Chapter 20

Remote Sensing and Fisheries

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20.1 Introduction

Satellite remote sensing is beginning to play a very important role for location of potential fishing zones and management of fishery resources by providing synoptic measurement of oceanic parameters such as sea surface temperature and colour. It is well known that changes in ocean conditions greatly influence the natural fluctuations of fish stocks. Hence, the information on variations in ocean conditions is necessary to understand the influence they cause on fish stocks and their distribution. This knowledge will immensely help in formulating the best fishery management and developing efficient harvesting strategies. At one time, the success of a fishing trip often depended on a fisherman's keen sense of sight, smell and hearing and the availability of a high vantage point (crow's nest) to scan for fish. The area covered is very small till the reach of naked eye. Remote sensing helps to get information about an object or event without being in physical contact from a vast area.

Many of the physical features in the ocean such as changes in temperature, wind speed, upwelling and eddies directly affect the productivity of the oceanic region. Due to these changes, particular areas in the ocean may become richer in nutrients and phytoplankton production. Sequential aggregation of fishes at all levels in the food chain is usually observed in areas of high productivity. Banse and Macclain (1986) reported that seasonal reversing of winds in Arabian Sea results in large-scale changes in sea surface temperature (SST) bringing the nutrients to euphotic zone. An understanding of the influence of ocean variability on fishery resources could be useful for timely prediction of productive fishing grounds. The data pertaining to ocean variability can be obtained by collecting sea truth data by deploying vessels and buoys equipped for oceanographic data collection. However, the data thus collected is on a smaller scale, discontinuous and restricted to the time when ships can cover the area of interest. Remote sensing is one of the most effective means for acquiring data synoptically on vast scale.

The fishing fleet in India is dominated by small and medium class of vessels. The effort put by these vessels is restricted up to about 120 m depth in the continental shelf. The potential yield of fishery resources in Indian EEZ has been estimated to be 3.92 million tonnes. At present, most of the oceanic and deeper water resources remain underexploited (Somvanshi, 2002). Commercial fishermen have always been concerned about making best catch for the amount of time expended in search of productive fishing grounds. Commercial fishing in deeper waters is economically more intensive due to escalating operational costs. It is necessary to utilize available technological and scientific tools like remote sensing, in order to ensure economical viability of fishing by reducing the search time for productive fishing grounds. Significant advances have taken place during the past two or three decades, both in the technology of remote sensing and in its application. Satellite remote sensing applications in Indian fisheries have been studied by Narain et al. (1992), Kumari et al. (1994), Chaturvedi et al. (2000), Ramana et al. (2000), Solanki et al. (2000), Nayak, S. (2001), Solanki et al. (2001), Chauhan et al. (2002), Nayak et al. (2003), Solanki et al. (2003), Chandran et al. (2004), Kumari and Nayak (2005), Solanki et al. (2005a; 2005b), Choudhury et al. (2007) and others.

20.2 Evolution of satellite remote sensing

The term 'remote sensing' was coined in 1960 by Mr. Evelyn Pruitt of the U.S. Office of Naval Research (Butler et al., 1988). The first aerial photographs were taken from a captive balloon in 1858. The U.S. satellite Explorer-6 transmitted the first image of the earth as seen from space in 1959. The forerunner of the advanced weather satellites, Tiros-1 was launched in 1960. There have been a number of experimental satellites launched subsequently which further demonstrated the value of remote sensing in the studies on marine environment. In recent years, several nations have launched their own remote sensing satellites. The use of satellite remote sensing in oceanography started in early 1970s. It expanded considerably in the late 1970s. The satellite with dedicated oceanographic sensors was first launched in 1978 (Laurs et al., 1984).

20.3 Satellite remote sensing in India

Remote sensing is an important part of Indian Space Programme. The Indian Remote Sensing Satellite missions started as early as 1979 with the launch of Bhaskara-1. Subsequently Bhaskara-2 was launched in 1981. Their payload consisted of TV cameras and radiometers. The first generation remote sensing Satellites IRS-IA with linear imaging self-scanning sensors was launched in 1988. IRS-P4 was launched in 1999 in order to meet the growing demand for utilizing remote sensing techniques for ocean related applications. This was the first operational ocean remote sensing satellite containing two sensors, *viz.*, (i) Ocean Colour Monitor (OCM) and (ii) Multi-frequency Scanning Micrometer Radiometer (MSMR).

OCM is an 8-channel payload in the visible and near infrared frequencies of the electromagnetic spectrum. The radiometric resolution of the sensor is 12 bits. The field view of the optics is ± 43° providing a swath of 1420 km from 720 km altitude. The resolution of the sensor is 360 m (Anon, 1999). Department of Space started its initial study on remote sensing of the marine resources using the Advanced Very High Resolution Radiometer (AVHRR) data of National Oceanic and Atmospheric Administration (NOAA) satellite during late 1970s. The knowledge thus acquired has resulted in designing Ocean Colour Monitor (OCM) sensor for IRS P4 and algorithms for the tropical seas. This sensor is capable of retrieving chlorophyll intensity using its 8 wavelength bands. The Multi-frequency Scanning Microwave Radiometer (MSMR) onboard IRS P4 is capable of retrieving data on sea surface temperature and sea surface winds.

20.4 Application of remote sensing in fisheries

Traditional fishermen from ages have been using visual form of remote sensing in locating schools from an elevated position such as crow's nest. The vision was enhanced by the use of binoculars or telescopes. Visual form of remote sensing is used in many fisheries worldwide even today. Visual spotting from aircraft or helicopter is used successfully for locating a number of pelagic species such as anchovy, swordfish, menhaden and tuna. Different species can be distinguished on the basis of their colour, behaviour and schooling patterns. The phenomenon of bioluminescence which is the emission of light by certain types of plankton, when they are disturbed by the movement of fish, has been used by fishermen to locate fish when bioluminescent organisms are abundant. Air-borne instruments have been used for making oceanographic measurements related to fisheries research and for locating potential zones.

Satellite remote sensing is advantageous due to its ability to view features associated with fish abundance in vast areas of ocean in the minimum possible time. In the past, remote sensing was used predominantly to assist in the efficient harvesting of natural resources. In recent times, it is being used for resource management and conservation, in addition to harvesting.

Variations in environmental conditions affect the recruitment, distribution, abundance and availability of fishery resources. Knowledge of particular conditions and processes affecting fish populations may often be deduced using remotely measured parameters such as concentration of dissolved and suspended matter, variations in primary production levels, distribution of surface isotherms, location of frontal boundaries, regions of upwelling, currents and water circulation patterns. Information on features such as fronts, eddies, gyres, currents and upwelling derived from satellites is useful in fisheries, since fishes usually congregate in these areas for feeding (Choudhury et al., 2007).

20.4.1 Ocean colour

Changes in ocean colour may serve as an indicator of the plankton abundance. The green colour is associated with the presence of chlorophyll, the light retaining pigment of phytoplankton. While ocean colour has long been used locally by fishermen to locate fish species, aircraft and satellite imagery can record colour variations over a much wider area in a more precise manner. Techniques have been developed to quantify biological productivity on the basis of chlorophyll distribution and abundance. The potential of using space data for acquiring ocean colour data from space was first demonstrated by Kemmerer et al. (1974). In this study, ocean colour measurements from Landsat were used to predict areas of high probability of occurrence of menhaden in the Gulf of Mexico. The ocean colour measurements by remote sensing are useful in the detection of oceanic fronts and circulation, estimation of chlorophyll concentration and identification of water masses. Laurs et al. (1984) has demonstrated that the distribution and availability of albacore tuna are related to ocean fronts. Shannon et al. (1983) predicted that the information available on chlorophyll gradients along with the thermal fronts could be possibly used as a management tool for fisheries purposes. Chaturvedi et al. (2000) attempted to establish inter-relationship between satellite derived chlorophyll (Sea WiFS images) and temperature profile with data collected from survey vessels during 1997-98. One constraint experienced in tropical waters is the narrow temperature ranges which could not always be linked to the aggregation and availability of fishes, unless it is integrated with some other parameter such as ocean colour (Solanki et al., 2000). Other parameters such as temperature gradient and wind direction may also be useful for this purpose. At present synchronous IRS-P4 OCM and NOAA-AVHRR SST data are used for the identification of potential fishing zone (PFZ). The fishery and oceanographic data collected during cruises are used for the forecast validation. IRS-P4 OCM Chlorophyll-a image showing distribution of algal bloom in oceanic waters, off Gujarat on 27 February 2000 is shown in Fig. 20.1.

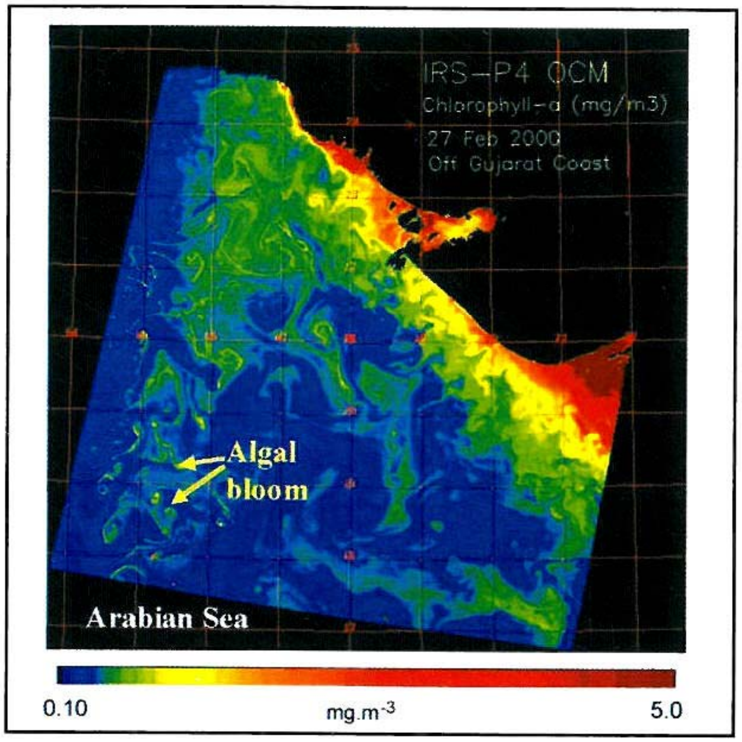

Fig. 20.1 IRS-P4 OCM Chlorophyll-a image showing distribution of algal bloom in oceanic waters, off Gujarat (27 February 2000)
(Source: SAC, Ahmedabad)

The features for potential fishing zone (PFZ) selection are indicated taking into consideration the extent of the area, magnitude, gradient, shape of the front, possibility for its persistence and operational constraints. Divergent fronts, eddies and meanders are indications of the ongoing oceanic process resulting in high productivity in that area and are possible PFZs. The advanced phase of productivity is indicated as chlorophyll features and probably in sea surface temperature (SST) image also as (i) strong gradients, (ii) persistence, (iii) features seen on both colour and SST image, (iv) upwelling stabilization phase, (v) centre of the core ring, (vi) edges of the warm core ring, (vii) anticyclonic eddy and (viii) cyclonic eddy (Somvanshi, 2002).

20.4.2 Sea surface temperature

Water temperature is an important factor in determining species distribution and thermal sensors can be used to produce maps of the sea surface temperature (SST). Such mapping can be used to identify upwelling areas and to locate boundary areas between warm and cold waters where certain species are known to congregate. The satellite infrared thermal data has been used very effectively for fisheries research in many countries (Laurs et al., 1984).

An attempt was made in India during 2002-2004, towards the application of satellite-derived SST and chlorophyll together in assisting the fishing industry located along the east coast of India (Choudhury et al., 2007). SST and chlorophyll concentration are retrieved from NOAA-AVHRR (NOAA-advanced very high resolution radiometer) and IRS-P4 OCM (OCM-ocean colour monitor) sensor respectively. Features are extracted from the SST and chlorophyll retrievals and these features are transferred onto a scaled base map called an integrated potential fishing zone (IPFZ) map.

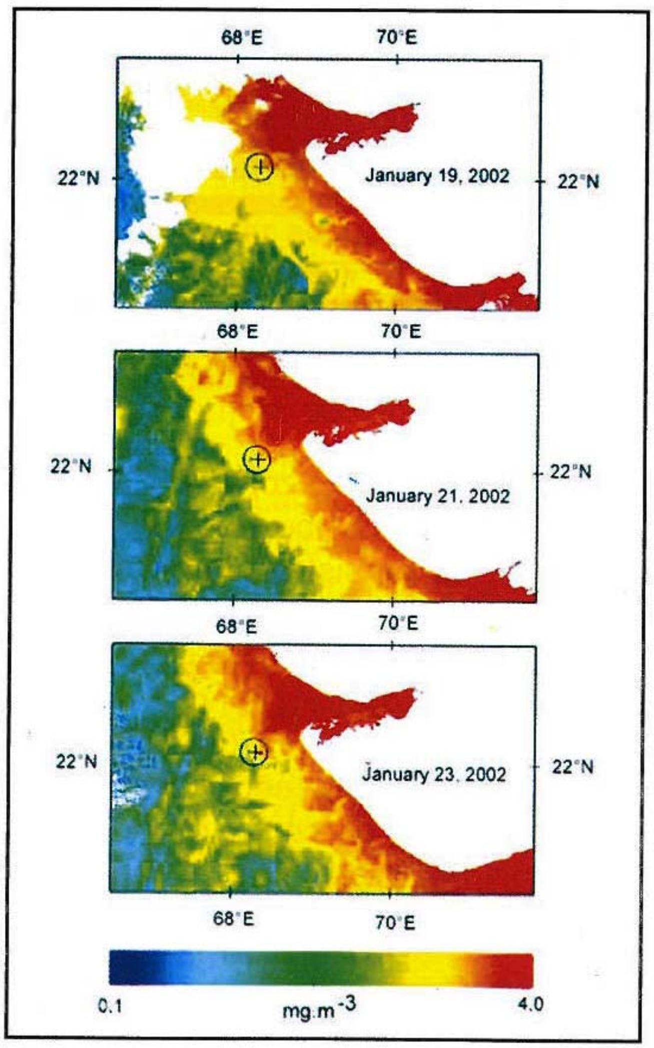

Fig. 20.2 Sequential Integrated Chlorophyll images of IRS-P4 showing good catches associated with strong gradients

The results of fishing surveys have indicated that the CPUE has been high in the IPFZ areas compared with surroundings. Studies conducted by Central Institute of Fisheries Technology (Cochin) and Space Applications Centre (Ahmedabad) for validating IRS-P4 OCM integrated chlorophyll images with the actual sea truth data, off Gujarat, during 2000-2002, indicated that poor landings of demersal trawlers were generally associated with areas of low chlorophyll concentration and higher landings of *Priacanthus hamrur* by trawlers operating off Dwaraka (Gujarat, India) were associated with the gradients or breaks seen in the integrated chlorophyll images (Fig. 20.2).

20.4.3 Wind stress measurements

A case study using Seasat-A Satellite Scatterometer (SASS) wind data to establish, quantify and document the extent and variability of wind-induced ocean flow indices on surface-layer transport was conducted by Laurs and Brucks (1985). Chandran et al. (2004) studied the drift of ocean colour features using satellite derived sea surface wind for updating potential fishing zone. Knowledge of surface-layer transport is important as they control the distribution of early life stages and thereby influence the recruitment and future harvest of marine organisms with planktonic life stages.

20.5 Satellite data products available for fisheries

Products based on satellite remote sensing have the potential to contribute significantly towards ensuring profits and judicious exploitation of resources. These products may include (i) SST charts, showing the location of thermal boundaries, (ii) ocean colour charts and (iii) integrated chlorophyll-SST charts, indicating potentially productive fishing areas. Sea-ice forecast chart, derived from polar orbiting satellite infrared imagery are used to facilitate safe navigation and fishing.

In India, SST data generated using NOAA-AVHRR satellite data and Chlorophyll data derived from IRS-P4 are used by the Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences, to make maps of potential fishing zones (PFZ), which are freely disseminated thrice a week throughout coastal India by fax, phone, internet, electronic display boards, newspaper and radio broadcasts, for the benefit of fishing community. Studies on the effectiveness of the PFZ advisories have suggested that they have helped to reduce search time and have significantly increased the catch per unit effort (CPUE) (Solanki et al., 2003; Zainuddin et al. 2004).

20.6 Remote sensing and aquaculture

The aquaculture industry is growing rapidly worldwide and represents an increasingly important source of seafood. Most aquaculture activities depend on maintenance of high environmental quality and routine monitoring of quality parameters, for operational purposes. The impact of aquaculture on water quality and adjacent ecosystem is also a matter of concern. Ocean colour products can potentially meet operational and conservation and monitoring needs cost effectively, with spatial and temporal coverage unachievable by any other methods (Parslow et al., 2000). The space scales associated with aquaculture application are generally small, requiring special resolution of 100 m or better for water quality and 30 m or better for benthic habitat. In India, IRS LISS II data was utilized to prepare coastal land use maps on 1: 50,000 scale along the Indian coast for detecting features facilitating site selection for brackish water aquaculture (Nayak, 2001).

20.7 Advantages of remote sensing technology applications in fisheries

Application of remote sensing technology in fisheries (i) helps the fishermen to reduce the scouting time for locating potential fishing zones, thus reducing total fishing time, expenditure on fuel and enhancing profitability of fishing operations, (ii) provide best possible advice in making fishery management decisions and to develop efficient harvesting strategies, (iii) provide means of estimating primary productivity of ocean at a given time and (iv) provide weather and sea ice forecasts facilitating greater safety during navigation and fishing operations.

20.8 Conclusion

In evolving the applications and in achieving the precision and perfection in forecasting the PFZ, several issues need to be addressed. The data generated should be disseminated to the fishermen in minimum possible time and for this purpose a strong communication network has to be developed. In certain oceanic areas, such as southwest coast of India, cloud cover frequently affects the sensor detection and predictions are rendered difficult or impossible. In order to determine PFZs for demersal trawling, algorithms for prediction of the aggregation of demersal resources in terms of time lag need to be better understood based on the depth and other associated features. It is also necessary to examine how various dissolved substances and optical processes influence the colour of coastal waters. Multiple parameter approach in the GIS environment need to be developed and refined further, using the parameters such as sea surface temperature, ocean colour, wind and sea surface height, for identifying zones of fish aggregation.

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