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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BIOLOGICAL PRODUCTIVITY OF THE INDIAN OCEAN

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Introduction

India has a long coast line of nearly 6,000 km with the Andaman and Nicobar Islands and the Laccadive Archipelago lying beyond her shores. The geographical position of India with the peninsular portion extending deep into the central part of the Indian Ocean gives her a locational advantage in marine fishing activities. At present though India contributes about 40% of the fish landings of the Indian Ocean, when viewed against the world production of 76 million tonnes of marine fish, her share is only 1.6 million tonnes representing less than 2%. A quarter of a million persons are actively engaged in actual fishing producing annual landings valued at Rs. 650 crores. The industry also provides employment to over 2 million persons. There are about 19000 mechanised crafts which land 35% of the total production. Over 400 crores rupees worth of sea food is exported to different countries annually.

Studies made during the International Indian Ocean Expedition as well as those conducted in the bordering countries reveal that there are several areas in the Indian Ocean which are exceptionally rich in nutrients,chlorophyll, organic production and zooplankton biomass. Consequently these areas could sustain large stocks of fish.

The Indian Ocean has an area of about 75 million square kilometers including Antarctica and some of the adjacent seas, as against 106 million sq km for the Atlantic and 180 million sq km for the Pacific Ocean. The shallow water areas form about 3.1 million sq km in the Indian Ocean. The shelf areas vary in width as well as in surface contour.

The West Coast of India, Ceylon and Pakistan have prominent shelves, whereas on the East Coast the shelves are narrow. The continental shelf area of India between 0 and 50 m depth is estimated at 1,91,972 km^2 and between 0 and 200 m depth at 4,52,060 km^2. The average width of the shelf from the shore-base varies from 32 km off the coast of Andhra Pradesh to 174 km off the coast of Maharashtra. In view of the declaration of 200 miles limit the Exclusive Economic Zone has a total area of 2.02 million sq km.

It is estimated that the rate of primary production on the east coast of India is at 0.63 gC/m^2/day on the shelf and 0.19 gC/m^2/day outside the shelf; the mean value within 50 m depth on the west coast is 1.24 gC/m^2/day, the daily rate of production for the rest of the west coast shelf being 0.47 gC/m^2/day and for the oligotrophic regions outside the shelf 0.19 gC/m^2/day.

Fishery Potential of the Indian Ocean

The fish landings in the Indian Ocean and the development during the last twenty-five years as compared to the Atlantic and Pacific Oceans present a poor comparison both in the progress and also in the yield ratio in terms of primary production.

It has already been indicated that with an annual net organic production of 3.9×10^9 tonnes for about two-third area of the Indian Ocean, the relative productivity of this area is in no way less than that of the rest of the world oceans. The yield ratio of carbon production as well as the estimated potential yield derived from the results of exploratory surveys indicate that the Indian Ocean can possibly support an annual sustainable yield of 11 million tonnes of fish. The continental shelf area in the Indian Ocean with an area of 3.1 million km^2 accounts for one seventh of the total fish production in the Indian Ocean.

The phytoplankton production for this area has been calculated, as 283 x 10^6 tonnes of carbon. This would be equivalent to 12 x 10^9 tonnes of phytoplankton by wet weight which can sustain an yield of 5 million tonnes which is more than the current production from the Indian Ocean.

According to the Indicative World Plan estimates, the world marine fish of currently exploited species with known techniques in areas already fished may amount to some 120 million tonnes by the end of the century. But the living resources of the sea are not limitless and higher yields will be possible only by envisaging utilisation of unconventional resources or aquaculture. The maximum yield in terms of carbon (which forms about 10% of the wet weight) is only 0.4% of the net primary production in the coastal areas and in the oceanic areas considerably less. When viewed in this light India and the Indian Ocean countries have a challenging task to bridge the gap between the present yield and the possible production. According to some experts an output of 20 million tonnes of fish per annum from the Indian Ocean towards the close of this century is a possibility if planned efforts are put in. It is here the utility of remote sensing technology comes in.

About 40% of the total exploitable stock from the Indian Ocean and adjacent seas could be expected from the Exclusive Economic Zone of the Indian Seas. Some estimates put the potential harvest at 4.5 million tonnes of fish from EEZ which is about three times the present yield. The fish biomass estimated from phytoplankton biomass will amount to 7 million tonnes, that is 0.06% of the wet weight of phytoplankton. Considering the conventional resources and their scope for further expansion of the harvestable stock and non-conventional resources (tunas, horse mackerel, flying fish, myctophids, gonostomatids, deep water prawns and crabs, cephalopods and molluscs) an yield of 5 million tonnes from the EEZ of India is a very reasonable estimate.

Chlorophyll, Primary Production & Relationship with Fishery

Chlorophyll measurements are indicative of bioproductivity of the sea. Sea surface chlorophyll has been considered to be significant in the food relations of oceanic fish resources such as tunas since a steady state relationship is possible between the forage of tunas and the chlorophyll through the food chain. This can be measured either by ***in situ*** or ***in vivo*** methods and recently by remote sensing. In a recent study off Cochin under the Joint Experiment Program between the Space Applications Centre (ISRO), Fishery Survey of India (Ministry of Agriculture) and Central Marine Fisheries Research Institute (ICAR), it was observed that a chlorophyll value of 6.4 mg/m^3 during October followed by a sharp fall during November (1.7 mg/m^3) and December (1.4 mg/m^3) when compared with the available fish catch rate data in the study area for the period from 1977-'81 showed that the mean monthly fish catch rate for October, November and December was directly proportional to the mean quantity of chlorophyll. This suggests that mapping of chlorophyll distribution either from airborne sensors optimised for ocean colour sensing or satellite scanners combined with 'sea truth' measurements will facilitate in better understanding of the resource potential and also the management of the fishery resources.

In the above study it was also found that a non-linear relationship exists between chlorophyll and resource availability which follows a characteristic 'S' shaped growth curve. There is an initial period of slow growth which eventually stabilises below a certain ceiling level. At a certain level it is observed that although there is a marginal increase in chlorophyll -a the fish catch shows an almost twofold increase. It is felt that it would be necessary to conduct synoptic studies of chlorophyll from space platform along with conventional measurements from the sea in order to develop appropriate algorithms so that the chlorophyll estimations can be used as an effective tool in forecasting the fishery resource.

The chlorophyll scanning experiments conducted by aircraft survey in 1980-81 in the Cochin area have shown extreme patchiness in the distribution of chlorophyll from 0.5 mg/m^3 to about 9 mg/m^3. Chlorophyll-a and pheopigments in many areas of the Arabian sea as observed during IIOE is 15 to 25 mg/m^2 for the water column (integrated value). Hence it can be concluded that chlorophyll values for water columns approximating to 15 mg/m^2 can sustain an yield of over 250 kg/ha/year of fish inclusive of both demersal and pelagic resources. Perhaps this could be tested as a sort of general guideline in the estimation of resources based on chlorophyll data for a larger area in future studies involving the application of remote sensing technology of chlorophyll scanning in intensely fished waters on our coasts.

Oceanic features such as chlorophyll distribution, ocean temperature, current boundaries, ocean fronts and slicks can be detected in satellite imagery. Scientifically planned data acquisition on these parameters useful for understanding the seasonal availability and areas of concentration of oceanic fishes such as skipjack and young yellowfin tunas, is an urgent necessity. Further, the use of satellite as a tool for studying migratory patterns of tunas using telemetric tags should also be further explored.

Remote Sensing of Sea Surface Temperature (SST) from multispectral infrared satellite observations offer wide opportunity to deduce the movement of tunas and other pelagic fishes which are largely depending on the variations in SST. Several investigations have been conducted earlier to understand the relation between the variations in sea surface temperature and availability of tunas. Based on the surface isotherms, 'thermal equator' has been identified and the movements of the latter have been studied in relation to the fishing ground of yellowfin tunas in the Indian Ocean. In the tropical areas, localised differences in the sea surface temperature also may help to locate areas of current boundaries, upwelling etc. where forage of tunas accumulate. High surface temperature gradients where the optimum temperature zones are narrow are the places of concentration of albacore and southern bluefin tunas. Most of the species of tunas respond directly to the temperature which forms the lower limit. It has recently been indicated that the 15°C, 20°C and 23°C isotherms are the lower normal boundary of occurrence of albacore, skipjack and yellowfin tunas respectively. As stated earlier, the mapping of the pattern of sea surface temperature by remote sensing from multichannel infrared and microwave satellite observations could be made use of for understanding the distribution and quantification of oceanic pelagics in the Exclusive Economic Zone of India.

It is hoped that the technology of remote sensing will enable locating the movement of fish shoals and their quantification in a more precise manner for better harvesting and management in future.