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Remote Sensing Applied in Marine Fishing: A Review on Indian Marine Fishing Industry Context

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***Abstract*—The increasing demand for food production due to the rising population has necessitated the use of advanced and efficient methods in the production process. Fishing in the coast (marine fishing) has also seen the same change, from rudimentary methods to use of data collected from various ocean monitoring platforms. The spatial data collected from these platforms require processing using dedicated systems running the required algorithms to ultimately acquire the information that help the fishing community to land the best catch with minimal effort and resources. This type of Geographic Information System (GIS) is being exploited for fishing in various parts of the world and this paper is aimed at understanding how such a system is employed and how they have rendered results (in Indian context) that would otherwise have been remotely achievable**.

Keywords- *Geographical Information System (GIS); Remote Sensing (RS);Fishing Industry*

I. INTRODUCTION

The term 'Remote Sensing' in its literary sense means perception from a distance i.e. perception of the physical properties of the subject without actually being in contact with the subject. It requires the use of a sensor that receives observable information about the object under inspection. It typically means the measurement of the electromagnetic radiation emitted from the object. Sometimes it may also mean the measurement using acoustic waves (sonar), magnetic fields and gravity. Remote Sensing can provide significant information about the ocean surface, its subsurface and other features in the form of satellite imagery both in the visible and invisible spectrum [10]. In the past, remote sensing was used predominantly to assist in the efficient harvesting of natural resources. Today it is being used for resource management, conservation and exploitation.

The presence, quantity and the distribution and abundance of fishery resources depends upon the various environmental parameters. Though it is not possible to measure remotely the entire range of conditions that effect the marine environment information of particular conditions and processes affecting fish populations, however, may often be deduced using measurements made by remote sensors, e.g., 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 [1]. These parameters may allow a forecast of fish distribution or more generally the definition of marine fish habitats. These are often easier to sense remotely than the presence of fish itself.

Remote sensing techniques can be utilized directly, indirectly or as general aids in the detection and assessment of fishery resources as we shall discuss in the following section.

II. METHODOLOGY

Fishing in the marine ecosystem at first requires locating the area of potential catch. This can be done using the following two methods:

1. Direct method
2. Indirect method

1. Direct method of fish detection:

Direct method of fish detection involves spotting the fish shoals visually or by using sensors such as sonar to detect the presence of schools of fish in the vicinity. In addition to providing the whereabouts of the fish shoals, sonar also enables the users to estimate the biomass of the potential catch. Fishing fleets which exploit major fisheries such as tuna and menhaden are dependent on visual fish spotting from aircraft to direct their fleets. [1]

2. Indirect method of fish assessment:

Another method of fish assessment is done by measuringthe parameters which affect its distribution and abundance. Much of the research dealing with environmental effects related to fisheries is concerned with the correlation of a single parameter with the spatial and temporal distribution of fish. It is most likely, however, that fish respond to the sum total of environmental factors. Thus, it becomes necessary to correlate a large number of parameters, obtained by remote sensing techniques, with fish distribution. [1]

Some of the environmental parameters that affect the distribution of fish are as follows:

i. Surface optical properties:

Normally sunlight penetrates sea water to a depth of tens of meters. However as the concentration of the water constituents increases, i.e. the water becomes more turbid, the penetration of sunlight is reduced as a result of absorption and scattering of the light waves. Depending on the specific characteristics of the materials present in the water, i.e. on their spectral signature, the absorption and scattering processes will vary with the wavelength of the incident radiation. Multispectral observations, therefore, can be employed to estimate the nature and concentration of the water constituents. Sensors are used to both sample and image water colour. [1]

Some important parameters which can be derived remotely from water emergent radiation, through the use of empirically constructed algorithms, are listed below.

a. Diffuse attenuation coefficient:

The diffuse attenuation coefficient at a specific wavelength is an apparent optical property. Its magnitude depends on the light distribution as a result of spreading, scattering and absorption that exists at the in situ point of measurement. This parameter, when correlated with Secchi disk depth and Munsellcolour hues, provides the means of physically categorizing water according to colour. Its value can be interpreted as a measure of water turbidity and it constitutes a valuable tool in fisheries studies. It has been established, for example, that turbidity and menhaden sighting in the Mississippi Sound are highly correlated. [1]

b. Total suspended matter (seston):

In addition to optical parameters, the total concentration of the absorbing and scattering agents can be used to classify surface waters by means of their colour. The utilization of this parameter may be most appropriate when classifying waters where inorganic and/or organic sediments make an important contribution to the optical properties of the surface layer. It may also be appropriate if sediment concentration has to be used as a natural tracer for the identification of water movement and frontal boundaries. [1]

c. Yellow substance:

The term yellow substance may be defined as the byproduct derived from the degradation of land and marine organic matter. It is an important parameter to monitor in the context of polluted coastal waters, since it may be used to identify marine areas where the exploitation of filter feeders, e.g., shellfish, could be hazardous. [1]

d. Chlorophyll pigments:

The concentration of chlorophyll pigments (the photosynthetic pigments of phytoplankton) is often considered as an index of biological productivity and, in an oceanic environment, it can be related to fish production. Chlorophyll concentrations above 0.2 mg/cu.m indicate the presence of sufficient planktonic life to sustain a viable commercial fishery. Chlorophyll pigments have a specific and distinctive spectral signature since they absorb blue (and red) light and reflect strongly the green, thus affecting ocean colour. Multispectral observations from airborne or space borne sensors, therefore, allow the deduction of phytoplankton concentration. [1]

e. Macrophytes:

In coastal areas it is common to find macrophytic vegetation (seaweed). These species play an important role in supporting marine life. Different kinds of seaweed have different light reflection properties. This distinction allows the differentiation of some seaweed species by the use of airborne or space borne passive visible sensors. The airborne sensors such as aerial cameras or radiometers are usually more effective in this domain. [1]

ii. Surface temperature:

Global surface temperature charts are produced on an operational basis. The geostationary satellites are principally used for the near-equatorial area as they provide thebest resolution in that area. [1]

iii. Circulation Features:

Several remote sensing techniques can provide information regarding surface circulation properties of importance in defining marine fish habitats. These include the location and evolution of frontal boundaries, upwelling areas, currents and circulation patterns in general. Optical and thermal characteristics of surface waters can be used as natural tracers of dynamic patterns. Hence, the previous discussion of sea surface colour and temperature should be considered again in light of this application. Microwave techniques, particularly the use of active sensors (radar altimeter) also have applications regarding large-scale circulation features. [1]

For example, the information about the dynamic characteristics of a basin can be achieved throughremote measurements of water surface vertical displacements. [1]

iv. Salinity:

Research, however, indicates the possibility of determining salinity with the use of microwave sensors to an accuracy of one part per thousand. The microwave properties of the sea surface are a function of its physical and chemical state. The emissivity of sea water is related to salinity. Change in salinity causes significant changes in the emissive brightness temperature of water for frequencies less than 5 GHz. The salinity can thus be determined remotely by measuring accurately the emissive brightness temperature of the sea water. The precision afforded by this technique may be adequate for mapping the spread of fresh water at a river mouth or for studying estuaries and near shore waters. [1]

v. Oil pollution:

The numerous methods used for oil detection at the sea. The visual method detects the presence of oil by the change in colour. Other visible-light phenomena used to detect oil slicks include EMR interference effects (colour banding) and the suppression of solar speckle by slicks. The microwave method, when passive techniques are used, is based on the difference of emissivity between the sea surface and the oil slick. Active radar sensors depend on small capillary wave backscatter to be dampened by the oil slick as a means of oil detection. Fluorescent properties of hydrocarbons may be detected and discriminated by appropriate lidars. These laser fluorosensors can also identify the basic types of oil (heavy, light, etc.) and provide a measurement of oil slick thickness. Thermal sensors identify oil by means of the difference in solar absorption and thermal emissivity between oil and water and they also provide a basic measurement of oil thickness. [1]

vi. Sea state:

It has been established for some time that rough sea conditions created by wind have an effect on the distribution of the fishery resources. SAR equipped aircraft or satellites can scan the sea state of fishing grounds and this information can be relayed to fishermen via a ground control station in near-real time. [1]

Although the effect of waves on the distribution of fish has been studied by several researchers, no attempt has been made so far to relate quantitatively the abundance of fish to any parameter of sea state. [1]

III. INDIAN FISHING INDUSTRY

India is a major producer of fish through aquaculture and ranks second in the world after China. In FY2013-14 India is the second largest producer of fish in the world contributing to 5.68% of global fish production. It is not only a source of livelihood for over 14 million people; but also needed for socio economic development of country, it has contributed Rs. 30,213 Cr. The vast resources of both inland and marine are indicative of the immense growth potential of the sector. Country has long coastline of about 8118 km and an exclusive economic zone of 2.02 million sq. Km. (Handbook on Fisheries Statistics, 2014) [5] with extensive freshwater resources, fisheries play a vital role. Presently, fisheries and aquaculture contribute 1.07 per cent to the national GDP and 5.30 per cent to agriculture and allied activities, while the average annual value of output during the Tenth Five Year Plan (2002-2007) was Rs 31,682.50 crores. [7]

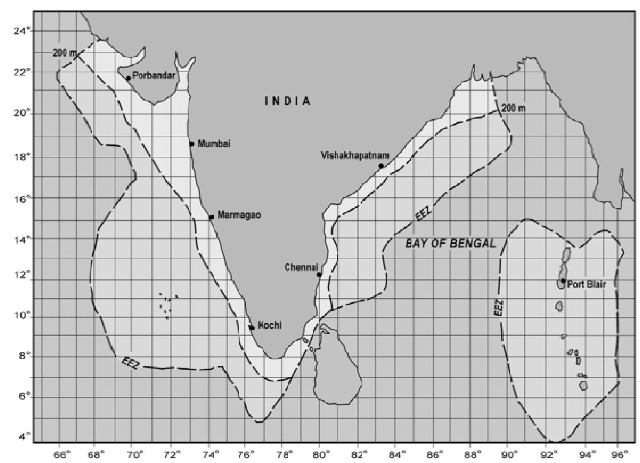

Figure 1: Exclusive Economic Zone of India [4]

Indian Marine Fisheries:

It contributes to food security and provides direct employment to over 1.5 million fisher people besides others indirectly dependent on the sector.

According to the CMFRI Census 2010, there are 3,288 marine fishing villages and 1,511 marine fish landing centres in 9 maritime states and 2 union territories. The total marine fisher folk population was about 4 million comprising in 864,550 families. [7]

The Indian coastline can be delineated into 22 zones, based on the ecosystem structure and functions.

India's marine capture fish production, increased from 520,000 tonnes in 1950 to 3.15 million tonnes in 2007. The bulk of the catch comprises oil sardines, followed by penaeid and non-penaeid shrimp, Indian mackerel, Bombay duck, croakers, smaller quantities of cephalopods, other sardines and threadfin breams (CMFRI 2008). [7]

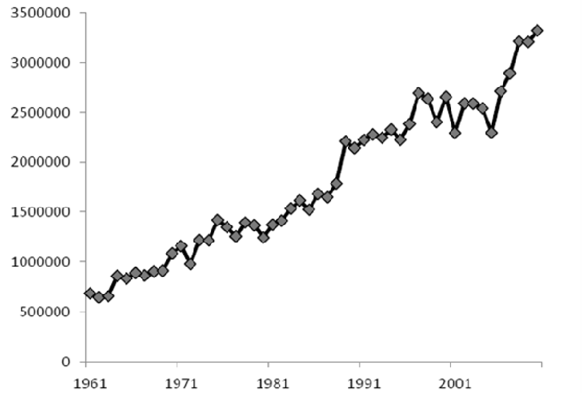

Figure 2: Trend of Marine Fish Catch (in tonnes), India [3]

Sl. No.	State/Union Territory	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
1	Andhra Pradesh	182.50	204.94	248.50	263.93	210.73	218.84
2	Goa	67.33	66.55	72.29	83.76	94.81	100.91
3	Gujarat	620.47	650.83	743.64	609.14	584.78	663.88
4	Karnataka	205.90	128.42	180.16	187.00	171.23	176.97
5	Kerala	566.57	593.78	603.29	608.52	601.86	558.91
6	Maharashtra	402.84	414.27	386.86	420.01	417.77	445.34
7	Odisha	121.09	113.89	115.01	116.88	121.93	122.21
8	Tamil Nadu	367.86	371.00	371.50	373.00	307.69	307.99
9	West Bengal	181.00	184.30	181.50	181.60	179.50	160.00
10	A & N Islands	27.62	27.02	28.23	31.06	32.60	12.05
11	Daman & Diu	16.38	21.52	11.26	13.77	12.51	17.72
12	Lakshadweep	12.00	13.65	7.50	10.03	11.96	11.96
13	Puducherry	38.95	39.60	40.11	42.80	31.50	19.27
	INDIA	2810.50	2829.77	2989.85	2941.50	2778.87	2816.05

Figure 3: Marine Fish Production (in '000 tonnes) state wise, India [9]

History of Remote Sensing in India Marine Fisheries:

The pioneering work in the application of remote sensing to marine fisheries in India was made in the FAQ/UNDP Pelagic Fisheries project during the years 1972-1974. The project succeeded in spotting and quantification of fish shoals using areal and vessels surveys. [11]

During 1980s, various organizations came together to use the data acquired from the various space borne sensors to create maps of various kinds for the coastal areas of India. In between 1980 and 1984, SAC (Space Application Center), CMFRI (Central Marine Fisheries Research Institute) and FSI (Fishery Survey of India) used data from several U.S. satellites such as Landsat, Nimbus-7, etc, in a Joint Experimental Programme (JEP), to identify suitable sensor parameters such as optimum special bands, sensitivity and special resolution and also developed methodologies to extract relevant information from the remotely sensed data to estimate the resource. Chlorophyll distribution maps were prepared for the coastal areas of Cochin was also prepared during this interval using the onboard color sensor of Nimbus-7. [11]

During 1985-1989, under IRS – Utilization programme, experiments were conducted in various coastal regions using to identify parameters for utilization in the exploitation of marine resources using varied sensors. An attempt was made using the satellite data of NOAA to locate the potential fishing grounds off the coast of Gujarat.The success of this experiment led to the preparation of potential fishing zones of the various maritime sates and the same were supplies using fax messages. [11]

Satellite Data Acquisition and processing in India:

Today, the National Remote Sensing Centre (NRSC) at Hyderabad is the central agency for reception, archival, processing and dissemination of remote sensing data in the country. NRSC acquires and processes data from all Indian remote sensing satellites like Cartosat-1, Cartosat-2, Resourcesat-1, IRS-1D, Oceansat-1 and Technology Experiment Satellite as well as foreign satellites like Terra, NOAA and ERS. [8]

The operational OCM sensor on board Oceansat-1 and more recently Oceansat-2 has provided excellent opportunity to monitor and study the bio-geological character of ocean around India. Algorithms have been developed for the retrieval of chlorophyll pigment and total suspended matter, characterization of colored dissolved organic carbon, underwater diffuse attenuation coefficient and marine aerosol optical depths. [2]

Various factorssuch as sea surface temperature (SST), chlorophyll concentration, currents, mixed layer depths, internal waves, winds, oxygen, salinity, predator-prey relationship, etc affect the aggregation of fish. The technique developed for the Potential Fishing Zone (PFZ) forecast (up to 2-3 days in advance) which combines chlorophyll information from OCM and sea surface temperature (SST) from NOAA-AVHRR has been validated and has shown success in the identifications of PFZ. [2]

There have been increasing demands from the ocean community for enhanced applications in biological, physical and geological oceanographic areas. The potential fishery zone mapping applications operationally carried out under NNRMS (National Natural Resources Management System) demand species specific forecasting as well as for long term forecast along with the marine weather information. [6]

General Air to Fishing Operations:

Remote sensing satellites provide more than just forecasting the zone of potential catch for the fishermen.Some of the assistances that satellites can offer include the following:

i. *Search and rescue at sea*:

Specialised remote sensing satellites are used to locate and facilitate therescue of sea vessels in difficulty after detecting the distress signals emitted by the vessels. Satellites such as INSAT 3A and INSAT 3D of ISRO perform such operations.Year 2013, saw search and rescue support to 14 distress incidents in Indian service area through Indian system and contributed to saving 94 human lives. [12]

ii. *Meteorological reports*:

Weather reports provided by meteorological satellites assist fishermen to schedule their fishing voyages.
Some satellites also enable the fishermen to spot and identify environmental hazards such as icebergs.

iii. *Bathymetry*:

Remote sensing using passive or active sensors may be used for creating a clear map of the underwater depths of the waterbodies. This enables safe surface or sub-surface navigation.

IV. CONCLUSION

The remote sensing application in India is nearly four decades old, starting from the coconut root wilt disease detection of 1970. Large number of nationally important applications has been carried out in this long run [2]. The application of remote sensing in coastal fishing in Indian context is just the tip of the iceberg. At present India holds the record for operating the largest constellation of remote sensing satellites [6]. New and advanced satellites for ocean monitoring (like Oceansat – 3, Risat – 4L, etc) are on the pipeline and the future for remote sensing applications in Indian marine fishing looks promising [6].

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