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Identification of Potential Fishing Zone (PFZ) Along Kerala Coast, India

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ABSTRACT

Parameters that refer to fish existence can be identified by remote sensing techniques using satellite sensor data. Identification of potential fishing zones with the aid of remote sensing technology is a crucial need for the fisher flocks to get profitable catch by less fuel consumption, effort, and time as well. In this study, two different parameters, chlorophyll concentration and sea surface temperature (SST), were taken from satellite-derived data. For this purpose, Aqua MODIS data were used for chlorophyll concentration, and NOAA-AVHRR data were used for SST extraction. The chlorophyll concentration in the deep-sea area is 0.2 mg/m^3 to 0.3 mg/m^3; however, at the close of the Kerala coast, the chlorophyll concentration is around 0.4 mg/m^3. For sea surface temperature, the obtained range is from 21 °C to 31 °C. Using SST and Chlorophyll, the potential fishing zone (PFZ) is mapped over the Kerala coast, India. The validation of the result was done by the Indian National Centre for Ocean Information Services (INCOIS) and found that the catch amount of a PFZ notified area is 2 to 6 times more than fishing in an unnotified fishing area, and the amount of extra profit was recorded 2 to 7 times more. This research will contribute to the improvement of the local livelihood of the fishermen and the economy in the country.

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Introduction

In India, around 7 million people live on the coastline spanning about 8,100 km, who depend upon fishing or related tasks to conduct their livelihood. Kerala is highly dependent upon the marine fisheries sector and earns a lot of foreign exchange through exporting fish and fisheries items, and so, this state is considered the highest seafood exporter among all other states of India (Reena and Renjumol, 2014). The state has 589.5 km of coastline, which is 10% of the total Indian coastline area, and with an exclusive economic zone (EEZ) of 218,536 sq km, which is considered the employment resource for the population of that state (Reena and Renjumol, 2014). The natural climatic support, such as high rainfall, runoff through rivers, has made the Kerala coastal region special for fish existence (DoF, GoK, 2025).

As fishing is a challenging task, it consumes time, effort, and money, due to fuel consumption for investing extra time in catching. A quick search of fish school distribution as well as production harvest can give a marvelous output for the fisher flock through higher profit in the lowest time and effort investment. PFZ forecasting at a suitable time can minimize the schedule of fishing operations (Nammalwar et al., 2013). Potential fishing zone (PFZ) is considered the short-term forecasting of the reliable area where there is the highest possibility of fish school availability in open water, especially in marine environment. It helps to operate the fishing gear in a targeted place that results in the reduction of bycatch from the ocean, which is an excellent practice of open water sustainable aquatic biodiversity management, and it is a global target nowadays. The catch and effort trend analysis, in tandem with a bio-economic model, has evaluated the effect of government policy on the Indian marine fishery (Bhathal, 2014). An extra benefit of using technology-aided support can reduce the overexploitation of the fisheries resources. To fulfill the protein consumption demand of a massive population, remote sensing (RS) and geographic information system (GIS) can be implement to detect the accurate location of fish school. For this purpose, the satellite-aided search method can be encouraged for operational use.

Different factors, such as oceanic fronts, eddies, meandering patterns, rings, and upwelling areas, indicate the presence of fish (Subramanian et al., 2014). In modern technology, to detect this area, satellite sensor data along with some oceanic factors i. e., upwelling, eddies, gyres, etc., is used. Parameters that affect the existence of fish shoals can be retrieved from the satellite sensor data and could be applied to identify the PFZ. Chlorophyll concentration and sea surface temperature (SST) are also associated with the distribution of fish shoals in the ocean (Subramanian et al., 2014). Those two factors can be retrieved from satellite imagery to generate PFZ forecasts. The application of satellite techniques in the fisheries sector was carried out by Laskar et al., (1981), Laurs et al., (1984), and other scientists. Retrieval of sea surface temperature, sea surface height, sea surface wind, and chlorophyll concentration can be done through continuous monitoring using the remotely sensed data (Stuart et al., 2011). Based on prevailing demand, this study was undertaken to analyze the spatio-temporal variability of sea surface temperature (SST) and chlorophyll concentration along the Kerala coast, and to identify potential fishing zones (PFZs) within the study area by validating them against existing fish catch data.

Materials and Methods

Study area

Kerala is a coastal state of India located in the southern part of the country (Figure 1). The geographical extension of the study area is 73.0° to 77.5° East Longitude and 7.0° to 12.5° North Latitude. The study area encompasses the coast of Kerala and some parts of Tamil Nadu State.

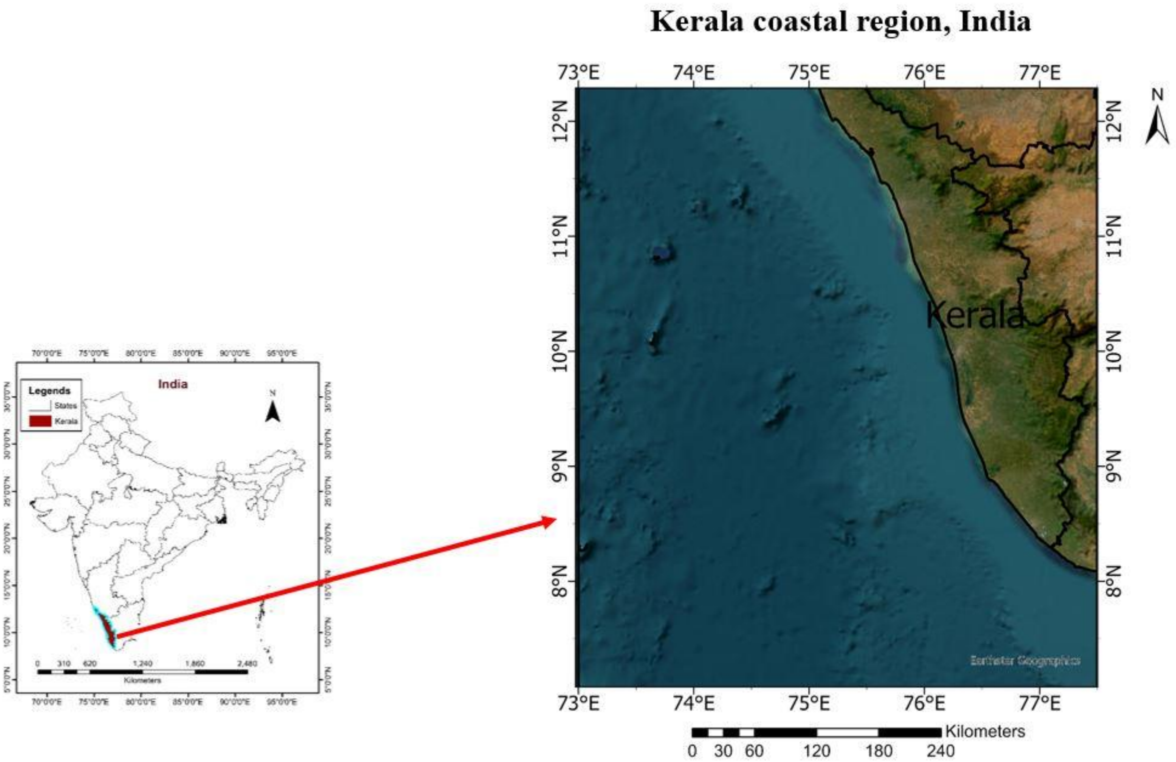

Figure 1. Image showing the study area (Kerala coastal region, India).

Dataset used

In this research, two types of data were used to retrieve sea surface temperature and chlorophyll concentration, and published harvest data were used as non-spatial data. For the estimation of chlorophyll concentration and sea surface temperature, Aqua-MODIS and NOAA-AVHRR data were used, respectively. To delineate the wind direction of the study area, the QuickSCAT data of 24th January, 2007, were taken and analyzed. The data specification used in this study is enumerated in Table 1.

Table 1: Data used for Chlorophyll, sea surface temperature (SST), and sea surface wind (SSW) analysis

Data	Sensor Name	Variable (s)	Spatial Resolution
Satellite (s)	MODIS (AQUA)	Chlorophyll Concentration	4 km
	NOAA-AVHRR	Sea Surface Temperature (SST)	1.1 km
	QuickSCAT	Sea Surface Wind (SSW)	(0.5°X0.5°)

During the research, all data from 24th January, 2007 for the Kerala coast of India were processed for PFZ map preparation. We have the catch data of 24th January, 2007 from a published article, and thus, the PFZ areas were validated.

Methodology

Two key oceanographic parameters were utilized for potential fishing zone (PFZ) mapping. For this purpose, two different satellite datasets were employed. Chlorophyll-a concentration data were obtained and processed from Aqua-MODIS Level-4 mapped products, available through NASA Ocean Color. For improved visualization, chlorophyll-a concentration values were considered up to 0.3 mg/m³. Similarly, sea surface temperature (SST) data were acquired from the NOAA-AVHRR Pathfinder dataset and processed for visualization. An SST range of 23 °C to 31 °C was used for general visualization, while a narrower range of 26 °C to 30 °C was applied for contour generation. Sea surface temperature (SST) contours were super imposed over chlorophyl concentration, and considering the thermal gradient and chlorophyl concentration, the potential fishing zone contours were drawn. Sea Surface Wind (SSW) data was obtained from QuickSCAT sensor that was used to identify the wind pattern and shifting possibility of prepared PFZ contours. All analyses were performed using ArcMap 10.6 software. The sequential workflow, from data acquisition to final output generation, is illustrated in Figure 2.

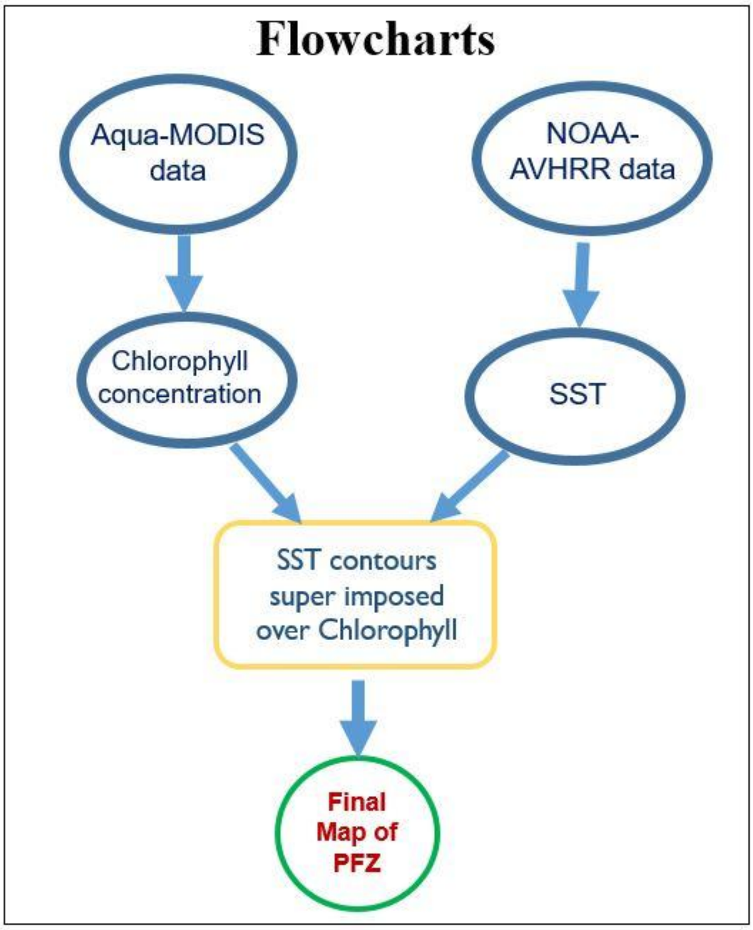

Figure 2. The figure showing the steps followed to get PFZ map.

Result

SST from NOAA-AVHRR data

Among the two different parameters, the sea surface temperature of the study area ranges from 23 °C to 31 °C. The higher amount of sea surface temperature was found in the near-coastal area. The maximum temperature (approximately 40°C) was found at the close coastal area; however, for better visualization, in this research, it was excluded and shown at a range of 23°C to 31°C. Small areas with higher temperatures were found in some deep ocean areas; however, the cause is unknown. The sea surface temperature (SST) retrieved from NOAA-AVHRR data dated on 24th January 2007 is shown in Figure 3.

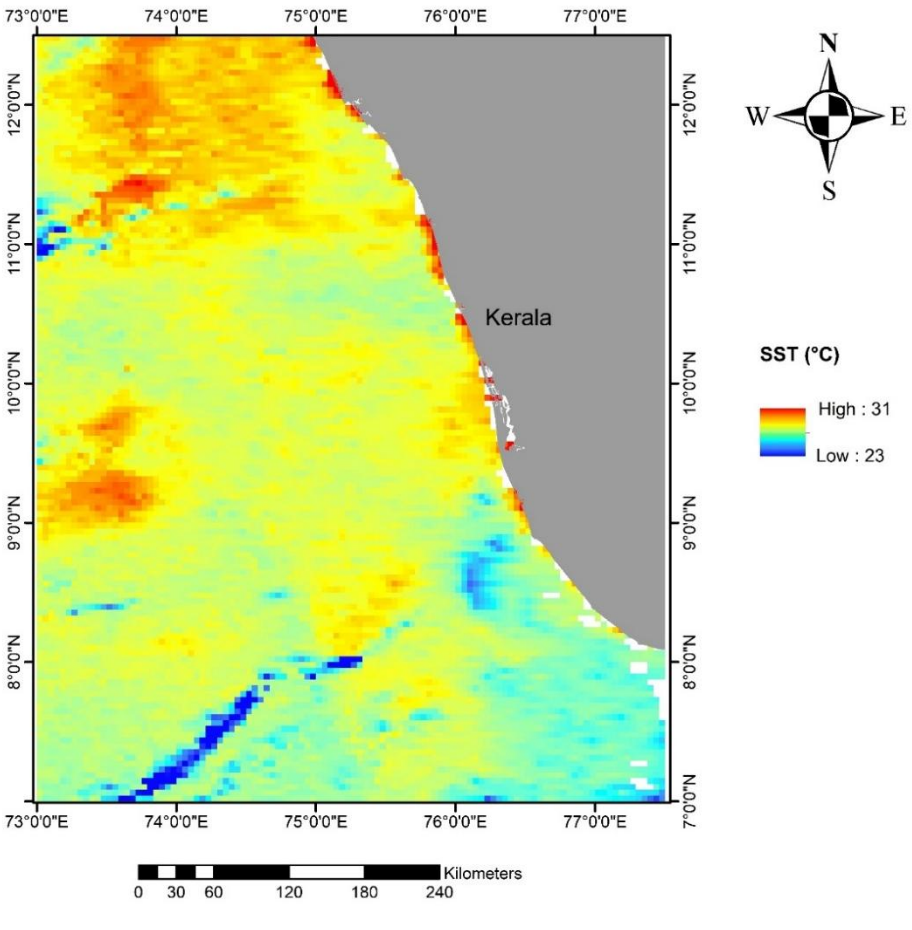

Figure 3. SST from NOAA-AVHRR data on 24.01.2007 of the Kerala coastal region, India.

Chlorophyll concentration from MODIS data

In the case of the chlorophyll concentration along the Kerala coastal region, on 24th January 2007, it was found that the highest chlorophyll concentration was close to the shore of the coast. It is thought that due to the runoff inflow from the land area, this region is nutritionally rich and very supportive for primary production. However, in the South-eastern part of the research area, a high concentration of chlorophyll in a circular shape was found, and it could be the cause of upwelling, as upwelling brings the cool and nutritionally rich water toward the surface layer of the ocean. This nutritionally rich area is suitable for phytoplankton growth.

The white area bears no chlorophyll data in that region. The figure of chlorophyll concentration is mentioned in Figure 4.

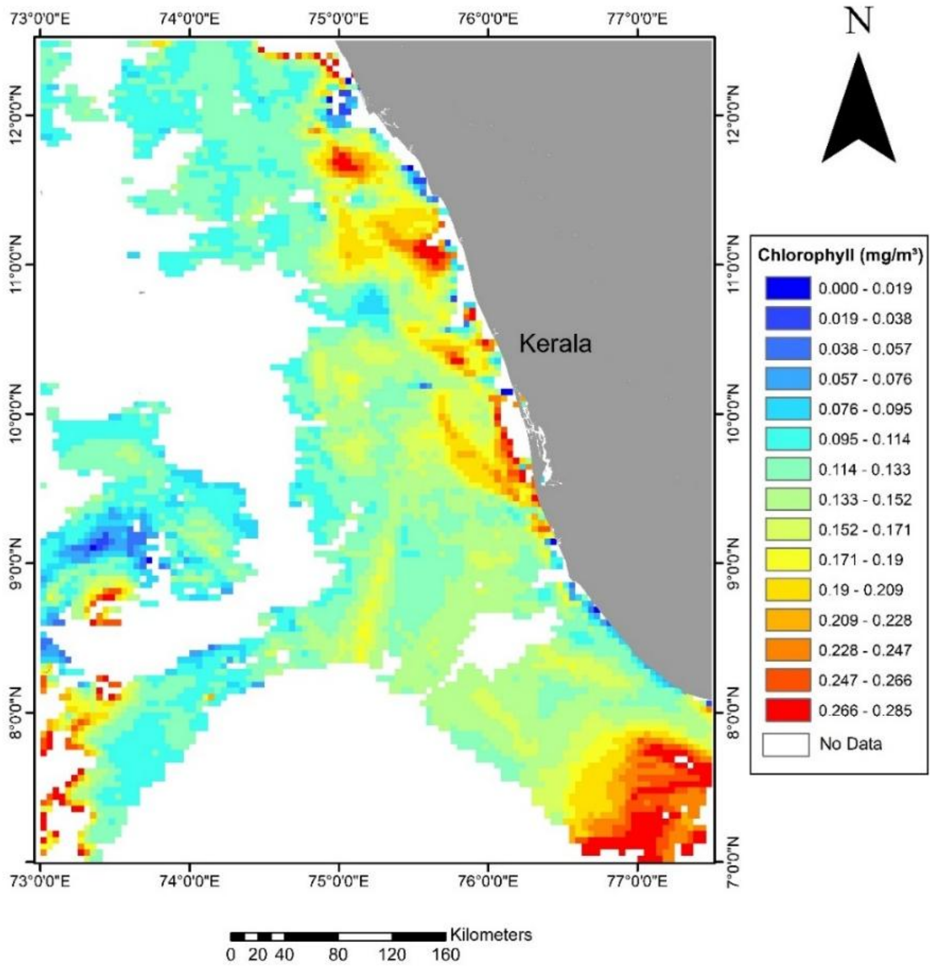

Figure 4. Chlorophyll concentration from MODIS data on 24.01.2007 at Kerala coastal region, India.

Chlorophyll concentration and SST contour

Sea surface temperature (SST) contours were prepared, and to demonstrate, the contours were ranged between 26 °C to 30 °C. After that, chlorophyll was superimposed on SST contours. Contours were prepared according to the thermal gradient. The figure of Chlorophyll superimposed by SST contours is shown in Figure 5.

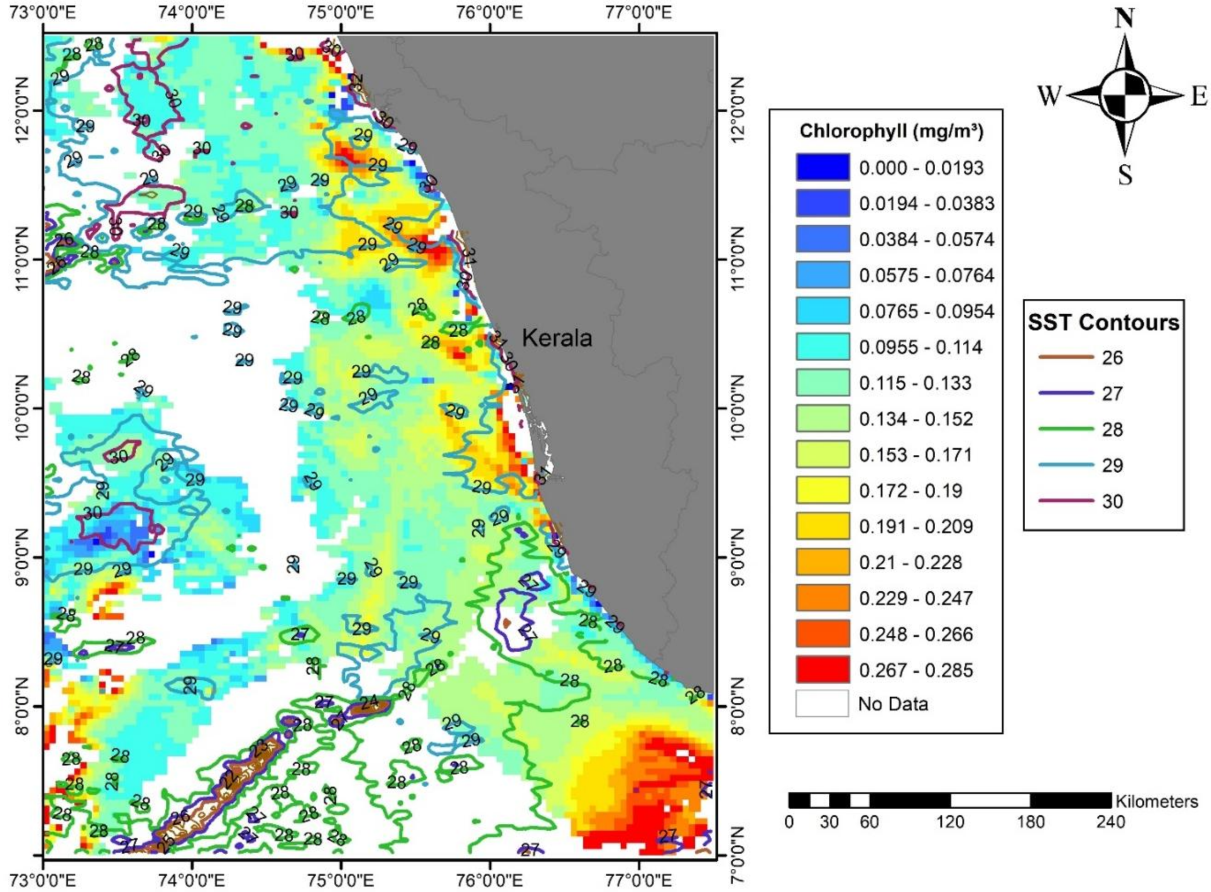

Figure 5. Chlorophyll super imposed by SST contour on 24.01.2007 along Kerala coastal region, India.

Extraction of PFZ contours

The potential fishing zone (PFZ) contours were drawn based on the sea surface temperature (SST), chlorophyll concentration and the thermal gradient. Most of the PFZ contours were recorded close to the coastal area in relation to the deep sea, considering the fishing activities easier and more convenient for the fishermen. The PFZ contours drawn over the study area is depicted by Figure 6.

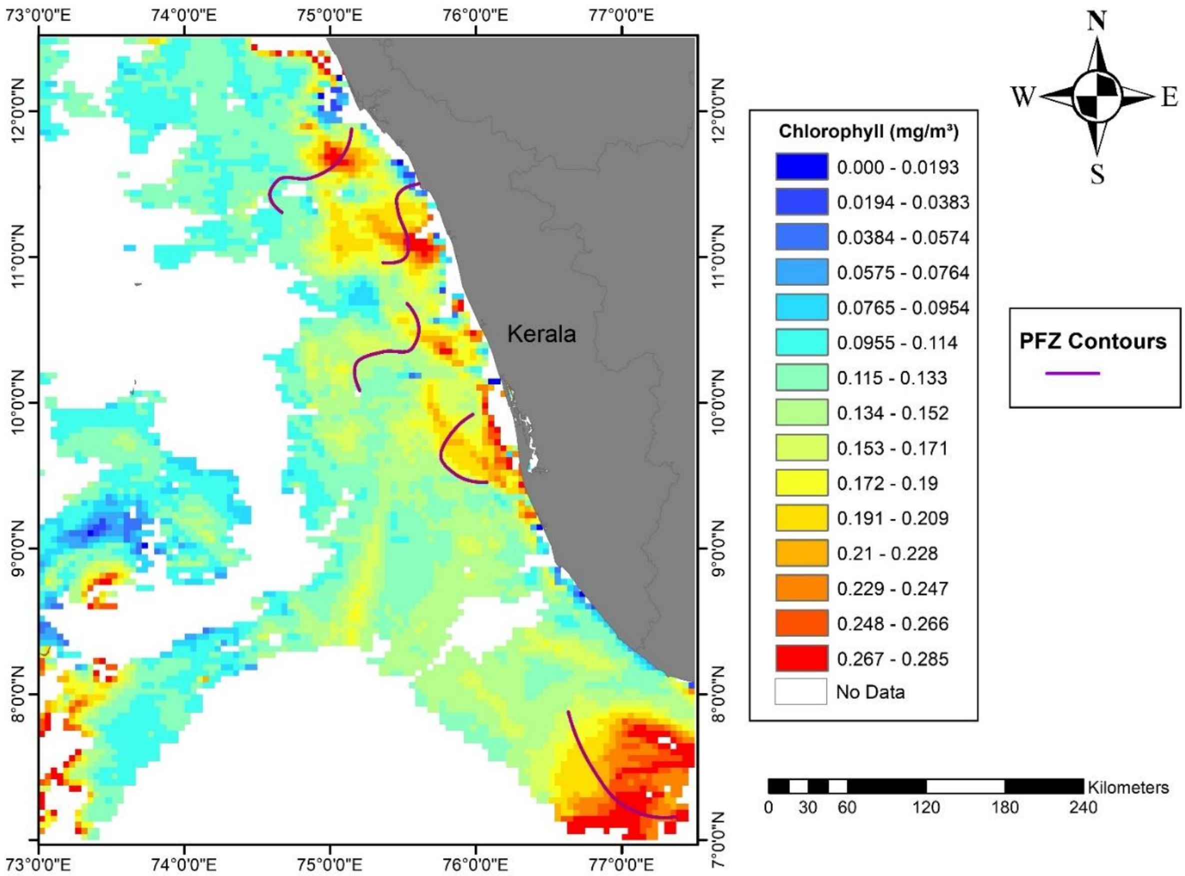

Figure 6. Extraction of PFZ contours on 24.01.2007 along the Kerala coast, India.

SSW using QuickSCAT data

To observe the sea surface wind (SSW) pattern, QuickSCAT data were used and plotted. The wind pattern represents the movement of the PFZ contours. Using the SSW direction, it can be identified where the PFZ contour will shift. If the fisher flock takes more time to reach the PFZ contour area, they can automate the operation according to the direction of wind was. The wind pattern of 24^{th} January 2007 (Figure 7) represents the higher wind speed at the South-eastern part of the study area and it moves to the Western area.

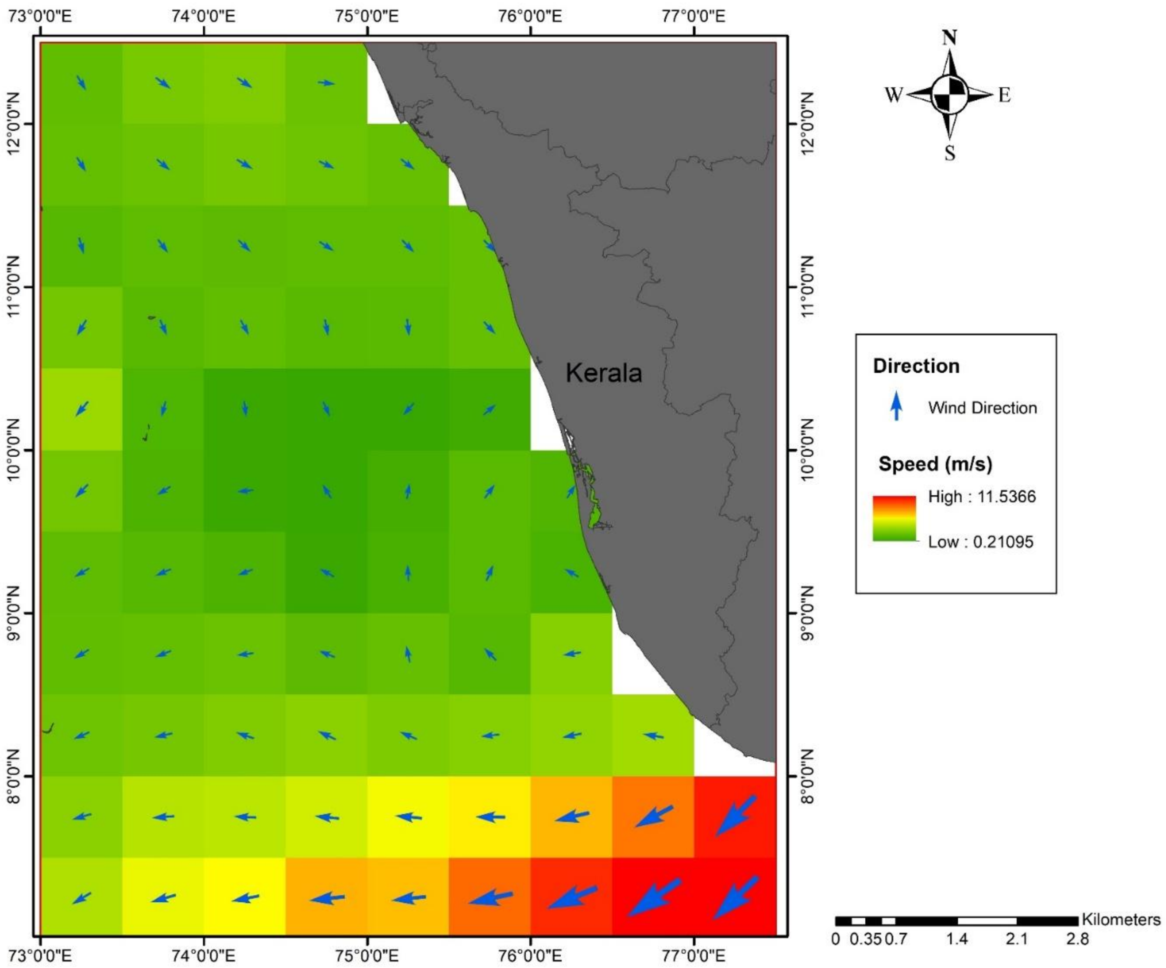

Figure 7. SSW using QuickSCAT data on 24.01.2007 along the Kerala coastal region, India.

For validation of the research results, catch data from a published paper were used. During the operation, two different fishing vessels with the same capacity and fishing gear were used. One was operated at the PFZ contour, another was at a non-PFZ area. It is recommended to catch fish in the middle of the contour. It was found that, in spite of being same capacity, the operation cost at the non-PFZ area was higher in relation to the PFZ area. However, the catch amount as well as the profit of the PFZ area was more than 4 times higher than that of the non-PFZ area. The quantitative result of the simultaneous fishing operations made using Figure 6 is given in Table 2:

Table 2. Quantitative result of the simultaneous fishing operations made using Figure 4, Date of fishing: 24.01.2007

Details (Experiment in Kerala)	**PFZ**	**Non-PFZ**
Name of the Boat	ER-26	ER-19
Type of Boat	Mech Ring Seine	Mech Ring Seine
Duration of total trip	11 Hrs	11 Hrs
Number of fishing hours	01	01
Number of sets	01	01
Number of Fisherman Engaged	37	35
Total catch (Kgs)	4100	850
Major Species Caught	Kera (Tuna)	Kera (Tuna)
Approximate cost of total catch(Rs) (@50 Rs/ Kg)	2,46,000	51,000
Total Expenditure in Operation (Rs)	1,28,960 (Fuel: 5,760) (Wage: 1,23,000)	30,740 (Fuel: 5,040) (Wage: 25,500)
Net Profit	1,17,040	20,260

Reference: Pillai VN et. al., 2007; Pillai and Nair., 2010

Discussion

The present study was conducted mainly depending upon two satellite-derived parameters, sea surface temperature and chlorophyll concentration, over the study area to identify a potential fishing zone. Same parameters were applied in previous study to detect PFZ (Nammalwar et al., 2013; Solanki et al., 2001). In their study, they also prepared maximum thermal gradient using those parameters and finally prepared relative thermal gradient. They also compared between the catch data of PFZ and non-PFZ area during validation and reached in a decision that is, the harvest variation is due to thermal gradient and chlorophyll concentration which is our research finding also. Solanki et al., 2015 used sea surface height anomaly (SSHa) for fish detection with the integration of satellite data and recommended that, negative SSHa with nutritionally rich water indicates higher primary production, which finally represents deep possibility of fish existence. In the study we identified that, fish species gather in highly primary production area due to food availability. At the South-eastern corner of the study area, we found highly chlorophyll concentrated area that is due to upwelling as well as highly nutrition bearing area. Same result was reported by Solanki et al., 2015 and they concluded that, fish school assemblage depends upon feeding ground and food availability. The harvest of PFZ notified area is approximately 5 times higher than the non-notified vessel harvest that is closely same to the study of Pillai and Nair, 2010. The continuous thermal and optical data from satellite sensor with the integration of sea surface height can assist to get more precise PFZ area.

Conclusion and Recommendations

Fishing from the PFZ identified area results in 2-4 times higher production in relation to the non-PFZ area, which can make a dramatic change in the economic status of the fisher flock. In this study, the higher chlorophyll concentration was found along the Kerala coastal region. In case of sea surface temperature, the temperature was high at the North-eastern side of the study area. PFZ contours were drawn considering chlorophyll concentration and sea surface temperature (SST), and it was recorded that most of the PFZ contour lies along the coastline in comparison to the deep sea. For SST, some higher temperature pockets were found over the study area; however, the real cause is still unknown. In some cases, a lower temperature area also contains a circular shape with high chlorophyll concentration, which could be a function of upwelling. Sea Surface Wind (SSW) controls the migration of PFZ contours, and it can be identified according to the direction of the wind. This research is highly beneficial to the local fisher community to harvest better catch per unit with less effort, time and fuel consumption as well. According to the output of the research, PFZ identification would good if we could get better resolution satellite data for chlorophyll and SST. In the future, it is proposed to help the fishermen go to the PFZ area hassle-free and using the shortest route. Also, a real-time PFZ map should be available to them with direct satellite connectivity.

Conflict of interest

There is no conflict of research interest.

Acknowledgements

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