Proceedings of the Seminar on

REMOTE SENSING IN MARINE RESOURCES

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Edited by

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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

REMOTE SENSING OF OCEAN COLOUR AND TARGETING OF FISH SCHOOLS FROM AIRBORNE SENSORS

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Abstract

Remote sensing from airborne sensors has been used for studying the well known pelagic schools of oil sardine and mackerel in the Arabian sea of the Indian Ocean. A high productivity is reported in the oceanic waters off Cochin preceding SW monsoon. A remote sensing experiment was carried out in the oceanic waters over North of Cochin coast involving vessel-based sea truth data collection synchronous to aircraft overflights during October, November and December 1981. Sensors flown on board aircraft were photographic camera system and an Ocean Colour Radiometer (OCR) having spectral channels almost similar to that of Nimbus-7 CZCS sensor. Fish schools could be directly spotted equally well on all the three types of films used viz., conventional colour (Kodak 2448), colour infrared (Kodak 2443) and panchromatic black-and-white (Kodak 2402) but only during October. An indirect method of mapping spatial distribution of phytoplankton pigment (responsible for primary productivity in oceanic waters) may in turn help in estimating the fish potential through an understanding of its conversion to other trophic states in the ocean food chain. Upwelling radiance data from OCR could be suitably used in the understanding of atmospheric effects and in developing a pigment algorithm.

Introduction

The present study was aimed at studying ocean parameters directly or indirectly linked to the availability of marine fish resources. Attempts have also been made at direct spotting of fish schools and its quantification (UNDP/FAO Pelagic Fisheries Project, Progress Report 4,8 & 9, 1972-74). One of the most important ocean parameters which can be remotely sensed is chlorophyll-a pigment (present in almost all phytoplankton). The standing stock of phytoplankton can be given approximately in terms of colour of the sea. This colour of the sea can be defined by a colour index which is the ratio of upwelling radiance/irradiance to the downwelling radiance/irradiance in the blue and green region of the electromagnetic spectrum (Curran, 1972; Clarke and Ewing 1974; Hovis and

Leung, 1977; Gordon and Clark, 1980; Hojerslev, 1980; Morel, 1980). Ocean colour estimation leads to the estimation of primary productivity and finally to the third level productivity i.e. fish in the ocean food chain. During October, November and December 1981 a remote sensing experiment was carried out in coastal waters over North of Cochin using vessel-based observations and aircraft overflights. The sensors used onboard aircraft were a bank of Hasselblad 500EL/M cameras and an Ocean Colour Radiometer (OCR) having spectral channels almost similar to that of CZCS sensor on Nimbus-7 satellite. Oceanic waters over North of Cochin are well known for the occurrence and abundance of pelagic schools of oil sardine ***(Sardinella longiceps)*** and mackerel ***(Rastrelliger kanagurta).***

Data Acquisition and Analysis

Sea Truth

Figure 1 shows the sea truth stations and vessel positions with respect to their operating station depth and flight lines in the study area. Data on oceanic parameters, namely, temperature, salinity, dissolved oxygen and chlorophyll-a were collected at station depth (surface to bottom) of 10,20,30,40 and 50m. Oceanic parameters were measured on water samples collected at the surface, 1 and 6m ocean depth. Two large vessels (17.5m overall length) and two small vessels (14.3m overall length) were deployed during sea truth data collection in synchronous with aircraft flights. The vessel positions as shown in Figure 1 were kept same for all the three time surveys i.e. during October, November and December, 1981.

A bank of three Hasselblad 500EL/M cameras with three film types viz., conventional colour (Kodak 2448), colour infrared (Kodak 2443) and panchromatic black-and-white (Kodak 2402) was flown on a Dakota aircraft at 2 km altitude. Visual interpretation technique was adopted in studying the aerial photographs. Apart from the above a Ocean Colour Radiometer (OCR) was also flown on the aircraft but at different altitudes. Data from the NRSA's aircraft sensor - OCR were used to examine the aspects of atmospheric correction and developing a pigment algorithm. The OCR is a high-gain scanning radiometer optimized for ocean-colour sensing with narrow bandwidths (11-14 nm). The spectral bands of this sensor are fixed at 445, 520, 550, 600, 670 and 750 nm, with ground resolution of about 60m at 1 km flying altitude. OCR data was collected at different flying altitudes i.e., 500, 700 and 1000m and recorded on a magnetic-tape for further processing using an in-house VAX-11/780 computer system. Upwelling radiance values in different spectral channels were finally calculated using the OCR system calibration data.

Results and Discussion

It was observed that there was no significant change during the three time observations i.e. October, November and December, in oceanic parameters such as dissolved oxygen, temperature and salinity indicating that the hydrographic conditions had more or less stabilized. A significant change in chlorophyll-a (hereafter referred to as pigment) concentration was observed with the highest average value during October (about 6.4 mg m^{-3}) followed by lower values during November (about 1.7 mg m^{-3}) and December (about 1.4 mg m^{-3}).

It was observed from the study of aerial photographs that fish schools could be directly spotted equally well on all the three film types used. Figure 2 shows one such photograph. However, it was seen that these schools could be spotted only during October and were largely confined to the near shore waters.

Radiance measurements from different altitudes can be used in removing the atmospheric contribution for retrieving the water leaving radiance by extrapolation so as to achieve the zero altitude radiance (Morel 1980). A similar approach was adopted here and is shown in Figure 3 for OCR data collected over deep-blue ocean water. However, this approach could not be applied to radiance data collected in areas with higher pigment concentrations. The next step in the analysis was to develop a pigment algorithm which relates the pigment concentration to the ratios of upwelling radiances at 440 or 445, 520, 550 and 670 nm. The concept of using radiance ratios for suitable wavelengths in remote sensing of ocean colour is described by Clark et al (1970); Arvesen et al (1973); Hovis and Leung (1977); Gordon and Clark (1980); Morel (1980) and Hojerslev (1980). A pigment algorithm as described by Gordon and Clark (1980) was used here by taking ratios of OCR spectral radiances which are close to CZCS bands, namely, $R_1 = L_u 445/L_u 550$, $R_2 = L_u 445/L_u 520$, $R_3 = L_u 520/L_u 550$ and $R_4 = L_u 445/L_u 670$. The upwelling spectral radiance (L_w) as derived from within near-surface water layers has been used in most of the algorithms (Morel and Prieur 1977; Gordon and Clark, 1980). In the present study an attempt was made to relate the upwelling radiance (L_u) as derived from aircraft sensor data, directly to the surface measurement of phytoplankton pigment concentration. The log-transformed upwelling radiance ratios (R_1, R_2, R_3 and R_4), pigment concentration and their least squares regression lines are shown in Figure 4. Table 1 gives a summary of the least squares regression analysis.

Table 1

Summary of least squares regression results of the log surface chlorophyll-a and log upwelling radiance ratios

Radiance ratios	Regression coefficients $\log_{10} a$	b	Coefficients of determination r^2	Standard error of estimate S y.x
R_1	0.290	-3.953	0.544	0.584
R_2	0.291	-7.524	0.762	0.779
R_3	0.100	-1.830	0.053	-
R_4	2.742	-7.185	0.663	0.560

The coefficients of determination (r^2) value was at a maximum for R_2 ($r^2 = 0.76$) followed by R_4 ($r^2 = 0.66$), R_1 ($r^2 = 0.54$) and least in R_3 ($r^2 = 0.05$). These results approximately match those observed by Gordon and Clark (1980). The best correlation was found in 445 nm versus 520 nm although it is certainly lower than the corresponding r^2 value of 0.97 ($L_w 440/L_w 500$) and 0.94 ($L_w 440/L_w 520$) reported by Gordon and Clark (1980). One of the main reasons for the low value of r^2 in the present investigation may be due to phaeopigments which are not included in the analysis. A poor correlation in R_3 is probably due to the spectral channels being centered in closely placed spectral region i.e. at 520 and 550 nm. The pigment concentrations used here are representative of the surface to 6m depth. The regression analysis for ratio R_2 was used in mapping spatial distribution of chlorophyll-a and is presented here for a portion of flight run number-R_1 (Figure 5). The computer classified chlorophyll-a concentration and the actual surface measurements during sea truth are also shown in Figure 5.

Conclusions

Direct spotting of fish schools is possible in certain period of the fishing season but does not seem to be feasible on an operational basis. Upwelling radiance ratios derived from OCR (aircraft sensor) could be related directly to surface measurement of chlorophyll-a concentration. A high correlation ratio-R_2 (L_u 445/ L_u 520) matches the maximum (445 nm) and minimum (520 nm) absorption characteristic of chlorophyll-a. The upwelling radiance data at various flying altitude was useful in removing the atmospheric effects. Regression analysis data was effectively used in mapping the spatial distribution of chlorophyll-a pigment.

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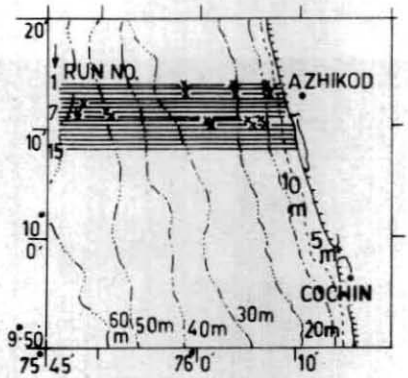

LEGEND

NAME OF THE VESSEL	VESSEL CODE	OPERATING DEPTH(m)	RUN No.
MEENA SACHATAK	V1	40,50	7.8
MEENA UTPADAK	V2	10,30,50	5
CADALMIN I	V3	10,20.30	1.3
CADALMIN IX	V4	10,20.30	9.10

0 6 12 18 km

Fig. 1 Study area showing vessel positions (X) and flight runs

Fig. 2 A panchromatic black-and-white aerial photograph showing fish schools (white patches)

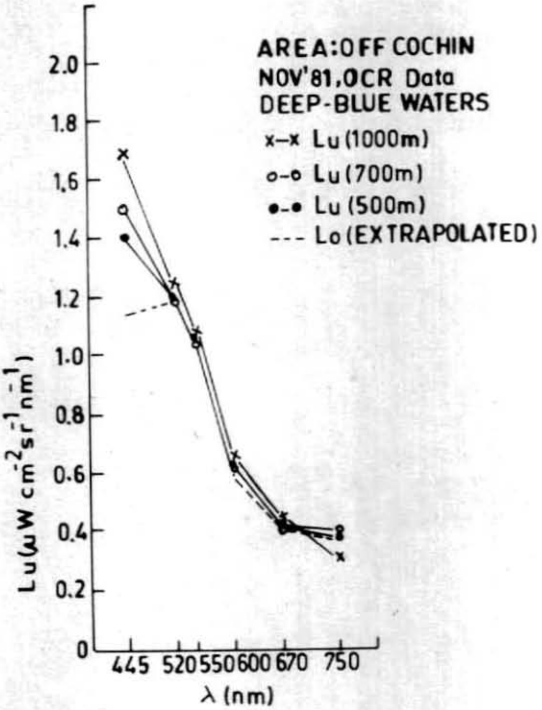

Fig. 3 Upwelling radiances measured over deep-blue waters from different flying altitudes

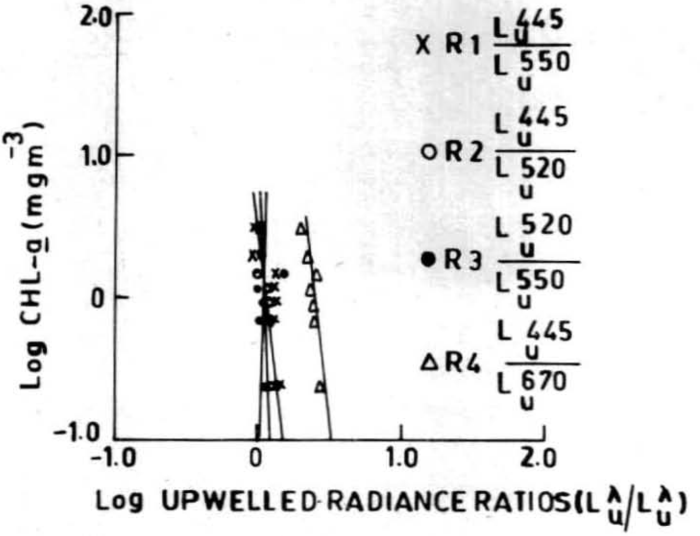

Fig. 4 Relationship between chlorophyll-a and upwelling radiance (L_u) ratios

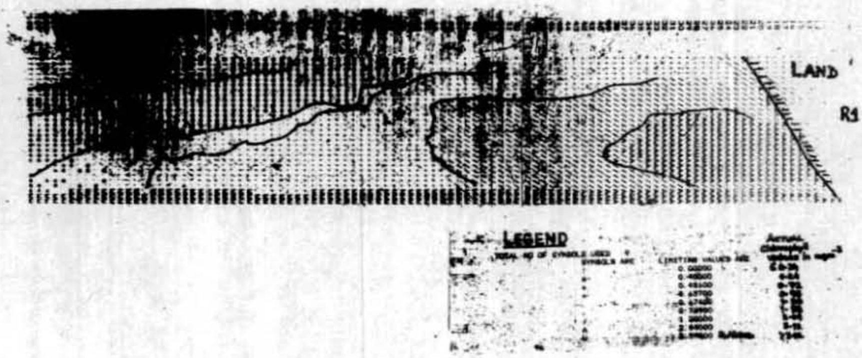

Fig. 5 Spatial distribution of chlorophyll pigment along a flight run - R_1 (OCR sensor data)