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Potential Fishing Zones Persistence along Southern Tamil Nadu: A Case Study

L. Ranjith, L. Loveson Edward[1], C. Kalidas, D. Linga Prabu, A. Mathan Babu, [2]K. Karuppasamy and P.U. Zacharia[3]

Tuticorin Regional Station, ICAR-Central Marine Fisheries Research Institute, Thoothukudi-628 001, India
[1]Visakhapatnam Regional Centre, ICAR-Central Marine Fisheries Research Institute, Visakhapatnam -530 003, India
[2]TNJFU-Dr. MGR. Fisheries College and Research Institute, Ponneri, Tamil Nadu-601 204, India
[3]ICAR-Central Marine Fisheries Research Institute, Kochi-682 018, India
**E-mail: ranjith_bfsc@yahoo.co.in*

Abstract: Indian National Centre Ocean Information Services (INCOIS) develops potential fishing zones (PFZs) advisory maps for the coastal/marine fishing community using satellite technology to forecast fish shoal aggregation. Two hundred and sixty (260 nos) PFZ advisory maps for Southern Tamil Nadu between November 2015 and October 2017 were analysed to determine the possible persistence of the Spatio-temporal relationship with location and depth with PFZ hits. For ease of understanding, the region's fishing areas were divided into seven zones (one-degree grid) and further subdivided into 16 grids from Gopalapattinam of Pudukkottai to Neerodi of Kanyakumari waters, Tamil Nadu. The analyses indicate that the PFZ's area's persistence was more along Thoothukudi waters (Zone 4; 43.21%) and Kanyakumari (Zone 7; 28.43%), with 581 and 585 hits, respectively. The Chi-square test for goodness of fit (χ^2 = 1320.36) proved a significant difference among the total number of zone-wise hits. The results of bathymetry grid plotting hoped that a maximum number of PFZ hits were in the nearshore (<50 m; 41.5%), followed by the mid-continental shelf (50 to 200 m; 29.7%) and the continental slope (>200 m; 28.8%) regions. The total number of hits was more during the monsoon season (549 hits), followed by pre-monsoon (307 hits), post-monsoon (297 hits), and the least was during the summer season (92 hits). The Chi-square test for independence of attributes (χ^2 = 22.47) of season-wise and region-wise data also concludes that there is a significant association between region and season of occurrences of PFZ hits.

Keywords: Bathymetry, Gulf of Mannar, Geo-coordinates, Palk Bay, PFZ

The Indian marine fishery resources are open-access fishery harvested by diverse fishing gears and crafts. Therefore, managing the limited life below the water was difficult (Sathianandan 2013). Indian marine fish production exhibited different developmental stages and leaps to 3.56 mmt in 2019. Tamil Nadu leads the marine fish production (7.75 lakh tonnes) maritime states (CMFRI 2020), with a coastline of 1076 km scattered and 13 coastal districts. It comprises the Coromandel Coast (357 km), Palk Bay (294 km), Gulf of Mannar (365 km) and the West coast between Kanyakumari and Neerody (60 km). The State has a fisherman population of 1.05 million from 608 marine fishing villages, of which 0.20 million are engaged in fishing (CMFRI 2012). Given the fishermen's welfare and future developmental plans for increased production, several organizations are strengthening the fishing community's livelihood. Besides the decrease in coastal fishery resources, fishers are venturing into deep water, increasing the scouting time, which many fishing trips may not be economically feasible (Sinha et al 2017). However, marine fish stocks' wild fluctuations were significantly affected by the changes in ocean conditions and studying this will help the changes in ocean conditions. Analyzing this will formulate a suitable fishery management plan for marine resources (INCOIS 2020). Therefore, it is necessary to understand the oceanological and environmental parameters that influence fish stocks and their distribution. At this juncture, INCOIS develops PFZ advisory maps based on Sea Surface Temperature (SST) and Chlorophyll over the Arabian Sea and Bay of Bengal retrieved from thermal infrared channels of NOAA-AVHRR and optical bands in IRS-P4 OCM/MODIS Aqua data (MSSRF 2020). Various electronic and social communication modes were used to disseminate the PFZs information along the Indian coastline and Island regimes (INCOIS 2020). PFZ advisories were found most valuable to traditional, motorized. Small mechanized sector fishers engaged in pelagic fishing activities such as ring seining, gill netting, etc. The fishers utilized the advisory maps, which revealed that the maps significantly reduced the scouting time and fuel consumption and effort (Victor 2012). PFZ data has been validated by conducting fishing trips in PFZ and non-PFZ regions along with coastal areas of India (Nammalwar et al 2013, George et al 2014). The possible trends of PFZs based on the frequency of their occurrences

have been utilized by various authors, viz Kerala coast (Kripa et al 2014), Maharashtra coast (Kamei et al 2014); Goa coast (Sreekanth et al 2016); North Andhra Pradesh coast (Edward et al 2019, Edward et al 2020). Studies have been conducted on the northern Tamil Nadu coast (Nammalwar et al 2013); however, no studies have been undertaken along the Southern Tamil Nadu coast. Hence, the current research attempts to conclude possible trends of PFZs along the Southern Tamil Nadu coast and analyze the frequency of its occurrences based on depths to help the fishermen recognize the fishing zones quickly and carry out fishing economically along the regions.

MATERIAL AND METHODS

The PFZ advisories received via email for Southern Tamil Nadu, India, from INCOIS, Hyderabad, for two years, from November 2015 to October 2017, were collected and used to analyze its frequency occurrences. The study site area was Southern Tamil Nadu viz Gopalapattinam of Pudukkottai (Lat. 09°00' to 10°00' and Long. 79°00' to 79°45') to Neerodi of Kanyakumari waters (Lat. 07°00' to 08°00' and Long. 77°00' to 78°00'). Every 1 x 1-degree grid falling into this area and connected with the fishing area was named zones starting from 1 to 7 from top to bottom (Fig. 1a). Each 1 x 1-degree grid is further divided into 16 smaller grids, starting from A to P, top to bottom and left to right (Fig. 1b). Details of each zone are given in Table 1, and the respective base maps are shown in Figures 1 a & b. A base map of INCOIS advisories with zones and smaller grids was overlaid in the PFZ advisory chart, and the PFZ lines (Special Oceanic Processes, SOPs indicated as curved line marking on the advisory chart) coinciding with the grids were recorded. Each occurrence of PFZ lines in a grid was taken as a hit. The number of PFZ hits on each grid was recorded for two years and taken for further plotting. The data were analyzed depth-wise, viz., up to 50 m - Near Shore (NS), 50 to 200 m - Mid Continental Shelf (MCS) and above 200 m - Continental Slope (CS) and region-wise for the frequency of its occurrences. Likewise, the raw data was segregated season-wise, viz., March to May as summer, June to August as pre-monsoon, September to November as Monsoon and December to February as post-monsoon seasons, based on the climate of this area (Ranjith et al 2018). The number of PFZ hits on each grid was added season-wise and taken for further plotting. The PFZ hit data for depth, season, area, and rainfall were statistically analyzed with SPSS software (Version 16.0) for Pearson's Correlation, Chi-square test for goodness of fit and Chi-Square test for independence of attributes. Colour-based hit charts for different depth zones and seasons were prepared based on the number of hits in each grid (Very high: > 30, High: 21-30, Medium: 11-20, Low: 1-10) using open-source software QGIS (Version 2.4.0) by incorporating required depth contour lines (50 m and 200 m)

Table 1. PFZ hits zone and its subgrids and region-wise geocoordinates along Southern Tamil Nadu

Region	Zone		Position	Sub- grids
Rameswaram waters*	1	Lat Long	09°00' to 10°00' 79°00' to 79°45'	9
	2	Lat Long	09°00' to 09°45' 78°15' to 79°00'	5
Thoothukudi waters**	3	Lat Long	08°24' to 09°00' 79°00' to 79°26'	5
	4	Lat Long	08°00' to 09°00' 78°00' to 79°00'	16
Kanyakumari waters**	5	Lat Long	08°00' to 08°21' 77°00' to 78°00'	6
	6	Lat Long	07°00' to 08°00' 78°00' to 78°48'	13
	7	Lat Long	07°00' to 08°00' 77°00' to 78°00'	16

Overlapping coastal regions: *Pudukottai waters & **Tirunelveli waters

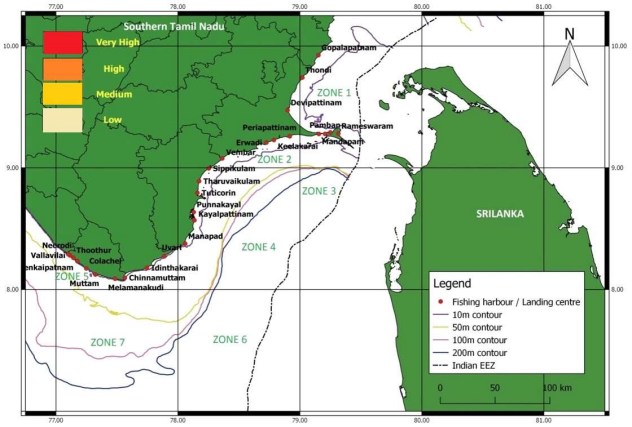

Fig. 1a. A base map of the Southern Tamil Nadu coast with different zones

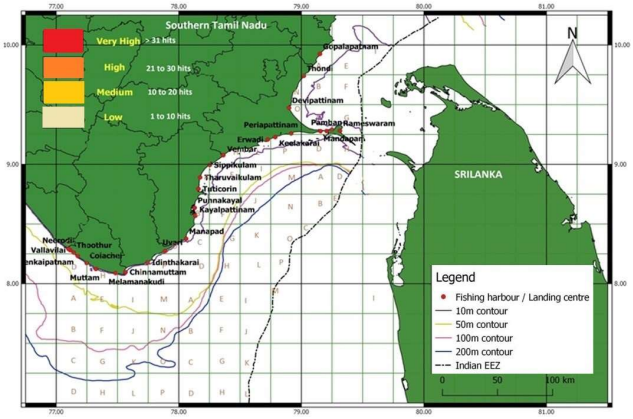

Fig. 1b. A base map of the Southern Tamil Nadu coast with different zones with sub-grids

in the study area. The monthly rainfall data for the study period were extracted from the Customized Rainfall Information System (CRIS) of the India Meteorological Department

RESULTS AND DISCUSSION

Zones and region wise: A detailed investigation of 260 PFZ advisory maps of Southern Tamil Nadu revealed their spatiotemporal relationship with geo-coordinates & depth and the persistence of the PFZ hits. The analyses indicate that PFZ hits (SOPs indicated as curved line marking on the advisory chart) were more between 8 to 9° N Latitude and 78 to 79° E Longitude of Thoothukudi waters, followed by between 7 to 8° N Latitude and 77 to 78° E Longitude of Kanyakumari waters. PFZ advisories were high from August to December (ranging between 12 to 18 nos per month), followed by January & February with 10 & 7 nos. PFZ hits were more between 8 to 9° N Latitude and 78 to 79° E Longitude of Thoothukudi waters, followed by between 7 to 8° N Latitude and 77 to 78° E Longitude of Kanyakumari. The trend is the same when we go through the number of grids with high and very high-frequency hits. Out of these zones, 3 and 4 come under Thoothukudi waters, and parts of Zones 5, 6 and 7 comes under Kanyakumari waters. Moreover, zone 1 and 2 comes under the Palk Bay waters. The PFZ hit data were plotted according to the different zones and smaller grids. Table 2 depicts the region/zone-wise number of PFZ hits and their percentage. The Chi-square test for goodness of fit ($\chi 2$ = 1320.36) also proved that there is a significant difference ($P<0.01$) among the total number of hits zone-wise, and it is not the same. As per Table 2, Zone 4 from Thoothukudi waters has the maximum number of PFZ hits (538), followed by Zone 7 (354) and 6 (196) from Kanyakumari waters. Kamei et al. (2014) opined that this might be due to the uniqueness of the particular zones' topographical locations.

Depth wise: The results of bathymetry grid plotting hoped that the maximum number of PFZ hits were in the nearshore (<50 m; 41.5%), followed by the mid-continental shelf (50 to 200 m; 29.7%) and the continental slope (>200 m; 28.8%) regions. When comparing the PFZ hit frequencies among different depth zones and regions (Table 3) nearshore (NS) area, which is less than 50 m depth, shows the maximum number of PFZ hits (517), which is about 41.5% of the total PFZ hits, followed by MCS (369) and CS (359) with 29.7 and 28.8% hits, respectively. The Chi-square test for independence of attributes (χ^2 = 123.15) of depth-wise and region-wise data also concludes that there is a significant association between a region and depth of occurrences of PFZ hits. From the colour-based hit chart (Figs. 2, 3 & 4), a definite trend in depth-wise PFZ hits has been depicted. Starting with more number hits along NS regions, there is a steady decrease in the frequency of hits as depth increases, leading to a reduction in hits' frequency. An earlier study along the southwest coast (Kripa et al 2014) found the NS region to be the most frequently occurring zone, followed by MCS and CS. The authors have described the effect of river flow and discharge in the NS regions on more PFZ than in outlying areas. But, Edward et al (2020) reported the higher PFZ hits in the north Andhra Pradesh coast's deeper waters and attributed the reasons to low saline pools and freshwater plumes away from the coast. The present study area's relatively high productivity may be due to river Thamirabarani down south and its influence on nearshore waters.

The region-wise analysis shows an increasing trend in PFZ hits frequency from Rameswaram to Kanyakumari waters (Table 3 and 4). The reason being during NEMS, the East India Coastal Current (EICC) in the western Bay of Bengal flows equatorward (from higher to lower latitudes), and the main flow turns around Sri Lanka and transports low saline waters into the Arabian Sea, which makes the Kanyakumari waters more productive (Mukherjee et al 2014). Rameswaram waters have the lowest (79) PFZ hits of the three regions studied, and the more productive area is Kanyakumari waters, with the highest number of PFZ hits (585), followed by Thoothukudi waters (581). In all three regions, nearshore waters are more productive when compared to MCS and CS. Season-wise analysis for all the respective areas also showed a similar cyclic pattern in the occurrence of PFZ during different seasons, with the lowest and peak during summer and monsoon, respectively.

Season wise: The total number of hits was more during monsoon season (37.1 %), followed by pre-monsoon (26.7 %), post-monsoon (26.1%), and the least was during the summer (10.1%) season (Figs. 5, 6, 7 & 8). The zone-wise PFZ hit data for different seasons are depicted in Table 4. The Chi-square test for independence of attributes (χ^2 = 22.47) of

Table 2. PFZ hits and their persistence in per cent contribution

Region	Zone	Hits*	% Hits
Rameswaram waters	1	57	4.58
	2	22	1.77
Thoothukudi waters	3	43	3.45
	4	538	43.21
Kanyakumari waters	5	35	2.81
	6	196	15.74
	7	354	28.43
Total		1245	100

*Chi-square test for goodness of fit, $\chi 2$ = 1320.36, significant – $P<0.01$

season-wise and region-wise data also concludes that it is a significant association between region and season of occurrences of PFZ hits. The plotting of PFZ advisories and lines revealed that the total number of hits was more during the monsoon season (549), followed by pre-monsoon (307), post-monsoon (297), and the least during the summer

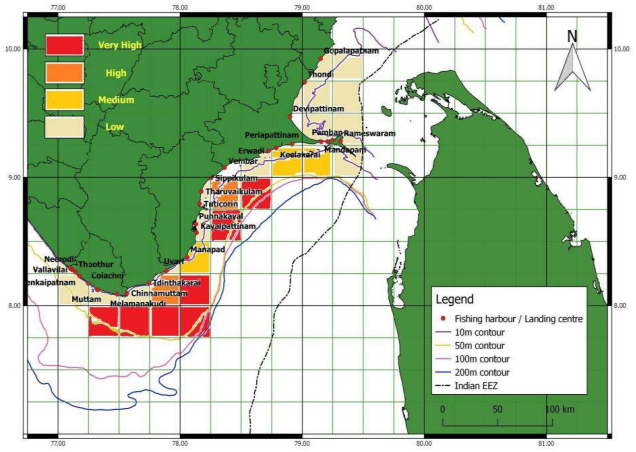

Fig. 2. Colour based hit chart for Near Shore (NS, <50 m) areas

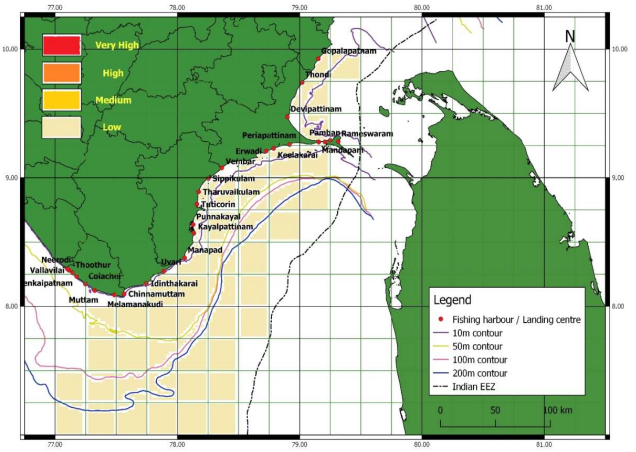

Fig. 5. Colour based hit chart for the summer season

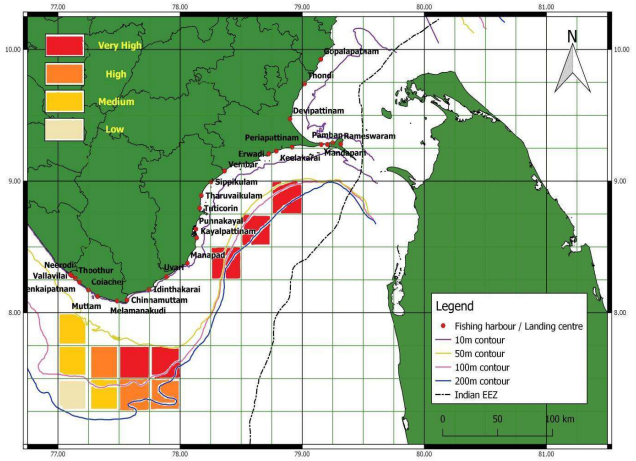

Fig. 3. Colour based hit chart for Mid Continental Shelf (MCS, 50-200 m)

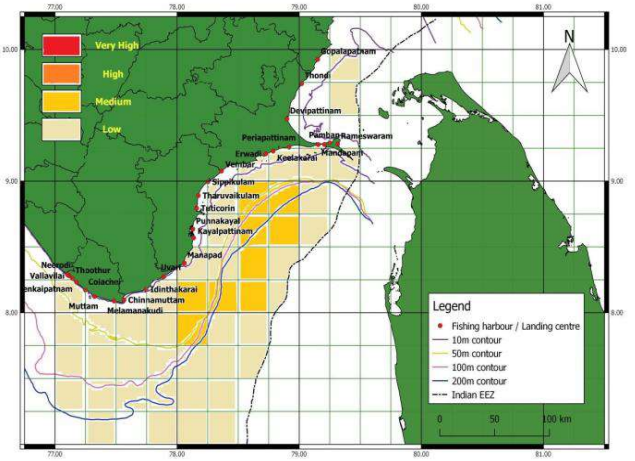

Fig. 6. Colour based hit chart for the pre-monsoon season

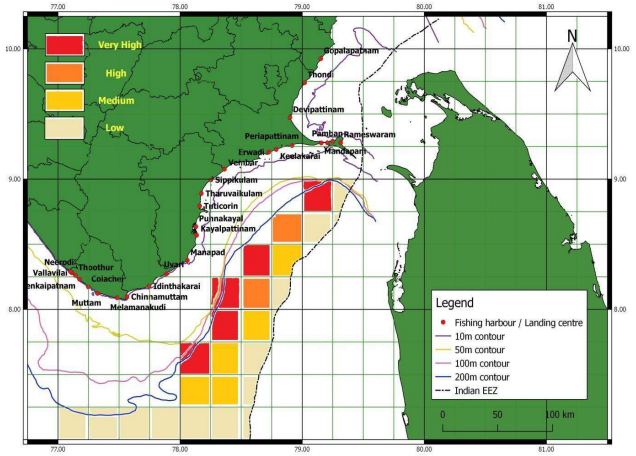

Fig. 4. Colour based hit chart for Continental Slope (CS, >200 m)

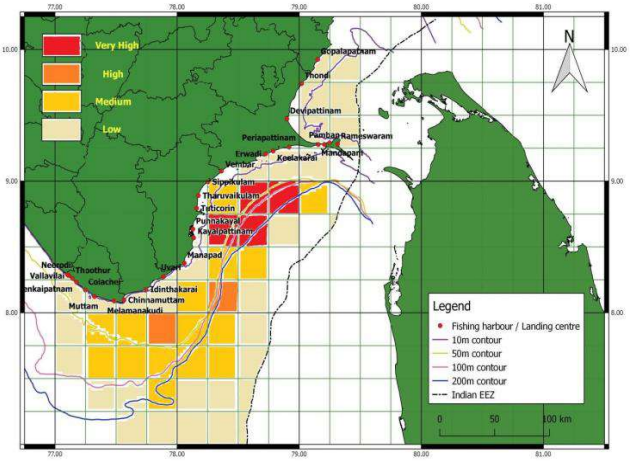

Fig. 7. Colour based hit chart for the monsoon season

Table 3. PFZ hits region-wise and depth-wise

Region	Depth zones*			Total
	< 50 m Nearshore	50 – 200 m Mid continental shelf	>200 m Continental slope	
Rameswaram waters	79	0	0	79
Thoothukudi waters	221	169	191	581
Kanyakumari waters	217	200	168	585
Total	517	369	359	1245

*Chi-square test for independence of attributes, $\chi 2 = 123.15$, significant – $P<0.01$

Table 4. PFZ hits region wise and season wise

Region	Seasons*				Total
	Summer	Pre-Monsoon	Monsoon	Post-Monsoon	
Rameswaram waters	9	14	33	23	79
Thoothukudi waters	35	166	269	111	581
Kanyakumari waters	48	127	247	163	585
Total	92	307	549	297	1245

*Chi-square test for independence of attributes, $\chi^2 = 22.47$, significant – $P<0.01$

season. The pattern of PFZ was cyclic during different seasons, with the lowest during summer followed by the increment in the number of hits during pre-monsoon and reaching a peak during Monsoon. Further, it decreases during post-monsoon, and the cycle of rotation continues. Pearson's Correlation (r = 0.97) also proved that there is a significant correlation between season-wise rainfall (mm) and PFZ hits in the study area (Fig. 9). This peak in the number of PFZ hits during monsoon may be due to the maximum rainfall in this season in the study area. Edward et al (2019) also observed a similar peak in monsoon seasons along the northern Andhra Pradesh coast due to the freshwater influx during Northeast Monsoon. Persistence in the PFZ's area was more along zone 4 of Thoothukudi waters due to the Thamirabarani River's discharge at Punnakayal estuary onset Northeast Monsoon (NEMS) creating more SOPs (Mukherjee et al 2014).

The data were analyzed region-wise, viz., Rameswaram waters, Thoothukudi waters, and Kanyakumari waters, for their frequency (Table 2). The region-wise analysis shows an increasing trend in PFZ hits' frequency as we move towards Kanyakumari waters. Rameswaram waters have the lowest (69) PFZ hits of the three regions studied. The relatively low productivity of nearshore waters may be due to the absence of significant rivers in the study area. Even though there is a river Thamirabarani south of the study area, its influence on nearshore waters is less. The present study area gets a considerable freshwater influx during the southwest monsoon. These offshore currents and low saline pools away from the coast support the present study for the occurrence of high-

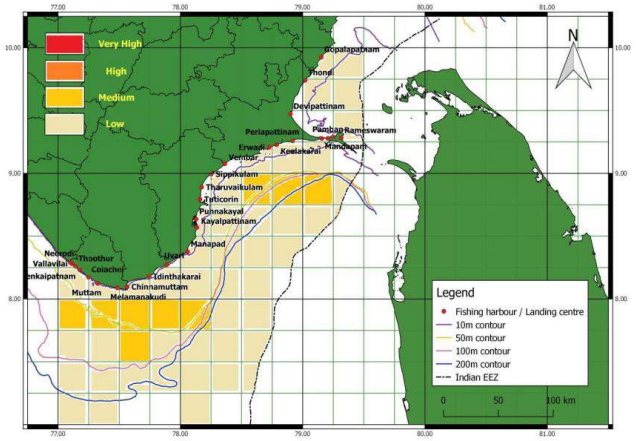

Fig. 8. Colour based hit chart for the post-monsoon season

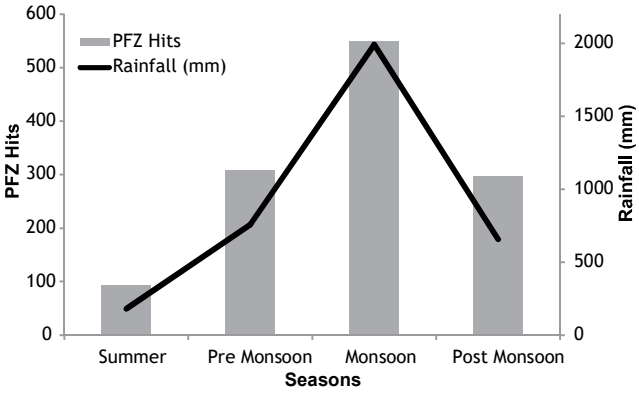

Fig. 9. Season wise rainfall (mm) and PFZ hits (r=0.97, significant, P<0.05)

frequency hit zones, mainly in the Mid Continental Shelf and Continental Slope depth zones. In the Andhra Pradesh Coast, Vinayachandran and Kurian (2007) confirm that freshwater plumes were located at a distance of 100 km away from the coast, supporting the similar occurrence of PFZ hits. Kripa et al (2014) state that relatively high river discharges in the area and high nutrient content in the releases because of high mangrove afforestation are likely causes of the persistent occurrence of PFZs in the Southeastern Arabian Sea of Kerala.

CONCLUSION

The present study reveals that the river Thamirabarani favours higher productivity in nearshore waters than in deeper areas. Season-wise and depth-wise analysis in the PFZ hits occurrence pattern was more in the coastal waters for all the regions. Thus, INCOIS, the remotely sensed data on PFZ advisories, is a helpful tool for enhancing fishermen's fish catch. The PFZ hits validation information provides baseline data for correlating the PFZs with marine fishery resources.

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