research (ICAR) for their keen interest and support to this programme. Thanks are due to Shri D.S. Kamat, the then Programme Manager, JEP., Prof. P.D. Bhavsar, Associate Director, SAC and Chairman, RSA, SAC and Dr. Baldev Sahai, Associate Director, IRS-Utilisation Programme and Head, Aerial Surveys Ground Truth and Photointerpretation Division, SAC for their guidance and encouragement. Our sincere thanks to colleagues at SAC, Mrs. V. Sudha, Dr. M.B. Potdar and Dr. P.C. Pandey for their support extended to us in many ways. Thanks are also due to Assistant Director of Cochin base, Fishery Survey of India (FSI), Skippers and crew members of **Meena Sachatak, Meena Utpadak** (FSI Vessels), **Cadalmin I & IX** (CMFRI Vessels). NRSA's flight crew and ground truth team's efforts are also thankfully acknowledged. We would like to thank Shri K.H. Bharadiya and Shri R.V. Nair for drawings, Shri K.M. Bhavsar for photographic support and Shri Naresh Bhatnagar for secretarial assistance.

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Contents

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Abstract

Landsat MSS data off Cochin Coast was analysed and an attempt made to look into the relationship between MSS gray values and concentration of pigment/particulate matter. MSS band 4 and 5 showed the maximum gray value range as compared to band 6 and 7. A density sliced image of band 4 was generated in the form of a color coded image showing the gray levels corresponding to various pigment levels. A multiple linear regression analysis was carried out for chlorophyll/particulate matter and gray values of band 4,5,6 and 7. Regression analysis showed that chlorophyll has a high correlation with the MSS data (r^2 = 0.95) and in particular with band 4 and 5 (r^2 = 0.85). Correlation with band 6 and 7 was relatively low (r^2 = < 0.74). As against this the particulate matter showed a poor correlation with MSS band 4 and 5 (r^2 = 0.32).

Introduction

Landsat satellite is primarily designed for land applicatios but has found use to some extent in oceanographic applications as well. Gower et al (1980) showed that an increase in reflectance in MSS 4 as against those in 5,6 and 7 could be associated with increase in phytoplankton concentration. Strong (1974) has found Landsat useful in mapping algal bloom. Ulbricht (1983) reported that MSS band 4 and 5 were best suited for studying mass accumulation of blue green algae. It has also been observed that Landsat MSS data has an edge over Nimbus-7 CZCS data as regards the mapping of chlorophyll concentration above 2 µg/l (Becker et al, 1978). In the present study an attempt is made to look into the relationship between the MSS gray values and oceanic parameters like chlorophyll-a and particulate matter. In the analysis Landsat data of November 10, 1981 has been compared with the sea truth data acquired on November 27, 1981.

Data Acquisition and Analysis

Sea truth data was collected in oceanic waters over North of Cochin on November 27, 1981 at various station depths, namely, 10,20,30,40 and 50m. Three vessels namely, Cadalmin I, Cadalmin IX and Meena Sachatak were deployed for data collection (Table 1). A Landsat MSS compatible Exotech Radiometer (Model 100.A) was used on vessel to measure radiance and irradiance in four bands

Table 1

Data on location of sea truth stations (November 27, 1981)

Vessel/Station No.	Station depth (m)	Location Lat. Long.	Time (hrs)
Cadalmin (V_1)			
1	10	10°13.2'N, 76°6.9'E	9.30
2	10	10°14'N, 76°6.8'E	10.00
3	20	10°14'N, 76°3.6'E	10.40
4	20	10°13.2'N, 76°3.8'E	11.00
5	30	10°13.2'N, 75°58.6'E	11.40
6	30	10°14'N, 75°58.6'E	12.00
Meena Sachatak (V_2)			
1	40	10°10.8'N, 75°56'E	10.35
2	40	10°11.6'N, 75°56'E	11.00
3	50	10°11.6'N, 75°54'E	11.45
4	50	10°10.8'N, 75°54'E	13.15
Cadalmin IX (V_3)			
1	10	10°9.6'N, 76°07'E	9.00
2	10	10°10.4'N, 76°6.7'E	9.45
3	30	10°10.2'N, 76°01.5'E	11.00

corresponding to Landsat MSS i.e. band 4 (500-600 nm), band 5 (600-700 nm), band 6 (700-800 nm) and band 7 (800-1100 nm). Apart from above the Secchi disc visibility was also measured. Table 2 gives details of parameters collected during sea truth. Figure 1 shows the relationship between Secchi disc depth and chlorophyll pigment/particulate matter at various stations. Landsat CCT was subjected to digital analysis.

Sea Truth

Water samples from sea truth stations were analysed for estimating chlorophyll-a (mg/m^3) and particulate matter (mg/l).

Satellite Data

The first step in the digital analysis was to locate the sea truth stations on

Table 2

Sea truth data at various stations (November 27, 1981)

Vessel/Station No.	Secchi disc depth (m)	Reflectance Band 4	Reflectance Band 5	Chlorophyll (mg/m^3)	Particulate matter (mg/l)
Cadalmin I(V_1)					
1	7.75	5.60	2.35	2.08	12.83
2	7.8	5.72	3.49	3.12	13.51
3	16.0	2.4	1.62	0.72	13.50
4	15.0	3.2	1.36	1.20	15.15
5	16.0	1.82	0.79	1.52	13.0
6	16.0	1.89	0.76	0.96	13.25
Meena Sachatak (V_2)					
1	20.0	2.52	2.63	0.24	17.40
2	20.5	1.33	0.84	-	-
3	21.3	2.77	1.36	-	-
4	23.1	2.94	2.91	0.48	19.9
Cadalmin IX (V_3)					
1	4.3	3.75	2.07	1.69	14.77
2	4.3	3.03	1.87	2.77	15.35
3	13.75	-	-	0.96	11.07

the image. For this purpose thirty ground control points on the land portion of the sub image covering ocean waters off Cochin coast were chosen. A two dimensional affine transformation was used to relate image coordinates with the corresponding coordinates on the map of the study area. A window (20 pixels x 20 scan lines) around each sea truth station was taken to determine the mean gray value and its standard deviation (Table 3).

An attempt was made to look into the relationship between chlorophyll-a pigment and particulate matter with the gray values (Figures 2 and 3). A density sliced image of band 4 (Figure 4) shows distinct pattern within the sea water related to variations in pigment levels. The landmass in the image was masked to value 0. The various colour codes correspond to various pigment levels (Table 4). Singh and Cracknell (1979) have used various functional forms to correlate the sea truth data with the Landsat MSS data. A multiple linear model was used to look into the relationship of all the four MSS bands with biological parameters.

Table 3

Gray values from LANDSAT image and their standard deviation

Vessel/Station No.	Gray values			
	Band 4	Band 5	Band 6	Band 7
Cadalmin I (V_1)				
1	45.28±2.28	25.78±2.02	1.17±1.42	0.82±0.95
2	45.44±2.41	25.53±2.05	1.37±1.55	0.89±1.00
3	38.50±2.01	20.30±1.88	0.17±0.59	0.42±0.71
4	38.32±1.93	19.65±1.89	0.03±0.28	0.30±0.64
5	34.06±1.74	15.56±2.02	0.0±0.05	0.27±0.61
6	34.23±1.65	15.53±1.90	0.01±0.10	0.27±0.61
Meena Sachatak (V_2)				
1	27.62±1.40	11.17±2.29	0.0±0.0	0.26±0.64
2	27.98±1.61	11.52±2.17	0.05±0.36	0.30±0.69
3	26.53±1.69	9.69±2.39	0.0±0.0	0.15±0.44
4	28.87±1.55	10.10±2.22	0.0±0.0	0.17±0.47
Cadalmin IX (V_3)				
1	42.81±3.15	22.11±2.99	0.17±0.61	0.39±0.76
2	43.88±2.52	23.77±2.26	0.26±0.73	0.36±0.69
3	37.44±1.80	17.58±1.94	0.18±0.18	0.38±0.71

Table 4

Colour codes for Figure 4

Colour codes	Density sliced range (Band 4 gray values)	Chlorophyll concentration (mg/m^3)
Deep blue	0-22	-
Cyan	23-26	0.00-0.20
Blue	27-30	0.21-0.70
Green	31-36	0.71-1.45

(Table 4 contd.)

Colour codes	Density sliced range (Band 4 gray values)	Chlorophyll concentration (mg/m^3)
Yellow	37-40	1.46-1.96
Red	41-50	1.97-3.22

The model is,

$$X = C_0 + C_1G_4 + C_2G_5 + C_3G_6 + C_4G_7$$

where C's are constants to be determined, X is pigment/particulate matter concentration and G_4 to G_7 are the gray values in MSS band 4 through 7.

The gray values of four MSS bands and biological data set were subjected to a multiple linear regression analysis. Results of the regression analysis is given in Table 5. Results of the regression analysis were also used in assigning various pigment levels in density sliced image of band 4 (Figure 4, Table 4).

Table 5

Results of the regression analysis

Physical quantity	Constant C_0	Regression coefficients Band 4 C_1	Band 5 C_2	Band 6 C_3	Band 7 C_4	Multiple correlation r^2
Chloro-phyll	-4.611	0.358 (0.84)	-0.288 (0.84)	3.85 (0.73)	-7.64 (0.70)	0.95
Particu-late matter	17.54	-0.327 (0.32)	0.777 (0.33)	5.72 (-0.07)	-19.62 (-0.19)	0.91

Figures in parenthesis give the correlation of the dependent variable with the corresponding independent variable.

As against pigment the particulate matter showed a poor correlation for individual MSS bands. A residual plot of measured versus calculated pigment and particulate matter is shown in Figure 5.

Results and Discussions

Sea truth data shows that there is an inverse relationship between Secchi disc depth and pigment/particulate concentration the lower is the Secchi disc depth the higher is the pigment concentration and vice versa (Figure 1). The pigment values are high at 10m depth and decline in off shore waters (Figure 1). Table 2 shows the dependence of Secchi disc depth and reflectance(Exotech Radiometer) on the concentration of chlorophyll pigment and particulate matter. It is observed that in general the reflectance in band 4 (green) is higher than in band 5 (red) with varying concentrations of pigment except at lower concentrations. Particulate matter did not show any relationship with gray values in band 4&5 which carry

information about ocean colour. Table 3 shows the gray values from Landsat MSS bands at various stations. It is clear from the above table that band 4 and 5 give maximum gray level range as compared to band 6 and 7. Gray values are higher in band 4 than in band 5 and shows a gradual decrease with increasing station depth. After 40m depth not much change was observed. This indicates that the turbidity decreases in off shore and this is also confirmed from Secchi disc depth. The density sliced image of band 4 (Figure 4) shows quite distinct pattern within the oceanic waters. Regression analysis (Table 4) shows that chlorophyll concentration is highly correlated with the MSS data (Multiple correlation, $r^2 = 0.95$) and particularly with band 4 and 5 ($r^2 = 0.84$) whereas correlation with bands 6 and 7 is relatively low ($r^2 = < 0.74$). The multiple correlation value ($r^2 = 0.91$) was high for particulate matter but showed a very poor correlation with individual bands i.e. 4,5,6 and 7. It is clear that band 4 and 5 provide the most useful information about ocean colour.

Conclusions

A high correlation was observed between the phytoplankton pigment concentration and gray values of Landsat MSS band 4 and 5. Particulate matter on the contrary showed a very poor correlation with MSS gray values. Also it is clear that high concentrations of pigment can be mapped to fairly satisfactory levels in the near shore waters using Landsat MSS bands 4 and 5. Density slicing of band 4 was useful in mapping pigment levels in near shore waters.

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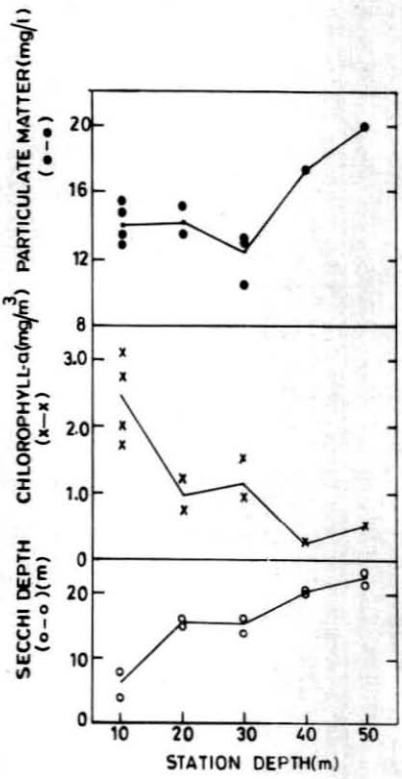

Fig. 1 Secchi disc depth, chlorophyll and particulate matter versus station depth

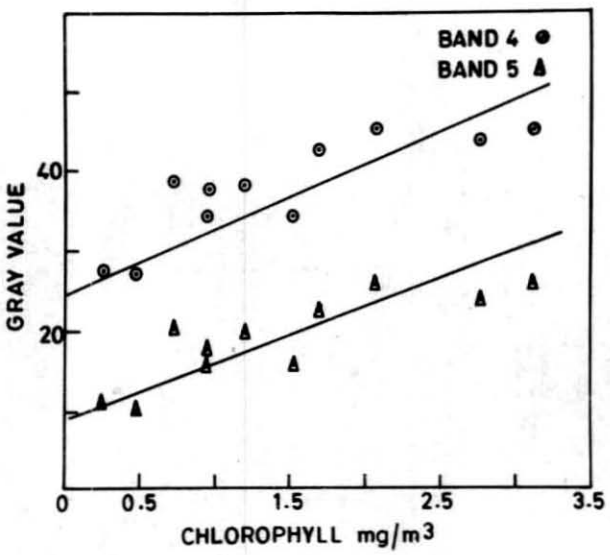

Fig. 2 Gray values (MSS band 4 and 5) versus chlorophyll-a

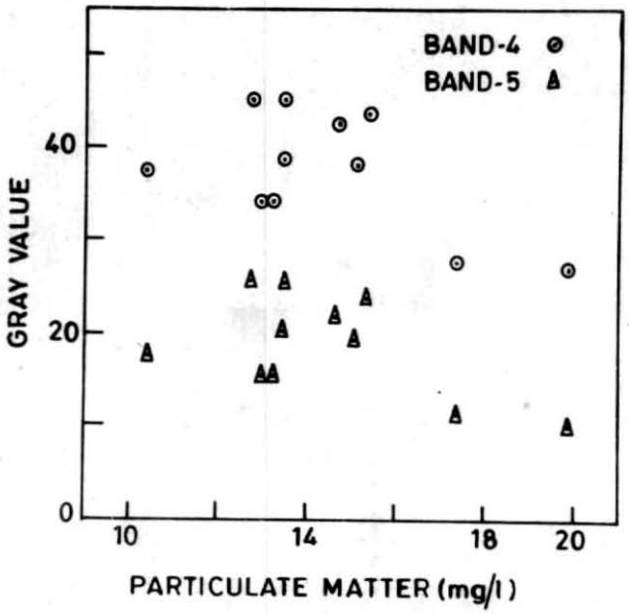

Fig. 3 Gray values (MSS band 4 and 5) versus particulate matter

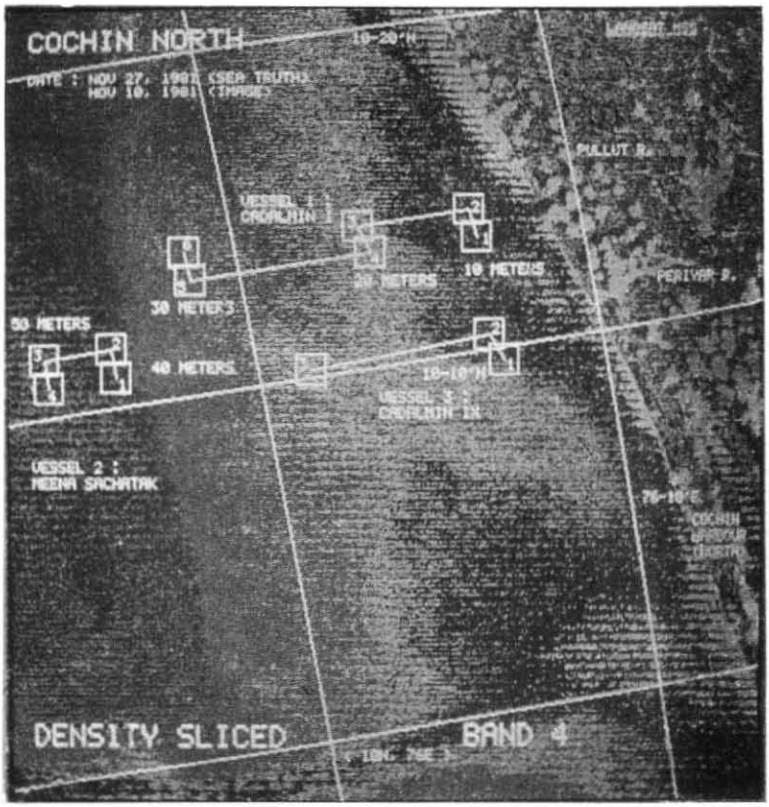

Fig. 4 Density sliced image of Landsat MSS band 4 for oceanic waters off Cochin (Path 155 Row 053, Nov., 10, 1981)

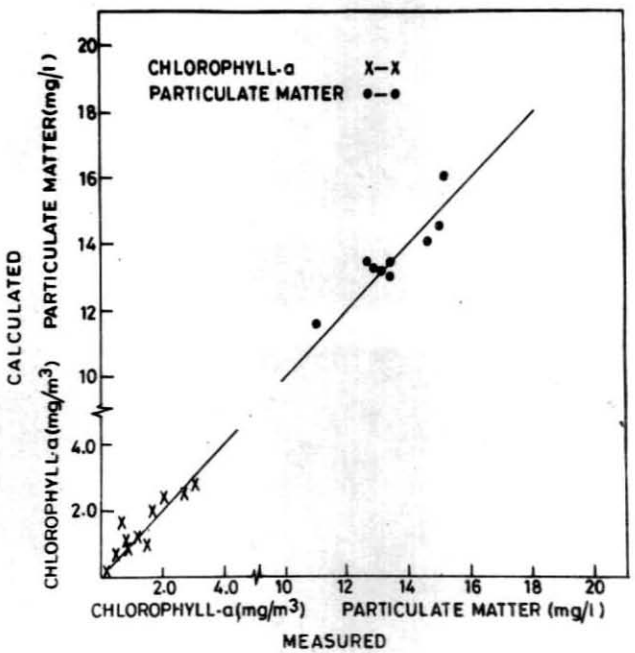

Fig. 5 Residual plot of calculated versus measured chlorophyll and particulate matter