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Potential fishing zone (PFZ) advisories-Are they beneficial to the coastal fisherfolk? A case study along Kerala coast, South India

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ABSTRACT : Intensive validation of Potential Fishing Zone (PFZ)advisories generated by the Indian National Centre for Ocean Information services(INCOIS) along the Kerala coast during the period 2006-2010 revealed a positive relationship between PFZ and occurrence/abundance of commercially important pelagic fishes. The usefulness of PFZ advisories for artisanal, motorized and small mechanized sector fishermen towards obtaining comparatively higher catch per unit effort for the major pelagics and thereby improving the economics of fishing operations is highlighted. Analysis of catch data from active fisherfolk and controlled experiments undertaken within and outside notified areas simultaneously showed that catch per unit effort (CPUE) was more in notified areas compared to un notified areas. The extra quantity of fish caught in notified areas is about 2 to 6 times The percentage of extra monetary benefit obtained in notified areas is about 2 to 7 times.

Keywords : Occurrence/abundance major pelagics, Kerala, satellite based PFZ advisory, validation.

INTRODUCTION

The aim of the present study is to establish, beyond doubt, the usefulness of PFZ advisories to the coastal fisherfolk along Kerala coast by way of working out the economics of operation of Ring seiners by employing identical vessels operating more or less identical fishing gear simultaneously within and outside notified areas (PFZ) through controlled experiments.

The usefulness of PFZ advisories for locating pelagic fish concentrations along Kerala coast was initiated jointly by Scientists of CMFRI, FSI and SAC as early as 1981 (Gopalan and Silas, 1985). Subsequently the usefulness of the technology for locating pelagic fish concentration along Kerala coast was established based on validation attempted since 1996 (Pillai *et.al.,* 1996, 1997, 1998, 2000, 2006, 2007)

BACKGROUND

In India, in the last few decades, fisheries research together with the technological advancement in the harvest and post-harvest scenario accelerated the process of transformation of a subsistence oriented traditional sector marine fisheries into a market oriented multi crore industrial sector activity with considerable strength and capabilities in essential infrastructures. With the result, the marine fish production has made great leaps through successive stages and the yield reached around 3.21 million metric tonnes by the year 2008.

Although the achievements were tremendous, gradually this common property was stressed and led to overharvest of at least a few easily vulnerable and target species and degradation of some of the fish habitats perhaps even to the extent of denudation by the unbridled human greed. The situation is closely similar to the global marine fisheries scenario wherein 70% of the fish stocks (mostly demersal and crustaceans) are either fully exploited, over fished, depleted or slowly recovering. Of late the emphasis is shifting from increasing production from coastal fisheries to sustaining the resource base.

Kerala state with a coast line of 590km ranks first for marine fish production in India, contributing more than 6 lakhs metric tonnes to the total annual production of 32 lakhs metric tonnes. The export of marine products from the State earns valuable foreign exchange besides affording innumerable job opportunities in the industry. The human population depending on fisheries has steadily increased over the years and reached at 602234 in 2005 (Anon, 2005). Kerala has been in the forefront of absorbing innovative and new technologies in fishing practices, which have led the marine fisheries sector to take a complex structure. The 1980s was an important period in the development of marine fisheries in Kerala. In the first half of the period the motorized sector grew rapidly and became the most important sector yielding maximum catch in 1988. By that time, ring seine became very popular in exploiting the pelagic resources and replaced the boat seines to a large extent. Huge size of the new net (450 to1000 m long) and large number of crew (30 to 50) needed for its operation necessitated larger boats with powerful outboard engines (3 outboard engines of 40hp each). This facilitated extension of fishing grounds for the motorized sector. The fishing grounds covered by the mechanized sector also got extended by increasing the boat size, fishing effort and efficiency through multi-day fishing during the late 90's.

During 2001-2008, the total marine fish production from Kerala varied from 5.14 lakh tonnes (2001) to 6.70 lakh tonnes (2008), with an annual average landings of 5.98 lakh tonnes (Srinath, 2005; CMFRI 2009). According to the CMFRI census 2005, it is estimated that there are 29,177 marine fishing craft in Kerala, of which 14,151 (49%) and 5,504 (19%) craft belong to the motorized and mechanized sector respectively and 9,522 (32%) constitute the traditional sector. The landings are mainly contributed by the mechanized (56%) and motorized (42%) sectors. In the mechanized/ motorized sector ring seine is the major contributor to the landings (3.04 lakh tonnes in 2008) followed by trawls (1.57 lakh tonnes in 2008). Other gears deployed by the fishermen included the gill nets, hooks and line, boat seine sand purse seines. Around 800 species of marine fishes are landed along the Kerala coast of which about 200 are commercially important and are classified as pelagics, demersals, crustaceans and cephalopods. The major pelagic resources include the oil sardine, lesser sardines, anchovies, mackerel, tunas, ribbon. fishes and carangids. The major demersal fish resources include sharks, rays, threadfin breams, lizardfishes, sciaenids and soles. Penaeid and non penaeid prawns, crabs, stomatopods and lobsters constitute crustacean resources while squids, cuttlefishes and octopus contribute the cephalopod landings. Pelagic groups dominate the landings forming 71% followed by demersals (14%), crustaceans (9%) and cephalopods (6%) (CMFRI, 2009). In the mechanized/ motorized sector, Ring seiners contributed 51% of the total landings dominated by Oil sardine, Mackerel and small Carangids (CMFRI, 2009).

In Seventies and eighties witnessed a sharp decline in marine fish production on the one hand and a sharp increase in fishing in puts and efforts on the otherhand. The subsequent increase in fishing pressure naturally led to over exploitation of fishery resources especially in the inshore waters where the different groups in the fishing sector engaged in cutthroat competition.

The traditional sector which dominated till 1983 declined fast and in 1986 its contribution to the total fish catch was only 4%. On the other hand the mechanized sector grew rapidly with a contribution of 46% in 1986, The recently originated motorised sector eclipsed the other two sectors and dominated the marine fishing scenario of Kerala since 1988 with a contribution of 51% to the total.

Considering the diversity of the fishery resources in these waters, suitable fishing gera for seasonal operation have been developed and utilized by the artisanal fishermen of Kerala. They are generally ecofriendly causing little or damage to the ecosystem. Subsequently the introduction of modern fishing technology such as Trawling and Purse seining – which have comparatively high catching power took over the share of artiasanal gears having higher catching efficiency and more suitable to the local conditions. Simultaneously, the introduction of outboard motors (OBMs) in the early eighties enhanced the fishing capabilities of the artisanal group. During this process some craft and gear which showed poor performance disappeared while others were modified and new ones created.

In the central region (Kollam to Chavakkad) the plank built canoe, which contributed the principal type of craft, the size has been gradually increased to nearly double to its original size due to change in the region of propulsion from manpower to OBM. The single boat "Thanguvala" was modified in to "Ring seine", a surrounding (encircling) gear.

In the northern region (Ponnani to Kasargod) the popular dug out Canoe was slightly modified to hold the OBM. The replacement "Kollivala" with "Ring seine" was one of the important impacts of motorization. During the motorization process, the Ring seine has made tremendous impact on other artisanal fishing gear and also brought changes in the fish production pattern along the belt. Motorisation enabled the transformation of boat seining into surrounding (encircling) method of Ring seining.

Based on the craft used and targeted fish the following types of Ring seines have emerged:

Craft wise	Targeted fish wise
Plank built Canoe Ringseine (Single boat or double boat types)	for Sardine- Ring vala for Anchovy- Choodavala
Dug out Canoe ring seine (with 4 dug out canoes with maximum of 7 canoes during bulk landings)	for Sardine- Rani vala for Anchovy- Mandu vala

The development of a variety of Ring seines as mentioned above operated by a single boat/2 boats/4 boats up to a maximum of 7 boats substantiate the innovation of artisanal fisherfolk along these lines.

Ring seines are broadly classified into 2 categories viz.

1. Thanguvala (medium size – 400 m × 60 m with mesh size 20 mm). Large size 800 to 1700 m with mesh size of 22 mm targeted at Sardine, Mackerel etc.
2. Chooda vala or disco vala (250 to 500 m/ 45-75 m with mesh size of 8-10 mm targeted at Anchovies.

The sharing of the pelagic and demersal common property fishery resources of the continental shelf waters has created, in the recent past, considerable tensions, law and order conflicts among various fishing communities in the coastal belt. The emergence of a scientifically informed governance system in the marine fisheries sector is a welcome sign. There is need to find a solution for the sustainable long-term economic utilization of these resources by maintaining the exploited fish stocks through proper regulatory measures. Possibilities of bringing down the searching time for pelagic shoaling fishes, which constitute more than 70% of the total fish landings, assume great significance since this factor can bring down the cost of fishing operations by way of savings on valuable fuel oil and human effort.

It is well known that the adaptation of fish to the surrounding marine environment is controlled by various physico-chemical and biological factors. Fishes are known to react to changes in the surrounding environmental conditions and migrate to areas where favourable environmental conditions in terms of seawater temperature, salinity, dissolved oxygen level etc., exist. The availability of food is an important factor that controls their occurrence, abundance and migrations in the sea. Sea Surface Temperature (SST) is the most easily observed environmental parameter and is quite often correlated with the availability of fish, especially pelagic fish. Changes in SST can result from changes occurring in the direction/ velocity of both horizontal and vertical circulation process in the sea. Many pelagic species are known to concentrate at current boundaries especially in areas with sharp horizontal temperature gradients. Monitoring the above mentioned parameters in space and time is time consuming and prohibitively expensive and a real time picture of any one of these parameters or a combination of the above becomes almost impossible. Indirect methods of monitoring selected parameters such as SST and phytoplankton pigments (Chlorophyll-a) at sea surface from satellites is found very ideal as it provides high repetivity and large spatial coverage.

The ocean fronts play a key role in the form of biogeographical boundaries. Very often distinct biotopes are separated by fronts attracting fishes into these areas. Many pelagics are known to concentrate at current boundaries especially in areas with sharp horizontal temperature gradients. Physical changes resulting out of changes resulting out of changes in sea water temperature, currents and coastal upwelling influence ocean productivity and distribution of species.

The use of satellite capabilities in fisheries research was studied by Laskar *et.al.,* (1981), Laurs *et.al.,* (1984) and others. Breaker (1982) used Advanced Very High Resolution Radiometer (AVHRR) and Coastal Zone colour Seanner (CZCS) data to demonstrate the role of oceanic fronts in the habitat and migration of albacore tuna, Arnone (1987) used CZCS and AVHRR data to understand the relationship between chlorophyll-a and SST. Mayors and Hick (1990) applied satellite derived SST data in realtime for the exploration of fishery resources in Australian waters.

In India, the Ministry of Earth Sciences, Govt.of India (erstwhile Department of ocean Development), Department of Space and several institutions under the Ministry of Agriculture persued an endeavor for over two decades jointly with the Maritime State Governments to provide Potential fishing Zone (PFZ) advisories to the Indian fishing community using SST data. Several experiments were conducted by Space Application Centre (SAC) (Dwivedi *et.al.,* 1988) and National Remote Sensing Centre (NRSC) erstwhile NRSA (Nath *et.al.,* 1991) which proved that SST data can be utilized for the preparation of PFZ advisories. Chlorophyll-a data and NOAA-AVHRR derived SST data were integrated and utilized for fishery resources exploration (Solanki *et.al.,* 2001 a and b). Exclusive validations were also conducted during late 1990s and early 2000 jointly by

Space Application Centre (SAC), Fishery Survey of India (FSI) and Central Marine Fisheries Research Institute (CMFRI) around the Indian coast.

In India, the efforts of oceanographers, Remote Sensing specialists and Fishery Scientists, resulted in a unique service called Potential Fishing Zone (PFZ) advisory. The PFZ forecast is issued thrice a week by the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad functioning under the Ministry of Earth Sciences, Govt. of India except during the fishing ban period and on cloudy days to around 200 active nodes spread around the entire coast line by FAX/Telephone messages and through Electronic Digital Display Boards installed at selected fish landing centres.The validity of the individual forecast is for a maximum of 3 days. This is the only short term marine fishery forecast available in the country for the benefit of small mechanized/ motorized sector fisherfolk working onboard a total of around 1,00,000 fishing vessels. The effort is part of the Common Minimum Programme (CMP), lead by the Govt. of India. The entire Indian coast is divided into 12 sectors inorder to generate the PFZ maps viz, Gujarat, Maharashtra, Karnataka and Goa, Kerala, South Tamil Nadu, North Tamil nadu, South AP, North AP, Orissa and West Bangal, Lakshdweep islands, Andaman and Nicobar Islands. The PFZ maps certain information on major landing centres in each sector, bathymetry, latitude and longitude in addition to identified features of individual PFZ viz.latitude, longitude, depth, direction and distances from each landing centre. These integrated PFZ advisories are prepared in English, Hindi and other local languages. The total number of users as on today is approximately around 30,000 which is about 30% of boat owners.

Continuous validation of PFZ forecasts is being undertaken along the entire Indian coast. Concurrent and quantitative feedback on the total fish catch (species wise)is obtained within and outside notified areas by undertaking simultaneous controlled experiments engaging more or less identical commercial fishing vessels employing more or less identical fishing gear.

MATERIAL AND METHODS

During the period under report (January, 2006-March, 2010) Potential Fishing Zone advisories released by INCOIS thrice a week during periods when there is less cloud cover (mainly between September and May) were disseminated to active fishermen groups along Kerala coast between Kollam in the south and Kannur in the north depending on the exact location of PFZ by personal contact, fax/ telephonic messages and information transferred through Electronic Digital Display Boards installed at five major fish landing centres viz Beypore, Munambam, Vypeen, Srayikkad and Neendakara. The feed back data was gathered in the prescribed format immediately on arrival of the vessel at the landing centre on completion of fishing activity.

A total of 165 PFZ advisories released by INCOIS were validated between January, 2006 and March, 2010 along Kerala Coast. Fishing data was gathered from a total of 450 Ring seiners, 300 Gill netters and 50 Bottom Trawlers. A total of 1240 Datasets (generated by these vessels) were utilized in the present study.

The quality (species –wise identification) as well as quantity (approximate) of fish catch is also reconfirmed by the enumerator on the spot (out at sea) when the enumerator who is invariably drawn from the fishermen community visits the area of fishing activity onboard a hired vessel or at the landing centre. The consolidation of the data gathered from different landing centres is undertaken every month and average CPUE for different types of operations calculated.

Necessary steps were always taken to ensure that the information transferred through individual advisory reaches active fishermen groups at the location within the minimum possible time. With the replacement of five numbers of old Electronic Digital Display Boards, with new ones and with the addition of another 5 new Electronic Digital Display Boards the quickness of forecast transmission is likely to improve further along the Kerala coast.

PFZ advisories brought out by INCOIS during the period under report were disseminated and validated through selected number of artisanal/motorized/ small mechanized sector fishing vessels based at Neendakara, Sakthikulangara, Thottappally, Ambalapuzha, Puarakkad, Alappuzha, Sherthala, Manakkodam, FortKochi, Vypeen, Munambam, Azhikkode, Nattika, Ponnani, Beypore, Puthiappa, Koylandi, Badagara, Mahe, Thalassery and Kannur landing centres depending on the location of individual PFZ.

A total of 55 controlled experiments were conducted by hiring more or less identical commercial fishing vessels (ring seiners) to obtain concurrent and quantitative feedback on the total fish catch (species wise) within and outside notified areas (PFZ). A representative drawn from the local fishermen community is also sent on board the hired vessel to obtain correct information pertaining to fishing activity.

The period from June to October (cloudy months) was also utilized for educating the fishermen groups on the usefulness of the technology by way of organizing/ participating in awareness campaigns arranged among active fishermen groups at major fishing harbours/landing centers.

Collection of simultaneous hydrographic data from the area where more or less identical hired fishing vessels were operated within and outside notified area, was undertaken onboard a 62’OAL Purse seiner since January, 2009 for attempting possible correlation with availability/ abundance of different species in space and time.

RESULTS AND DISCUSSION

PFZ advisories generated from satellite retrieved SST and Chlorophyll were found to be good indicators of the availability/abundance of pelagic fishes such as sardines, mackerel, anchovies, tunas and carangids. These advisories are found beneficial to artisanal, motorized and small mechanized sector fishermen engaged in pelagic fishing activities such as ring seining, purse seining, gill netting etc. for locating concentrations of these highly migratory pelagic species, there by reducing the searching time which inturn resulted in the saving of valuable fuel oil and also human effort. In view of the likely concentration of pelagic shoals in thermal boundaries and areas of phyto/zoo plankton abundance, the fishing undertaken in Potential Fishing Zones provide comparatively higher catch per unit effort.

Out of total of 55 controlled experiments conducted engaging more or less same size/BHP Ring seiners, employing more or less identical fishing gear, 13 yeilded Oil sardine (Sardinella longiceps), 15 Mackerel (Rastrelliger kanagurta), 13 Carangids, 3 yellow fin Tuna (Thunnus albacares-Young ones locally called “Kera”, 3 Coastal Tuna, 2 Anchovies (Stolephorus spp) one each Cuttle fish (Sepia pharaonis) and Poovalan shrimp (Metapenaeus dobsoni).

Average catch per unit effort within and outside PFZ has been worked out for individual species and presented in Table 1, Fig. 1.

Table 1 : Average CPUE-2006-2010.

S.No.	Major sps caught	No.of expts	within PFZ	outside PFZ
1	*S. longiceps*	13	3284.61	555.76
2	*R. kanagurta*	15	2426.86	537.33
3	*T. albacares*	3	2833.33	566.66
4	*A. rochei*	4	3300	870
5	*K. pelamis*	3	1133.33	350
6	*S. commerssoni*	2	1375	237.5
7	*A. djedaba*	2	4450	1075
8	*M.cordyla*	6	2800	500
9	*D. russelli*	4	2856.25	461.25
10	*F. niger*	1	2200	375
11	*M. dobsoni*	1	2500	450
12	*S. pharaonis*	1	1350	700

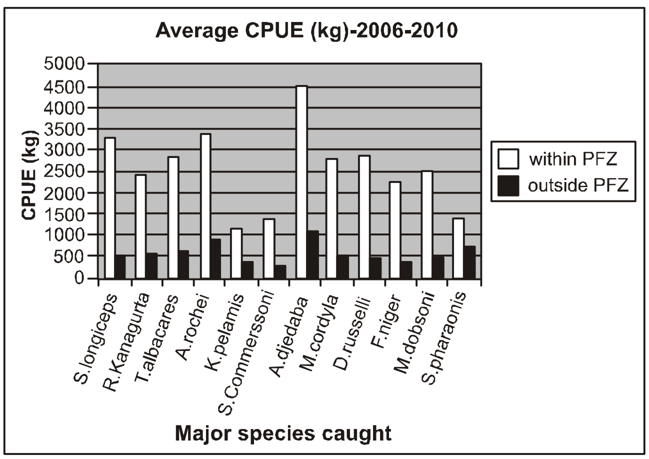

Fig. 1.

Table 2 : Value realization, 2006-2010.

S.No.	Major sps caught	No.of expts	within PFZ	outside PFZ
1	*S. longiceps*	13	73076.92	12834
2	*R. kanagurta*	15	213890	29376.67
3	*T. albacares*	3	165333.3	33666.67
4	*A. rochei*	4	128000	37600
5	*K. pelamis*	3	56666.6	17500
6	*S. commerssoni*	2	69000	11000
7	*A. djedaba*	2	218250	52875
8	*M. cordyla*	6	103416.7	19554.17
9	*D. russelli*	4	142812.5	23062.5
10	*F. niger*	1	110000	18750
11	*M. dobsoni*	1	250000	67500
12	*S. pharaonis*	1	11450	6042

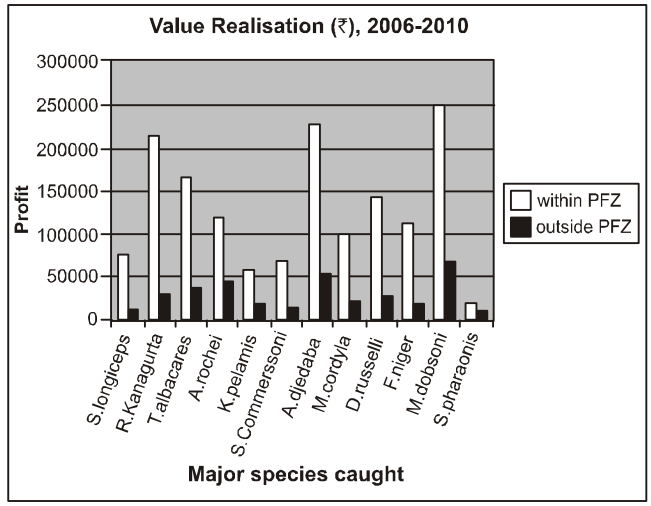

Fig. 2.

Table 3 : Sharing by owner of vessel, 2006-2010.

S.No.	Major sps caught	No.of expts	within PFZ	outside PFZ
1	*S. longiceps*	13	44894.31	4412.923
2	*R. kanagurta*	15	69543.66	13711.53
3	*T. albacares*	3	78146.66	12886.67
4	*A. rochei*	4	60606	15419.75
5	*K. pelamis*	3	24860	6042.667
6	*S. commerssoni*	2	31637.51	2637.5
7	*A. djedaba*	2	1429925	41692.5
8	*M. cordyla*	6	55644.16	6298.83
9	*D. russelli*	4	82025	8055.5
10	*F. niger*	1	88541	5725
11	*M. dobsoni*	1	121350	42616
12	*S. pharaonis*	1	6442	2866

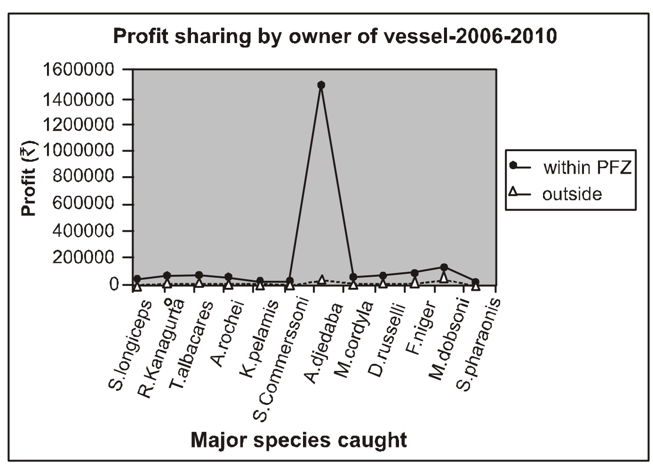

Fig. 3.

Table 4: Quantitaive Results of the simultaneous fishing operations made using Fig.4.

Date of fishing: March 22, 2007

Details (Experiment in Kerala)	**PFZ**	**Non PFZ**
Name of the Boat	MRR-II	ER-27
Type of Boat	Mech. Ring Seine	Mech. Ring Seine
Duration of Total Trip	5 HI's	5 Hrs
Number of fishing hours	01	01
Number of sets:	01	01
Number of Fishermen Engaged	30	32
Total Catch (Kgs)	1800	700
Major Species Caught	Indian Mackerel	Indian Mackerel
Approximate cost of total catch (Rs) (@ 45 Rs /Kg)	81,000	31,500
Total Expenditure in Fishing Operation (Rs)	46,100 (Fuel: 5, 040) (Wage:40,500)	21,700 (Fuel:5,400) (Wage: 15,750)
Net Profit	34,900	9,800

Source: V.N. Pillai *et. al.,* 2007

Table 5 : Quantitaive Results of the simultaneous fishing operations made using Fig. 5.

Date of fishing: March 16, 2006

Details (Experiment in Kerala)	**PFZ**	**Non PFZ**
Name of the Boat	MRR-8	ER-10
Type of Boat	Mech. Ring Seine	Mech. Ring Seine
Duration of Total Trip	9 Hrs 30 Min	7 Hrs 15 Min
Number of fishing hours	01	01
Number of sets:	01	01
Number of Fishermen Engaged	37	36
Total Catch (Kgs)	7200	1800
Major Species Caught	Carangids	Carangids
Approximate cost of total catch (Rs) (@ 50 Rs/Kg)	81,000	90,000
Total Expenditure in Fishing Operation (Rs)	77,600 (Fuel: 5, 400) (Wage:72,000)	21, 440 (Fuel:3,240) (Wage: 9, 000)
Net Profit	2,82,400	68,560

Source: V.N. Pillai *et. al.,* 2007

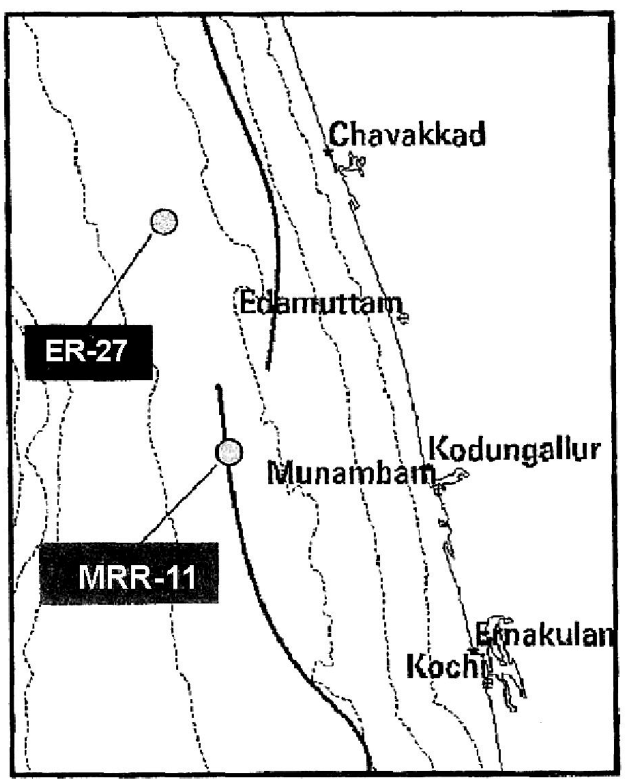

Fig. 4. SST based PFZ Forecast issued on March 21, 2007.

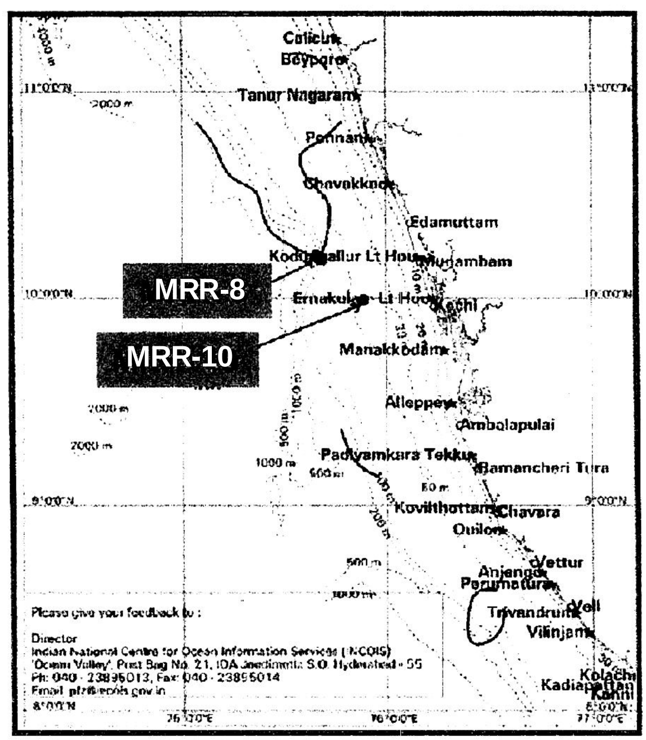

Fig. 5. SST based PFZ Forecast issued on March 21, 2007.

Table 6 : Quantitaive Results of the simultaneous fishing operations made using Fig. 6.

Date of fishing: January 24, 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 Fishermen Engaged	37	35
Total Catch (Kgs)	4100	850
Major Species Caught	Kera	Kera
Approximate cost of total catch (Rs) (@ 50 Rs/Kg)	2,46,000	51,000
Total Expenditure in Fishing 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

Source: V.N. Pillai *et. al.,* 2007

Table 7 : Quantitaive Results of the simultaneous fishing operations made using Fig. 7.

Date of fishing: February 24, 2007

Details (Experiment in Kerala)	PFZ	Non PFZ
Name of the Boat	ER-19	ER-26
Type of Boat	Mech. Ring Seine	Mech. Ring Seine
Duration of Total Trip	10 Hrs	10 Hrs
Number of fishing hours	01	01
Number of sets:	01	01
Number of Fishermen Engaged	33	30
Total Catch (Kgs)	3800	700
Major Species Caught	Kera	Kera
Approximate cost of total catch (Rs) (@ 50 Rs/Kg)	1,90,000	35,000
Total Expenditure in Fishing Operation (Rs)	99,820 (Fuel: 4320) (Wage: 95,000)	23,040 (Fuel: 5,040) (Wage: 17,500)
Net Profit	90,180	11,960

Source: V.N. Pillai *et. al.,* 2007

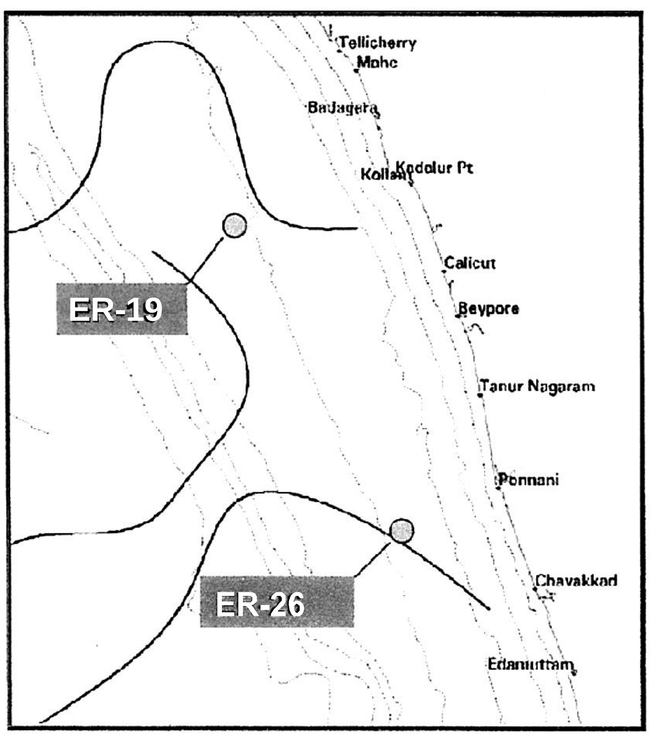

Fig. 6. SST based PFZ Forecast issued on January 22, 2007.

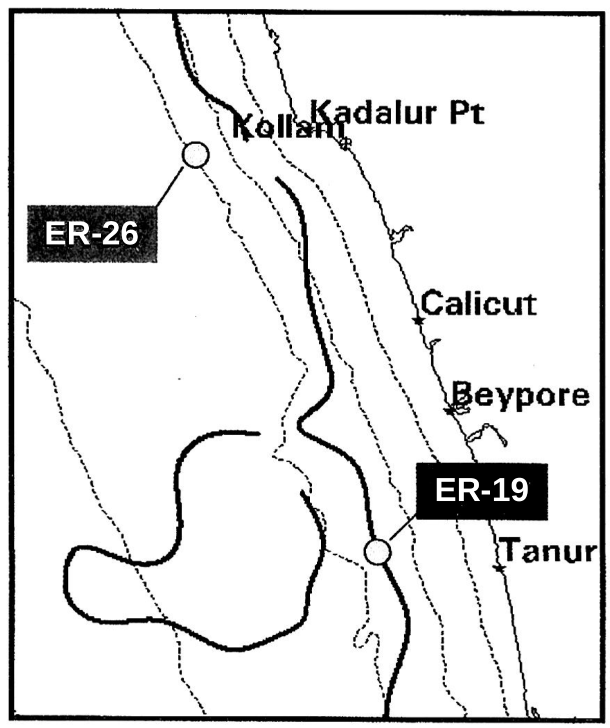

Fig. 7. SST based PFZ Forecast issued on January 22, 2007.

On an average the CPUE obtained within PFZ was invariably many times (2 to 6 times) the CPUE obtained out side PFZ (Fig. 4, 5, 6, 7 and Table 4, 5, 6, 7) Average value realization within PFZ was 2 to 7 times more than that obtained outside PFZ (Table 2., Fig. 2.)

Average profit shared by the owner of the vessel within PFZ was 2 to 10 times more than that obtained outside PFZ (Table 3, Fig. 3).

Positive relationships between PFZ resulting out of comparatively high gradients of SST/Chlorophyll and fishable concentrations of commercially important fishes was found only in respect of pelagic and column fishing activities such as purse seining, ring seining gillnetting and trolling activities. In the case of bottom trawling activity the relationship was found to be negligible except in the case of pelagics, which undertake diurnal vertical migration (eg. Mackerel, Horse mackerel).

SST based advisories are found more advantageous for locating mackerel, tuna, anchovies and carangids whereas Chlorophyll based advisories are found more advantageous for locating matured oilsardine and lesser sardine shoals which are herbivorous in feeding habits with feeding preference for phytoplankton. Comparison of reduction in searching time for oil sardine obtained for PFZ fore casts originating out of SST imageries and Chlorophyll imageries revealed the advantage of the latter for locating oil sardine shoals.

The study revealed that the reduction in searching time as well as CPUE reported for pelagic shoaling fishes is mainly dependent on the following factors.

(*a*) The time lag between satellite data acquisition/ dissemination of PFZ advisory to the end user and the fishing activity in view of the fact that the characteristics of the thermal front as well as the surface Chlorophyll concentration are likely to get dissipated through horizontal/vertical circulation processes active in the area and also consumption at different trophic levels.

(*b*) The fishing methods adopted viz. gill netting, ring seining, purse seining and trolling and the time at which the fishing activity is undertaken

(*c*) Type of fish targeted. The top/bottom depth of the thermocline is a major factor controlling the effectiveness of operation of purse seines and ring seines. Unless the fishing gear has a vertical hanging, which extends beyond the depth of the thermocline, depending on the time of activity, a certain percentage of the fish shoal is likely to escape through the bottom before the gear is pursed.

Catchability and in turn CPUE in Purse seining as well as Ring seining is comparatively high when fishing operations are conducted during early morning and late evening hours in view of the fact that metabolic activity is comparatively low among pelagics during dawn and dusk. Metabolic activity increased by noon with increasing sea water temperature. Success of gill netting is found to be comparatively high during night time when the gear is released after sunset and hauled in before sunrise especially during the new moon phase.

Catchability and in turn CPUE in Purse seining as well as Ring seining is comparatively low at times when shoals are sighted at subsurface levels during day time due to difficulties in encircling the shoal in view of the comparatively higher metabolic activity exhibited by the fish as well as mistake likely to be committed in assessing the depth at which the shoal is moving because of distortion caused by direct sunlight (eg. Oil sardine shoals off Kerala during the months of January, February March and April).

Depending on the behaviour of individual species in relation to variations in sunlight intensity, sea water temperature, salinity, dissolved oxygen demands, feeding habits, feeding preferences and breeding habits, suitable fishing gear will have to be employed for catching different types of fishes viz: oil sardine, mackerel, tuna, anchovies, carangids, seer fish etc which mostly belong to annual year class and their availability (which shows large scale fluctuation from, year to year) very much depends on the changes in the prevailing environmental conditions which ultimately decide the success of their spawning activity, mortality of eggs and larvae, recruitment to the fishery, availability of suitable feed for further growth, shoreward/ seaward/alongshore migrations, diurnal vertical migrations etc.

Among fishes like mackerel, oil sardine, anchovies, small tunas, carangids and seer fish, maximum advantage in terms of reduction in searching time as well as increase in CPUE are found in respect of ring seining and purse seining. In the case of mackerel, since the matured fish is known to undertake vertical migrations, matured mackerel is also caught in bottom trawling gear during day tome especially during the summer months when they migrate to subsurface waters to avoid comparatively warmer surface waters. Possibly due to the effect of global warming, of late, the tendency is found more or less during all the months except during the rainy season (SW and NE monsoon).

It was noted that fishing operations undertaken on or closer to dates on which related SST/chlorophyll imageries have been received yielded positive results. When the gap increased the yield within PFZ is likely to come down unless the features remain more or less at the same location as revealed by the succeeding satellite imagery. This is especially so when the coastal currents (monsoon drifts) take effect during the period November-March (NE monsoon drift which is northerly along the west coast).The monsoonal drift during SW monsoon (June to September) does not assume much significance in view of total fishing ban/trawl ban along west coast and absence of advisories during the south west monsoon period. This also could be the possible explanation for a certain percentage of success outside the PFZ and failures within the declared PFZ.

In order to make profit, individual boats will have to reduce the cost of operation to the bearest minimum by way of reducing the fuel consumption since the actual fish catch will depend on many environmental factors which influence the availability and abundance of a particular species of fish in space and time. In the absence of PFZ advisories these vessels will have to blindly search for fish shoals of suitable dimension in order to catch them. In the absence of PFZ, very often these vessels spend lot of fuel for searching and return to the base with out coming across a single shoal.

In general, oil sardine shoals are found nearer to the coast between a running distance of 15 to 30 km or even nearer whereas mackerel, coastal tuna and carangid shoals are invariably found away from the coast beyond 30 km. The comparatively higher unit returns for mackerel, tuna and carangids to a certain extent compensate the extra cost on fuel.

In the case of multi-day fishing activity lasting for a week or so (as in the case of purse seiners operating along Kerala, Karnataka and Goa coast), the economics of operation will improve greatly since the vessel is not returning to the base every day there by saving fuel. The fish catches can be brought to the shore periodically by carrier boats in case the total catch exceeds the frozen storage capacity of the mother boat.

Out of a total 60 controlled experiments conducted employing more or less identical Ring Seiners (13-21m OA L/90-140 BHP within and outside notified areas, the profit earned by individual Ring Seiners engaged in daily fishing activity within PFZ was found to be considerably higher compared to vessels which operated outside PFZ (Table 1) because of comparatively higher CPUE and through reduction in searching time resulting in the saving of valuable fuel oil and human effort.

INCOIS initiated action for incorporating wind component in PFZ advisories where possible area of shifting feature is also indicated in the advisory, since August 2009. Results of validation experiments conducted with more or less identical vessels off Kerala provided the advantage of the shifting feature to active fishermen engaged in pelagic fishing activities.

CONCLUSIONS

The study revealed that Potential Fishing Zone advisories, the only short-term forecast for marine fisheries available in the country which are brought out on the basis of satellite Sea Surface Temperature (SST) and chlorophyll imageries is found useful for locating pelagic fish concentrations. The major beneficiaries are the artisanal and small- mechanized/ motorized sector fishermen. Timely forecasts of PFZ based on SST and or surface chlorophyll concentrations can help in obtaining higher catch per unit effort and for minimizing the searching time for shoaling fishes which in turn can result in the saving of valuable human effort and also fuel for the mechanized/ motorized vessels there by bringing down the overall cost of fishing operations.

Fishing operations undertaken on or closer to dates on which related SST/chlorophyll images have been received yielded positive results. When the gap increases the yield within PFZ is likely to come down unless the features remain more or less in the same location as revealed by the succeeding satellite imagery. The fish catch within PFZ area gave higher CPUE and net profit compared to the results of operations outside PFZ areas. Average income derived by vessels which operated in the PFZ areas were considerably higher than vessels which operated outside PFZ areas. Fishing expenses were also comparatively less for vessels which operated within PFZ through reduction in searching time which in turn resulted in saving of valuable fuel oil and also human effort.

Approximately 71% of the total marine fish catch along Kerala coast is from pelagic species. Oil sardine, mackerel, anchovies, tunas, seer fishes, carangids etc; constitute about 65% of the pelagic stock that is about 35% of the total marine fish catch of the country as a whole. The usefulness of PFZ advisories for the marine fishermen engaged in different types of pelagic fishing activities does not need any further emphasis.

To sum up, where fishing is targeted at a pelagic resource which is migratory in habit, the PFZ will definitely provide an advantage in terms of reduction in searching time, in turn reduction in the consumption of fuel oil and human effort and also an increase in CPUE which ultimately will make the fishing operation economically viable.

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